BLANKE LAB CHAIR IN COGNITIVE NEUROPROSTHETICS

EPFL

Voices and robots: Simulating auditory-verbal hallucinations (AVH) through robotically-induced self-other voice confusion

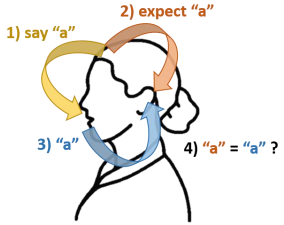
Pavo Orepić, SPRiG seminar, 27.04.2022

Pavo Orepić

PhD

EPFL

OLAF
BLANKE



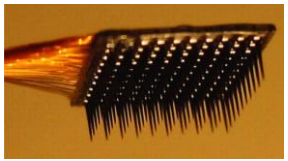
Robotically-induced hallucinations
Self-other voice discrimination

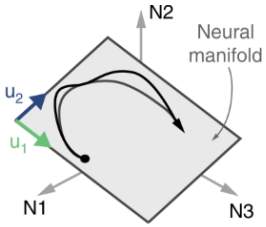
Postdoc

UNIVERSITÉ DE GENÈVE

TIMOTHÉE
PROIX

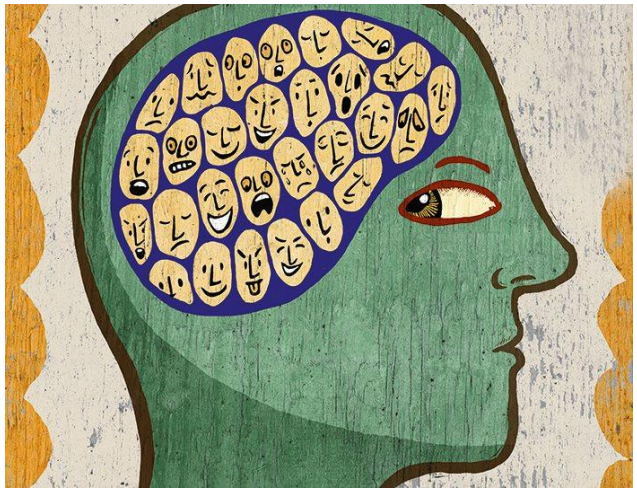
ANNE-LISE
GIRAUD





iEEG for (inner) speech
Dynamical systems

Auditory-verbal hallucinations (AVH)



- *"hearing voices"*
- *>70% of people suffering from schizophrenia*
- *Highly distressing*

Bauer et al., 2011; Kelleher et al., 2012

Motivation

Auditory verbal hallucinations (AVH) are thought to arise as a misattribution of internal self-voice towards other agents.

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Outline

Part I: Self-voice perception

Part II: Robotically-induced self-voice misperceptions

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- Study 1: Behavioral aspects
- Study 2: Neural underpinnings

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- Study 3: Robotic sensorimotor stimulation alters self-voice perception
- Study 4: …which is dependent on breathing
- Study 5: Inducing AVH in healthy individuals

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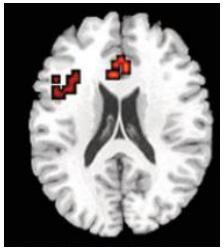
Self-voice perception

Self-voice is understudied

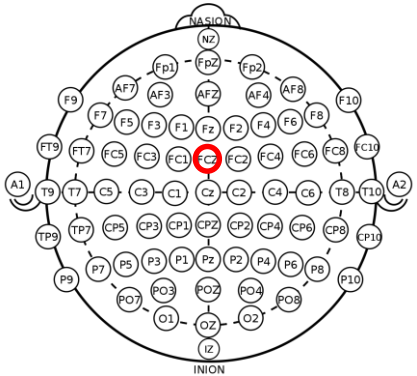
- (only) 3 imaging studies
- Self-voice activations
  - Right & left inferior frontal sulcus / gyrus
  - Right parainsular cortex
  - Right anterior cingulate gyrus

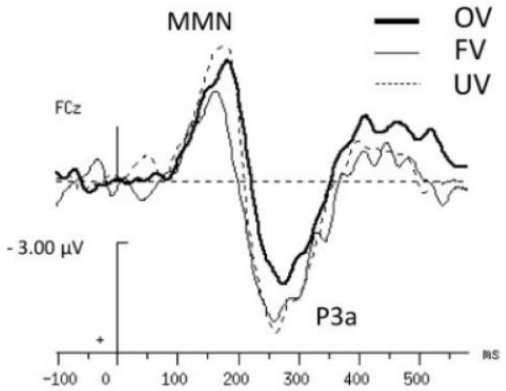


Allen et al., 2005; Kaplan et al., 2008; Nakamura et al., 2001

Self-voice: EEG

- Confined to oddball paradigms & single-electrode analysis
- Lower/higher P3 component on fronto-central sites



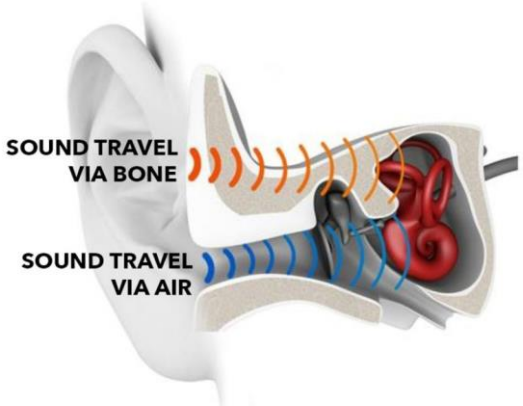


Conde et al., 2015, 2016, 2018; Graux et al., 2013, 2015; Liu et al., 2019

Difficulties in self-voice research

- *"I don't sound like that"*
- *Unpleasantness*
- *More accuracy with other voices*

Lack of bone conduction



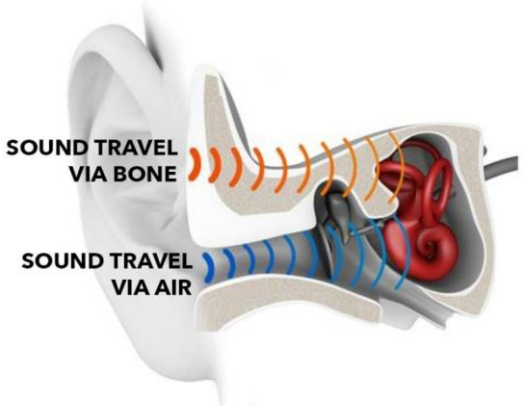
Audition + *Vibrotactile excitation*

Audition

Image by Headphonesty.

Lack of bone conduction

1. Physical transformation of the sound of our voice
2. Multisensory excitation



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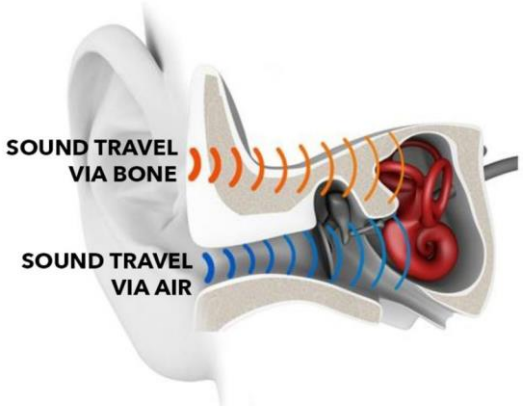

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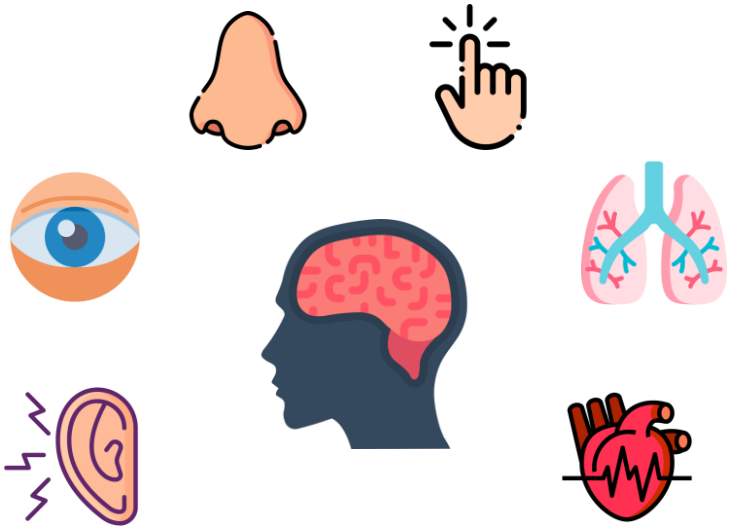
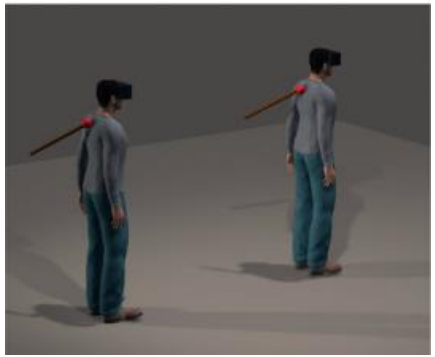
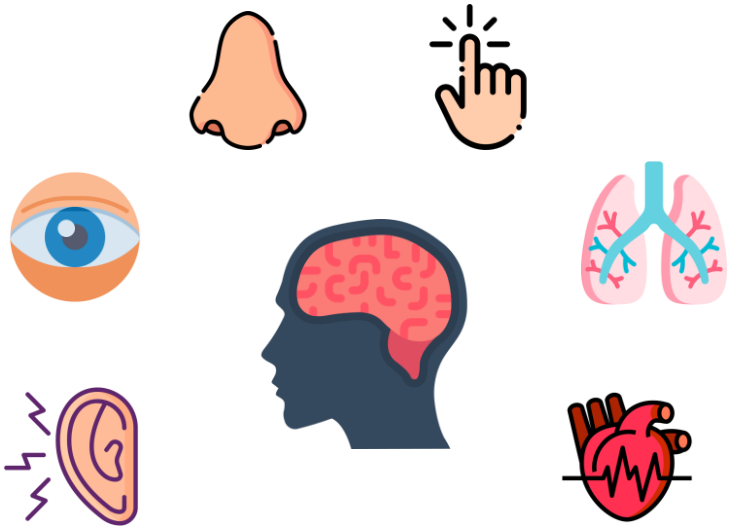
The multisensory self



