DÉPARTEMENT D'ÉTUDES COGNITIVES

Assessment of individual listening strategies in amplitude-modulation detection and phoneme categorisation tasks

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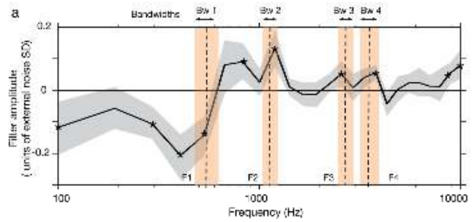
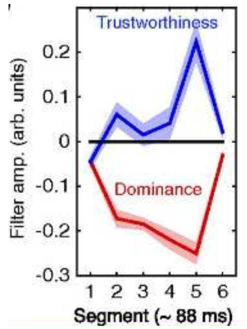
Auditory revcorr studies (full diagram on https://dbao.leo-varnet.fr/)

high level

paralinguistics

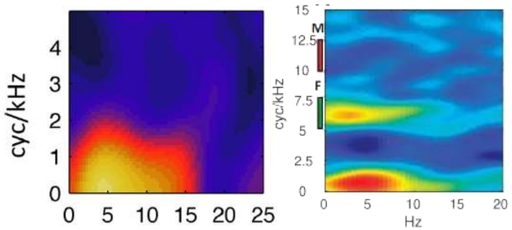
[Ponsot et al., 2018a, 2018b]





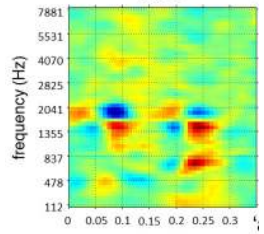
sentence recognition

[Venezia et al., 2016, 2019]



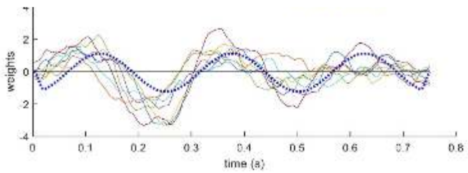
phoneme categorisation

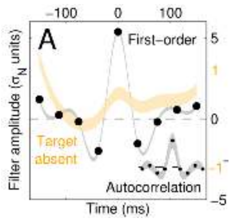
[Varnet et al., 2013, 2015]

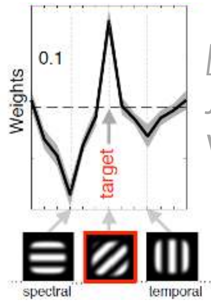


modulation perception

[Ponsot et al., 2020; Joosten & Neri, 2012; Varnet & Lorenzi 2022]

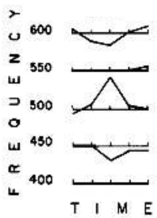


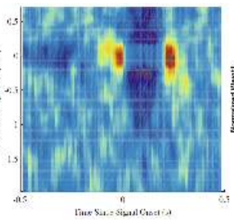


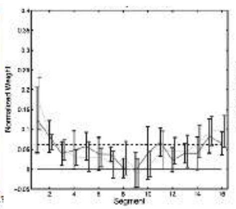


pure-tone detection & loudness perception

[Ahumada & Lovell, 1971; Shub & Richards, 2009; Ponsot et al. 2013]





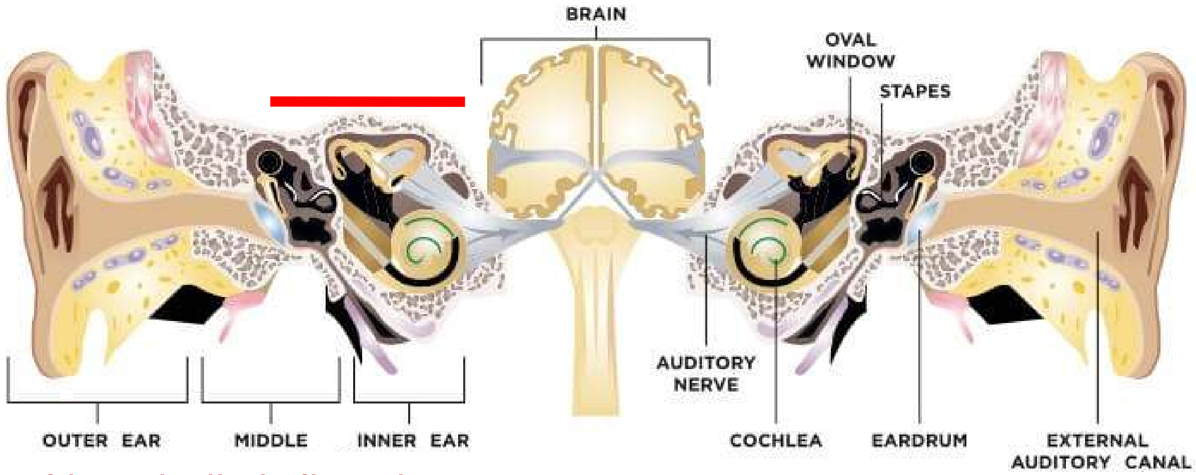


low level

Application to binaural hearing?

- The revcorr method is a behavioural method:
  Link between the **“stimuli”** and the **“participant’s responses”**

- In auditory tasks, the “stimuli” are transformed into a **time-frequency internal representation** before they are related to the “participant’s responses”



Here:
- Cochlear filter bank
- Inner hair cell

Sounds are “monaural”, although diotic listening

Image from: https://www.happyearshearing.com/hearing-loss/how-the-ear-works/ (download on:

Intrinsic fluctuations and revcorr

- The key aspect in the ACI method is the external variability of the background noises:

- Masking of a steady-state noise: Partly due to random envelope fluctuations within the critical bands (aka **intrinsic fluctuations**)

- The **revcorr** approach: Effect of intrinsic fluctuations in a perceptual task

