

Paris II – Simulating the perception of soundscapes, speech-, AM-, and FM-sounds

The fastACI toolbox: A flexible framework to investigate auditory perception using reverse correlation

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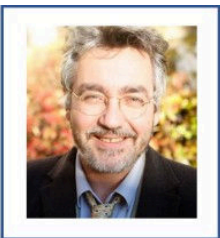
Laboratoire des Systèmes Perceptifs, École normale supérieure (ENS),
PSL University, Paris, France

19-20 January 2023

15th General Meeting AABBA, Vienna, Austria

We are... the “Modulation Group” at ENS

Christian Lorenzi



First, a few words here...

Main project:
HearBiodiv

+ **Christian's friends**

Léo Varnet



Main projects:
fastACI
DRdyaDS

Modelling
Soundscapes

Perception of
Biophony

Perception of
Biodiversity

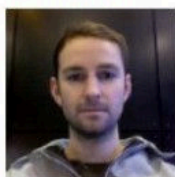
E Grinfeder



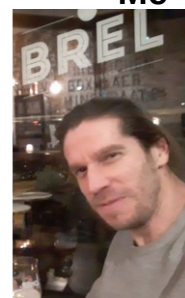
N Miller



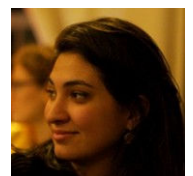
R McWalter



Me



Géraldine Carranante
Post-doc, Philosopher



Hearing biodiversity: the HearBiodiv project



Christian Lorenzi

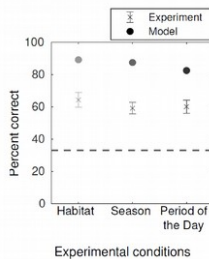
Frédéric Apoux, Elie Grinfeder, Richard McWalter & Nicole Miller

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<https://anr.fr/Project-ANR-20-CE28-0011>

Soundscape perception

- Efficiency of humans in discriminating natural soundscapes?
- Acoustic cues and auditory mechanisms?

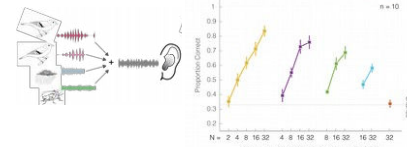


Biophony perception

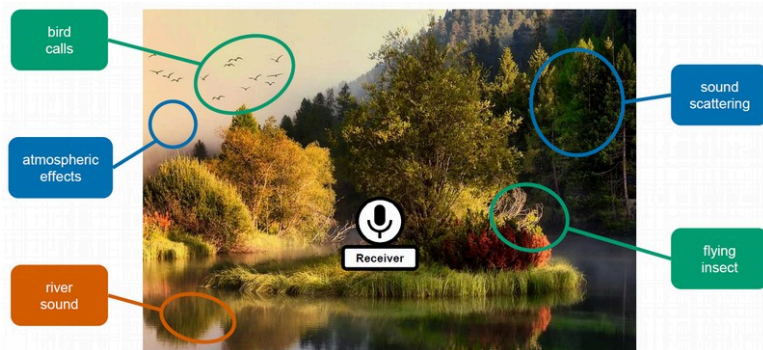


- What auditory features distinguish biological from non-biological sounds?
- An auditory 'life-detector' in the human brain?

Biodiversity perception

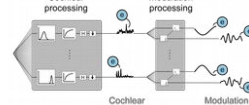


Human auditory ecology



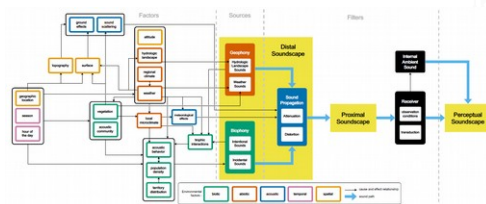
An interdisciplinary investigation of 'natural soundscape' perception by humans

Auditory modelling



- What are the processing mechanisms and stages?
- Can we predict human behaviour?

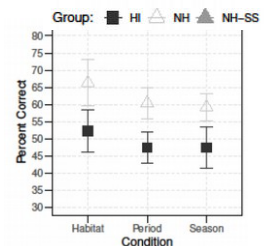
Soundscape reconstruction



- Can we reconstruct 'ecologically-valid' natural soundscapes?
- Could we use these mixtures to probe rigorously auditory mechanisms?

