

Cognitive control, brain systems and clinical applications

Kenneth Hugdahl

**Department Biological and Medical Psychology
University of Bergen**

**Division of Psychiatry and Department of Radiology, Haukeland University
Hospital, Bergen, Norway**



"Cognitive control" in everyday life...



Heterogeneity of concepts and terms

Baddeley & Hitch (1974)	Central executive, working memory	Braver & Cohen (2000)	Select, maintain, update information related to goals
Lezak (1983)	Volition, planning, purposive action, set shifting, effective behavior	Braver et al. (2002)	Focus on task-relevant information, inhibit inappropriate prepotent responses
Norman & Shallice (1986)	Supervisory attention system	Jurado & Rosselli (2007)	Inhibition of overlearned behavior, shift of focus from irrelevant to relevant information
Anderson et al. (2001)	Attention control, cognitive flexibility, goal setting	Zelazo & Cunningham, (2007)	Executive functions (EF) refer to higher-order cognitive functions relating to control of thought, action, and emotion
Delis et al. (2001)	Flexibility of thinking, inhibition, problem solving, planning, concept formation, abstract thinking, creativity		
Miller (2000)	cognitive] behavior to override ..habitual responses, to orchestrate behavior in accord with intentions	Miyake et al. (2000)	Shifting, updating inhibition

Cognitive control – an operational definition

Cognitive control is invoked to resolve cognitive conflict (Braver et al, 2002; Botvinick et al., 2001).

Cognitive conflict occurs in situations with simultaneous presence of strong and weak stimulus elements, where the strong element causes a perceptual bottom-up response tendency, and where there is a top-down urge to process the weak element.

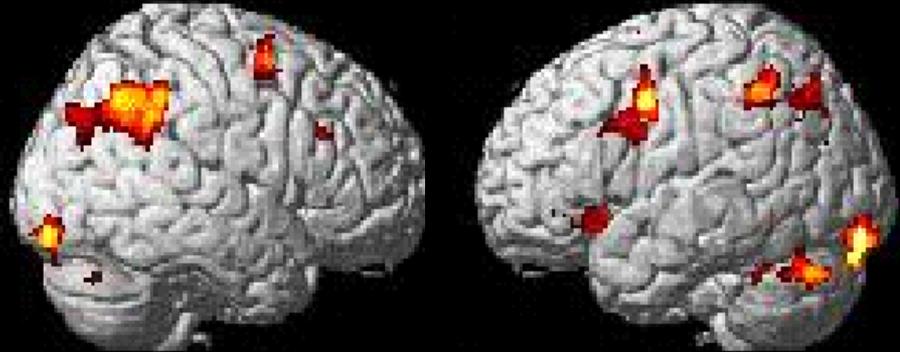
Cognitive control is thus the use of cognitive resources to successfully manage cognitive conflict and to resolve stimulus or instruction interference (Hugdahl et al., 2009)

Example: Stroop interference

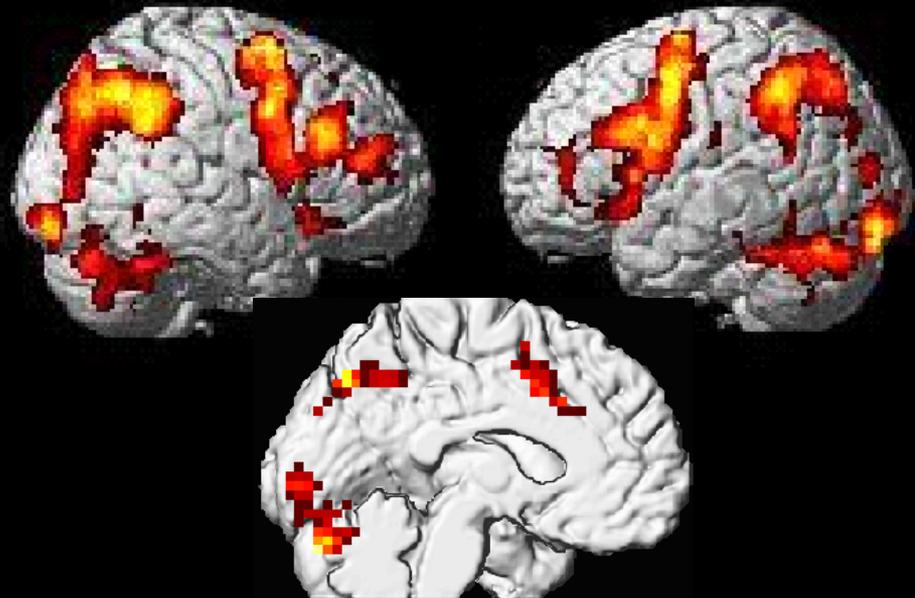
RED YELLOW BLUE GREEN

YELLOW BLUE RED GREEN

"Is the color *word* the same as the word 2-back"



"Is the color *ink* the same as the ink 2-back"

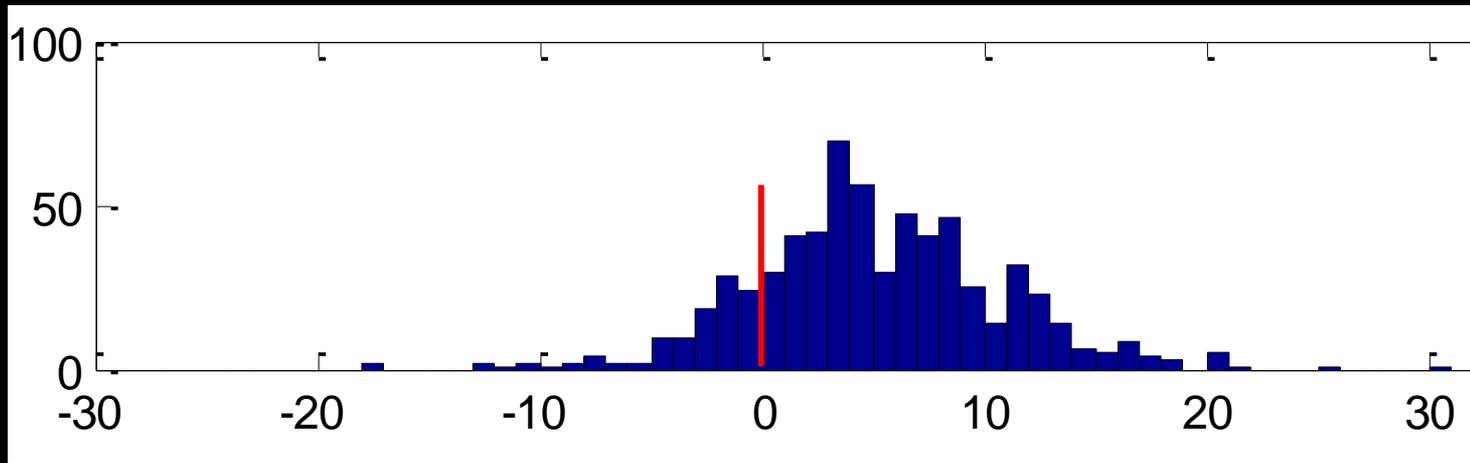


An auditory speech perception task: The dichotic listening paradigm

- Speech sound lateralization
- Temporal lobe integrity
- Attention and executive functions
- Processing speed
- Impaired processing in clinical groups



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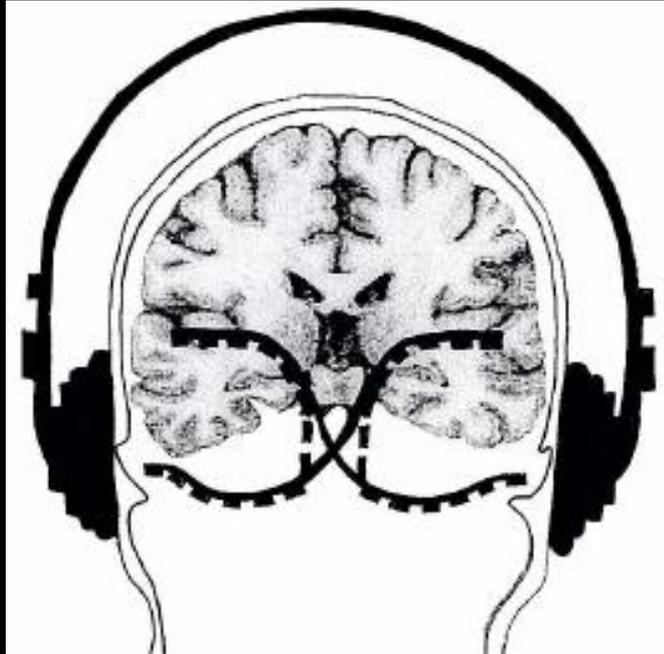


Right Ear – Left Ear difference score: *The right ear advantage (REA)*

The neural basis of the REA:

The wiring of the auditory pathways and the asymmetry for speech perception

(Kimura 1967 "Structural Model")



REA:

A bottom-up, stimulus-driven, perceptual effect, with a strong (right ear) and a weak (left ear) stimulus element

Robust (but not 100%) effect:

