

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

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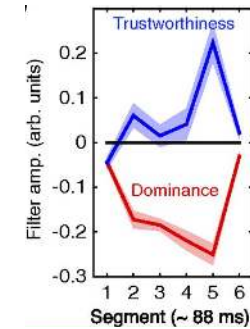
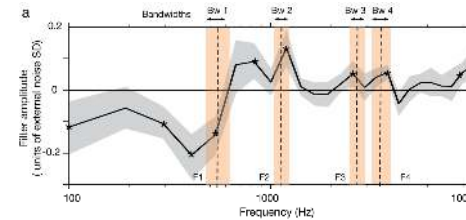
Session: Spatial Hearing II,  
ICA 2022, Gyeongju, South Korea

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

high level

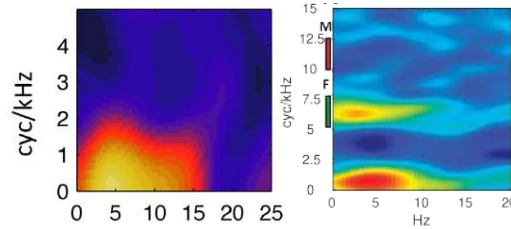
## paralinguistics

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



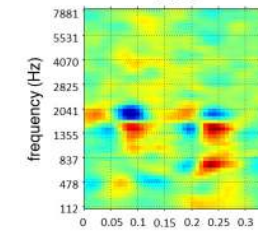
## sentence recognition

[Venezia et al., 2016, 2019]

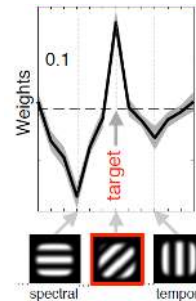
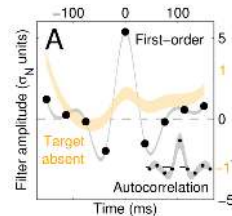
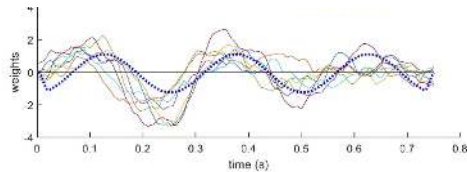


## phoneme categorisation

[Varnet et al., 2013, 2015]



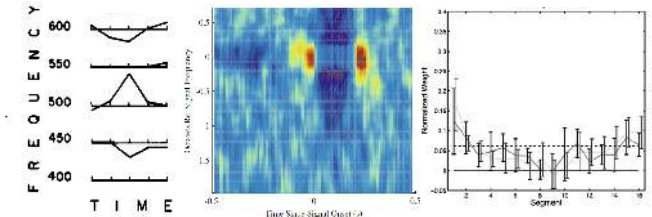
## modulation perception



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

## pure-tone detection & loudness perception

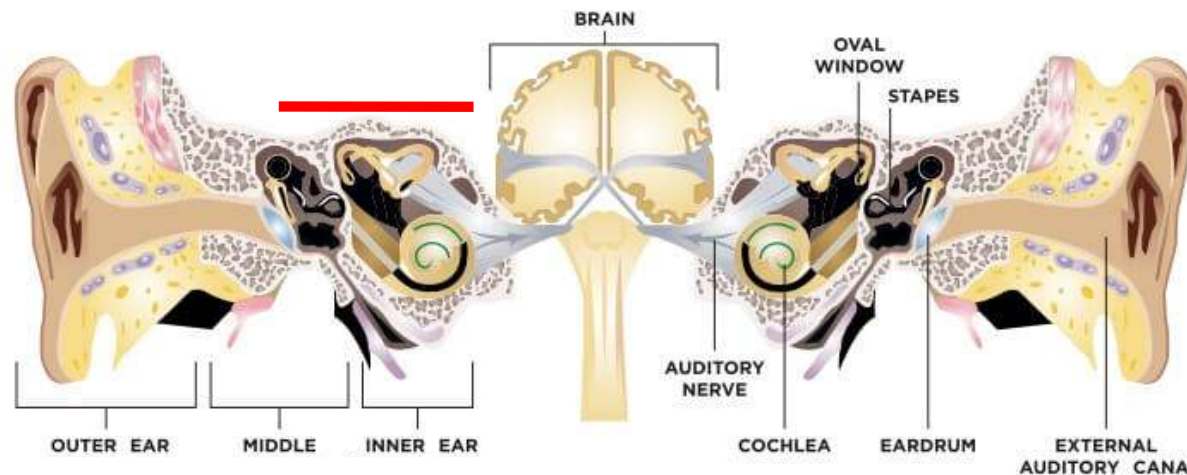
[Ahumada & Lovell, 1971; Shub & Richards, 2009; Ponsot et al. 2013]



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.happyyearshearing.com/hearing-loss/how-the-ear-works/> (download on: 2020)