- Efficiency of humans in discriminating changes in biodiversity?
- Specialised mechanisms for biodiversity perception?

Effects of hearing loss



- Do we lose these abilities with sensorineural hearing loss?
- If so, can we rehabilitate such auditory deficits with hearing aids?

Sequoia National Park

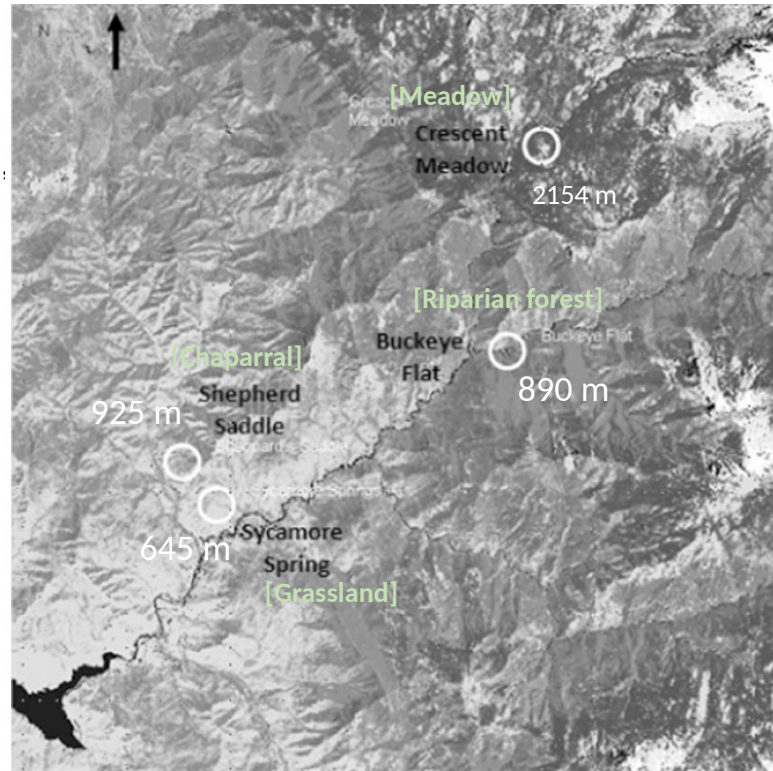
4 (pristine) temperate terrestrial biomes

- **Habitats:** 4
(BF, CM, SH, SY : riparian forest, meadow, chaparral, grassland)
- **Seasons:** 4 (fall, winter, spring, summer)
- **Periods of the day:** 4 (T1, T2, T3, T4)



Periods of the day

- T1 (0-5-7am)
- T2 (11am)
- T3 (4-5pm)
- T4 (8-11pm)



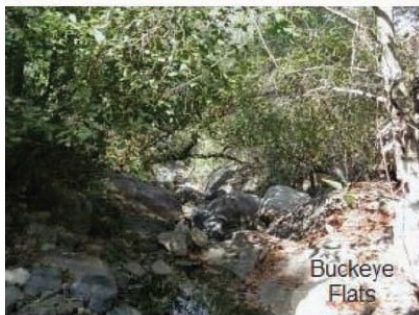
Krause et al. (2011) Landscape Ecology



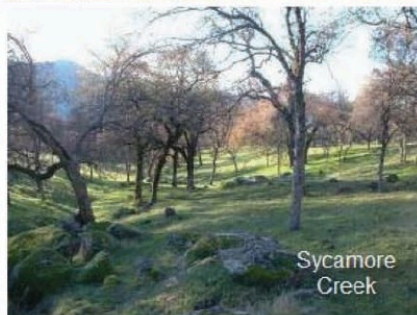
Crescent Meadow



Shepherd's Saddle



Buckeye Flats



Sycamore Creek

Krause et al. (2011) Landscape Ecology

5760 (2-sec) samples

[4 habitats x 4 seasons
x 4 periods of the day] x 90 samples

non-overlapping samples
(taken contiguously from 30-sec long recordings)