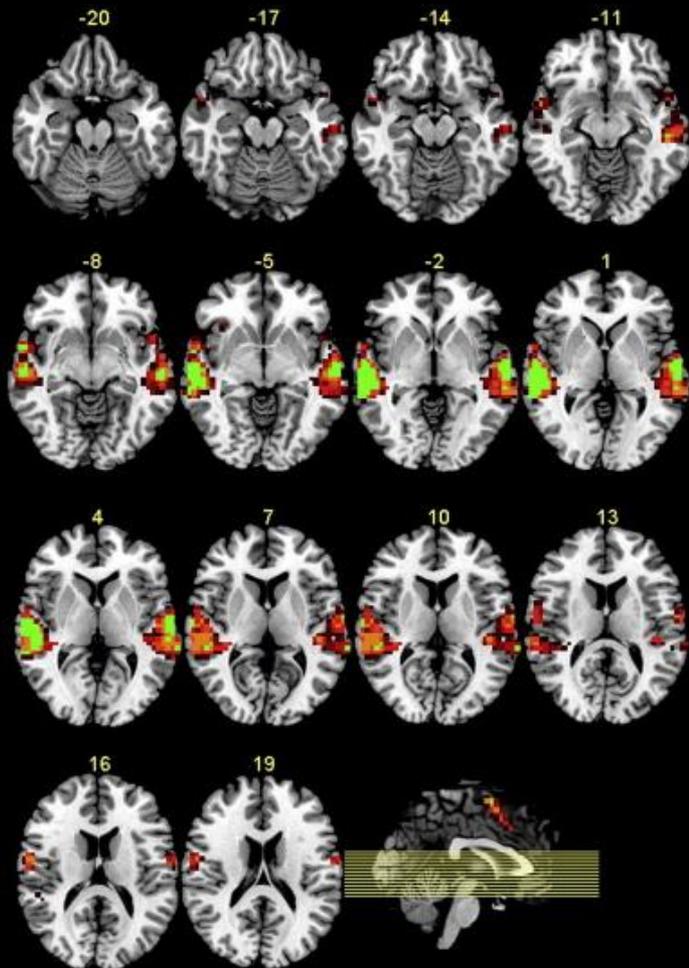
English 83%

German 87.5%

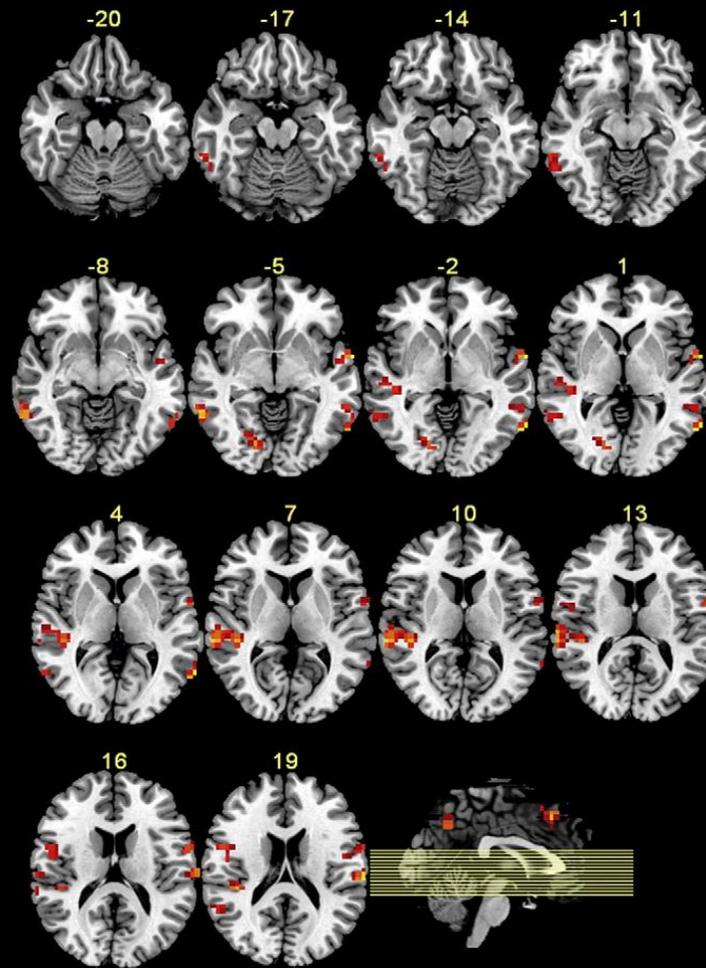
Norwegian/Swedish 86.5%

...supported by fMRI - BOLD activation data

Probability maps (>80%, >60%)



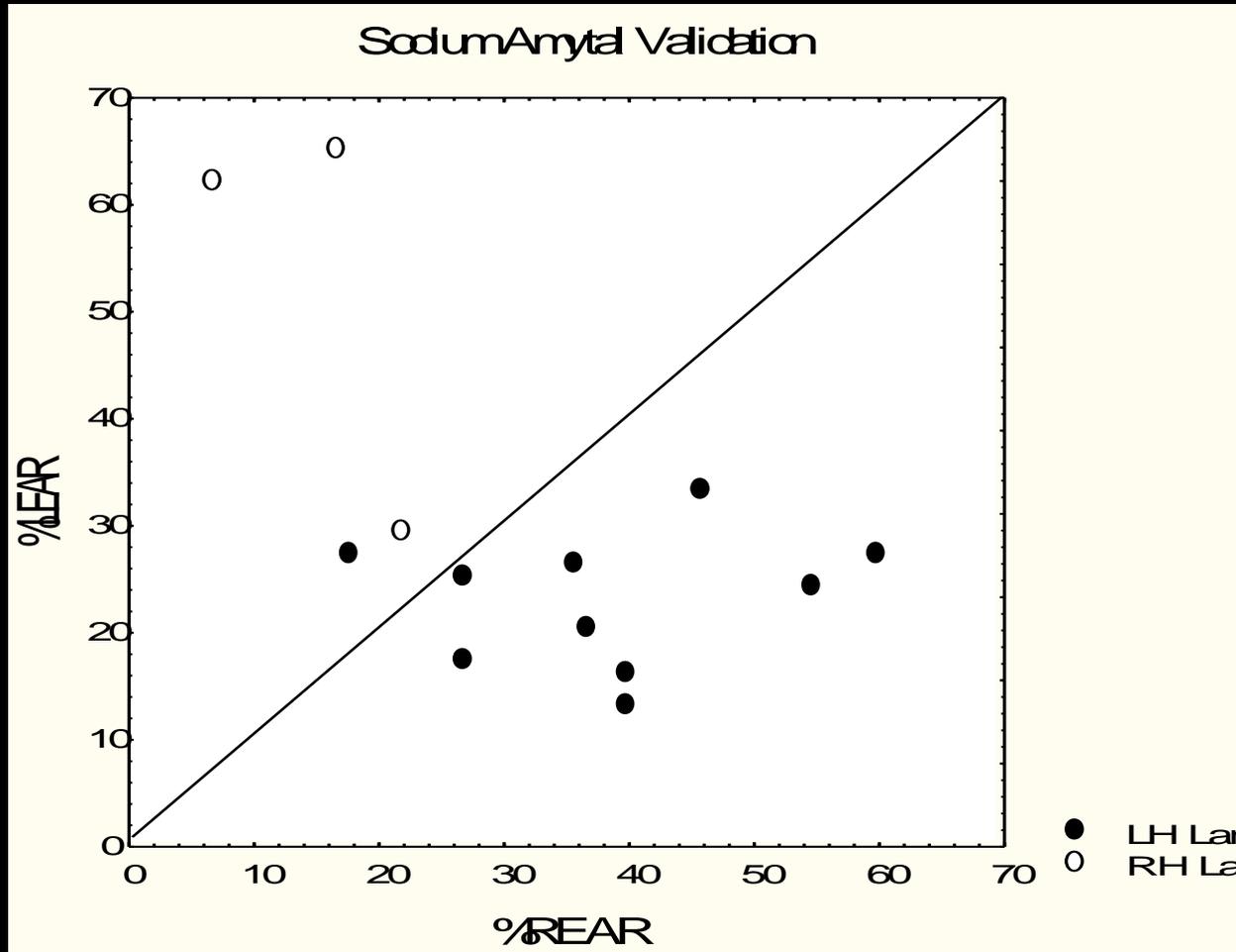
ICC > .85



Van den Noort, Specht, Hugdahl et al., 2008, *Neuroimage*; (see also Rimol, Savoy, Hugdahl et al., *Neuroimage*, 2005; Dos Santos Sequira, Specht, Hugdahl, *Laterality*, 2009)

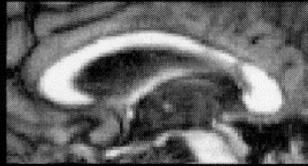
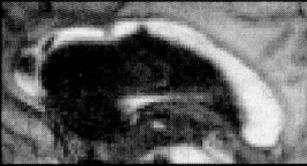
NB! Imaging data cannot prove causality!

The "Gold Standard" validation: Sodium-Amytal (Wada)-test



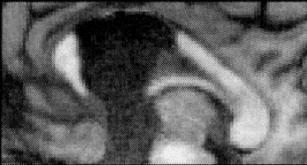
...and "true" lesion studies

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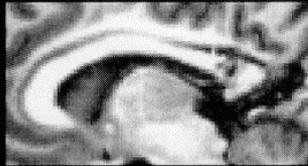
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142



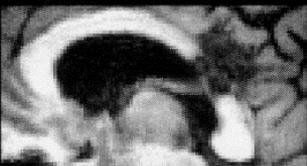
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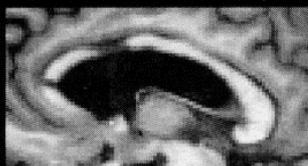
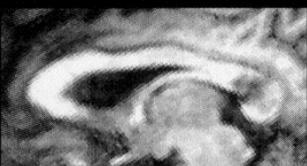
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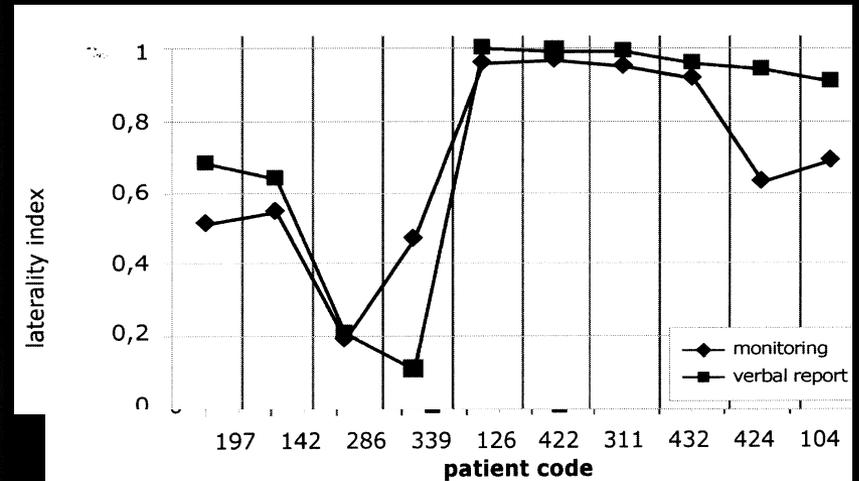
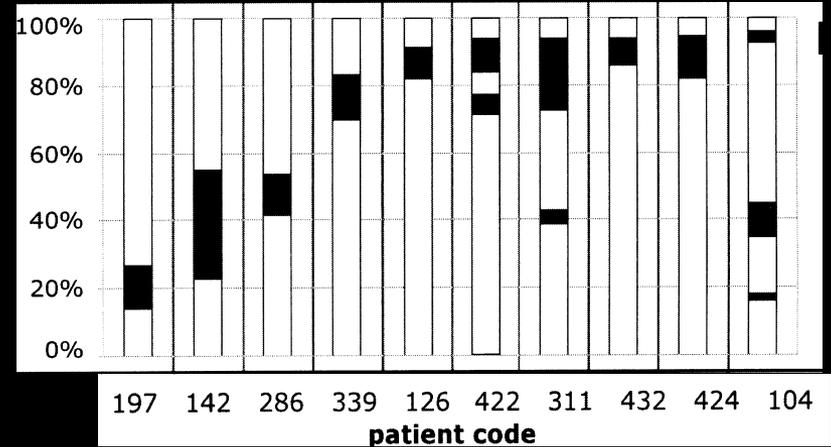


