Assessing listening effort (processing load) during speech perception in noise, using the method of pupillometry

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ZUIVEL
GROENTE
RECLAME

An individual's attempts to compensate and communicate optimally require vigilance: a constant effort to hear and pay attention
(Demorest and Erdman, 1986)

Netherlands Longitudinal Study on Hearing (NL-SH) *

Need for Recovery (NfR) (cohort of 1000 employees)

- Degree to which employee recovers from stressful work activities
- Acute, short-term reaction
- Predictor of health complaints and sick-leave in the long term

"It's difficult to concentrate in the hours after working"
"I find it difficult to relax at the end of a working day"

With every dB increase in hearing loss, NfR increased with percent points

Hearing loss & sick-leave in a sample of 210 employees) (Kramer et al., 2006)

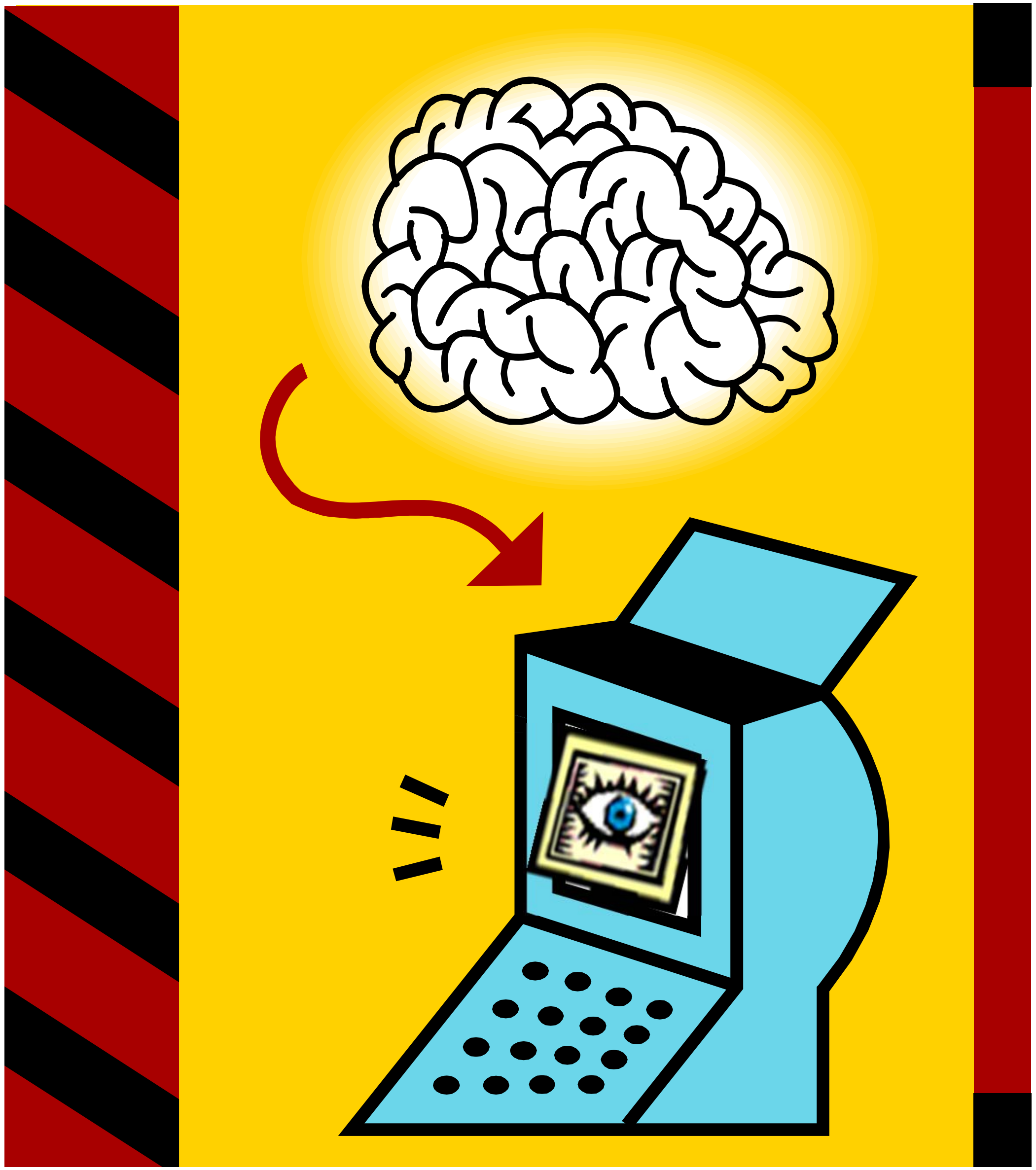
Employees with hearing loss more likely to report sick leave due to mental distress

Self-reported hearing problems & long-term stress (Hasson et al., 2009)

Negative relationship ability to recover from stress & self-reported hearing difficulty

* (Nachtegaal et al., 2009)

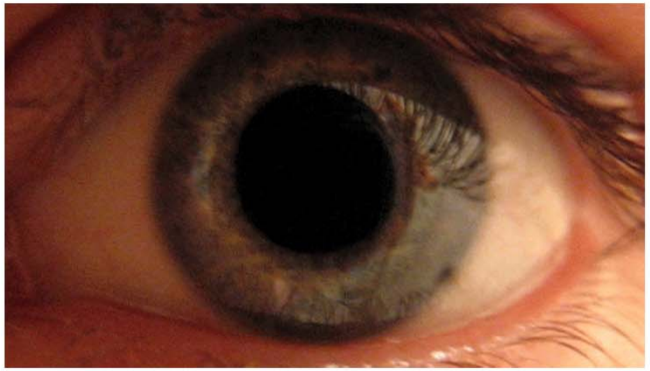
Objective test



Pupillometry

Task evoked pupil dilation is a sensitive measure of cognitive processing load

- Digit list recall (Granholm et al., 1996)
- Recall of lists in reversed order (Taylor, 1981)
- Arithmetic test complexity (Ahern & Beatty, 1981)
- Syntactic complexity sentences (Piquado et al., 2010)



Cognitive processing → frontal activation → reticular formation → pupil dilatation (parasympathetic & sympathetic system) *(Siegle et al., 2004; Recarte et al., 2008)*

How does the pupil respond?

