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## **Auditory reverse correlation: a choose-your-own-adventure presentation**

Géraldine Carranante, Léo Varnet

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# Introduction

Choose-your-own-adventure books: a concept originally proposed by Raymond Queneau (*“Un conte à votre façon”*), and later extended to books, card games, video games, movies...  
...and now to scientific presentations!



## Rules of the game:

- As we proceed with the presentation, we will encounter crossroads where you must choose between different paths.
- Two options represented by colors will appear on the slides: raise the colored panel corresponding to your choice.
- Majority wins.

Choose your own  
adventure

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Léo Varnet

## Introduction

Auditory revcorr: a  
review

Decoding speech

L'amie/La mie  
experiment

Gender-fair language

Aba/ada experiment

Stop consonants  
experiment

Diversity

fastACI toolbox

Auditory revcorr:  
technical details

Internal representation

Conceptual plurality

Conclusion



# Auditory revcorr

**Reverse correlation** (aka **revcorr**) is the perfect tool to reveal perceptual cues used in a psychophysical task, based on purely behavioral data... in particular for auditory categorization tasks. [Varnet et al. 2013, 2015; Varnet & Lorenzi, 2022; Osses & Varnet, 2023]

**Core idea:** adding **random fluctuations** to the stimulus and measure how they affect the participant's responses on a trial-by-trial basis.

Choose your own  
adventure

Géraldine Carranante,  
Léo Varnet

Introduction

Auditory revcorr: a  
review

Decoding speech

L'amie/La mie  
experiment

Gender-fair language

Aba/ada experiment

Stop consonants  
experiment

Diversity

fastACI toolbox

Auditory revcorr:  
technical details

Internal representation

Conceptual plurality

Conclusion

Original Article

## High-Frequency Sensorineural Hearing Loss Alters Cue-Weighting Strategies for Discriminating Stop Consonants in Noise

Léo Varnet<sup>1</sup>, Chloé Langlet<sup>1</sup>, Christian Lorenzi<sup>1</sup>,  
Diane S. Lazard<sup>2</sup>, and Christophe Micheyl<sup>3</sup>

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JASA ARTICLE

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

Léo Varnet<sup>1</sup> and Christian Lorenzi<sup>1</sup>

Laboratoire des Systèmes Perceptifs, Département d'Études Cognitives, École Normale Supérieure,  
Université Paris Sciences & Lettres, Centre National de la Recherche Scientifique, 75005 Paris, France

### Abstract

There is increasing evidence that (NH) individuals, even when we perceptual strategies is an impor two complementary approaches: noise and (b) measuring the relt recordings altered by the addi spectrotemporal locations of The cue-weighting strategies we frequency loss, and 15 HI list amplification to compensate fo than on the low-frequency cui differences in internal noise. It

frontiers in  
HUMAN NEUROSCIENCE

## Using auditory classification images for the identification of fine acoustic cues used in speech perception

Léo Varnet<sup>1,2\*</sup>, Kenneth Knoblauch<sup>3</sup>, Fanny Meunier<sup>1,2,4</sup> and Michel Hoen<sup>1,2</sup>

<sup>1</sup> Neuroscience Research Centre, Brain Dynamics and Cognition Team, INSERM U1028, CNRS UMR5292, Lyon, France

<sup>2</sup> Ecole Doctorale Neurosciences et Cognition, Université de Lyon, Université Lyon 1, Lyon, France

<sup>3</sup> Integrative Neuroscience Department, Stern Cell and Brain Research Institute, INSERM U846, Bron, France

<sup>4</sup> Institut de Neurosciences de la Sorbonne, CNRS UMR7156, Paris, France

METHODS ARTICLE  
published 10 December 2013  
doi: 10.3389/fnhum.2013.00866



ary noise on sound perception results from the mas random intrinsic envelope fluctuations arising from es on this phenomenon to probe AM detection strat ght normal-hearing listeners were asked to detect the ne carrier using a yes-no task with 3000 trials/participi verse-correlation analysis was then carried on the 4 scts of the stimulus' temporal envelope influences simulated with different implementations of a modul nan listeners were able to track the position of AM f showed a marked temporal decay and a consistent p ilated data, this was interpreted as an evidence for nvelope fluctuations. © 2022 Acoustical Society of A

# Auditory revcorr

**Reverse correlation** (aka **revcorr**) is the perfect tool to reveal perceptual cues used in a psychophysical task, based on purely behavioral data... in particular for auditory categorization tasks. [Varnet et al. 2013, 2015; Varnet & Lorenzi, 2022; Osses & Varnet, 2023]

## Time to choose

- Tell me more about previous auditory revcorr studies
- No, I just want to build my own auditory revcorr experiment

Original Article

### High-Frequency Sensorineural Hearing Loss Alters Cue-Weighting Strategies for Discriminating Stop Consonants in Noise

Léo Varnet<sup>1</sup>, Chloé Langlet<sup>1</sup>, Christian Lorenzi<sup>1</sup>, Diane S. Lazard<sup>2</sup>, and Christophe Micheyl<sup>3</sup>

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

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Choose your own  
adventure

Géraldine Carranante,  
Léo Varnet

Introduction

Auditory revcorr: a  
review

Decoding speech

L'amie/La mie  
experiment

Gender-fair language

Aba/ada experiment

Stop consonants  
experiment

Diversity

fastACI toolbox

Auditory revcorr:  
technical details

Internal representation

Conceptual plurality

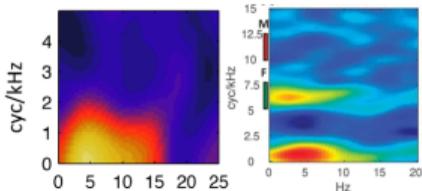
Conclusion

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

high level

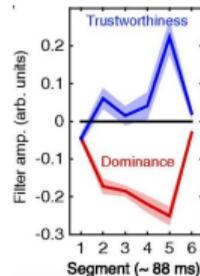
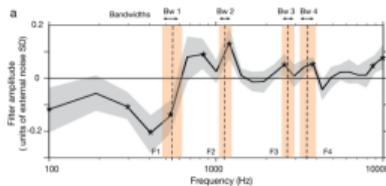
## sentence recognition

[Venezia et al., 2016, 2019]



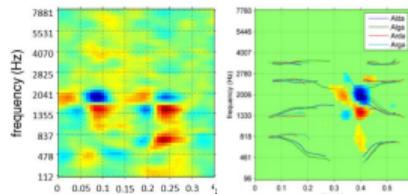
## paralinguistics

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

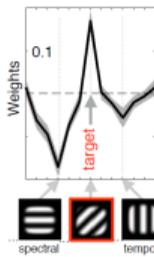
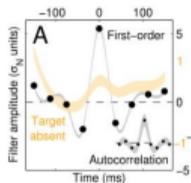
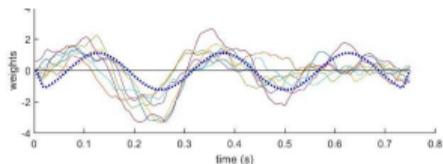


## phoneme categorization

[Varnet et al., 2013, 2015]



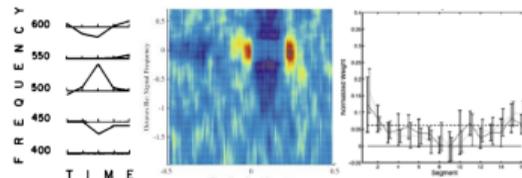
## modulation perception



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

## pure-tone detection & loudness perception

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



low level

# Auditory revcorr review

Choose your own adventure

Géraldine Carranante, Léo Varnet

Introduction

Auditory revcorr: a review

Decoding speech

L'amie/La mie experiment

Gender-fair language

Aba/ada experiment

Stop consonants experiment

Diversity

fastACI toolbox

Auditory revcorr: technical details

Internal representation

Conceptual plurality

Conclusion

The interpretation of the resulting “kernel” varies:

- Some say it is a **direct image of our mental representations** [e.g. Ponsot et al 2018]
- Others that it is merely a **trace of the auditory processes** [Varnet & Lorenzi, 2022]
- The most radical psychophysicists argue that it should rather be seen as a **transparent descriptor of the data**, not the system [Neri, 2018]

There is also a large heterogeneity in the experimental parameters (e.g., yes/no or 2AFC? CI or Bubbles?)

We are currently preparing a review of the philosophical and practical aspects of reverse correlation.

Title	Authors	Year	Journal	Ref id	Auditory process/Task	N in N stimuli	category N trials	N alternatives	N participants	CI/bubble	Performances	SNR	CI model	D
Spectro-Temporal Weighting of Loudness	Oberfeld, Heeren, Reni	2012	PLoS ONE	499	Loudness perception	1	2 (low mean / hiq 3003 for the spec 2 (soft / loud) x 2 5 listeners x 2 lab CI				grand mean of AI fixed		multiple logistic r	
Temporal loudness weights for sounds with Ir	Ponsot, Susini, Saint Pi	2013	Journal of the Ac	1175	Loudness coding Intensity discrimi	1	2 (low mean / hiq 200 * 6 blocks fg 2 (soft / loud)			8 CI	not reported	fixed	logistic regression in	
Spectral weights for overall level discriminati	Doherty, Lutfi,	1996	Journal of the Ac	622	Loudness coding Intensity discrimi	2	2 (low mean / hiq 1000 2 (soft / loud)		11 normal hearin	CI	d'=1	adjusted individu	linear regression s	
Stimulus Features in Signal Detection	Ahumada, Lovell,	1971	Journal of the Ac	42	pure-tone detect Tone-in-noise del	1	2 (tone absent, ti 50 X 32 repetitioi 2 (tone absent, ti 10 (exp 1), 7 (exp CI				fixed to XXX?	linear regression w		
Time and frequency analyses of auditory sign	Ahumada, Marken, Sar	1975	Journal of the Ac	43	pure-tone detect Tone-in-noise del	1	2 (tone absent, ti 400 X 8 repetitioi 2 (tone absent, ti			6 CI	mean d'=1,9	fixed to XXX?	linear regression w	
Psychophysical spectro-temporal receptive fi	Shub, Richards,	2009	Hearing Researcf	494	pure-tone detect Tone-in-noise del non 1 (in a free runni NA (10 blocks)		NA			2 for condition 1, CI	?	fixed to 0 dB	Conditional averi ?	
Identification of stimulus cues in narrow-bani	Schönfelder, Wichmani	2013	Journal of the Ac	1164	pure-tone detect Tone-in-noise del	1	2 (tone absent, ti ~20k-22k			6 CI	60%-90% depent fixed (4 different logistic regression w			
Dynamic Reweighting of Auditory Modulator	Joosten, Shamma, Lore	2016	PloS One	676	modulation perc detection of loud	1	2 (5.5ka2.8k (incren		2	10 CI	74%±6% (incren Fixed individually)	Conditional averi s		
Human pitch detectors are tuned on a fine sc	Joosten, Neri,	2012	Biological Cybern	294	pure-tone detect Frequency discr	2	2 (5,5kHz target i>7000 in 100 tria			2 7+EJ (and an add CI	74%+/-5% SD, d'' individually fixed	conditional averz M		
Mechanisms of Spectrotemporal Modulation	Ponsot, Varnet, Wallae	2021	Trends in Hearing		modulation perc spectro-tempora	2	2 (mod present, mod absent)			2 (modulation presented in 1st / 2 CI	XXX	individually fixed	conditional averz s	
Probing temporal modulation detection in w	Varnet & Lorenzi	2022	Journal of the Acoustica		modulation perc Sinusoidal AM de	1	2	3000		2	8 CI	fixed 70,7% (mez m adaptative	Conditional averi w	
Speech Reductions Cause a De-Weighting of	Varnet, Meunier, Hoen	2016	Interspeech	786	phoneme percep consonant categori	1	4	1000		2	7 CI	mean 60.2% +/- : adjusted individu	Conditional averi bi	

# Auditory revcorr review

Choose your own  
adventure

Géraldine Carranante,  
Léo Varnet

Introduction

Auditory revcorr: a  
review

Decoding speech

L'amie/La mie  
experiment

Gender-fair language

Aba/ada experiment

Stop consonants  
experiment

Diversity

fastACI toolbox

Auditory revcorr:  
technical details

Internal representation

Conceptual plurality

Conclusion

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There is also a large heterogeneity in the experimental parameters (e.g., yes/no or 2AFC? CI or Bubbles?)

We are currently preparing a review of the philosophical and practical aspects of reverse correlation.

## Time to choose

- Yay! philosophy!
- Can you be more specific? Give us some examples of how revcorr can be applied to speech perception.

**“Cracking the speech code”**: finding the auditory primitives of speech comprehension



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“Cracking the speech code”: finding the auditory primitives of speech comprehension

- Which acoustic cues underlie the segmentation of the speech signal into words?
- Which acoustic cues allow listeners to differentiate one phoneme from another?



“**Cracking the speech code**”: finding the auditory primitives of speech comprehension

- Which acoustic cues underlie the segmentation of the speech signal into words?
- Which acoustic cues allow listeners to differentiate one phoneme from another?

No easy answer, due to the spectrotemporal complexity of natural speech.



# Decoding speech

Choose your own  
adventure

Géraldine Carranante,  
Léo Varnet

Introduction

Auditory revcorr: a  
review

Decoding speech

L'amie/La mie  
experiment

Gender-fair language

Aba/ada experiment

Stop consonants  
experiment

Diversity

fastACI toolbox

Auditory revcorr:  
technical details

Internal representation

Conceptual plurality

Conclusion

“**Cracking the speech code**”: finding the auditory primitives of speech  
comprehension

- Which acoustic cues underlie the segmentation of the speech signal into words?
- Which acoustic cues allow listeners to differentiate one phoneme from another?