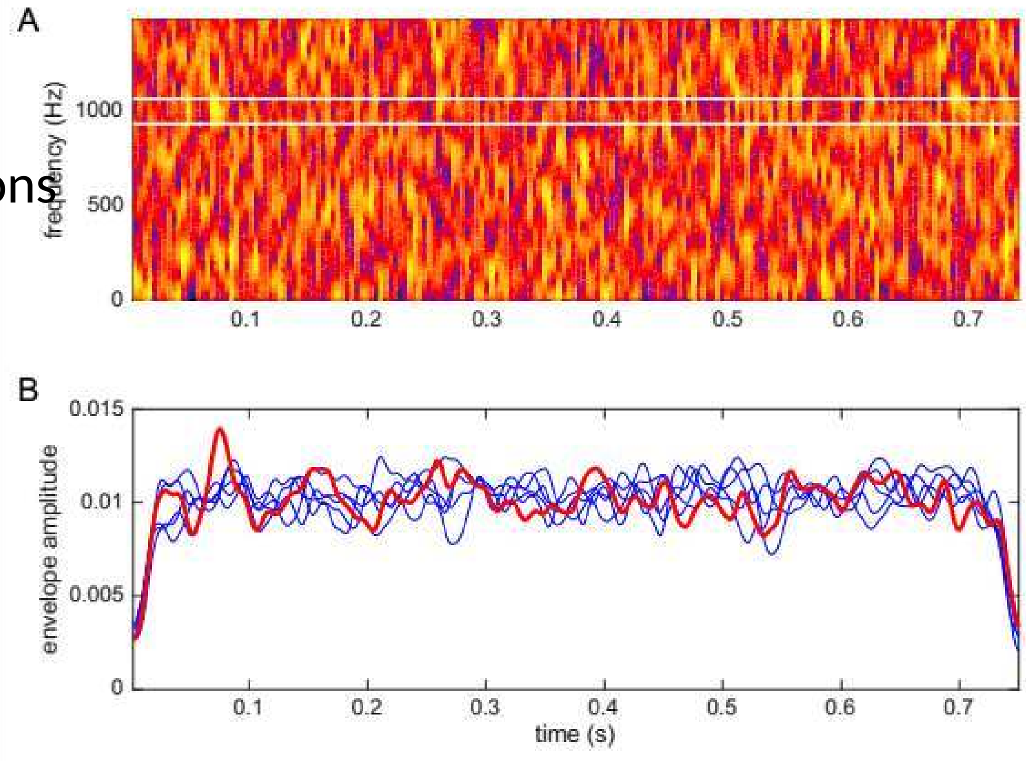


FIG. 1. Illustration of intrinsic envelope fluctuations

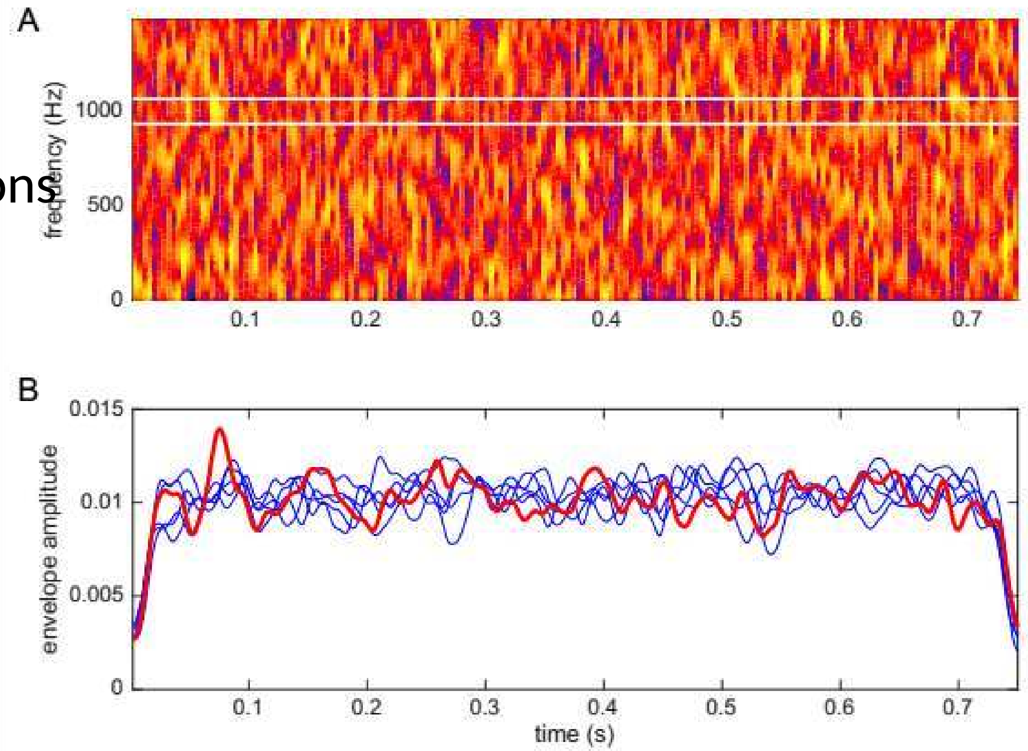
(Varnet & Lorenzi, 2022, JASA)

This figure:
white noise in an AM detection task

Here also:
for a phoneme discrimination task

Intrinsic fluctuations and revcorr

- The key aspect in the ACI method is the external variability of the background noises:



- Masking of a steady-state noise:
  Partly due to random envelope fluctuations within the critical bands
  (aka **intrinsic fluctuations**)
- The **revcorr** approach: Effect of intrinsic fluctuations in a perceptual task

Objective: use revcorr to visualise the **listening strategies in different tasks** using the intrinsic fluctuations of a steady-state noise

Objective of this study

[Varnet et al., 2013]
[Osses & Varnet, 2021]
[Varnet & Lorenzi, 2022]

Comparison of the listening strategies of the same two participants (SA and SB):

- In four tasks:

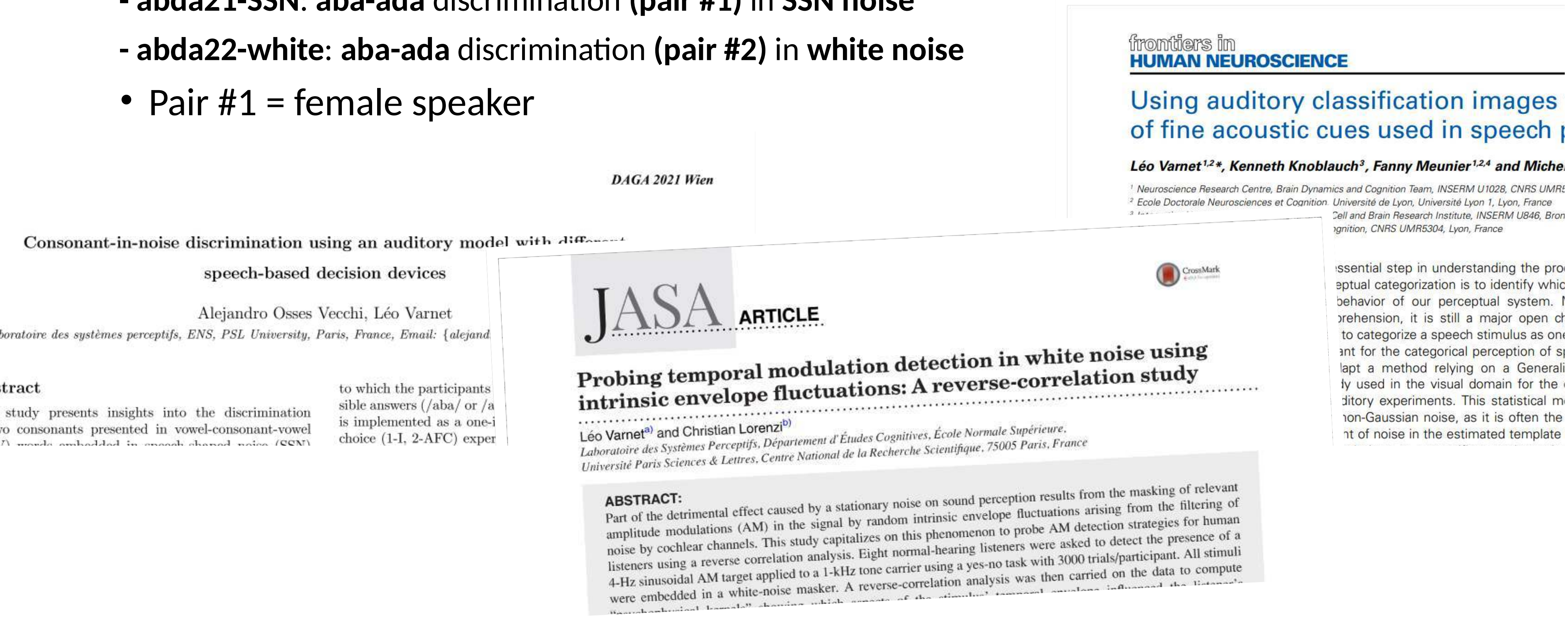
- mod22: amplitude modulation (AM) detection in **white noise**

