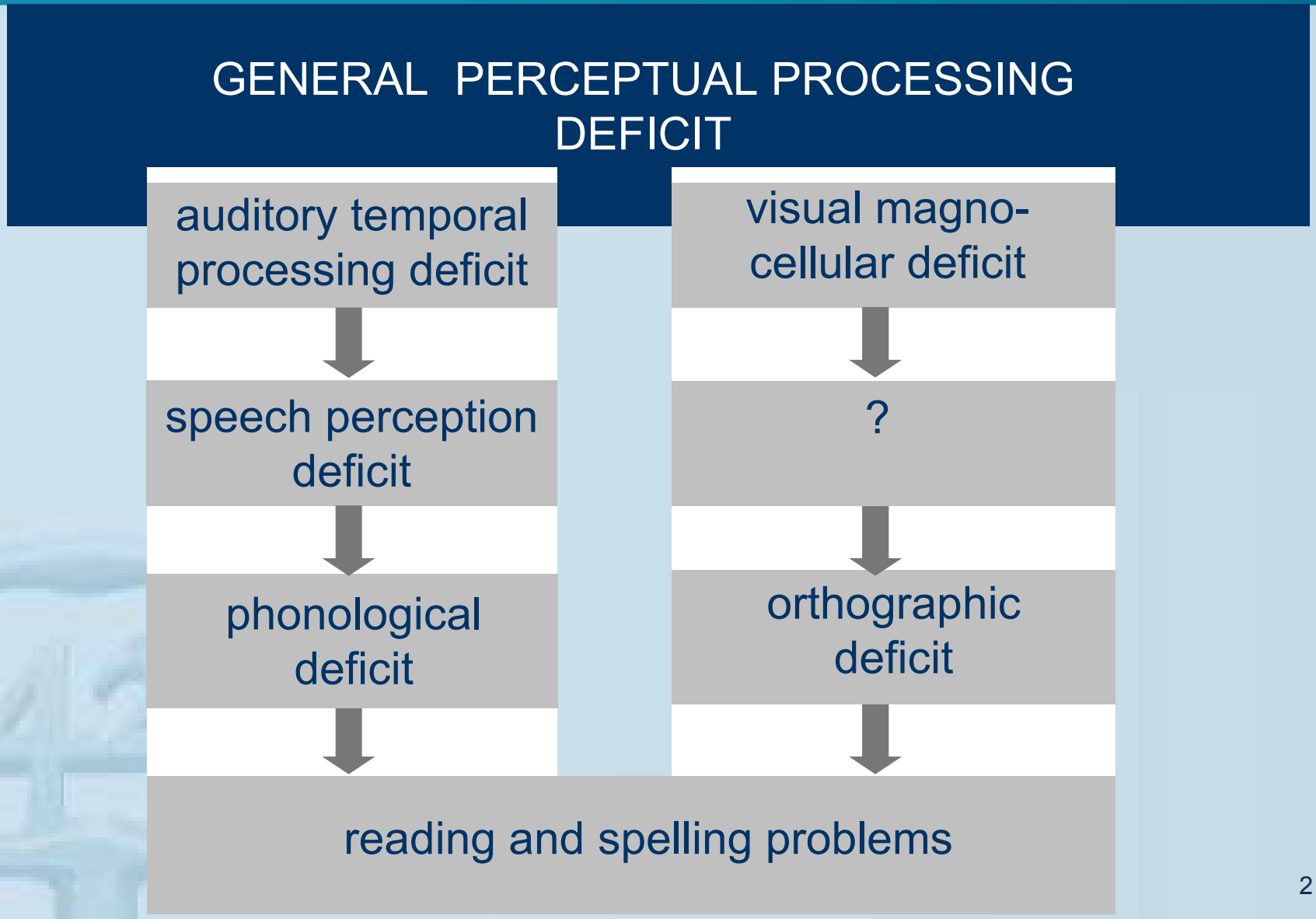
KATHOLIEKE UNIVERSITEIT LEUVEN

Is auditieve verwerking anders bij dyslexie?

Hanne Poelmans, Maaike Vandermosten, Heleen Luts, Bart Boets, Pol Ghesquière, Jan Wouters

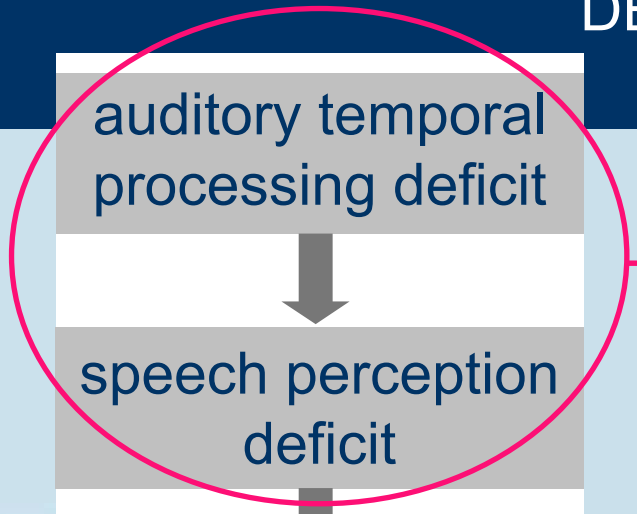
ExpORL, Dept. Neurosciences &
Center for Parenting, Child Welfare and Disabilities
K.U.Leuven, Belgium