Blanke et al., 2104, 2015; Icons by Schappelle, FlatIcon, Freepik, and Phatplus

The multisensory self





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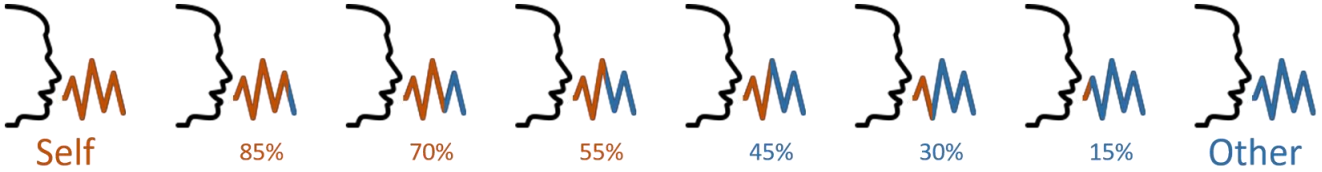
Bone conduction headset

SOVD task



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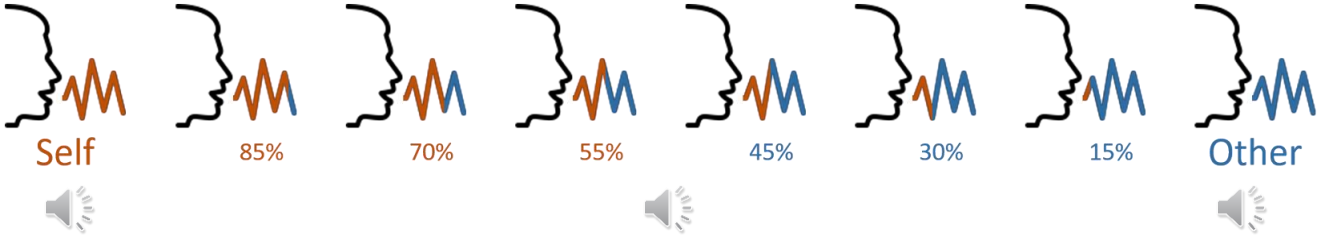

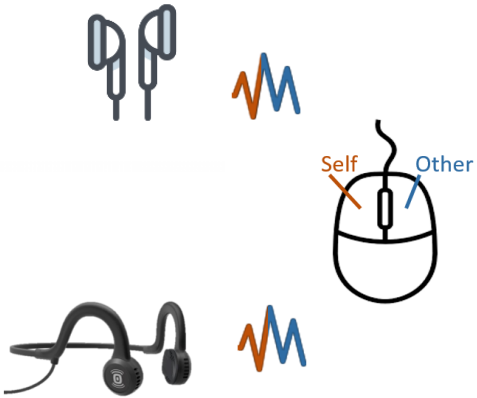

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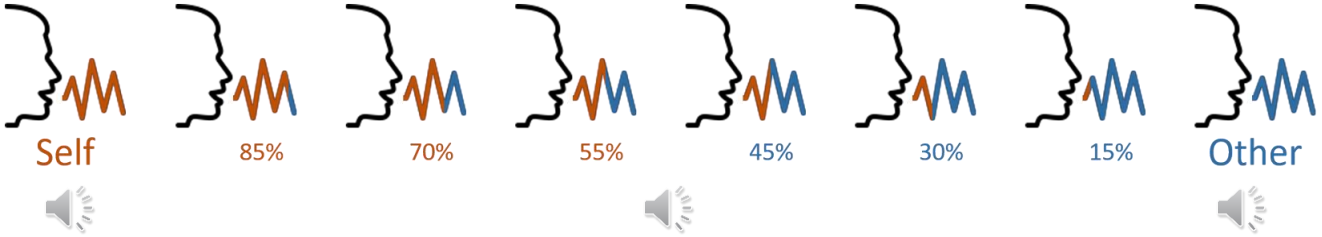
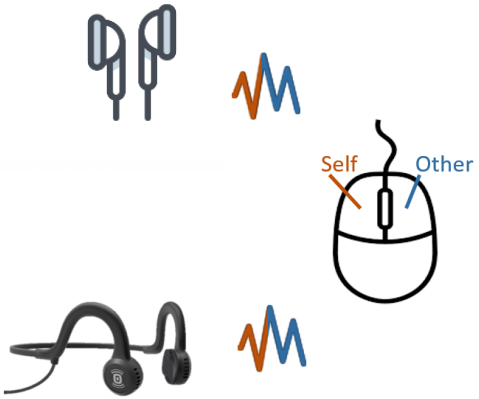
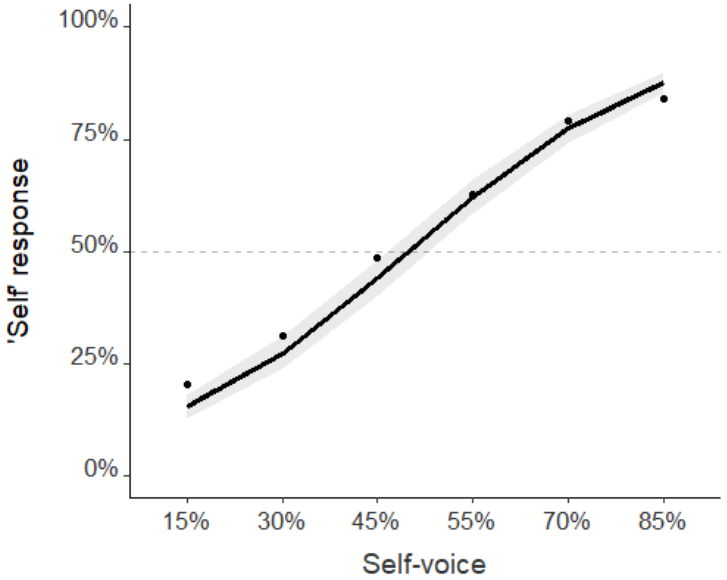
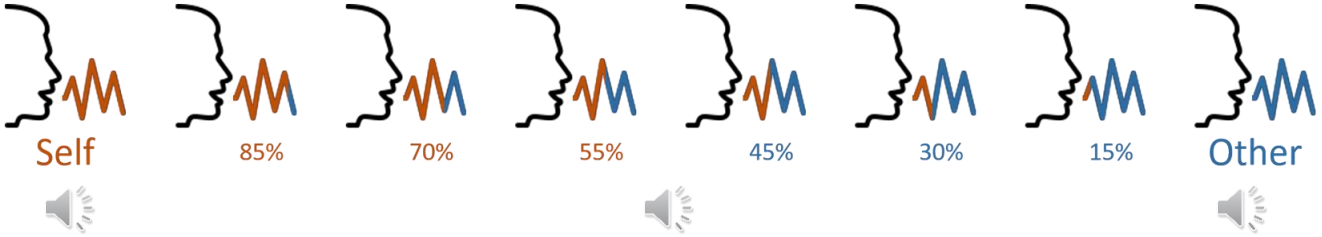

Self
85%
70%
55%
45%
30%
15%
Other


Self
Other


100%
75%
50%
25%
0%
'Self' response
15%
30%
45%
55%
70%
85%
Self-voice

SOVD task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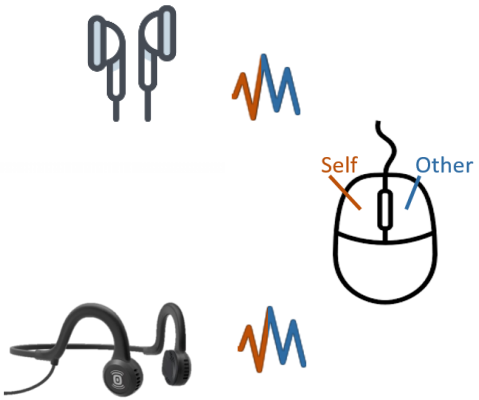
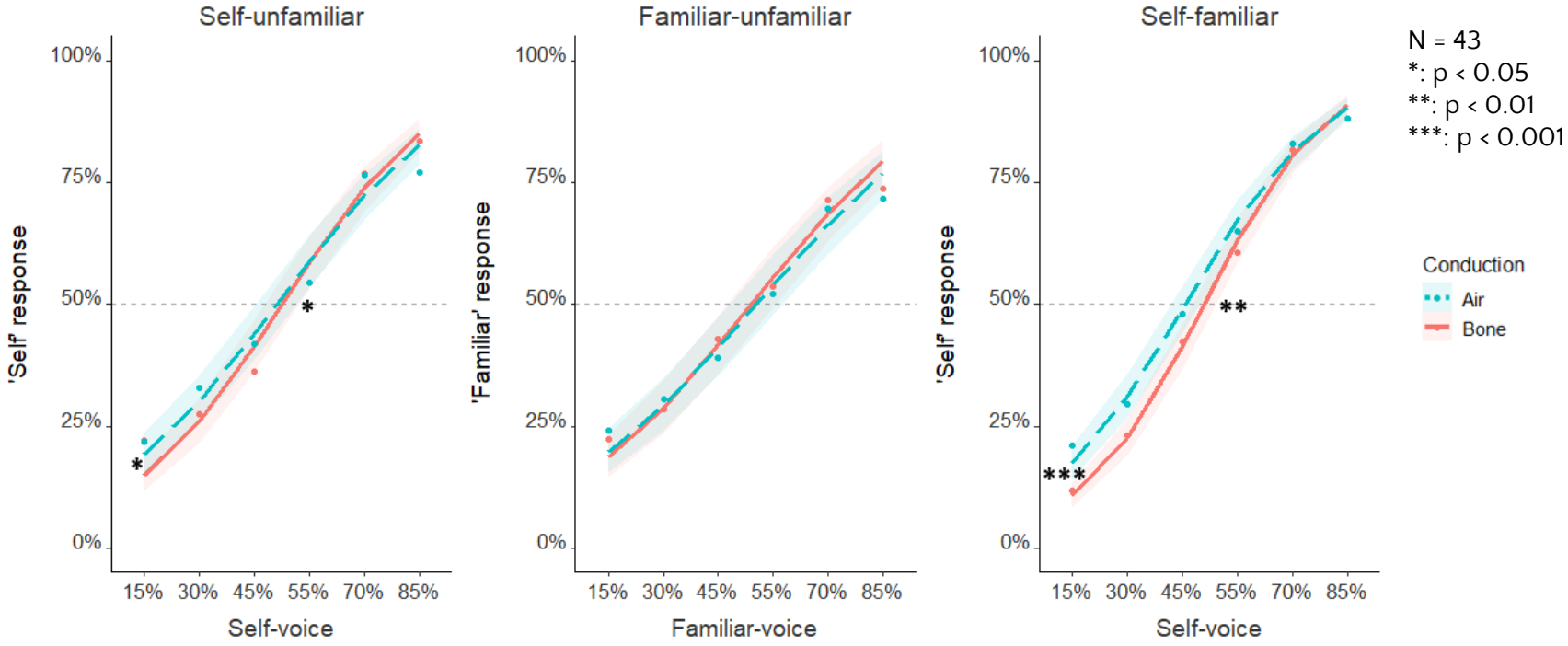

Self
Other

Bone conduction
100%
75%
50%
25%
0%
'Self' response
15%
30%
45%
55%
70%
85%
Self-voice

Study 1: Main finding



Bone conduction improves performance in self-related tasks.