Psychophysical experiments

Discrimination task – Paradigm: **Oddity task, 3-AFC**

Dependent variable = Discrimination performance (percent correct)

Chance level=33%

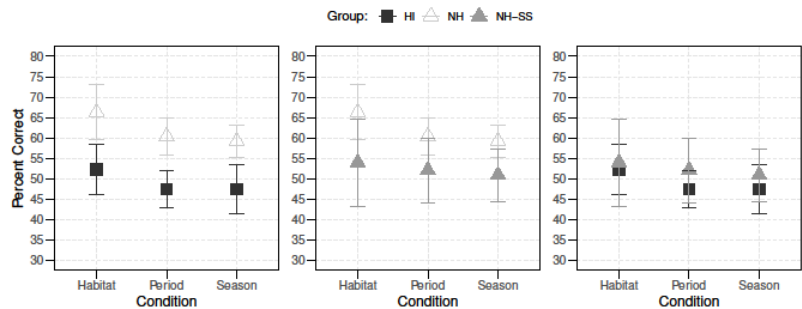
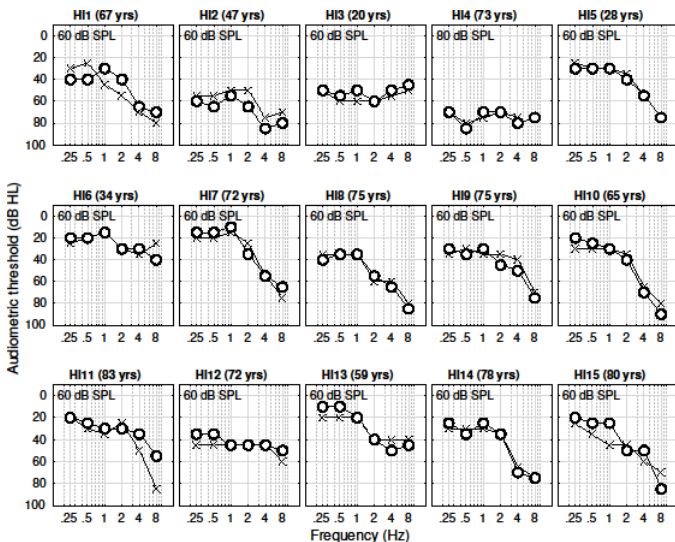
Perfect performance = 100%



*Difficult task
Easy to instruct*



Effects of sensorineural hearing loss



- Hearing loss **degrades** the ability to discriminate habitat, period of the day and season
- **Reduced audibility** is partly responsible for this deficit
- However, **supra-threshold auditory deficits** and/or **sub-optimal decision strategies** may also contribute to this deficit



Miller et al.
(submitted)

Exploring phoneme representations and their adaptability using fast Auditory Classification Images – fastACI

Léo Varnet (PI), Alejandro Osses

Christian Lorenzi, Laurianne Cabrera, Willy Serniclaes



fastACI toolbox v1.2: a MATLAB toolbox for investigating auditory perception using reverse correlation (<https://github.com/aosses-tue/fastACI>)

<https://anr.fr/Project-ANR-20-CE28-0004>

Cracking the speech code

(or other “codes”)

Speech is a **complex code** (acoustics → phonetics)

Which **acoustic cues** allow the listener to differentiate one phoneme from another?

No easy answer, due to the spectro-temporal complexity of natural speech



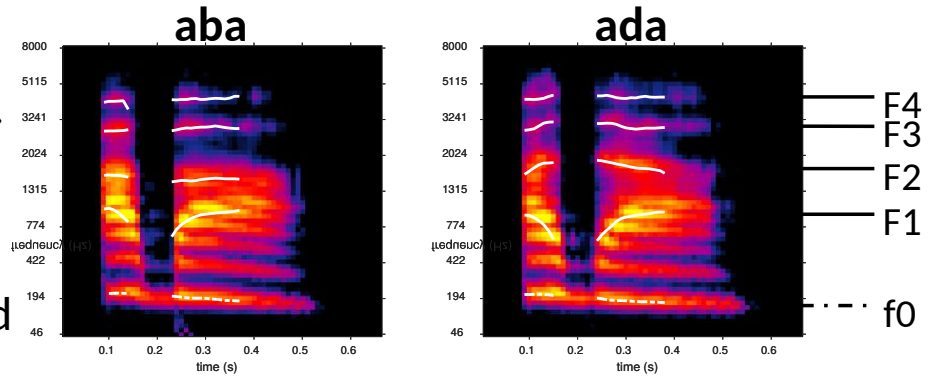
Cracking the speech code

(or other "codes")

How do we distinguish « aba » from « ada »?

