The impact of bilateral cochlear implantation on listening effort revealed through measurements of pupil dilation

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elevated listening effort
Consequences of elevated listening effort

- Stress
- Fatigue
- Need for recovery after work
- Unemployment
- Early retirement
- Social isolation

higher in people with hearing impairment, because of increased listening effort

Edwards, 2007
Nachtegaal et al. 2009
Kramer et al. 2006
Järvelin et al. 1997
Danemark & Coniavitis Gellerstedt 2004
Demorest & Erdman 1986
Grimby & Ringdahl 2000
Keep this in mind...

Reduction of listening effort should be a goal of treatment.
Measurement of effort

Surveys / questionnaires

Reaction time

Multi-tasking interference
Pupil dilation: an index of cognitive load

\[ S^2_j = \frac{1}{n_j - 1} \sum_{i=1}^{n_j} (Y_{ij} - \bar{Y}_j)^2 \]
Testing procedure
Testing procedure

Baseline
3 s

Sentence
(2 - 3.8 s)

Wait
(rehearsal)
1.5 s
Testing procedure

<table>
<thead>
<tr>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
</tr>
<tr>
<td>Sentence</td>
</tr>
<tr>
<td>Wait (rehearsal)</td>
</tr>
<tr>
<td>Prompt</td>
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Pupil dilation – bilateral CIs

Better ear

![Graph showing pupil dilation response to stimulus]

- Change in Pupil Diameter (mm)
- Time (s) relative to stimulus offset
- Stimulus
- Response
- Silence
- Easy
- Hard

Wait
Pupil dilation – bilateral CIs

Better ear • Poorer ear

![Graph showing pupil dilation over time](image)
Pupil dilation – bilateral CIs

Better ear  Poorer ear

Bilateral

 Tested Ear
 Poorer Ear
 Better Ear
 Bilateral

Model Fit

Change in Pupil Diameter (mm)

Time (s) relative to stimulus offset

0.4
0.3
0.2
0.1
0.0

easy

hard
Summary

When listening with both ears, listeners exerted less effort than when listening with the better ear.

• Lesson: Even if the second ear is not as good, it can help to reduce listening effort.
Some caveats to consider

Measuring listening effort in children will be much more challenging

Ideal situation: testing unilateral patients who then obtain a second implant, rather than post-hoc testing of bilateral patients
Conclusions

Listening effort can be an important part of outcome measurements

* Especially when word recognition scores don’t convey the benefits that patients report

Quantification of listening effort can play a role in:

* counseling
* healthcare advocacy
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