- abda13-white: **aba-ada** discrimination **(pair #1)** in **white noise**

- abda21-SSN: **aba-ada** discrimination **(pair #1)** in **SSN noise**

- abda22-white: **aba-ada** discrimination **(pair #2)** in **white noise**

- Pair #1 = female speaker

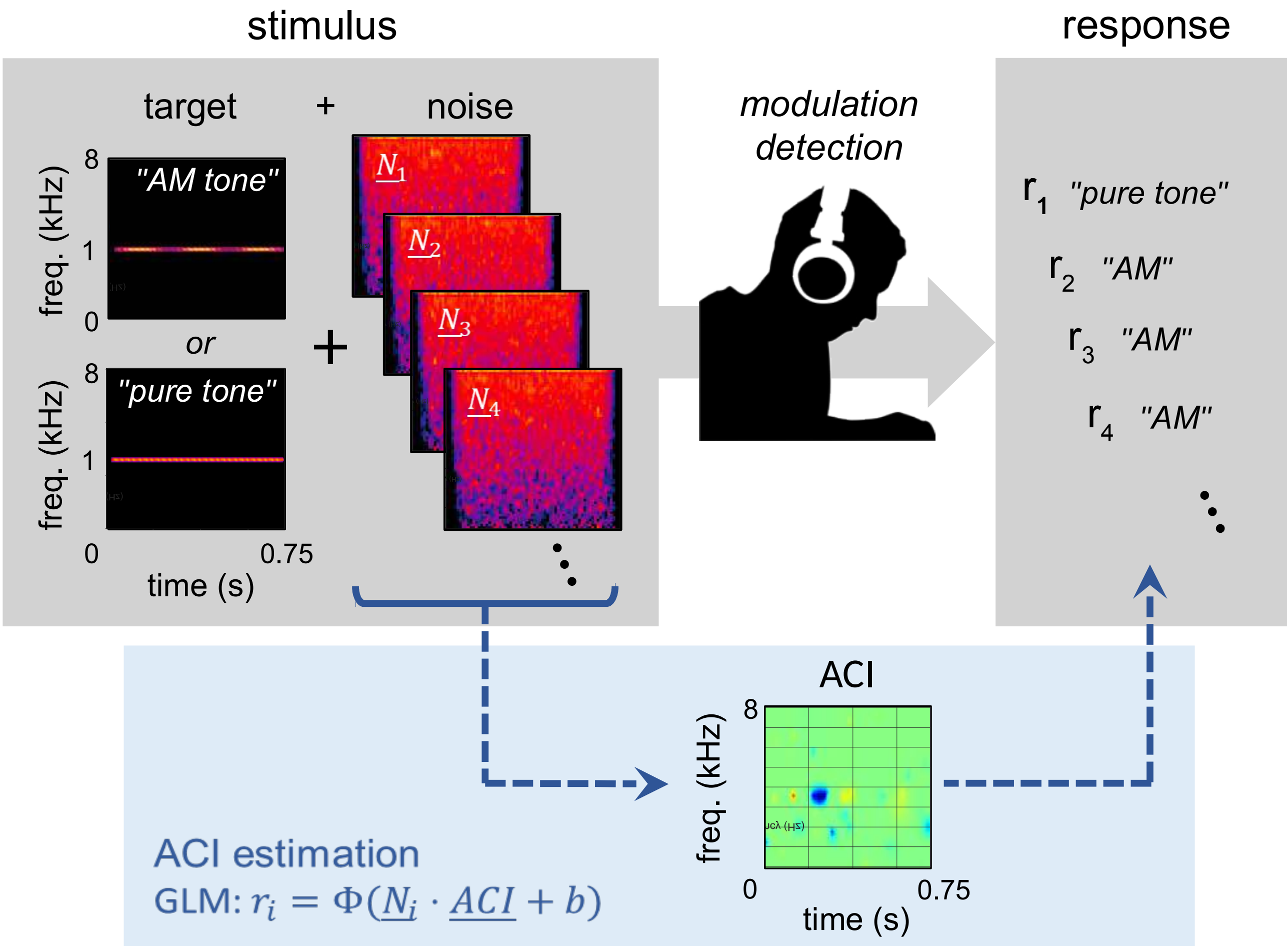


AM detection

Stimuli: AM tone or pure tone in a white noise (65 dB SPL). Carrier frequency = 1000 Hz. Modulation frequency = 4 Hz

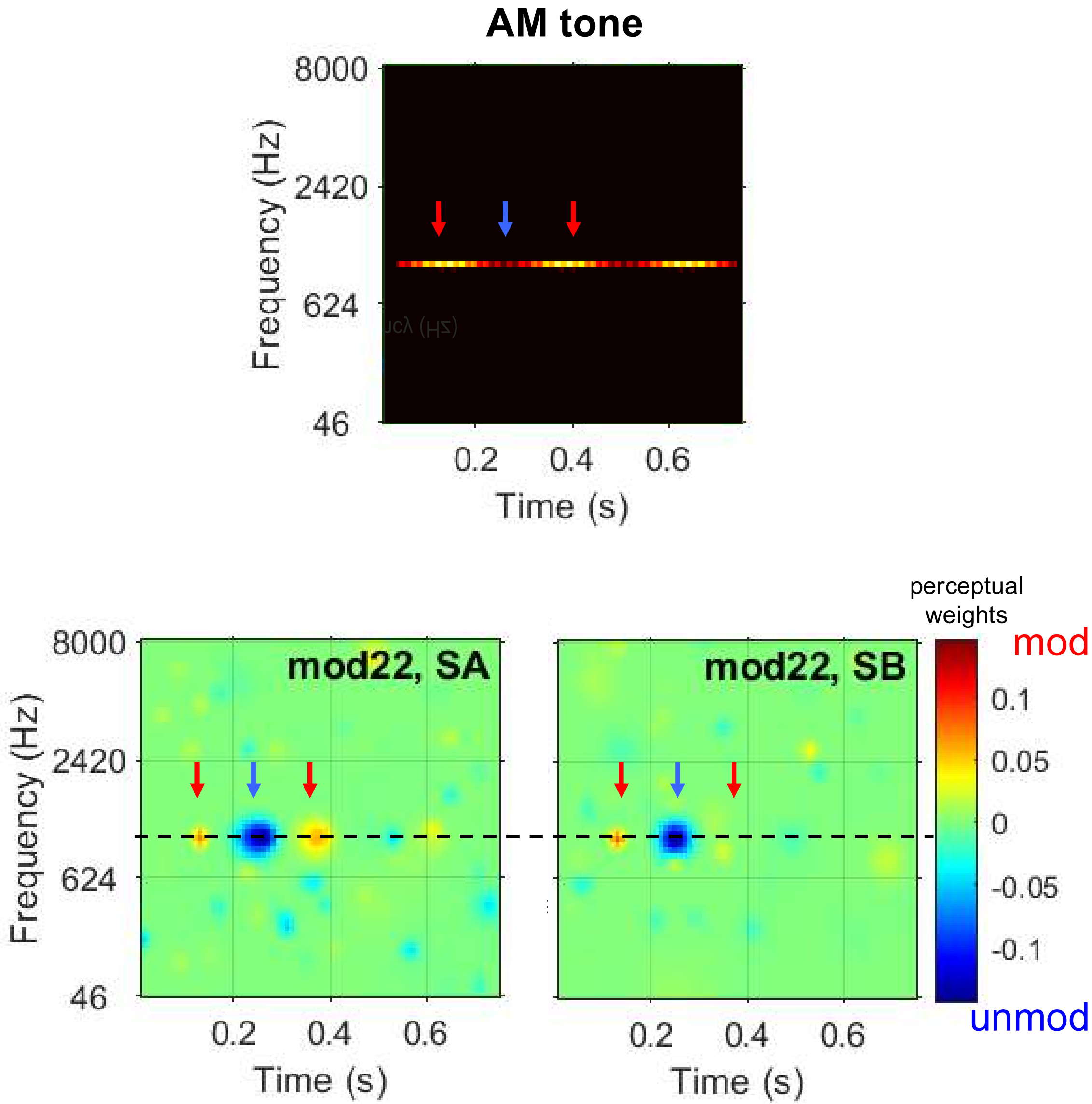
Task:
“AM tone” or “pure tone”?