Study 1: Summary

- Bone conduction improves self-other voice discrimination
- Self-voice is fundamentally a multimodal construct
  - ...and not "just" an auditory percept
  - ...building up on the multisensory accounts of bodily self-consciousness

Cerebral Cortex, 2021;00: 1–15

https://doi.org/10.1093/cercor/bhab329
Original Article

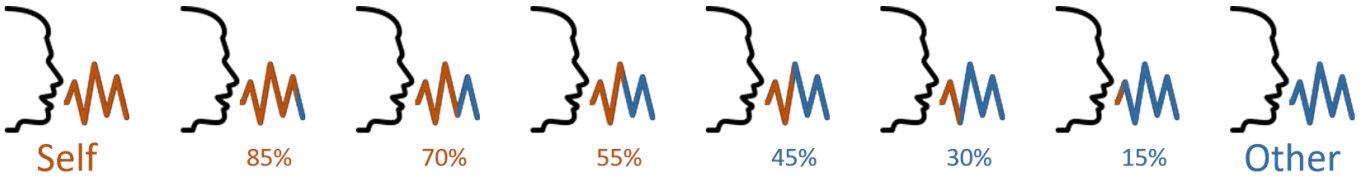
ORIGINAL ARTICLE

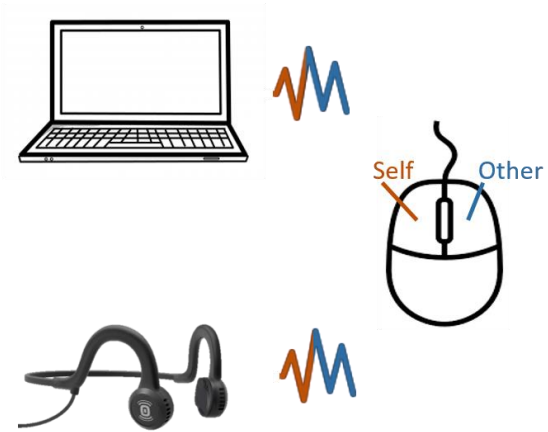
EEG Spatiotemporal Patterns Underlying Self-other Voice Discrimination

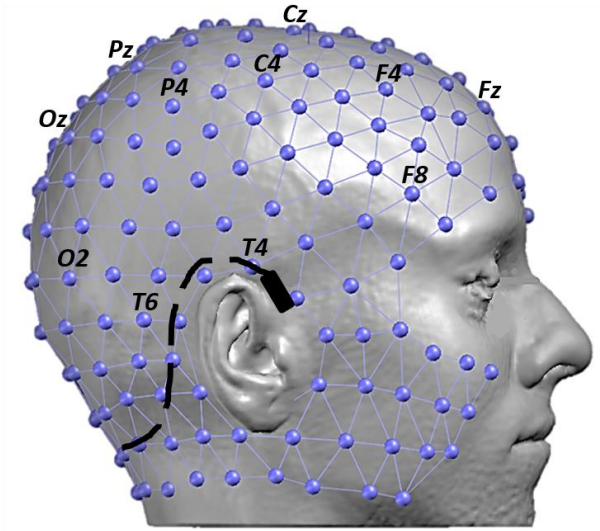
Giannina Rita Iannotti[1,2,†], Pavo Orepic[3,†], Denis Brunet[1,4], Thomas Koenig[5], Sixto Alcoba-Banqueri[3], Dorian F. A. Garin[2], Karl Schaller[2], Olaf Blanke[3] and Christoph M. Michel[1,4]

GIANNINA
RITA
IANNOTTI

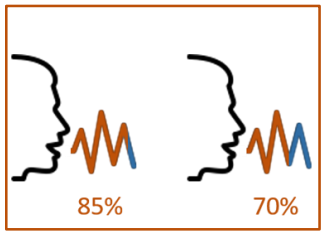
High-density EEG setup



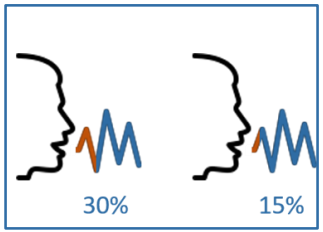




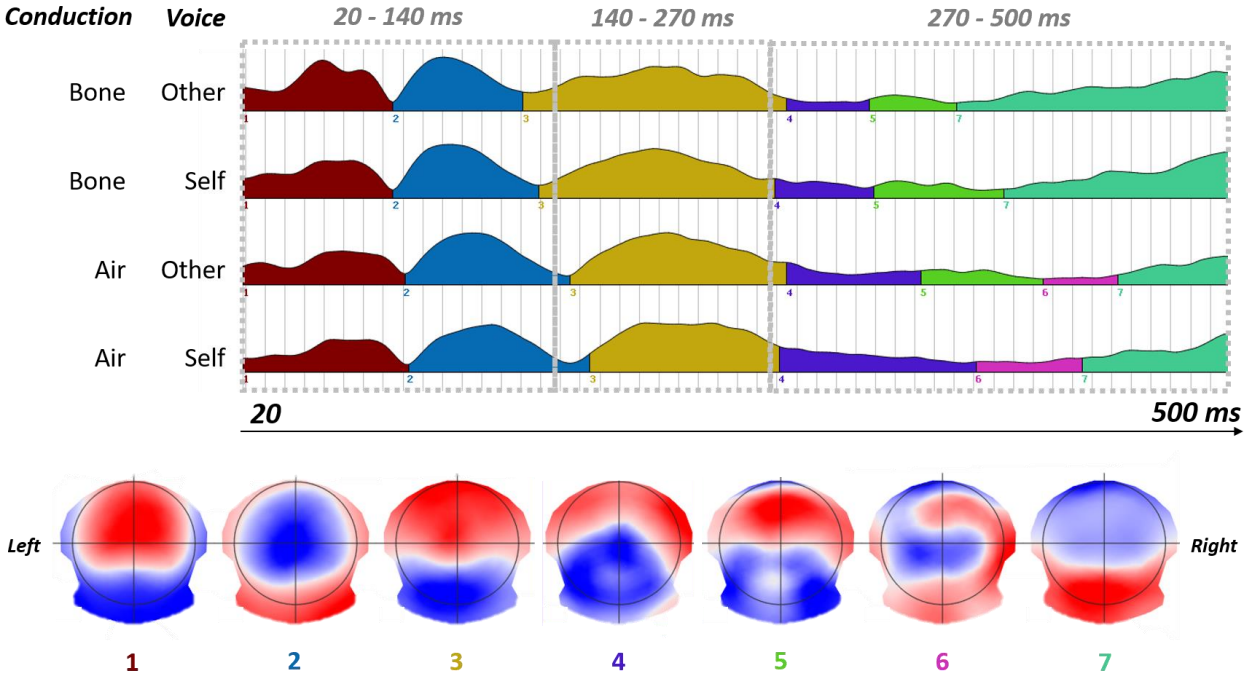
Microstate segmentation



Self



Other



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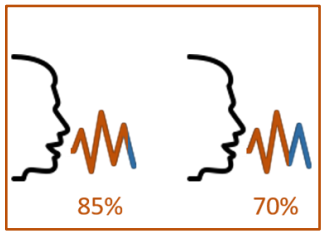

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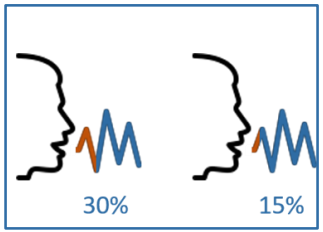

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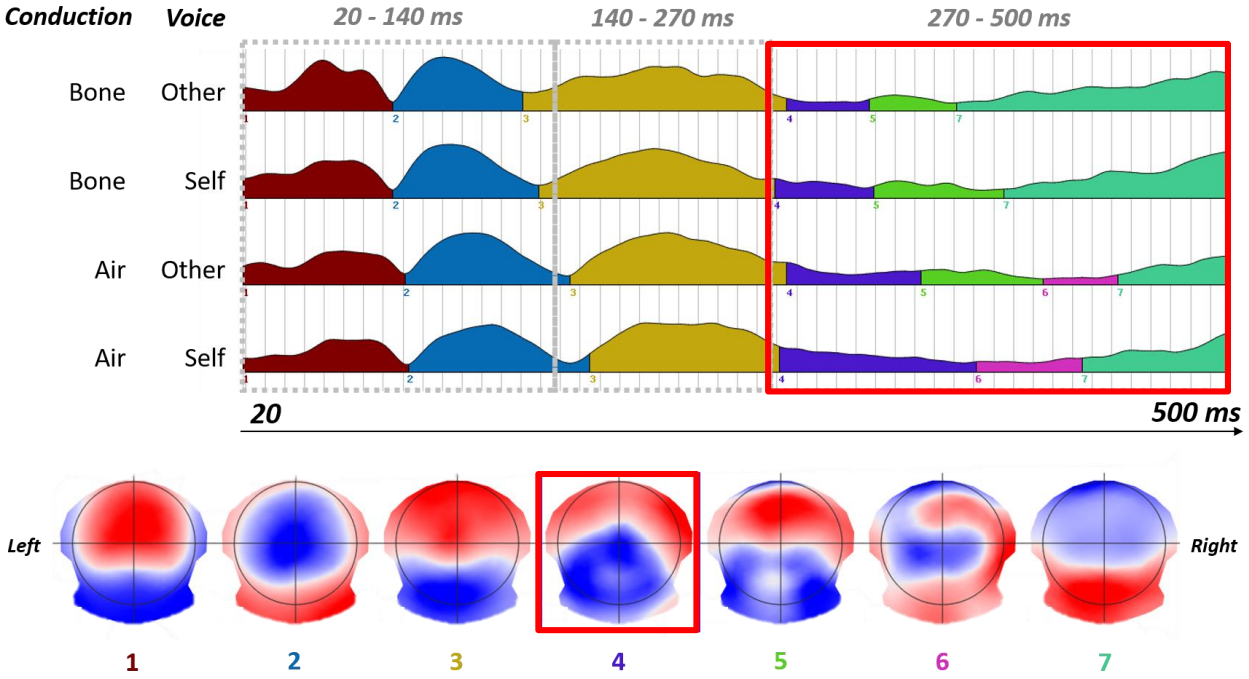
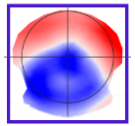