Theoretical framework: dyslexia



Aims of the project: study 1

GENERAL PERCEPTUAL PROCESSING DEFICIT

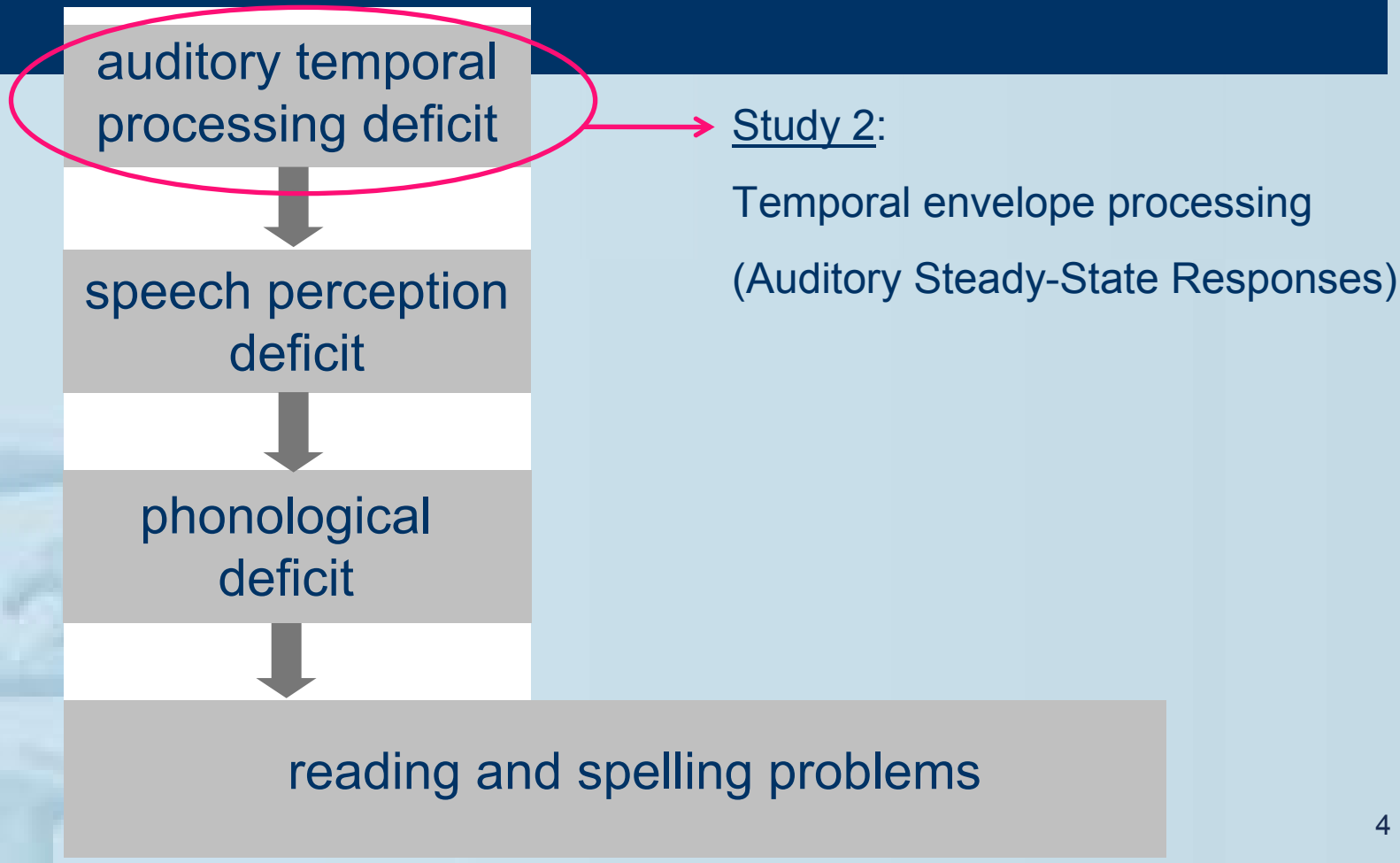


Study 1:

Categorical perception

Aims of the project: study 2

GENERAL PERCEPTUAL PROCESSING DEFICIT



Study 2:

Temporal envelope processing

(Auditory Steady-State Responses)

Subjects: 62 adults

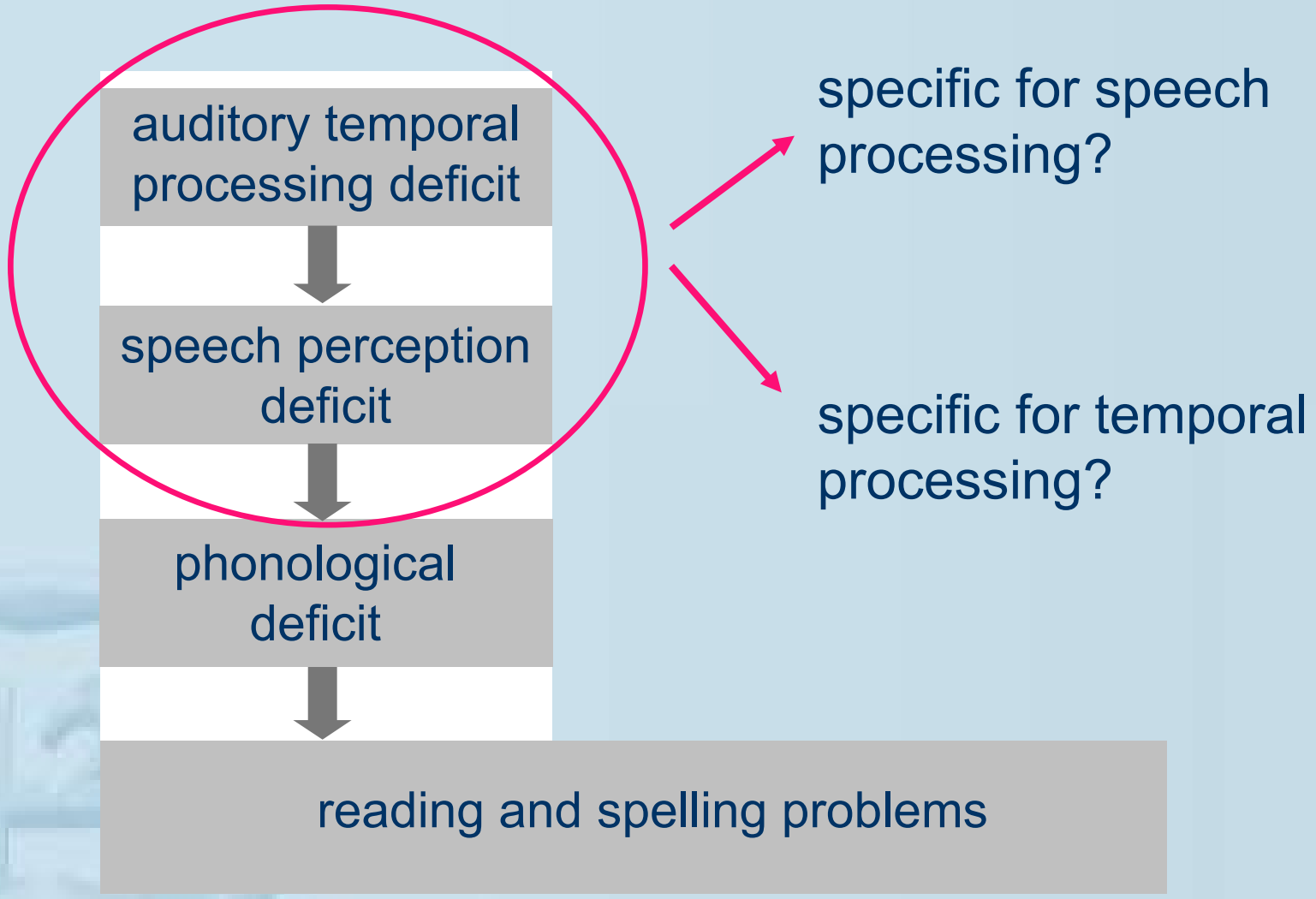
MATCHING CRITERIA:

age, gender, educational level, non-verbal IQ

	Dyslexics (n = 31)	**Normal readers (n = 31)**
Gender (male/female)	9/22	9/22
Age (years)	21 (3)	21 (3)
Non-verbal IQ (WAIS-III Matrices)	108 (13)	106 (10)
Word reading***	64 (11)	98 (11)
Pseudo-word reading***	60 (10)	104 (14)
Spelling***	17 (4)	25 (2)