(or another pair of contrasting sounds)

- Many acoustical differences between « aba » and « ada » (e.g., formant trajectories)
- Which ones are actually used by the auditory system?

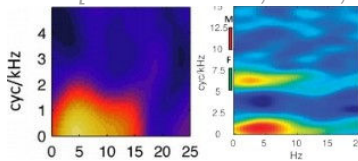


Auditory revcorr studies (full diagram on <https://dbao.leo-varnet.fr/>)



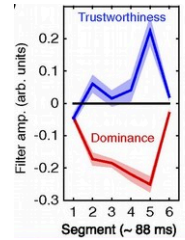
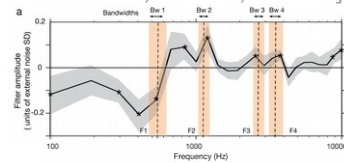
sentence recognition

[Venezia et al., 2016, 2019]



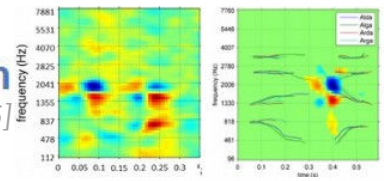
paralinguistics

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



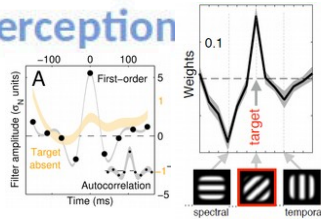
phoneme categorization

[Varnet et al., 2013, 2015]



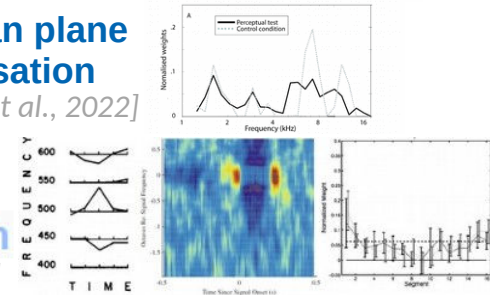
modulation perception

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



median plane localisation

[Lladó et al., 2022]

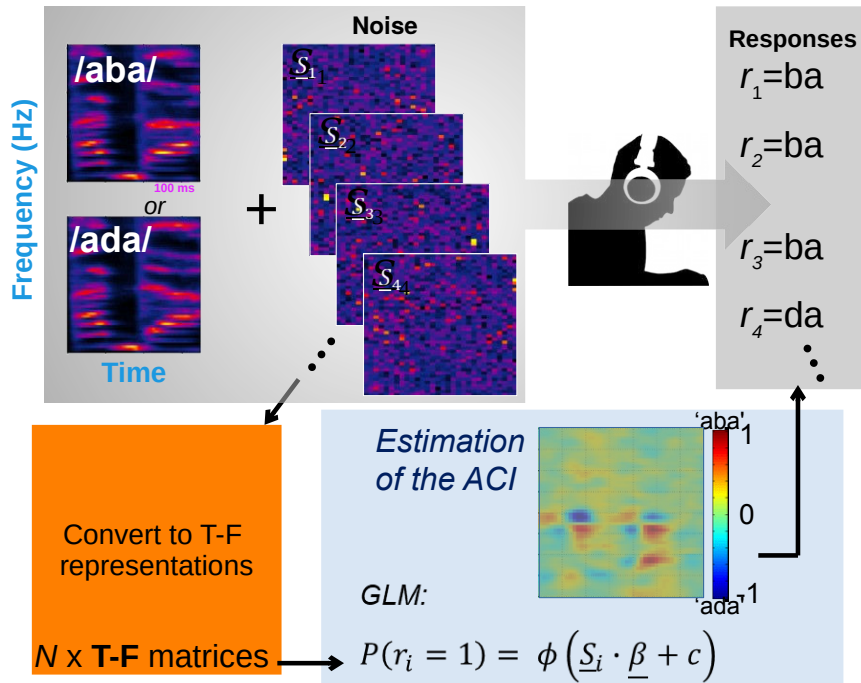


pure-tone detection & loudness perception

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

Phoneme discrimination using the ACI method

- The reverse correlation method allows to experimentally assess the cues that are relevant in a discrimination task: ACIs