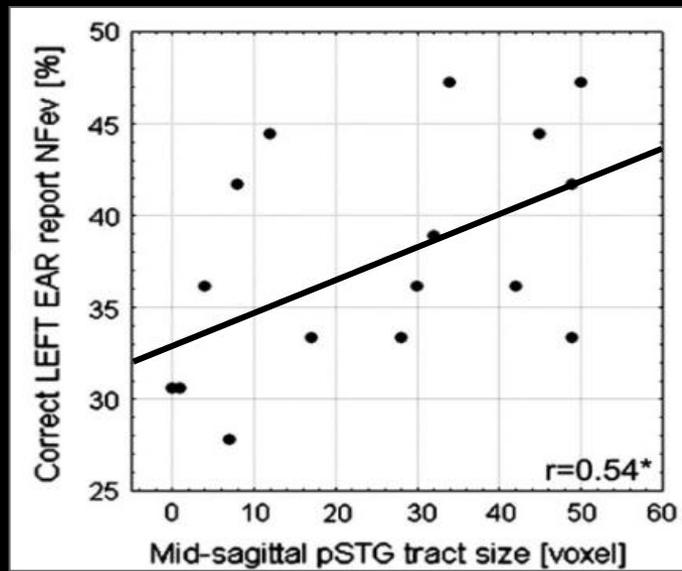
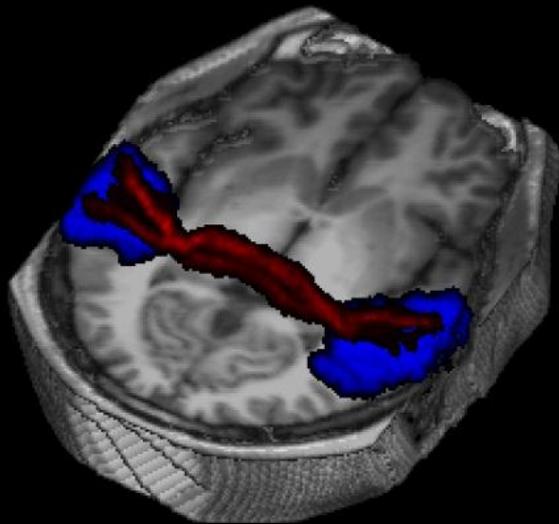
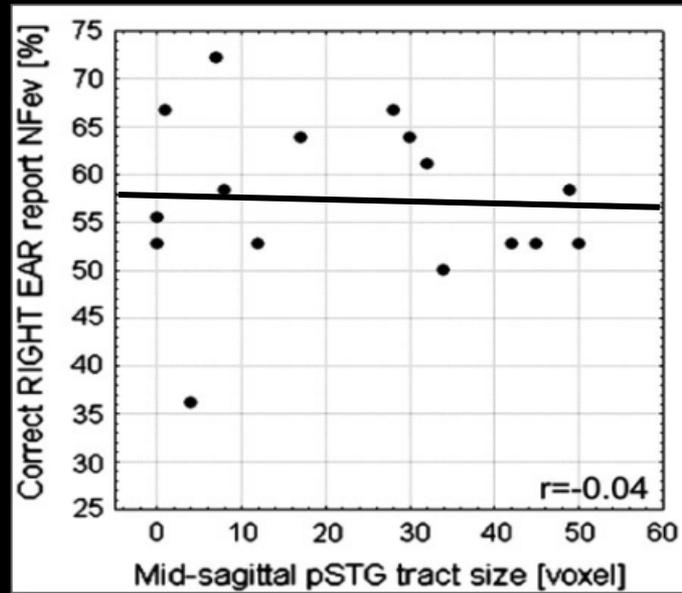
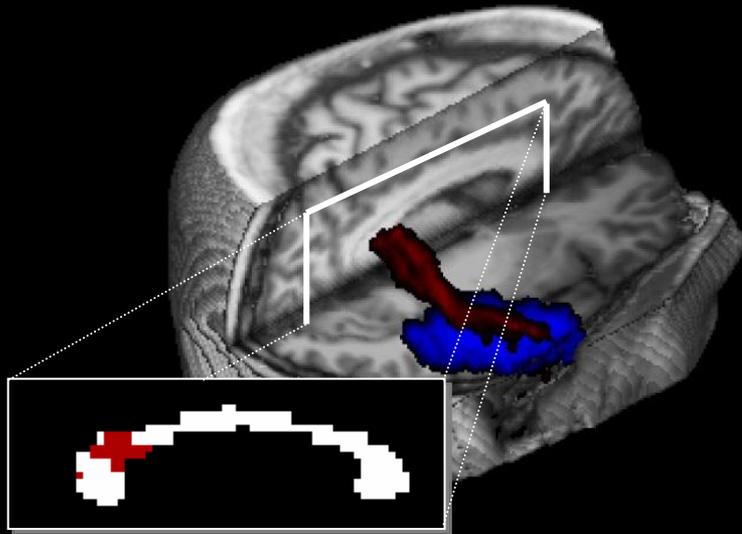
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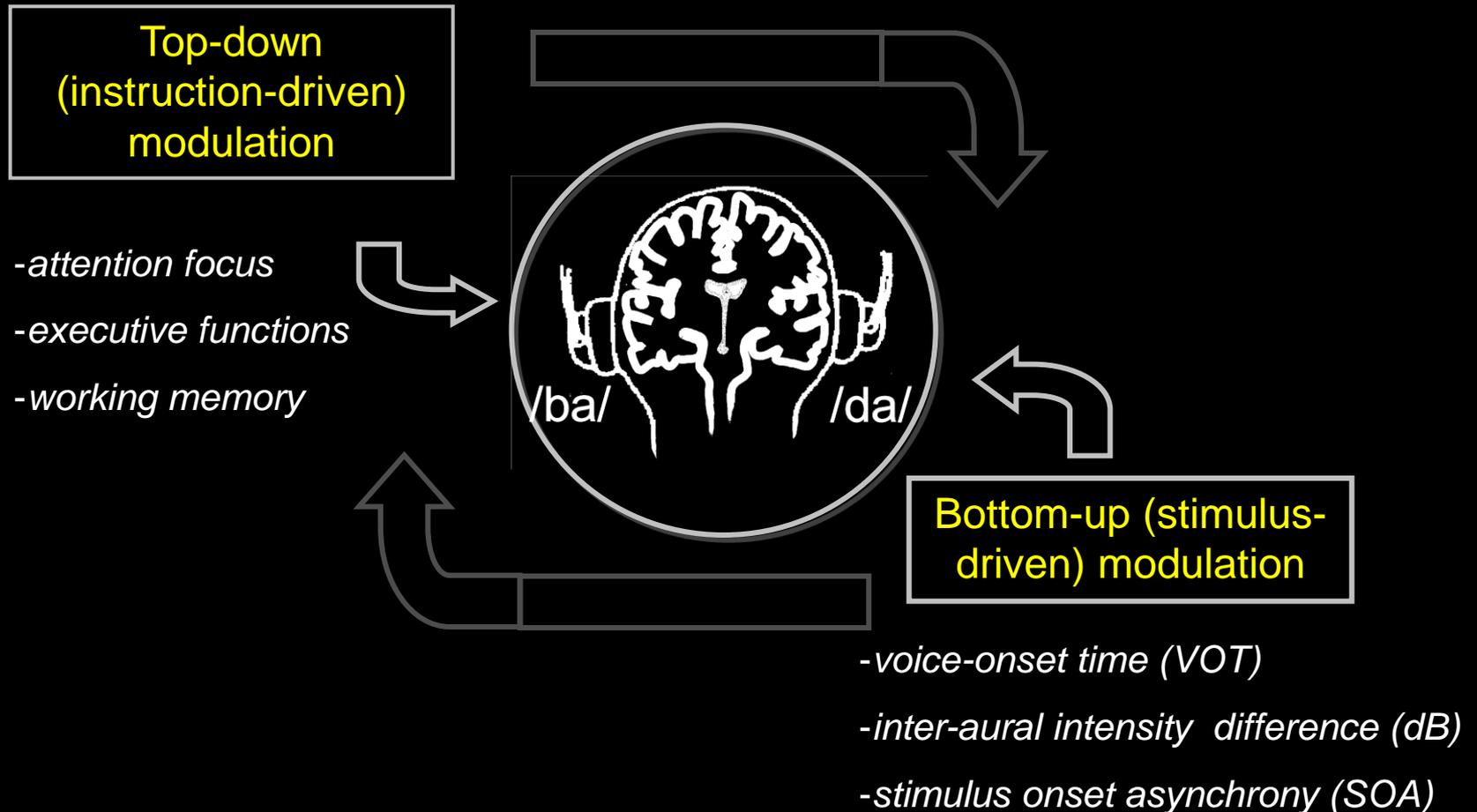


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Modulation of the REA



The forced-attention paradigm

NON-FORCED (NF)

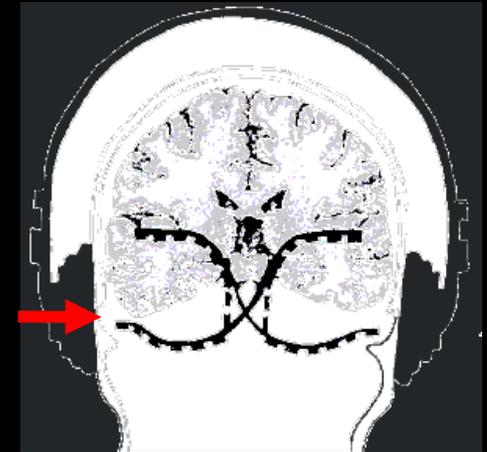
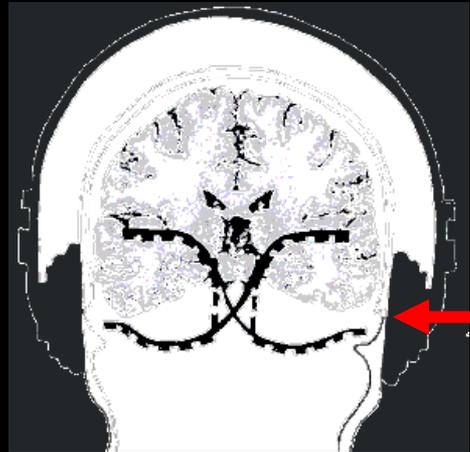
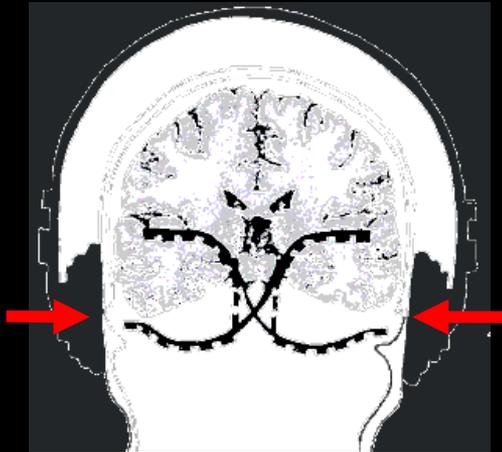
"report the syllable you hear more clearly"