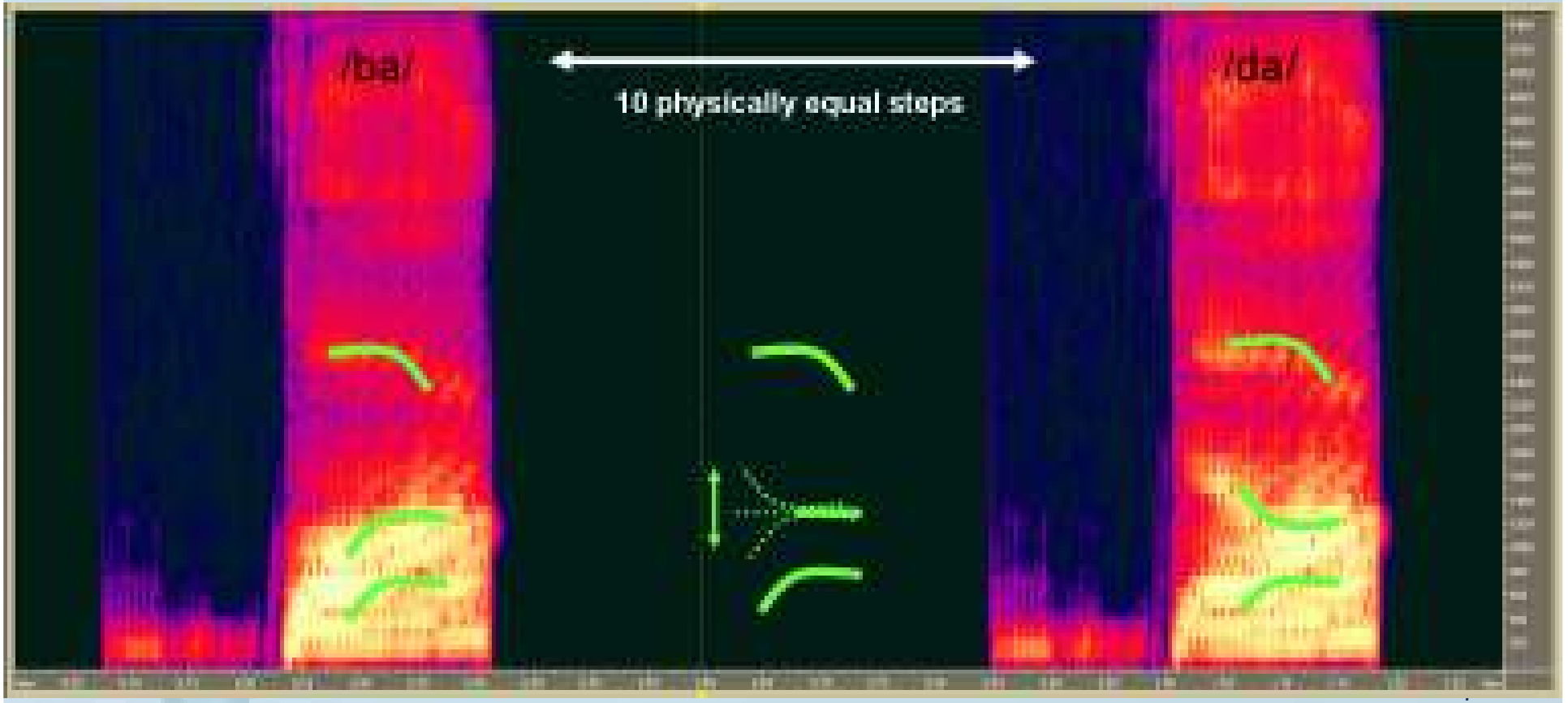
*** $p < .001$

Study 1: Categorical perception

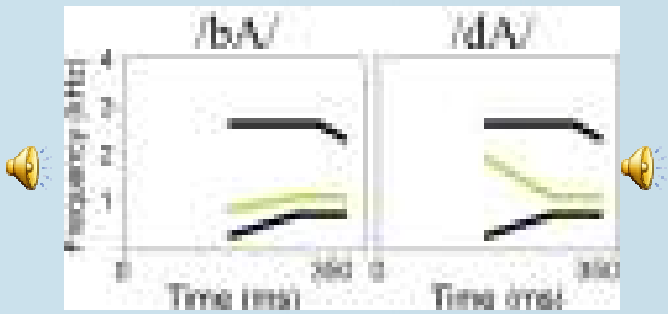
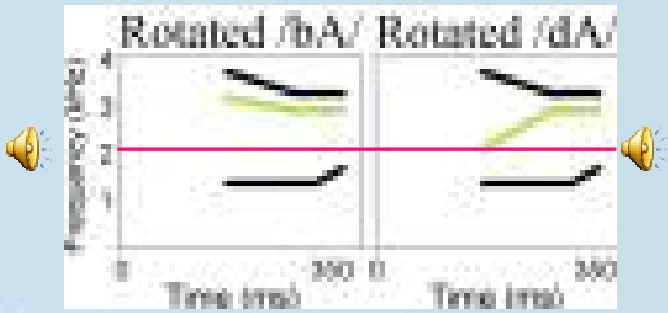


Categorical perception

- Categorical perception: speech sounds are perceived in a categorical manner (for example /ba/ or /da/), despite small acoustical differences between each stimulus



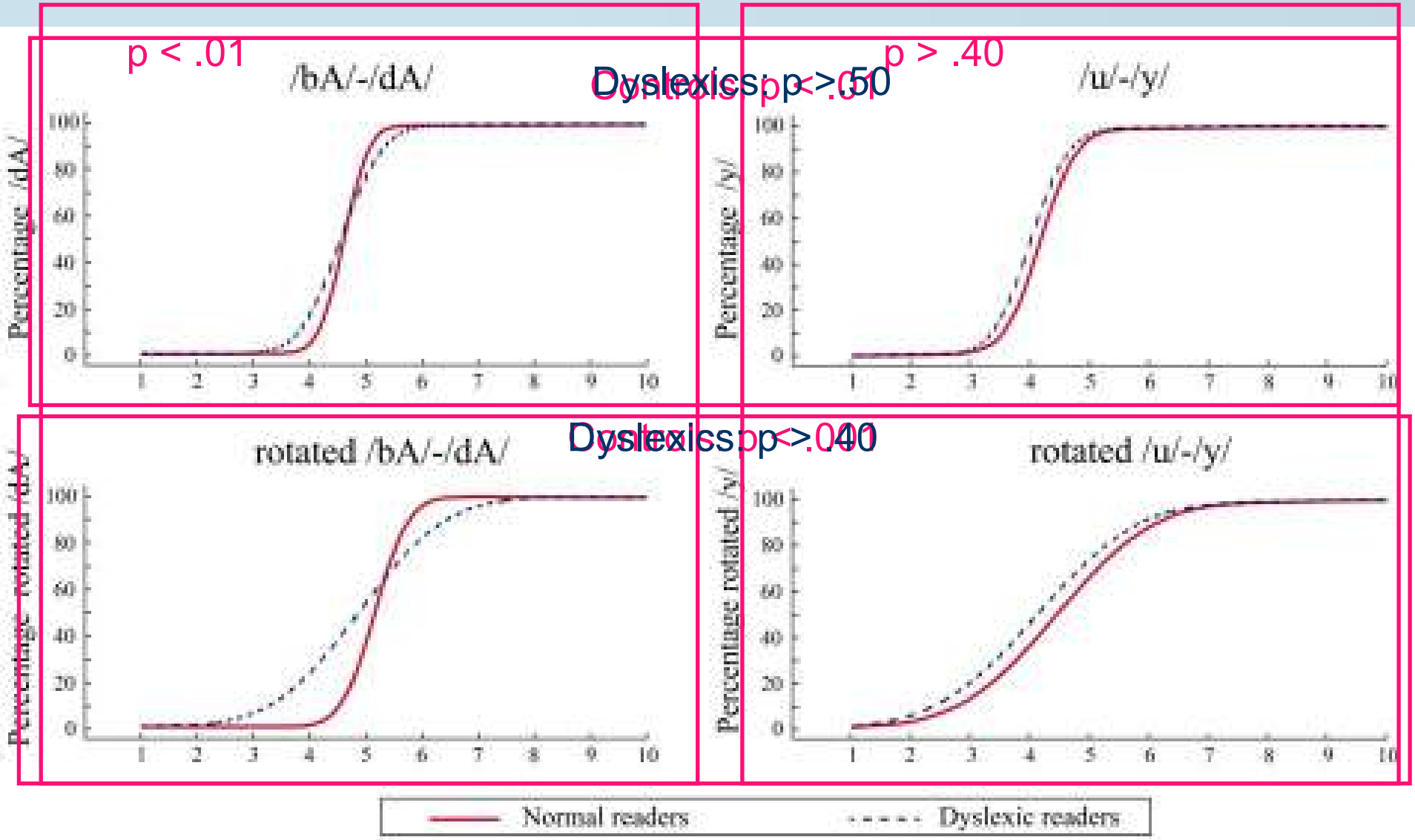
Factorial design

	Temporal	Non-temporal
Speech		
Non-speech		

- Similar acoustic complexity of stimuli across conditions
- Test procedures identical for all conditions
  - 10-step continuum
  - Categorical perception: ABX-identification task

