Listening effort and fatigue: insights from pupillometry

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Introduction

- *Listening effort* refers to the mental exertion required to attend to, and understand, an auditory message

- *Listening-related fatigue* refers to extreme tiredness resulting from effortful listening

McGarrigle et al (2014)
Why do we care?

“...I can attest to the fatigue caused by prolonged intensive listening in noise through hearing aids. It seemed like the listening efforts were diverting some of my cognitive resources; so much effort was being devoted to getting the signal that I sometimes missed part of the message”

(Bess & Hornsby, 2014). Paediatric Audiologist with bilateral hearing loss
Why do we care?

- Frequent anecdotal reports of fatigue from hearing-impaired individuals

- The mental effort required to listen for individuals with hearing loss detracts from other cognitive skills (e.g. memory, comprehension)

- From a clinical perspective, a reliable objective measure of listening effort and fatigue could:
  - Inform counselling sessions
  - Inform intervention strategies
  - Shed light on cases of uncertainty about the need for intervention
Pupillometry

• Measurement of the size of the eye’s pupil

• Changes occur as a result of neural inhibition of parasympathetic activity in the brainstem (‘locus coeruleus’)

• Provides an index of task-evoked cognitive processing (memory, attention) below threshold of conscious awareness

• Resting pupil size (i.e., non task-evoked) decreases when a person is sleepy and/or fatigued, reflecting parasympathetic dominance

Pupillometry

Pupil **dilation** reflects listening effort – *larger* task-evoked pupil size in more challenging listening conditions (Zekveld et al, 2010)

Pupil **constriction** reflects fatigue – *smaller* resting pupil sizes in more subjectively fatigued individuals (Morad et al, 2000)
Gaps in knowledge

• Is *task-evoked* pupil size sensitive to changes in listening effort during a more naturalistic listening task?

• Is *resting* pupil size sensitive to changes in listening-related fatigue following mental exertion?
Research Questions

1. Can we replicate the pupil response ‘effort’ effect using our own stimuli/equipment? (Experiment 1)
Experiment 1: Method

• Speech recognition task (repeating back sentences in noise)

• Three listening conditions:
  i. *Easy* (+15 dB SNR)
  ii. *Hard* (-8 dB SNR)
  iii. *Passive* (No response required, both easy/hard exposure)

• Pupil response: Relative change in normalised pupil size from baseline (1 second of noise pre speech-onset)
Study 1: Results

Pupil response (N = 18)

- **Easy**
- **Hard**
- **Passive**

Condition

- Time relative to speech onset (in s)
Study 1: Results

Pupil response (N = 18)

- **Condition**
  - Easy
  - Hard
  - Passive

- **Axes**
  - Y-axis: Normalised pupil size
  - X-axis: Time relative to speech onset (in s)
Study 1: Results

Task-evoked pupil response (N = 18)
Research Questions

1. Can we replicate the ‘effort’ effect using our own stimuli/equipment? (Experiment 1)

2. Can this effect be detected in more realistic speech processing conditions? (Experiment 2)
“Bob lives near a beautiful park and loves going for long walks there during Spring. This time he decided to bring binoculars to see if he could spot any pigeons in the trees. Fortunately, he managed to catch a glimpse of one perching in its nest.”
Procedure

Order A

1. Easy Trial Block: 30 mins
2. Resting Pupil: 1 min
3. Self-report: 2 mins
4. Hard Trial Block: 30 mins
5. Resting Pupil: 1 min
6. Self-report: 2 mins

Order B

1. Hard Trial Block: 30 mins
2. Resting Pupil: 1 min
3. Self-report: 2 mins
4. Easy Trial Block: 30 mins
5. Resting Pupil: 1 min
6. Self-report: 2 mins
Experiment 2: Results

Pupil response (N = 28)
Experiment 2: Results

Pupil response (N = 28)
Experiment 2: Effort

Task-evoked pupil response (N = 28)

Condition
- Easy
- Hard

Normalised pupil size

- Easy: Lower pupil size
- Hard: Higher pupil size
Experiment 2: Effort

Self-report effort (N = 28)
Research Questions

1. Can we replicate the ‘effort’ effect using our own stimuli/equipment? (Experiment 1)

2. Can this effect be detected in more realistic speech processing conditions? (Experiment 2) ✓
Research Questions

1. Can we replicate the ‘effort’ effect using our own stimuli/equipment? (Experiment 1)

2. Can this effect be detected in more realistic speech processing conditions? (Experiment 2)

3. *Is pupillometry also sensitive to differences in listening-related fatigue?* (Experiment 2)
   - *Empirical evidence?*
Procedure

Order A

- **Easy Trial Block** (30 mins)
- Resting Pupil (1 min)
- Self-report (2 mins)
- **Hard Trial Block** (30 mins)
- Resting Pupil (1 min)
- Self-report (2 mins)

Order B

- **Hard Trial Block** (30 mins)
- Resting Pupil (1 min)
- Self-report (2 mins)
- **Easy Trial Block** (30 mins)
- Resting Pupil (1 min)
- Self-report (2 mins)
Experiment 2: Results

Resting pupil (N = 28)

Condition
Easy
Hard

Resting pupil size
1300
1200
1100
1000
900
800
Experiment 2: Self-report

Self-report Fatigue (N = 28)

Fatigue ratings

Condition

Easy

Hard
Research Questions

1. Can we replicate the ‘effort’ effect using our own stimuli/equipment? (Experiment 1)

2. Can this effect be detected in more realistic speech processing conditions? (Experiment 2)

3. *Is pupilometry also sensitive to differences in listening-related fatigue?* (Experiment 2)
Listening task effects?.....
Task effects

Pupil response in both tasks

Condition
RecEasy
RecHard
RecPassive
SPVEasy
SPVHard

Normalised pupil size

Time relative to speech onset (in s)

-1 0 1 2 3 4 5 6
Task effects

Pupil response in both tasks

Condition:
- RecEasy
- RecHard
- RecPassive
- SPVEasy
- SPVHard

Normalized pupil size

Time relative to speech onset (in s)
Task effects

Task-evoked pupil response

Normalised pupil size

Condition
- RecEasy
- RecHard
- RecPassive
- SPVEasy
- SPVHard
Conclusions

• *Task-evoked* pupil response is sensitive to differences in listening effort in a naturalistic listening task

  ➢ The strength of this response appears to depend on the type of listening task used

• *Resting* pupil size may also reflect fatigue associated with sustained effortful listening
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• THANK YOU FOR LISTENING EFFORTFULLY! (And sorry if you’re now fatigued…..)
References