FORCED RIGHT (FR)

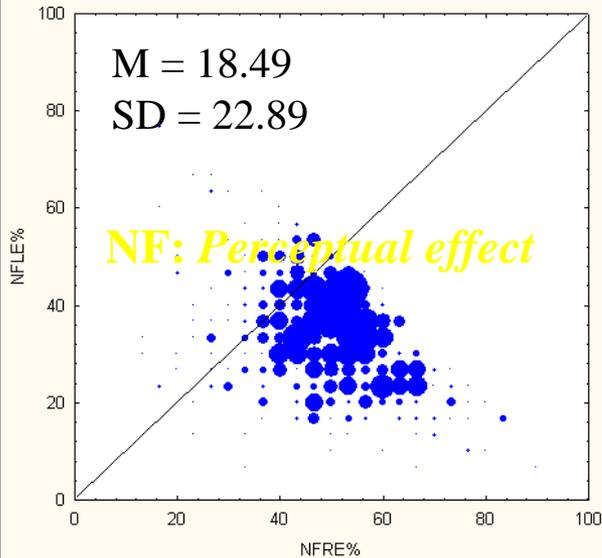
"report the syllable presented to the right ear"

FORCED LEFT (FL)

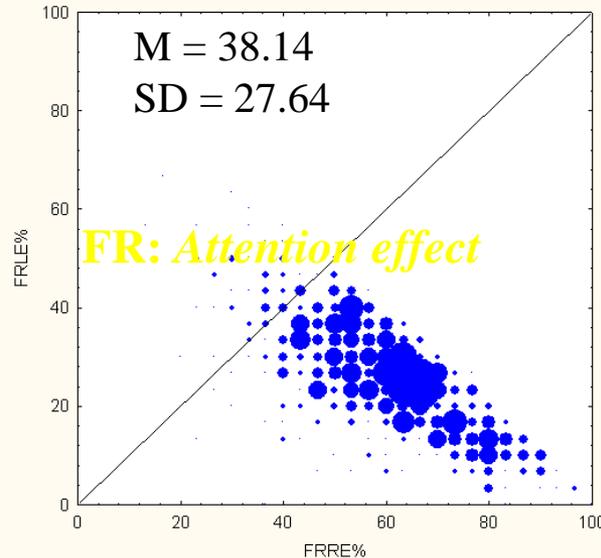
"report the syllable presented to the left ear"



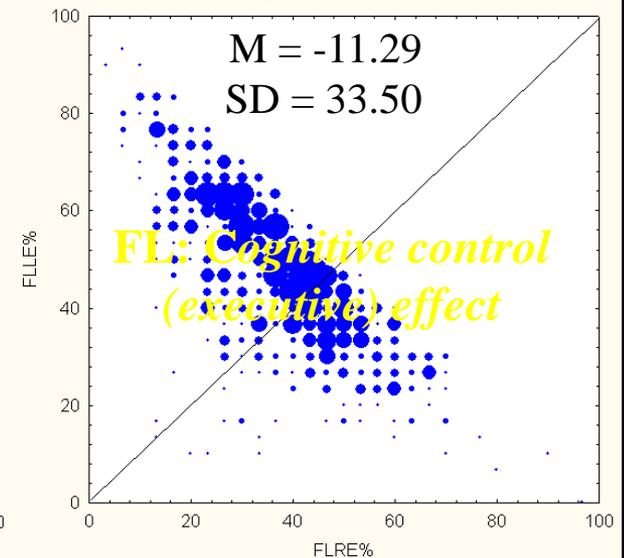
Bubble Scatterplot (NF_FR_FL bare voksne .sta 34v*651c)



Bubble Scatterplot (NF_FR_FL bare voksne .sta 34v*651c)



Bubble Scatterplot (NF_FR_FL bare voksne .sta 34v*651c)



Hugdahl & Andersson, *Cortex*, 1986

Hugdahl, K & Davidson, R.J. (Eds.). *The Asymmetrical Brain*, (2003). MIT Press, USA

... the 'evolution' of an explanation

1986

THE "FORCED-ATTENTION PARADIGM" IN DICHOTIC LISTENING TO CV-SYLLABLES: A COMPARISON BETWEEN ADULTS AND CHILDREN

Kenneth Hugdahl and Lis Andersson
(University of Bergen)

Cortex (1986) 22, 417-432

"...a few recent investigators have argued that the REA-effect may be brought about by a bias to selectively attend to the right side... The argument is that when subjects are left free to report the items, they may chose the order in which they report, andattend to the right and left ear stimulus. Bryden (1982) has argued that it should be easier to focus attention on items from the right ear.

Although it is somewhat unclear *why* it should be easier to "listen" to the right ear, it is obviously important to control for effects of attention" (p. 418)

1995

BRAIN AND LANGUAGE 49, 189-201 (1995)

Attentional Effects in Dichotic Listening

ARVE E. ASBJØRNSEN AND KENNETH HUGDAHL

University of Bergen, Norway

"Although there seems to be some consensus among researchers ...that attentional factors modulate a structurally based ear advantage..there seems to be little, or no, consensus as to the basis of the attentional effect....Generally speaking, attentional effects in DL can be the result of two processes: facilitation of correct reports from the attended ear or inhibition of intrusions from the unattended ear...(or) both processes being present.

...these results are surprising from both structural...and attentional.. models of dichotic listening. One would predict enhancement of ear advantages during forced attention..to be mediated by facilitation of correct reports from the attended ear, rather than inhibition of reports from the non-attended ear" (p. 198)

2010

Scandinavian Journal of Psychology, 2009, 50, 11-22 DOI: 10.1111/j.1467-9450.2008.00676.x

Cognition and Neurosciences

Attention and cognitive control: Unfolding the dichotic listening story

KENNETH HUGDAHL,^{1,2} REINE WESTERHAUSEN,¹ KIMMO ALIHO,³ SVYATOSLAV MEDVEDEV,⁴ MATTI LAINE⁵ and HEIKKI HAMÄLÄINEN⁶

¹Department of Biological and Medical Psychology/Cognitive Neuroscience Group, University of Bergen, Norway

²Division of Psychiatry, Haukeland University Hospital, Bergen, Norway

³Department of Psychology, University of Helsinki, Finland

⁴Institute of the Human Brain, Russian Academy of Sciences, St. Petersburg, Russia

⁵Department of Psychology, Åbo Akademi University, Turku, Finland

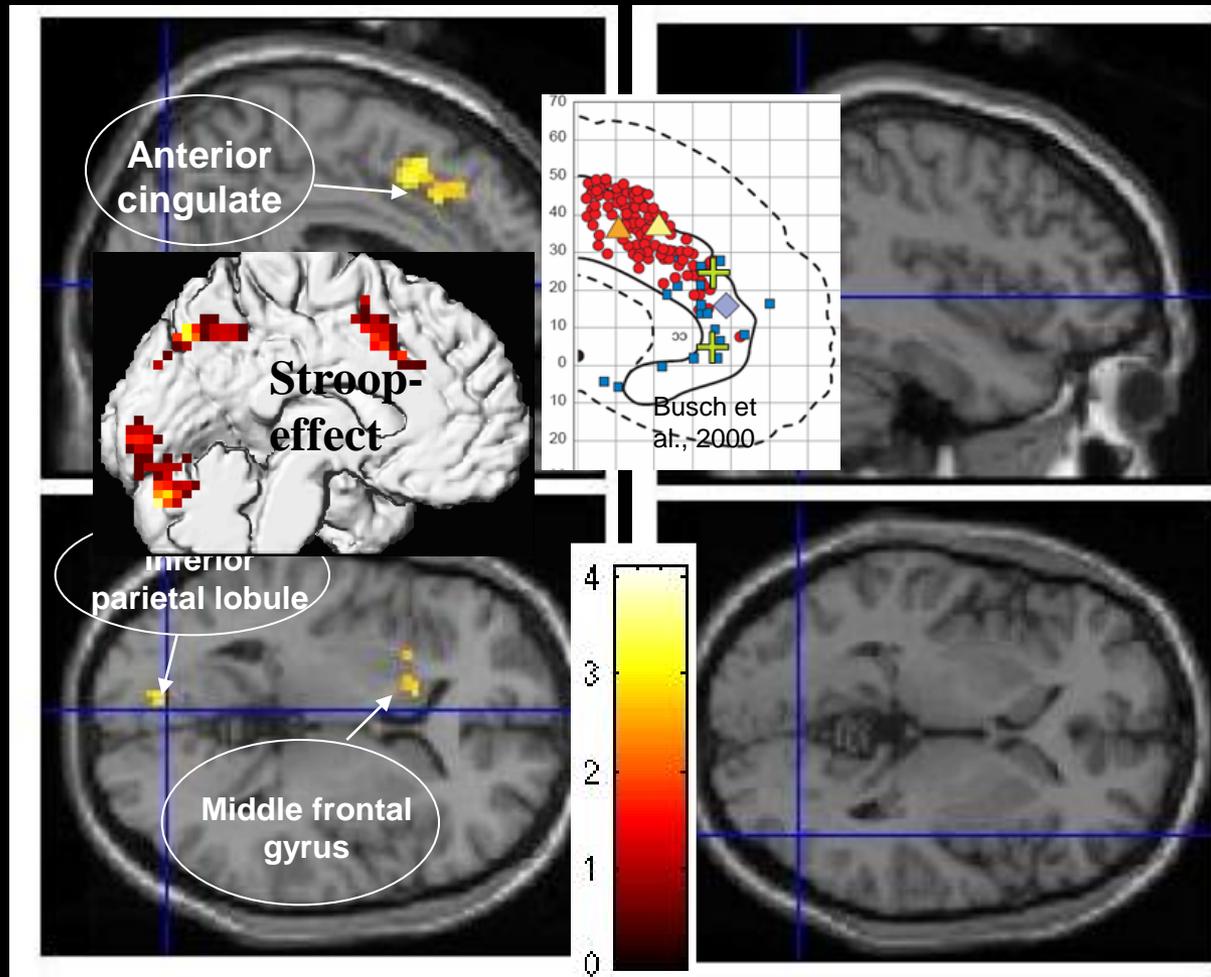
⁶Department of Psychology and Center for Cognitive Neuroscience, University of Turku, Finland

" We now believe that instructions to focus attention on the right or left ear stimulus induces different degrees of cognitive conflict and a corresponding need for (executive) cognitive control strategies... It was found that patients with schizophrenia could not modulate the REA when instructed to focus attention and reporting the left ear stimulus, while they were able to modulate the REA when ..focus on..right ear stimulus. Considering that the..task is easy to perform it should not be more difficult to report the left ear stimulus, than to report..right ear stimulus.