Blesser, 1972, JSHR
Scott et al, 2000, Brain

Results: categorical perception



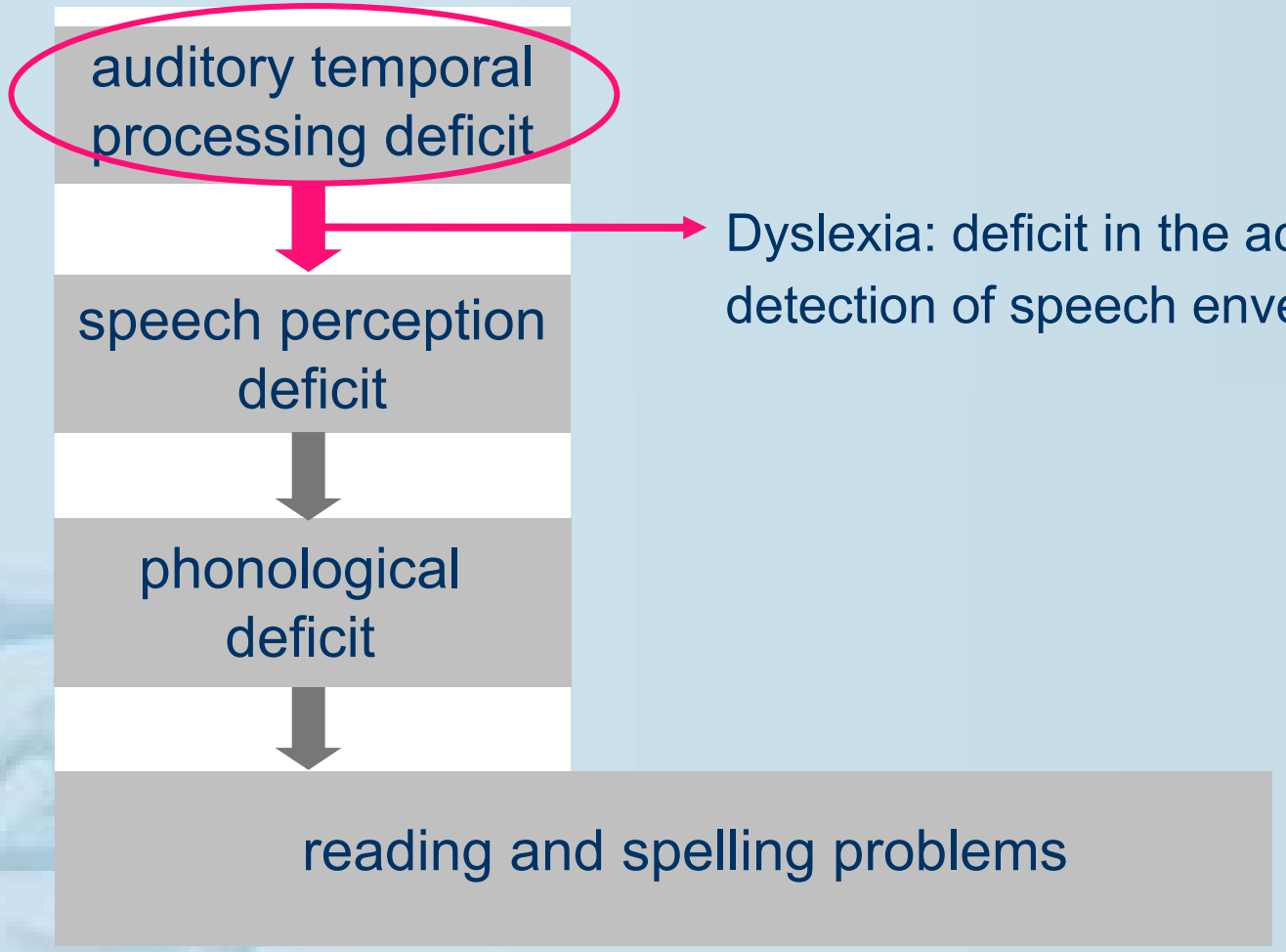
Study 1: Conclusions

	temporal	non-temporal
speech	/bA/-/dA/ *	/u/-/y/
non-speech	Rotated /bA/-/dA/ *	Rotated /u/-/y/

- Slope of temporal vs. non-temporal contrasts
  - Temporal: dyslexics < controls
  - Non-temporal: dyslexics = controls

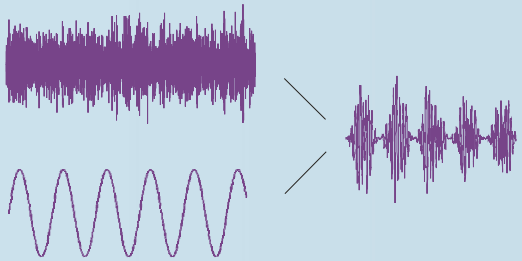
- Slope of speech versus non-speech contrasts
  - Speech: dyslexics = controls
  - Non-speech: dyslexics = controls

Study 2: Auditory steady-state responses (ASSR)



Auditory steady-state responses (ASSR)

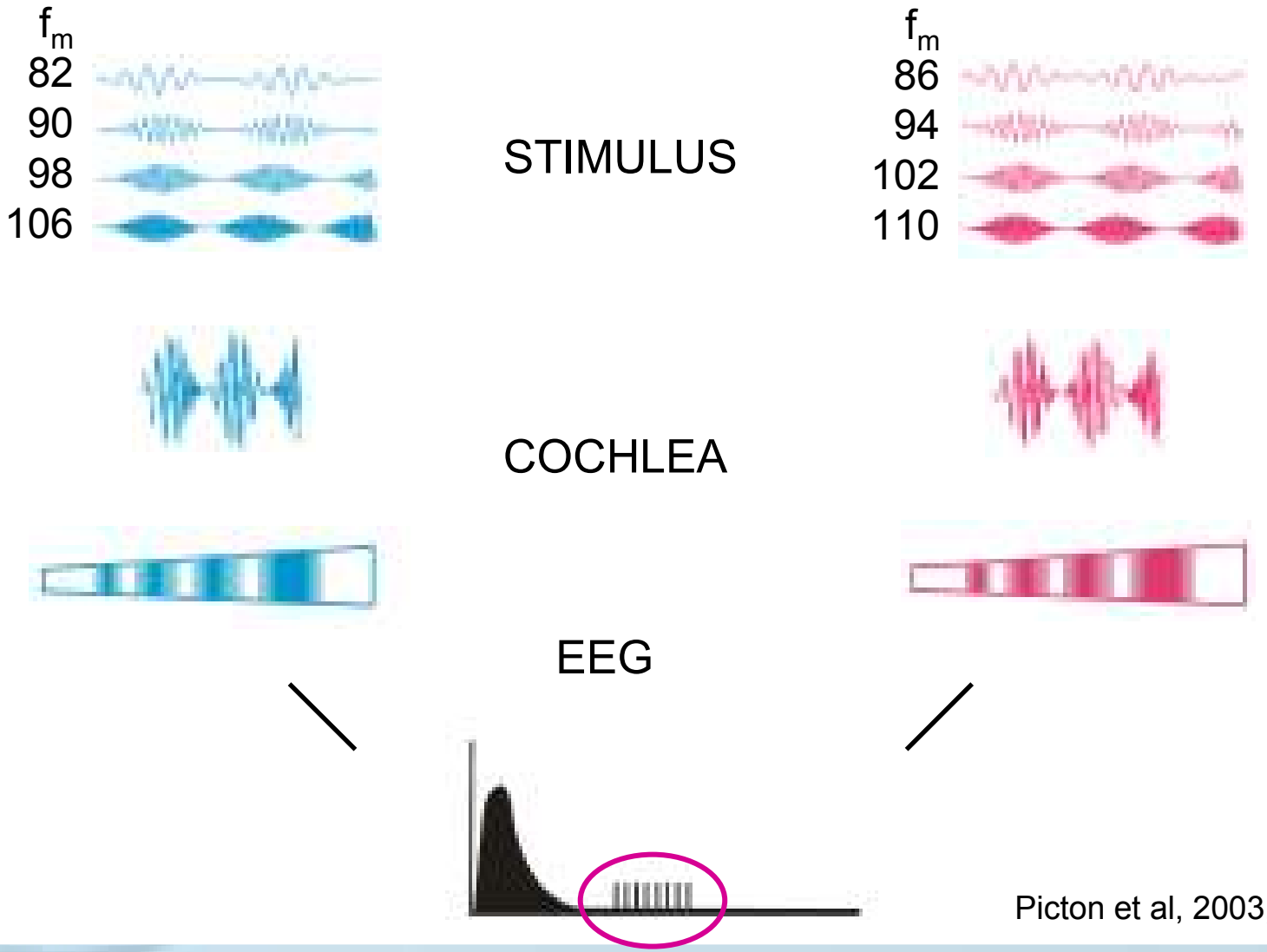
- ASSRs are periodical electrical brain responses, evoked by amplitude modulated signals



