Factors in preference for noise reduction processing

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Relating hearing loss and executive functions to hearing aid users’ preference for, and speech recognition with, different combinations of binaural noise reduction and microphone directionality

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Directional Processing and Noise Reduction in Hearing Aids: Individual and Situational Influences on Preferred Setting
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Investigating Differences in Preferred Noise Reduction Strength Among Hearing Aid Users

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NR processing ‘dilemma’
- Trade-off: Noise attenuation vs. speech distortion (e.g. Kates, 2008)
- HA users seem to respond differently to these conflicting effects (Marzinzik, 2000; Houben et al, 2012)
- Some HA users prefer strong NR despite poorer speech recognition

Aims of current study
- To investigate the ability of a number of psychoacoustic, audiological, and self-report measures aimed at indexing noise tolerance, distortion sensitivity, and other ‘sound personality’ traits to predict NR preference
- To investigate the long-term stability and signal-to-noise ratio (SNR) dependence of NR preference
Participants

- Chosen to have clear preferences or clear dislikes for strong NR (‘NR lovers’ vs. ‘NR haters’), as determined ~1 year earlier
  - Previously, total of 60 elderly experienced HA users tested
    - Pairwise comparisons re. overall preference for ‘inactive’, ‘moderate’, and ‘strong’ NR at input SNRs of 0 and +4 dB
    - Binaural coherence-based NR (Neher, Front Neurosci 2014)
    - Single-microphone, modulation-based NR (Neher et al, J Am Acad Audiol 2016)

- For the current study…
  - Calculation of aggregate preference scores based on both datasets
  - Selection of 27 participants, including 23 ‘unambiguous’ ones as well as 4 ‘borderline’ ones who tended to converge at moderate NR
Participants ctd.

- Bilateral, symmetrical, sensorineural hearing losses
- At least 1.5 yrs of experience with bilateral HAs
- No psychiatric disorders (e.g. depression)
- Age-appropriate to mildly impaired cognition as per “DemTect” (Kalbe et al, 2004)
- Main group characteristics (means and ranges):

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Age (yrs)</th>
<th>PTA4 (dB HL)</th>
<th>Read. span (%-corr.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NR lovers</td>
<td>14</td>
<td>70 (64-78)</td>
<td>47 (34-58)</td>
<td>40 (22-57)</td>
</tr>
<tr>
<td>NR haters</td>
<td>13</td>
<td>73 (61-81)</td>
<td>44 (29-67)</td>
<td>39 (20-56)</td>
</tr>
</tbody>
</table>

All $p > 0.05$
HA signal processing

- Real-time simulation of bilateral HAs
  - Implemented on Master Hearing Aid platform (Grimm et al, 2006), controllable via test software

- Signal processing (as before)
  - Binaural coherence-based NR (Grimm et al, 2009), individual linear amplification (NAL-RP), headphone equalisation

- NR strength
  - Controlled by varying algorithmic parameter $\alpha$ from 0 (= inactive) over 0.75 (= moderate) to 2 (= strong)

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Estimated binaural coherence NR gain (dB)

- $\alpha = 0$
- $\alpha = 0.75$
- $\alpha = 2$

Estimated binaural coherence

NR gain (dB)

0 0.2 0.4 0.6 0.8 1
-30 -25 -20 -15 -10 -5 0

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Noise attenuation vs. speech distortion at +4 dB SNR

- $\alpha = 0$
- $\alpha = 0.75$
- $\alpha = 2$

Waveforms of S and N

Spectrograms of S+N

<table>
<thead>
<tr>
<th>$\Delta$AI-SNR</th>
<th>HASQI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.6 dB</td>
<td>0.86</td>
</tr>
<tr>
<td>2.8 dB</td>
<td>0.68</td>
</tr>
</tbody>
</table>
Speech stimuli & measurements

- **Speech stimuli (virtual acoustics)**
  - Recordings made in reverberant cafeteria with two behind-the-ear HA dummies on head-and-torso simulator (Kayser et al, 2009)
    - S: Sentences from Oldenburg sentence test convolved with head-related impulse responses of nearby, frontal source
    - N: Extracts from recording of fully occupied cafeteria

- **Measurements**
  - Self-adjusted NR strength
    - Task: “Adjust $\alpha$ to preferred level for prolonged listening”
    - Input SNRs: [0, +4] dB; 3 test runs each
Acceptable noise level (ANL) \cite{Nabelek1991}:

- Level of N adjusted so (i) S no longer understandable, (ii) S very easily understandable, and (iii) N just tolerable while listening to S; ANL = 65 − L_{N(iii)} dB
- NR: {inactive, moderate, strong}; 3 test runs each

Sensitivity to speech distortions \cite{Brons2014}:

- Detection thresholds for S distortions caused by NR processing
- Task: “Which of two sounds was different from a reference sound?” (3I-2AFC)
- Ref.: S unprocessed; Target: S processed with NR gains for S+N; Levels equalised and roved; 2 test runs
Measurements ctd.

- Self-reported ‘sound personality’ (Meis et al, 2016)
  - 46-item inventory for predicting usage of, and preference for, HA technology
    - F1: Disturbance by noise
    - F2: Importance of sound quality
    - F3: Noise sensitivity
    - F4: Avoidance of unpredictable sounds
    - F5: Openness towards loud/new sounds
    - F6: Preference for warm sounds
    - F7: Details in environmental sounds/music
Results
- NR haters prefer weaker NR than NR lovers ($p < 0.01$)
- Both groups prefer stronger NR at higher SNR ($p < 0.01$)
NR lovers tend to be more sensitive to noise (→ inactive NR, \( p = 0.058 \))

For NR lovers, noise tolerance improves by 3.7 and 4.5 dB with moderate and strong NR, respectively (both \( p < 0.001 \))
NR lovers tend to be less sensitive to S distortions than NR haters ($p = 0.06$)

$\alpha$ at threshold: 0.31 vs. 0.44
No differences among groups (all $p > 0.05$)

Group differences most apparent for…

- F4: Avoid unpredictable sounds ($p = 0.065$)
- F6: Prefer warm sounds ($p = 0.21$)
- F3: Noise sensitivity ($p = 0.24$)
Correlations among measures

- Aggregate pref. scores and self-adjusted $\alpha$-values
  - $r = 0.64$, $p < 0.001$

- Detect. thresholds for S distortions, ANLs, self-reported traits, and self-adjusted $\alpha$-values
  - All $|r| < 0.3$, $p > 0.1$
Summary

- Preferred NR strength is a very individual trait
- Preferred NR strength appears generally stable over time, at least for experienced HA users
  - NR haters show greater tendency to change groups than NR lovers
- Preferred NR strength increases with input SNR, irrespective of group membership
- Acceptable noise levels and detection thresholds for speech distortions may be able to predict group membership, but further research is needed
Thanks for listening!
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Literature