VUmc

Speech Reception Threshold (SRT) in noise test (Plomp & Mimpen, 1979)

Intelligibility level

- Adaptively estimate the Speech-to-Noise Ratio (SNR) required for: 50% correct, 71% correct , 84% correct

Type of background noise

- Stationary noise, fluctuating noise, or interfering speaker

Task demand

- Word identification (in stationary noise, 79% correct)
- Noise-burst-in-stationary-noise detection (79% correct)
- No demand, just listening to noise alone, with/without responding

Test modality

- Auditory versus visual

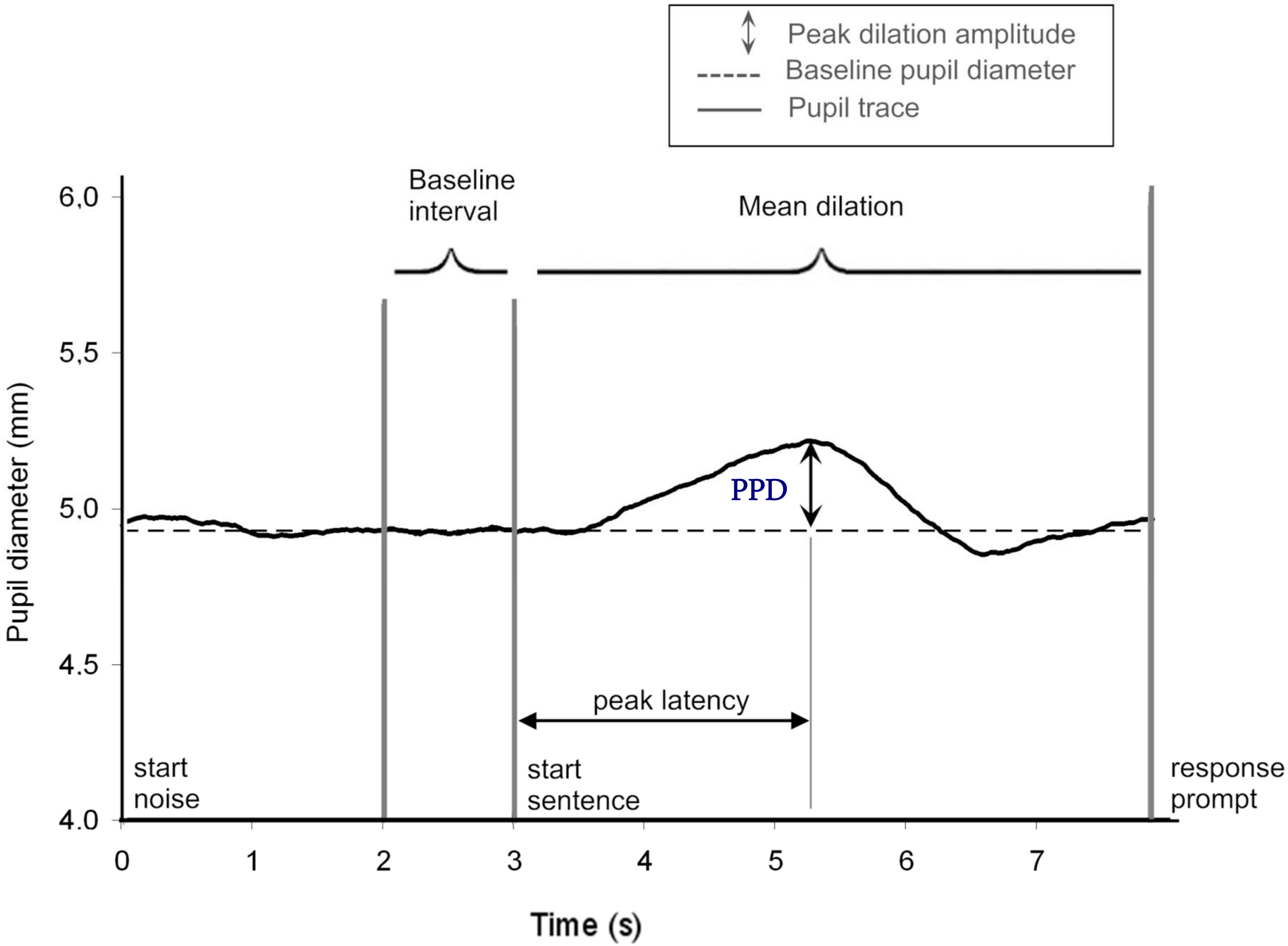
Relation to self-report

- Subjective effort ratings after each test

Hearing impaired vs. Normal hearing

Pupil dilation is recorded during the tests

Pupil response: methods



Overview of the results of 4 published studies:

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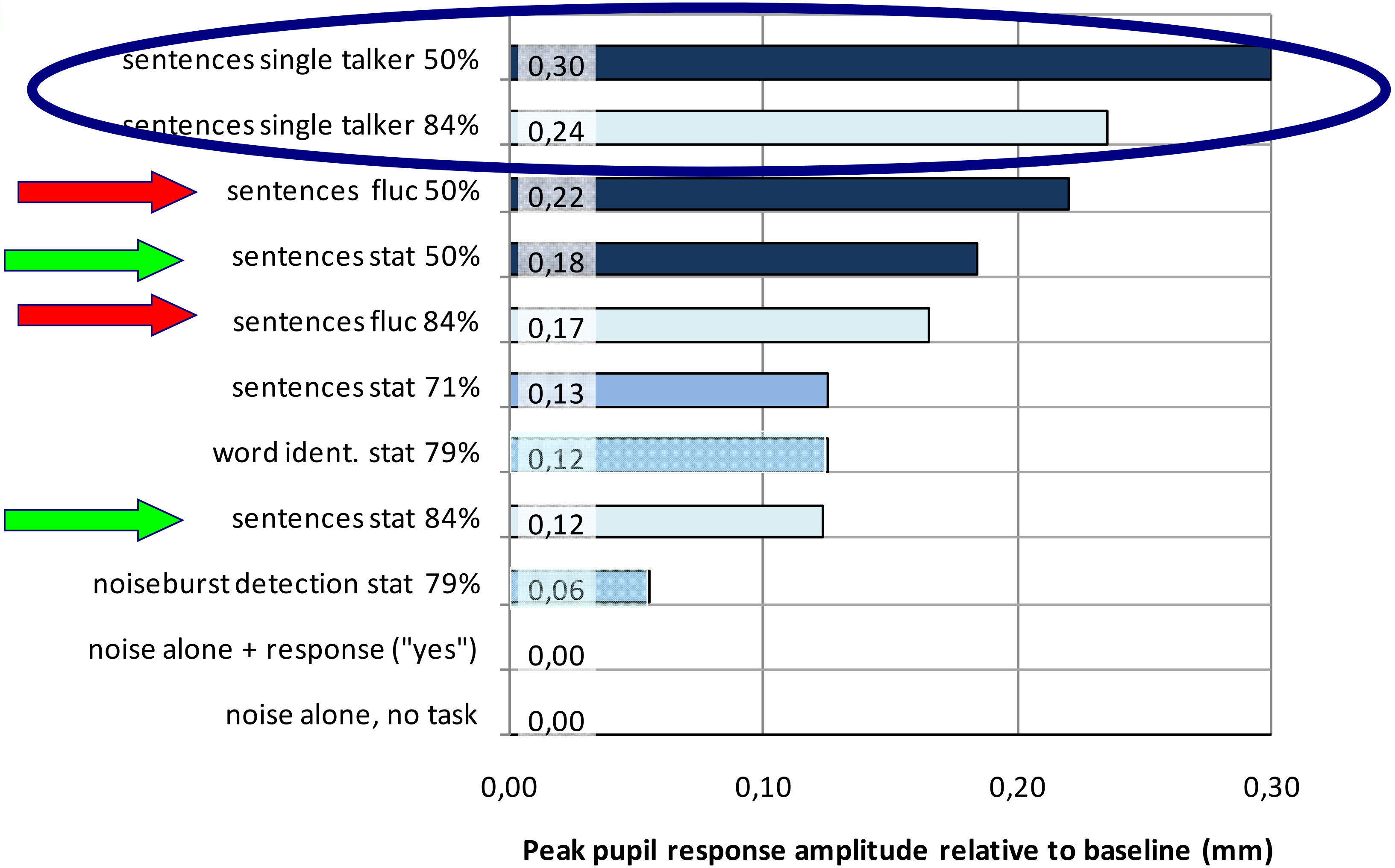
Intelligibility, background noise, task demand

Normally hearing adults

Intelligibility effect



-Zekveld et al. (2010), Ear and Hearing 31

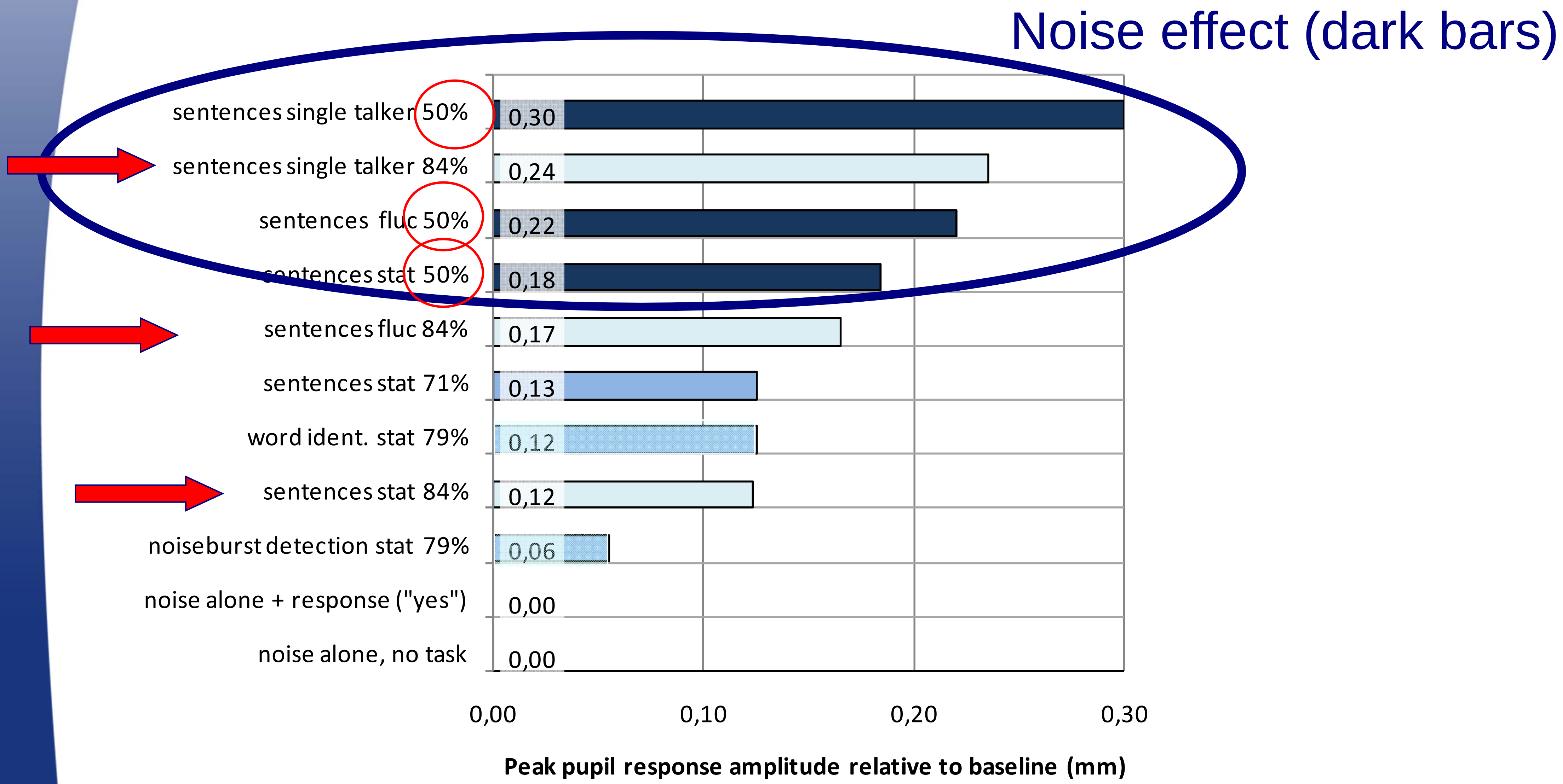
-Zekveld et al. (2011), Ear and Hearing 32