- ASSRs have their generators in the brainstem or the cortex, dependent on the rate of amplitude modulation
  - AM 80Hz and higher: brainstem
  - AM 40Hz and lower: important cortical components

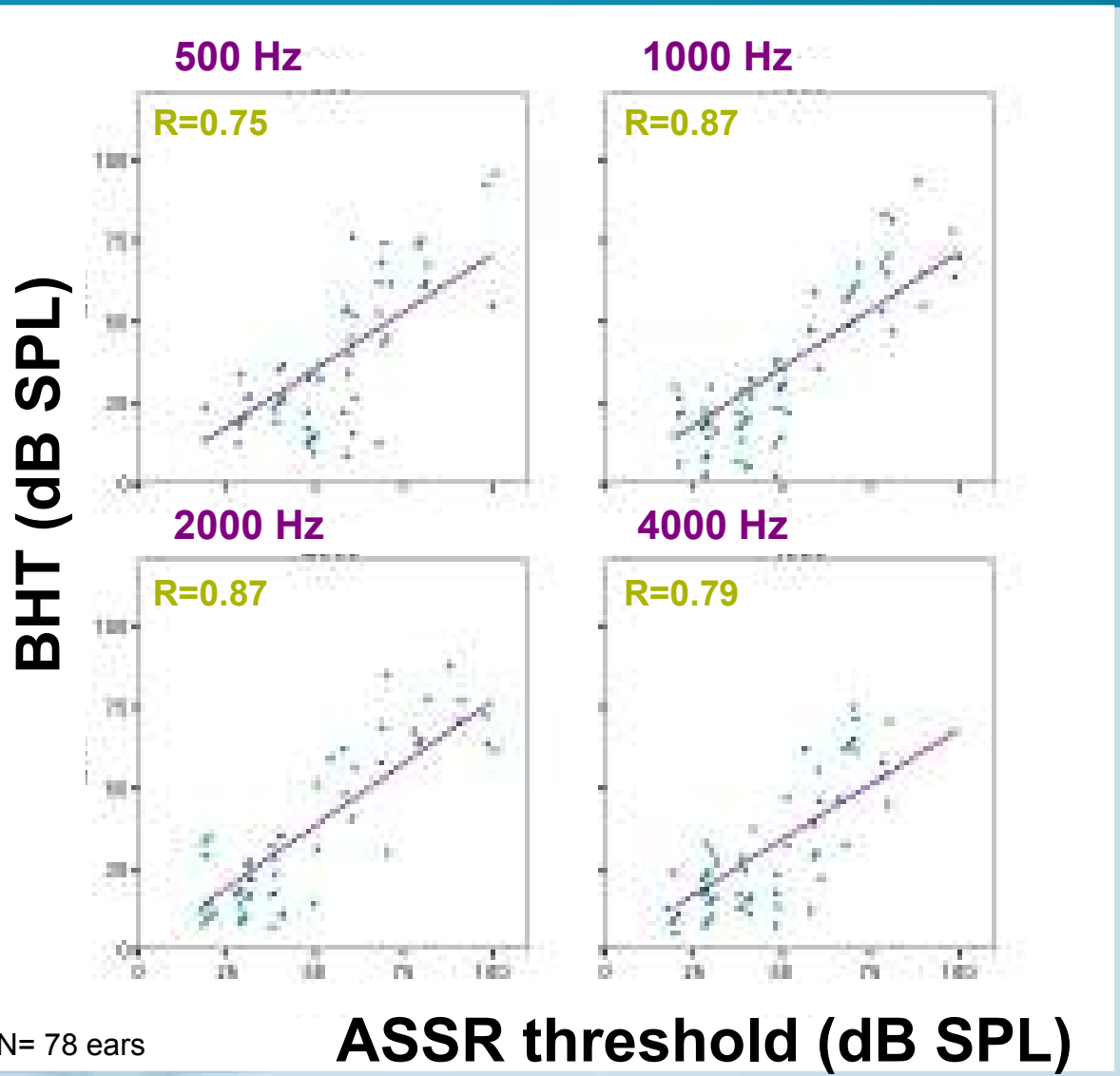
- ASSRs in 4-20Hz modulations: an objective auditory performance measure related to the processing of speech envelope cues

ASSR: Multiple – stimulus



Picton et al, 2003, IJA

ASSR vs Behavioral hresholds in children



N= 78 ears

Overall R=0.83

Time between both measurements: median of 17 mo

Mean difference

16 dB ± 13 dB

Luts et al, 2006, ANO
Alaerts et al, 2009, ANO

Aim of the study

- Aim: Auditory temporal envelope processing deficit in dyslexia?