Map 4 occurrence



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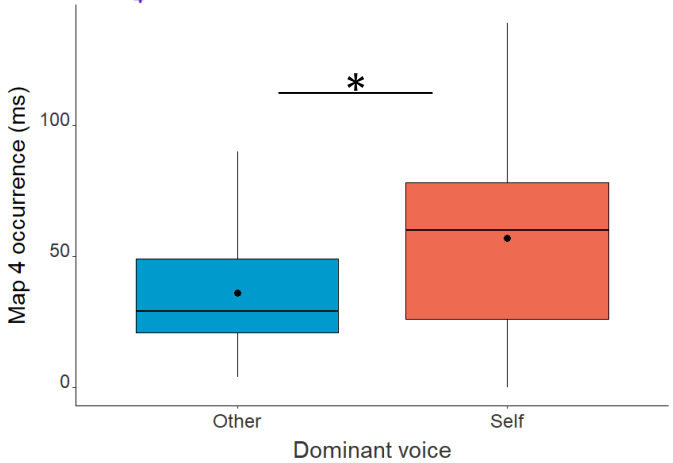
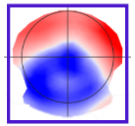


Map 4 occurs more often with self-voice.

Map 4 occurrence



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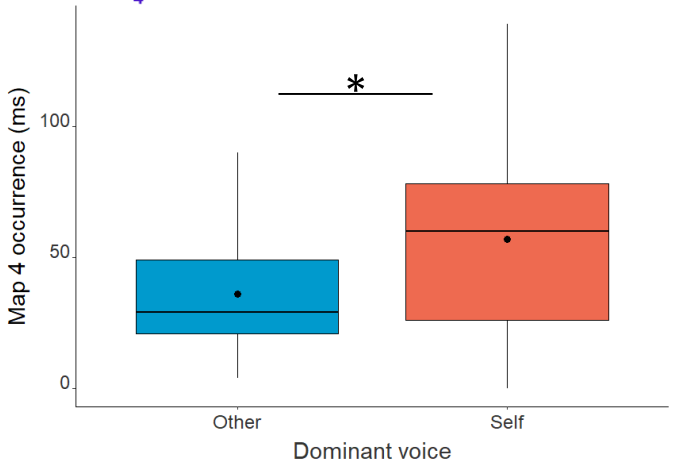
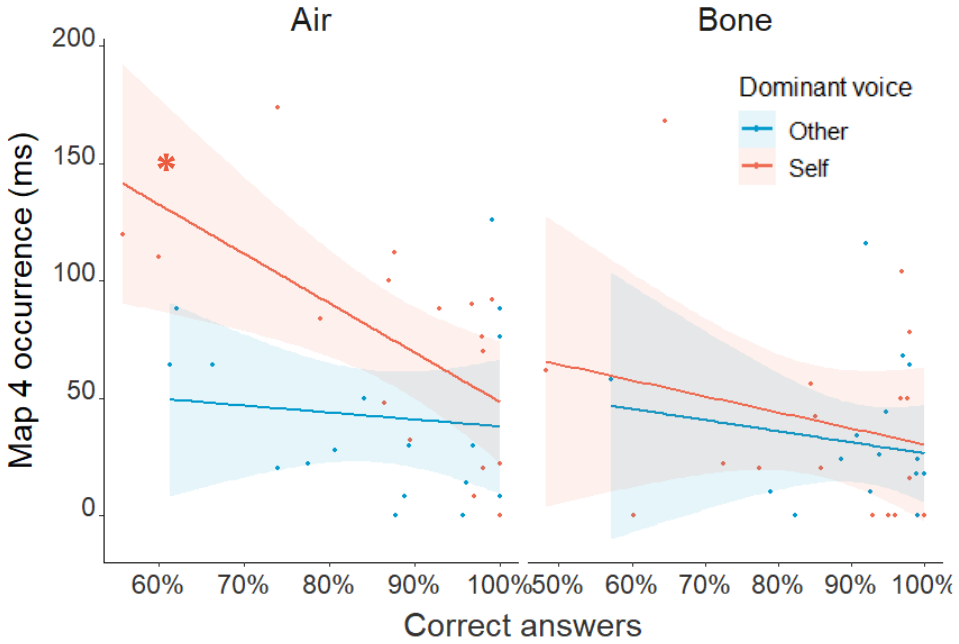
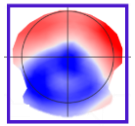
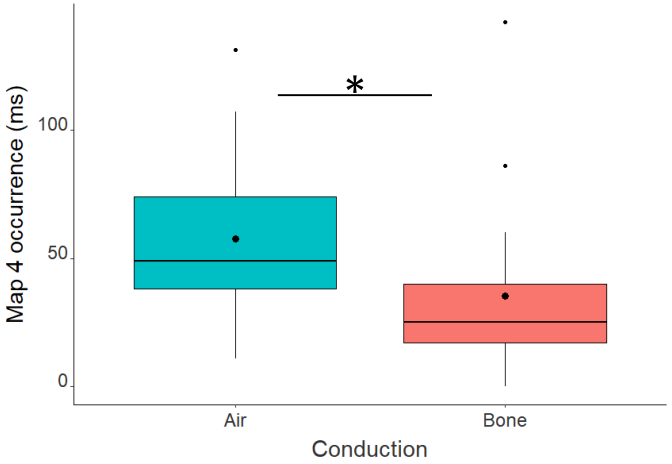


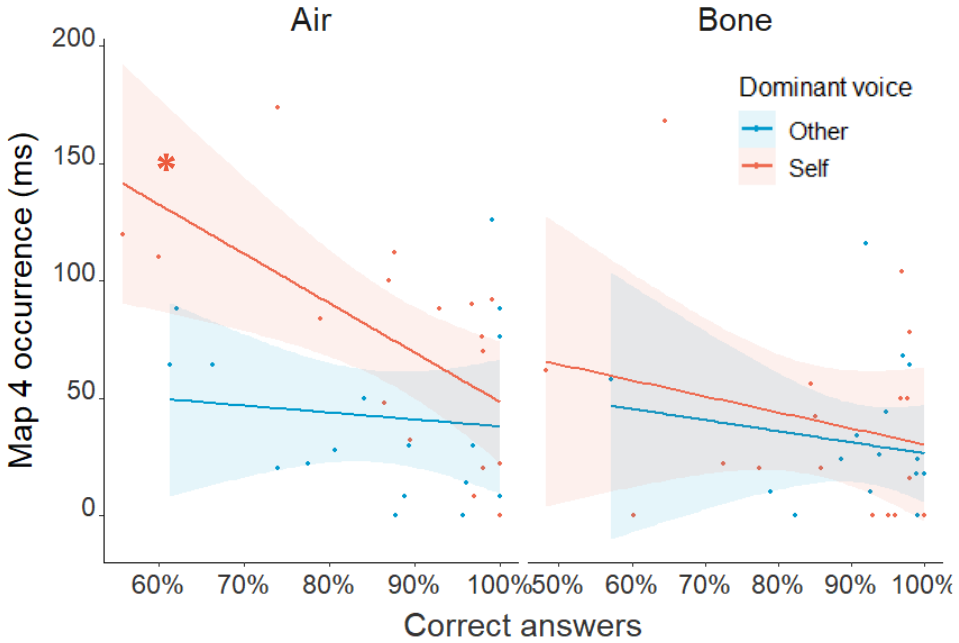


Map 4 as a self-referencing mechanism – comparing heard voice with the internal representation.

Map 4 occurrence

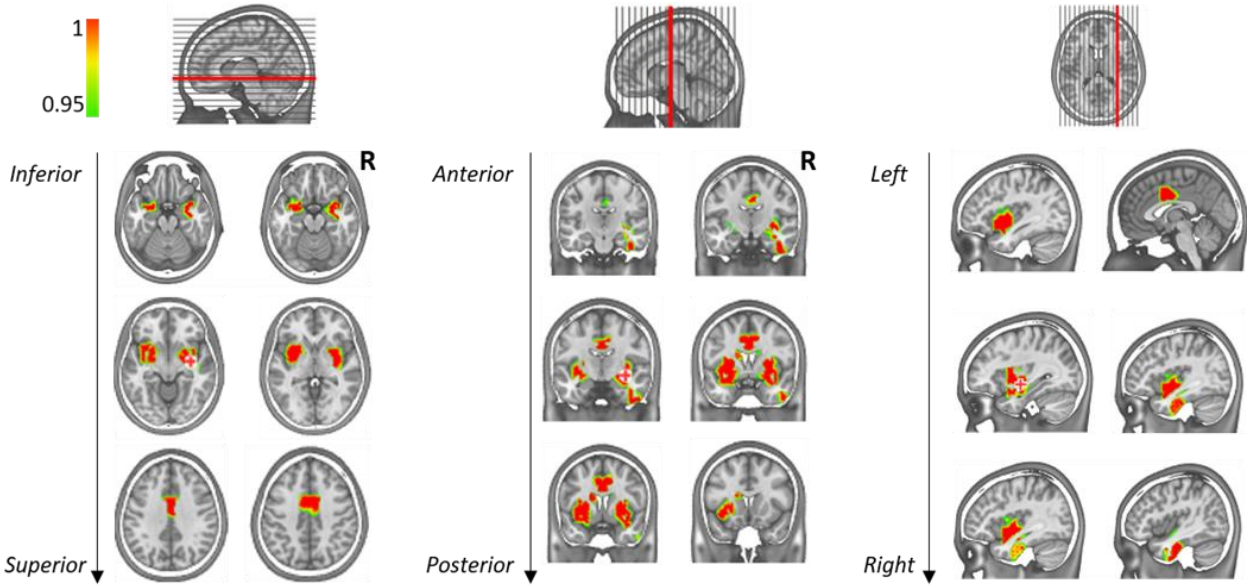






Map 4 occurs more often with air conduction, where task is more difficult.