# 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

**This figure:**  
**white noise in an AM detection task**

**Here also:**  
**for a phoneme discrimination task**

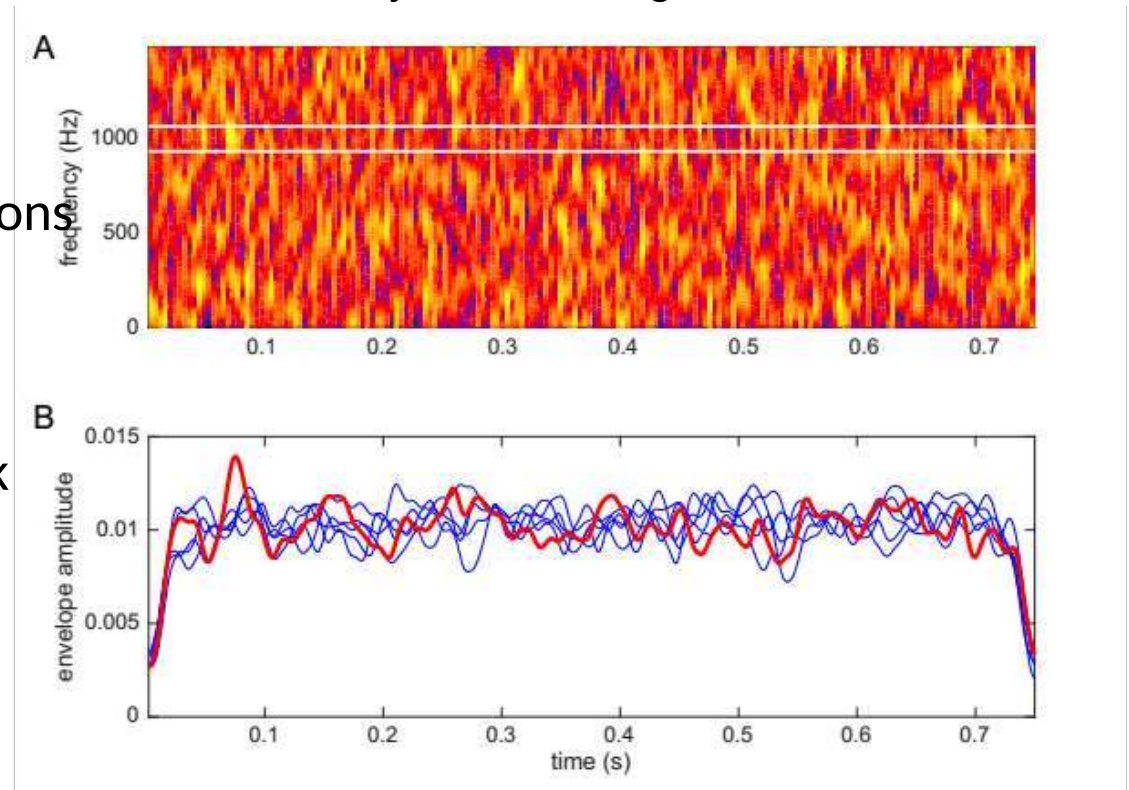
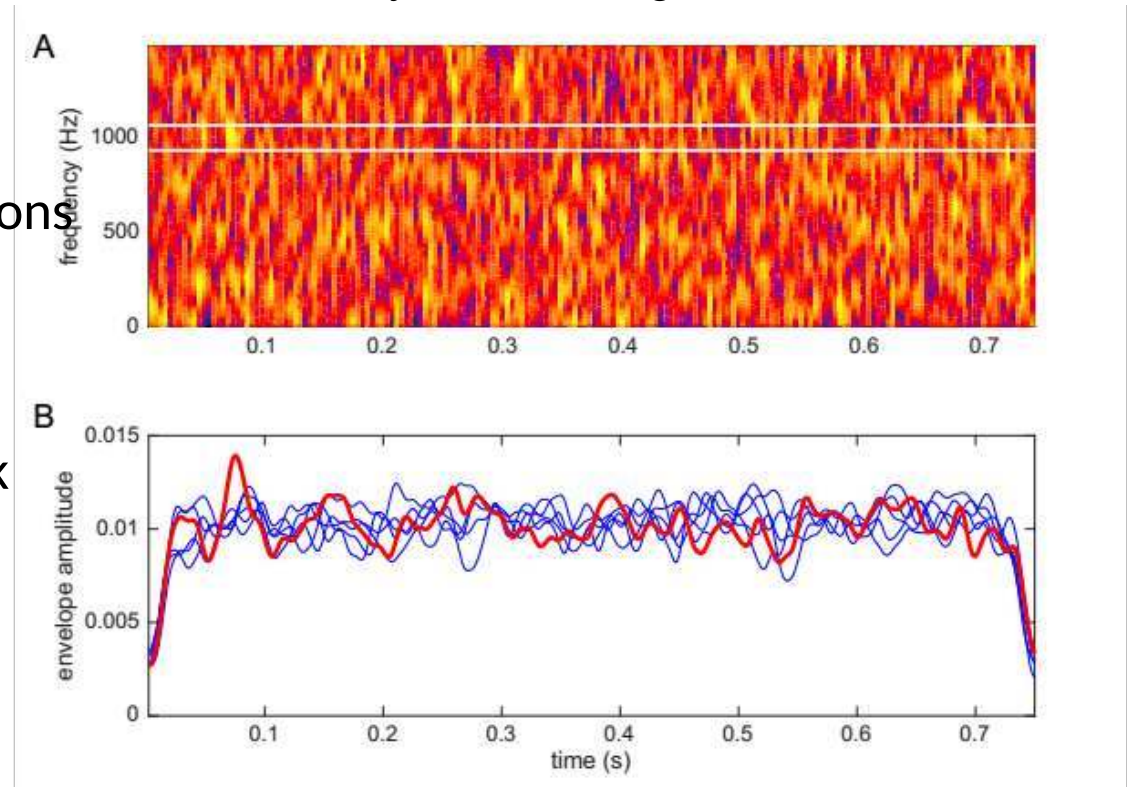


FIG. 1. Illustration of intrinsic envelope fluctuations  
(Varnet & Lorenzi, 2022, JASA)

# Intrinsic fluctuations and revcorr

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(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



[Varnet et al., 2013]

[Osses & Varnet, 2021]

[Varnet & Lorenzi, 2022]

# Objective of this study

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

DAGA 2021 Wien

frontiers in  
HUMAN NEUROSCIENCE

Using auditory classification images  
of fine acoustic cues used in speech

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Consonant-in-noise discrimination using an auditory model with different

speech-based decision devices

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Abstract

This study presents insights into the discrimination of two consonants presented in vowel-consonant-vowel (VCV) words embedded in speech-shaped noise (SSN).

to which the participants provided audible answers (/aba/ or /a/). This is implemented as a one-to-one choice (1-I, 2-AFC) experiment.

JASA ARTICLE

Probing temporal modulation detection in white noise using  
intrinsic envelope fluctuations: A reverse-correlation study

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## ABSTRACT:

Part of the detrimental effect caused by a stationary noise on sound perception results from the masking of relevant amplitude modulations (AM) in the signal by random intrinsic envelope fluctuations arising from the filtering of noise by cochlear channels. This study capitalizes on this phenomenon to probe AM detection strategies for human listeners using a reverse correlation analysis. Eight normal-hearing listeners were asked to detect the presence of a 4-Hz sinusoidal AM target applied to a 1-kHz tone carrier using a yes-no task with 3000 trials/participant. All stimuli were embedded in a white-noise masker. A reverse-correlation analysis was then carried on the data to compute the "acoustical template" showing which aspects of the stimulus temporal envelope influenced the listeners' responses.