Experimental design:

- Noise fixed, variable speech level
- 1-up, 1-down weighted procedure (Kaernbach, 1991) to track 70.7% correct responses: down step = 1 dB, up step = 2.4 dB
- Little level roving of ± 2.5 dB

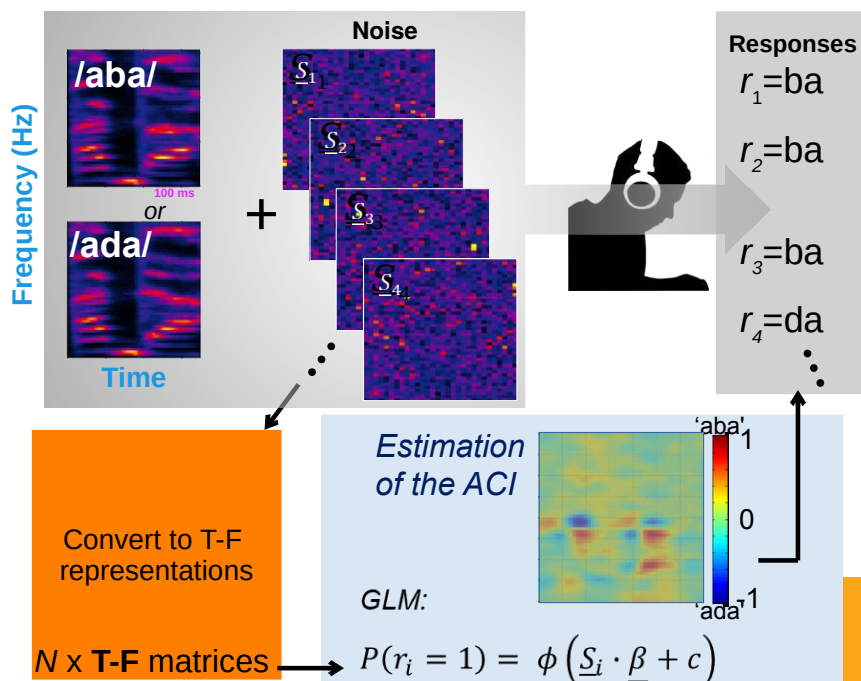
Participant's response

		'ba'	'da'
Presented	'ba' ("target")	Hit	Miss
	'da' ("no target")	False Alarm	Correct Rejection

ACI is built from $(H+FA) - (M+CR)$

One weighting function per participant,¹³ the Auditory Classification Image (ACI)

Phoneme discrimination using the ACI method: Replicability



- 1) Generate sounds (`experiment_init.m`)
- 2) Collect data for N participants `fastACI_experiment`
- 3) Post-process the data `fastACI_getACI`

Flexible environment:

`experiment_cfg`
`experiment_set`
`experiment_user`

Similar to AFC experiments

Phoneme discrimination using the ACI method: Replicability

bioRxiv preprint doi: <https://doi.org/10.1101/2022.12.27.522040>; this version posted December 27, 2022. The copyright holder for this preprint (which was not certified by peer review) is the author/funder, who has granted bioRxiv a license to display the preprint in perpetuity. It is made available under aCC-BY-NC-ND 4.0 International license.