Map 4 localization

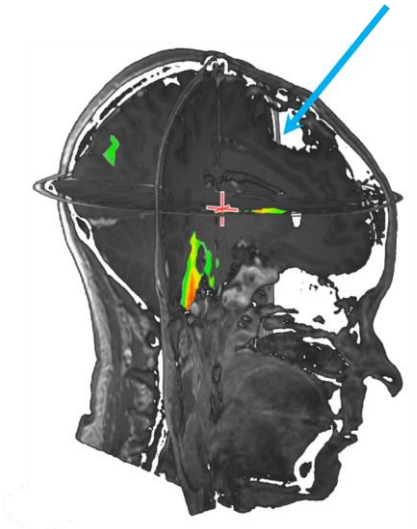


- *R insula*
- *R hippocampus*
- *R & L amygdala*
- *R & L putamen*
- *Middle cingulum*

Maximum of activation of Map 4 is localized in the right insula.

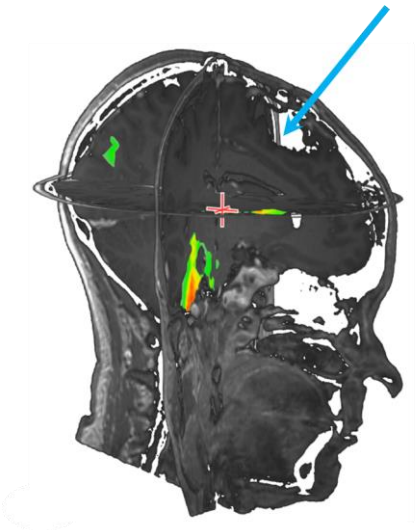
Case report: depersonalization

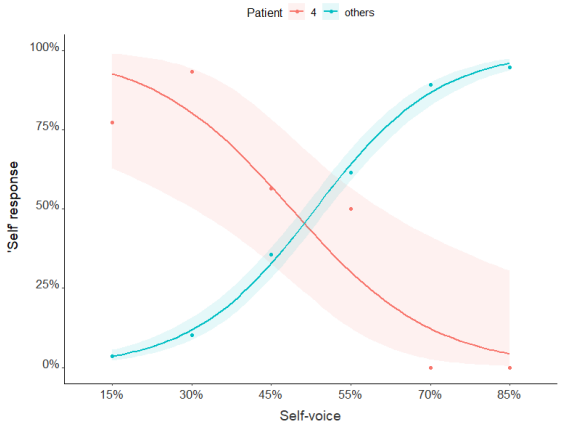
left frontal parasagittal meningioma



Case report: depersonalization

left frontal parasagittal meningioma





Case report: depersonalization

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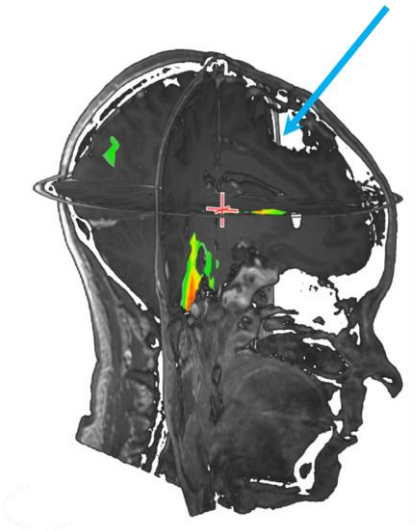
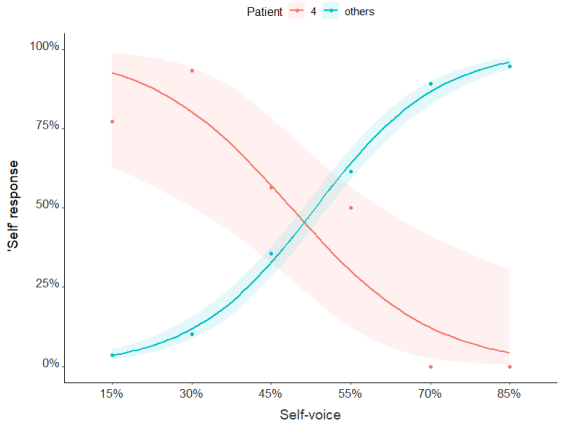
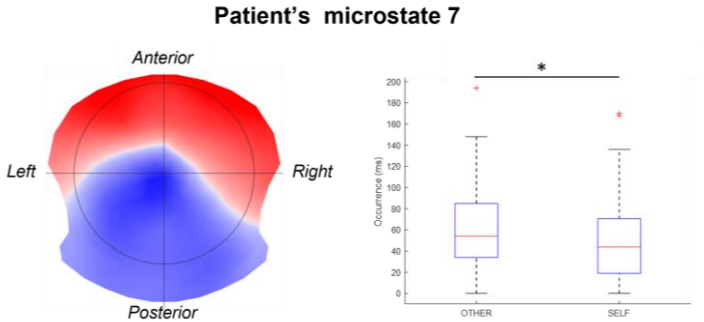


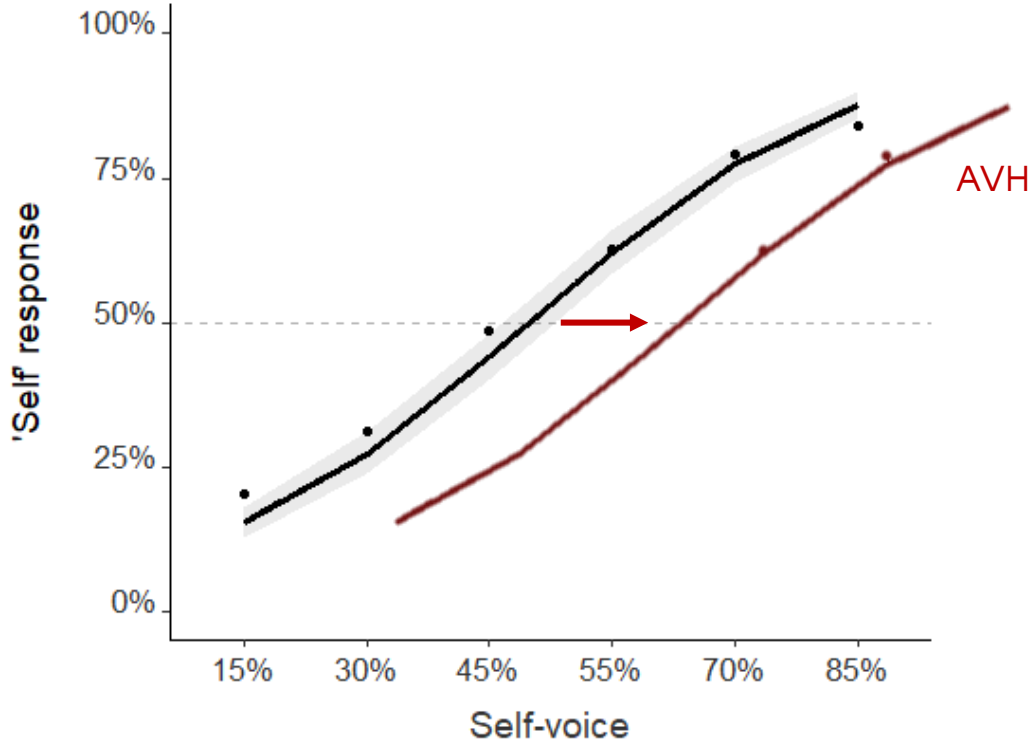


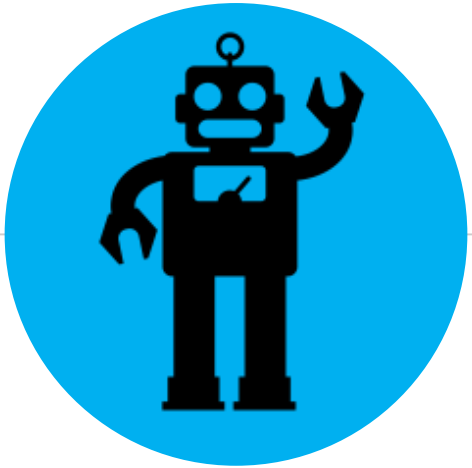


Part 1: Summary

- Self-voice is a multimodal construct
  - Use bone conduction in self-voice studies!
- SOVD EEG pattern
  - ~345 ms post-stimulus
  - maximal activation in the right insula
  - clinical application – reflects post-surgical personality alterations

AVH: bias to hear the **other** voice?





Robotically-induced self-voice misperceptions

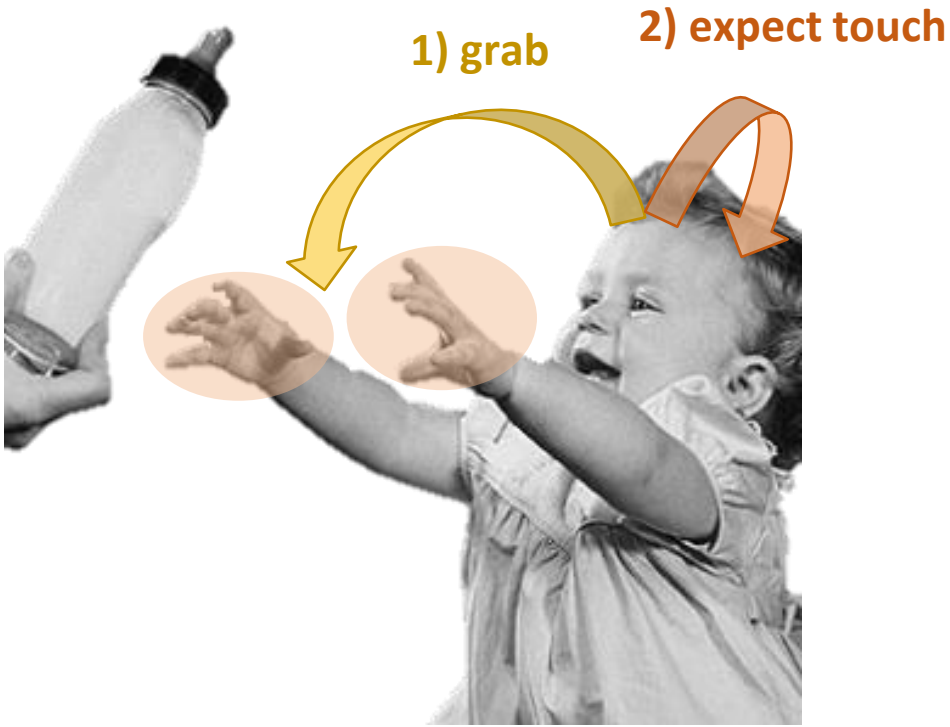
Motivation

*Auditory verbal hallucinations (AVH) are thought to arise as a **misattribution** of internal **self-voice** towards other agents.*