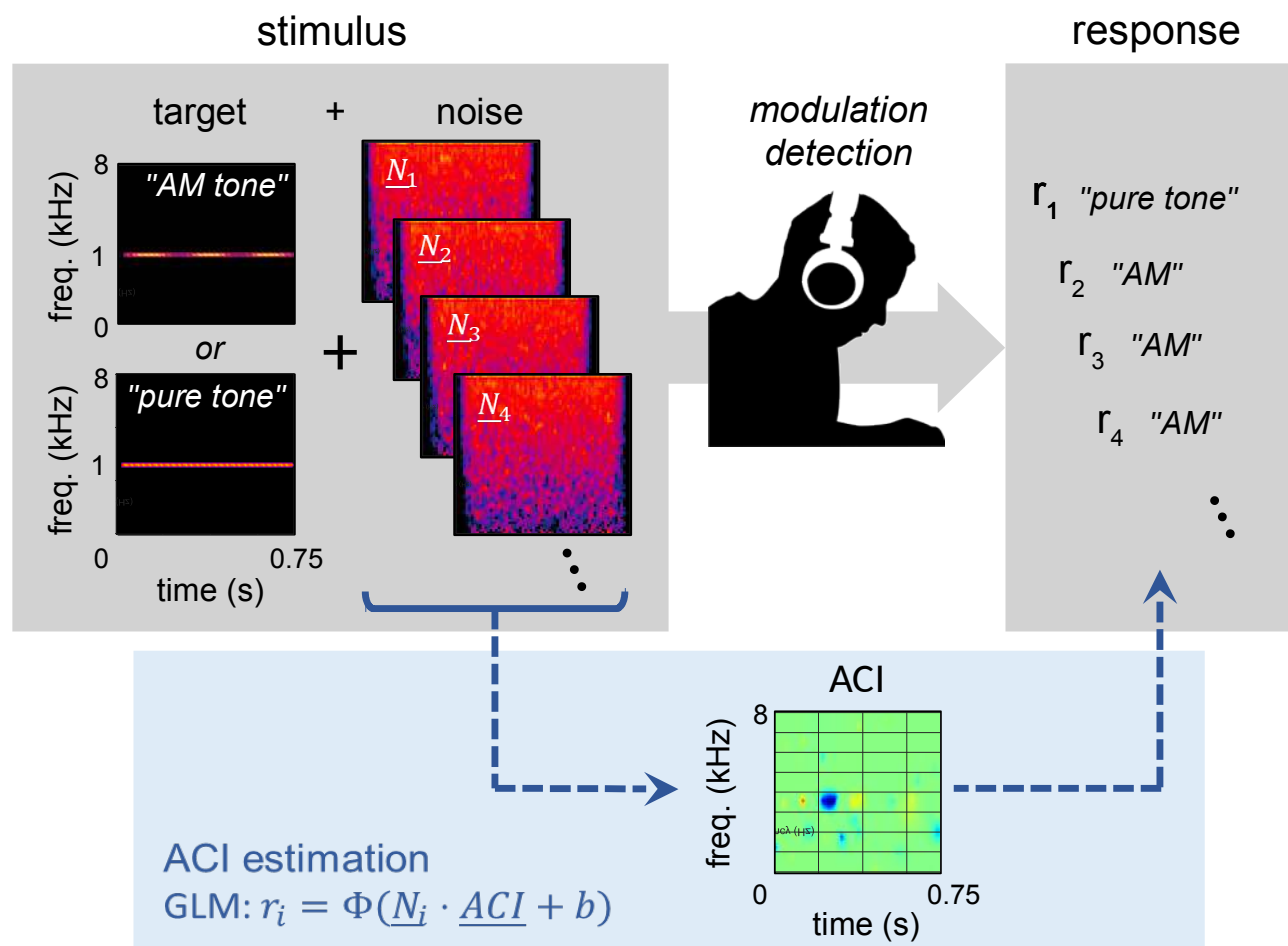
essential step in understanding the perceptual categorization is to identify which behavior of our perceptual system. In comprehension, it is still a major open challenge to categorize a speech stimulus as one of the many possible words. This is important for the categorical perception of speech. We present a method relying on a Generalized Linear Model (GLM) which is typically used in the visual domain for the analysis of auditory experiments. This statistical method allows us to probe the non-Gaussian noise, as it is often the case in the estimated template.