Modulation depth:
Adapted to obtain 70.7% of correct responses



Results

- Set of positive and negative weights arranged horizontally
- Only noise fluctuations around (1000 Hz) influence the decision
- If the noises have intrinsic fluctuations similar to the modulation target, they induce an «AM tone» response
- The main cue in the task: Presence of an envelope minimum at 0,25 s
[Varnet & Lorenzi, 2022]

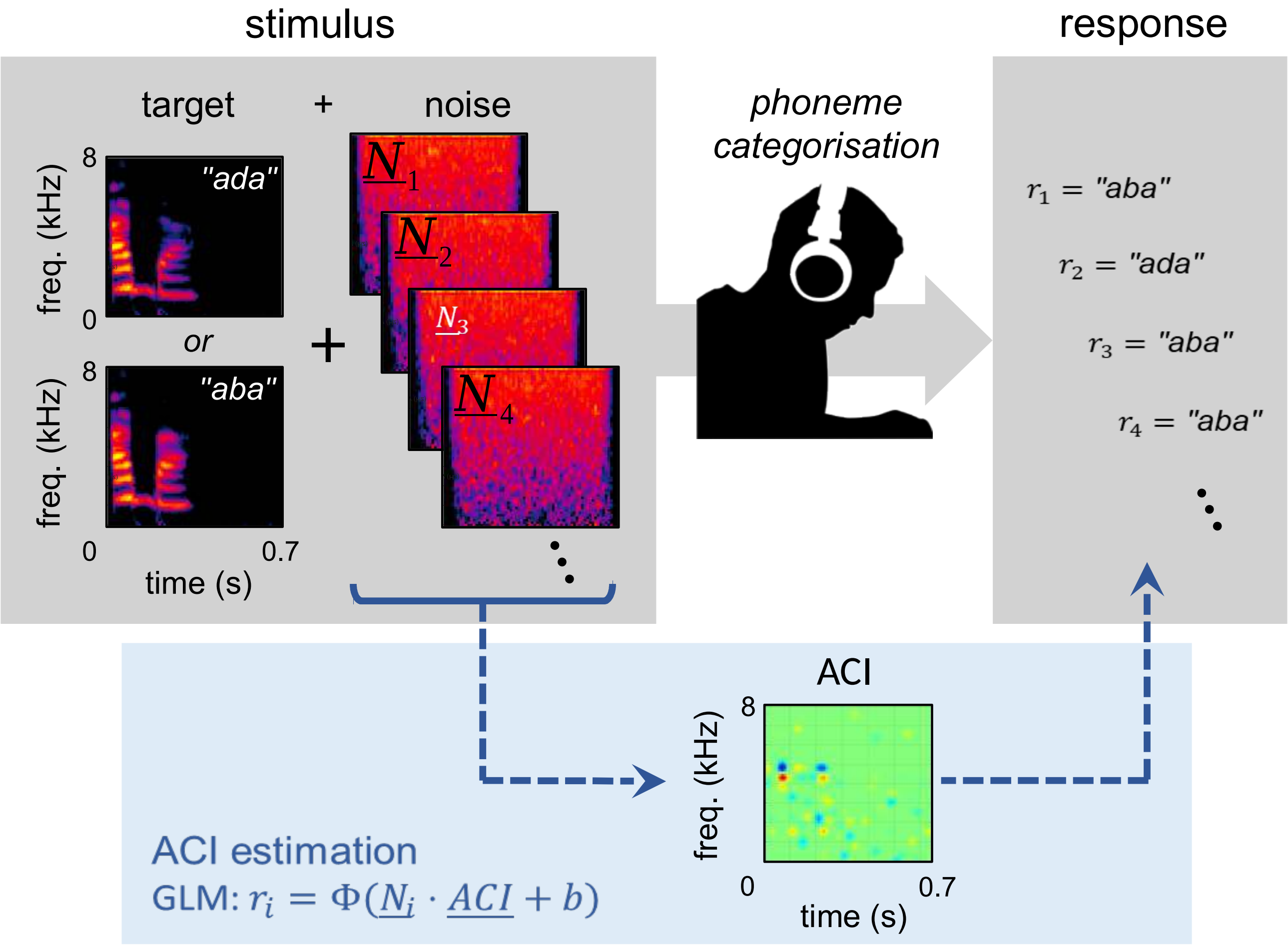


Aba-ada discrimination

Stimuli: «aba» ou «ada» in a background noise (65 dB SPL).