...the FL situation..involves ..cognitive conflict and need for inhibitory control to counteract a bottom-up right ear response tendency...the ability to maintain focus in the presence of competing or interfering stimuli." (p. 14)

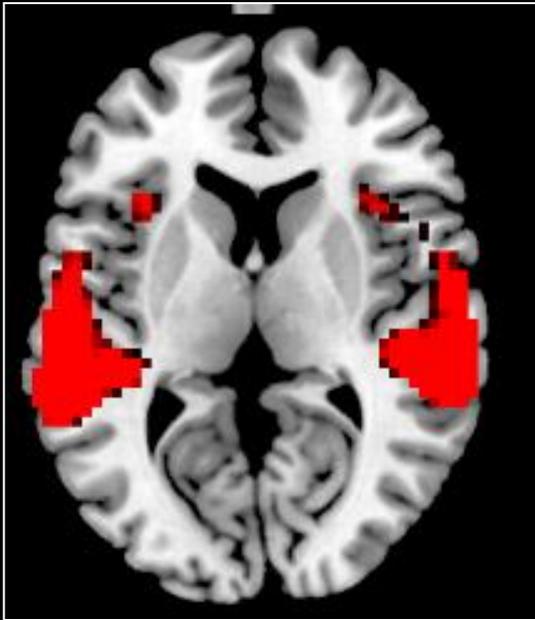
FL instruct – FR instruct

FR instruct – FL instruct



Thomsen, Rimol, Ersland, Hugdahl et al., *Neuroimage*, 2005

Cortical networks being activated in the three instruction conditions (NF, FR, FL)



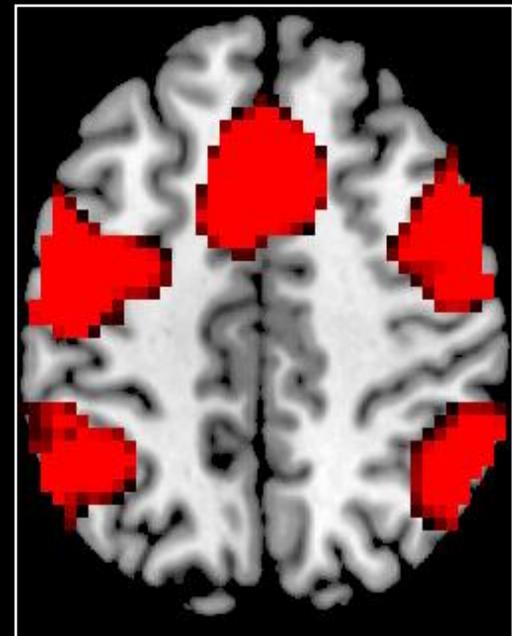
NF

Perceptual network



FR - NF

Dorsal attention network

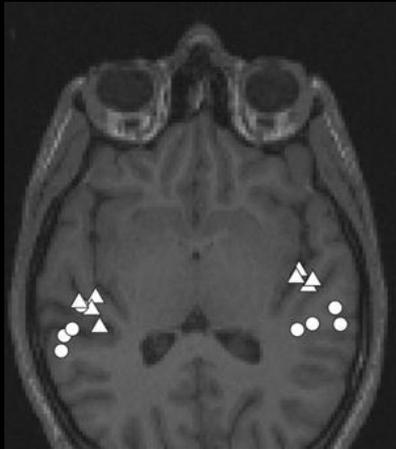


FL - NF

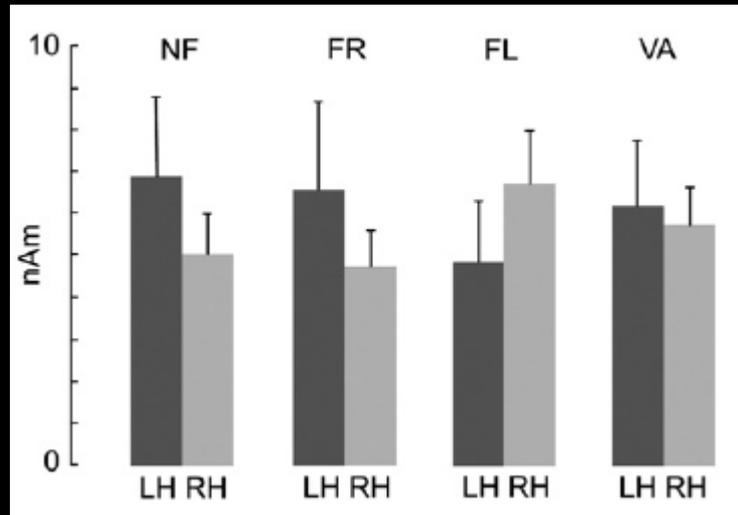
Cognitive control network

Modified after
Westerhausen, Hugdahl et
al., *Cerebral Cortex*, 2010

...supported from sustained magnetic fields in the auditory cortex (MEG study)



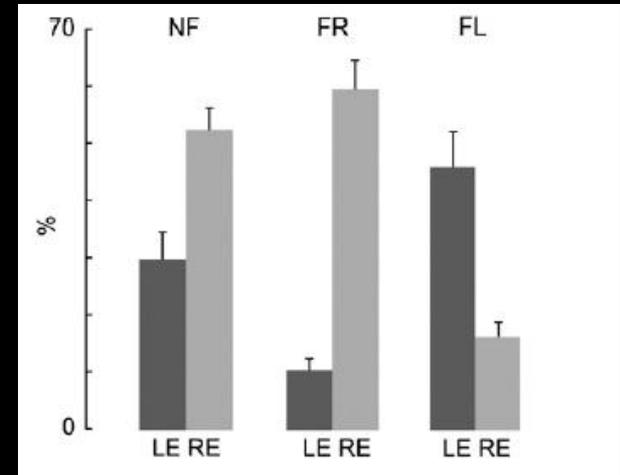
Equivalent current dipole (ECD) locations in one participant for the N1m responses (white circles) and sustained fields (SFs; white triangles)



Amplitudes of minimum-current estimates (MCEs) for the sustained fields (SFs). Mean amplitudes of MCEs for SFs in the auditory cortex of the left and right hemisphere (LH and RH, respectively) in the three auditory attention conditions, and a visual control condition (VA)

"Thus selective attention during dichotic listening leads to stronger processing of speech sounds in the auditory cortex contralateral to the attended direction."
(Abstract)

NB! Behavioral data validation



Ratio of detected targets, with a target syllable either in the left (LE) or right (RE) ear.

Clinical Groups that fail in the FL attention instruction condition

Child Disorders/Conditions

- Dyslexia
- ADHD
- SLI
- Born pre-term
- APD

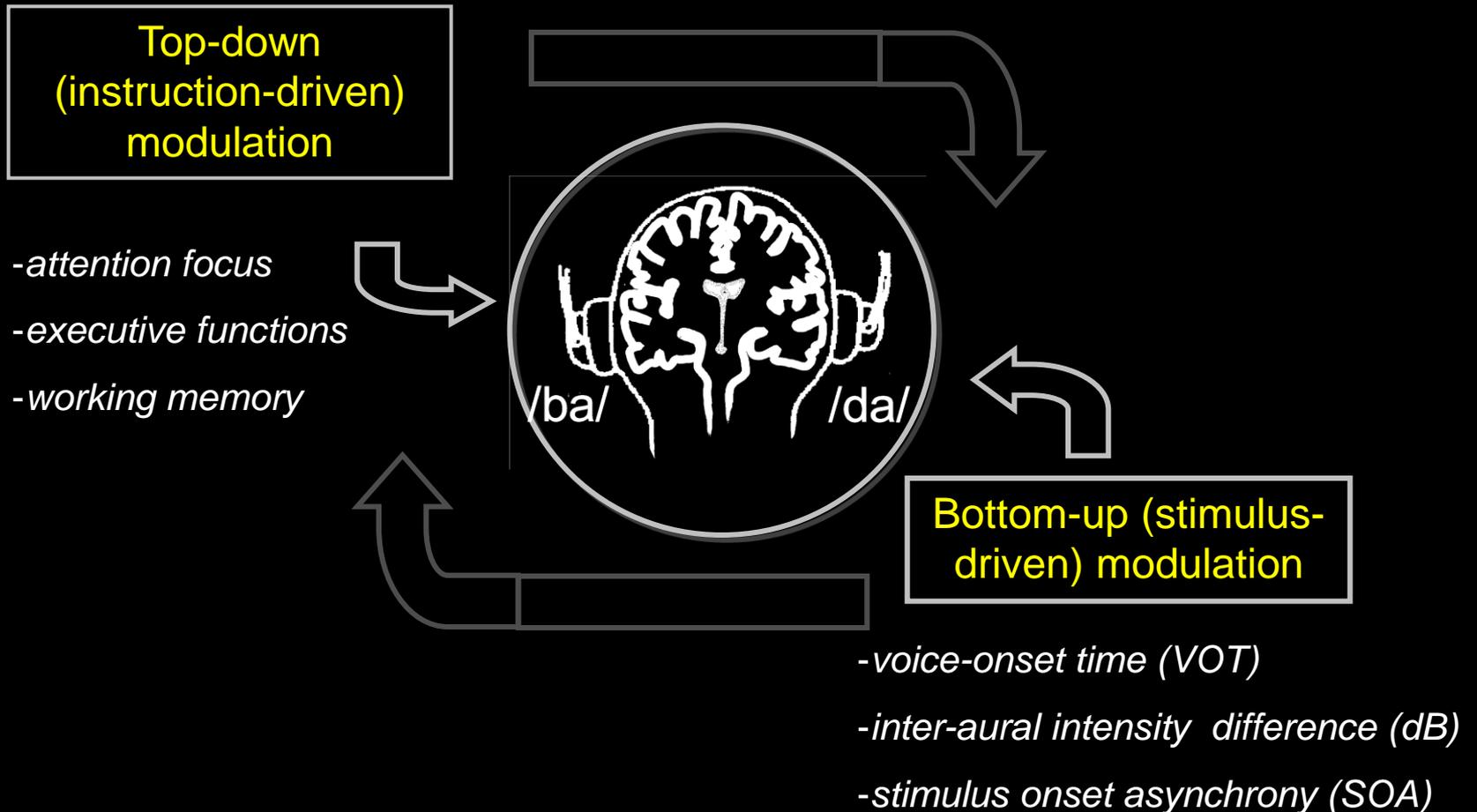
Adult Disorders/Conditions

- Schizophrenia
- Depression
- AD/Aging
- MS
- PTSD
- Klinefelter's syndrome
- Sleep Deprivation