No easy answer, due to the  
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Time to choose

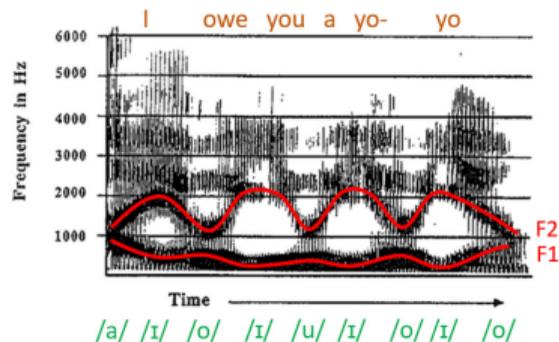
- Let's talk about segmentation cues!
- Let's talk about phonetic cues!

# Segmentation cues

How do listeners find the boundaries between words in continuous speech? (e.g. “I owe you a yoyo”)

- lexical cues [McClelland & Elman, 1986]
- phonotactic cues [McQueen, 1998]

... but that's not the whole story!



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[pubs.aip.org/asa/jel](https://pubs.aip.org/asa/jel)



## Prosodic cues to word boundaries in a segmentation task assessed using reverse correlation

Alejandro Osses,<sup>1,a)</sup> Elsa Spinelli,<sup>2</sup> Fanny Meunier,<sup>3</sup> Etienne Gaudrain,<sup>4</sup> and Léo Varnet<sup>1</sup>

<sup>1</sup>Laboratoire des Systèmes Perceptifs, Département d'Études Cognitives, École Normale Supérieure, PSL University, CNRS, Paris, France

Choose your own  
adventure

Géraldine Carranante,  
Léo Varnet

Introduction

Auditory reverc: a  
review

Decoding speech

L'amie/La mie  
experiment

Gender-fair language

Aba/ada experiment

Stop consonants  
experiment

Diversity

fastACI toolbox

Auditory reverc:  
technical details

Internal representation

Conceptual plurality

Conclusion







# Segmentation cues

Choose your own  
adventure

Géraldine Carranante,  
Léo Varnet

Introduction

Auditory revcorr: a  
review

Decoding speech

L'amie/La mie  
experiment

Gender-fair language

Aba/ada experiment

Stop consonants  
experiment

Diversity

fastACI toolbox

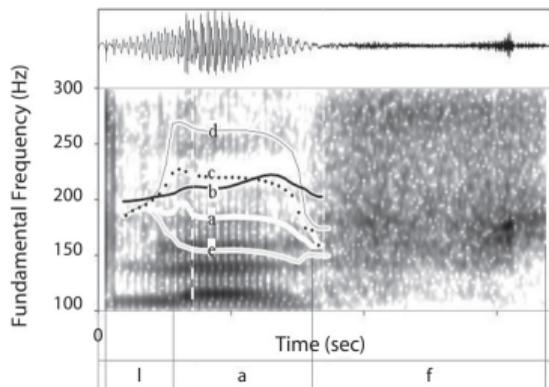
Auditory revcorr:  
technical details

Internal representation

Conceptual plurality

Conclusion

Standard approach for identifying segmentation cues: **manipulating** acoustic content



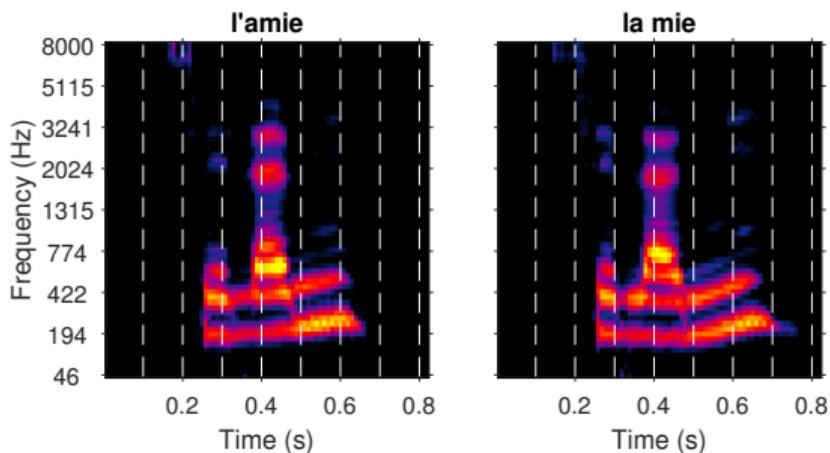
By artificially modifying the  $f_0$  on a specific phonetic segment and running a perceptual experiment, we can demonstrate that this particular information is a cue for segmentation [[Spinelli, Grimault, Meunier & Welby, 2010](#)].

**Limitations** of this hypothesis-driven approach: potential cues tested one at a time

# L'amie/La mie experiment [Osses et al., 2023]

**Topic:** Acoustic cues for the segmentation of a speech sentence into words.

**Targets:** 2 phonetically identical sentences /selami/ ( $t_0$ ="c'est l'amie" and  $t_1$ ="c'est la mie"), equalized in duration and rms [Spinelli et al., 2010].



The targets were divided into 100-ms segments. Then, the  $f_0$  trajectory in each segment was replaced by a random  $f_0$  trajectory and each segment was compressed or stretched by a random amount, using WORLD [Morise et al., 2016].

**Stimuli:** 800 target sounds resynthesised with random  $f_0$  and segment lengths.

**Task:** Indicate whether the target was "c'est l'amie" or "c'est la mie".

Choose your own  
adventure

Géraldine Carranante,  
Léo Varnet

Introduction

Auditory revcorr: a  
review

Decoding speech

L'amie/La mie  
experiment

Gender-fair language

Aba/ada experiment

Stop consonants  
experiment

Diversity

fastACI toolbox

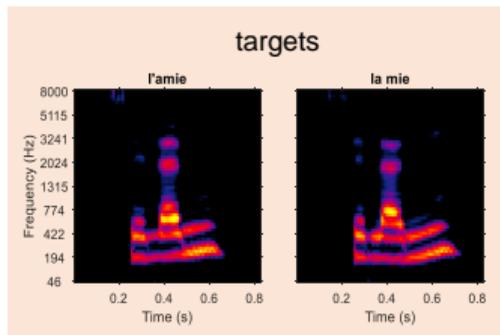
Auditory revcorr:  
technical details

Internal representation

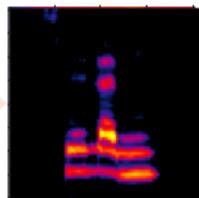
Conceptual plurality

Conclusion

# L'amie/La mie experiment [Osses et al., 2023]



stimulus for trial  $i$   
(random prosody)



segmentation



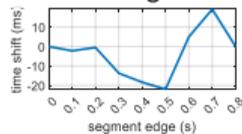
participant's  
response

$$r_i = \begin{cases} 1 & (\text{"l'amie"}) \\ 0 & (\text{"la mie"}) \end{cases}$$

with random  $f_0$



and random segment length



Choose your own  
adventure

Géraldine Carranante,  
Léo Varnet

Introduction

Auditory revcorr: a  
review

Decoding speech

L'amie/La mie  
experiment

Gender-fair language

Aba/ada experiment

Stop consonants  
experiment

Diversity

fastACI toolbox

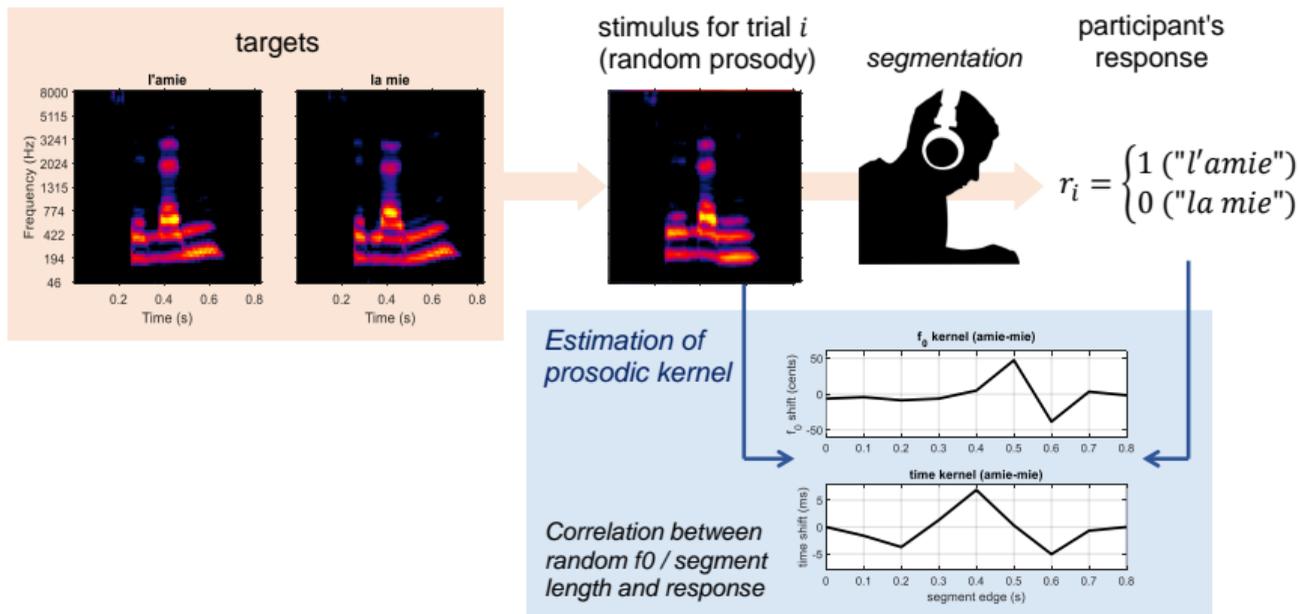
Auditory revcorr:  
technical details

Internal representation

Conceptual plurality

Conclusion

# L'amie/La mie experiment [Osses et al., 2023]



We obtain two kernels ( $f_0$  kernel and time kernel), indicating which aspects of the prosody are used as segmentation cues.

Choose your own  
adventure

Géraldine Carranante,  
Léo Varnet

Introduction

Auditory revcorr: a  
review

Decoding speech

L'amie/La mie  
experiment

Gender-fair language

Aba/ada experiment

Stop consonants  
experiment

Diversity

fastACI toolbox

Auditory revcorr:  
technical details

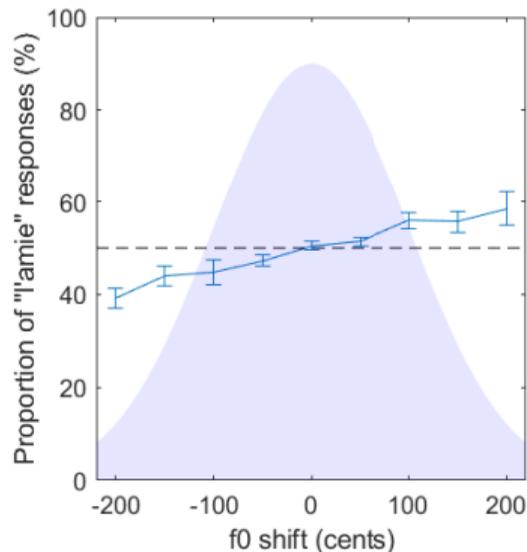
Internal representation

Conceptual plurality

Conclusion

# Results: effect of $f_0$ on /a/ segment

- There is a systematic effect of the random  $f_0$  at 0.5 s (/a/ segment) on the response of participants.

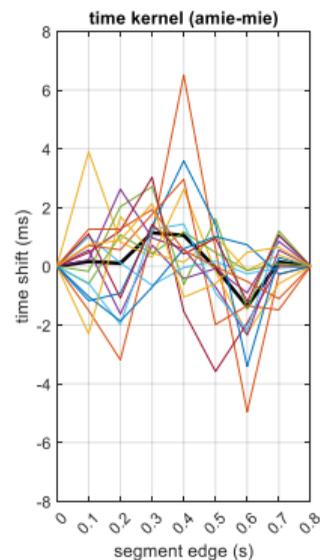
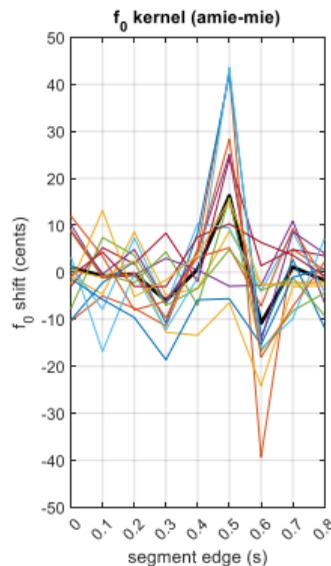






# Results: prosody kernels

- Considerable variability at the group level (N=16)



Choose your own  
adventure

Géraldine Carranante,  
Léo Varnet

[Introduction](#)

[Auditory revcorr: a  
review](#)

[Decoding speech](#)

**[L'amie/La mie  
experiment](#)**

[Gender-fair language](#)

[Aba/ada experiment](#)

[Stop consonants  
experiment](#)

[Diversity](#)

[fastACI toolbox](#)

[Auditory revcorr:  
technical details](#)

[Internal representation](#)

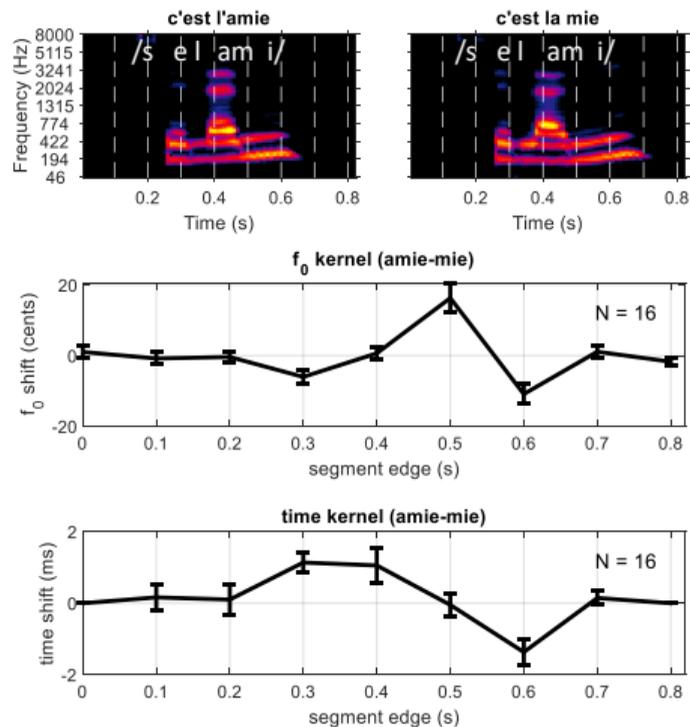
[Conceptual plurality](#)