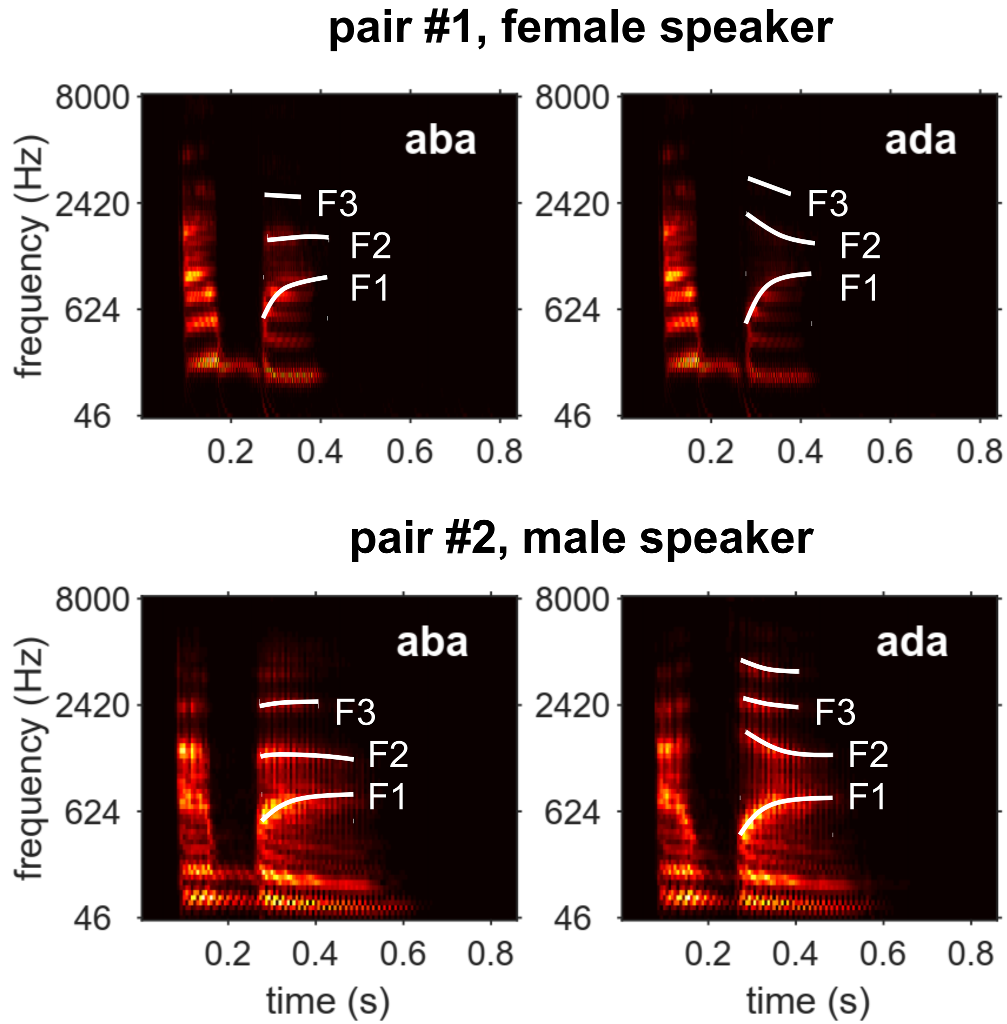
Task:
Do you hear «aba» or «ada»?

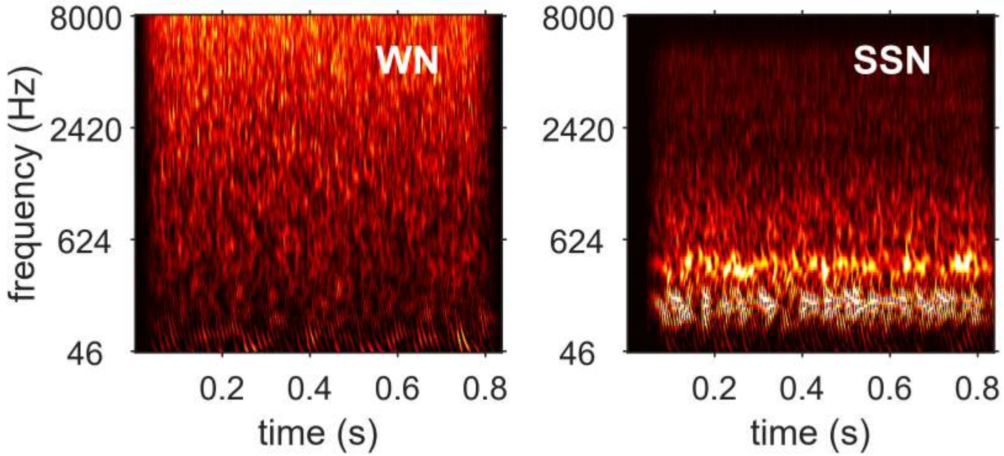
SNR: Adapted to obtain a 70.7% of correct responses



Stimuli

- Two pairs of aba-ada words (uttered by a male or female speaker)

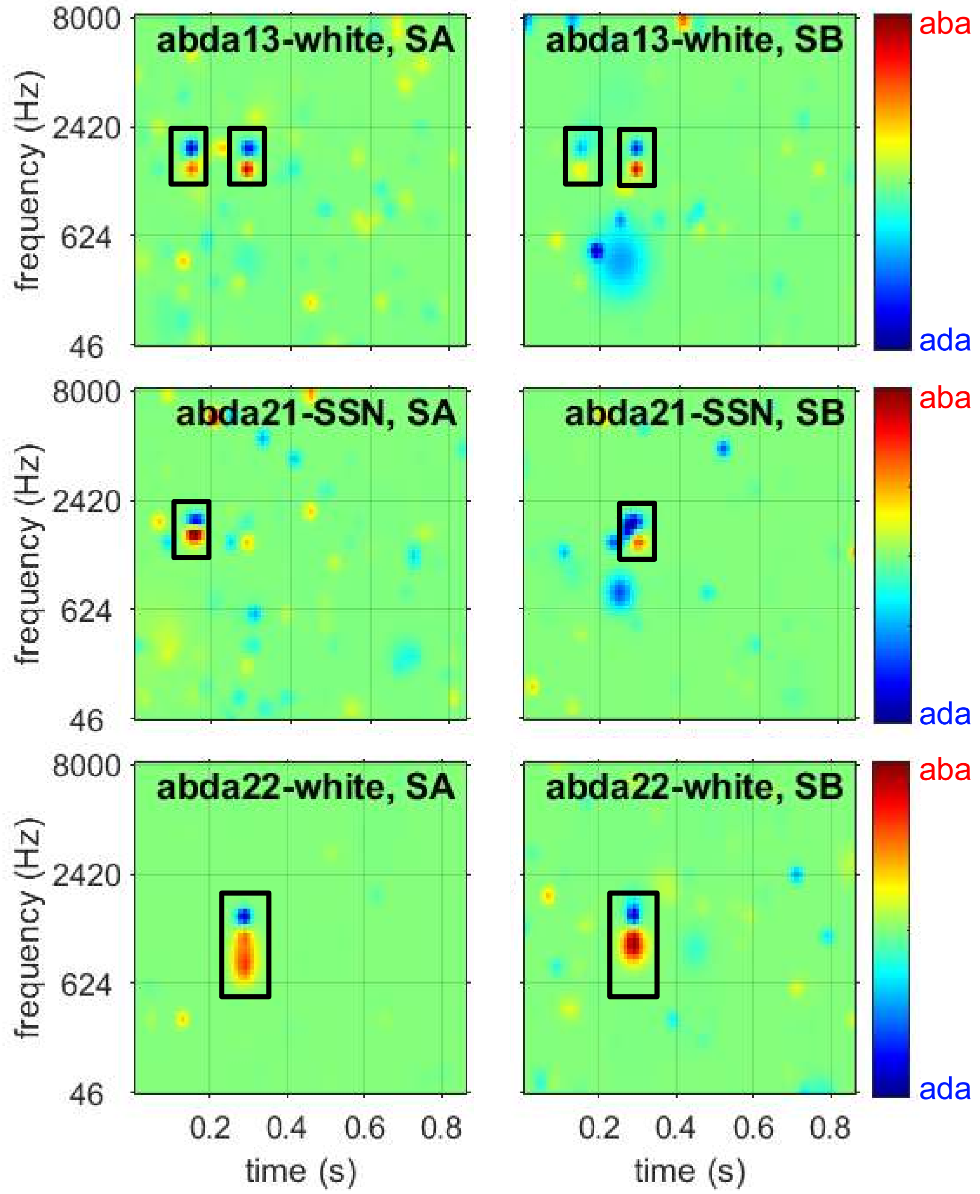




- The **transition of the second formant (F_2)** allows to distinguish aba and ada *[Liberman et al., 1952]*