-Kramer et al. (2012), J Lang Cogn Processes, in press

-Koelewijn et al. (2012), Ear and Hearing 33

Overview of the results of 4 published studies

VUmc



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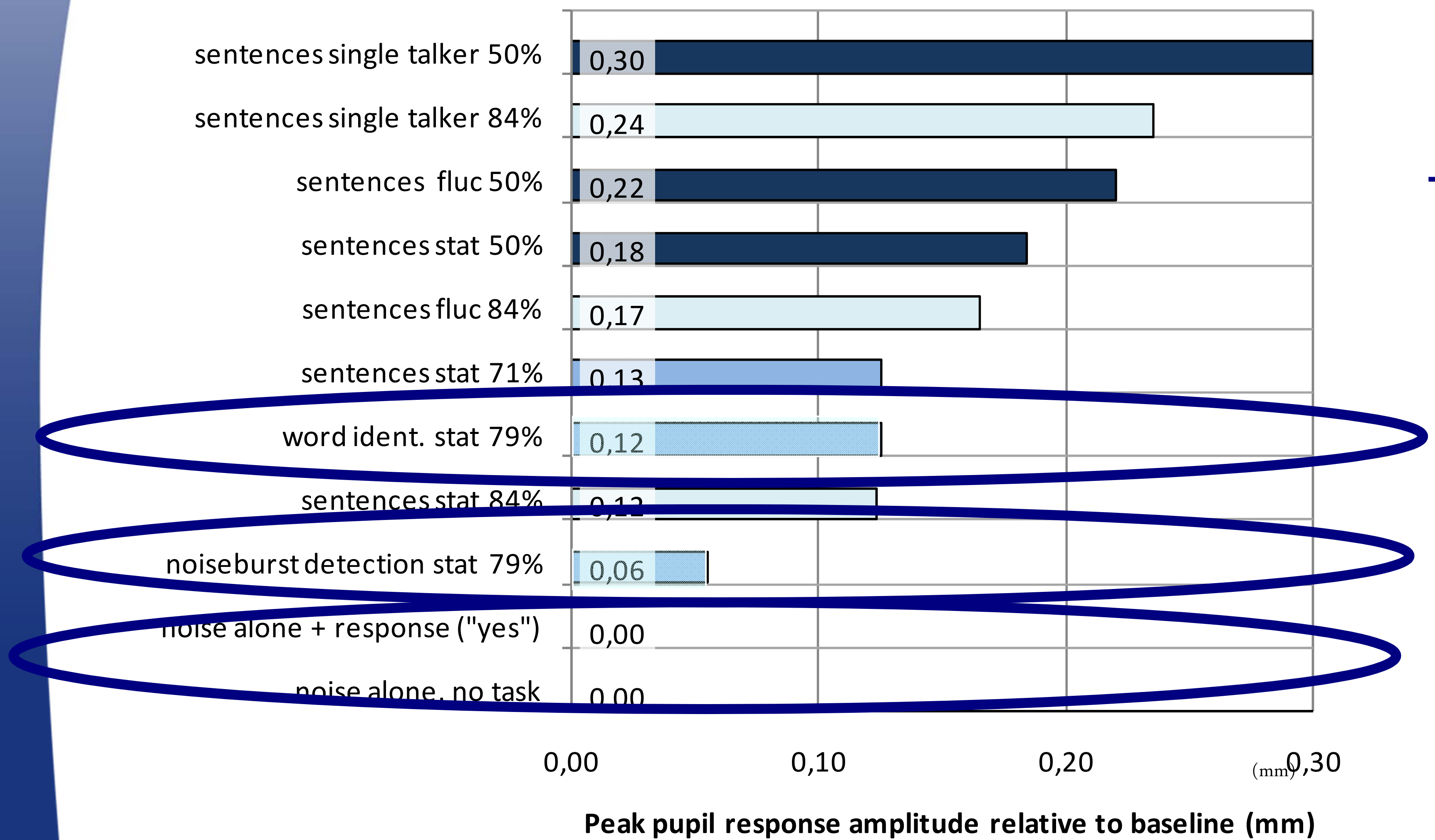
Overview of the results of 4 published studies

VUmc



Task effect

- -Zekveld et al. (2010), Ear and Hearing 31
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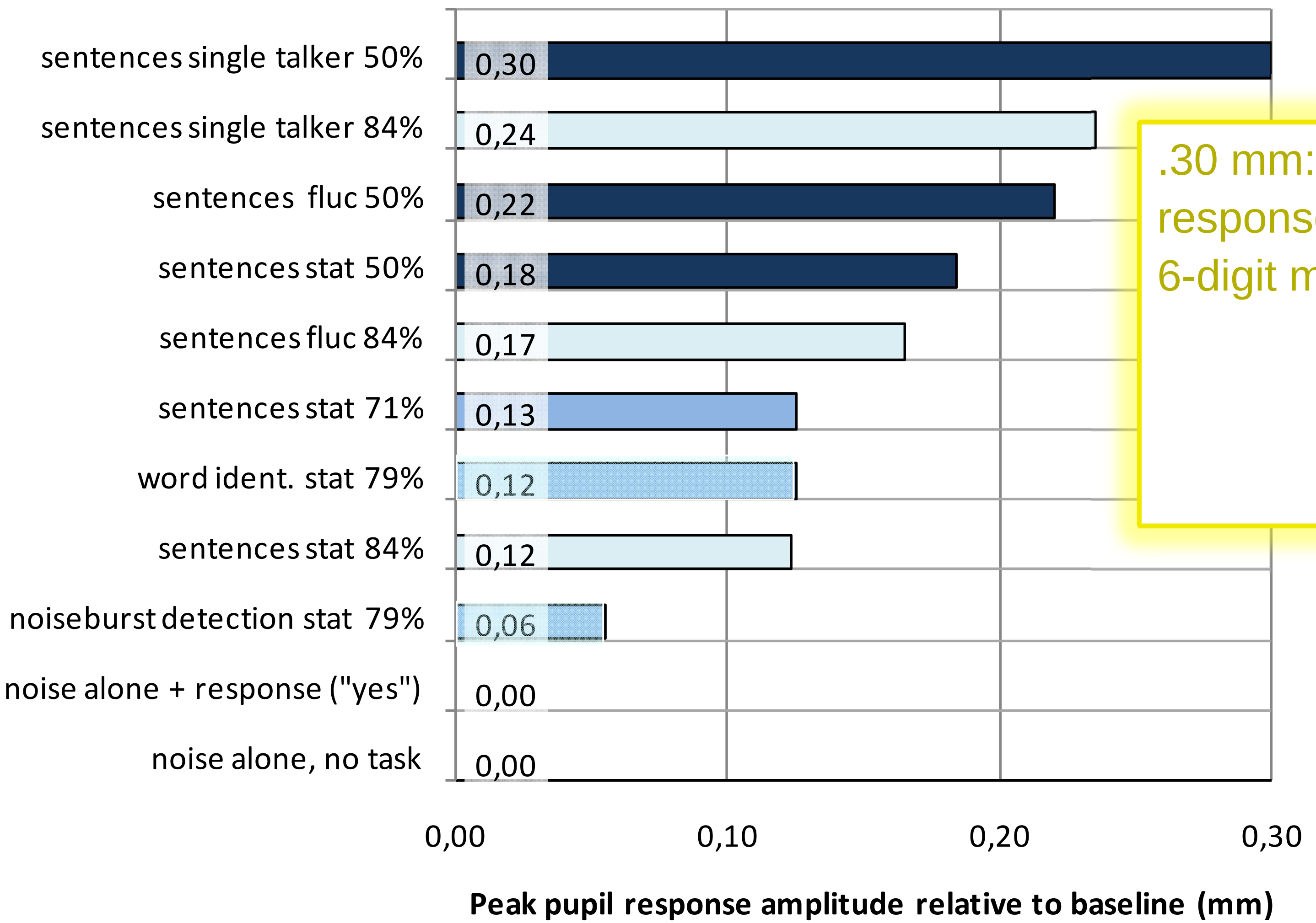
Overview of the results of 4 published studies:



