

Attention Mobilization as a Modulator of Listening Effort

Evidence from Pupillometry

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¹Institute for Systems Research

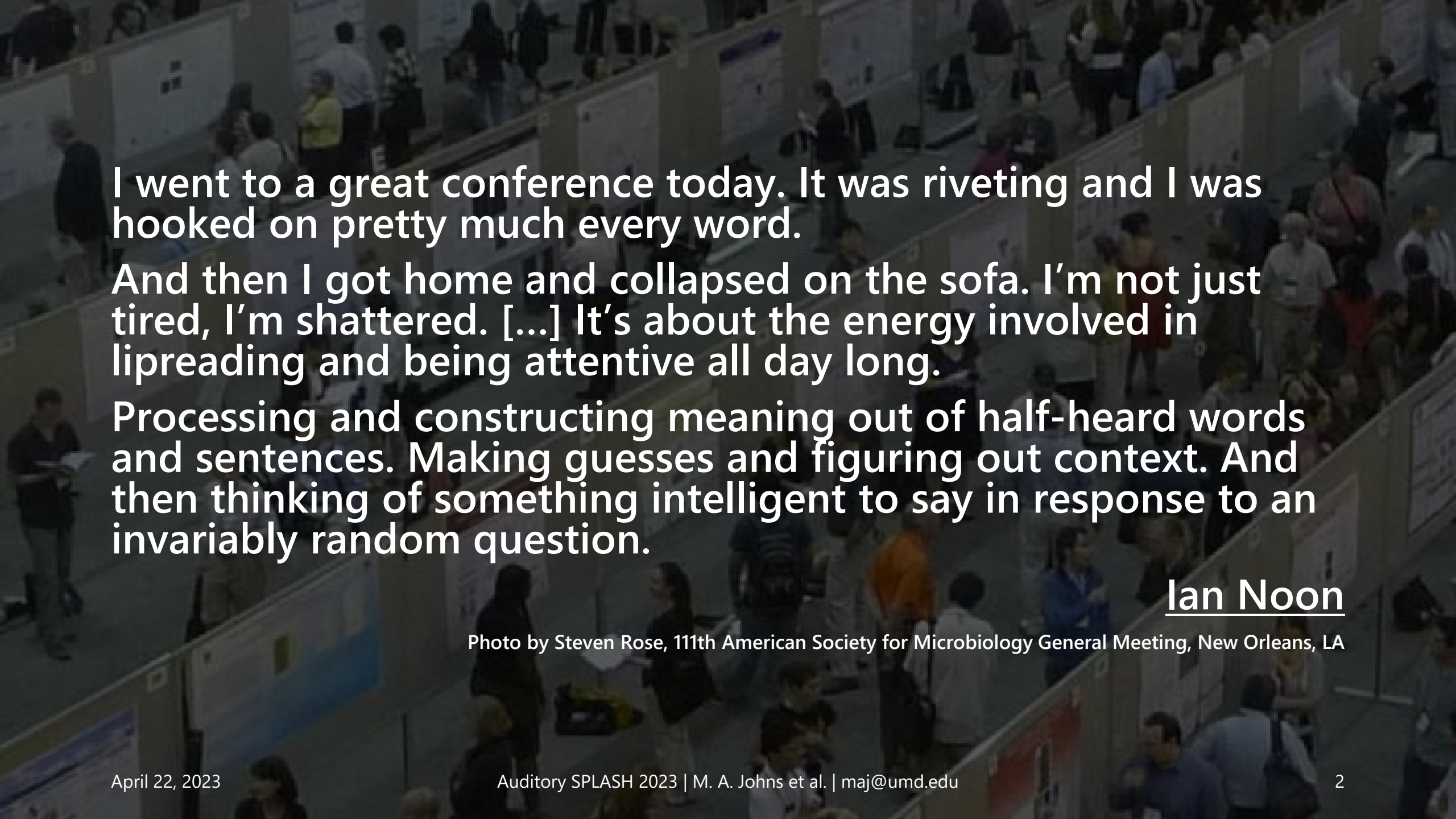
²Electrical and Computer Engineering

³Hearing and Speech Sciences

⁴



Walter Reed
National Military
Medical Center



I went to a great conference today. It was riveting and I was hooked on pretty much every word.

And then I got home and collapsed on the sofa. I'm not just tired, I'm shattered. [...] It's about the energy involved in lipreading and being attentive all day long.

Processing and constructing meaning out of half-heard words and sentences. Making guesses and figuring out context. And then thinking of something intelligent to say in response to an invariably random question.

Ian Noon

Photo by Steven Rose, 111th American Society for Microbiology General Meeting, New Orleans, LA

Understanding speech is difficult, especially in noisy contexts.



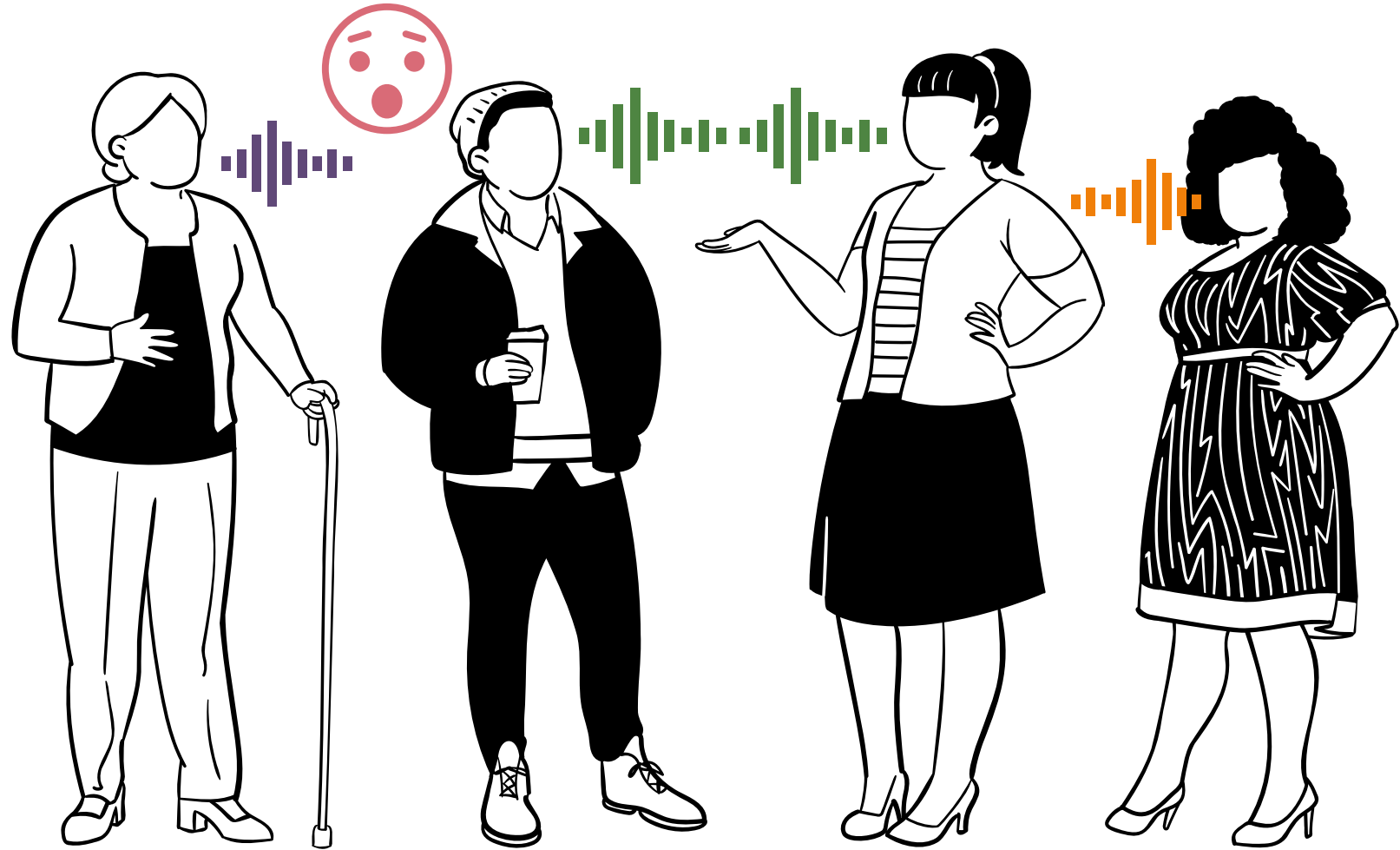
Alain et al., 2018; Killion et al., 2004; Zekveld et al., 2010

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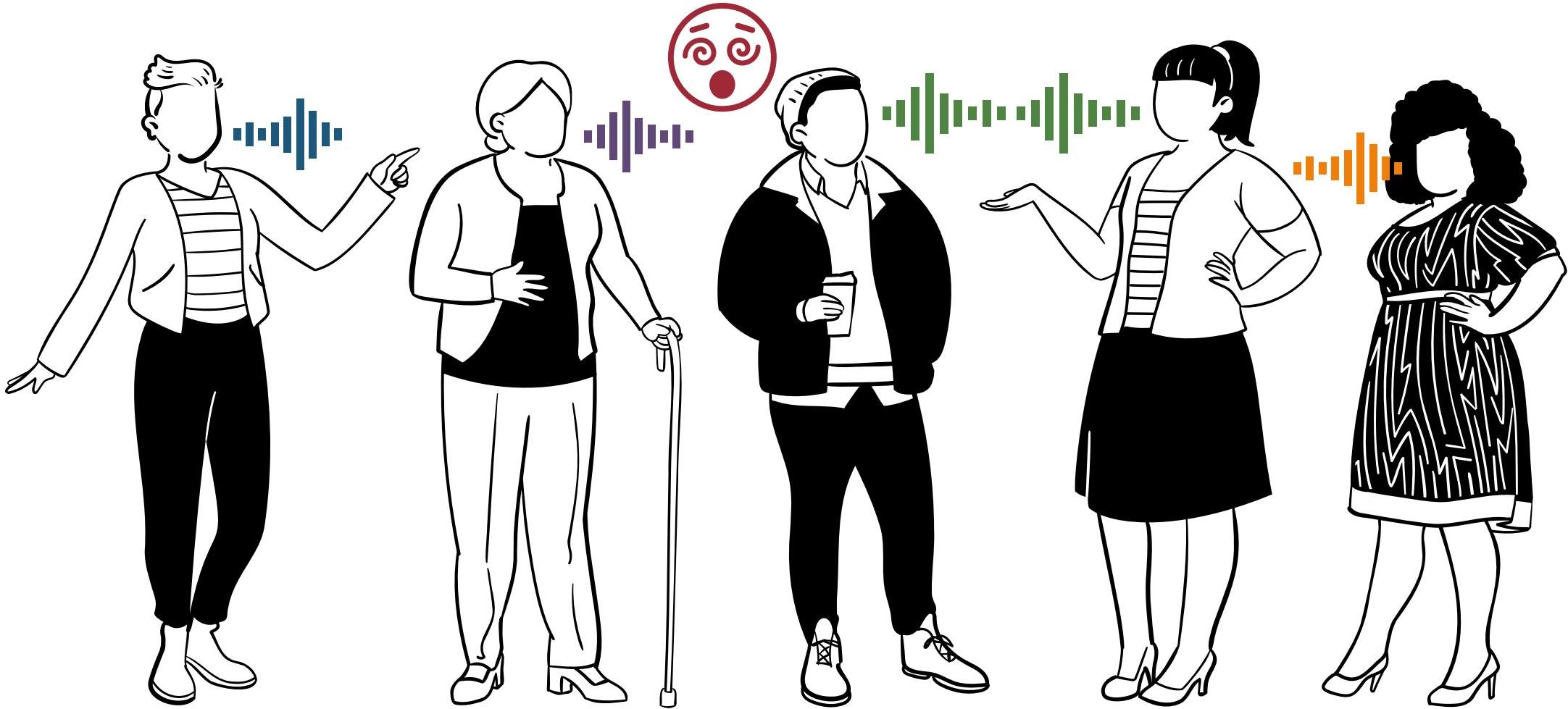
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Understanding speech is difficult, especially when sustained.

Winn, 2023

Jabberwocky, Lewis Carroll



'twas brillig, and the slithy toves
did gyre and gimble in the wabe:
all mimsy were the borogroves,
and the mome raths outgrabe.

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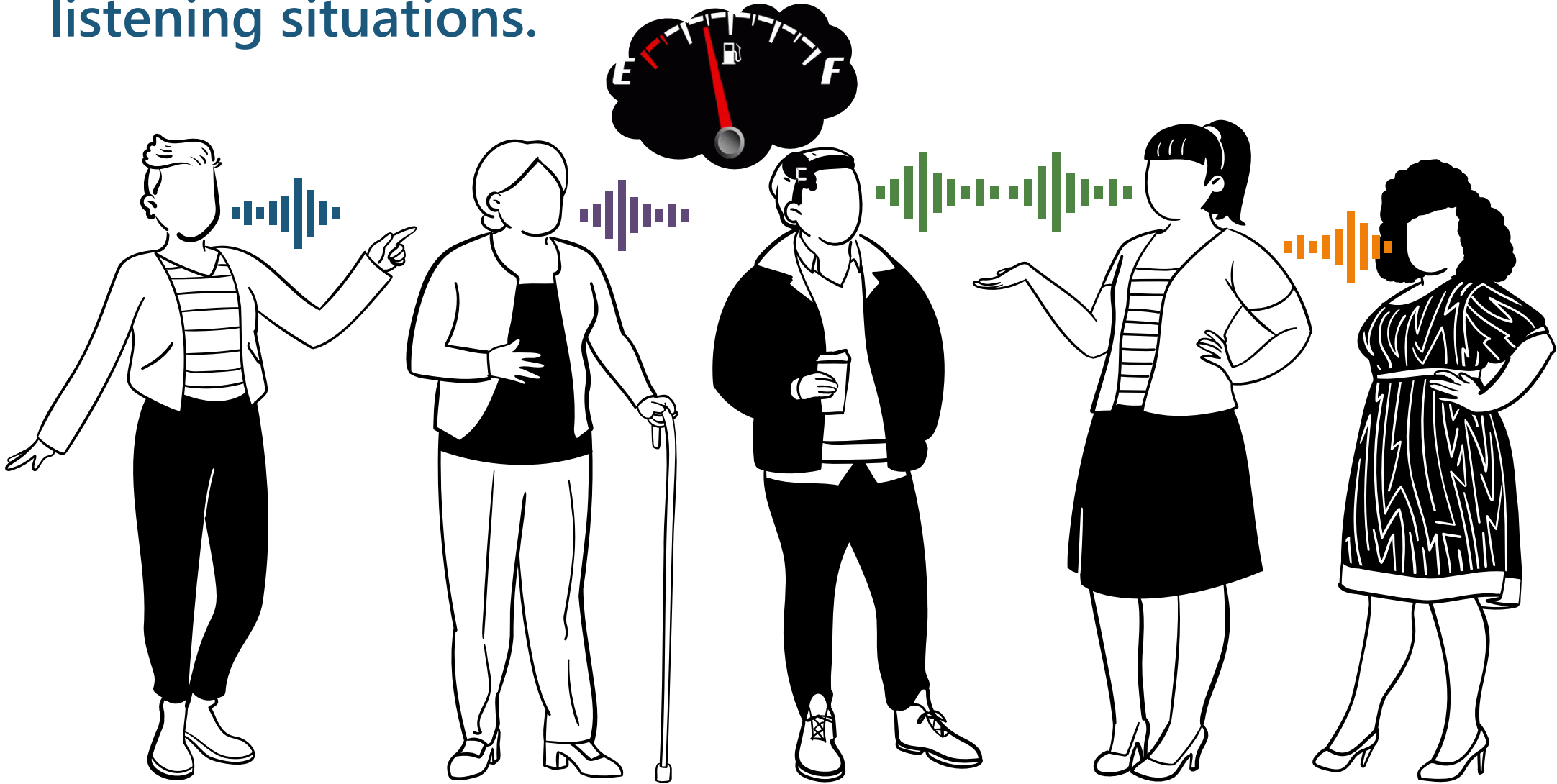
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Listeners have limited cognitive resources to handle difficult listening situations.