Results

- Set of positive et negative cues arranged **vertically**…

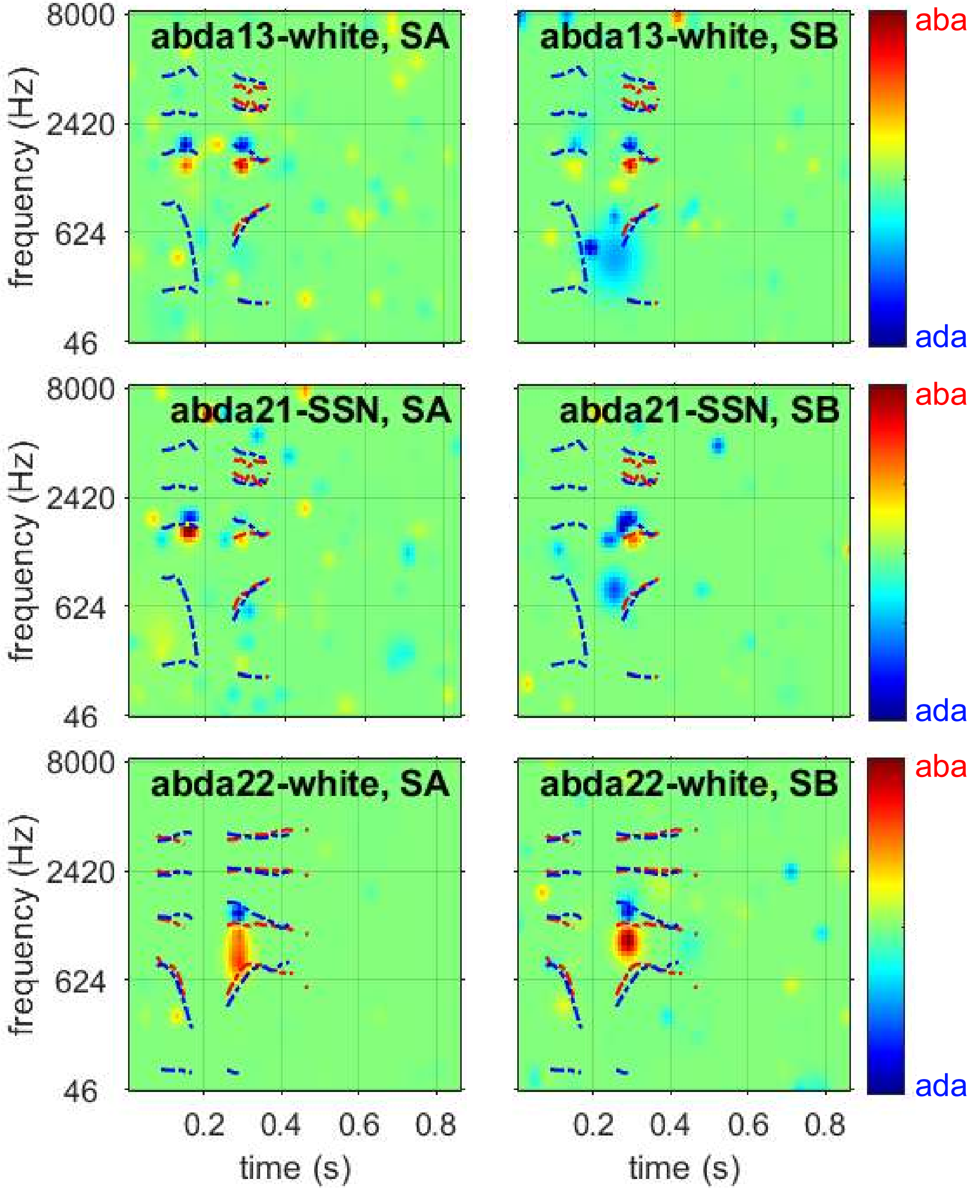


Results

- Set of positive et negative cues arranged **vertically**…
- … they correspond to the F_2 transition

So: F_2 is an acoustic cue used to discriminate /aba/ from /ada/

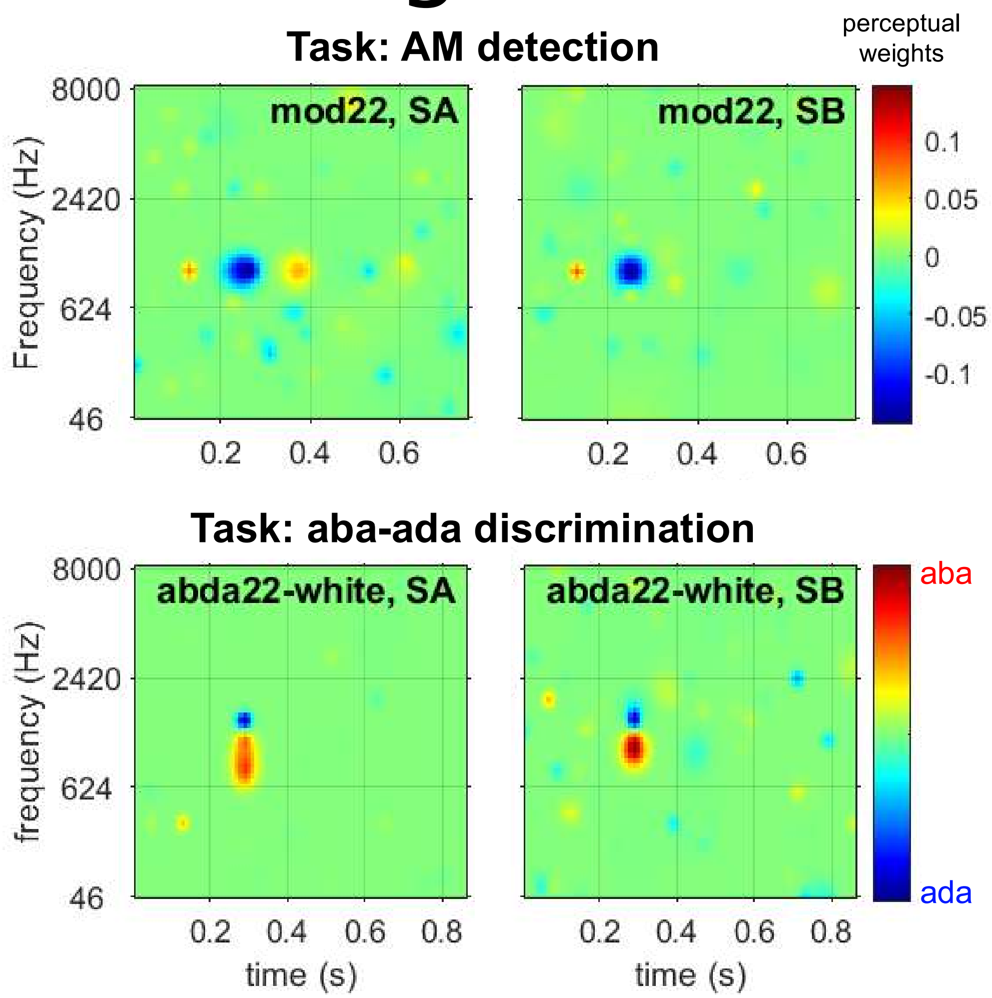
- Other cues can be involved in this task