.30 mm: corresponds to pupil response during
6-digit memory task

-Zekveld et al. (2010), Ear and Hearing 31
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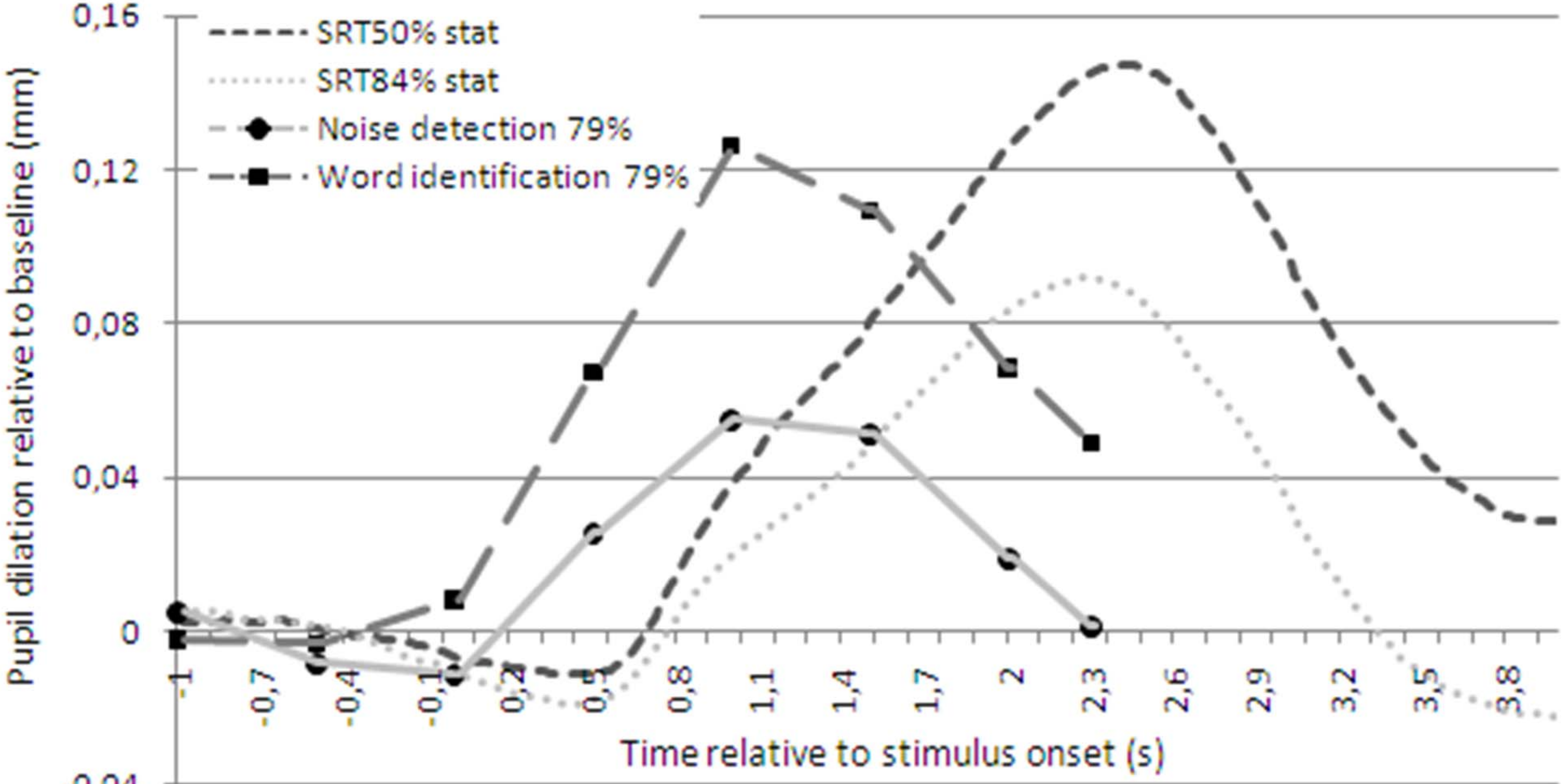
-Koelewijn et al. (2012), Ear and Hearing 33

