Listening effort and fatigue: insights from pupillometry

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Background

Listening effort refers to the mental exertion required to attend to and understand an auditory message (McGarrigle et al, 2014). Listening-related fatigue is the mental tiredness assumed to be related to sustained incidences of listening effort and is frequently reported in individuals with hearing loss.

One potential objective measure of listening effort is pupilometry. Pupil size is thought to be sensitive to changes in the listening effort required to understand speech in noise, with larger pupil sizes reflecting online listening demand (Zekveld et al, 2010).

In an attempt to increase ecological validity, this study investigates how changes in the pupil size during more realistic (extended) speech passage processing in noise may reflect changes in listening effort and/or listening-related fatigue.

Hypothesis: Pupil size will show a relative increase at the early stages of speech processing (0 - 3 seconds post speech-onset) in the more challenging listening condition, reflecting an increase in listening effort.

Method

Stimuli and Design

Novel speech passages (see figure 1 for example) were recorded by a female speaker and digitally mixed with multi-talker babble to create two listening conditions:

- Easy (+15 dB signal-to-noise ratio)
- Hard (-8 dB signal-to-noise ratio)

Procedure

- For each trial, participants were presented with a speech-in-noise passage
- Following each passage, participants were required to indicate by pressing ‘yes’ or ‘no’ on a button box whether or not an image presented (e.g. one of the images in ‘figure 1’) was mentioned in the previous speech passage
- Using an eyetracker, the participant’s pupil response was automatically recorded for the duration of the spoken passage (each of which was between 13-18 seconds long).

Results and Discussion

We found a significant interaction effect between listening condition and time-bin, F(4,7) = 3.08, p = .043, η² = .66. Pairwise t-tests revealed significantly smaller pupil size in the Hard versus the Easy listening condition in time-bin four (9 - 12 secs post speech-onset) only, t(47) = 3.03, p = .004, d = .46.

Figure 2. Normalized pupil response during the course of speech passage processing for each listening condition (all passages after 12 secs post speech-onset).

Conclusions

- As well as being able to detect early (attention-related) changes in listening effort, pupillometric methods may also be able shed light on listening-related fatigue at later stages of speech processing
- Changes in the size of the time-bin four effect over time are consistent with the pronounced experience of listening-related fatigue in the more challenging listening condition evident in the latter stages of the experiment
- The absence of any significant early effect-related effect could be explained by a number of possible factors:
  - Listening task not sufficiently taxing to elicit an ‘effort’ response
  - ‘Effort’ effect is task-dependent – previous speech repetition studies are more perceptually challenging (as listeners must identify and repeat every spoken utterance). A follow-up study will examine this possibility by asking participants to repeat back sentences using the same stimuli
  - A reliable objective measure of listening effort and/or listening-related fatigue would be of particular value as an additional outcome measure for audiologists assessing hearing aid benefit and listening disability

References