- **Bilingualism**
- **Congenital Blindness**



Modulation of the REA

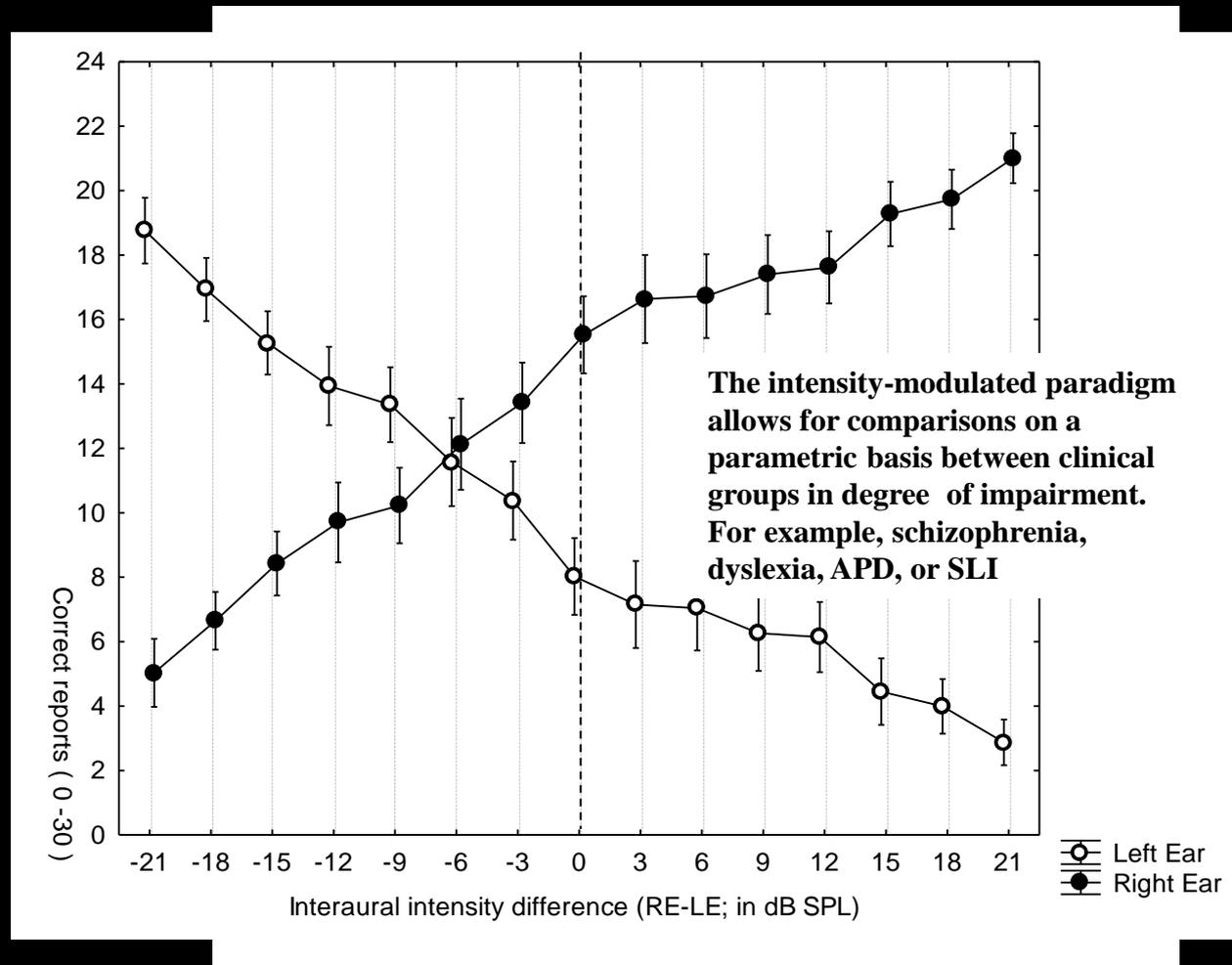


Parametrical manipulation of perceptual salience: How strong is the REA?



By gradually increasing the signal intensity in one ear relative the other, it should be possible to parametrically manipulate perceptual salience, and cognitive conflict

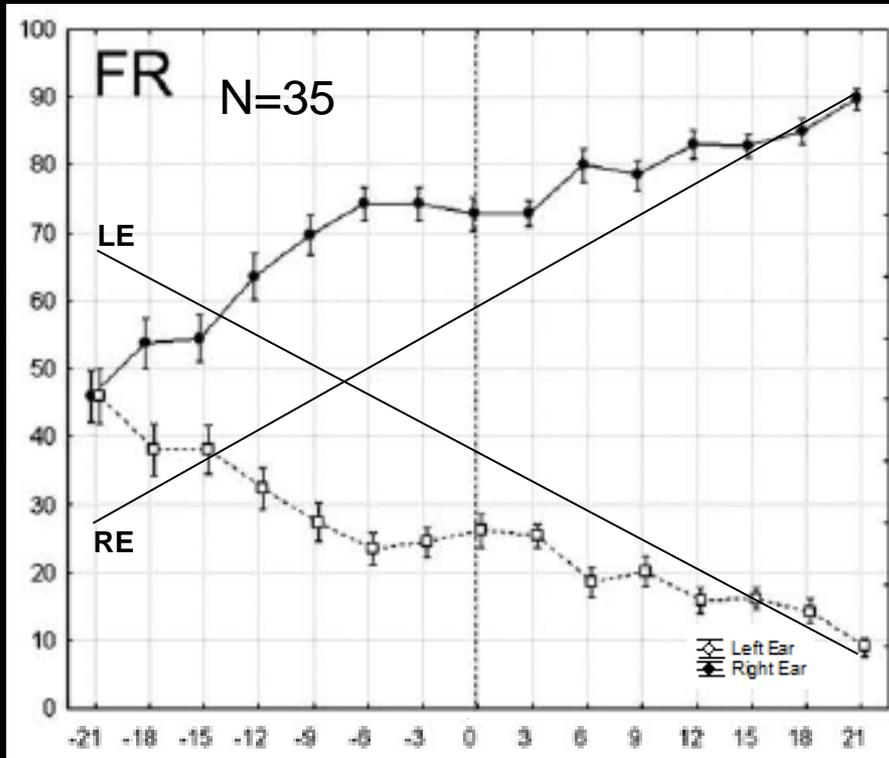
The question then becomes how much the intensity of e.g. the left ear stimulus would have to be increased before the REA yields to a left ear advantage (LEA), thus, expressing a cognitive concept (REA) in physical terms (dB)