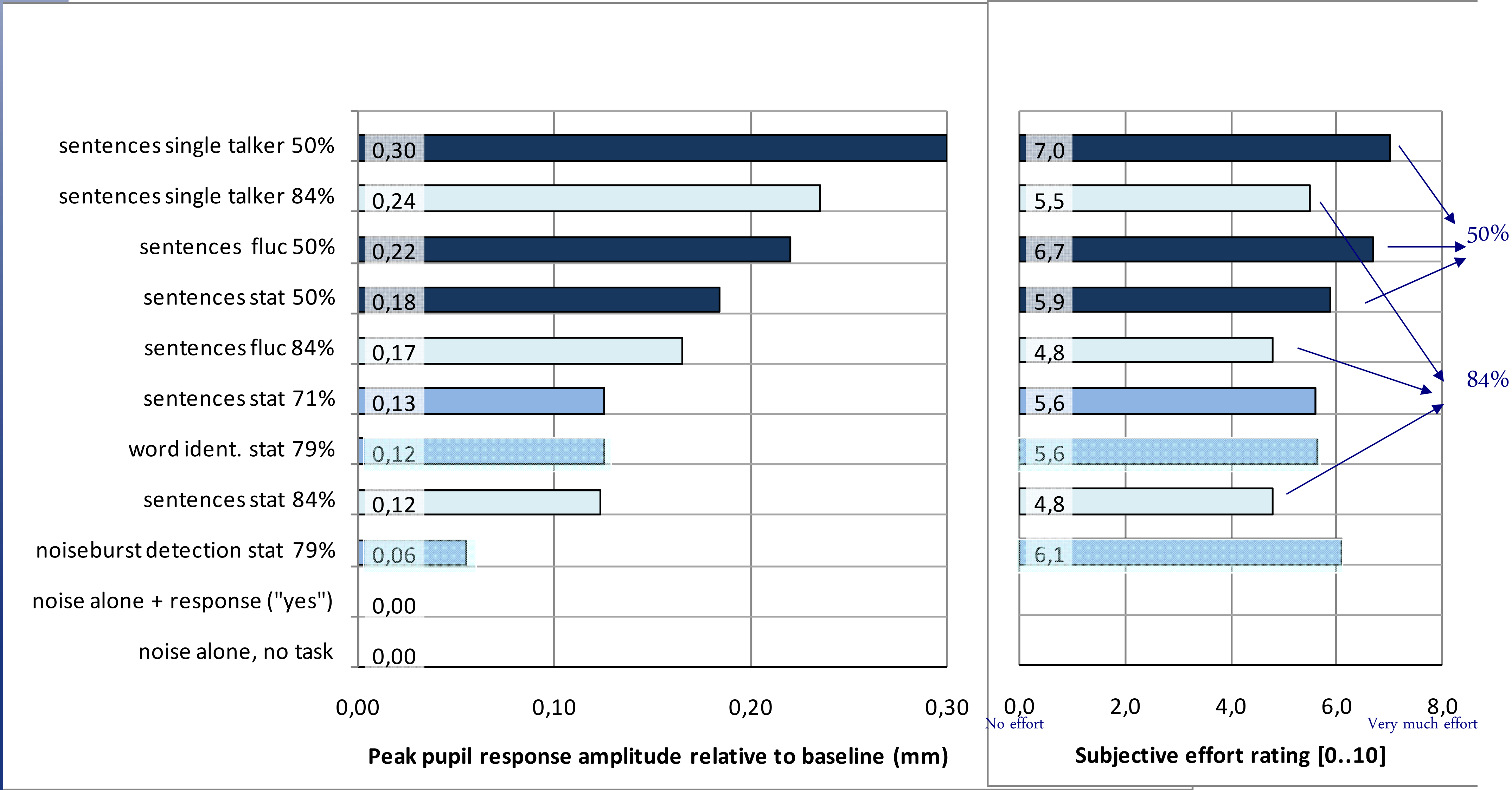
Peak latency (relative to stimulus onset)

VUmc



Mean pupil trace in four listening conditions. SRT = speech reception threshold. Data are from Zekveld et al.2010, 2011 and Koelewijn et al.2012(SRT conditions) and from Kramer et al. In press (noise detection and word identification conditions).

Relation with subjective effort ratings

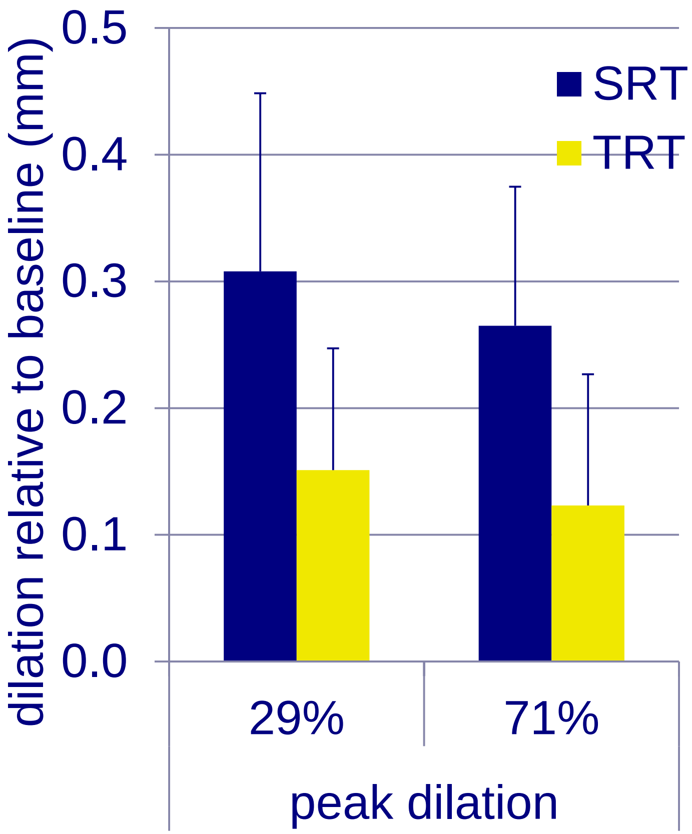


Pattern of results of pupillometric data and effort ratings differ

Relatively small range in effort ratings

Effect of stimulus modality: TRT vs SRT

Text Reception Threshold test
Zekveld et al. (2007)