Self-monitoring

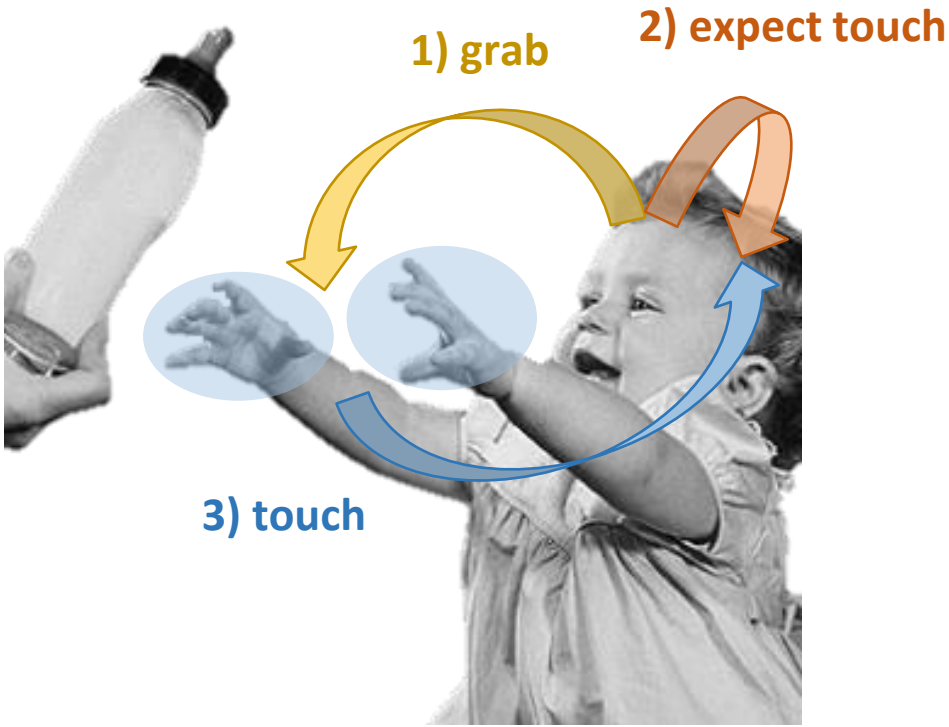
Blakemore et al., 2000; Miall & Wolpert, 1996; Wolpert et al., 1995; Image adapted from Getty Images.

Self-monitoring



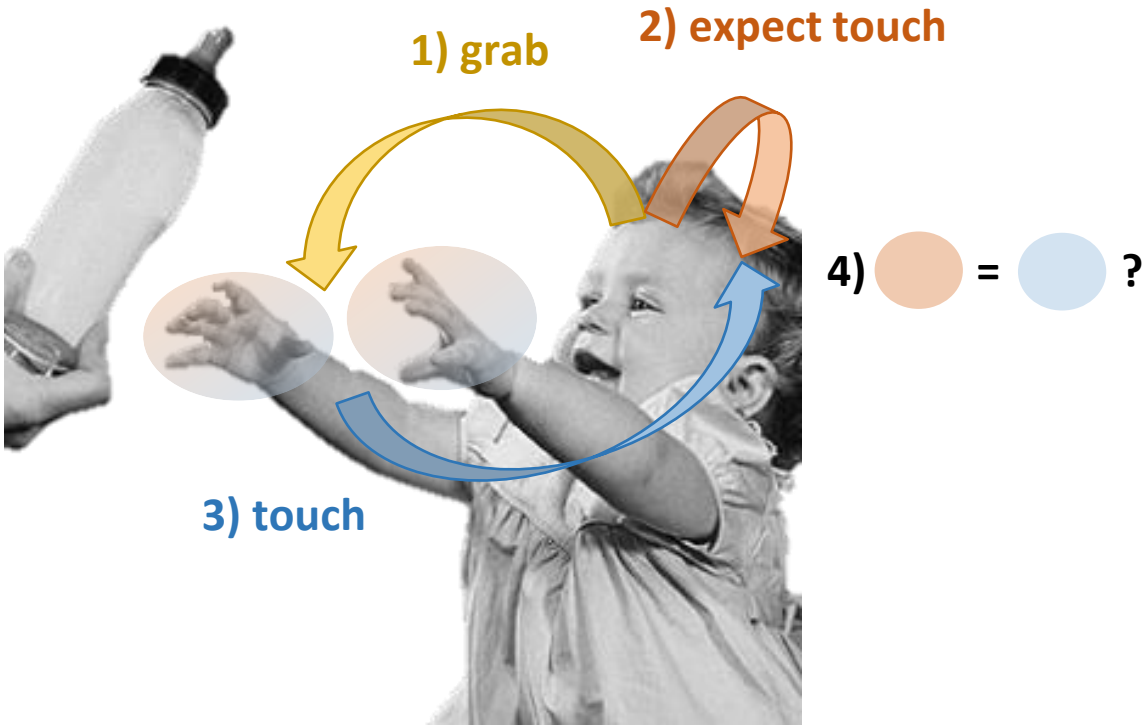
Blakemore et al., 2000; Miall & Wolpert, 1996; Wolpert et al., 1995; Image adapted from Getty Images.

Self-monitoring



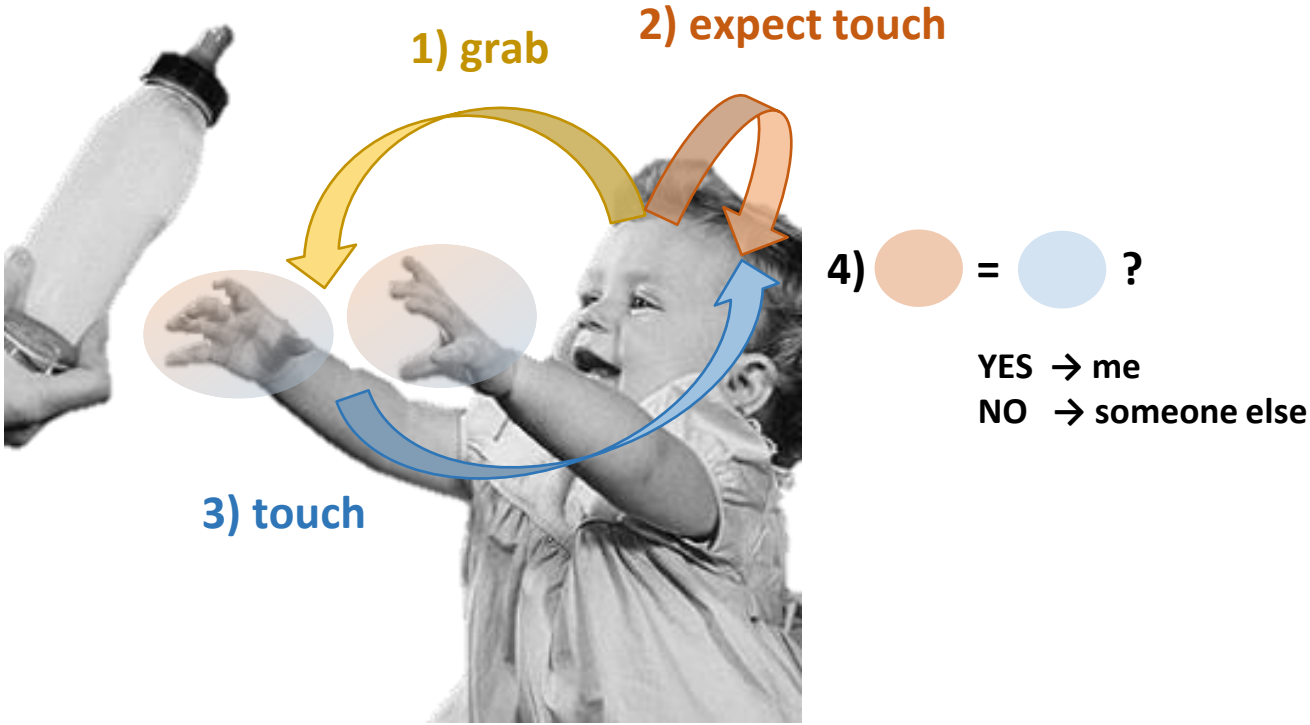
Blakemore et al., 2000; Miall & Wolpert, 1996; Wolpert et al., 1995; Image adapted from Getty Images.

Self-monitoring



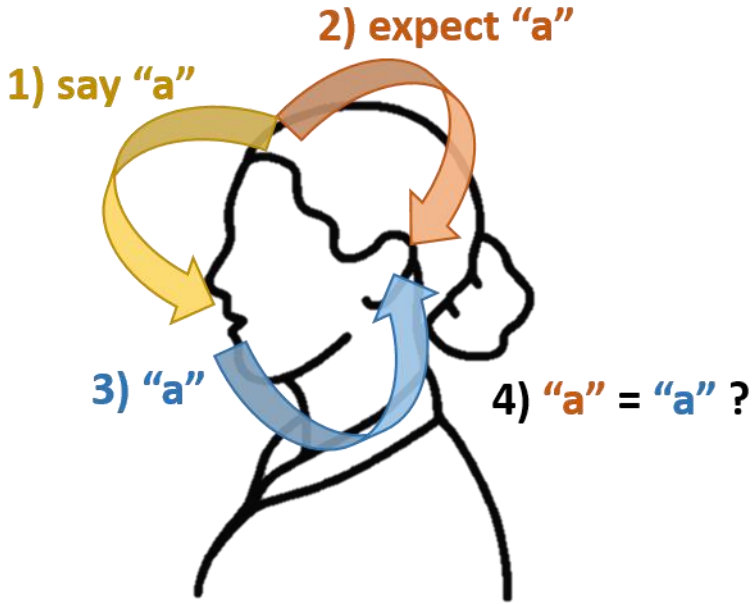
Blakemore et al., 2000; Miall & Wolpert, 1996; Wolpert et al., 1995; Image adapted from Getty Images.