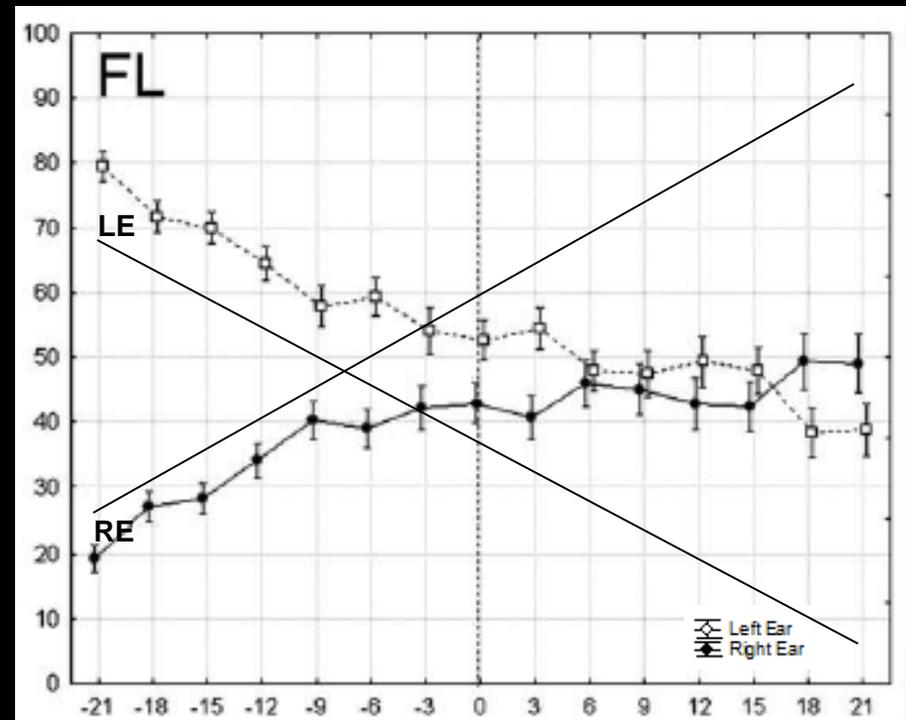
Unpublished data, Bergen fMRI Group

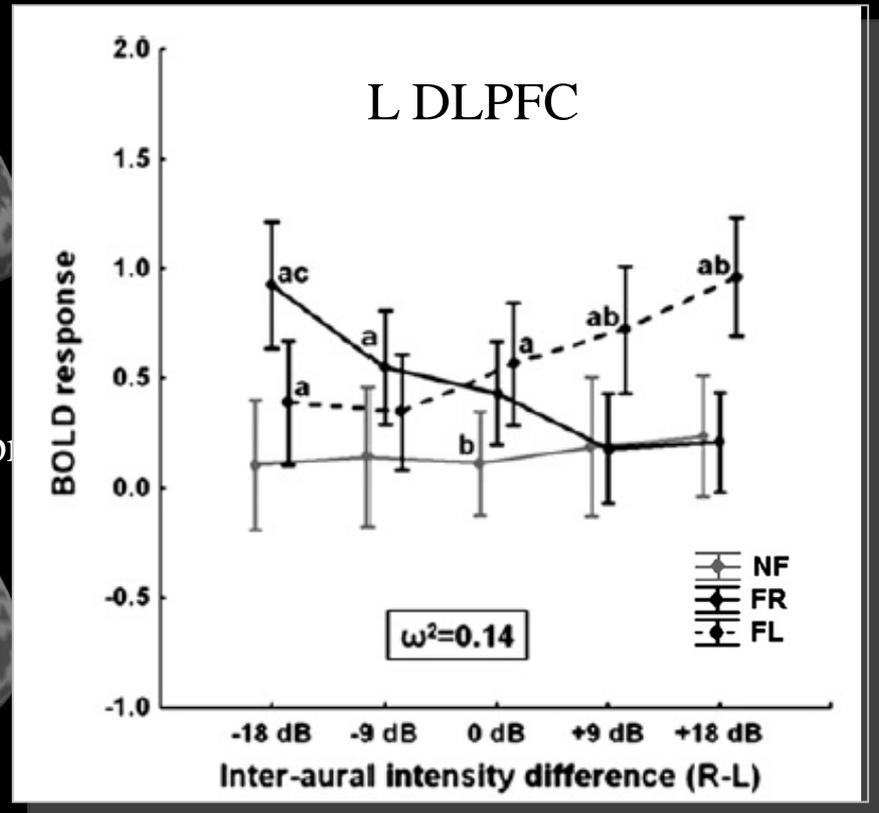
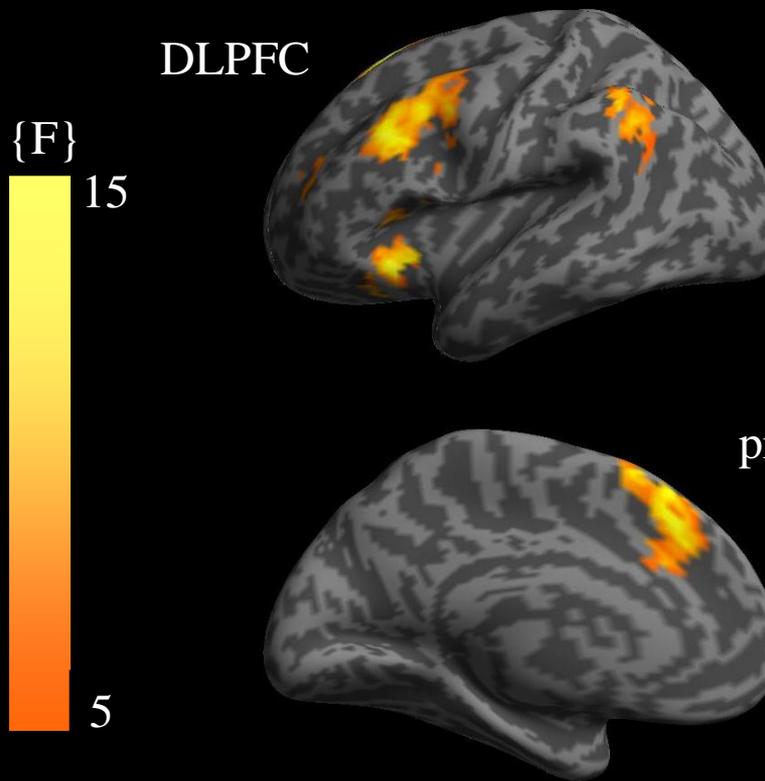
Hugdahl, Westerhausen, Alho, Hämäläinen et al, *Neurosci Letters*, 2008

...bringing it all together, combining top-down and bottom-up manipulation



- Quantifying degree of perceptual conflict and allocation of attention and cognitive control resources
- How strong is the top-down effect?

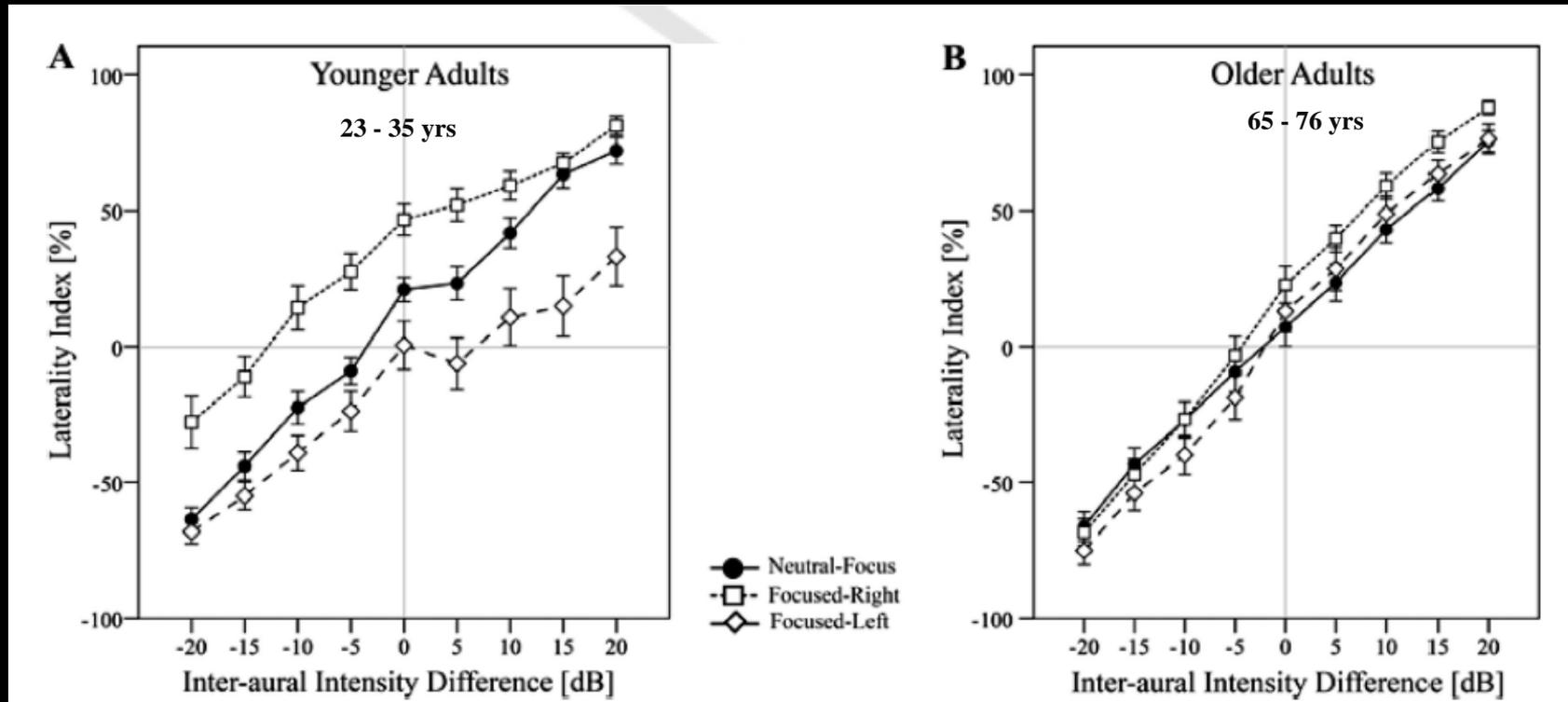




Interaction effect FWE $p < 0.05$

N=40

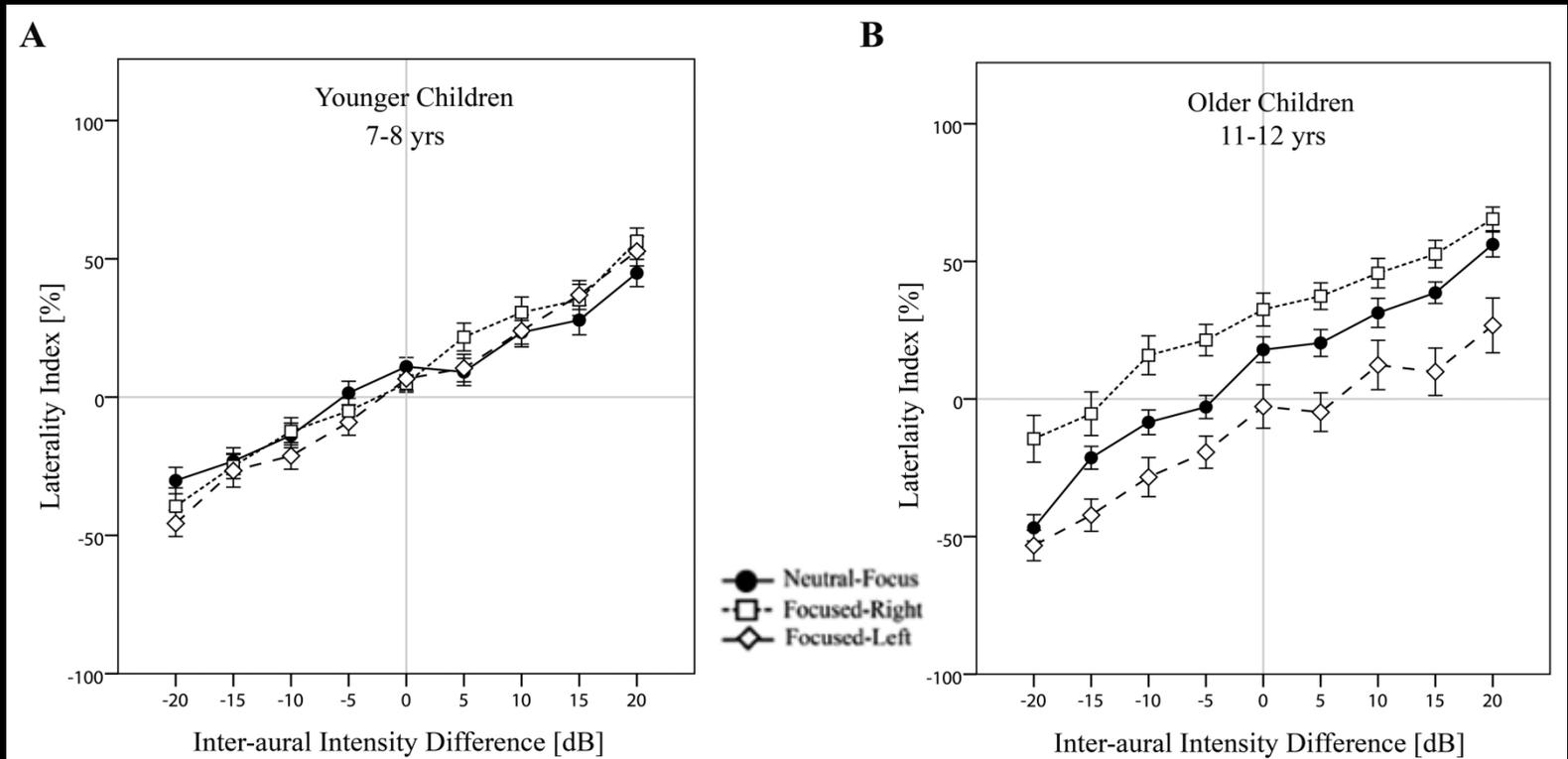
Development of cognitive control across the life-span