# AM detection

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

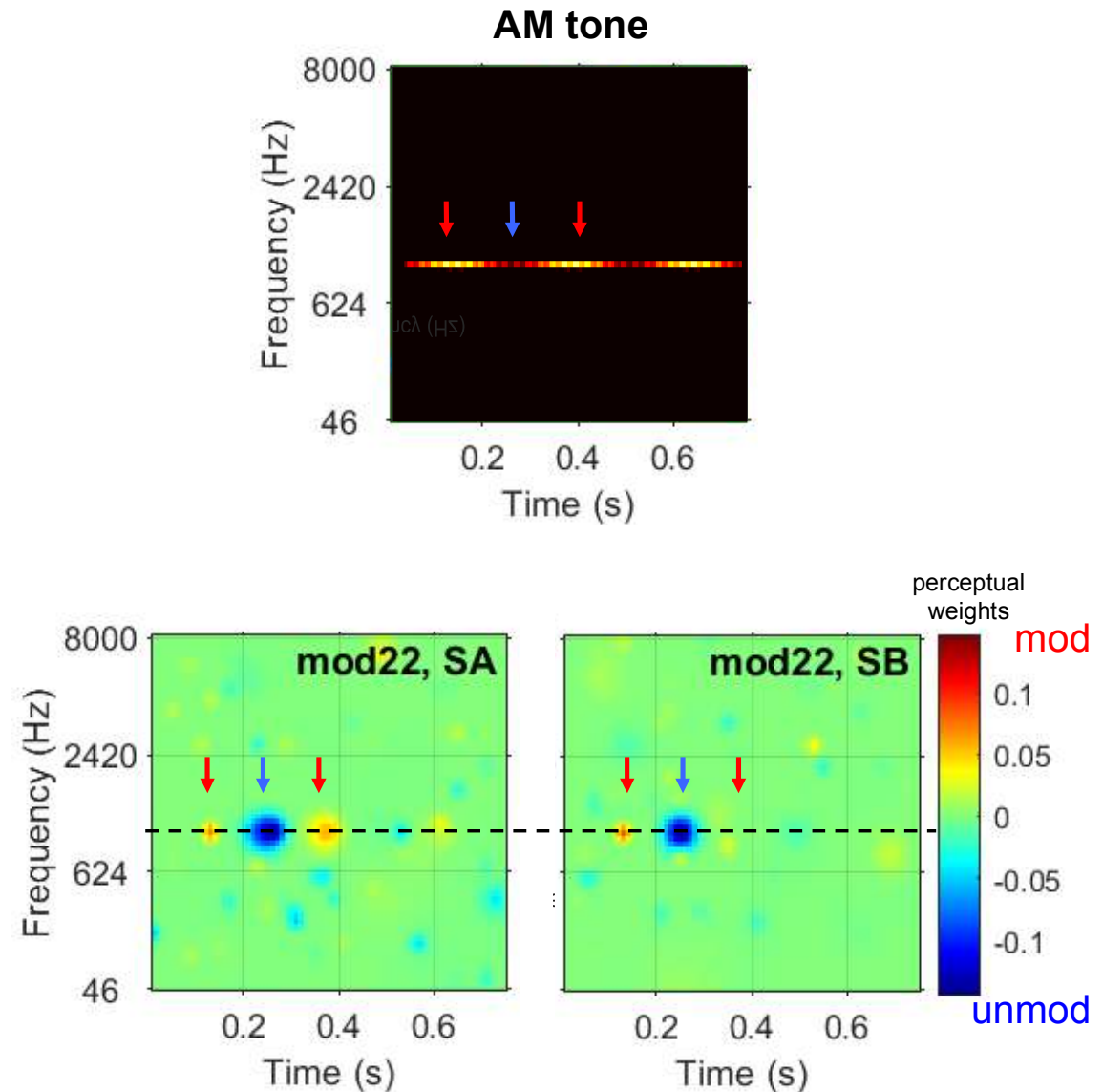
**Task:**  
“AM tone” or “pure tone”?