[Conclusion](#)



# Results: prosody kernels

- Considerable variability at the group level (N=16)
- Nevertheless, a clear prosodic pattern emerges
- Two main segmentation cues can be identified: the relative  $f_0$  of vowels /e/, /a/ and /i/ and relative duration of vowels /e/ and /i/.
- Again, consistent with previous findings obtained using hypothesis-driven methods [Spinelli et al. 2010; Welby, 2007; Shoemaker, 2014]



Choose your own  
adventure

Géraldine Carranante,  
Léo Varnet

Introduction

Auditory revcorr: a  
review

Decoding speech

L'amie/La mie  
experiment

Gender-fair language

Aba/ada experiment

Stop consonants  
experiment

Diversity

fastACI toolbox

Auditory revcorr:  
technical details

Internal representation

Conceptual plurality

Conclusion

# Results

Choose your own  
adventure

Géraldine Carranante,  
Léo Varnet

Introduction

Auditory revcorr: a  
review

Decoding speech

L'amie/La mie  
experiment

Gender-fair language

Aba/ada experiment

Stop consonants  
experiment

Diversity

fastACI toolbox

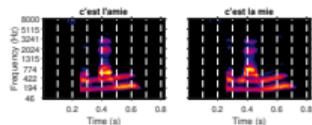
Auditory revcorr:  
technical details

Internal representation

Conceptual plurality

Conclusion

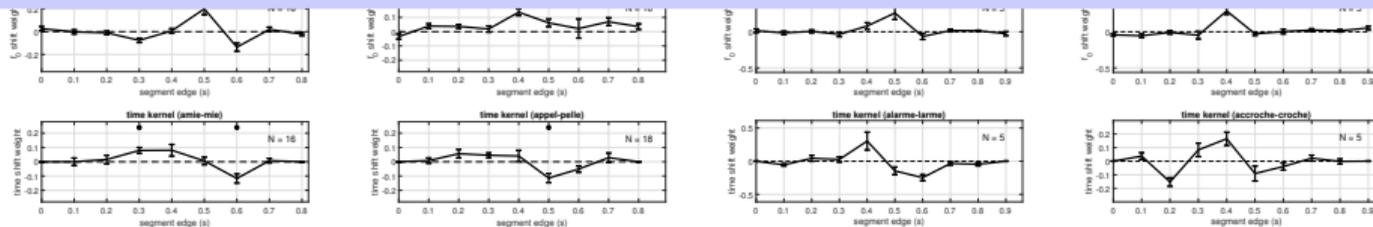
- Similar results were found for other pairs of ambiguous stimuli.
- Secondary cues seem to depend on the phonetical content of the targets (e.g. duration of the second syllable).



- Similar results were found for other pairs of ambiguous stimuli.
- Secondary cues seem to depend on the phonetical content of the targets (e.g. duration of the second syllable).

## Time to choose

- Wait! You said “L'amie”? Why not “L'ami”? Or “L'ami·e”
- Can we move on to the study of phonetic cues?



# Gender-fair language and masculine bias [Spinelli, Chevrot & Varnet, 2023]

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Géraldine Carranante,  
Léo Varnet

A recent psycholinguistics study on grammatical gender, gender-fair language and perceptual biases. Collaboration with Elsa Spinelli from LPNC (Grenoble).

Introduction

Auditory revcorr: a  
review

Decoding speech

L'amie/La mie  
experiment

Gender-fair language

Aba/ada experiment

Stop consonants  
experiment

Diversity

fastACI toolbox

Auditory revcorr:  
technical details

Internal representation

Conceptual plurality

Conclusion

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## Neutral is not fair enough: testing the efficiency of different language gender-fair strategies

Elsa Spinelli<sup>1</sup>, Jean-Pierre Chevrot<sup>2</sup> and Léo Varnet<sup>3\*</sup>

<sup>1</sup>Laboratoire de Psychologie et NeuroCognition, Université Grenoble Alpes, CNRS, Grenoble, France,

<sup>2</sup>Laboratoire Lidilem, Université Grenoble Alpes, Grenoble, France, <sup>3</sup>Laboratoire des Systèmes Perceptifs,

# Gender-fair language and masculine bias [Spinelli, Chevrot & Varnet, 2023]

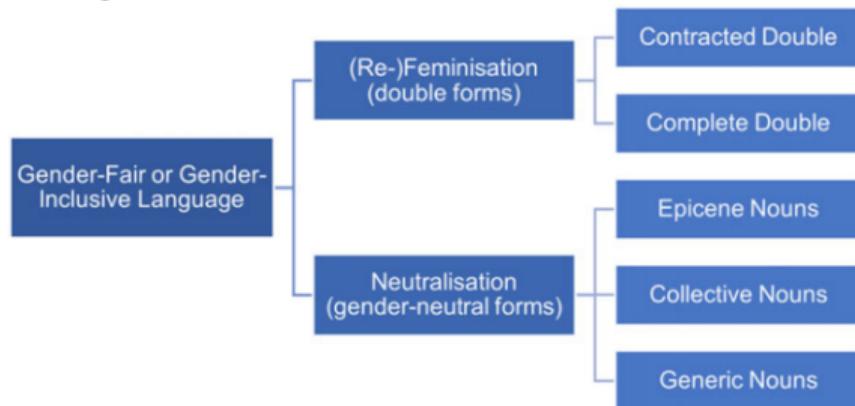
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In languages with grammatical gender, such as French, it has been evidenced that using masculine forms as a generic reference induces a bias favoring masculine specific representations [Brauer & Landry, 2008; Gygax et al., 2008; Xiao et al., 2022].

Two main strategies to counteract these gender biases [Tibblin et al., 2022]:

- **Neutralization** (e.g. gender-unmarked forms such as “l’enfant”)
- **Re-feminization** (e.g. contracted double forms such as “un·e enfant”)



Here, we explored the relative efficiency of these strategies.

Introduction

Auditory revcorr: a  
review

Decoding speech

L'amie/La mie  
experiment

Gender-fair language

Aba/ada experiment

Stop consonants  
experiment

Diversity

fastACI toolbox

Auditory revcorr:  
technical details

Internal representation

Conceptual plurality

Conclusion



# Gender-fair language and masculine bias [Spinelli, Chevrot & Varnet, 2023]

Choose your own  
adventure

Géraldine Carranante,  
Léo Varnet

Introduction

Auditory revcorr: a  
review

Decoding speech

L'amie/La mie  
experiment

Gender-fair language

Aba/ada experiment

Stop consonants  
experiment

Diversity

fastACI toolbox

Auditory revcorr:  
technical details

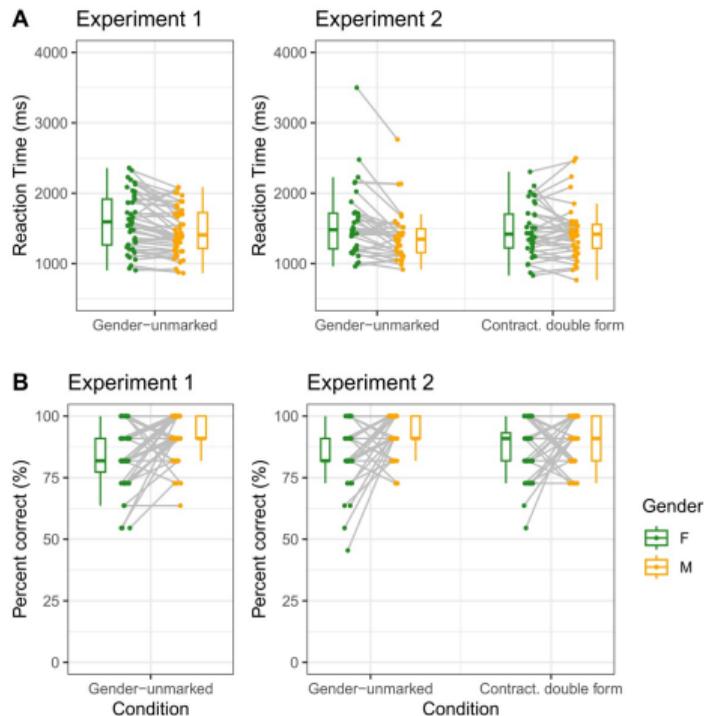
Internal representation

Conceptual plurality

Conclusion

Longer response times for sentences beginning with “elle” compared to “il” in the Gender-unmarked condition, but not in the Contracted double condition.

Gender-unmarked forms do not fully neutralize the masculine bias, while contracted double forms (here using the mid-dot) are more effective in promoting gender balanced representations.



# Gender-fair language and masculine bias [Spinelli, Chevrot & Varnet, 2023]

Choose your own  
adventure

Géraldine Carranante,  
Léo Varnet

Introduction

Auditory revcorr: a  
review

Decoding speech

L'amie/La mie  
experiment

Gender-fair language

Aba/ada experiment

Stop consonants  
experiment

Diversity

fastACI toolbox

Auditory revcorr:  
technical details

Internal representation

Conceptual plurality

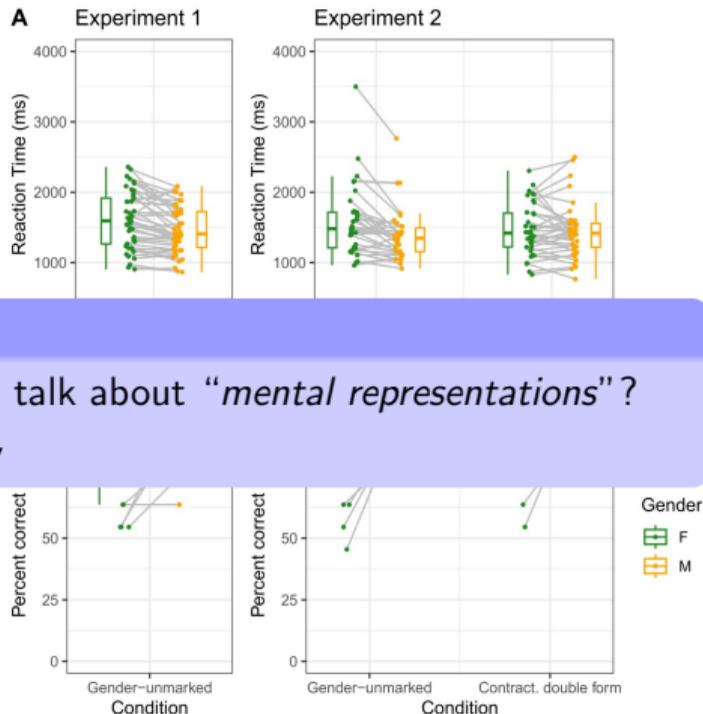
Conclusion

Longer response times for sentences beginning with “elle” compared to “il” in the Gender-unmarked condition, but not in the Contracted double condition.

## Time to choose

- By the way, what do we mean when we talk about “*mental representations*”?
- Yeah, I have the same question actually

mid-dot) are more effective in promoting gender balanced representations.



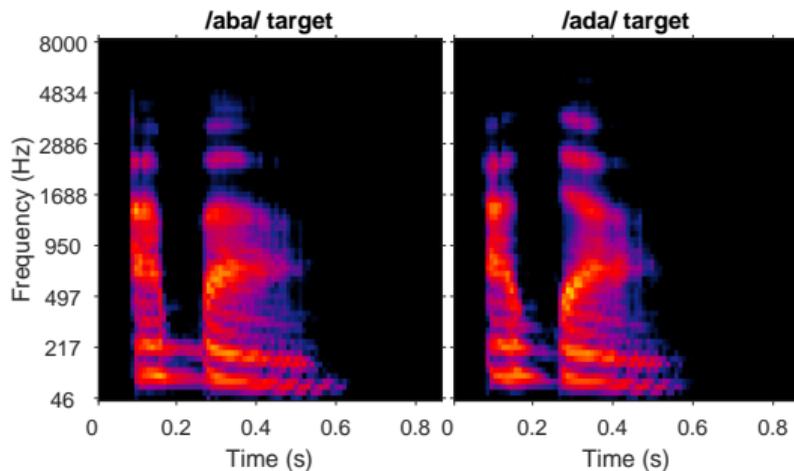
# Aba/Ada experiment [Osses & Varnet, 2023]

**Topic:** perception of stop consonants /b/ and /d/.

**Targets:** 2 VCV sounds ( $t_0$ =/aba/ and  $t_1$ =/ada/) from the Oldenburg Logatome Corpus [Wesker et al., 2005], equalized in duration and rms.



