What can pupillometry tell us about listening effort and fatigue?

Ronan McGarrigle
Edwards (2007)
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?

• Frequent anecdotal reports of fatigue and stress from hearing-impaired individuals (“I can hear but I can’t understand” etc.)

• 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
How do we measure listening effort and fatigue?

• **Self-report**
  - Questionnaires or rating scales

• **Behavioural**
  - Single listening task response time
  - Slower RTs in more challenging conditions = More listening effort (Houben et al, 2013)
  - Slower RTs as the experiment progresses = More fatigue (less vigilance)
How do we measure listening effort and fatigue?

• *Physiological*

- EEG, skin conductance, **pupillometry**

- Pupil size modulated by changes in the brainstem (‘locus coeruleus’) - sensitive to changes in attention and memory (Beatty, 1982)

- Pupil size also closely tied with autonomic activity (parasympathetic dominance = smaller pupil size)
Pupillometry

Pupil \textit{dilation} reflects listening effort - \textbf{larger} pupil size in more challenging listening conditions (Zekveld et al, 2010)

Pupil \textit{constriction} reflects fatigue – \textbf{smaller} pupil sizes in more subjectively fatigued individuals (Morad et al, 2000)
Listening tasks

• **Speech repetition**
  - Sentence repetition (Zekveld et al, 2010)

• **Speech memory**
  - Sentence recall (Piquado et al, 2010)
  - Sentence-final word recall (Pichora-Fuller et al, 1995)

• **Speech comprehension**
  - Narrative recall (Piquado et al, 2012)
Gaps in knowledge

• How does pupil size change during the course of processing more extended speech passages?

• Can the effort effect be replicated in more naturalistic listening conditions?

  ➢ Listening task which requires semantic processing and understanding of ‘jist’
Study 1: Methodology

• *Speech-Picture Verification (SPV) task*

  ➢ Participants were presented with speech and multi-talker babble noise passages in either ‘Easy’ (+15 dB SNR) or ‘Hard’ (-8 dB SNR) listening conditions

  ➢ Following the speech passage, an image appeared on the screen. Participants were required to indicate by pressing ‘yes’ or ‘no’ on a button box whether or not the image presented was mentioned in the previous speech passage
“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 analysis

- Fixation
- Background noise
- Speech onset
- Image presentation

0 sec
2 sec
3 sec
16 - 21 sec
Pupillometry analysis

• Baseline = Pupil size during 2-3 seconds

• Pupil response = Relative change in pupil size from baseline during speech processing

• Hypothesis
  ➢ Larger early pupil response in ‘hard’ versus ‘easy’ listening condition
Results

Pupil response

Normalized pupil size

Time relative to speech onset (in s)

Condition
Easy
Hard
Results

Pupil response

Normalized pupil size

Time relative to speech onset (in s)

-2 -1 0 1 2 3 4 5 6 7 8 9 10 11 12

Condition
- Easy
- Hard

p = .113

* p = .004

d = .42
Post-hoc Fatigue analysis

- Do baseline pupil sizes get smaller as the experiment progresses?
  - Looking at baseline values (pupil size during noise-alone presentation) across the duration of the experiment
Baseline analysis

Significant main effect of ‘Timing’ (Start vs End of each Block), $p < .05$
Post-hoc Fatigue analysis

• Is the Timebin four (fatigue) effect larger in the latter stages of the experiment?

  ➢ Average baseline used

  ➢ Looking at Time-bin four only over the course of the experiment
Time-bin Four analysis

Significant 3-way (all variables). And a 2-way (Block 2 only) interaction (p’s < .05) with smaller time-bin four mean pupil size found in ‘Hard’ versus ‘Easy’ listening condition at the End of Block 2 only.
Fatigue Discussion

• Do baseline pupil sizes get smaller as the experiment progresses?
  - Yes, within each block

• Is the Timebin 4 (fatigue) effect larger in the latter stages of the experiment?
  - Yes, specifically in the 2nd half of Block 2.
Effort Discussion

• **Effort** prediction
  
  - Larger early pupil response in ‘hard’ versus ‘easy’ listening condition

• Trend, but no significant difference

• Why?
  
  - SPV task not sufficiently taxing to elicit ‘effortful’ response?
  - Effort effect is task-dependent - in previous studies, task is more perceptually challenging?
Conclusions

• Pupillometry may not only reveal information about effort/cognitive load, but also listening-related fatigue

• This may be used in practice to complement current audiological assessment tools in the clinic
Future research

• Sentence repetition task - can we replicate ‘effort’ effect using this task with our own stimuli?

• What are the cognitive predictors of listening-related fatigue and how does memory load affect this phenomenon?

• Can this task be used in the child population?

• Other physiological measures of effort/fatigue (e.g. skin conductance)?
Acknowledgements

• Castang Foundation

• Supervisors: Professor Kevin Munro and Drs. Piers Dawes and Andrew Stewart.

• THANK YOU FOR LISTENING EFFORTFULLY!
References