Perceptual strategies of normal-hearing listeners and hearing-aid users for consonant discrimination in noise

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1. Introduction

• Phonetic categorization is a complex process involving the detection and combination of **multiple acoustic cues** [1, 2]. For example, the discrimination of /da/ and /ga/ in noise relies on (at least) two cues [2]:
- a **primary cue (cue 1)** on the 2nd and 3rd formant onsets
- a **secondary cue (cue 2)** on the 1st formant onset

• Understanding how human listeners use such cues and how these perceptual strategies are impacted by hearing loss is an important step toward designing more effective speech-processing algorithms for hearing-impaired (HI) or normal-hearing (NH) individuals [3].

• In particular, **supra-threshold deficits** are known to affect the weighting strategies and the use of speech cues, and may explain why HI listeners often gain limited benefit from a hearing aid [4,5].

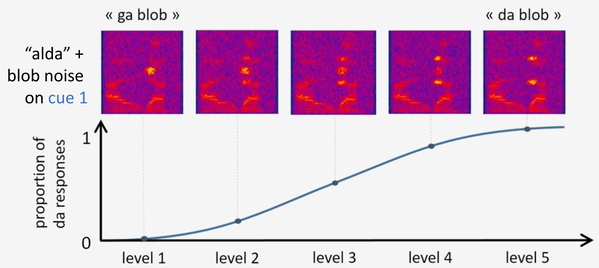
• Here, we measured the sensitivity of listeners to **cue 1** and **cue 2** in a /da/-/ga/ categorization task. Using this method, we **compared the weighting strategies** of NH and HI listeners for consonant discrimination in noise.

2. Methods

• **Blob noise**: white noise with an additional bump of noise enhancing one of the acoustic cues → a noise that **shifts perception** from da to ga (or from ga to da).

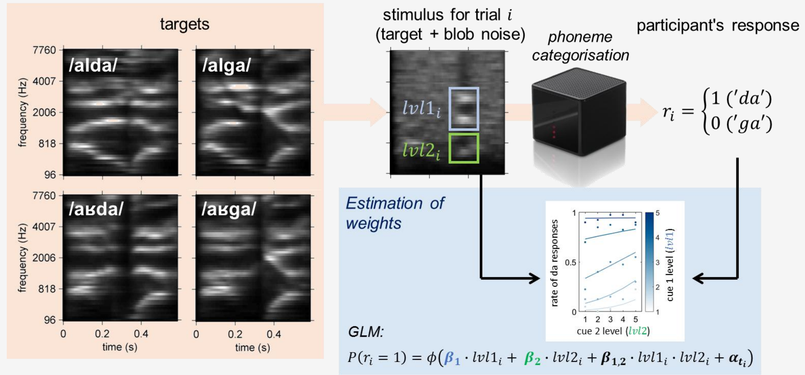
• By varying the energy of the blob and measuring the proportion of confusions, we can estimate the **sensitivity** of a listener to the corresponding cue.

• Joint measurement of the weightings of **two separate cues** in the phonetic decision → **2-dimensional /da/-/ga/ continuum** with 5 levels per dimension, totalling 25 blob noise configurations.



Example of 1-dimensional blob noise continuum on cue 1 and schematic representation of the corresponding psychometric function.

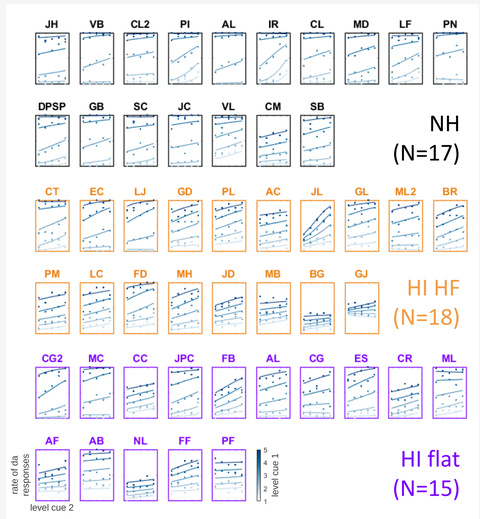
• **1000 trials** per participant (4 target X 25 blob noises X 10 repetitions).
• The data was fed to a Generalized Linear Model to get individual estimates of β_1 and β_2 (participant's weights on cue 1 and cue 2.)