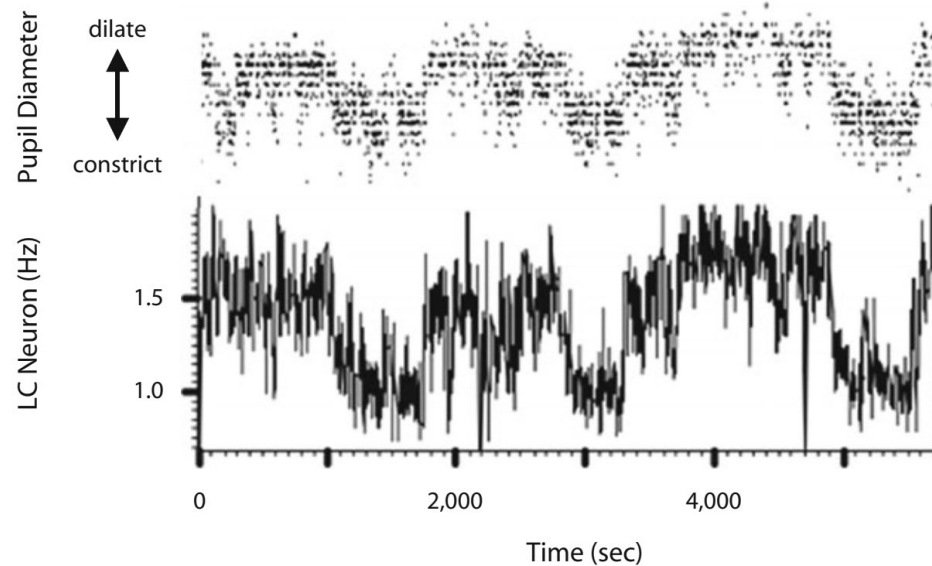
Pichora-Fuller et al., 2016

Listeners use top-down mechanisms to mobilize and allocate their attention for effortful listening.

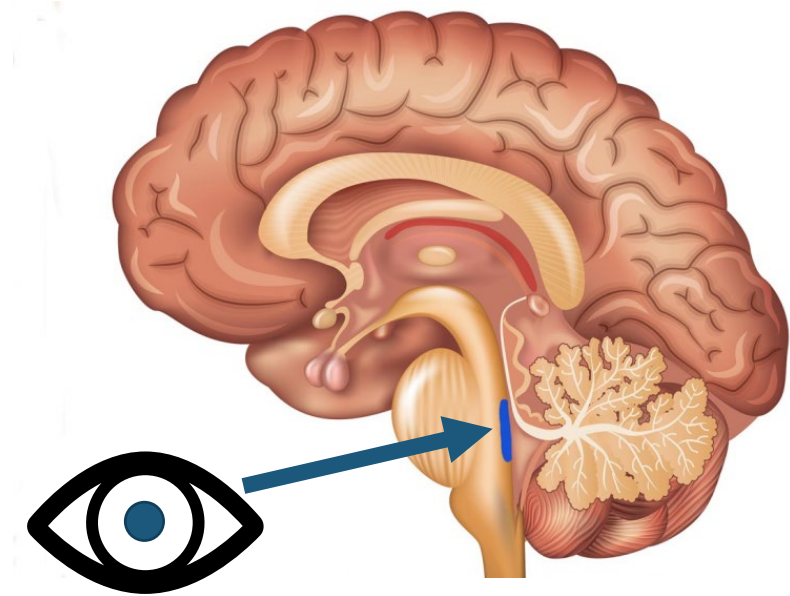
Pichora-Fuller et al., 2016
Seropian et al., 2022



Pupil size is linked to locus coeruleus (LC) activity.



Rajkowski, Kubiak, & Aston-Jones, 1993
see also Gilzenrat et al., 2010



Murphy et al., 2014
Elman et al., 2017

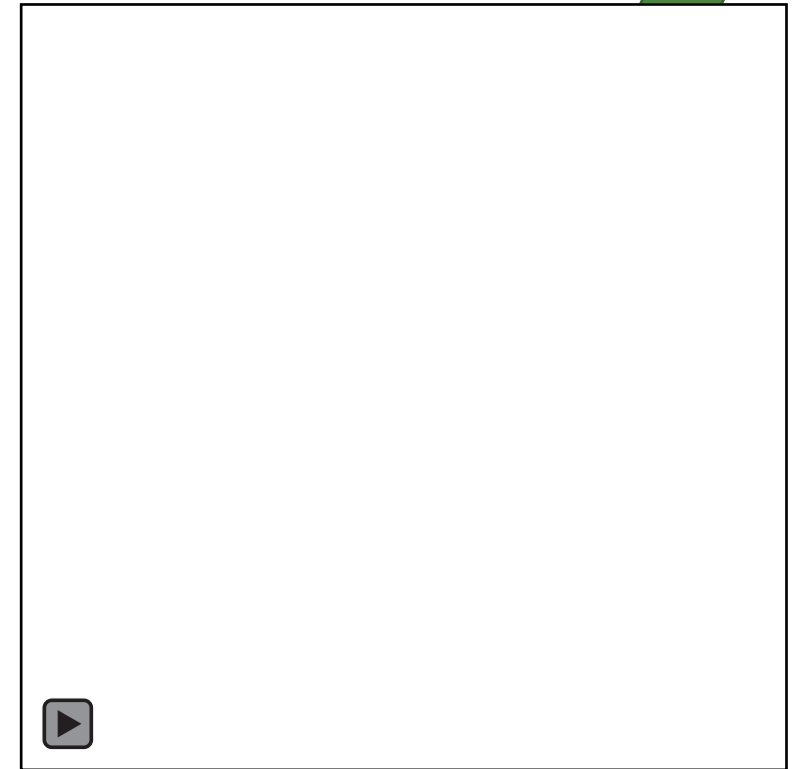
Pupil size as an indicator of attentional states.

Baseline Pupil Size

- Tonic locus coeruleus activity
- Anticipatory arousal
Ayasse & Wingfield, 2020
- Attention mobilization
Seropian et al., 2022

Task-Evoked Pupil Response (TEPR)

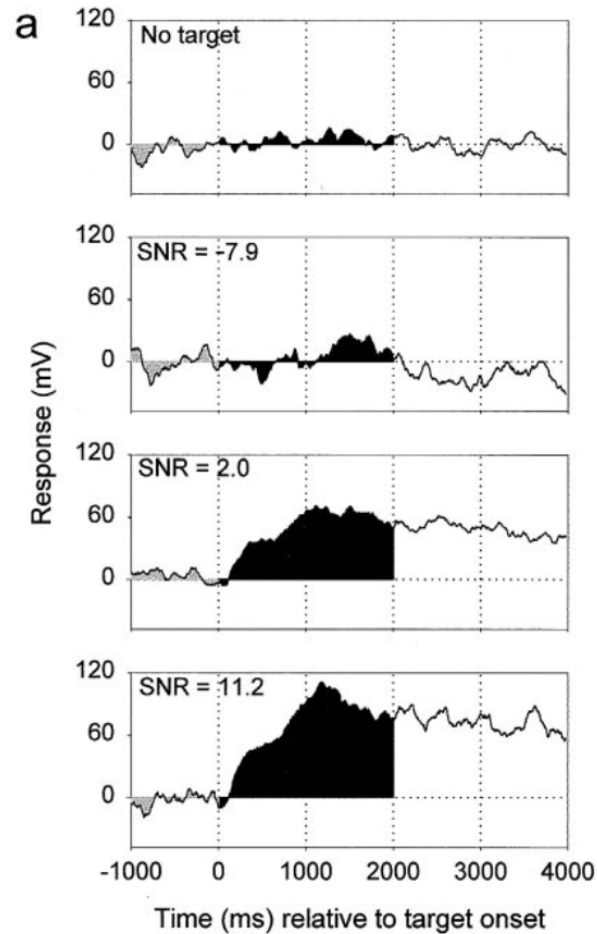
- Phasic locus coeruleus activity
- Task performance
McGinley et al., 2015
- Effort
Winn, 2016



Darwin the Cat
(not the naturalist)

Pupil size as an indicator of attentional states.

Bala and Takahashi, 2000

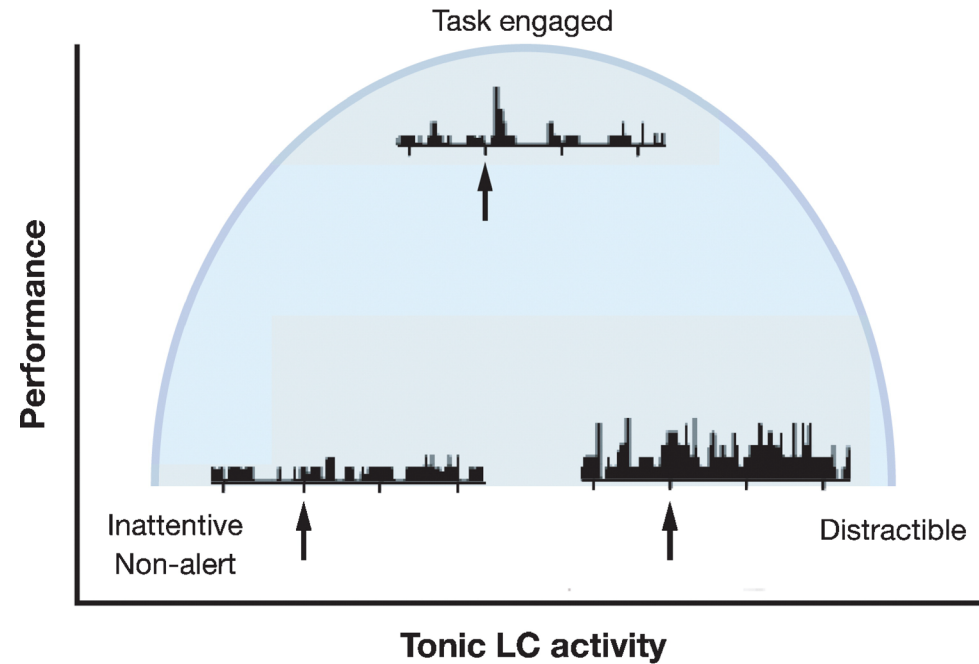


Lu et al., 2018

Cash-Padgett et al., 2018; Photo by Charles J. Sharp

Tonic and phasic LC activity are not (always) independent.