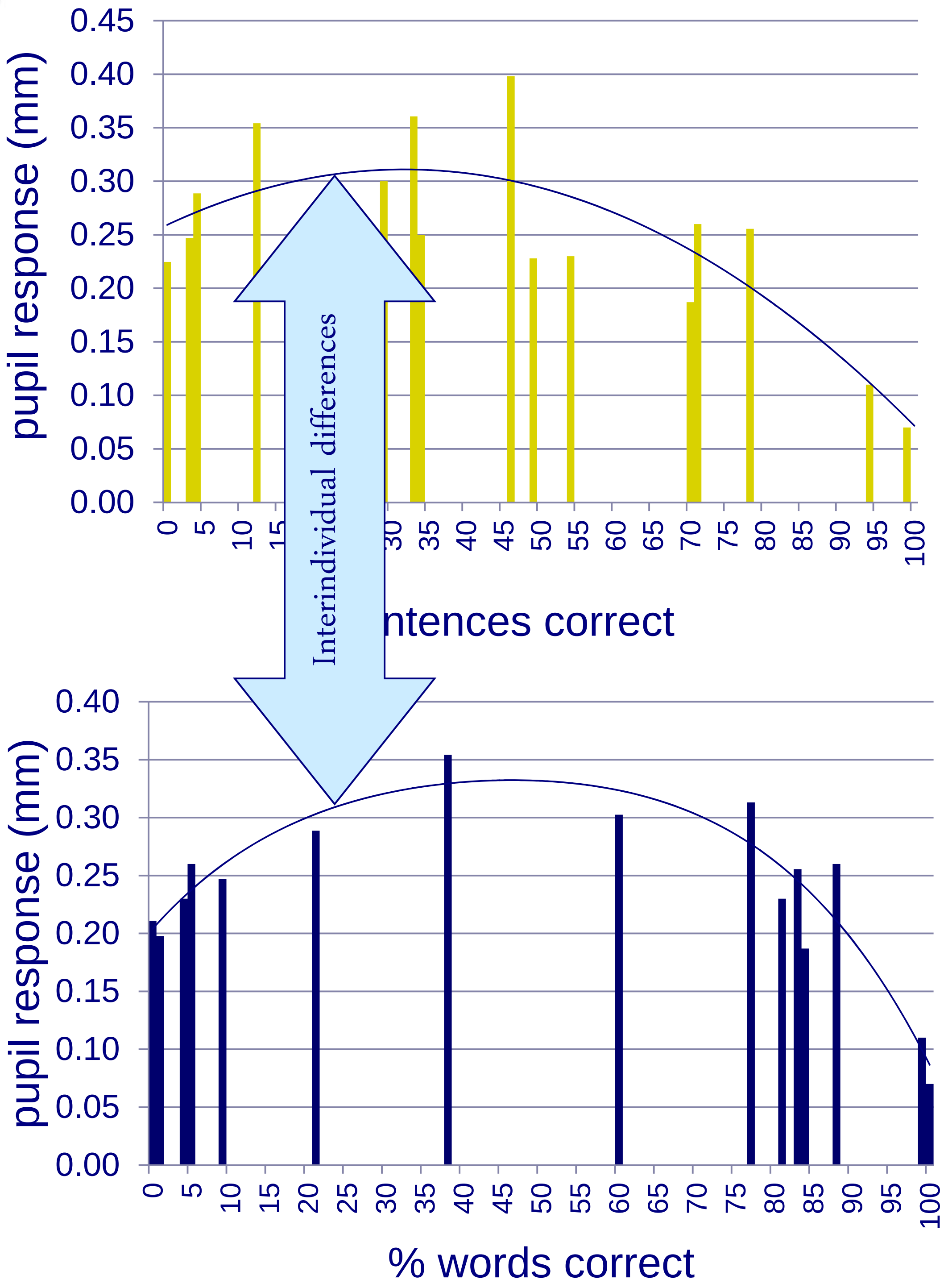


Main effects of test modality ($p < 0.001$)
and difficulty level ($p < 0.05$),
No interaction effect

Zekveld, Festen, Kramer (2012), under review

Similar performance differences in the visual and auditory modality affected the pupil response similarly!

Relation intelligibility and PPD: Inverse U-shape



-Speech masked by single-talker

- < 50% overload conditions?