Alejandro Osses



Choose your own  
adventure

Géraldine Carranante,  
Léo Varnet

Introduction

Auditory revcorr: a  
review

Decoding speech

L'amie/La mie  
experiment

Gender-fair language

**Aba/ada experiment**

Stop consonants  
experiment

Diversity

fastACI toolbox

Auditory revcorr:  
technical details

Internal representation

Conceptual plurality

Conclusion

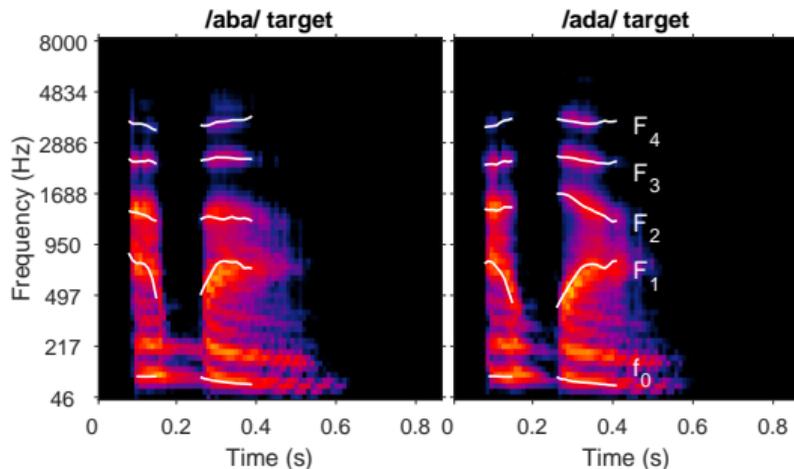
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Alejandro Osses



Choose your own  
adventure

Géraldine Carranante,  
Léo Varnet

Introduction

Auditory revcorr: a  
review

Decoding speech

L'amie/La mie  
experiment

Gender-fair language

**Aba/ada experiment**

Stop consonants  
experiment

Diversity

fastACI toolbox

Auditory revcorr:  
technical details

Internal representation

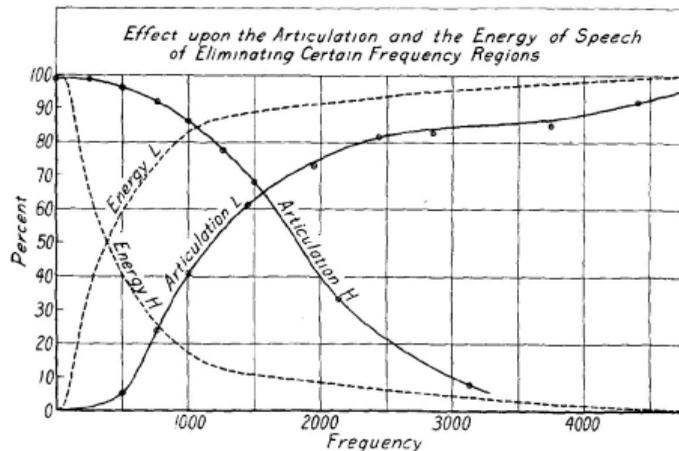
Conceptual plurality

Conclusion

# Aba/Ada experiment [Osses & Varnet, 2023]

One solution: using **reduced speech**

- Low-/high-pass filtered speech [Fletcher, 1922]



Choose your own  
adventure

Géraldine Carranante,  
Léo Varnet

Introduction

Auditory revcorr: a  
review

Decoding speech

L'amie/La mie  
experiment

Gender-fair language

**Aba/ada experiment**

Stop consonants  
experiment

Diversity

fastACI toolbox

Auditory revcorr:  
technical details

Internal representation

Conceptual plurality

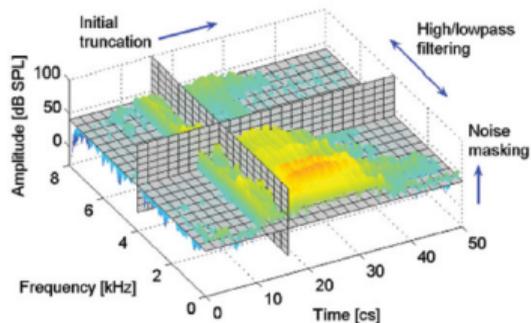
Conclusion



# Aba/Ada experiment [Osses & Varnet, 2023]

One solution: using **reduced speech**

- Low-/high-pass filtered speech [Fletcher, 1922]
- Synthetic speech continuum [Liberman et al., 1954]
- 3-Dimensional Deep Search [Li & Allen, 2012], etc...



Choose your own  
adventure

Géraldine Carranante,  
Léo Varnet

Introduction

Auditory revcorr: a  
review

Decoding speech

L'amie/La mie  
experiment

Gender-fair language

**Aba/ada experiment**

Stop consonants  
experiment

Diversity

fastACI toolbox

Auditory revcorr:  
technical details

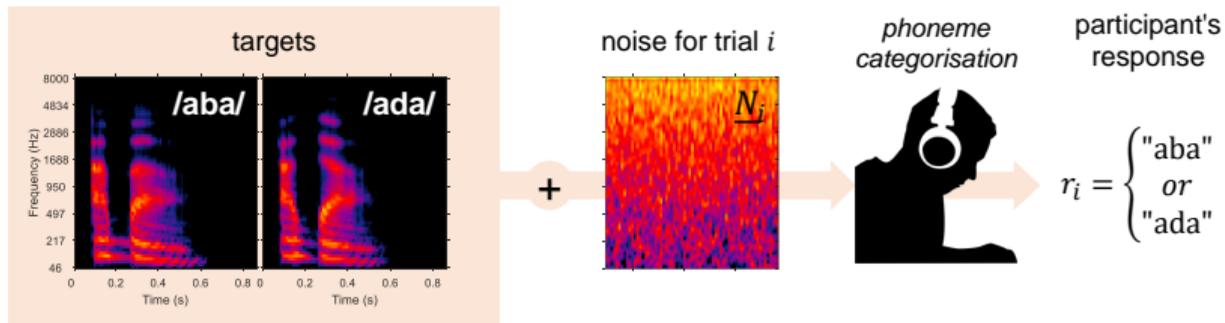
Internal representation

Conceptual plurality

Conclusion



# Aba/Ada experiment [Osses & Varnet, 2023]



Choose your own  
adventure

G eraline Carranante,  
L eo Varnet

Introduction

Auditory revcorr: a  
review

Decoding speech

L'amie/La mie  
experiment

Gender-fair language

**Aba/ada experiment**

Stop consonants  
experiment

Diversity

fastACI toolbox

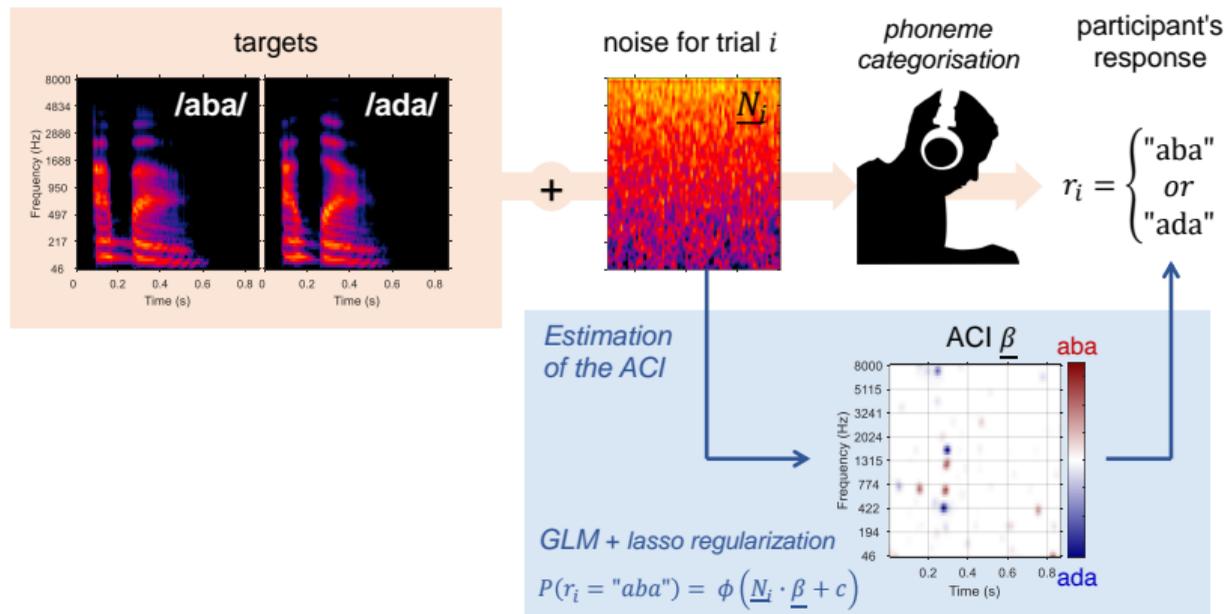
Auditory revcorr:  
technical details

Internal representation

Conceptual plurality

Conclusion

# Aba/Ada experiment [Osses & Varnet, 2023]



**Auditory Classification Image (ACI):** time-frequency matrix of decision weights. Shows how a specific noise configuration can mislead the participant.

Choose your own adventure

G eraldine Carranante,  
L eo Varnet

Introduction

Auditory revcorr: a review

Decoding speech

L'amie/La mie experiment

Gender-fair language

Aba/ada experiment

Stop consonants experiment

Diversity

fastACI toolbox

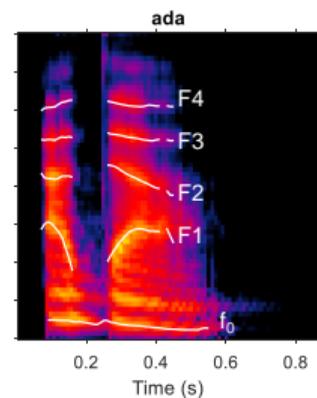
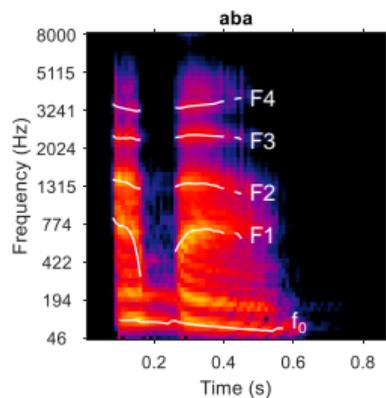
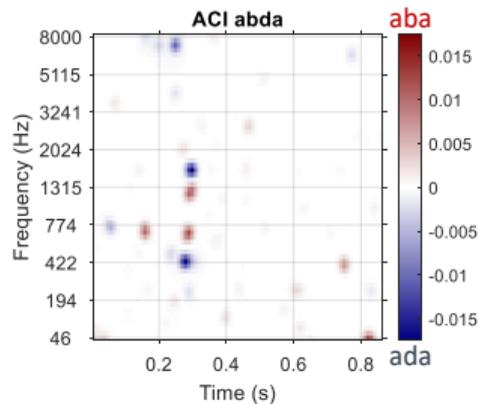
Auditory revcorr: technical details

Internal representation

Conceptual plurality

Conclusion

# Results [Osses & Varnet, 2023]



Choose your own  
adventure

Géraldine Carranante,  
Léo Varnet

[Introduction](#)

[Auditory revcorr: a  
review](#)

[Decoding speech](#)

[L'amie/La mie  
experiment](#)

[Gender-fair language](#)

**[Aba/ada experiment](#)**

[Stop consonants  
experiment](#)

[Diversity](#)

[fastACI toolbox](#)

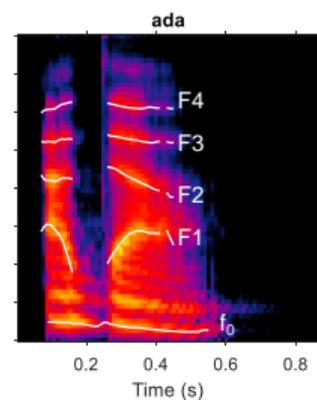
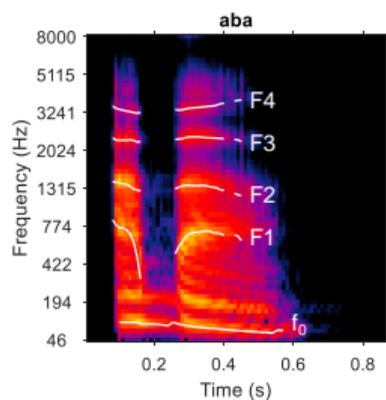
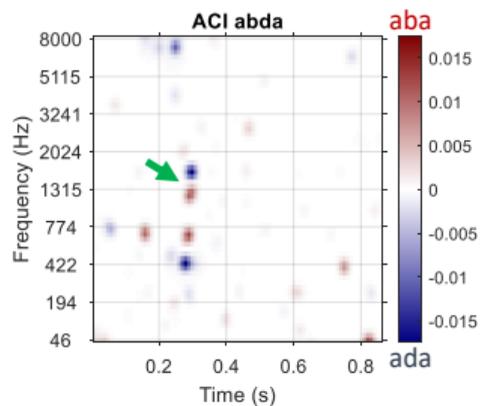
[Auditory revcorr:  
technical details](#)

[Internal representation](#)

[Conceptual plurality](#)

[Conclusion](#)

# Results [Osses & Varnet, 2023]



Choose your own  
adventure

Géraldine Carranante,  
Léo Varnet

[Introduction](#)

[Auditory revcorr: a  
review](#)

[Decoding speech](#)

[L'amie/La mie  
experiment](#)

[Gender-fair language](#)

**[Aba/ada experiment](#)**

[Stop consonants  
experiment](#)

[Diversity](#)

[fastACI toolbox](#)

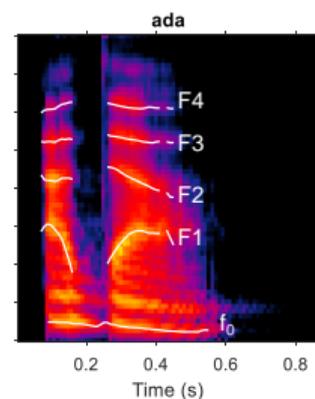
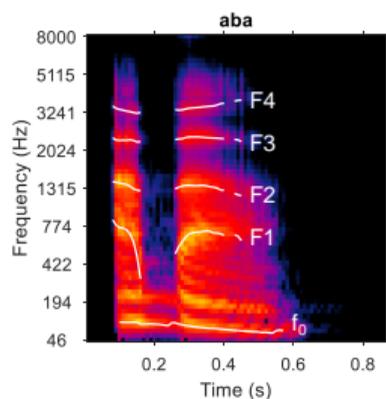
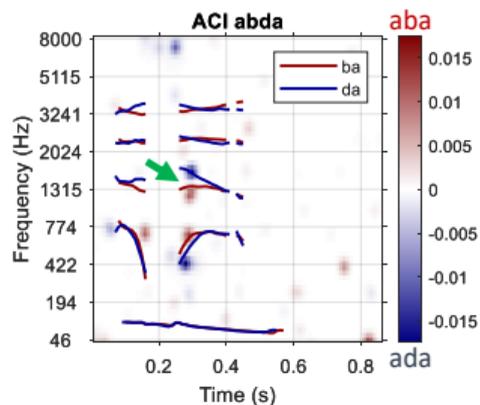
[Auditory revcorr:  
technical details](#)

[Internal representation](#)

[Conceptual plurality](#)

[Conclusion](#)

# Results [Osses & Varnet, 2023]



- The analysis successfully identified the **main cue** for the task (F2 onset), consistent with the phonetics literature [Lieberman et al., 1954]...