YERKES-DODSON RELATIONSHIP



Aston-Jones & Cohen, 2005

McGinley et al., 2015

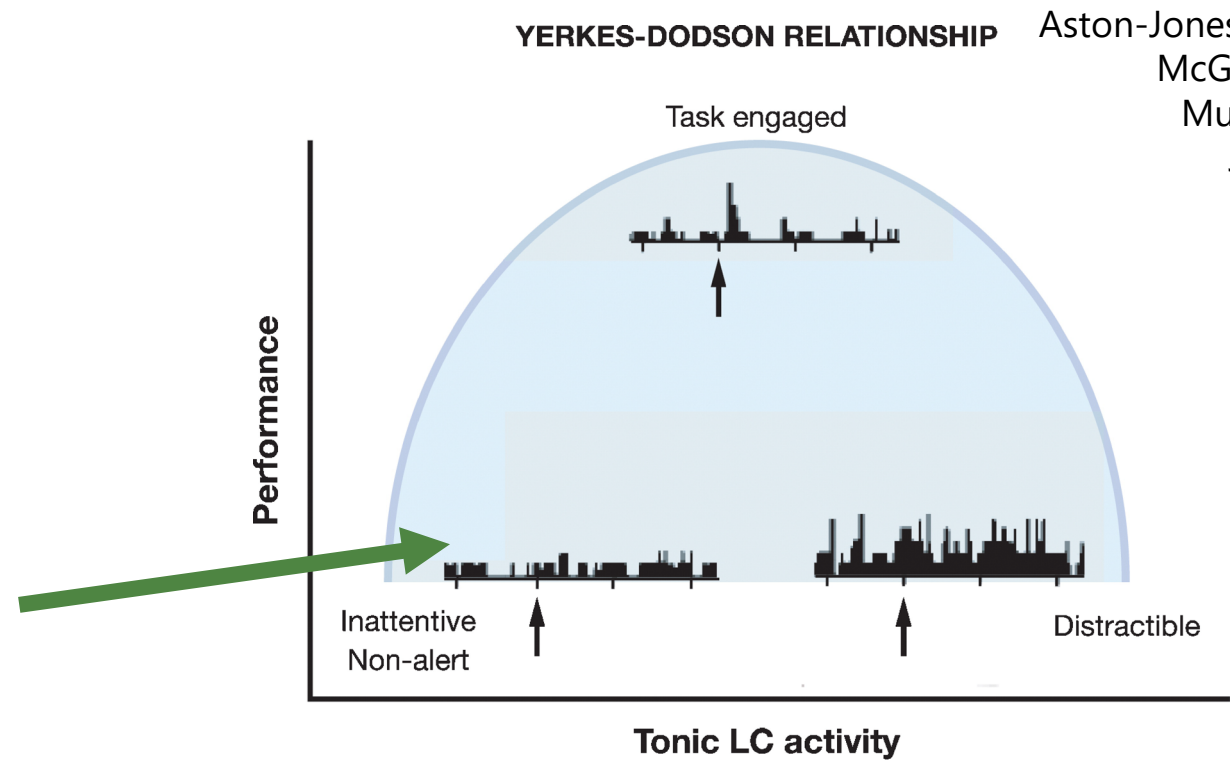
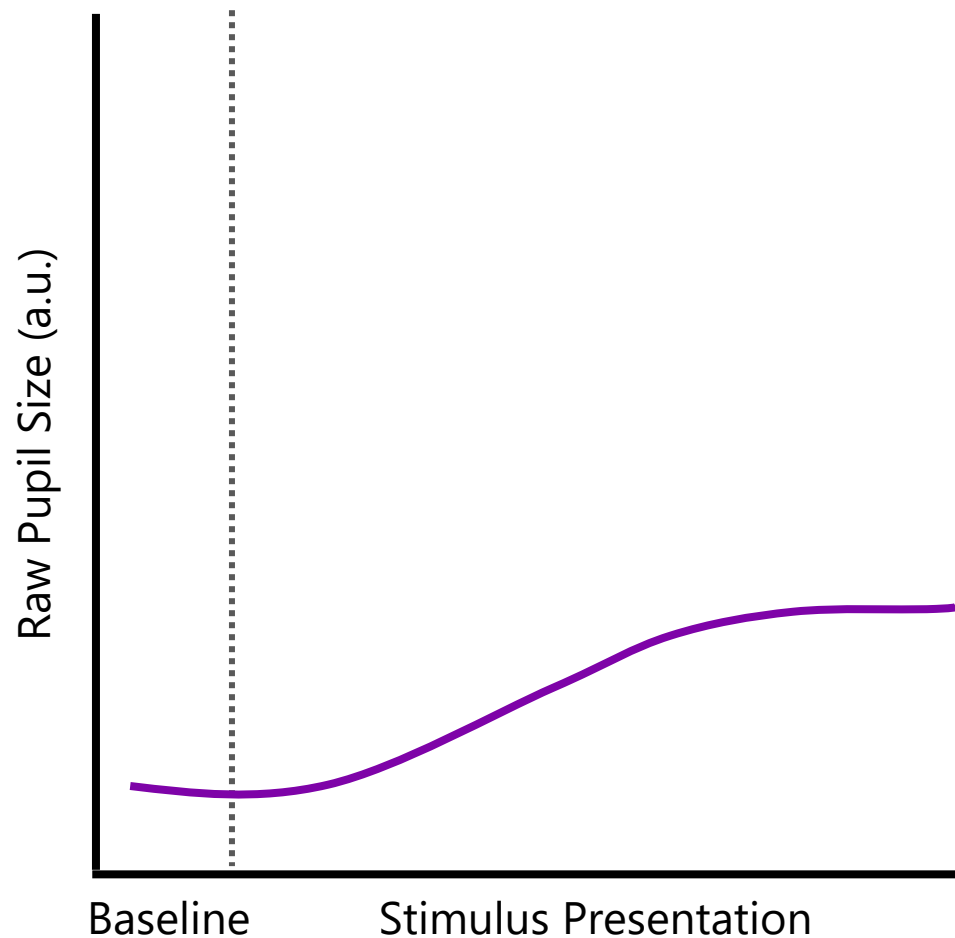
Murphy et al., 2011

Joshi et al., 2016



← different people, time points, and contexts →

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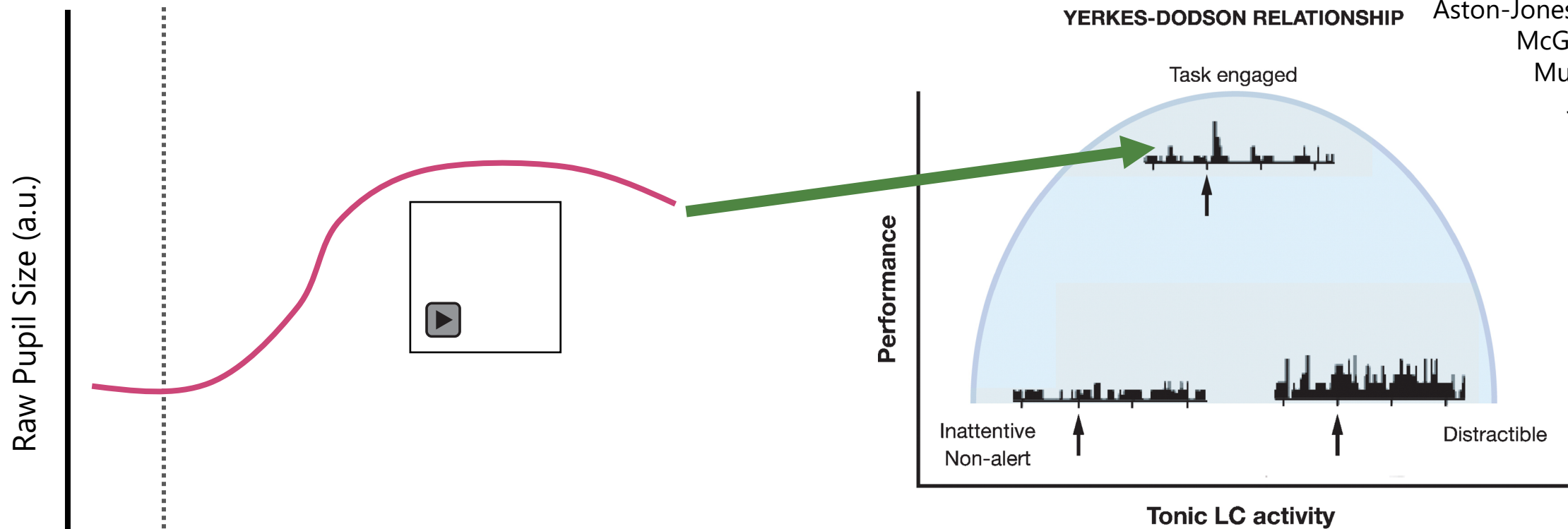


Aston-Jones & Cohen, 2005
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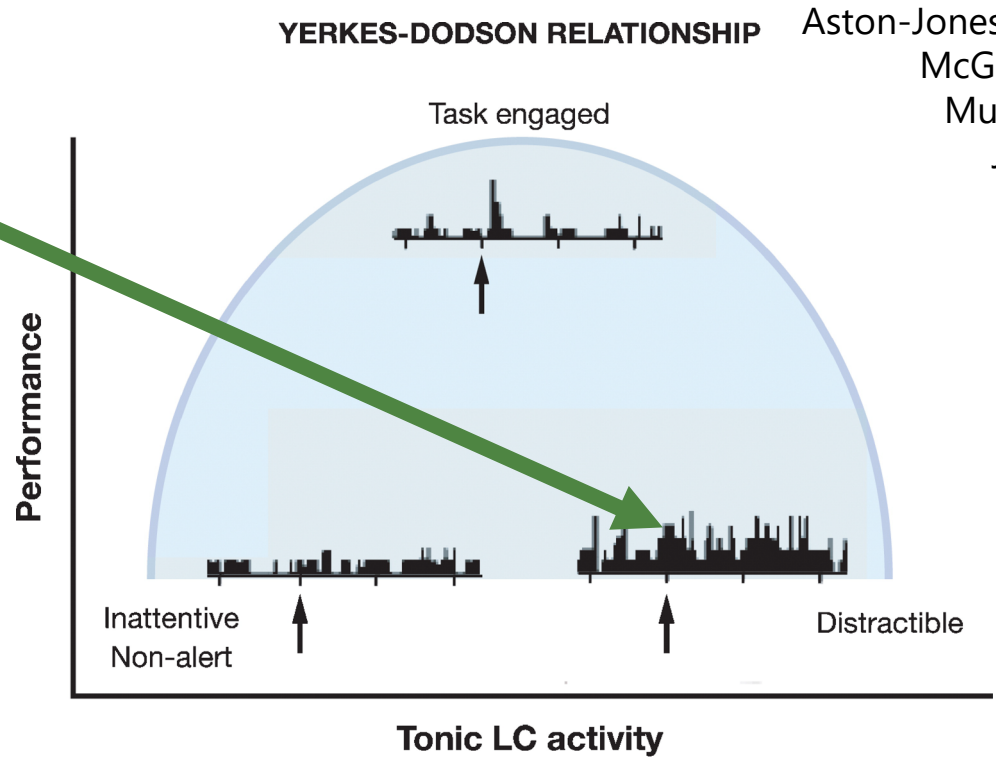
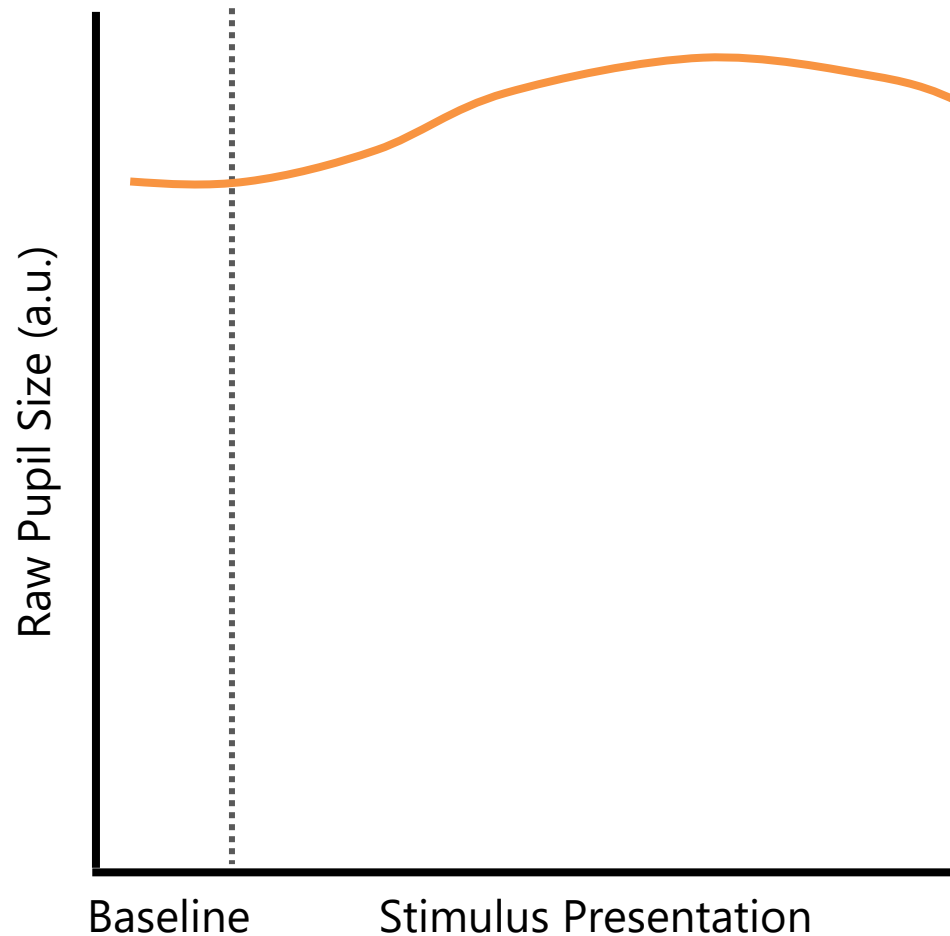


Aston-Jones & Cohen, 2005
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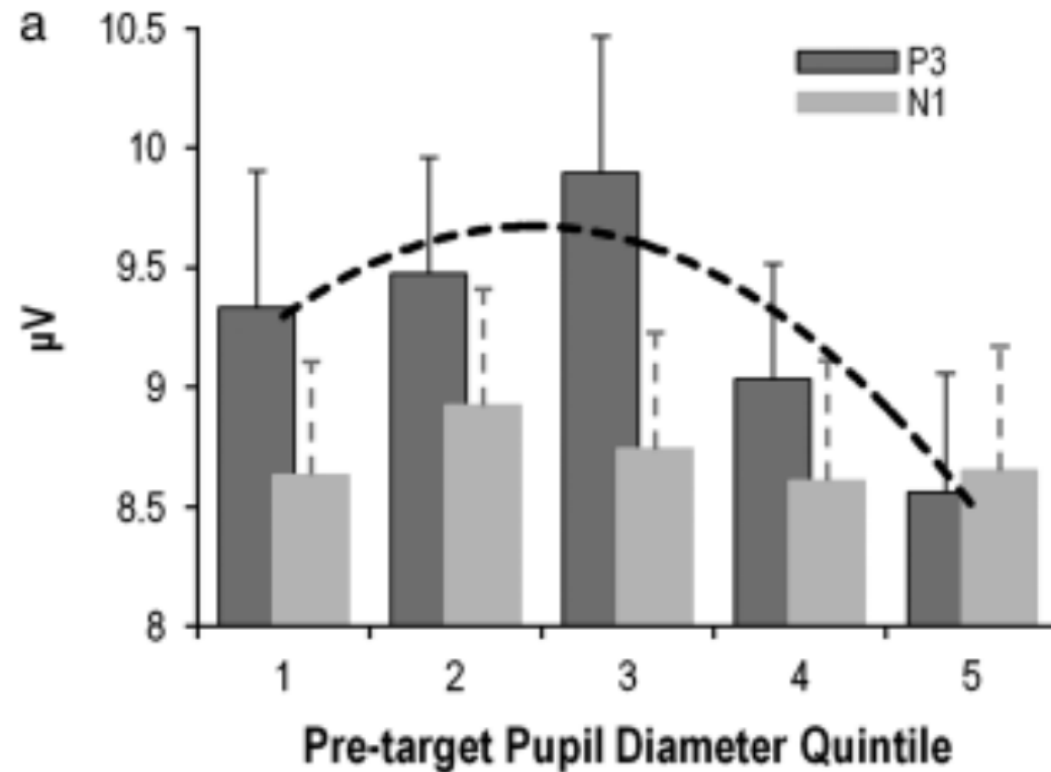
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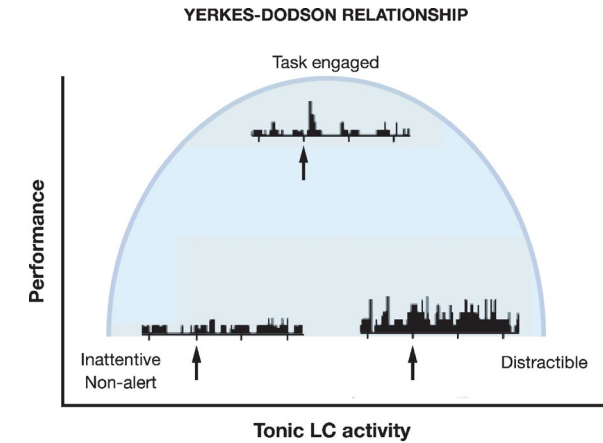
Aston-Jones, G and Cohen, JD. 2005
Annu. Rev. Neurosci. 28:403-50