Data from the Max-Planck Institute for Human Development, Berlin, Germany

Passow, Westerhausen, Wartenburger et al *Psychology and Aging* (2012)

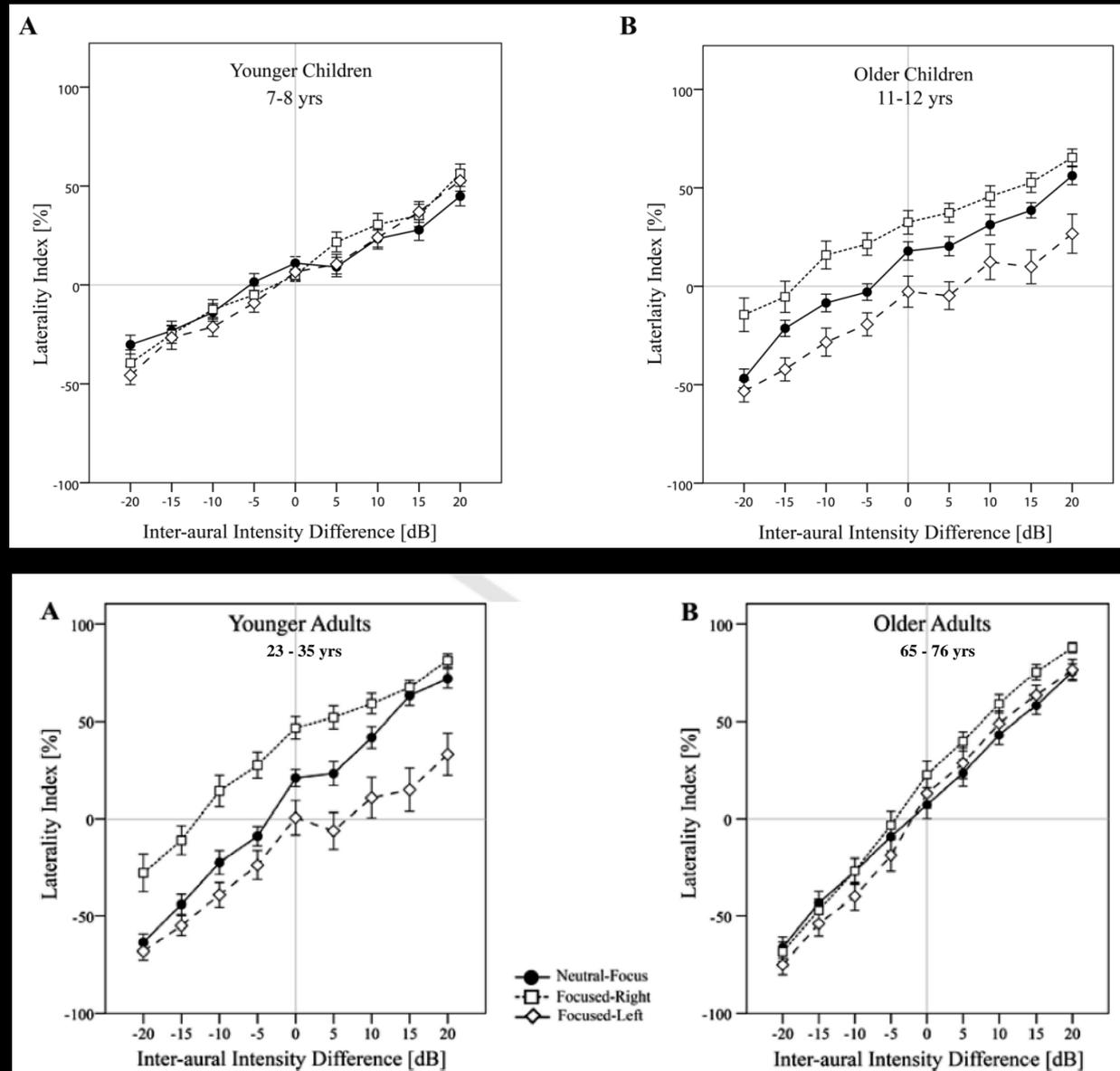
...and applied to children



Data from the Max-Planck Institute for Human Development, Berlin, Germany (Passow, Westerhausen, Wartenburger et al in revision)

...and putting the groups together

- Younger children and older adults are more driven by the bottom-up intensity manipulation, with less room for cognitive dynamics
- Older children and young adults show sensitivity to the top-down instruction manipulations, with a wider dynamic range for the young adults
- A parametric approach to assessing complex cognitive processes in special condition and clinical groups
- The low level demands in the task makes it suitable for use also in severely disabled groups

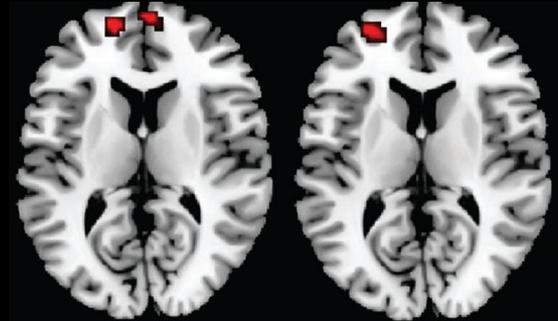


Where do we go from here ?

Pharmacological fMRI

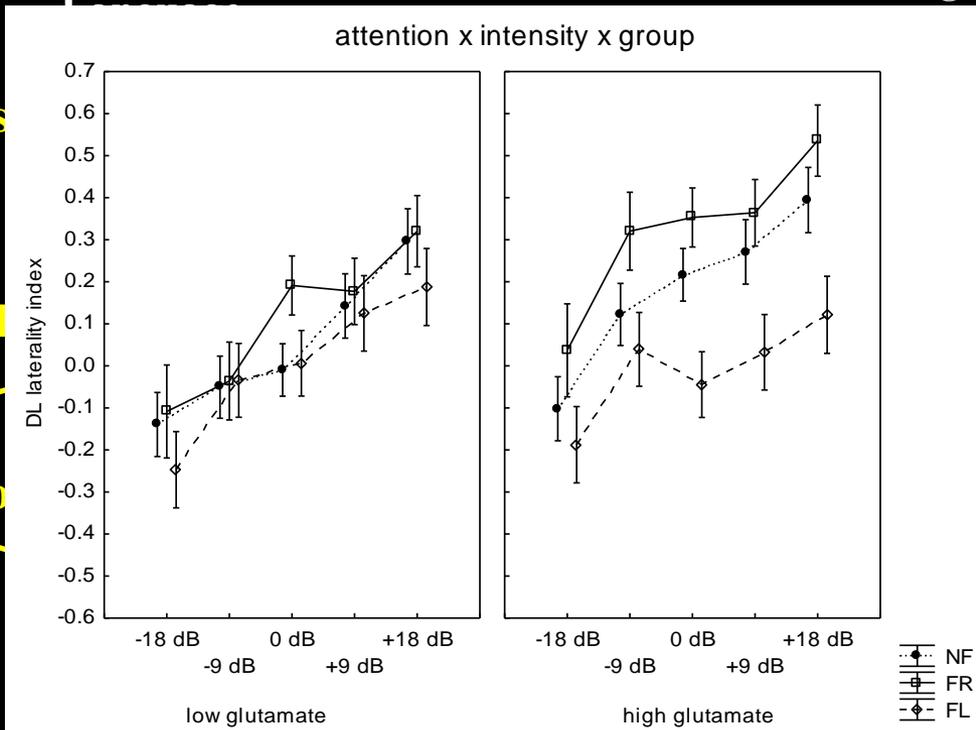
- **Clinical/Social**
Symptoms/Syndromes/Diagnoses
- **Cognitive**
Attention, Memory, Executive,

Give a drug that block the receptor action. Correlate with BOLD activation on a voxel-basis in drug-naive



ations

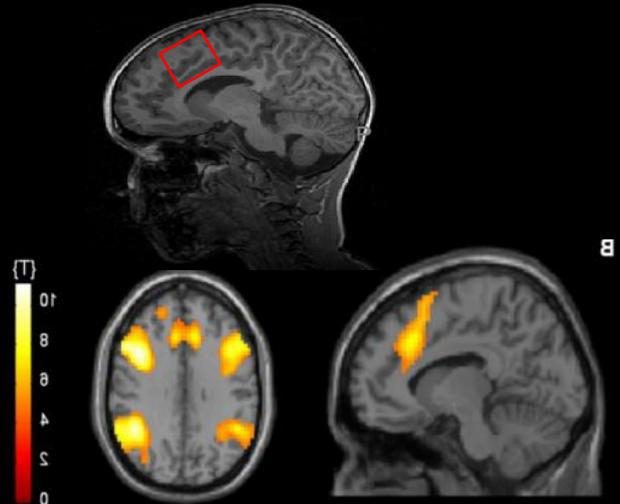
Westerhausen, Hugdahl et al., *Cerebral Cortex*, 2009



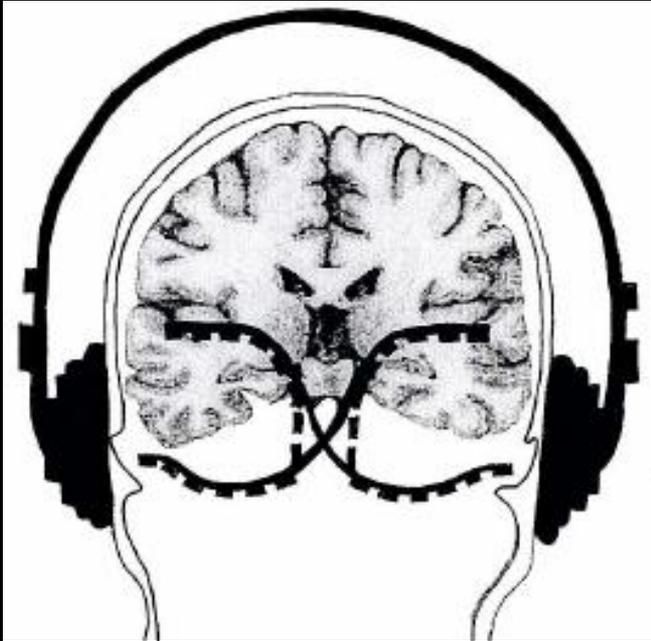
MRS correlations

BOLD
brain
in the

ROI



Summary



- The more complex the cognitive process, the simpler the experimental task or paradigm
 - Not requiring additional cognitive processes
 - Equally easy to understand and perform for children, elderly, and severely disabled patients
-
- study of cognitive control across the life span
 - application to clinical groups
 - application to "special ability" groups
 - parametric quantification of cognitive control, increasing resolution
 - training of cognitive control



**Thanks for showing excellent
cognitive control during my
presentation!**