1. Neurophysiological (ASSR) and/or psychophysical?

2. In optimal or degraded listening conditions?
   → subtle deficit?

3. At what level of auditory processing?
   → brainstem or cortex?

Subjects

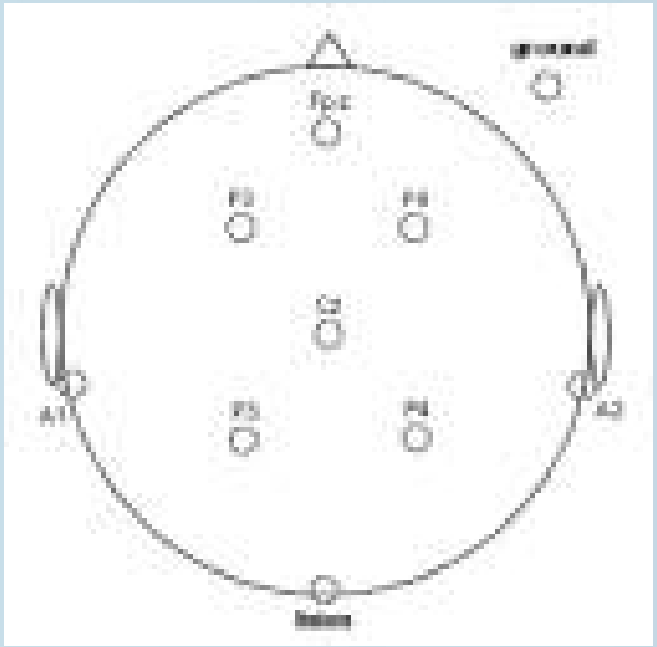
- Supplementary subject criteria:
  - right handed
  - tested at right ear: normal hearing thresholds
  - test-retest differences < 10dB SNR on all electrodes
  - control group: selection word/nonword reading
    - excl: controls < 5th percentile of normal distribution of controls
  - 24 normally reading + 29 dyslexic adults
- Psychophysical AM detection
  - 3 alternative forced choice task (3AFC)
  - amplitude modulated speech-weighted noise: 20 Hz, variation modulation depth
  - monaural presentation at 70 dB SPL

Auditory steady-state responses (ASSR)

- Multichannel ASSR
  - 8 channels
  - 2 x 5 min: test + retest
  - Signal-to-noise ratio (SNR) and Coherence

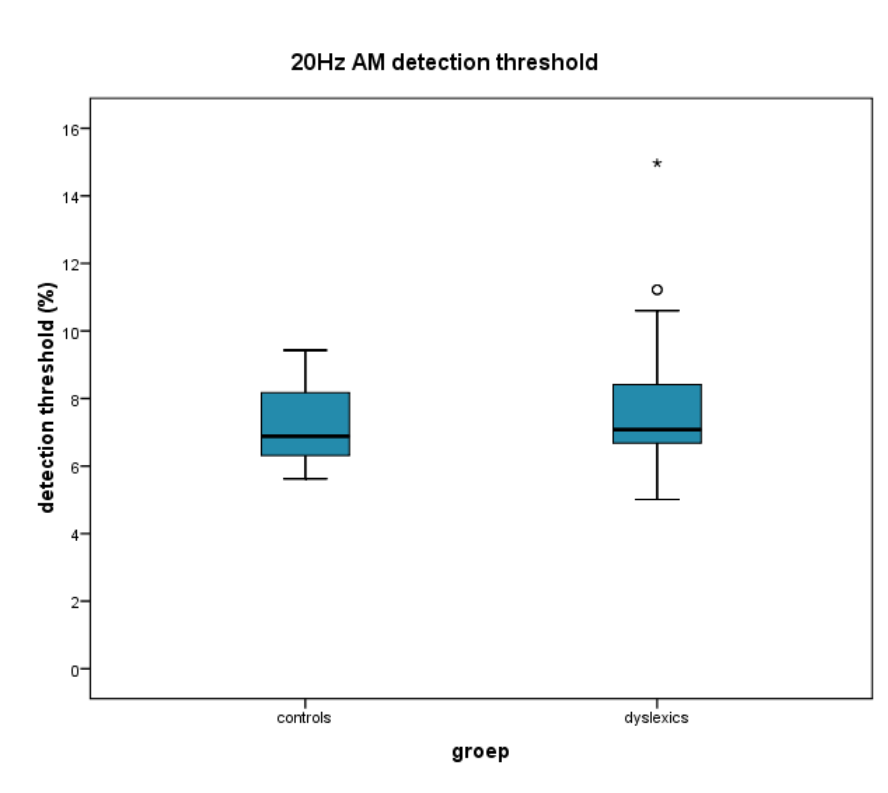
$$Cnk(f) = |Wnk(f)|^2 / Wnn(f)\, Wkk(f)$$

  - stimuli
    - AM speech-weighted noise:
      - 80Hz 100%AM
      - 20Hz 100%AM
      - 20Hz 40%AM
    - monaural presentation at 70 dB SPL



Psychophysical results

- Psychophysical 20Hz AM detection



- no difference between control and dyslexic subjects *(p > 0.1)*

- AM detection threshold
  - controls: 7.2% *(SD: 1.2%)*
  - dyslexics: 7.8% *(SD: 2.1%)*

Results: ASSR

Optimal or degraded listening conditions?

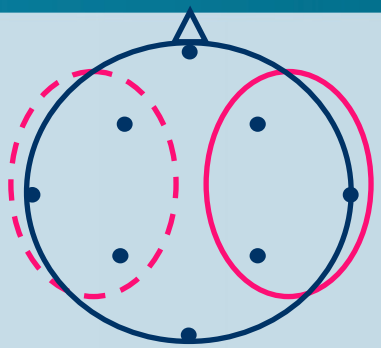
- 20Hz 100%AM - 20Hz 40%AM

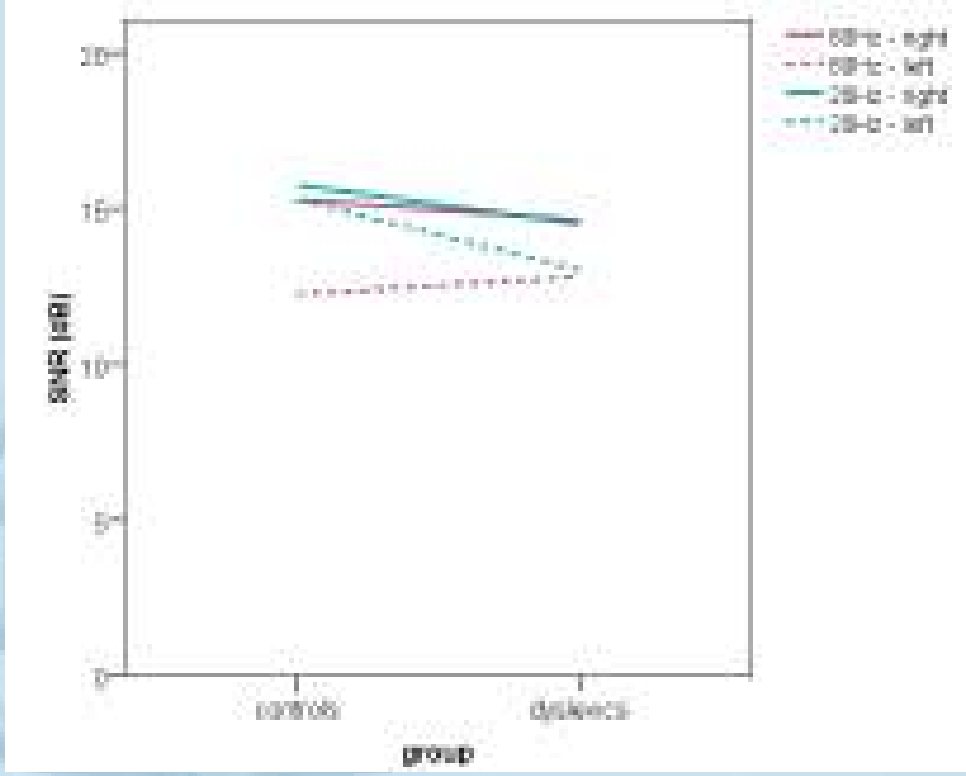
- SNR 100%AM > SNR 40%AM *(3.9dB; p<.001)*
- no difference between control and dyslexic subjects *(p > 0.1)*

Results: ASSR

Brainstem or cortex?