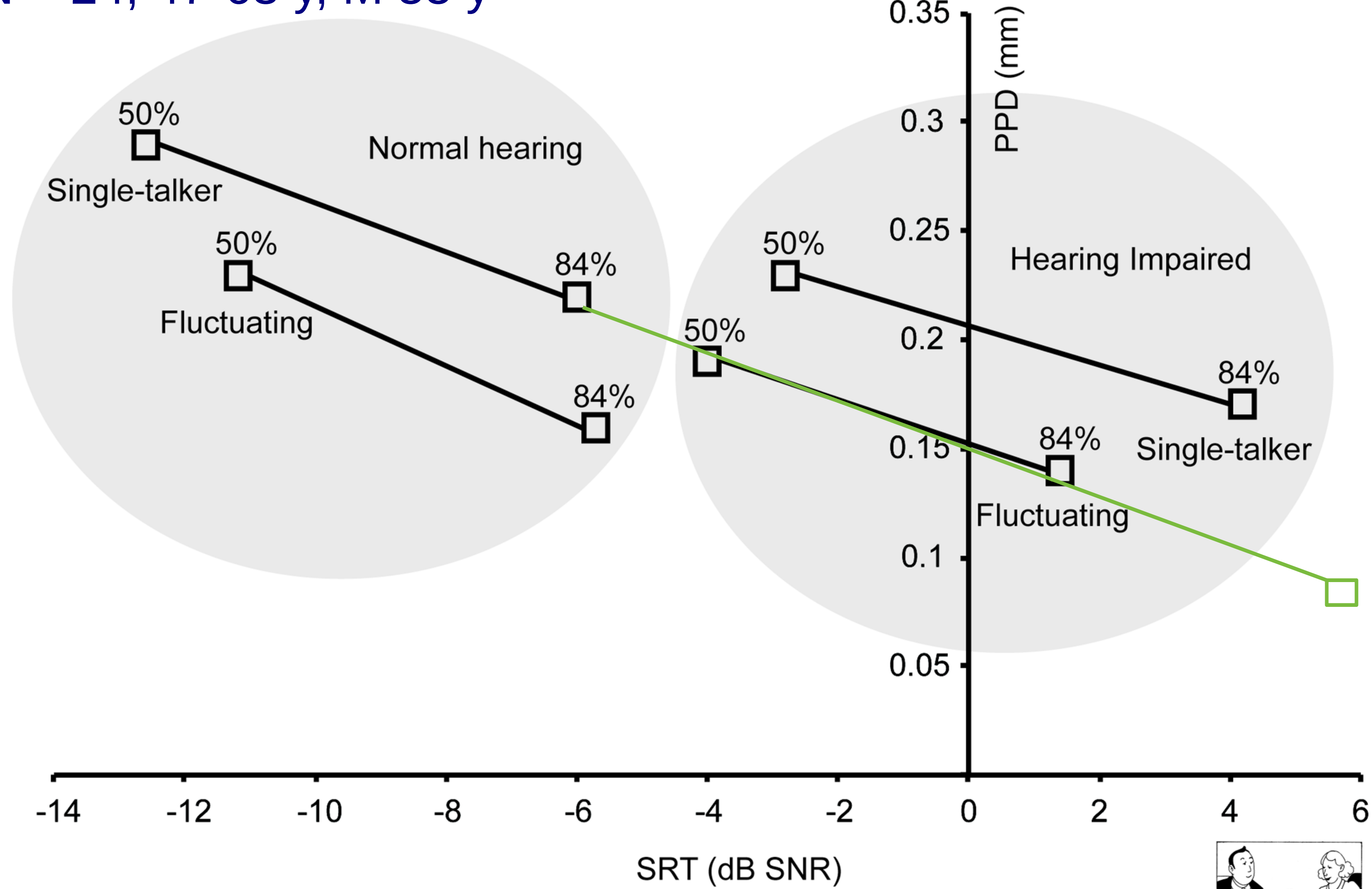
Zekveld et al., (2012) *under review*

Zekveld & Kramer, *under review*

Listening effort as function of SNR

N = 24, 47-63 y, M 55 y

N = 32, 31-76 y, M 59 y



Summary of results

Evidence that the pupil response is a

promising, precise, robust objective measure of processing load

- results have been replicated
- hypotheses have been confirmed

… several questions remain……………….

- Individual differences in the pupil response?

  Partly explained by cognitive abilities

  (Zekveld et al., 2011, 2012; Koelewijn et al., 2012)

Future

- Effects of hearing loss: perhaps strategy differences, habituation?

- Relation with other physiological measures (fMRI)

- Age effects on pupil response?

- Translation of laboratory based pupil response to daily life stress

For more information...

Kramer et al. (1997) Audiology 36, 155-164

Zekveld et al. (2010) Ear and Hearing 31, 480-490

Zekveld et al. (2011) Ear and Hearing, *32*, 498-510.

Kramer, et al. (2012). Lang Cogn Processes, in press (Epub available).

Koelewijn, et al. (2012). Ear and Hearing 32, 291-300.

Koelewijn, et al. (2012). Int J Otolaryng, in press.

Zekveld et al. (2012) INCE conference proceedings

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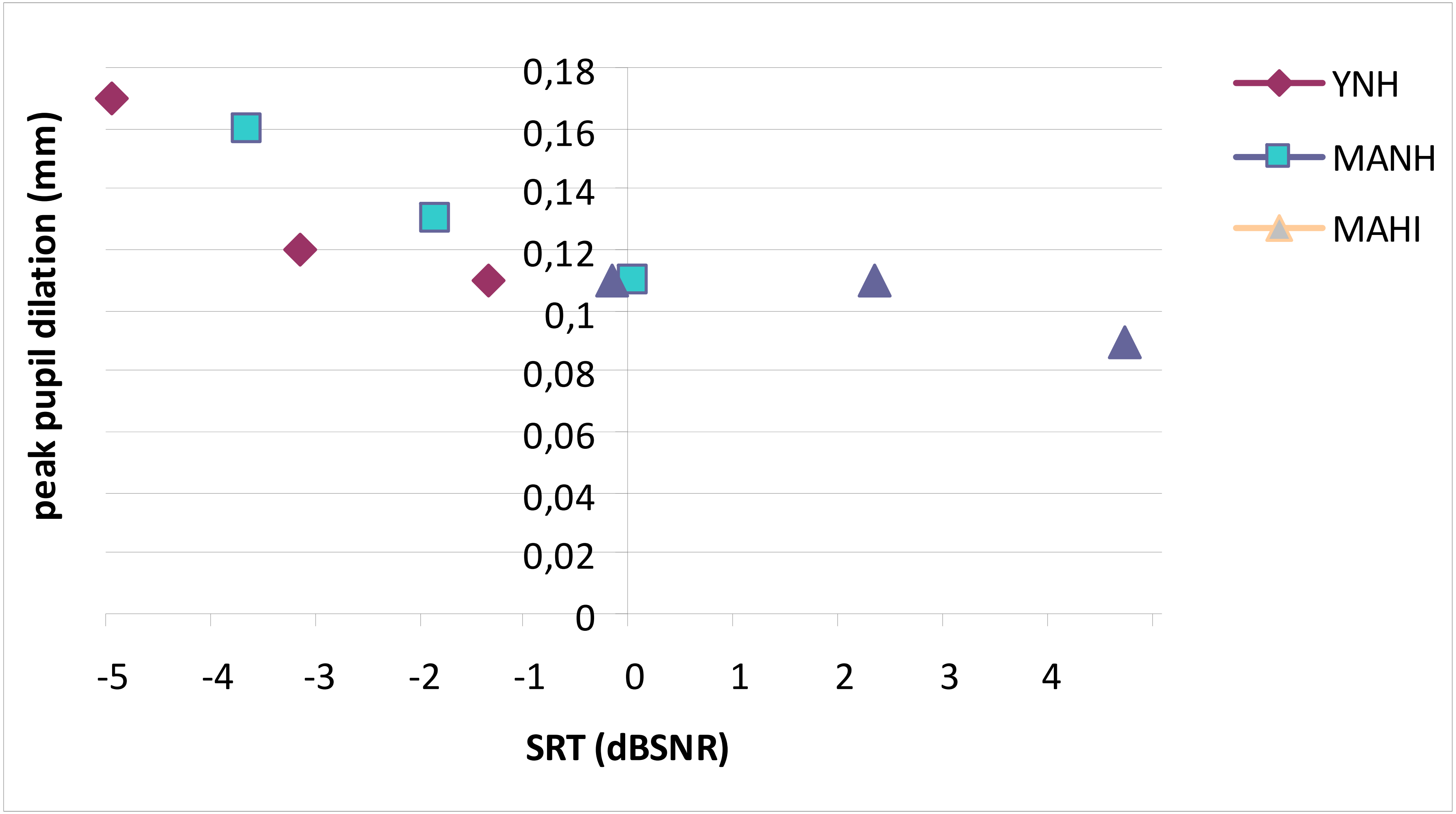
Thank you for your listening effort!


peak pupil dilation (mm)
0,18
0,16
0,14
0,12
0,1
0,08
0,06
0,04
0,02
0
-5
-4
-3
-2
-1
0
1
2
3
4
SRT (dBSNR)
YNH
MANH
MAHI