**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]*





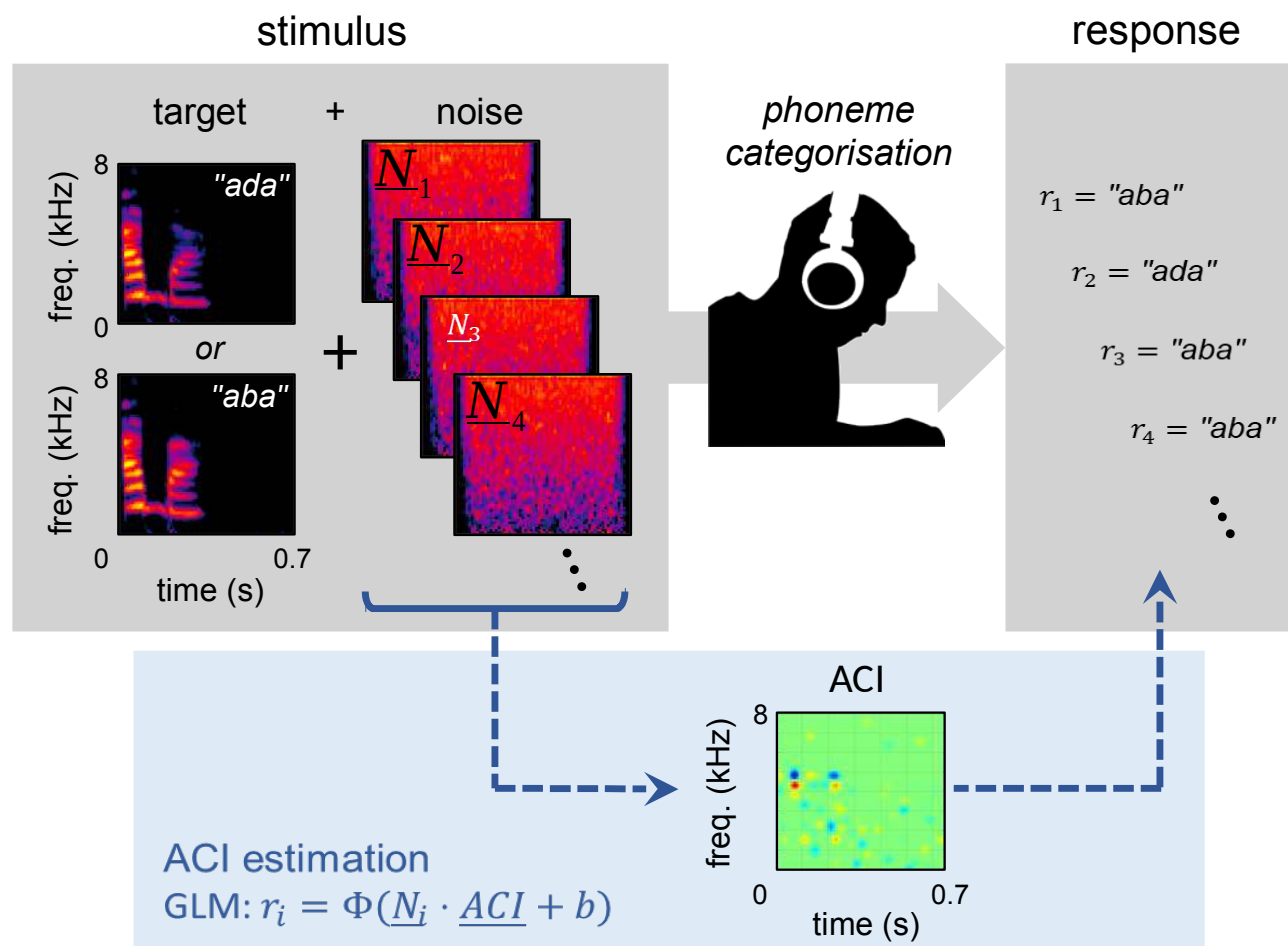
# Aba-ada discrimination

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

**Task:**

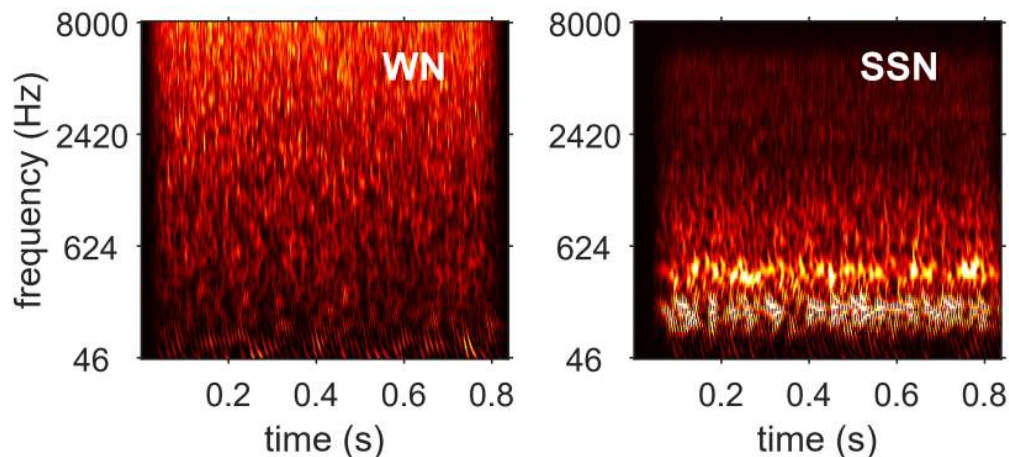
Do you hear «aba» or «ada»?

**SNR:** Adapted to obtain a 70.7% of correct responses

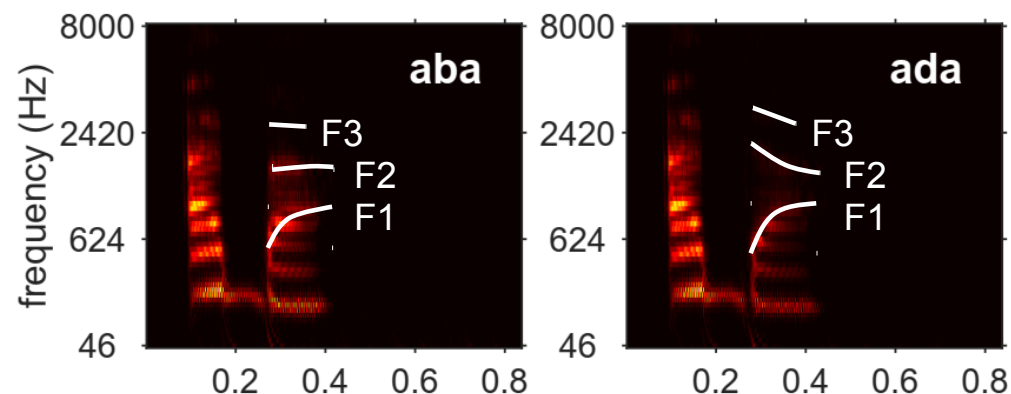


# Stimuli

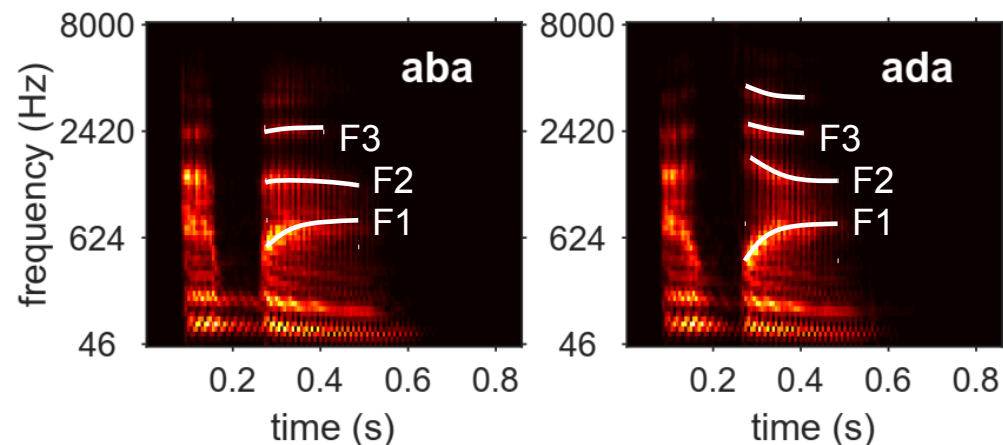
- Two pairs of aba-ada words (uttered by a male or female speaker)