- 80Hz 100%AM – 20Hz 100%AM



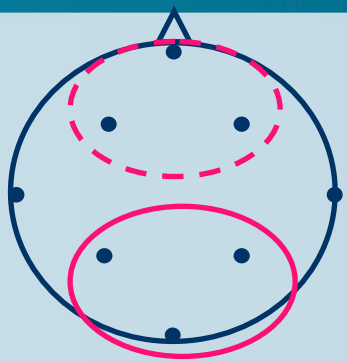


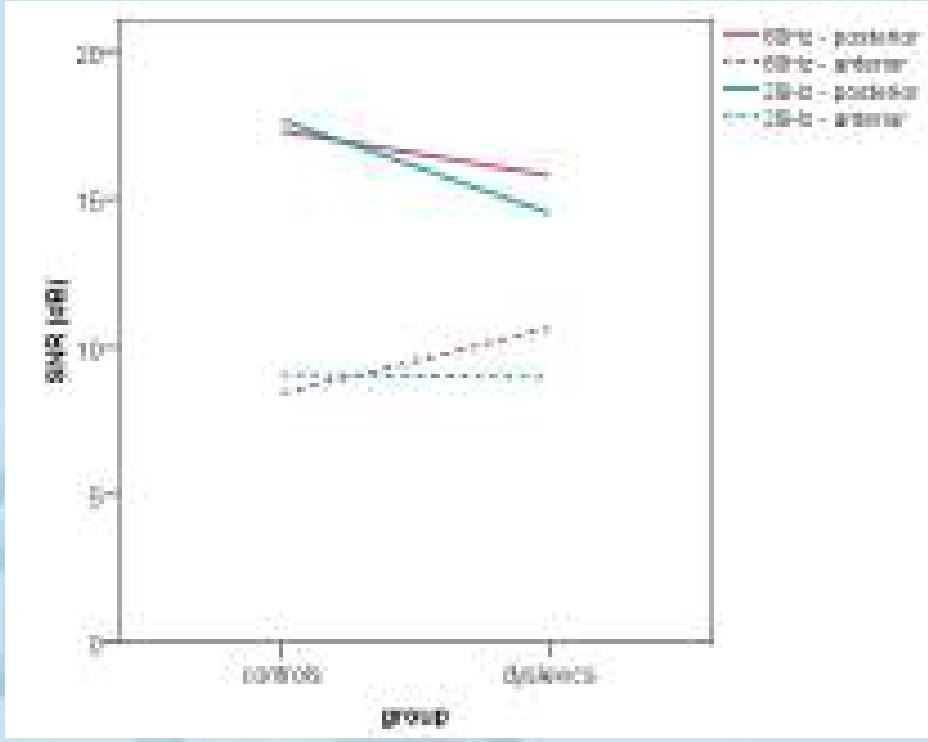
- left-right comparison:
  - 80Hz100% AM
    - right > left *(2.4dB; p<.001)*
  - 20Hz100% AM
    - right > left *(1.0dB; p<.025)*

Results: ASSR

Brainstem or cortex?

- 80Hz 100%AM – 20Hz 100%AM



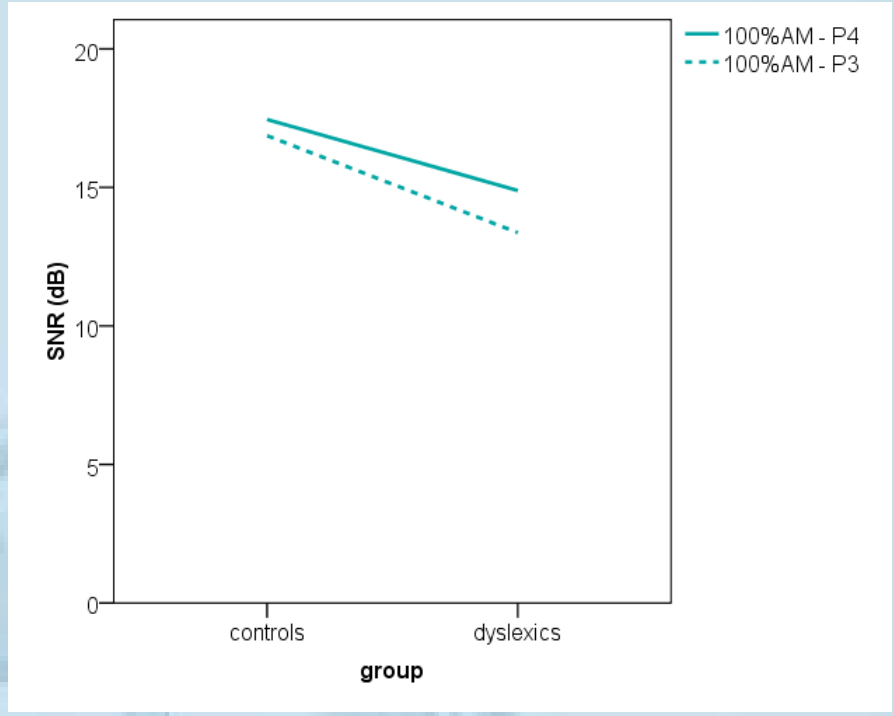


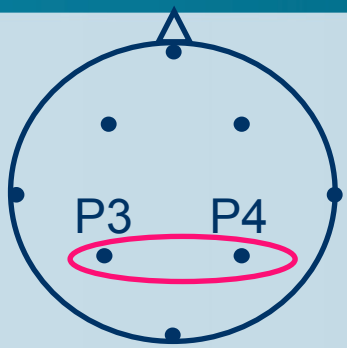
- anterior-posterior comparison:
  - 80Hz 100% AM
    - posterior > anterior
      (7.0dB; p<.001)
  - 20Hz 100% AM
    - posterior > anterior
      (7.1dB; p<.001)
    - controls higher response than dyslexics on posterior electrodes
      (3.1 dB; p<.025)

Results: ASSR

Brainstem or cortex?

- 20Hz 100%AM





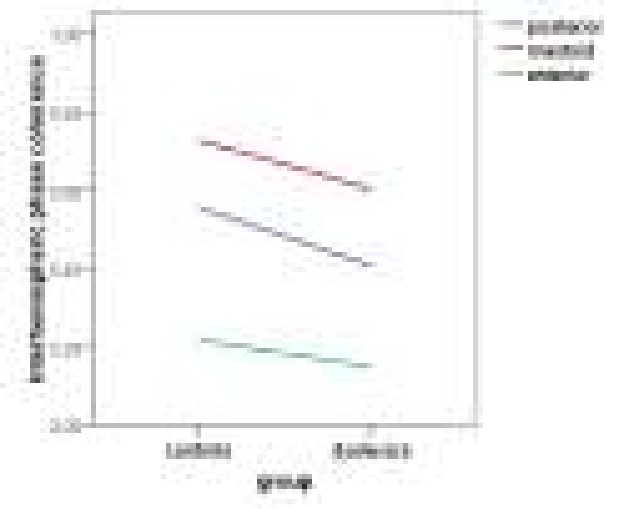
- P3-P4 comparison:
  - 20Hz 100% AM

  - right > left *(1.1dB; p<.05)*

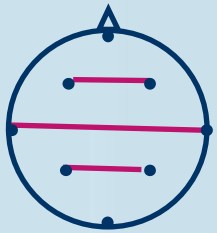
  - controls higher response than dyslexics on both electrodes *(3.0dB; p=0.035)*