A microscopic investigation of the effect of random envelope fluctuations on phoneme-in-noise perception

Alejandro Osses^{1, a)} and Léo Varnet¹

Laboratoire des systèmes perceptifs, Département d'études cognitives, École normale supérieure, Université Paris Sciences & Lettres, CNRS, 75005 Paris, France

In this study, we investigated the effect of specific noise realizations on the discrimination of two consonants /b/ and /d/. For this purpose, we collected data from twelve participants, who listened to the words /b/ or /ada/ embedded in one of three background noises. The data were analyzed on a trial-by-trial basis using the reverse-correlation method. The results revealed that it is possible to predict the category responses with better-than-chance accuracy purely based on the spectro-temporal distribution of the random envelope fluctuations of the corresponding noises, without taking into account the actual targets. The effect of the noise fluctuations explained on average 13.3% of the variance in the participants' responses in white noise, a proportion that increased up to 13.3% for noises with larger amount of fluctuations. The estimated time-frequency weights revealed that the target signal originated from confusions between noise fluctuations and relevant acoustic cues from the target. Substantially similar conclusions were obtained from simulations using an artificial listener. We argue that this token-specific effect of noise is a form of informational masking.

To obtain the figures from the main text:

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publ_osses2022b_JASA_figs('fig5b_suppl');
```

that is not expected to change when different noise tokens are used, as long as enough noise tokens are used in the experiments. As a consequence, the results related to the fixed, long-term noise statistics do not depend on the specifics of the noise.

1. INTRODUCTION

Studies of speech-in-noise perception often rely on the speech reception threshold (SRT) as a measure of the listener's performance. The SRT is defined as the signal-to-noise ratio (SNR) at which the listener can correctly identify the target phoneme.

Similar to the `exp_*.m` scripts from AMT

Phoneme discrimination using the ACI method: Replicability

Raw- and post-processed data need to be on disk following one of two possible structures:

- Using default directories
- Using the data as posted on Zenodo

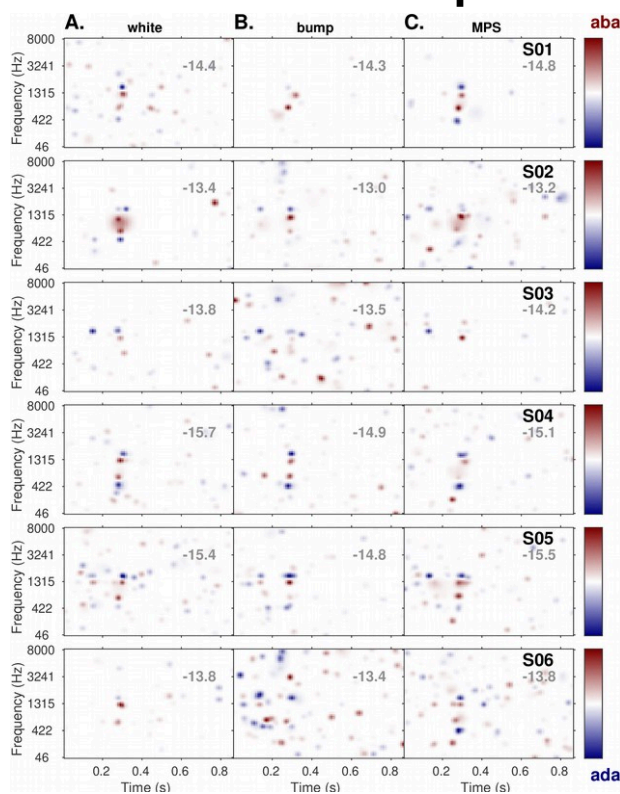
The screenshot shows the Zenodo dataset page for the paper. The dataset is titled "Raw and post-processed data for the microscopic investigation of the effect of random envelope fluctuations on phoneme-in-noise perception" and was created on December 23, 2022. It has 181 views and 0 downloads. The dataset is described as containing three main folders: 01-Stimuli, 02-Raw-data/fastACI, and 02-Raw-data/ACI_sim. The page also includes a search bar, navigation links, and a list of keywords including "Auditory classification Images (ACIs)" and "Speech-in-noise".

Phoneme discrimination using the ACI method: Replicability

For instance:

```

24 dir_zenodo=[pwd filesep]; % current directory
25 flags = {'zenodo', ...
26         'dir_zenodo', dir_zenodo};
27
28 %% To recreate, e.g., main fig 6:
29 publ_osses2022b_JASA_figs('fig6', flags{:});
    
