Measuring listening-related effort and fatigue in young adults and children

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Overview

• **Listening-related effort and fatigue**
  - What do we mean and why do we care?
  - How are they measured?
  - Listening tasks?
  - Pupillometry

• **Measuring listening-related effort and fatigue in:**
  - Young NH adults
  - NH children (aged 8 – 11 years)

• **Summary of findings**
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
“...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

Measuring listening effort and fatigue

• **Self-report**
  - For example, NASA task load index for effort

![Effort scale diagram](image)

• **Limitations**
  - Limited mechanistic insight
  - Potential biases

Hart & Staveland (1988); Larsby et al (2005)
Measuring listening effort and fatigue

• *Behavioural (RTs)*
  
  **Effort**
  
  ➢ Single listening task\(^1,^2\)
    
    ➢ Slower RTs in more challenging conditions = Increased listening effort

\(^1\)Gatehouse & Gordon (1990), \(^2\)Houben et al (2009)
Measuring listening effort and fatigue

• *Behavioural (RTs)*

  **Effort**
  - Single listening task
    - Slower RTs in more challenging conditions = Increased listening effort
  - Dual-task 1-7

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Measuring listening effort and fatigue

- **Behavioural (RTs)**

  **Effort**
  - Single listening task
    - Slower RTs in more challenging conditions = Increased listening effort
  - Dual-task

  **Fatigue**
  - RT change (or performance decrement) over time

Hornsby (2013)
Measuring listening effort and fatigue

• Physiological

Effort
- Electroencephalography (EEG) \(^1-^4\)
- Skin conductance \(^5\)
- Pupillometry \(^6-^{12}\)

Fatigue
- Cortisol \(^{13}\)

Listening tasks?
Listening tasks?

• Speech recognition

Pros:
- Requires speech segregation
- Store and recall information

Cons:
- Not representative of naturalistic communication
- Limited use of contextual information
- Requires surface-level processing only
Gaps in research

• More naturalistic listening task?

• What about fatigue?

• Underlying physiological mechanisms?
  ➢ Change over time?

• Child population?
Listening task

• Speech-picture verification task

➤ Extended speech passages providing more contextual information
  ❖ More representative of everyday communication

➤ Analyse potential changes over time during listening
“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.”
Pupillometry

• Measurement of the size of the eye’s pupil

• Collected continuously during virtually any task of interest

• Not under direct cognitive control

Kuchinsky et al (2014)
Pupillometry

- Linked to a well-studied neurophysiological system
- Modulated in part by changes in locus coeruleus (LC) activity, which regulates our states of attention and arousal

Aston-Jones & Cohen (2005)
Pupillometry

Pupil **dilation** - Larger task-evoked pupil size reflects increased task-related arousal/attention $^{1-8}$

Pupil **constriction** reflects decreased arousal – **smaller** pupil sizes associated with self-reported fatigue $^{9,10}$

Research Question

• Are self-report, RT, and pupillometric measures sensitive to differences in listening-related effort and fatigue during a naturalistic listening task in a group of:

1. NH Young adults
Procedure

**Order A**

- **Easy Trial Block**
  - 30 mins

- **Self-report**
  - 2 mins

- **Hard Trial Block**
  - 30 mins

- **Self-report**
  - 2 mins

**Order B**

- **Hard Trial Block**
  - 30 mins

- **Self-report**
  - 2 mins

- **Easy Trial Block**
  - 30 mins

- **Self-report**
  - 2 mins
Results: Accuracy

\[ N = 24 \]

Performance Accuracy

% Correct

Easy

Hard
Results: Effort

$N = 24$

**Self-report Effort**

**Correct trial RTs**

- **Condition**: Easy, Hard

- **Easy**
- **Hard**
Results: Fatigue

$N = 24$

Self-report Fatigue

RTs over each Trial Block

Condition
- Easy
- Hard

Rating

RT (in ms)

Trial

1 23 46
**Analysis: Pupillometry**

**Baseline**

- Pupil size during 2-3 seconds
- Recorded on a trial-by-trial basis.

**Pupil response**

- Relative change in pupil size from baseline during speech processing
Results: Pupillometry

Pupil response: Cubic model fit

$N = 24$
Results: Pupillometry

Pupil response: Cubic model fit

$N = 24$
Discussion

• Pupillometry sensitive to early attention-related differences between listening conditions
  ➢ *Self-report* and *RT* also sensitive to SNR

• Difference over time in listening-related *fatigue* between SNRs detected using pupillometry
  ➢ No difference in *self-report* and/or *RT* measures
Research Question (2)

- Are self-report, RT, and pupillometric measures sensitive to differences in listening-related effort and fatigue during a naturalistic listening task in a group of:

1. NH Young adults
2. NH Children (aged 8 – 11 years)
Child Study: Methodology

- Self-report scale for assessing a child’s current level of fatigue
- Shorter duration blocks (32 trials) – approximately 20 mins
- New ‘hard’ condition = -2 dB SNR
- 41 NH children (aged 8 – 11 years)
Results: Accuracy

\[ N = 38 \]

Performance Accuracy

- Easy
- Hard

% Correct

Condition
- Easy
- Hard
Results: Effort

$N = 38$

Correct trial RTs

Condition
- Easy
- Hard
Results: Fatigue

$N = 41$

Self-report Fatigue

$N = 38$

RTs over each Trial Block
Results: Pupillometry

Pupil response: Quartic model fit

Condition
- Easy
- Hard

$N = 27$
Results: Pupillometry

Pupil response over time

N = 27

Condition
- Easy
- Hard
Discussion

• No evidence of listening-related *fatigue* across all three measures

• Pupillometry reveals early differences in attention/arousal between listening conditions
  ➢ Despite no difference in accuracy, self-report, and RT measures
Conclusions

• Pupillometry can provide information about:
  ❖ Listening-related fatigue in young adults as a function of SNR
    ➢ Otherwise undetected using self-report and RT measures alone
  ❖ Attention-related changes in children as a function of SNR
    ➢ Otherwise undetected using self-report and RT measures alone
Implications

• Clinical feasibility?
  ➢ Pupillometry currently limited to research settings
  ➢ Eyetrackers not especially expensive, but require some expertise to analyse
  ➢ Pupillometry used to validate a more practical measure of effort/fatigue?
Future Directions

• Clinical population?
  ❖ Cognitive factors?

• Develop listening task?
  ❖ Requires more detailed understanding
  ❖ Address listening difficulties in children
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• THANK YOU FOR LISTENING EFFORTFULLY! (And sorry if you’re now fatigued.....)