Self-monitoring



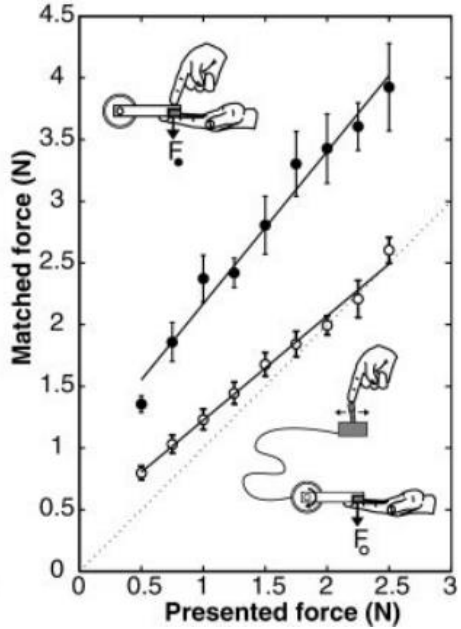
Blakemore et al., 2000; Miall & Wolpert, 1996; Wolpert et al., 1995; Image adapted from Getty Images.

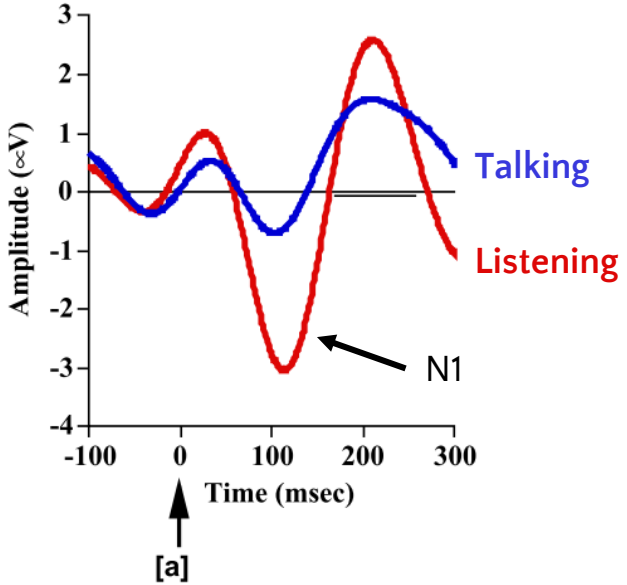
Auditory-verbal self-monitoring



Ford & Mathalon, 2005; Frith, 1992; Moseley, et al., 2013

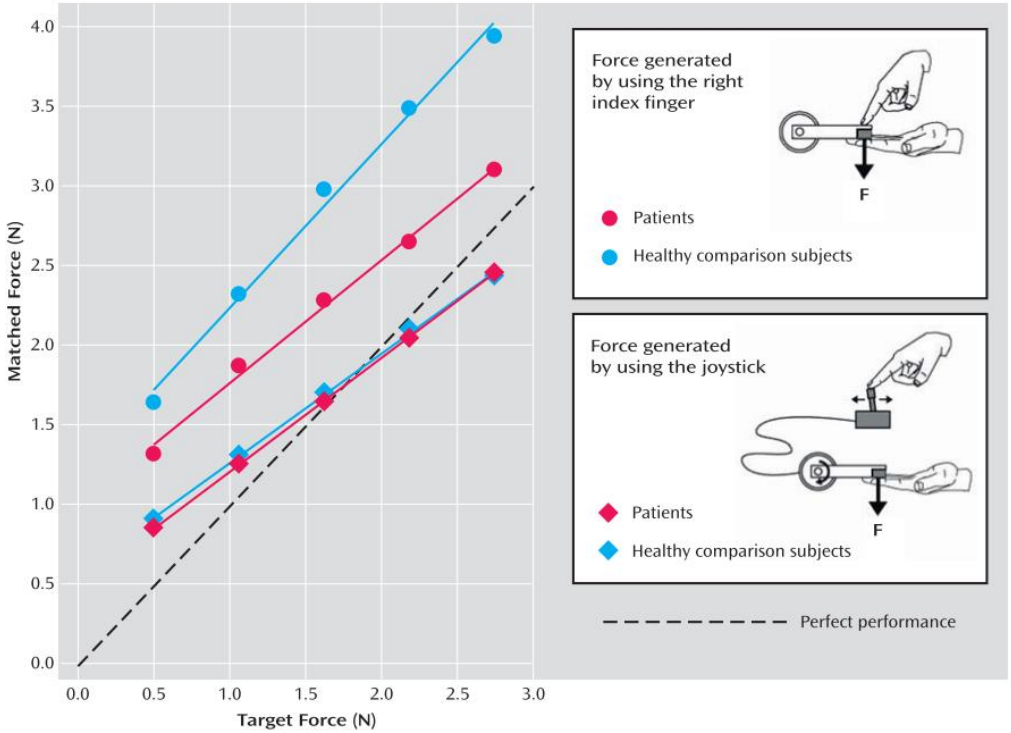
Self-attenuation

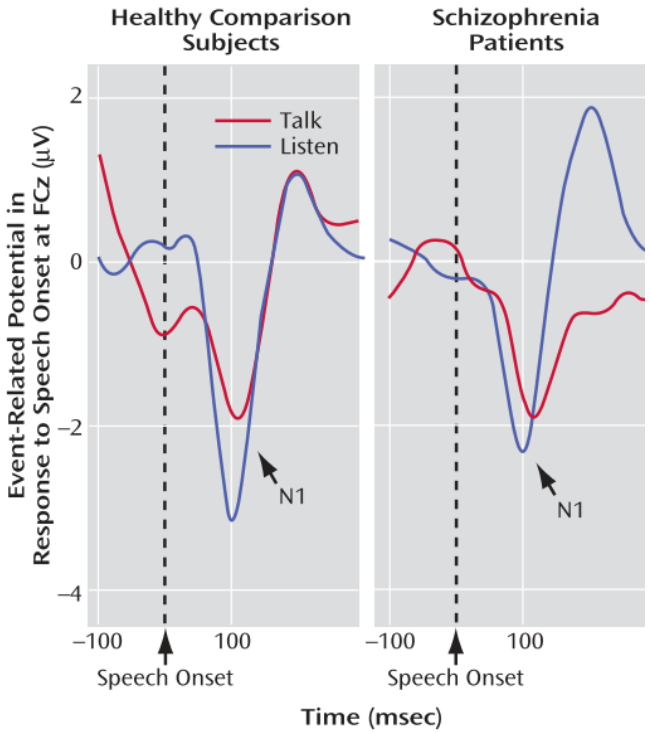




Shergill et al., 2003; Ford & Mathalon, 2005

Schizophrenia: Self-monitoring deficits





Shergill et al., 2005; Ford et al., 2007

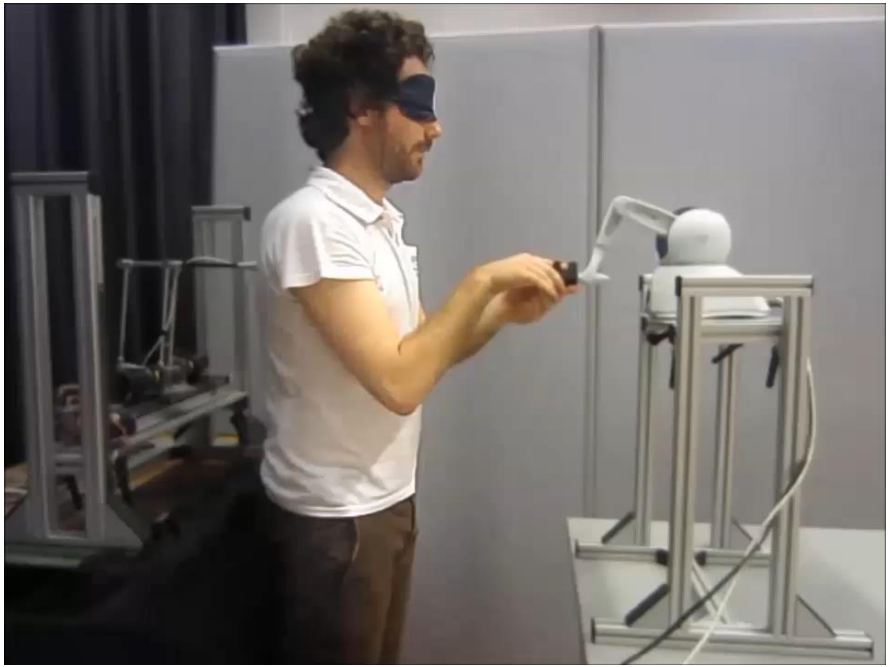
Schizophrenia: Self-monitoring deficits

Passivity sensations

AVH

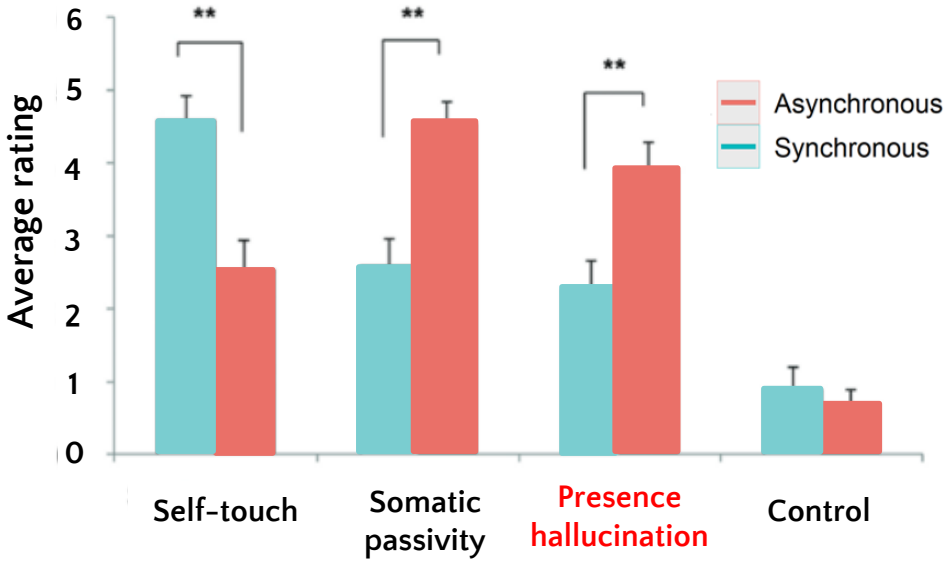
Images by Shutterstock/Dooder.