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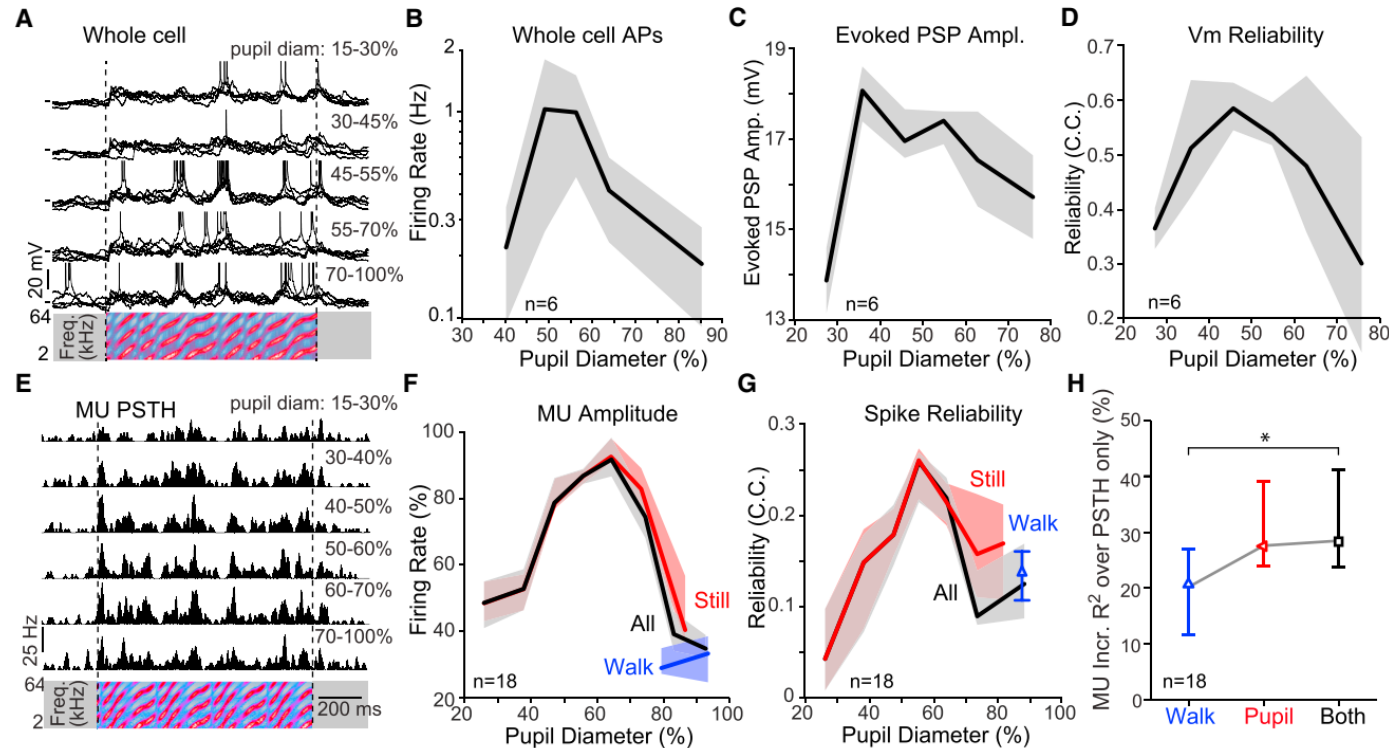


Murphy et al., 2011

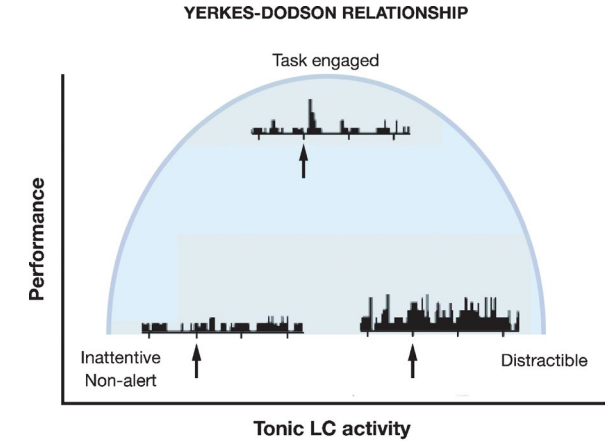


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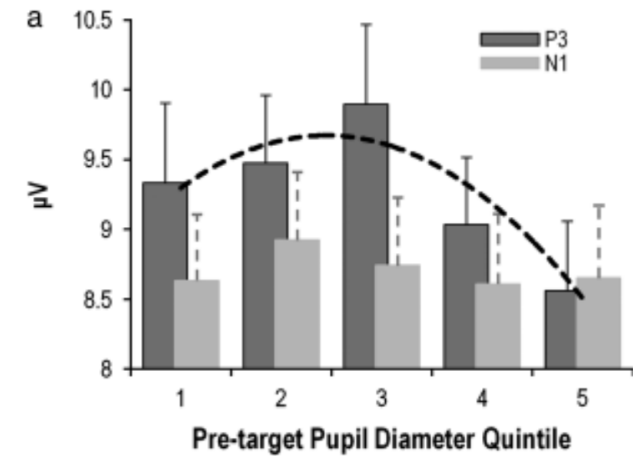
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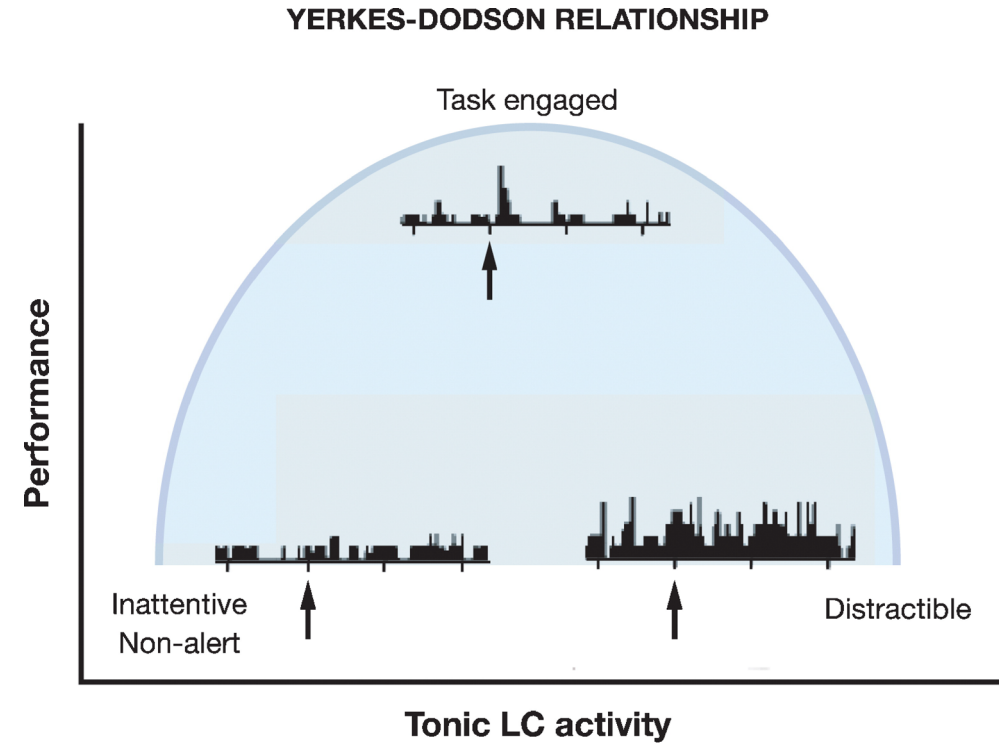


Aston-Jones, G and Cohen, JD. 2005
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Murphy et al., 2011

How does anticipated difficulty affect listening effort in a sustained listening task?



Aston-Jones, G and Cohen, JD. 2005
Annu. Rev. Neurosci. 28:403–50

zzz



← different people, time points, and contexts →

How does stimulus repetition in a blocked signal-to-noise ratio (SNR) design impact the baseline pupil size and the TEPR?

■ Participants

- 13 younger adults
- Hearing thresholds within normal limits

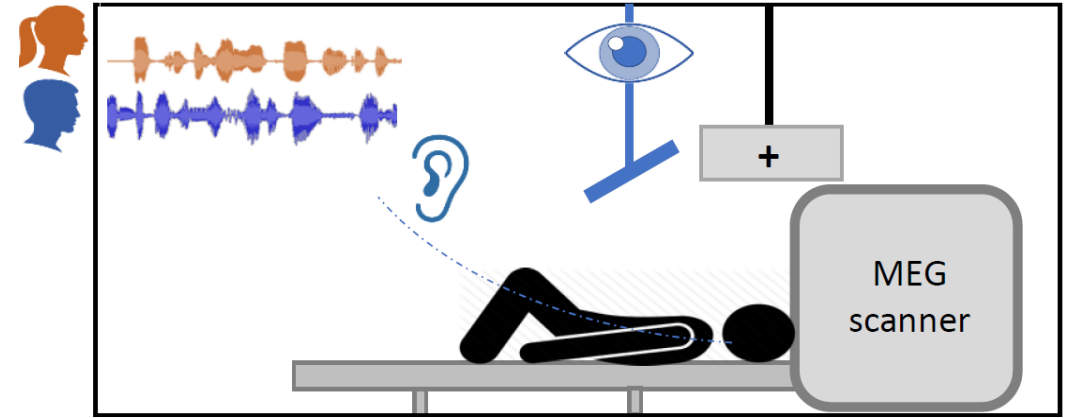
■ Stimuli

- 60 second audiobook passages from *The Legend of Sleepy Hallow*

Karunathilake et al., 2022 (bioRxiv)

■ Manipulations

- SNR: 0 dB vs -6 dB
- Passage Repetition: Trial 1, 2, 3
- Passages blocked by SNR