Choose your own  
adventure

Géraldine Carranante,  
Léo Varnet

Introduction

Auditory revcorr: a  
review

Decoding speech

L'amie/La mie  
experiment

Gender-fair language

Aba/ada experiment

Stop consonants  
experiment

Diversity

fastACI toolbox

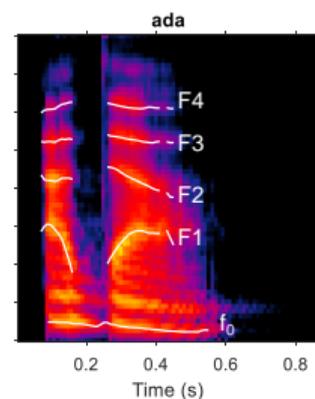
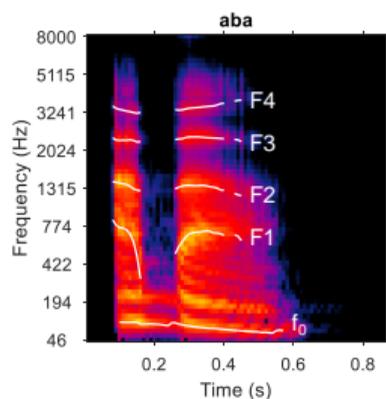
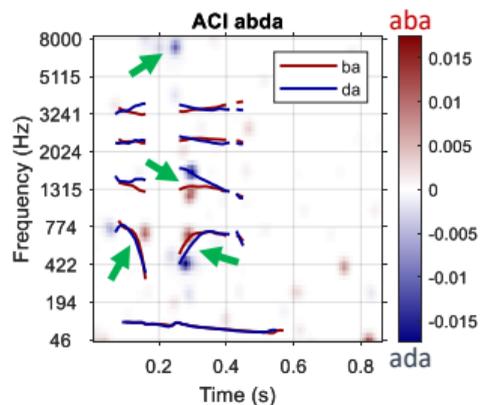
Auditory revcorr:  
technical details

Internal representation

Conceptual plurality

Conclusion

# Results [Osses & Varnet, 2023]



- The analysis successfully identified the **main cue** for the task (F2 onset), consistent with the phonetics literature [Lieberman et al., 1954]...
- ...as well as several **secondary cues** (e.g., F1 onset).

Choose your own  
adventure

Géraldine Carranante,  
Léo Varnet

Introduction

Auditory revcorr: a  
review

Decoding speech

L'amie/La mie  
experiment

Gender-fair language

Aba/ada experiment

Stop consonants  
experiment

Diversity

fastACI toolbox

Auditory revcorr:  
technical details

Internal representation

Conceptual plurality

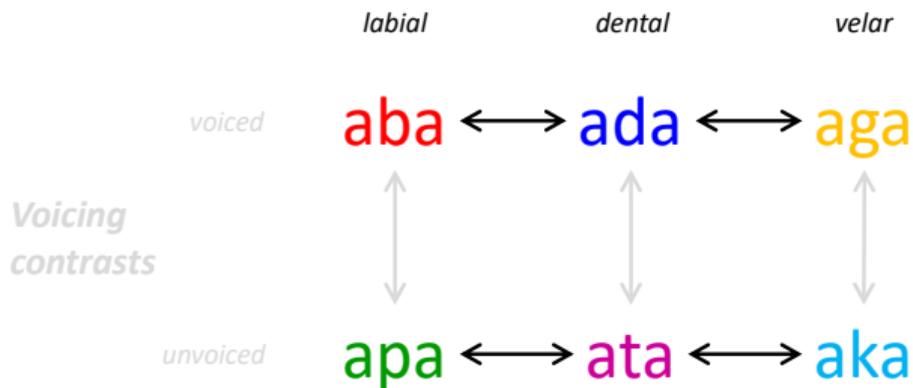
Conclusion



# Stop consonants experiment [Carranante et al., in prep.]

- Discrimination task in noise
- 6 target sounds (plosive C in context /aCa/)
- 7 participants × 7 contrasts, 4.000 trials/condition

## Place of articulation contrasts

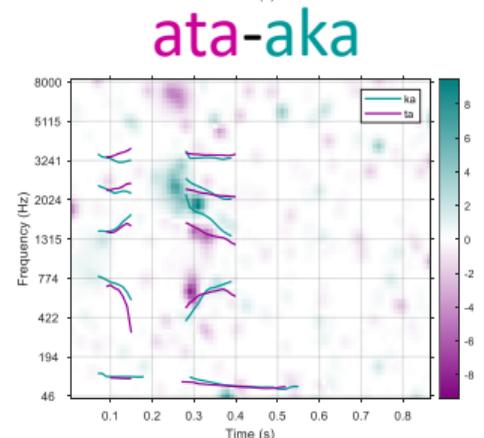
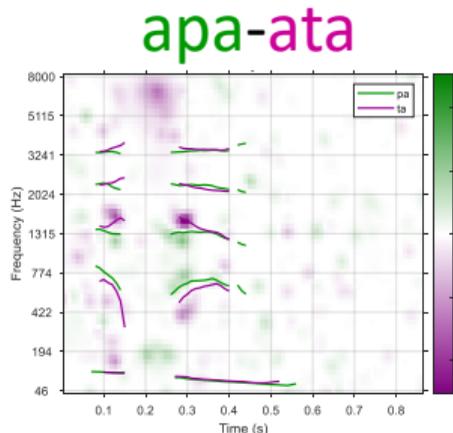
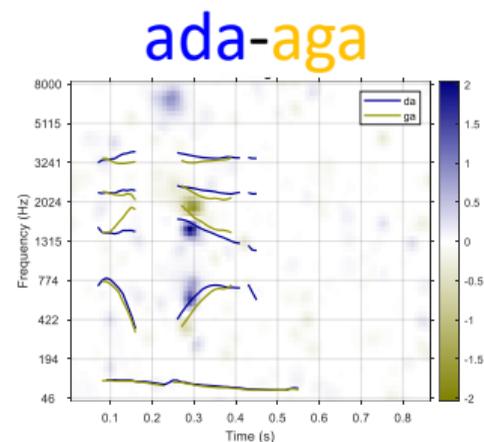
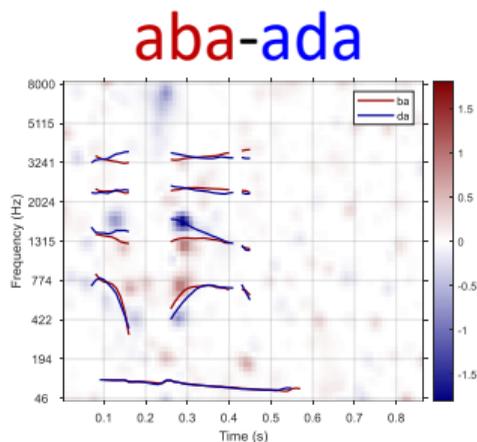




# Group-averaged ACIs

## Place of articulation cues:

- F2 onset
- F1 onset
- release burst (/d/ and /t/)
- coarticulation on F1 and F2



Choose your own  
adventure

Géraldine Carranante,  
Léo Varnet

Introduction

Auditory revcorr: a  
review

Decoding speech

L'amie/La mie  
experiment

Gender-fair language

Aba/ada experiment

Stop consonants  
experiment

Diversity

fastACI toolbox

Auditory revcorr:  
technical details

Internal representation

Conceptual plurality

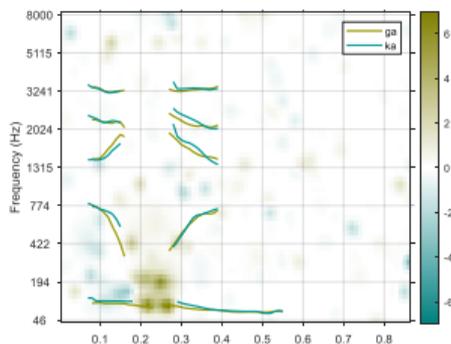
Conclusion

# Group-averaged ACIs

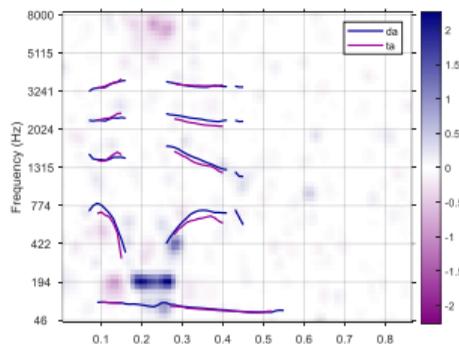
## Voicing cues:

- voicing bar
- F1 onset
- release burst (only for /t/)

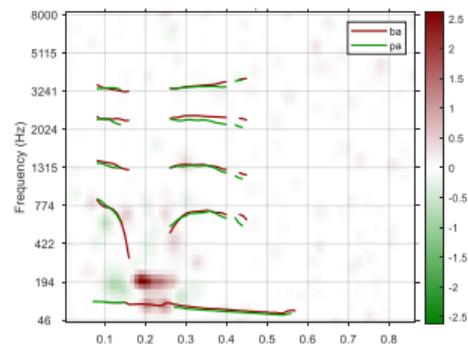
aga-aka



ada-ata



aba-apa



Choose your own  
adventure

Géraldine Carranante,  
Léo Varnet

[Introduction](#)

[Auditory revcorr: a  
review](#)

[Decoding speech](#)

[L'amie/La mie  
experiment](#)

[Gender-fair language](#)

[Aba/ada experiment](#)

[Stop consonants  
experiment](#)

[Diversity](#)

[fastACI toolbox](#)

[Auditory revcorr:  
technical details](#)

[Internal representation](#)

[Conceptual plurality](#)

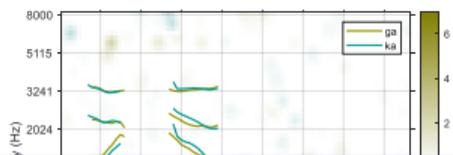
[Conclusion](#)

# Group-averaged ACIs

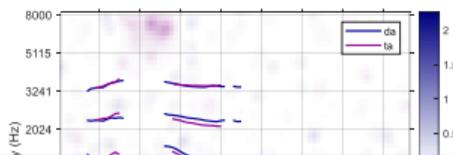
**Voicing cues:**

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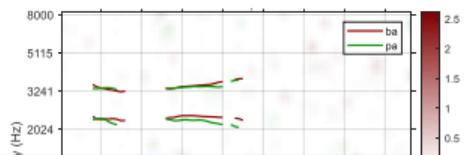
aga-aka



ada-ata



aba-apa



Time to choose

- These are the group-averaged ACIs. What about individual results?
- Ok but the concept of “phoneme” has multiple definitions in the linguistic litterature. How do you deal with that?

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adventure

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Introduction

Auditory revcorr: a  
review

Decoding speech

L'amie/La mie  
experiment

Gender-fair language

Aba/ada experiment

Stop consonants  
experiment

Diversity

fastACI toolbox

Auditory revcorr:  
technical details

Internal representation

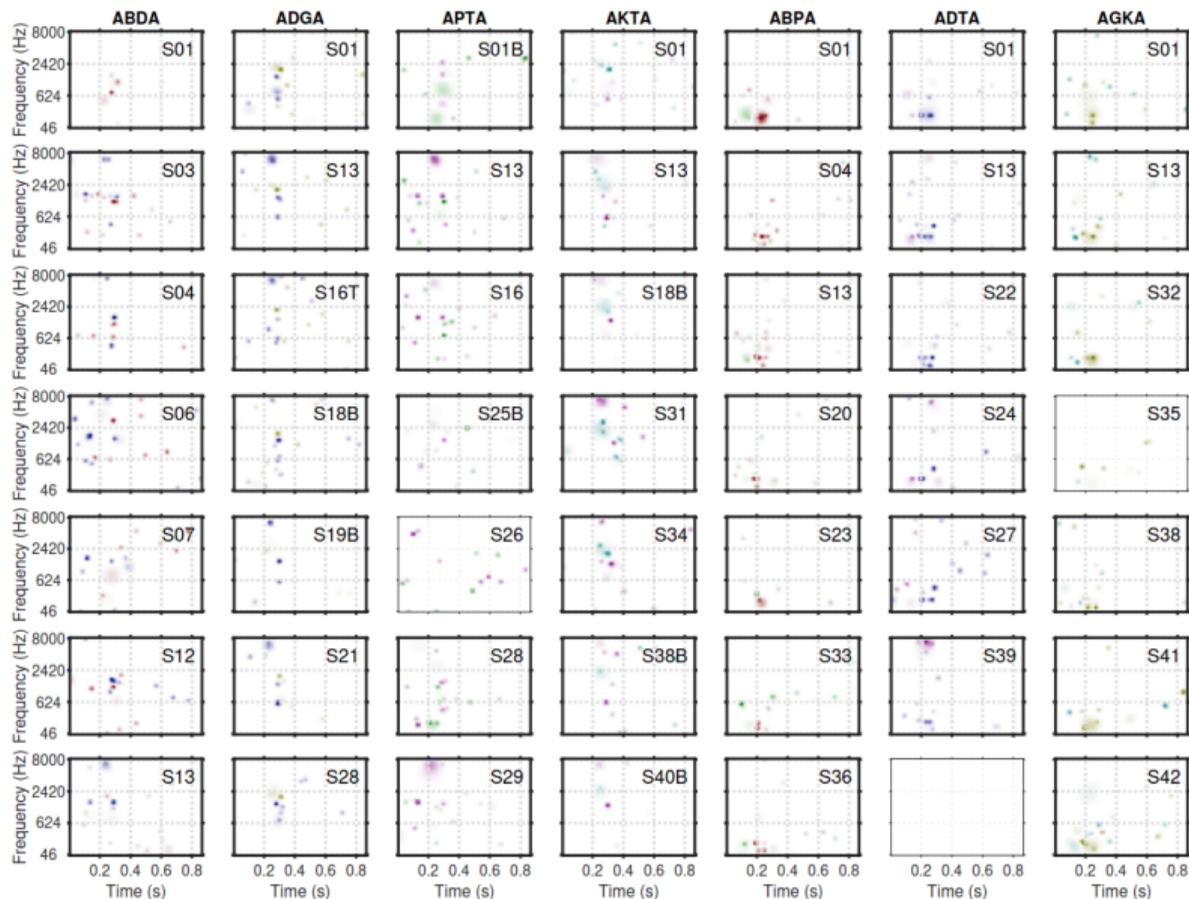
Conceptual plurality

Conclusion





# Interindividual diversity



Choose your own  
adventure

Géraldine Carranante,  
Léo Varnet

[Introduction](#)