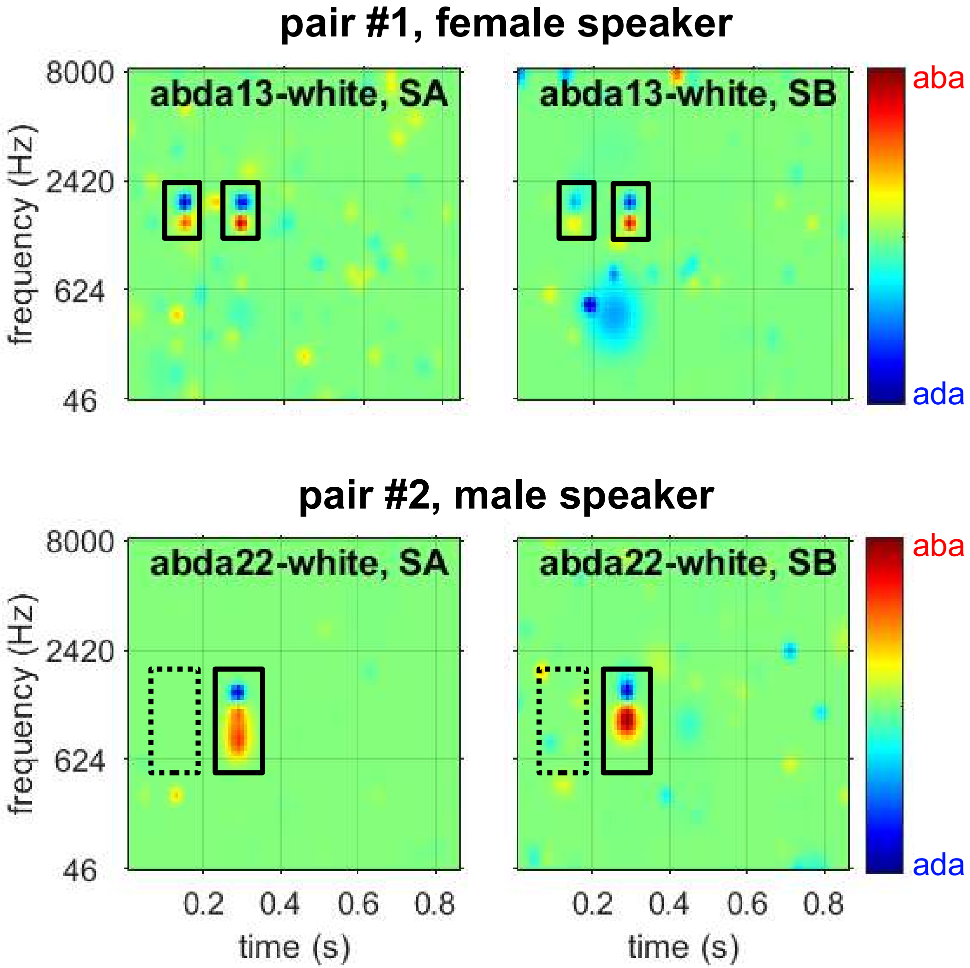
AM detection / aba-ada categorisation

- Revcorr can estimate the **listening strategies** in different tasks, i.e., identify the **acoustic cues** that are effectively used by the listeners

- Horizontal or vertical arrangement of weights for tasks that are temporal or vertical in essence