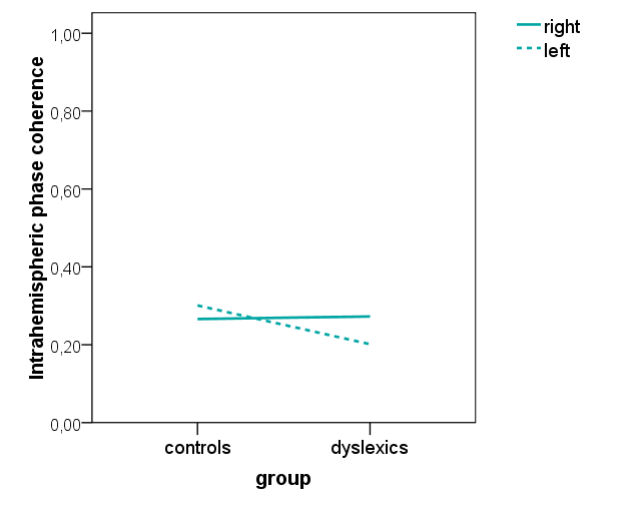
Results: ASSR

- Phase coherence: 20Hz 100% AM

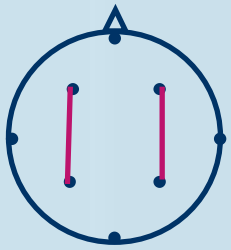


- Interhemispheric coherence
  - controls larger coherence than dyslexics *(diff: 0.1; p<.01)*



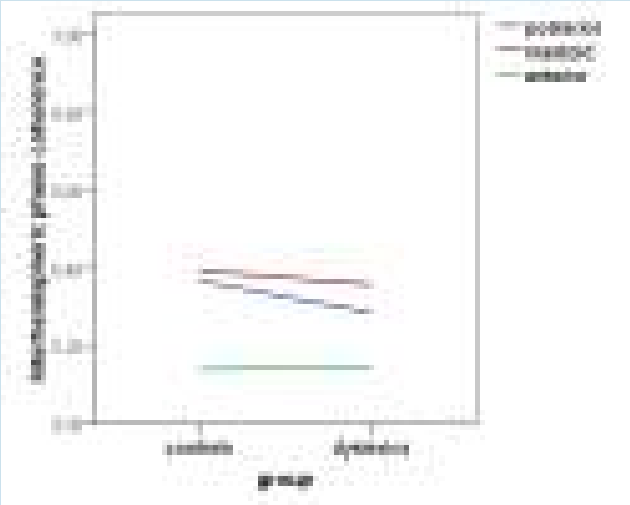


- Intrahemispheric coherence
  - controls: left = right *(diff: 0.04; p>.35)*
  - dyslexics: left < right *(diff: 0.07; p=.05)*

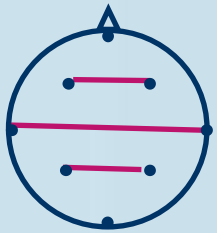


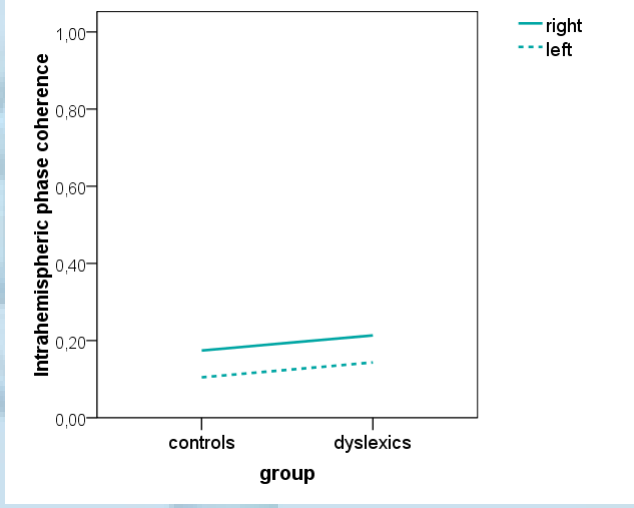
Results: ASSR

- Phase coherence: 80Hz 100% AM

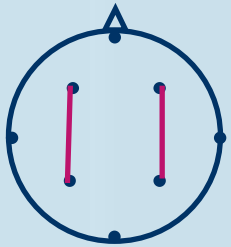


- Interhemispheric coherence
  - controls = dyslexics *(diff: 0.04; p>.30)*





- Intrahemispheric coherence
  - right > left *(diff: 0.1; p<.01)*
  - controls = dyslexics *(diff: 0.04; p>.30)*

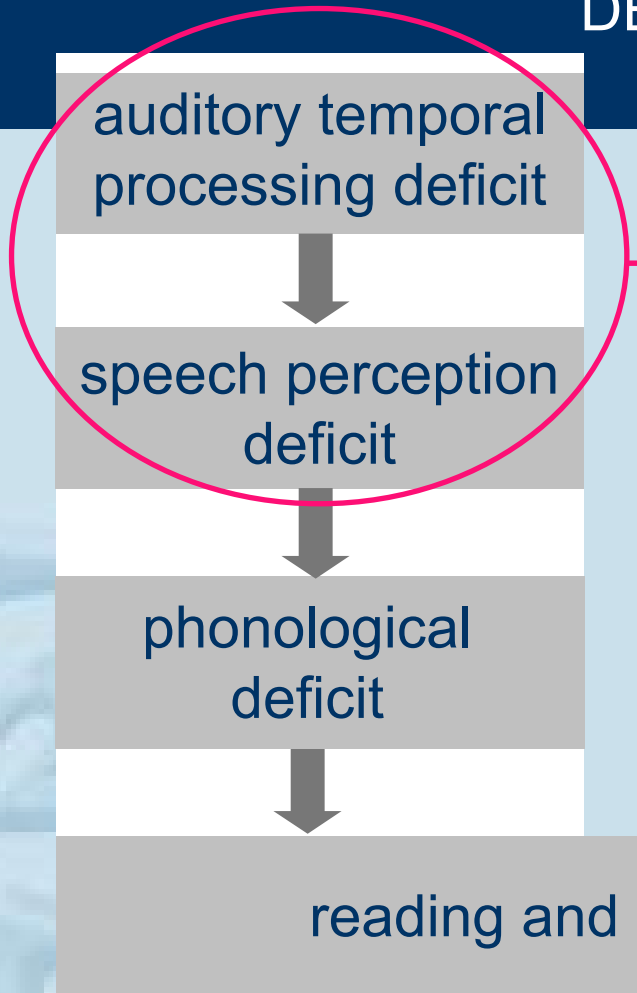


Conclusions: ASSR

- Dyslexic subjects show different processing of amplitude modulated sounds
- Both in optimal as in degraded listening conditions
- At 20 Hz modulation frequencies (not 80 Hz)
  - Difference at cortical level, not peripheral
- Difference only found neurophysiologically
  - Compensation strategies?

General conclusions

GENERAL PERCEPTUAL PROCESSING DEFICIT



Study 1:

- categorical speech perception deficit in dyslexia
- this deficit is not specific for speech, but for the “temporal” characteristics in speech and non-speech

General conclusions

GENERAL PERCEPTUAL PROCESSING DEFICIT

speech perception deficit

phonological deficit

reading and spelling problems

Study 2:

- dyslexics show different processing of AM sounds
- group differences only present at cortical level
- in both optimal as degraded listening conditions

DYSlexia COllaboration Leuven (DYSCO)

Centre for Parenting, Child Welfare and Disabilities, K.U.Leuven, Belgium

Maaike Vandermosten, Sofie Dendache, Bart Boets, Pol Ghesquière

ExpORL, Dept. Neurosciences, K.U.Leuven, Belgium

Hanne Poelmans, Heleen Luts, Jan Wouters

Radiology, UZLeuven, Belgium

Stefan Sunaert

Centre for Applied Hearing Research, DTU Elektro, Denmark

Sébastien Santurette, Torsten Dau