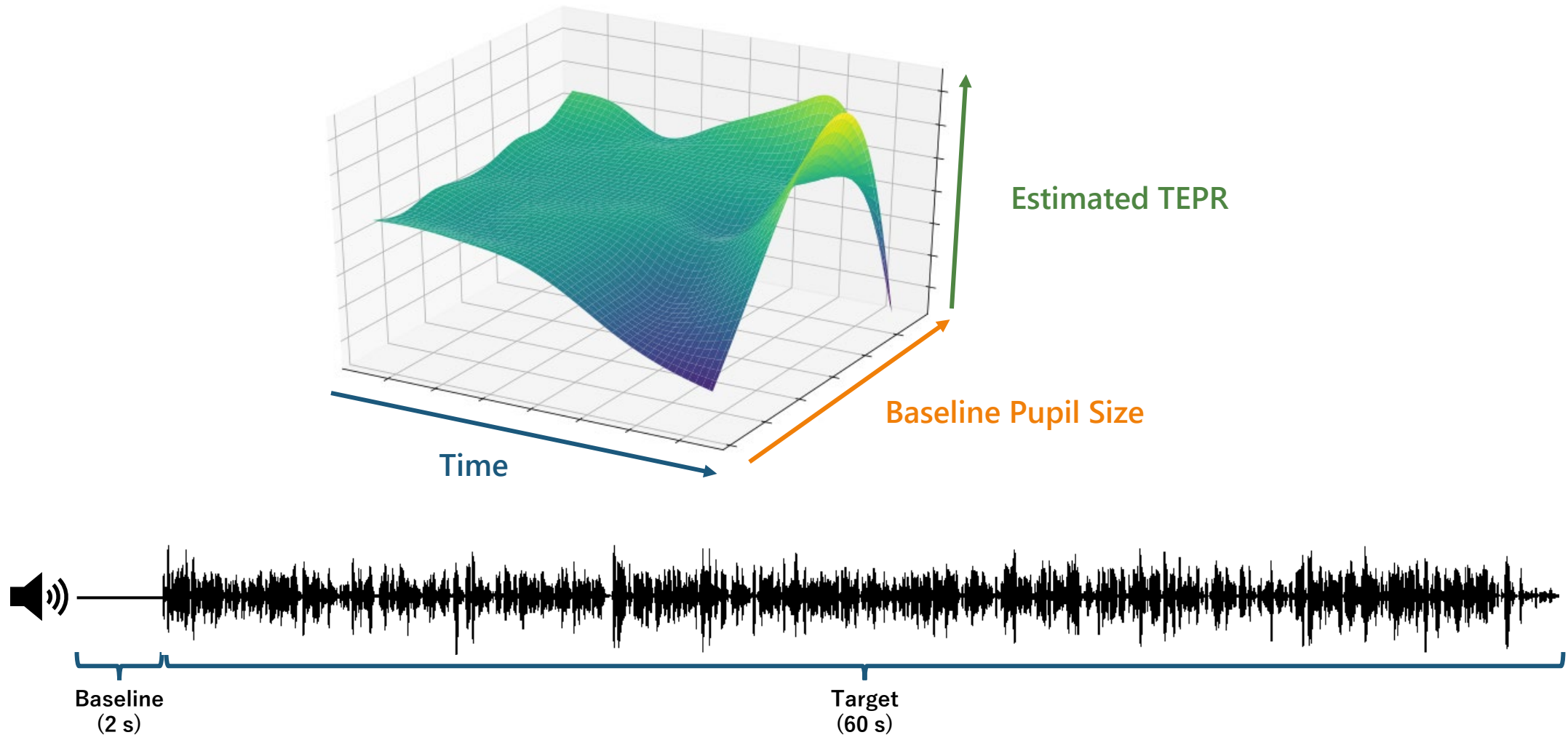
0 dB, attend female



-6 dB, attend male

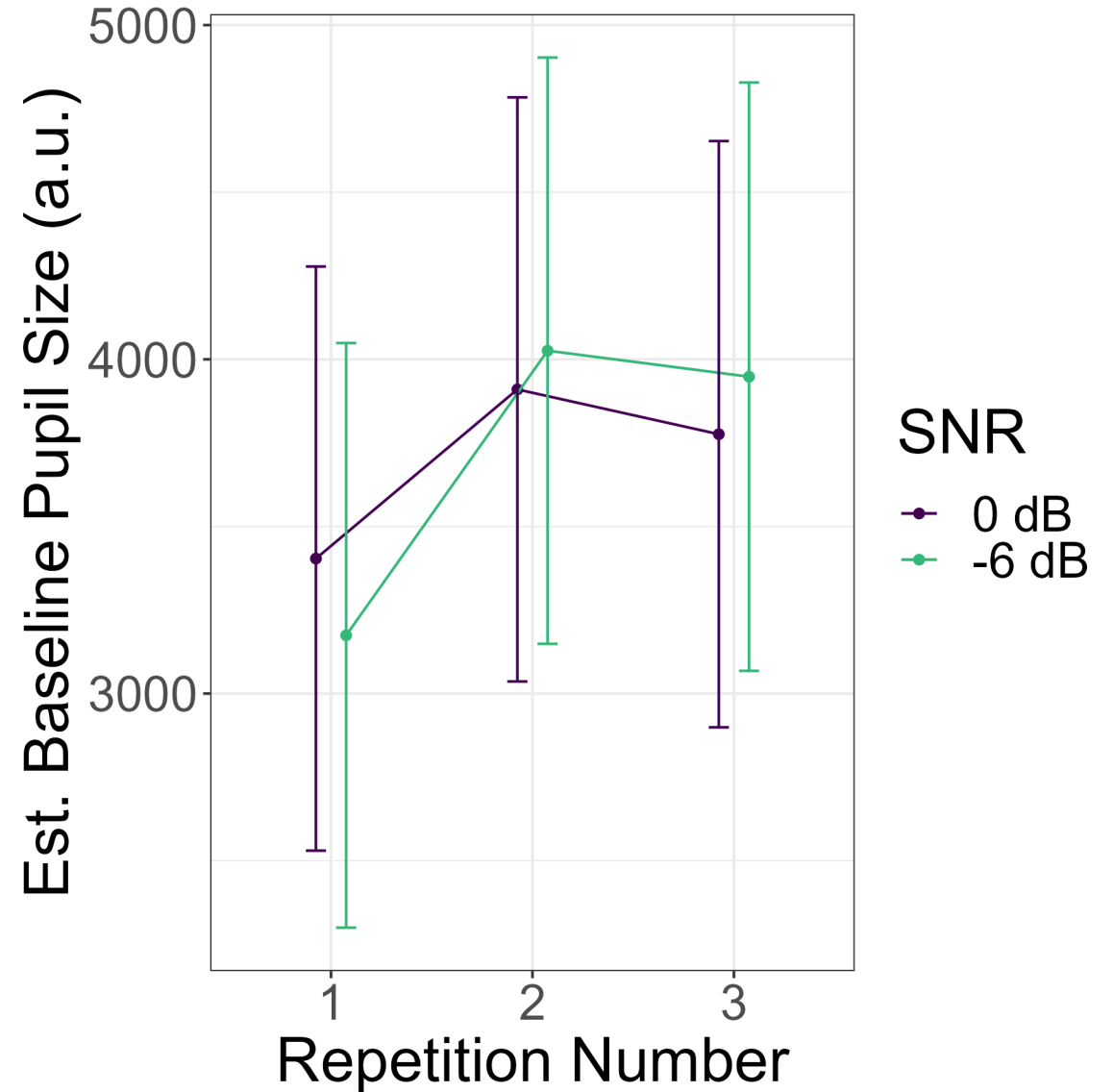


Using GAMMs to model the task-evoked pupil response.

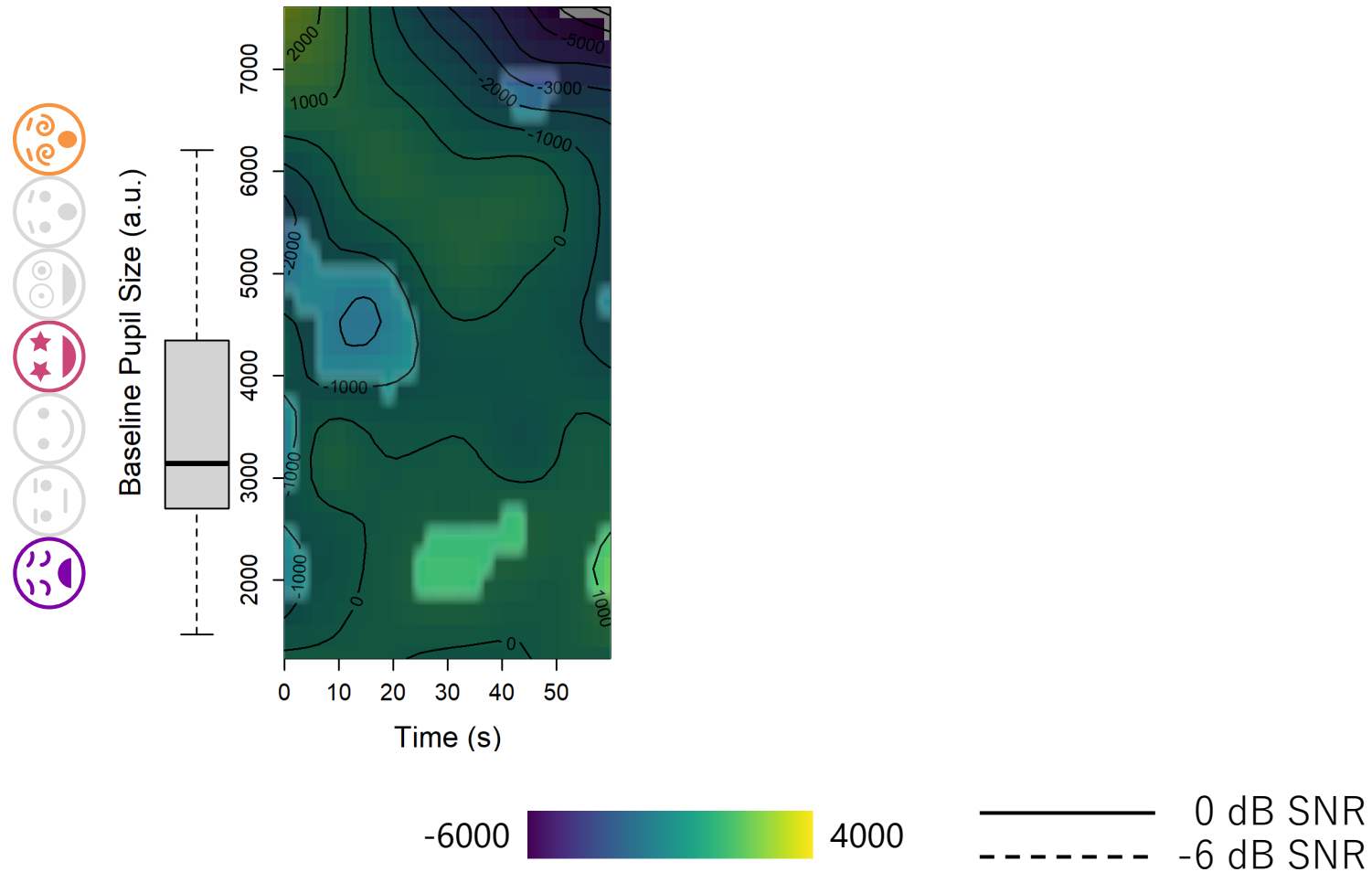


Repetition results in increased, sustained anticipatory arousal

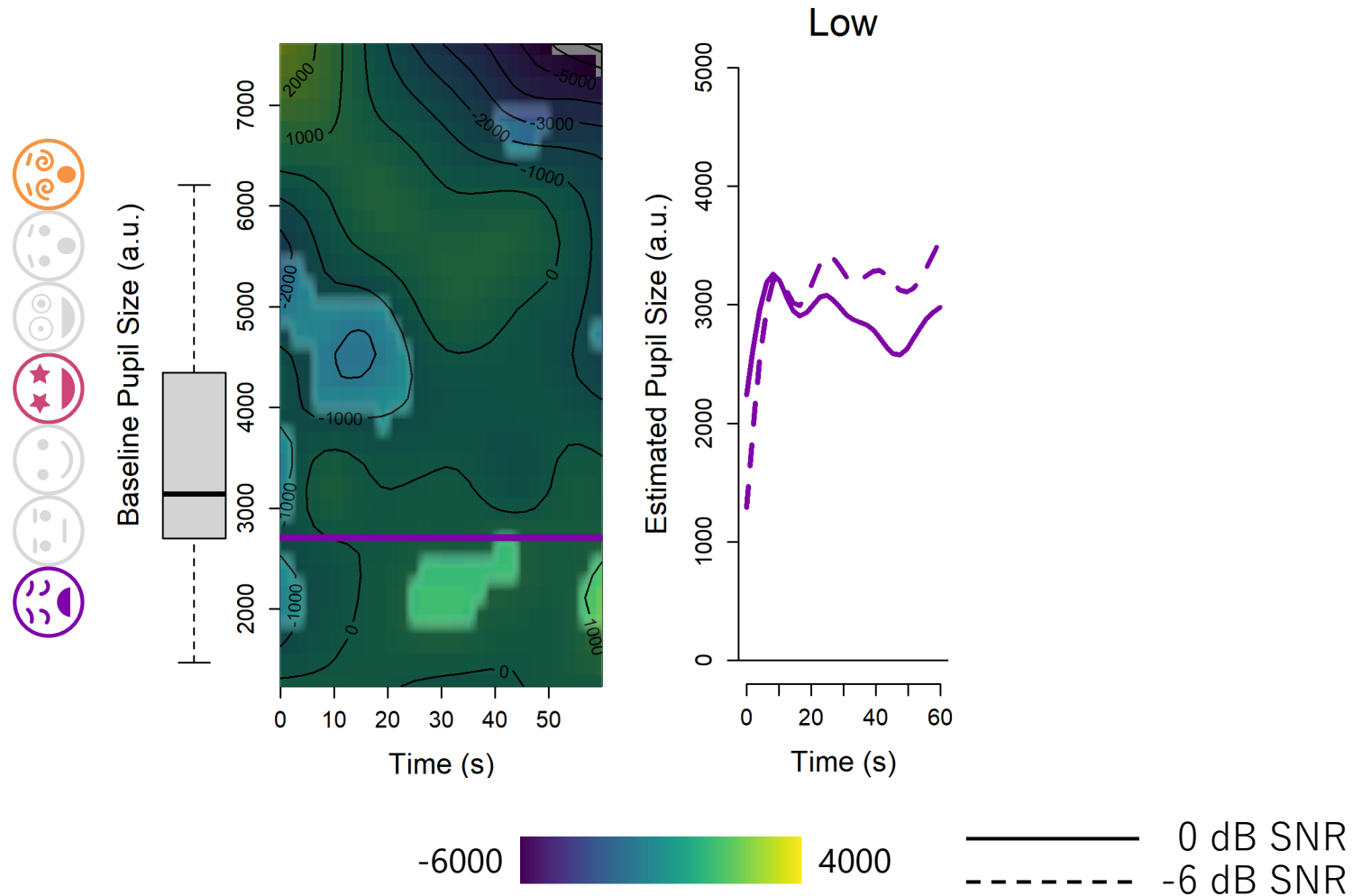
- Baseline pupil size significantly increases from the first to second repetition.
- How does this affect effort during listening?



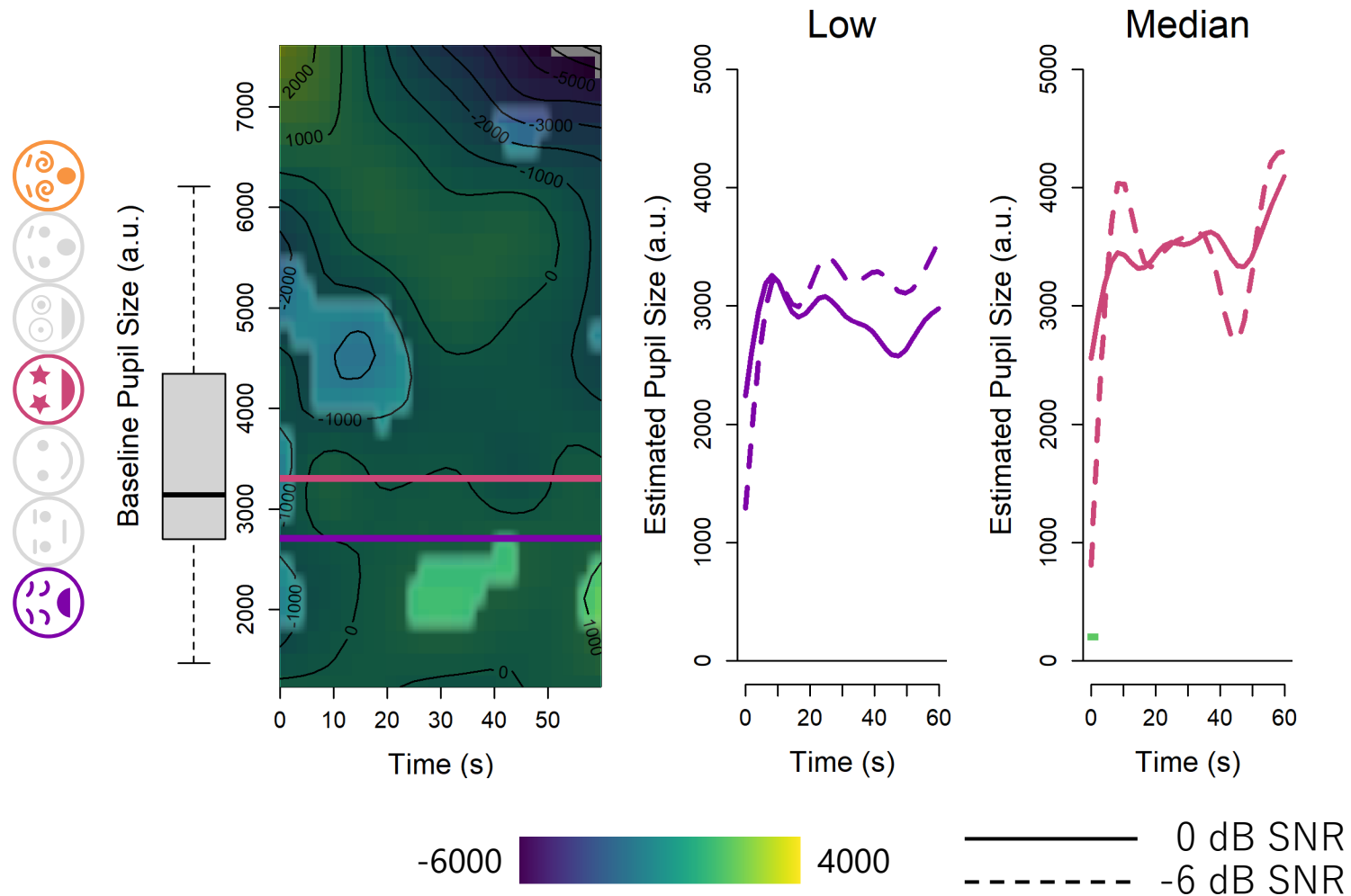
Trial 1: -6 dB SNR condition minus 0 dB SNR condition