[Auditory revcorr: a  
review](#)

[Decoding speech](#)

[L'amie/La mie  
experiment](#)

[Gender-fair language](#)

[Aba/ada experiment](#)

[Stop consonants  
experiment](#)

**Diversity**

[fastACI toolbox](#)

[Auditory revcorr:  
technical details](#)

[Internal representation](#)

[Conceptual plurality](#)

[Conclusion](#)

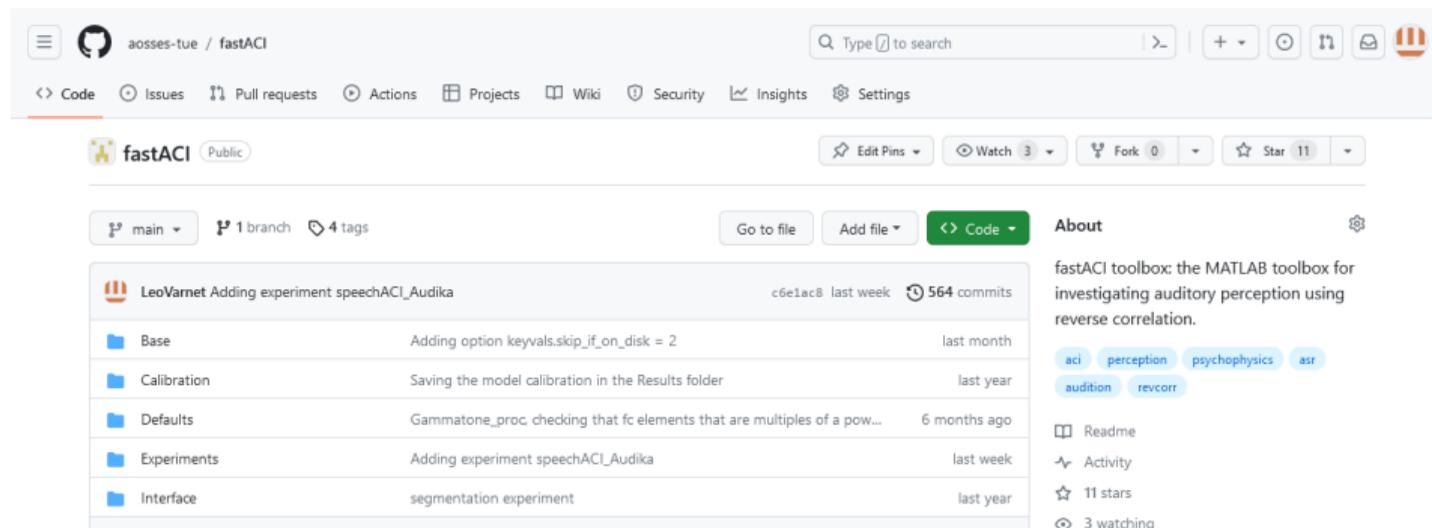


# The fastACI toolbox

**Code available on GitHub** as an open-source MATLAB toolbox with documentation and demo experiments [Osses & Varnet, 2021]: <https://github.com/aosses-tue/fastACI>

All experiments can be replicated within the toolbox and all analyses and figures can be exactly reproduced (fully reproducible workflow).

Connects with other open-source projects such as **WORLD-Straight** or the **Auditory Modelling Toolbox**.



The screenshot shows the GitHub repository page for 'aosses-tue / fastACI'. The repository is public and has 11 stars and 3 watchers. The main branch is 'main' with 1 branch and 4 tags. The repository contains several folders: Base, Calibration, Defaults, Experiments, and Interface. The 'Experiments' folder is highlighted, showing a commit by LeoVarnet titled 'Adding experiment speechACI\_Audika' from last week, with 564 commits. The 'About' section describes the toolbox as 'the MATLAB toolbox for investigating auditory perception using reverse correlation' and lists tags: aci, perception, psychophysics, asr, audition, and revcorr. The repository also has a README, activity, and 11 stars.

Folder	Description	Last Commit
Base	Adding option keyvals.skip_if_on_disk = 2	last month
Calibration	Saving the model calibration in the Results folder	last year
Defaults	Gammatone_proc checking that fc elements that are multiples of a pow...	6 months ago
Experiments	Adding experiment speechACI_Audika	last week
Interface	segmentation experiment	last year

Choose your own  
adventure

Géraldine Carranante,  
Léo Varnet

Introduction

Auditory revcorr: a  
review

Decoding speech

L'amie/La mie  
experiment

Gender-fair language

Aba/ada experiment

Stop consonants  
experiment

Diversity

**fastACI toolbox**

Auditory revcorr:  
technical details

Internal representation

Conceptual plurality

Conclusion

# The fastACI toolbox

**Code available on GitHub** as an open-source MATLAB toolbox with documentation and demo experiments [Osses & Varnet, 2021]: <https://github.com/aosses-tue/fastACI>

## Time to choose

- How does it work? I want to know more.
- Yeah yeah, cut the sales crap. I want to see what it really does.

The screenshot shows the GitHub repository for 'aosses-tue / fastACI'. The repository is public and has 11 stars and 3 watchers. The commit history shows a recent commit by LeoVarnet titled 'Adding experiment speechACI\_Audika' with 564 total commits. The repository structure includes folders for Base, Calibration, Defaults, Experiments, and Interface. The 'About' section describes the toolbox as a MATLAB tool for investigating auditory perception using reverse correlation. The repository also includes a README, activity feed, and 11 stars.

Commit	Message	Time
c6e1ac8	Adding option keyvals.skip_if_on_disk = 2	last month
	Saving the model calibration in the Results folder	last year
	Gammatone_proc checking that fc elements that are multiples of a pow...	6 months ago
	Adding experiment speechACI_Audika	last week
	segmentation experiment	last year

Choose your own  
adventure

Géraldine Carranante,  
Léo Varnet

Introduction

Auditory revcorr: a  
review

Decoding speech

L'amie/La mie  
experiment

Gender-fair language

Aba/ada experiment

Stop consonants  
experiment

Diversity

**fastACI toolbox**

Auditory revcorr:  
technical details

Internal representation

Conceptual plurality

Conclusion

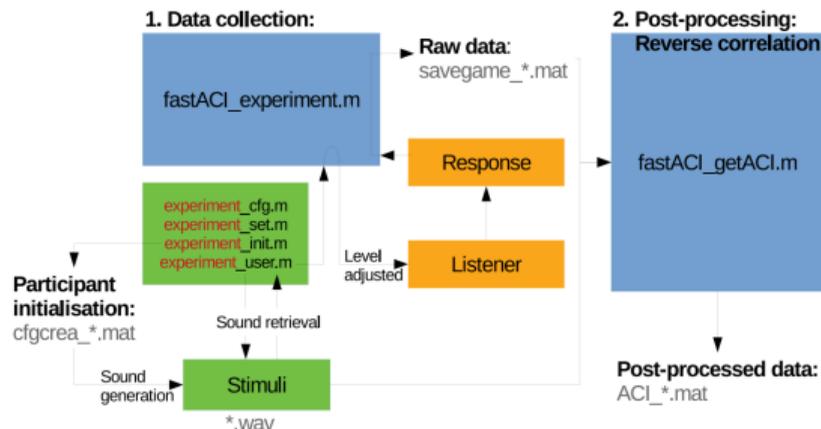
# The fastACI toolbox

The **experiment** is defined by a set of 4 scripts listing the experimental parameters, similar to the *AFC toolbox* [Ewert, 2013]. Stimuli are stored on disk or can be re-generated from their seed.

A basic text-based **interface** allows the participants to enter their responses.

Optionally, the participant can be replaced by a model from AMT [Majdak et al, 2021].

The base functions and subfunctions from the fastACI environment ensure the **data collection and analysis**.



Choose your own  
adventure

Géraldine Carranante,  
Léo Varnet

Introduction

Auditory revcorr: a  
review

Decoding speech

L'amie/La mie  
experiment

Gender-fair language

Aba/ada experiment

Stop consonants  
experiment

Diversity

**fastACI toolbox**

Auditory revcorr:  
technical details

Internal representation

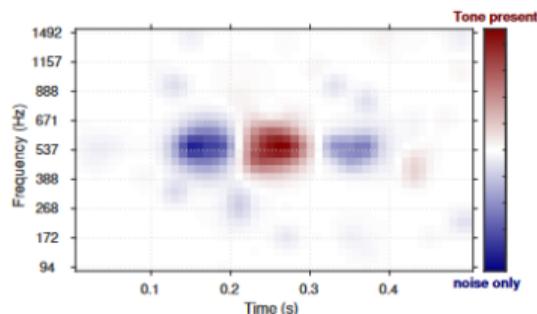
Conceptual plurality

Conclusion

# The fastACI toolbox

A few experiments are available natively:

- `speechACI_Logatome-aCCa-S43M` [Carranante et al., in prep]
- `segmentation` [Osses et al., 2023]
- `speechACI_Logatome-abda-S43M` [Osses & Varnet, 2023]
- `modulationACI` [Varnet & Lorenzi, 2022]
- `speechACI_varnet2015` [Varnet & Lorenzi, 2015]
- `speechACI_varnet2013` [Varnet & Lorenzi, 2013]
- ...and even `ahumada1975` [Ahumada, Marken, & Sandusky, 1975]



Choose your own  
adventure

Géraldine Carranante,  
Léo Varnet

Introduction

Auditory revcorr: a  
review

Decoding speech

L'amie/La mie  
experiment

Gender-fair language

Aba/ada experiment

Stop consonants  
experiment

Diversity

**fastACI toolbox**

Auditory revcorr:  
technical details

Internal representation

Conceptual plurality

Conclusion

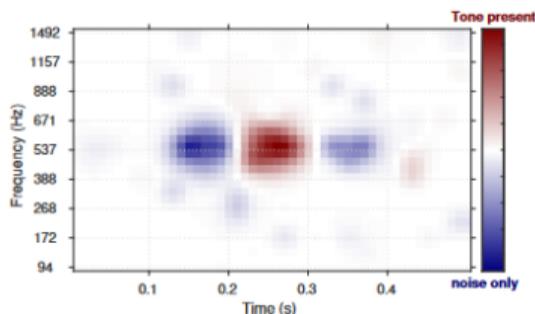
# The fastACI toolbox

A few experiments are available natively:

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- `speechACI_Logatome-abda-S43M` [Osses & Varnet, 2023]
- `modulationACI` [Varnet & Lorenzi, 2022]

## Time to choose

- I'm curious about this `segmentation` experiment
- I'm curious about this `speechACI_Logatome-abda-S43M` experiment



Choose your own  
adventure

Géraldine Carranante,  
Léo Varnet

Introduction

Auditory revcorr: a  
review

Decoding speech

L'amie/La mie  
experiment

Gender-fair language

Aba/ada experiment

Stop consonants  
experiment

Diversity

fastACI toolbox

Auditory revcorr:  
technical details

Internal representation

Conceptual plurality

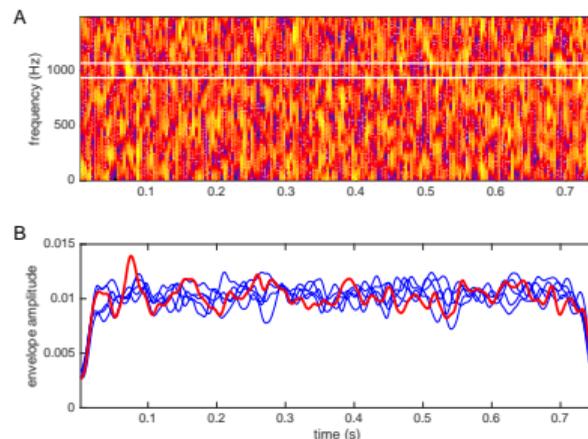
Conclusion

# Intrinsic fluctuations and revcorr

Part of the deleterious effect of a steady noise on speech perception is due to the confusion of useful modulations in the signal with **intrinsic envelope fluctuations** arising from the filtering of noise into cochlear critical bands

[*Dau et al., 1997, 1999*]

Using the revcorr method to **probe internal representations of sounds** by relating random envelope fluctuations of masking noise with the response of listeners on a trial-by-trial basis



Envelopes for 6 realizations of a white noise, bandpass-filtered between 935 and 1068 Hz

Choose your own  
adventure

Géraldine Carranante,  
Léo Varnet

Introduction

Auditory revcorr: a  
review

Decoding speech

L'amie/La mie  
experiment

Gender-fair language

Aba/ada experiment

Stop consonants  
experiment

Diversity

fastACI toolbox

Auditory revcorr:  
technical details

Internal representation

Conceptual plurality

Conclusion

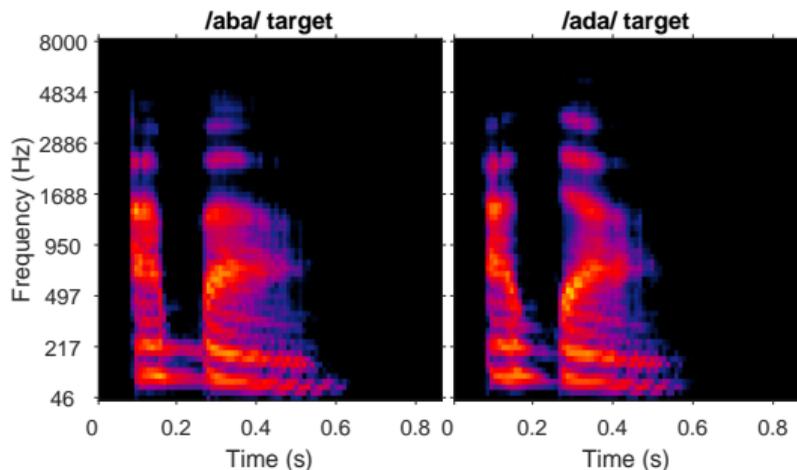
# Aba/Ada experiment [Osses & Varnet, 2023]

**Topic:** perception of stop consonants /b/ and /d/.

**Targets:** 2 VCV sounds ( $t_0$ =/aba/ and  $t_1$ =/ada/) from the Oldenburg Logatome Corpus [Wesker et al., 2005], equalized in duration and rms.