pair #1, female speaker



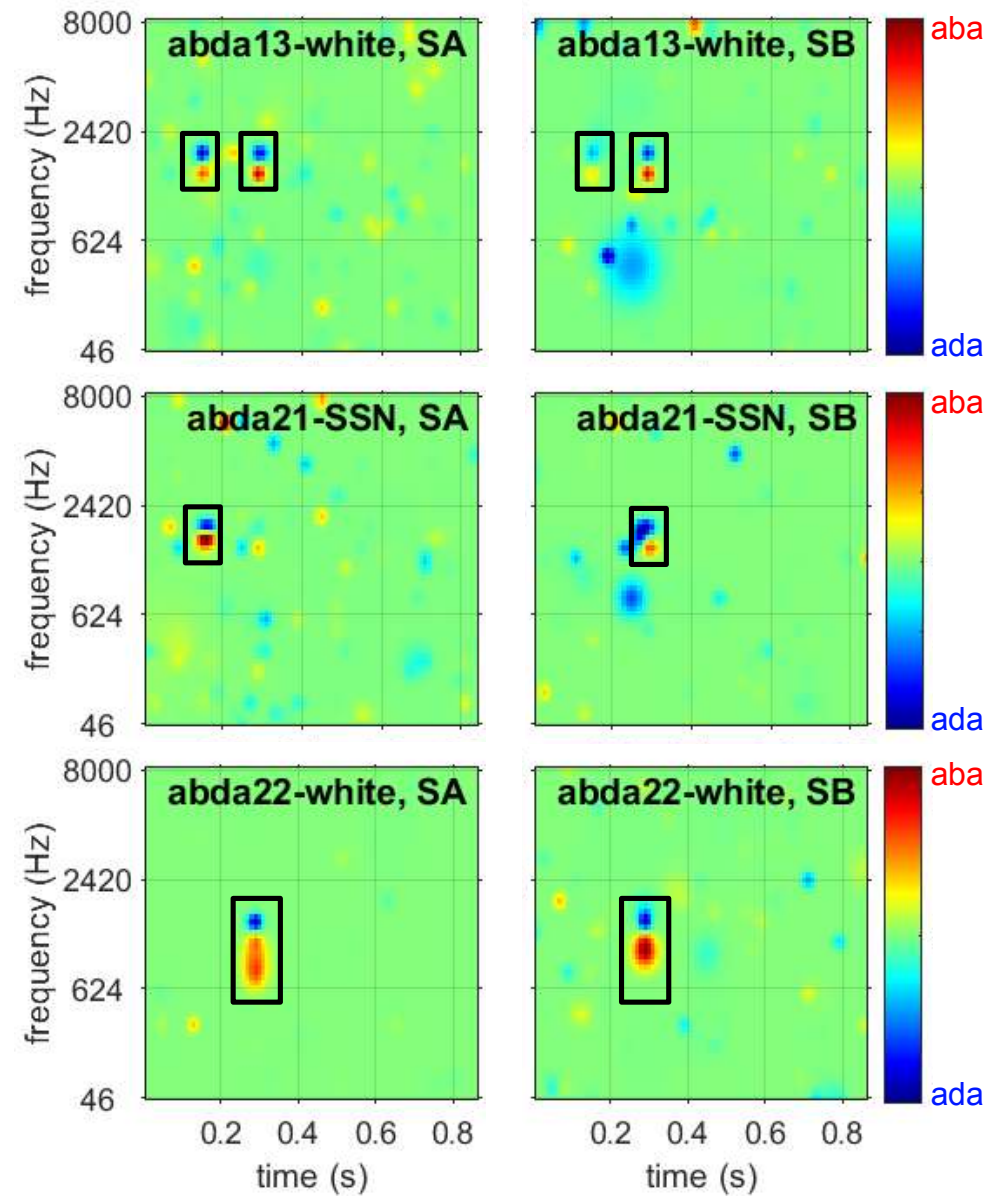
pair #2, male speaker



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

# Results

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

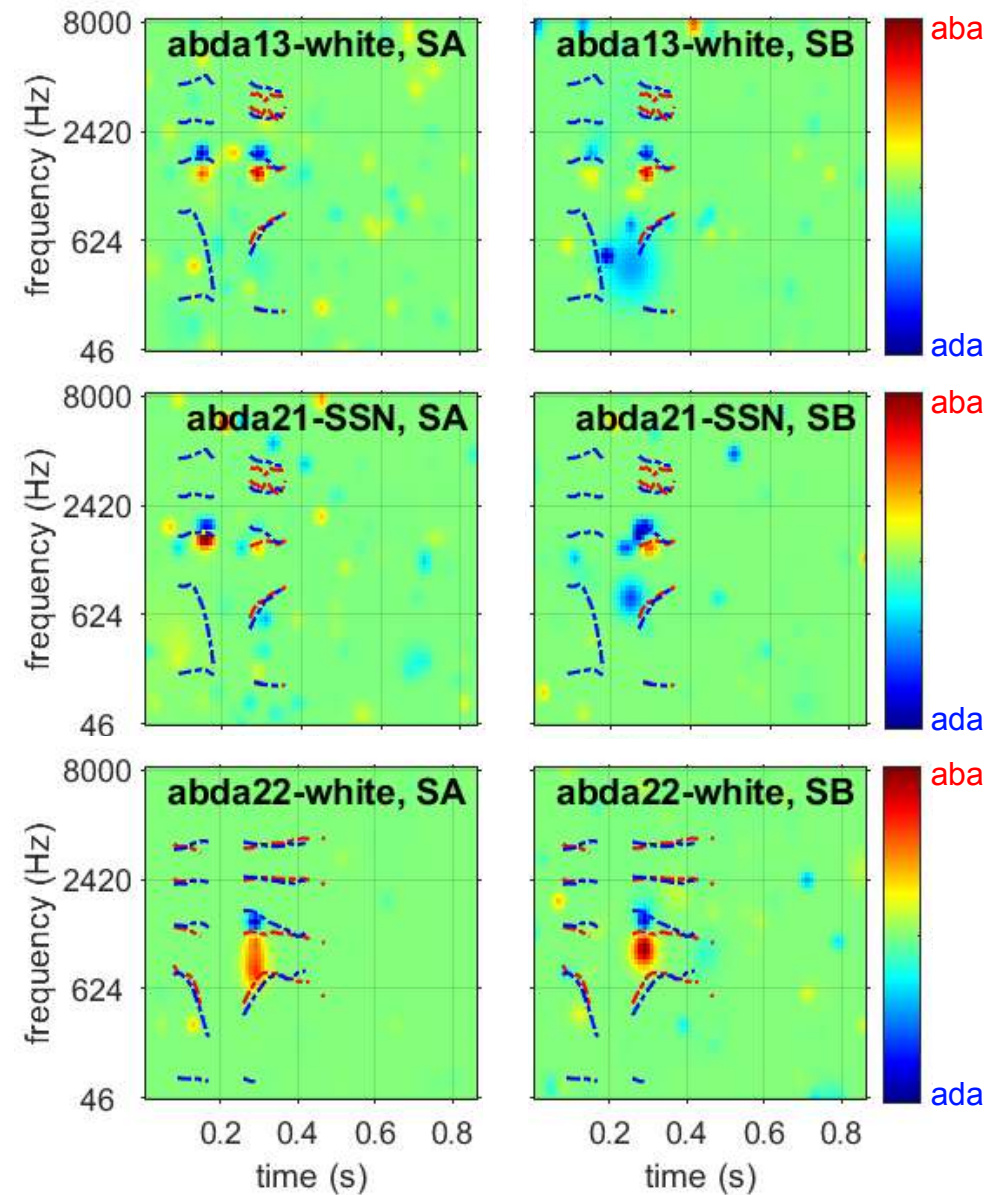


# Results

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

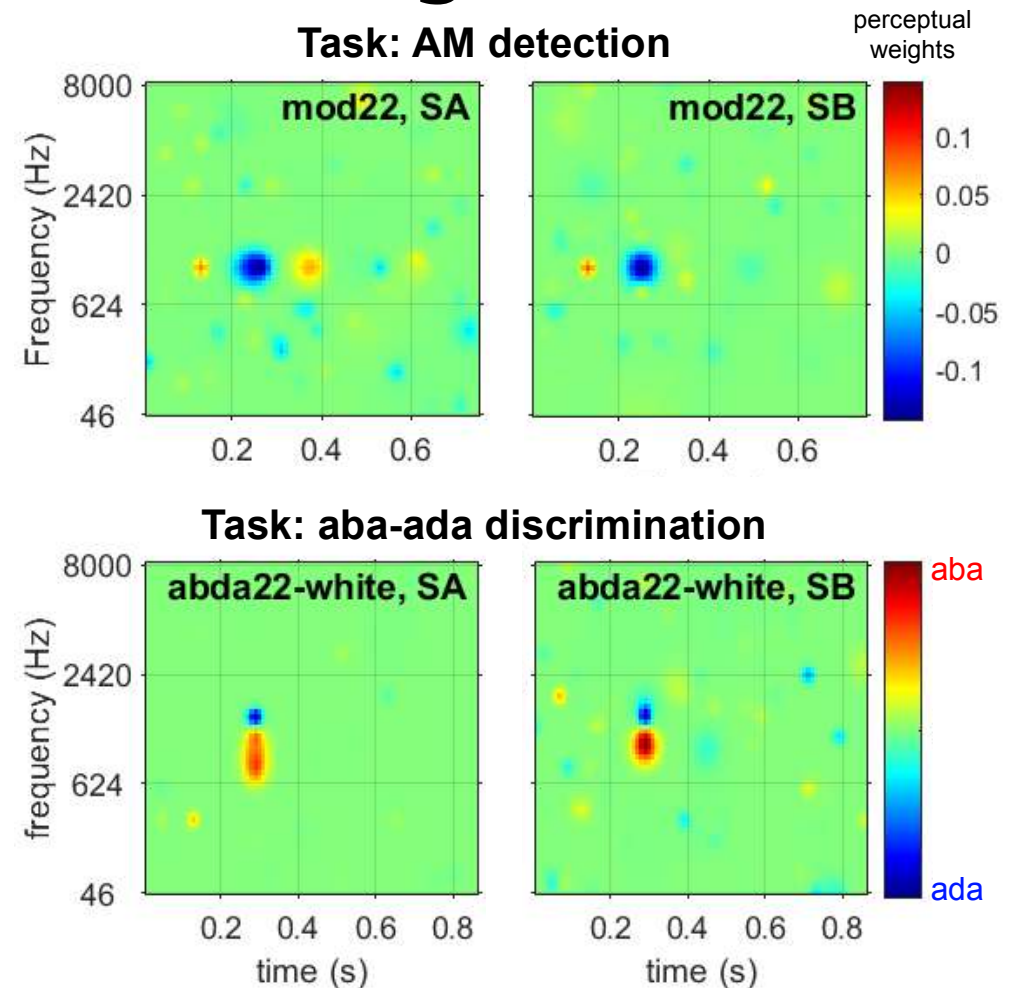
So:  $F_2$  is an acoustic cue used to discriminate /aba/ from /ada/