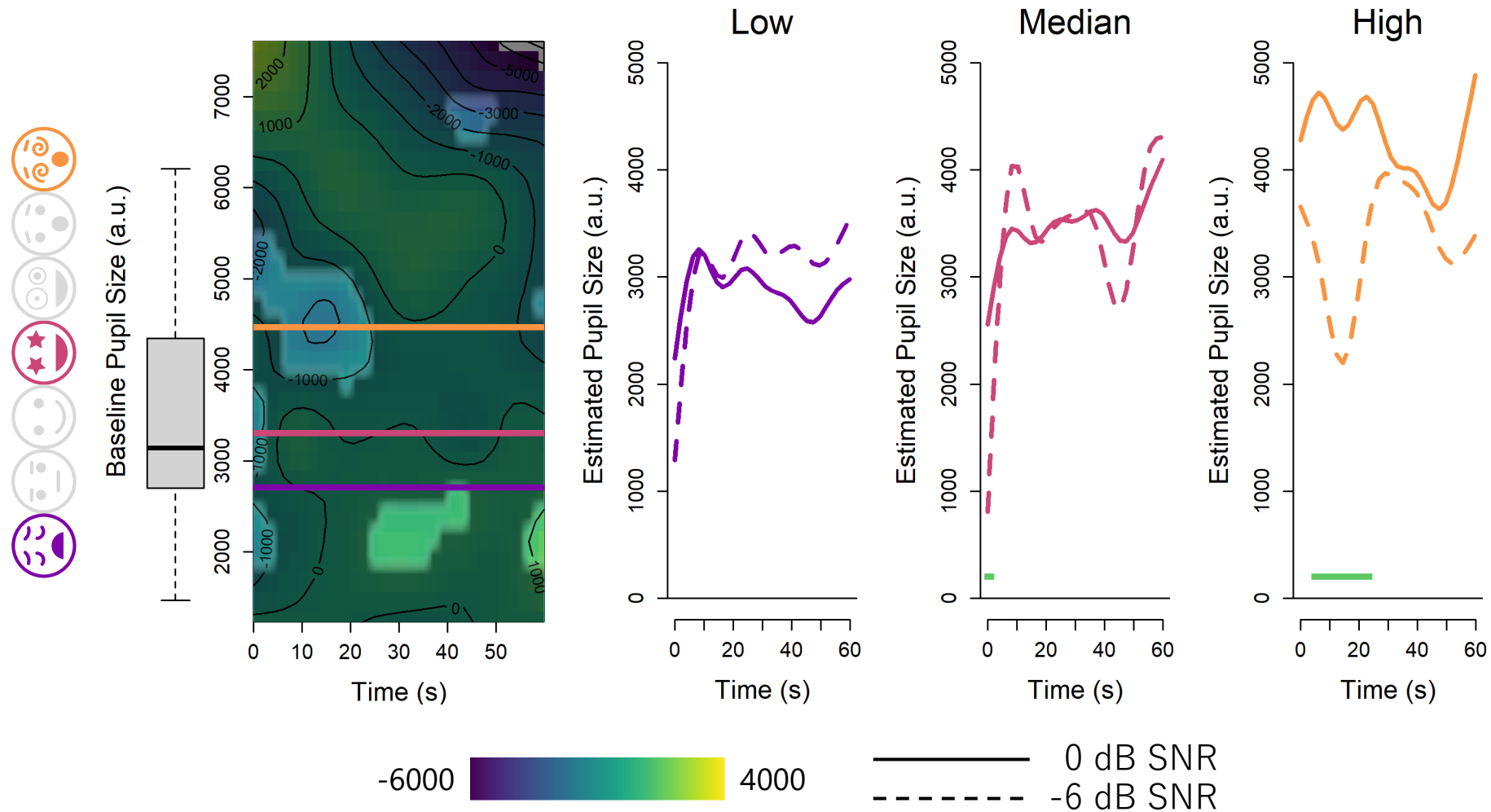
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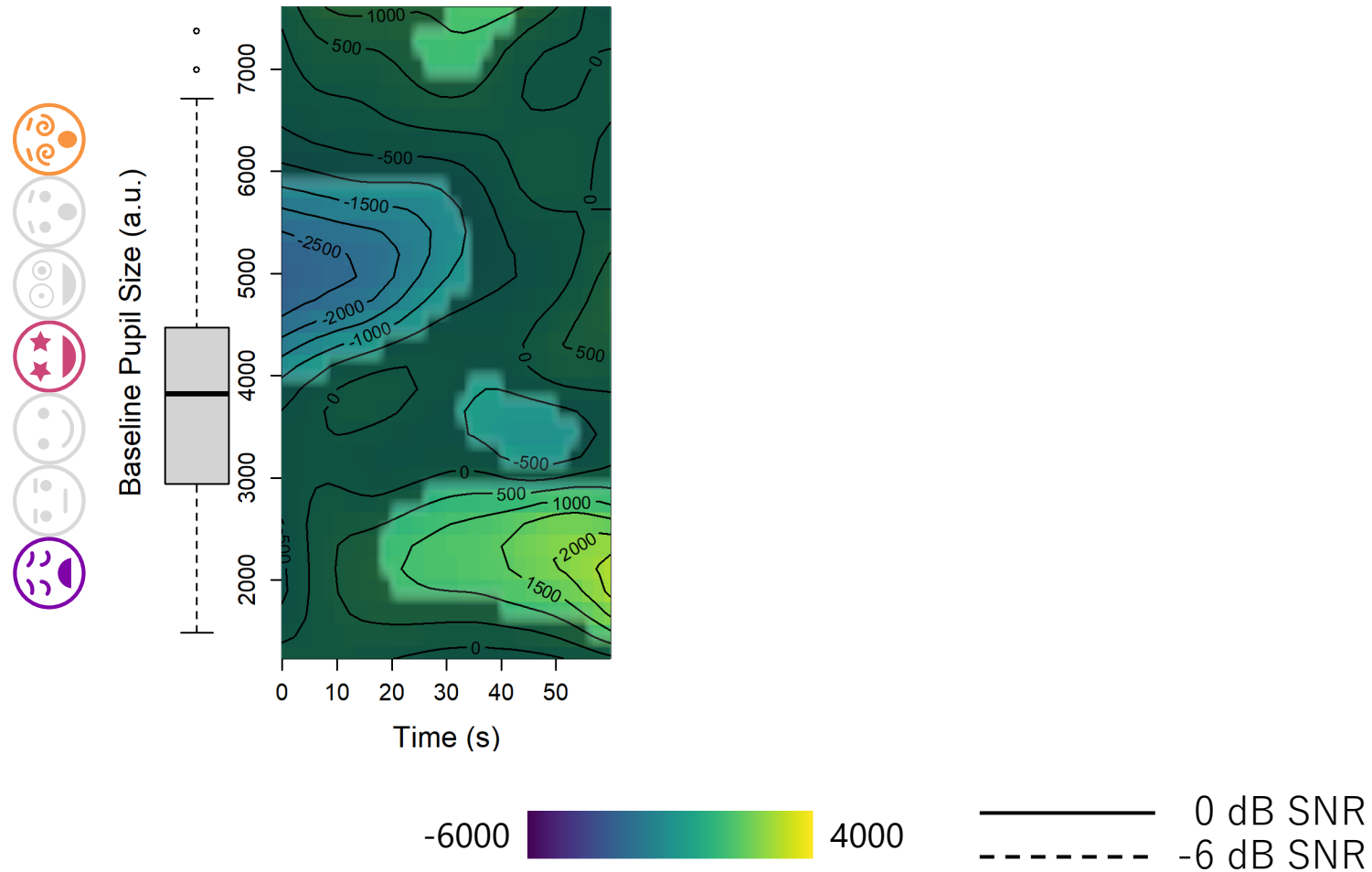
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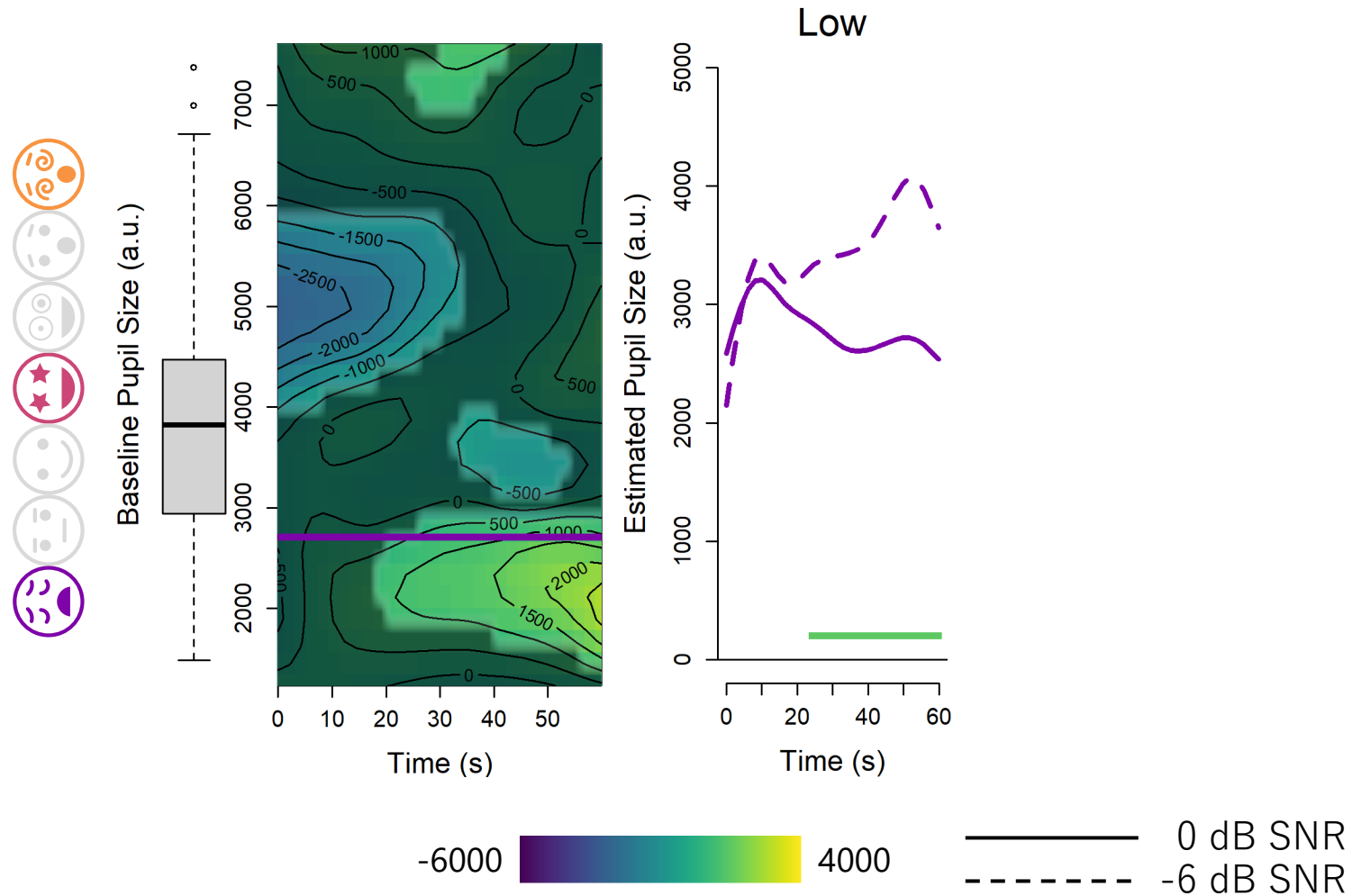
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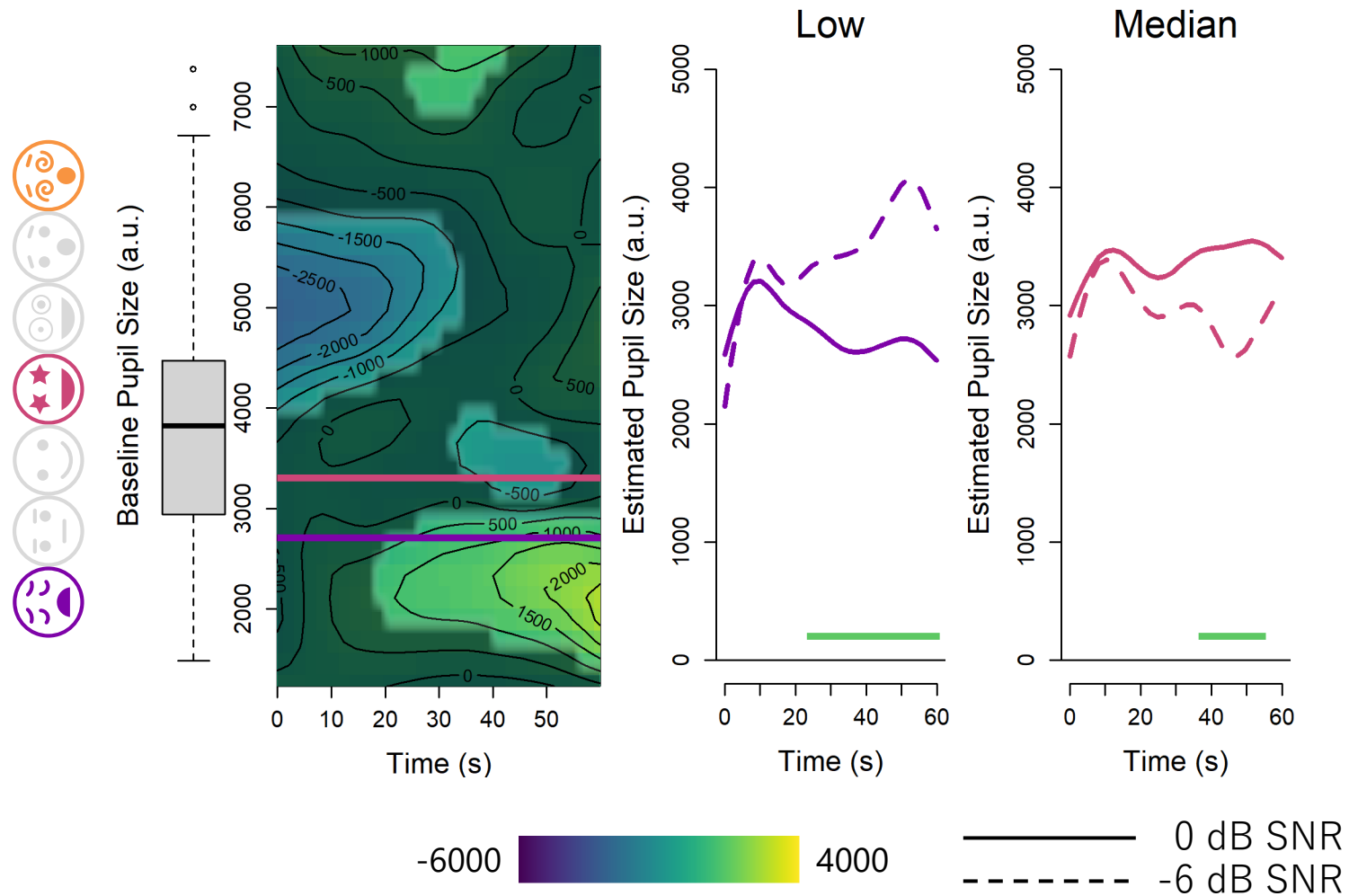
Trial 2: -6 dB SNR condition minus 0 dB SNR condition