**Stimuli:** Target sounds in additive white noise (+ 2 non-stationary background conditions).

**SNR** adapted continuously to ensure a correct response rate of 70.7%.



Choose your own  
adventure

Géraldine Carranante,  
Léo Varnet

Introduction

Auditory revcorr: a  
review

Decoding speech

L'amie/La mie  
experiment

Gender-fair language

Aba/ada experiment

Stop consonants  
experiment

Diversity

fastACI toolbox

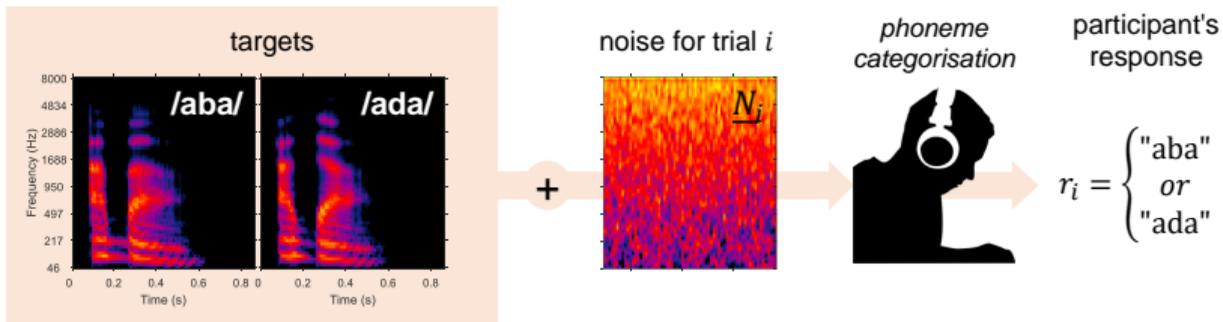
Auditory revcorr:  
technical details

Internal representation

Conceptual plurality

Conclusion

# Aba/Ada experiment [Osses & Varnet, 2023]



Choose your own  
adventure

G eraline Carranante,  
L eo Varnet

Introduction

Auditory revcorr: a  
review

Decoding speech

L'amie/La mie  
experiment

Gender-fair language

Aba/ada experiment

Stop consonants  
experiment

Diversity

fastACI toolbox

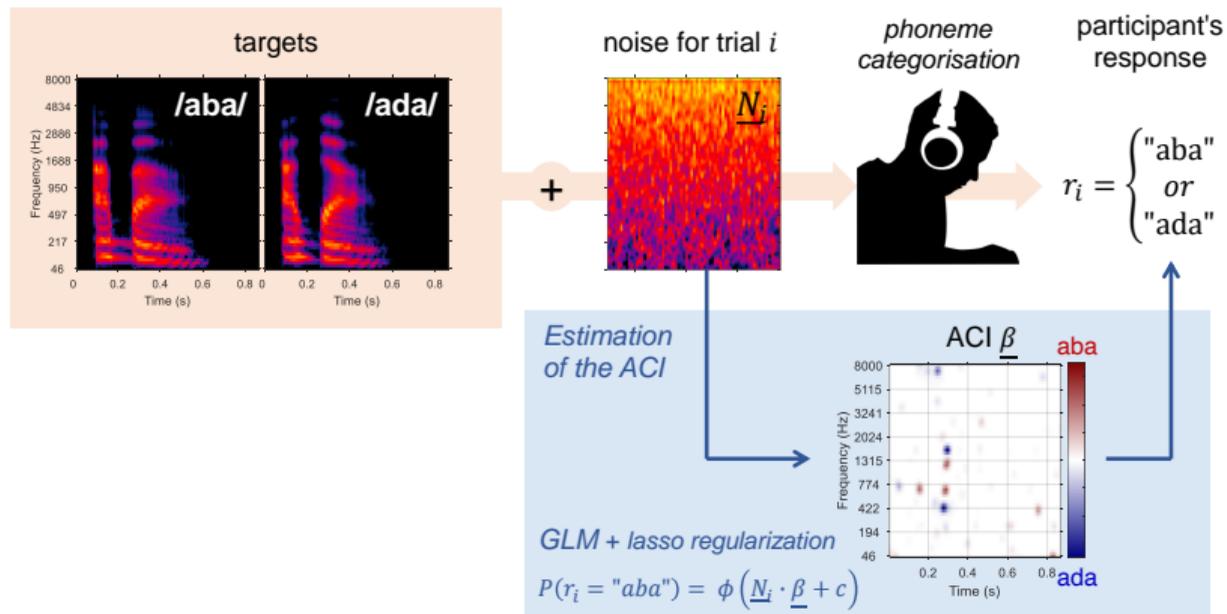
Auditory revcorr:  
technical details

Internal representation

Conceptual plurality

Conclusion

# Aba/Ada experiment [Osses & Varnet, 2023]



**Auditory Classification Image (ACI):** time-frequency matrix of decision weights. Shows how a specific noise configuration can mislead the participant.

Choose your own  
adventure

Géraldine Carranante,  
Léo Varnet

Introduction

Auditory revcorr: a  
review

Decoding speech

L'amie/La mie  
experiment

Gender-fair language

Aba/ada experiment

Stop consonants  
experiment

Diversity

fastACI toolbox

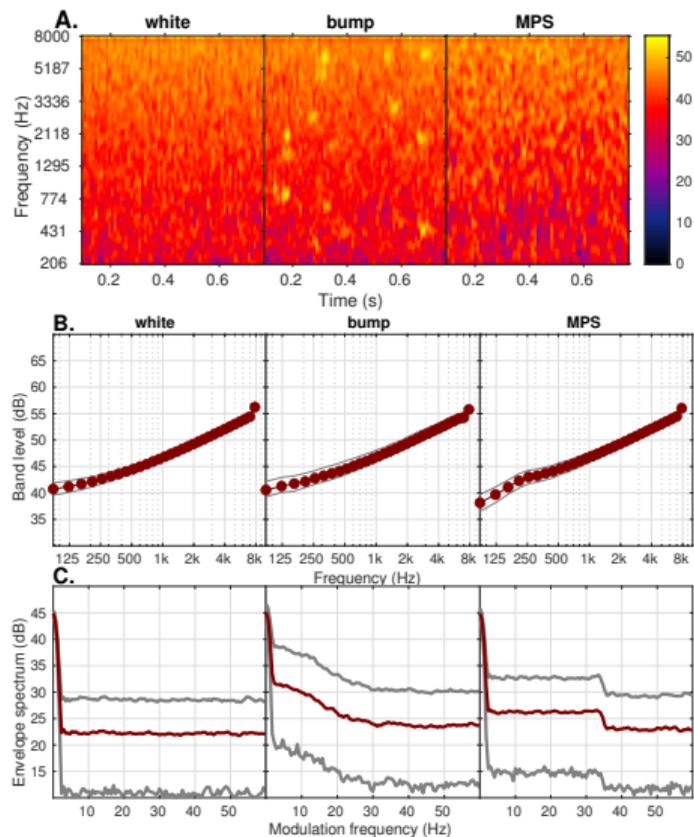
Auditory revcorr:  
technical details

Internal representation

Conceptual plurality

Conclusion

# Aba/Ada experiment [Osses & Varnet, 2023]



Three different types of noise:

- white noise
- bump noise (white noise with spectrotemporal regions of enhanced energy, randomly distributed)
- MPS noise (white noise low-pass filtered in the modulation domain)

Each participant performs 4.000 categorizations in each of the 3 noise conditions (12.000 trials  $\approx$  4h30)

Choose your own  
adventure

Géraldine Carranante,  
Léo Varnet

[Introduction](#)

[Auditory revcorr: a  
review](#)

[Decoding speech](#)

[L'amie/La mie  
experiment](#)

[Gender-fair language](#)

[Aba/ada experiment](#)

[Stop consonants  
experiment](#)

[Diversity](#)

[fastACI toolbox](#)

[Auditory revcorr:  
technical details](#)

[Internal representation](#)

[Conceptual plurality](#)

[Conclusion](#)

# Fitting procedure

Choose your own  
adventure

Géraldine Carranante,  
Léo Varnet

[Introduction](#)

[Auditory revcorr: a  
review](#)

[Decoding speech](#)

[L'amie/La mie  
experiment](#)

[Gender-fair language](#)

[Aba/ada experiment](#)

[Stop consonants  
experiment](#)

[Diversity](#)

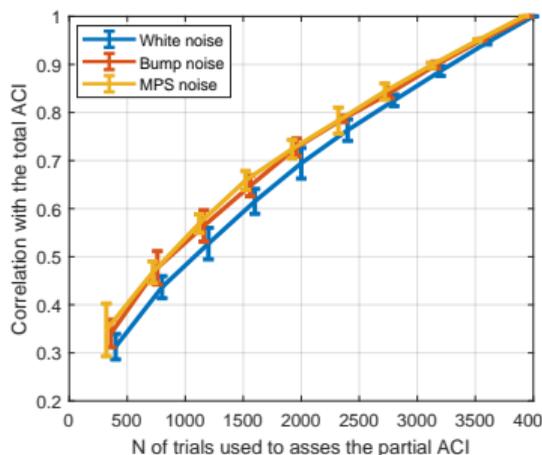
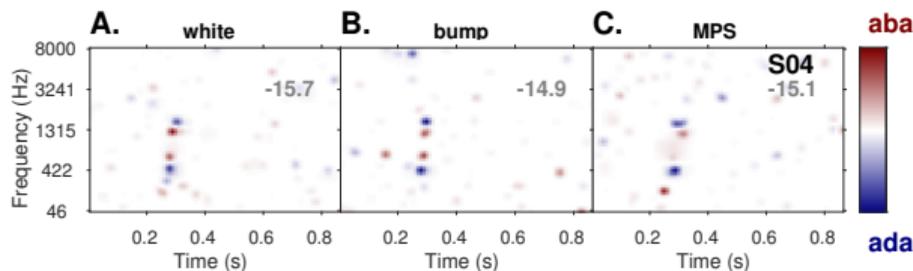
[fastACI toolbox](#)

[Auditory revcorr:  
technical details](#)

[Internal representation](#)

[Conceptual plurality](#)

[Conclusion](#)



Effects of type of noise:

- The final images are similar overall, with some minor differences
- The two types of noises with enhanced envelope fluctuation converge more rapidly

→ Towards an adaptive bump noise?

# Fitting procedure

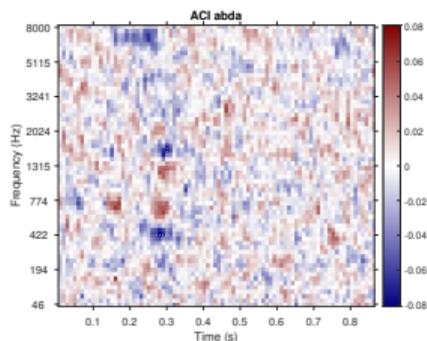
Choose your own  
adventure

Géraldine Carranante,  
Léo Varnet

Comparing 3 different fitting procedures on the same set of data (4.000 trials in the bump noise condition).

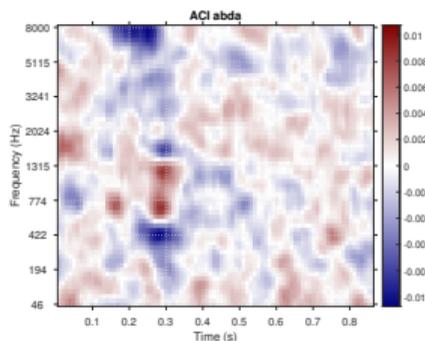
## Simple correlation

[Ahumada, 1996]



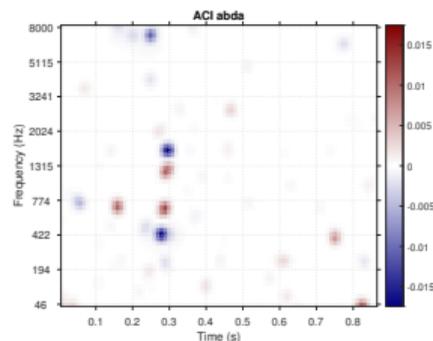
## GLM with L2 penalty

[Varnet et al., 2013]



## GLM with L1 penalty on a Gaussian Pyramid basis

[Osse & Varnet, 2023]



$$P(r_i = \text{"aba"}) = \Phi(\underline{N}_i^T \cdot \underline{ACI} + c) \quad (1)$$

Introduction

Auditory revcorr: a  
review

Decoding speech

L'amie/La mie  
experiment

Gender-fair language

Aba/ada experiment

Stop consonants  
experiment

Diversity

fastACI toolbox

Auditory revcorr:  
technical details

Internal representation

Conceptual plurality

Conclusion

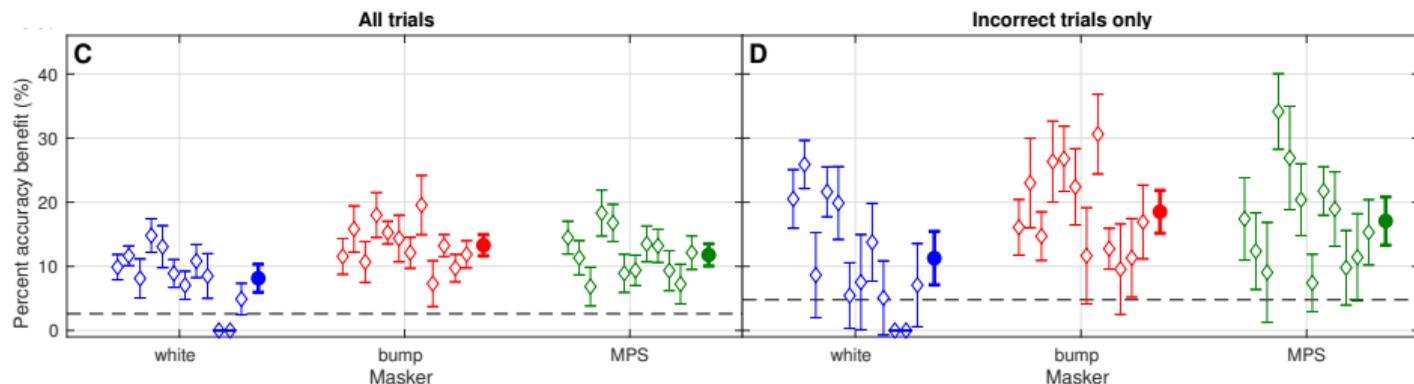
# Fitting procedure

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adventure

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The predictive performance of the model is quite low because the GLM does not include any information about the target sound. The effect of noise fluctuations alone explains  $\approx 8\text{-}12\%$  of the participants' responses

⇒ The estimation of the ACI relies only on a small subset of the data.