```



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Replicability of other studies

- **Full replicability:**

Osses & Varnet (2021, DAGA) - osses2021c

Osses & Varnet (2022, BioRxiv) – osses2022b

Osses, Lorenzi, & Varnet (2022, ICA) – osses2022d

Ongoing data collection by Géraldine & Léo

- **Partial replicability:**

Varnet et al. (2013)

Varnet et al. (2022)

```

%% List of fastACI experiments:
'speechACI_varnet2013'; % with SSN maskers
'speechACI_Logatome-abda-S43M';
'speechACI_Logatome-apta-S43M'; % extra contrasts
'speechACI_varnet2013'; % with white noise
'modulationACI';
    
```

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The fastACI framework is extensible...

- New experiments in *_cfg, *_set, *_user, *_init files
 - If sounds are monaural = monaural reproduction
 - If sounds are stereo = 2-Ch reproduction
- Ongoing:
 - Documentation
 - If sounds are stereo - 2-Ch ACIs

Before a release:

- Strict validation of all previously existing functionalities, revision of default configurations

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Extensibility, example: ILD experiment with diotic noises

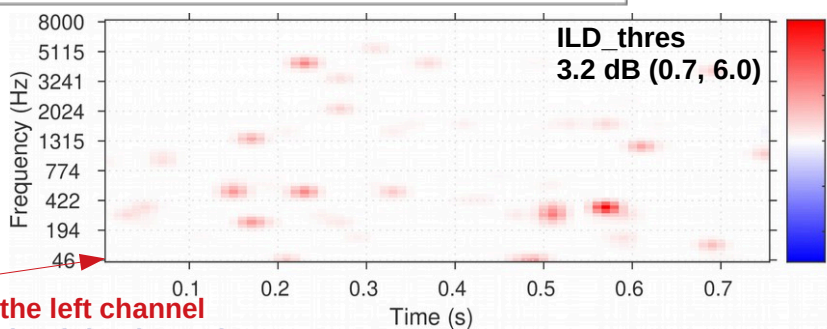
```

1 experiment = 'localisationILD'; % ILD with diotic white noises
2 subject = 'osses2022a'; % reserved word —> artificial listener
3 fastACI_experiment(experiment, subject); % (mod-filter-bank model, Q=1)
    
```

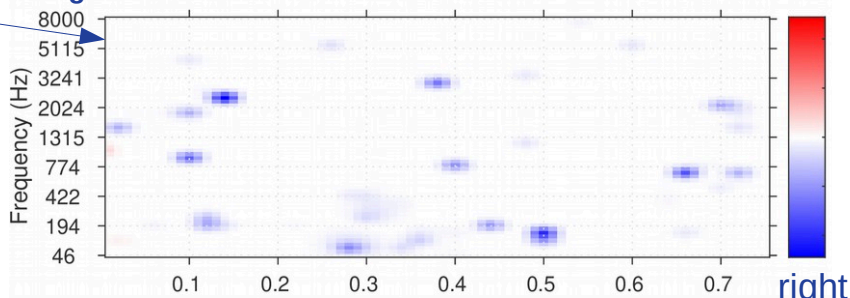
The experiment:

- Diotic white noise waveform on both ears, but higher level for the target direction
- 70.7% correct
- N = 3000 trials

Thanks Glen !



ACI for the left channel
ACI for the right channel



Participant's response

	'left'	'right'
Left: louder ("target")	Hit	Miss
Right: louder ("no target")	False Alarm	Correct Rejection

Presented

Summary

- Reverse correlation method using fastACI:
Trial by trial analysis for a supra-threshold task
- Possibility to run listening experiments with real and artificial listeners
- fastACI provides a flexible framework for further extensions
- Try it out and contact me (or Léo or Christian) if you want to implement a new experiment (Steven, Glen, Pedro?)



fastACI toolbox v1.2: a MATLAB toolbox for investigating auditory perception using reverse correlation (<https://github.com/aosses-tue/fastACI>)



DEC

DÉPARTEMENT
D'ÉTUDES
COGNITIVES



Thank you for your attention!

Alejandro Osses¹, Léo Varnet, Christian Lorenzi

(ale.a.osses@gmail.com)

Do you have any question, comment or other type of input?

References

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