- Other cues can be involved in this task



# AM detection / aba-ada categorisation

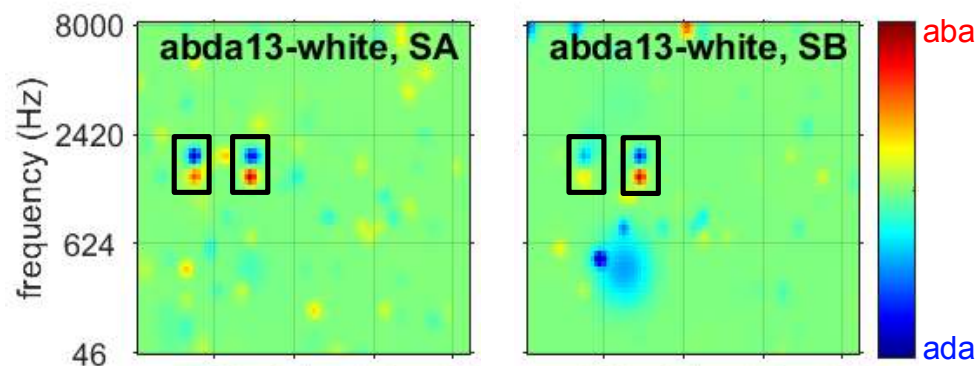
- Revcorr can estimate the **listening strategies** in different tasks, i.e., identify the **acoustic cues** that are effectively used by the listeners
- Horizontal or vertical arrangement of weights for tasks that are temporal or vertical in essence