Introduction

Auditory revcorr: a  
review

Decoding speech

L'amie/La mie  
experiment

Gender-fair language

Aba/ada experiment

Stop consonants  
experiment

Diversity

fastACI toolbox

Auditory revcorr:  
technical details

Internal representation

Conceptual plurality

Conclusion

# Fitting procedure

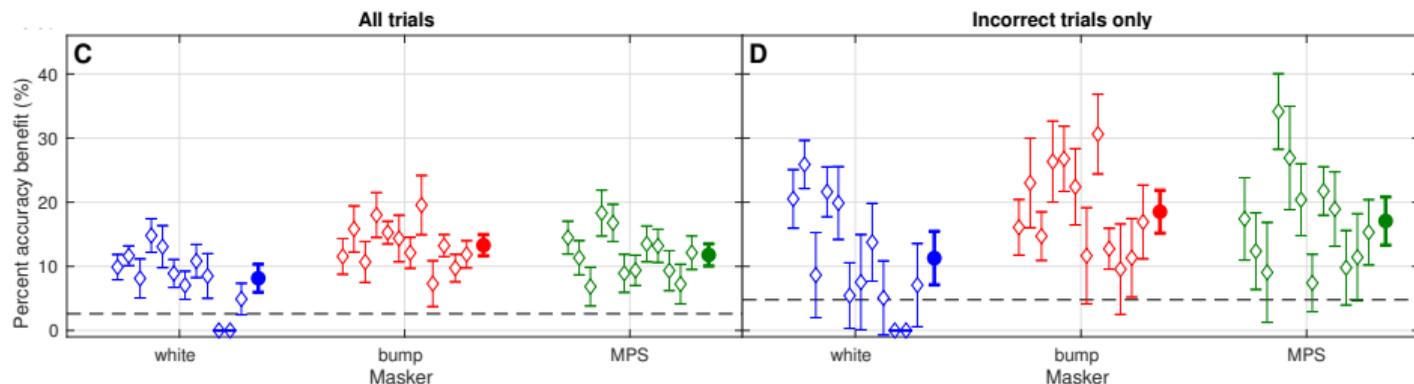
Choose your own  
adventure

Géraldine Carranante,  
Léo Varnet

The predictive performance of the model is quite low because the GLM does not include any information about the target sound. The effect of noise fluctuations alone

## Time to choose

- Ok that's all well and good, but what's the point of this research?
- Yeah I have the same question actually



Introduction

Auditory revcorr: a  
review

Decoding speech

L'amie/La mie  
experiment

Gender-fair language

Aba/ada experiment

Stop consonants  
experiment

Diversity

fastACI toolbox

Auditory revcorr:  
technical details

Internal representation

Conceptual plurality

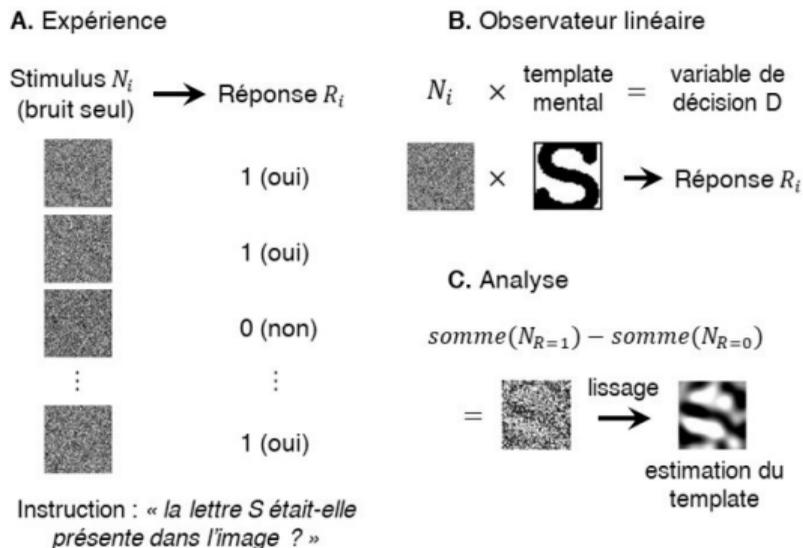
Conclusion





# Defense of structural representations

CI are mostly interpreted via the linear observer model [Murray, 2011, Gosselin et al., 2003]



In this model, the perceptual system uses the *template* to "confront it" to the incoming sensory information in order to detect the signal in it.

The template represents key characteristics of the signal, used for its detection.

















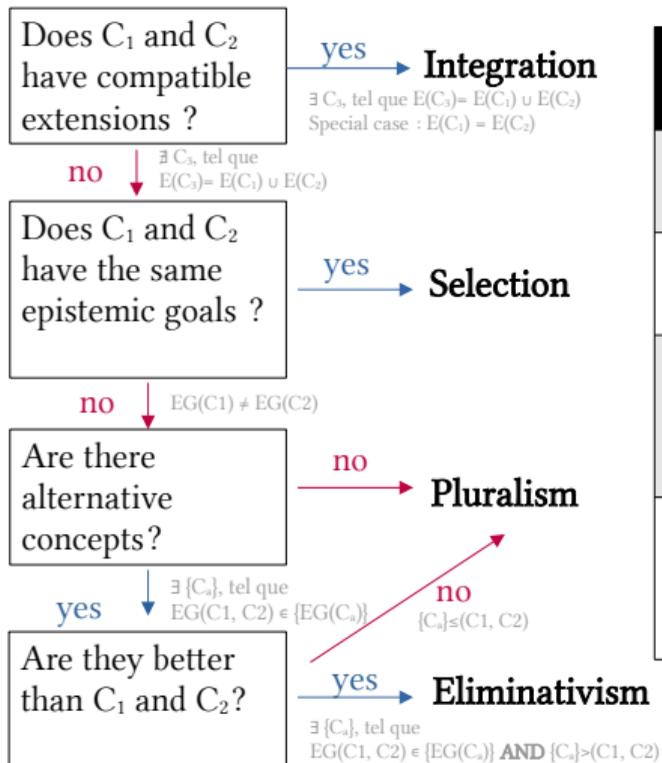




# Decision Tree

For  $C_n$ , well-formed scientific concepts

Initial step :  $I(C_1) \neq I(C_2)$



Solution	Context in which it is the <i>best</i> solution
Integration	<ul style="list-style-type: none"> <li>Compatible extension</li> </ul>
Selection	<ul style="list-style-type: none"> <li>Incompatible extensions</li> <li>Same epistemic goals</li> </ul>
Pluralism	<ul style="list-style-type: none"> <li>Incompatible extensions</li> <li>Different epistemic goals</li> <li>There is no better alternative concept</li> </ul>
Eliminativism	<ul style="list-style-type: none"> <li>Different extension</li> <li>Different epistemic goal</li> <li>There are better alternative concepts</li> </ul>

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Géraldine Carranante,  
Léo Varnet

Introduction

Auditory revcorr: a review

Decoding speech

L'amie/La mie experiment

Gender-fair language

Aba/ada experiment

Stop consonants experiment

Diversity

fastACI toolbox

Auditory revcorr: technical details

Internal representation

Conceptual plurality

Conclusion



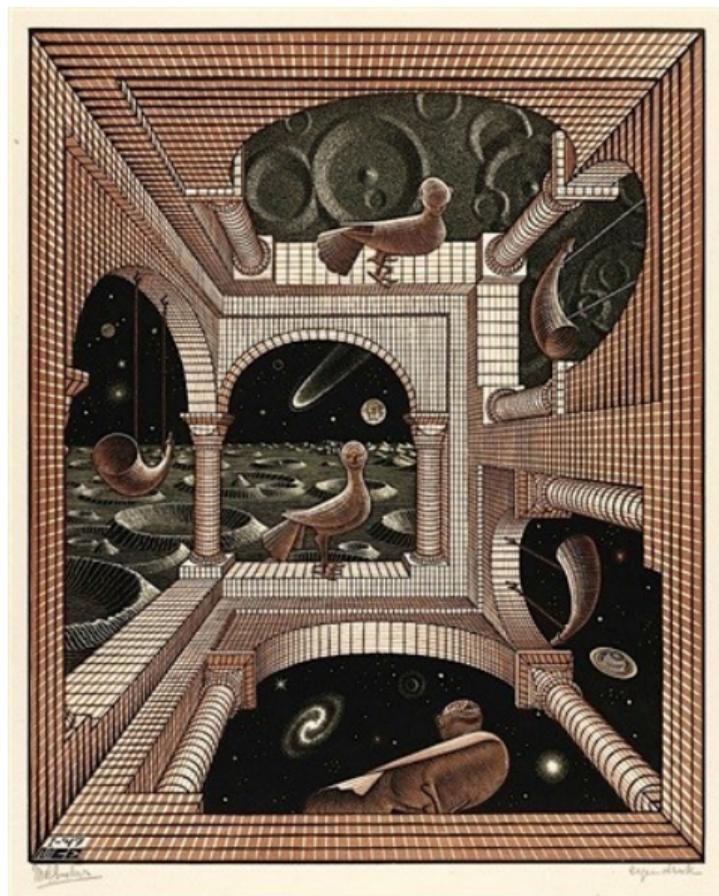


# Conclusion

A fruitful collaboration between psychophysics and philosophy.

A philosophy of science “in the lab”

A psychophysical approach with a special care for the definition of concepts.



Choose your own  
adventure

Géraldine Carranante,  
Léo Varnet

Introduction

Auditory revcorr: a  
review

Decoding speech

L'amie/La mie  
experiment

Gender-fair language

Aba/ada experiment

Stop consonants  
experiment

Diversity

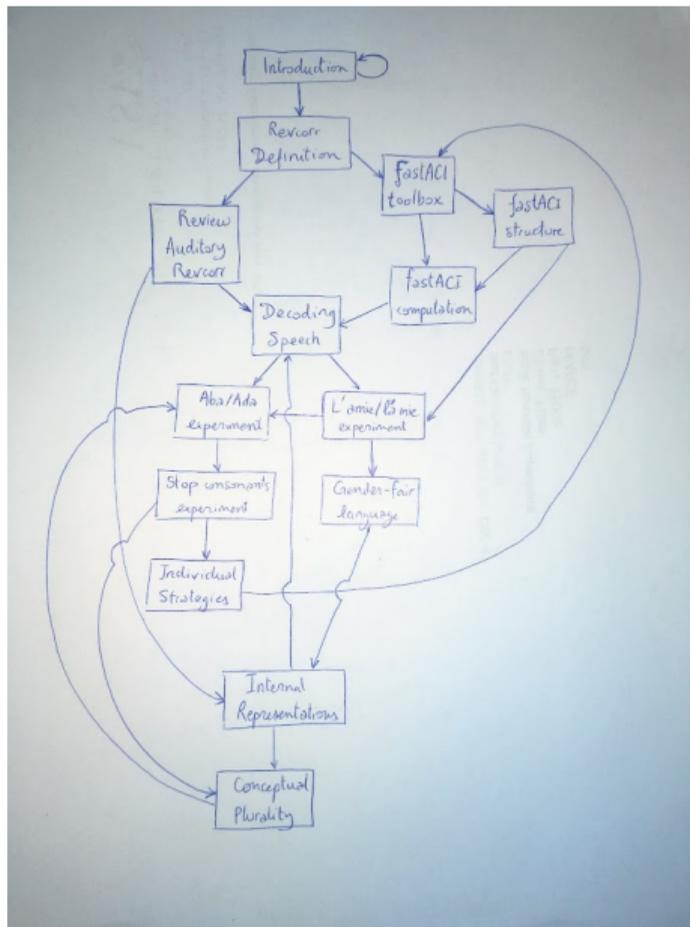
fastACI toolbox

Auditory revcorr:  
technical details

Internal representation

Conceptual plurality

Conclusion



Choose your own  
adventure

Géraldine Carranante,  
Léo Varnet

Introduction

Auditory revcorr: a  
review

Decoding speech

L'amie/La mie  
experiment

Gender-fair language

Aba/ada experiment

Stop consonants  
experiment

Diversity

fastACI toolbox

Auditory revcorr:  
technical details

Internal representation

Conceptual plurality

Conclusion

# Thanks for your attention!



Léo Varnet, Géraldine Carranante, Alejandro Osses



Fanny Meunier, Étienne Gaudrain, Elsa Spinelli, Maria Giavazzi

Choose your own  
adventure

Géraldine Carranante,  
Léo Varnet

Introduction

Auditory revcorr: a  
review

Decoding speech

L'amie/La mie  
experiment

Gender-fair language

Aba/ada experiment

Stop consonants  
experiment

Diversity

fastACI toolbox

Auditory revcorr:  
technical details

Internal representation

Conceptual plurality

Conclusion