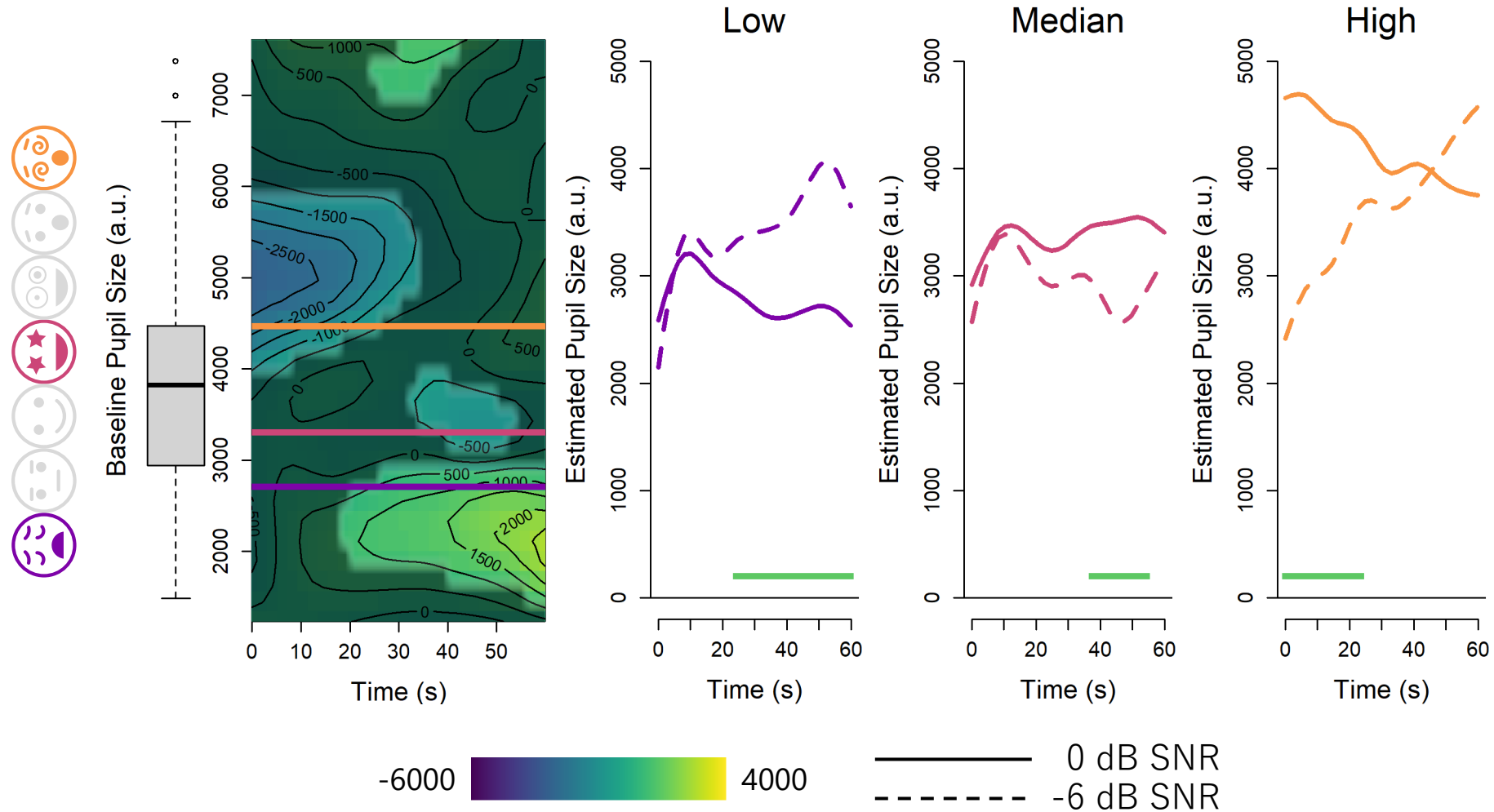
Trial 2: -6 dB SNR condition minus 0 dB SNR condition



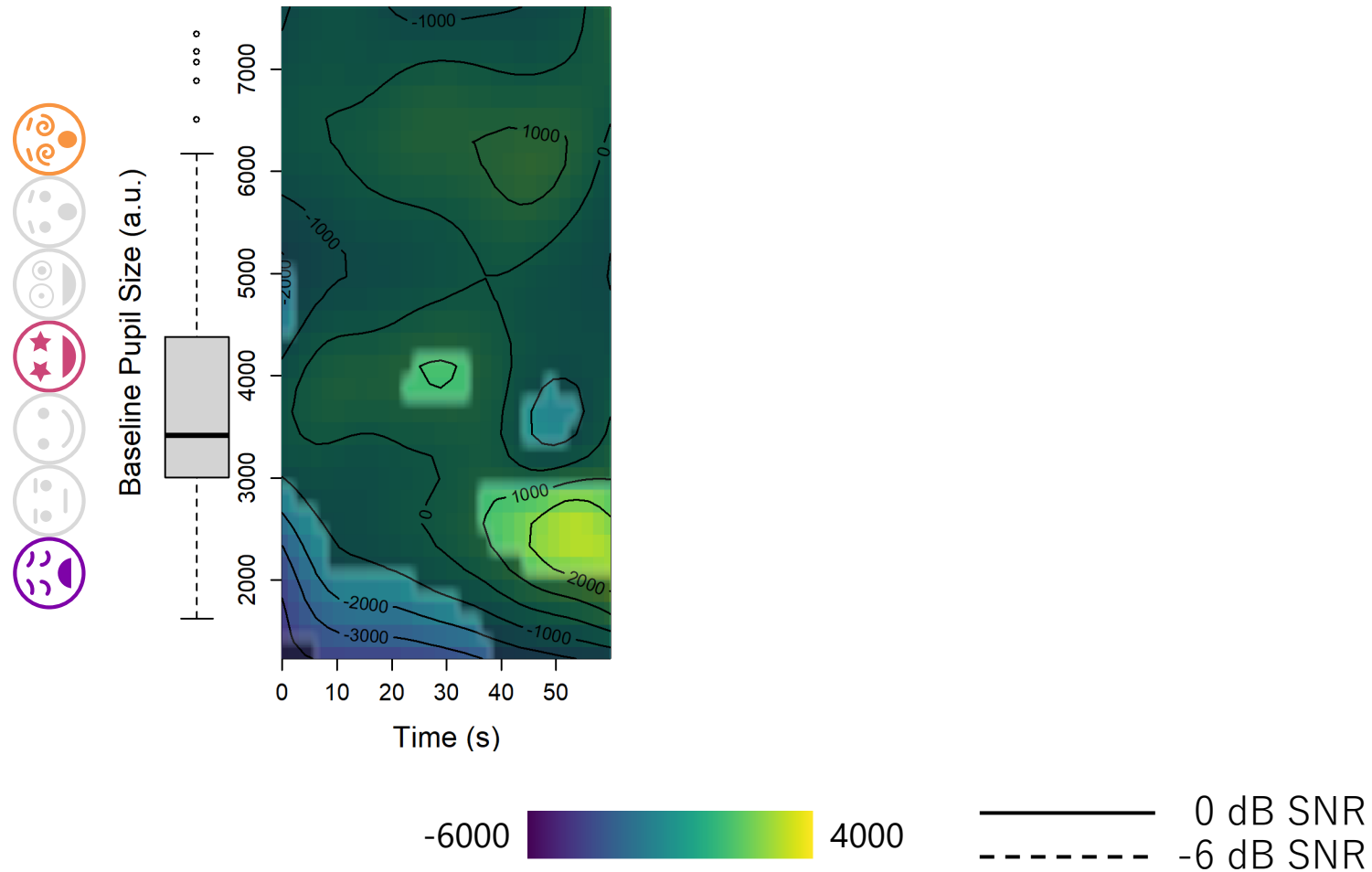
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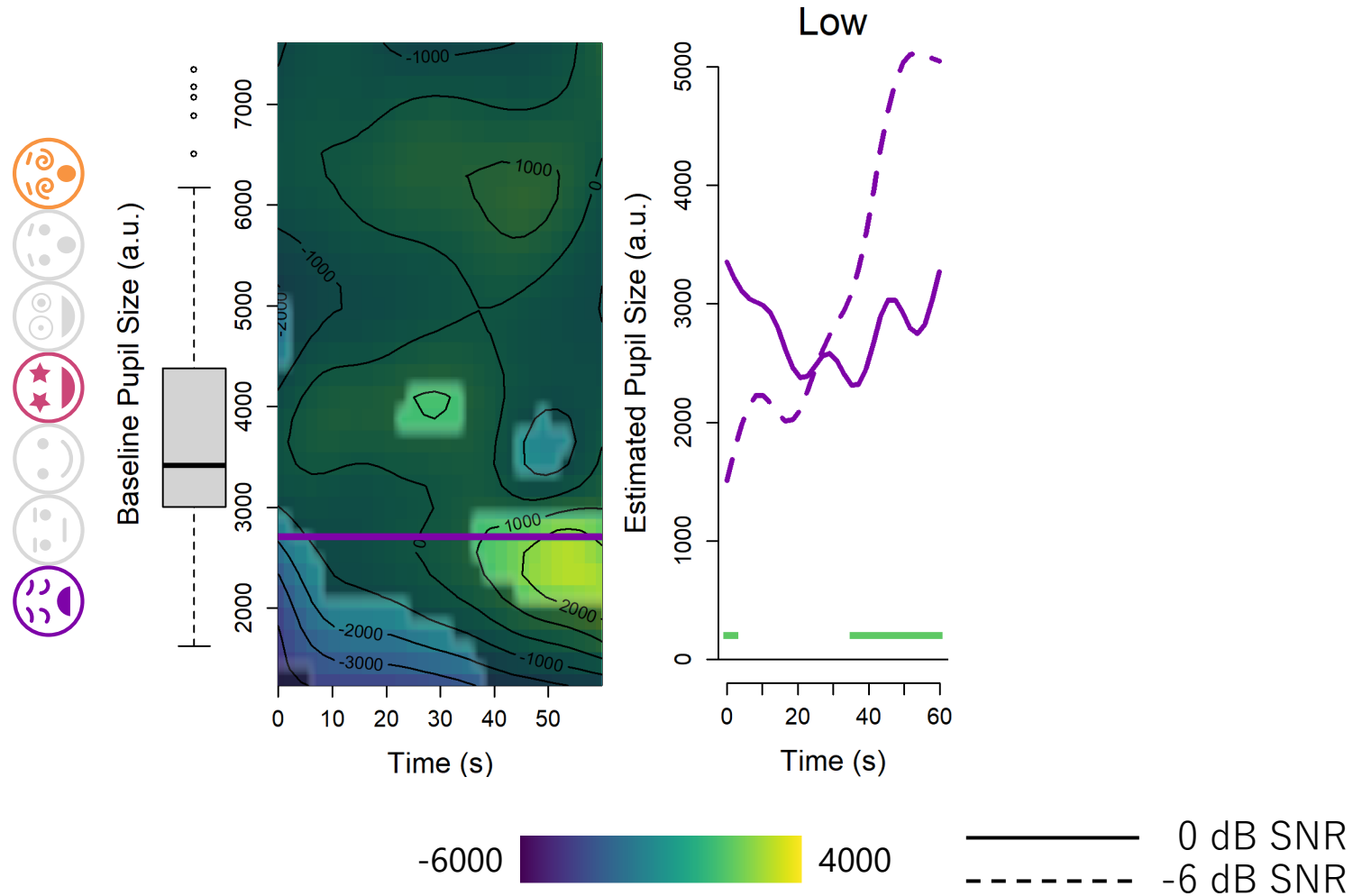
Trial 2: -6 dB SNR condition minus 0 dB SNR condition