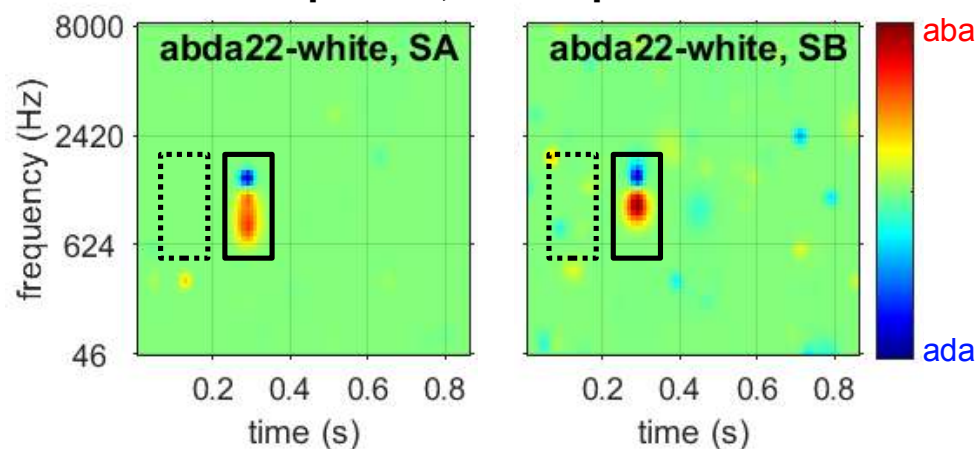
# Comparison of listening strategies

pair #1, female speaker



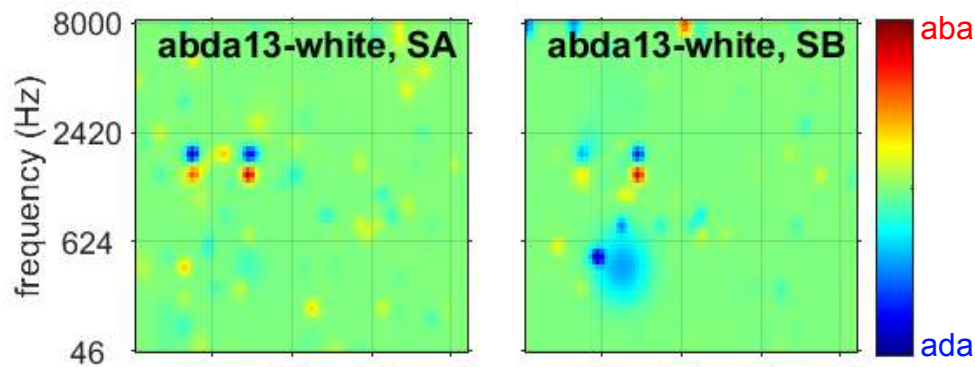
- Aba-ada, pair #2 does not show a salient cue for the first syllable, it does for pair #1.

pair #2, male speaker

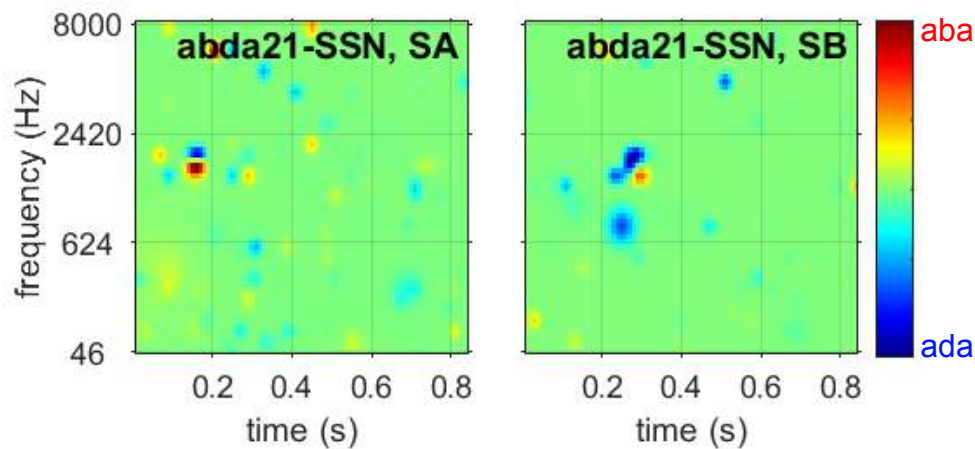


# Comparison of listening strategies

White noise (WN)

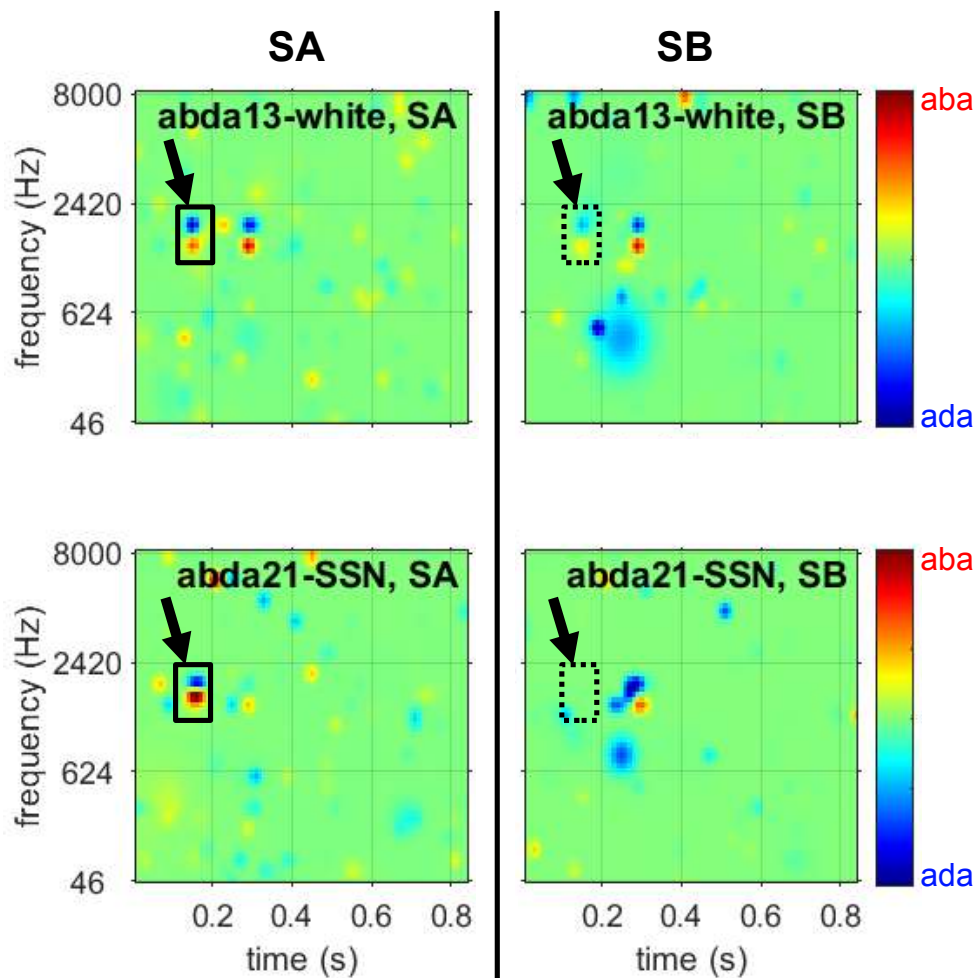


Speech-shaped noise (SSN)



- 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 ( $N \approx 4000$ )

# 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](mailto: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>)

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