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Speech-in-noise processing in elderly hearing-impaired listeners with or without hearing aid experience: Eye-tracking and fMRI measurements

Julia Habicht, Oliver Behler, Birger Kollmeier & Tobias Neher
Medizinische Physik and Cluster of Excellence "Hearing4all", Oldenburg University, Oldenburg, Germany

INTRODUCTION

Wendt et al. (2014) developed an eye-tracking paradigm for estimating how quickly a participant can grasp the meaning of an acoustic sentence-in-noise stimulus that is presented concurrently with two similar pictures, only one of which depicts the sentence meaning correctly (the "presenting" time). Previously, we found that hearing-impaired (HI) listeners with hearing aid (HA) experience had shorter processing times than HI listeners without HA experience, despite no differences in speech intelligibility (Habicht et al., 2016, 2017). Peele and Wingfield (2016) suggested that HI listeners recruit regions outside the core speech processing network (comprising middle temporal and inferior frontal gyri) to achieve speech comprehension. Here, we adapted the eye-tracking paradigm for functional magnetic resonance imaging (fMRI) measurements to address the following research question:

Is HA experience associated with reduced recruitment of brain regions outside the core speech comprehension network?

EYE-TRACKING MEASUREMENTS

Speech material (Usil et al. 2013)
Two sentence structures with different levels of linguistic complexity (‘low’ and ‘high’).

<table>
<thead>
<tr>
<th>Low</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Der müde</td>
<td>Den müden</td>
</tr>
<tr>
<td>Drache</td>
<td>Drache</td>
</tr>
<tr>
<td>fesselt</td>
<td>fesselt</td>
</tr>
<tr>
<td>den</td>
<td>der</td>
</tr>
<tr>
<td>Großer</td>
<td>große</td>
</tr>
</tbody>
</table>

Meaning: The tired dragon ties up the big panda.

Picture sets
One picture illustrates the situation described in the spoken sentence (→ target). The other picture illustrates the same situation with interchanged roles (→ competitor).

Task
“Select the picture that matches the acoustic stimulus by pressing a button as fast as possible after the acoustic presentation!”

Outcome
Eye-fixation rate over time allows estimating when the participant must have grasped the sentence meaning.

FMRl MEASUREMENTS

Stimuli
Sentence-in-noise stimuli with corresponding picture sets from eye-tracking (SPIN_{\text{Low}}, SPIN_{\text{High}}). Stationary speech-shaped noise with only one picture as baseline.

Task
“Select the target picture by pressing a left or right button after the acoustic presentation!”

Outcome
Brain activation as inferred via blood oxygenation level dependent (BOLD) contrasts.

PARTICIPANTS

Matched groups of experienced (eHA) and inexperienced (iHA) HA users.

Table 1: Mean age, PTA across 0.5, 1, 2, and 4 kHz, reading span (RS), and SRT_{\text{AERA}} scores for the two listener groups.

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (yr)</th>
<th>PTA (dB HL)</th>
<th>RS (s-corrected)</th>
<th>SRT_{\text{AERA}} (dB SNR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>eHA (N = 13)</td>
<td>68.8</td>
<td>33.9</td>
<td>43.0</td>
<td>−1.6</td>
</tr>
<tr>
<td>iHA (N = 14)</td>
<td>68.8</td>
<td>31.1</td>
<td>38.9</td>
<td>−1.7</td>
</tr>
</tbody>
</table>

AMPLIFICATION

All stimuli spectrally shaped according to the National Acoustic Laboratories-Revised’ (Byrne et al. 2001) prescription rule using the Master Hearing Aid (Grimm et al. 2008) and presented via earphones.

RESULTS

Eye-tracking measurements

Table 1: Significant effects from novel model ANOVA.

<table>
<thead>
<tr>
<th>Factor</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ling. complexity</td>
<td>21.0</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Listener group</td>
<td>5.5</td>
<td>0.026</td>
</tr>
</tbody>
</table>

Figure 2: Mean processing times for the two listener groups and levels of linguistic complexity.

fMRI measurements

Stimulus type:
4. A: As expected, relative to the noise-only stimuli, the SPIN stimuli led to more activation in bilateral superior temporal gyri, left superior and inferior frontal gyri, right middle frontal gyrus, left precentral gyrus, and bilateral middle occipital gyri (cf. Lee et al. 2016).

4. B: Ling. complexity: As expected, relative to the SPIN_{\text{Low}} stimuli, the SPIN_{\text{High}} stimuli led to more activation in bilateral inferior and middle frontal gyri, left precentral, right middle occipital and left superior temporal gyri (cf. Lee et al. 2016).

5. A: Listener group × stimulus type: As expected, relative to the eHA group, the iHA group showed more activation for the SPIN stimuli relative to the noise-only stimuli in left precentral, left cerebellum, right medial frontal gyrus, and left superior temporal gyrus (cf. Peele et al. 2011).

5. B: Listener group × ling. complexity: Consistent with our eye-tracking results (see above), no interaction between listener group and linguistic complexity observable.

CONCLUSIONS

Our results support the idea that HA experience (1) positively influences the ability to process noisy speech quickly and (2) reduces the recruitment of brain regions outside the core speech comprehension network, regardless of linguistic complexity.

REFERENCES


Wendt, D. et al. (2014). An eye-tracking paradigm for analysing the processing time of sentences with different linguistic complexities. PLoS ONE 9(6), DOI: 10.1371/journal.pone.0101786.

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