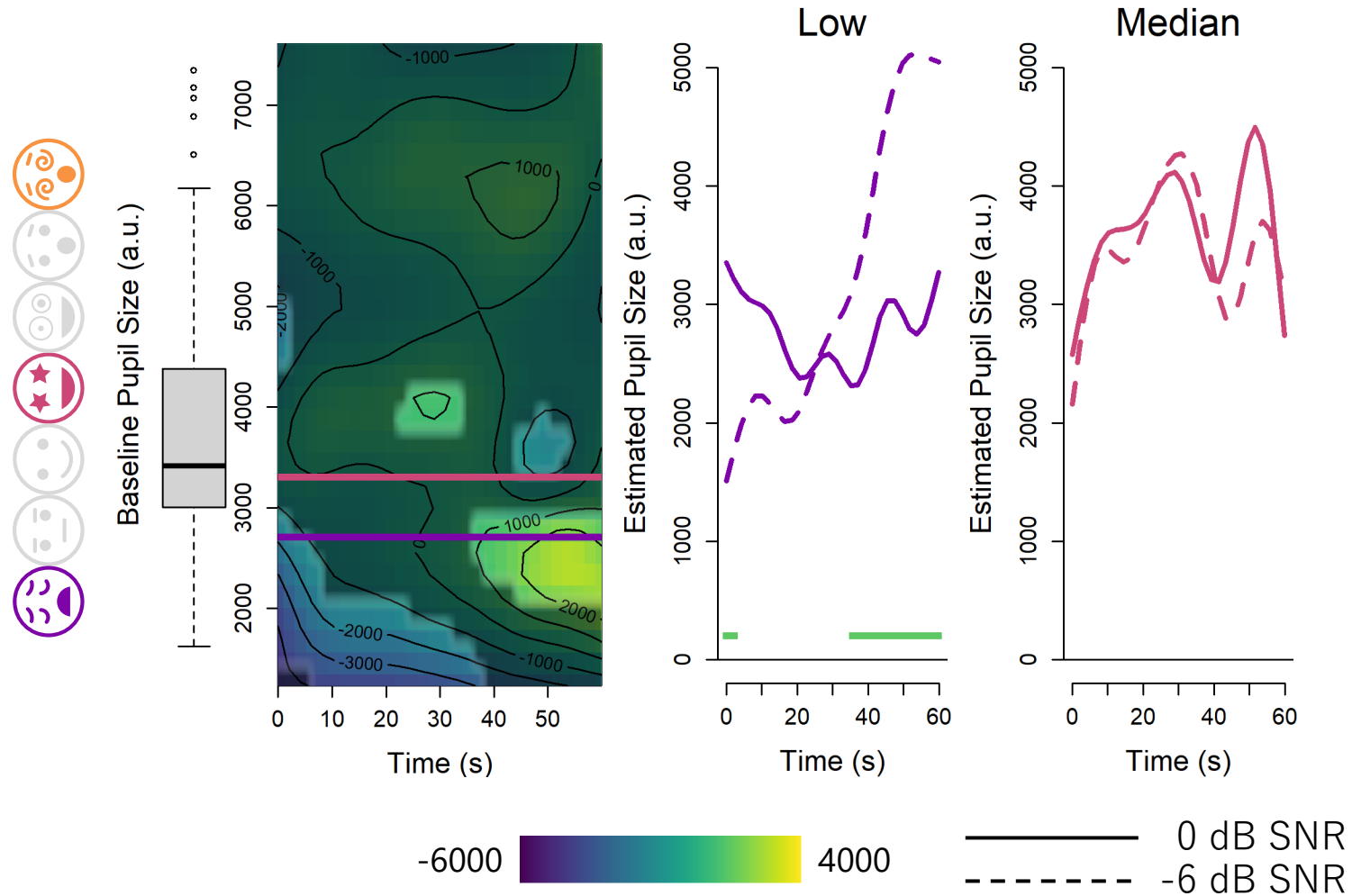
Trial 3: -6 dB SNR condition minus 0 dB SNR condition



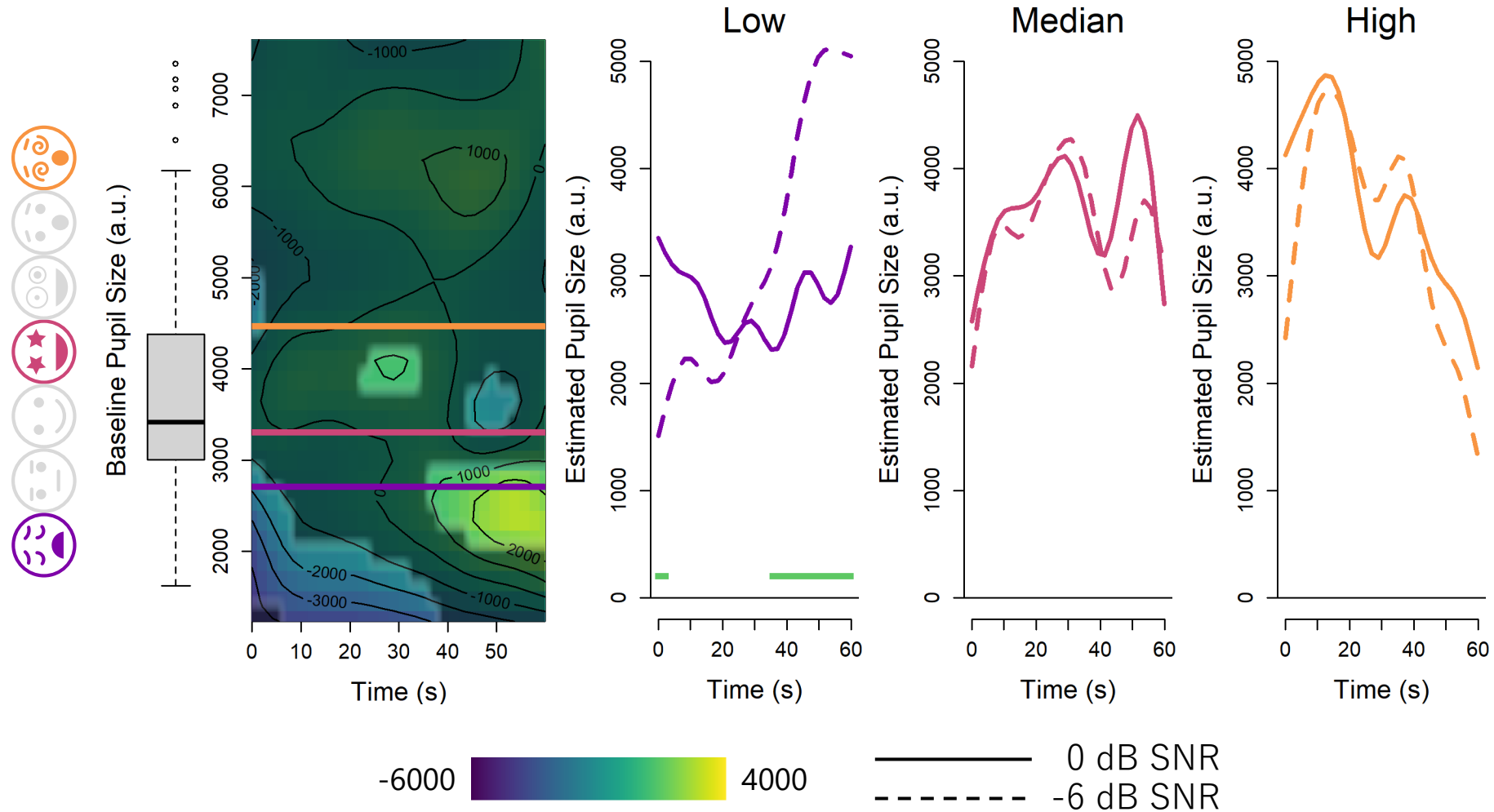
Trial 3: -6 dB SNR condition minus 0 dB SNR condition

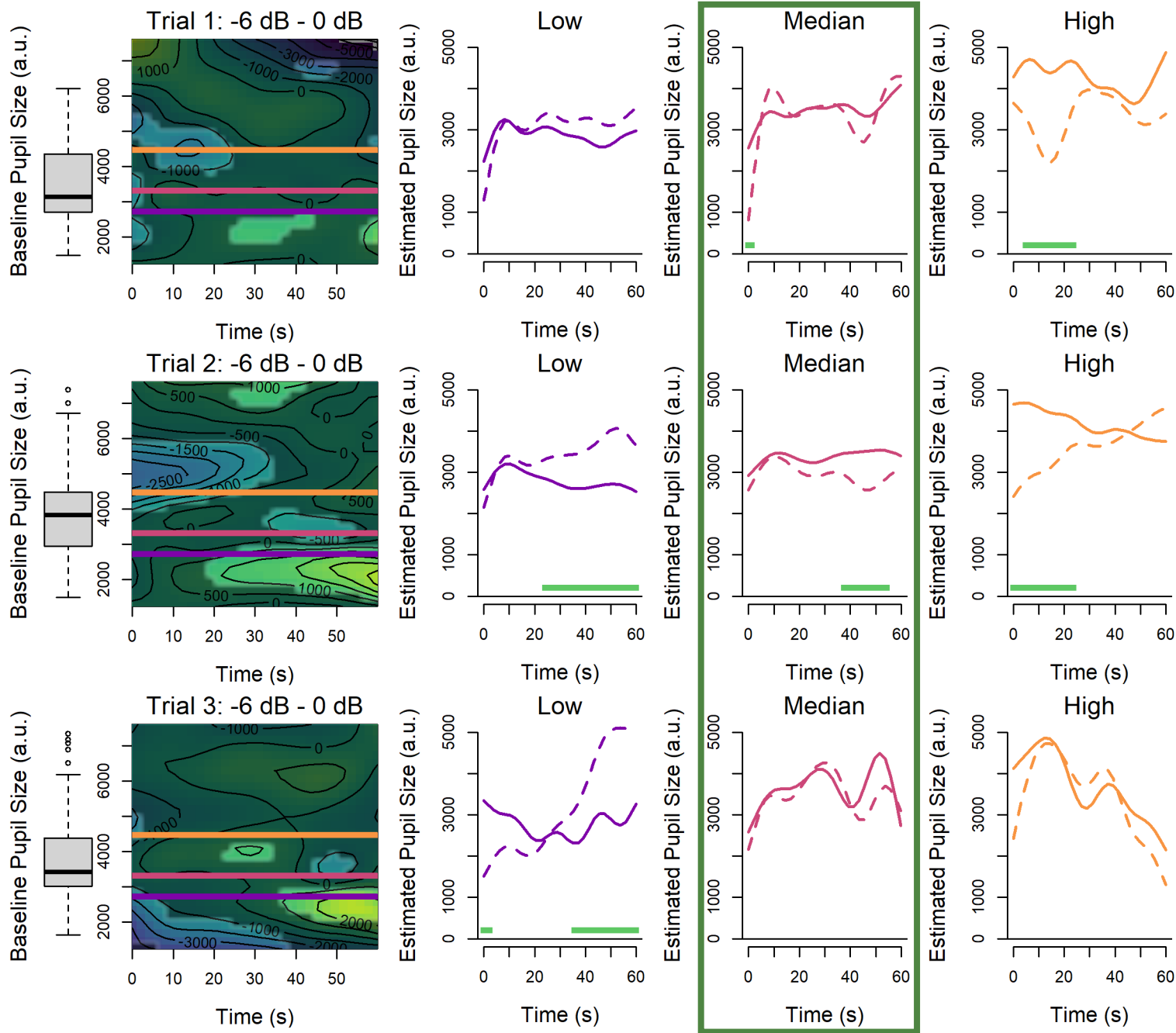


Trial 3: -6 dB SNR condition minus 0 dB SNR condition

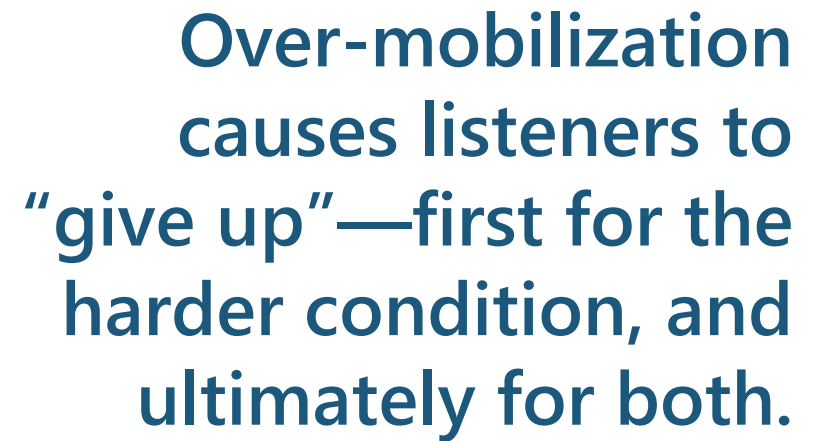


Trial 3: -6 dB SNR condition minus 0 dB SNR condition





Optimal mobilization
reduces the effect of
SNR on listening effort.



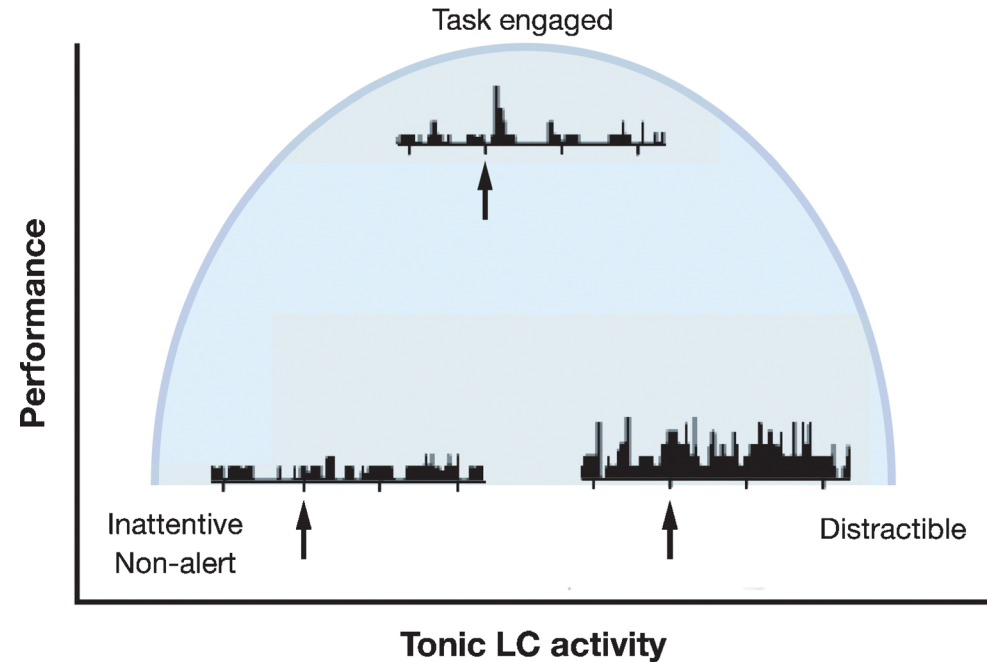
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Attention mobilization affects sustained listening effort.

Both attention **mobilization** (baseline pupil size) and **allocation** during listening (TEPR) change when listeners can anticipate upcoming challenges.

Both measures of pupil size **together** can inform us of how individuals deal with effortful listening.

YERKES-DODSON RELATIONSHIP



Aston-Jones, G and Cohen, JD. 2005
Annu. Rev. Neurosci. 28:403–50

zzz



← different people, time points, and contexts →

Assessing auditory stream segregation in different domains.





Olivia Bermudez-Hopkins
 Lien Decruy
 Jason Dunlap
 Sydney Hancock
 Janani Perera
 Ed Smith
 UMD GAMMs Club
 Computational Sensorimotor
 Systems Lab

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