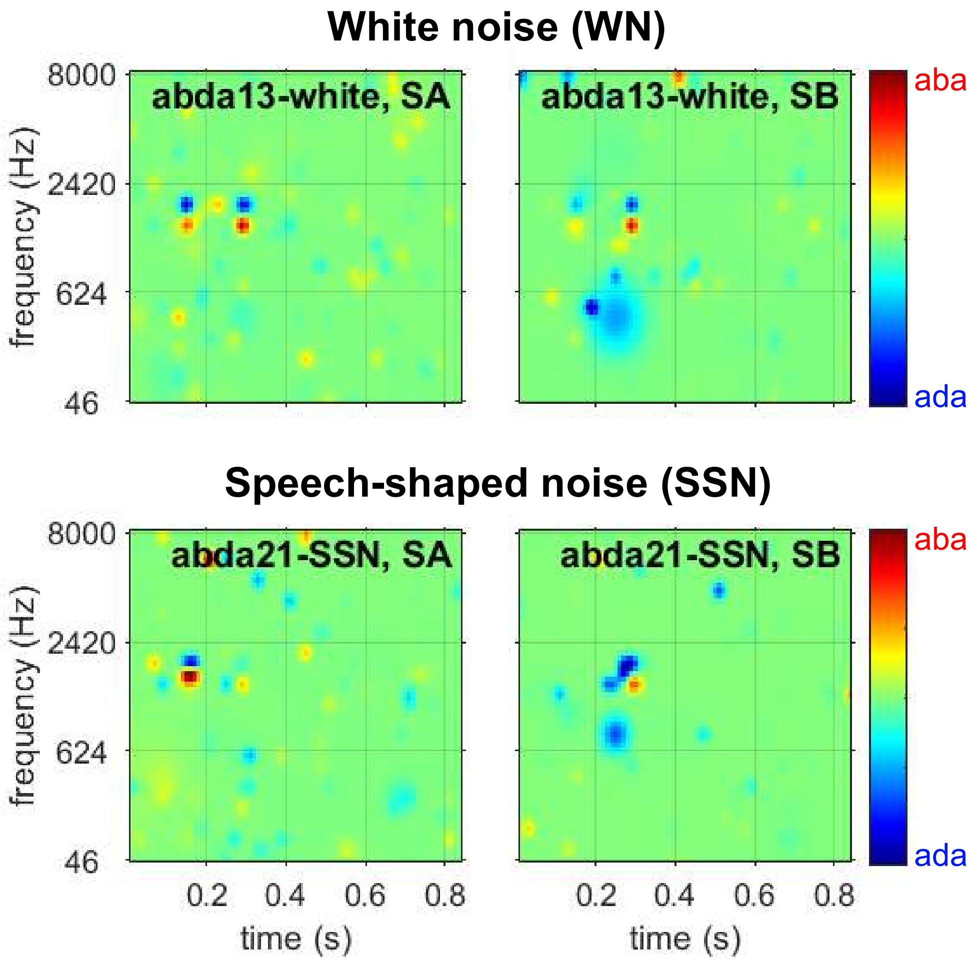


Comparison of listening strategies



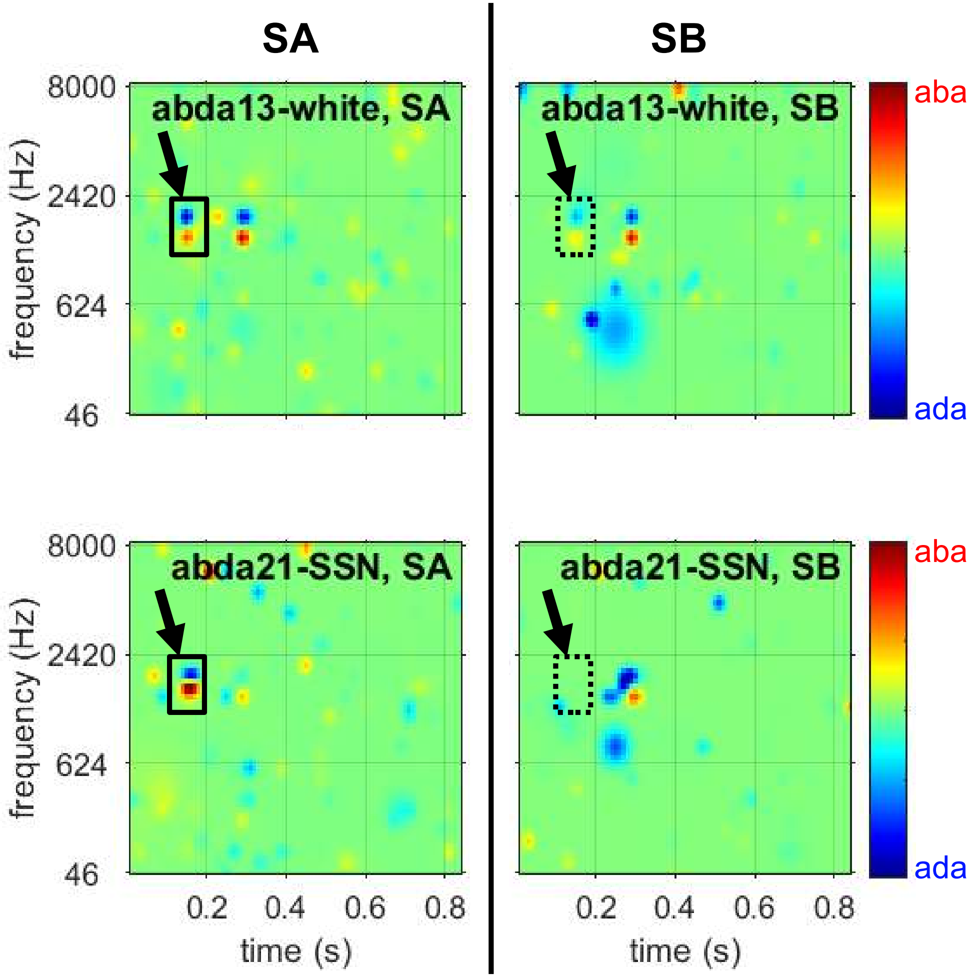
- Aba-ada, pair #2 does not show a salient cue for the first syllable, it does for pair #1.

Comparison of listening strategies



- Aba-ada, pair #2 does not show a salient cue for the first syllable, it does for pair #1.
- No systematic difference linked to the type of background noise (WN or SSN)

Comparison of listening strategies



- Aba-ada, pair #2 does not show a salient cue for the first syllable, it does for pair #1.
- No systematic difference linked to the type of background noise (WN or SSN)
- Participant SA seems to relay more on the cues in the first syllable than SB: This suggests an individualised listening strategy?
  [Osses & Varnet, 2022, preregistration]
  Paper in preparation

Auditory classification images (ACIs)

- Purely **behavioural approach** that allows to visualise **individualised listening strategies** for different (simple) perceptual tasks ("ear-tracker")

fastACI toolbox v1.0: a MATLAB toolbox for investigating auditory perception using reverse correlation (https://github.com/aosses-tue/fastACI)

- Possibility to combine with an auditory model or "artificial listener" *[Osses & Varnet, 2021]*
- Limit: Number of trials for each pair of sounds to be contrasted (N ≈ 4000)

감사합니다 ... for your attention...

I'm grateful to my coauthors / colleagues / Friends:

Christian **Lorenzi**   Léo **Varnet**

... and to our collaborators through the years:

Emmanuel **Ponsot**

Laurianne **Cabrera**

Diane **Lazard**

Michel **Hoen**

Fanny **Meunier**

Please contact me (ale.a.osses@gmail.com)
if you want to implement your listening experiment in the fastACI toolbox

fastACI toolbox v1.0: a MATLAB toolbox for investigating auditory perception using reverse correlation (https://github.com/aosses-tue/fastACI)

References

Ahumada, A., & Lovell, J. (1971). Stimulus features in signal detection. *J. Acoust. Soc. Am.*, *49*, 1751–1756. doi: 10.1121/1.1912577

Liberman, A. , Delattre, P., and Cooper, F. (1952). The role of selected stimulus-variables in the perception of the unvoiced stop consonants. Am. J. Psychol. 65, 497–516. doi: 10.2307/1418032

Osses, Alejandro;, & Varnet, L. (2021). Consonant-in-noise discrimination using an auditory model with different speech-based decision devices. *DAGA*, 298–301. https://hal.archives-ouvertes.fr/hal-03345050

Osses, Alejandro, & Varnet, L. (2022a). *A microscopic investigation of the effect of random envelope fluctuations on phoneme-in-noise perception*. https://osf.io/4ju3f/

Osses, Alejandro, & Varnet, L. (2022b). Auditory reverse correlation on a phoneme-discrimination task: Assessing the effect of different types of background noise. *ARO Mid-Winter Meeting*. https://hal.archives-ouvertes.fr/hal-03553443v1

Ponsot, E., Arias, P., & Aucouturier, J.-J. (2018). Uncovering mental representations of smiled speech using reverse correlation. *J. Acoust. Soc. Am.*, *143*, EL19–EL24. doi: 10.1121/1.5020989

Ponsot, E., Susini, P., Saint Pierre, G., & Meunier, S. (2013). Temporal loudness weights for sounds with increasing and decreasing intensity profiles. *J. Acoust. Soc. Am.*, *134*, EL321-6. doi: 10.1121/1.4819184

Shub, D., & Richards, V. (2009). Psychophysical spectro-temporal receptive fields in an auditory task. *Hear. Res.*, *251*, 1–9. doi: 10.1016/j.heares.2009.02.007

Varnet, L., Knoblauch, K., Meunier, F., & Hoen, M. (2013). Using auditory classification images for the identification of fine acoustic cues used in speech perception. *Front. Hum. Neurosci.*, *7*, 1–12. doi: 10.3389/fnhum.2013.00865

Varnet, L., Knoblauch, K., Serniclaes, W., Meunier, F., & Hoen, M. (2015). A psychophysical imaging method evidencing auditory cue extraction during speech perception: A group analysis of auditory classification images. *PLoS One*, *10*, 1–23. doi: 10.1371/journal.pone.0118009

Varnet, L., & Lorenzi, C. (2022). Probing temporal modulation detection in white noise using intrinsic envelope fluctuations: A reverse correlation study. *J. Acoust. Soc. Am.*, *151*, 1356–1366. doi: 10.1121/10.0009629