This approach was used in three groups of listeners:
- **17 normal-hearing (NH)** participants
- **18 hearing-impaired (HI HF)** participants with high-frequency loss
- **15 hearing-impaired (HI flat)** participants with approximately flat loss

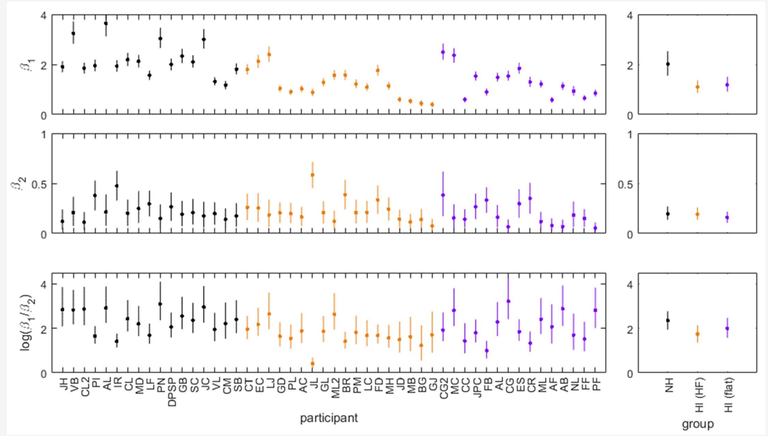
• For all HI participants, audibility was restored with a **simulated hearing aid** (NAL-R algorithm, fitted individually).

• The weights were estimated at the individual and group level through a Bayesian hierarchical GLM.



Data measured for all participants (dots) and predictions of the model (lines), averaged across targets. The proportion of 'da' answer is plotted as a function of cue 2 level, with cue 1 level as a parameter (shade of blue).

3. Results



Estimated values for parameters β_1 and β_2 at the individual (left) and group (right) levels, with 95% credible intervals. The lower panel shows the values of the log sensitivity ratio $\log(\beta_1/\beta_2)$

• **Large within-groups and between-groups variability** in the weightings of the two cues.
• **log sensitivity ratio** $\log(\beta_1/\beta_2)$: relative importance of cue 1 and cue 2 in the decision, irrespective of the influence of other factors such as internal noise.
• The variability in the individual weights comes mostly from internal noise (not from an individual inability to make use of one particular cue).
• **HI HF participants relied slightly less heavily on cue 1** (relative to **cue 2**), compared to **NH** individuals, even though their hearing loss was corrected through amplification.

4. Conclusions

1. The **blob noise method** allows the experimenter to measure the weighting strategies of listeners or groups of listeners engaged in **natural speech categorization in noise**.

2. We observed a large inter-individual variability in the absolute values of the weights, mostly due to **internal noise**.

3. Despite the fact that they are provided with a simulated hearing aid, **HI HF listeners are unable to adapt their strategy to come back to that of a NH participant**. This inability to weight the cues efficiently may explain why they often obtain limited benefit from their hearing aid.

References:

1 Li, F., Menon, A. & Allen, J. B. A psychoacoustic method to find the perceptual cues of stop consonants in natural speech. *The Journal of the Acoustical Society of America* 127, 2599-2610, doi:10.1121/1.3295689 (2010).

2 Varnet, L., Knoblauch, K., Serniclaes, W., Meunier, F. & Hoen, M. A Psychophysical Imaging Method Evidencing Auditory Cue Extraction during Speech Perception: A Group Analysis of Auditory Classification Images. *PLoS ONE* 10, e0118009, (2015).

3 Abavisani, A. & Allen, J. B. Evaluating hearing aid amplification using idiosyncratic consonant errors. *The Journal of the Acoustical Society of America* 142, 3736, doi:10.1121/1.5016852 (2017).

4 Turner, C. W. & Brus, S. L. Providing low- and mid-frequency speech information to listeners with sensorineural hearing loss. *The Journal of the Acoustical Society of America* 109, 2999-3006, doi:10.1121/1.1371757 (2001).

Acknowledgements: L. Varnet was supported by Starkey Hearing Technologies and ENS Paris. The study was approved by the Ethical Committee CPP Ile de France III with the ID RCB : 2016-A01769-42.