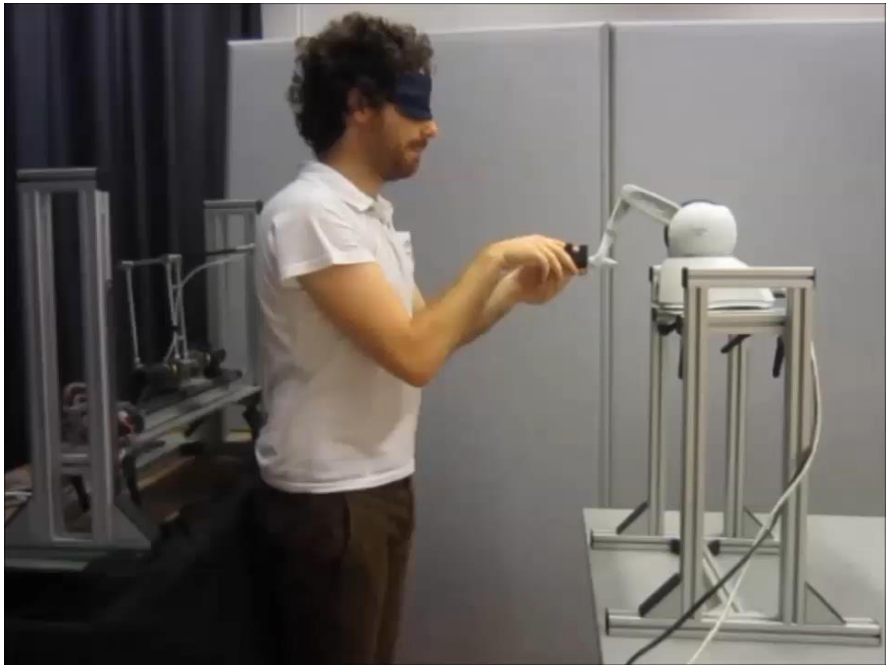
Robotically-mediated sensorimotor stimulation



Blanke et al., 2014

Asynchronous stimulation





Adapted from Blanke et al., 2014

Robotically-induced AVH

Schizophrenia Research 231 (2021) 170–177

Contents lists available at ScienceDirect

Schizophrenia Research

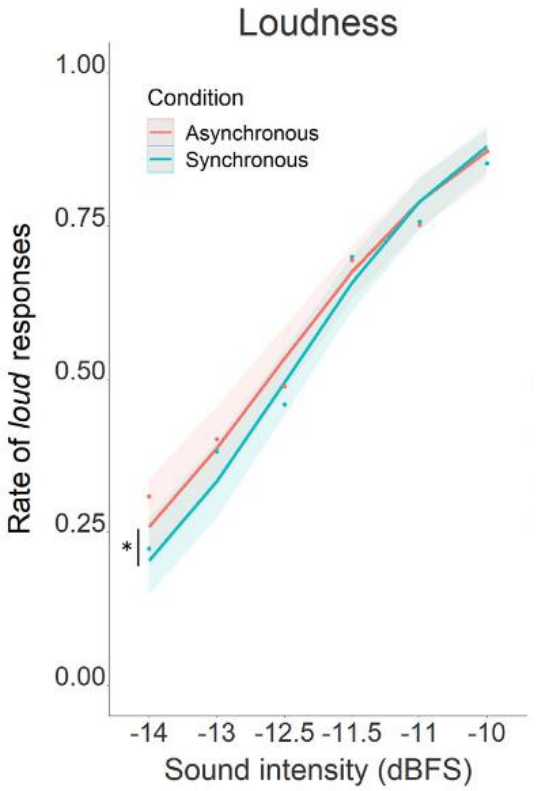
journal homepage: www.elsevier.com/locate/schres

Sensorimotor conflicts induce somatic passivity and louden quiet voices in healthy listeners

Pavo Orepic [a], Giulio Rognini [a], Oliver Alan Kannape [a], Nathan Faivre [b,1], Olaf Blanke [a,c,*,1]

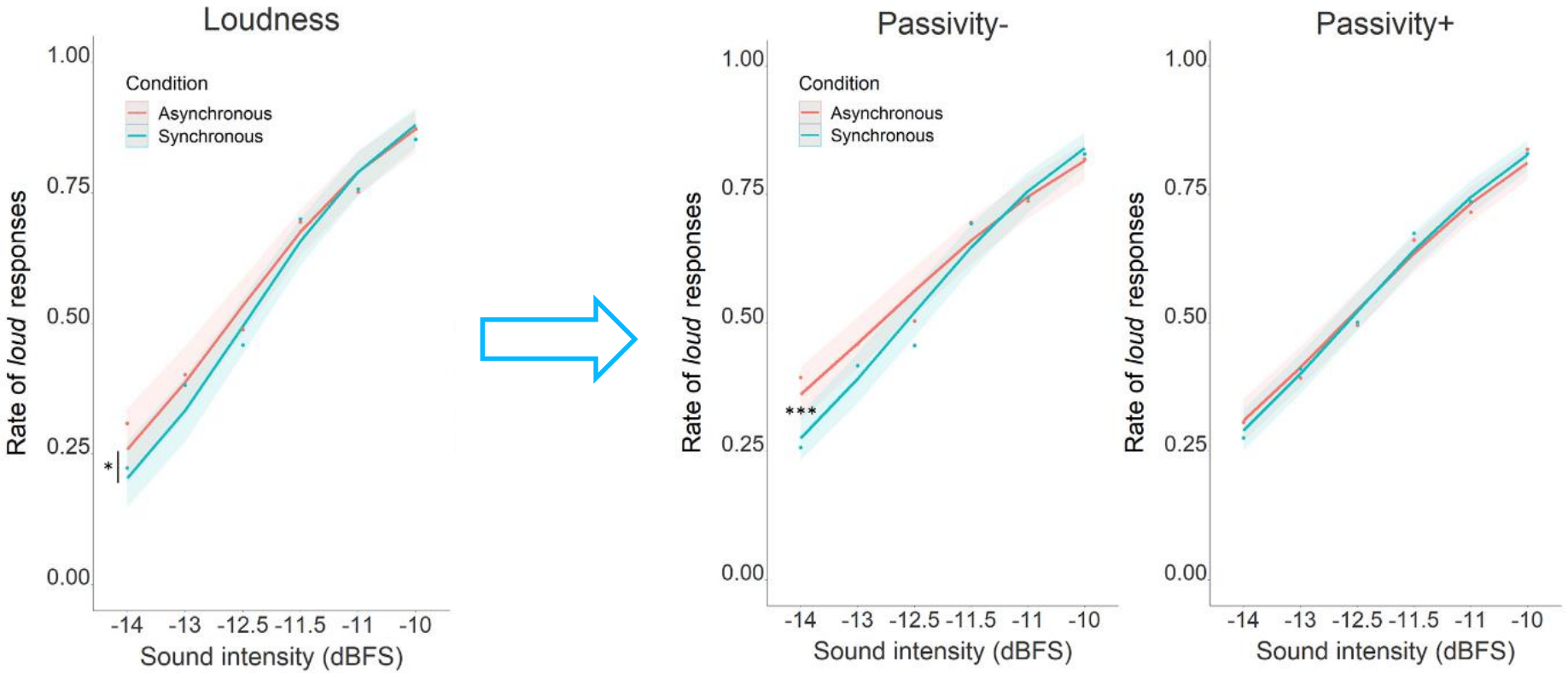
[a] Laboratory of Cognitive Neuroscience, Center for Neuroprosthetics and Brain Mind Institute, Faculty of Life Sciences, Swiss Federal Institute of Technology (EPFL), Switzerland
[b] Univ. Grenoble Alpes, Univ. Savoie Mont Blanc, CNRS, LPNC, 38000 Grenoble, France
[c] Faculty of Medicine, University of Geneva, Geneva, Switzerland

Experiment 2: Results



Quiet voices are perceived as louder during asynchronous stimulation.

Experiment 2: Results



Quiet voices are perceived as louder in participants without somatic passivity.

DOI: 10.1111/psyp.14016

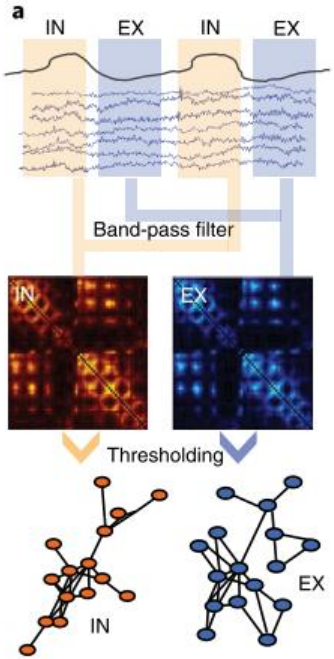
PSYCHOPHYSIOLOGY SPR WILEY

ORIGINAL ARTICLE

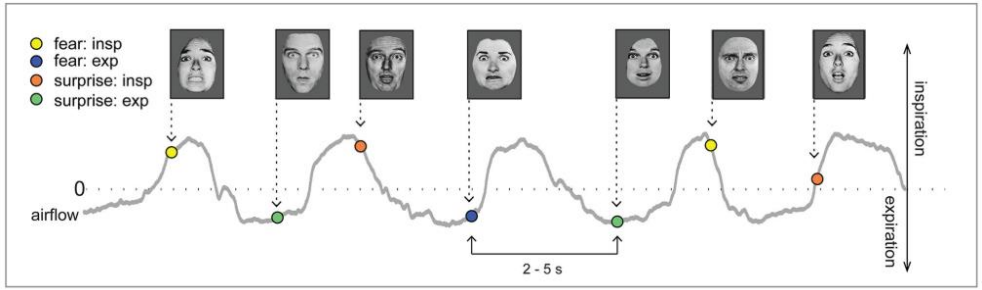
Breathing affects self-other voice discrimination in a bodily state associated with somatic passivity

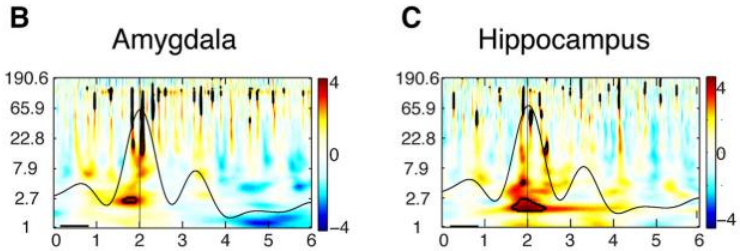
Pavo Orepic[1] | Hyeong-Dong Park[2,3] | Giulio Rognini[1] | Nathan Faivre[4] | Olaf Blanke[1,5]

Breathing affects cognition



Perl et al. 2019

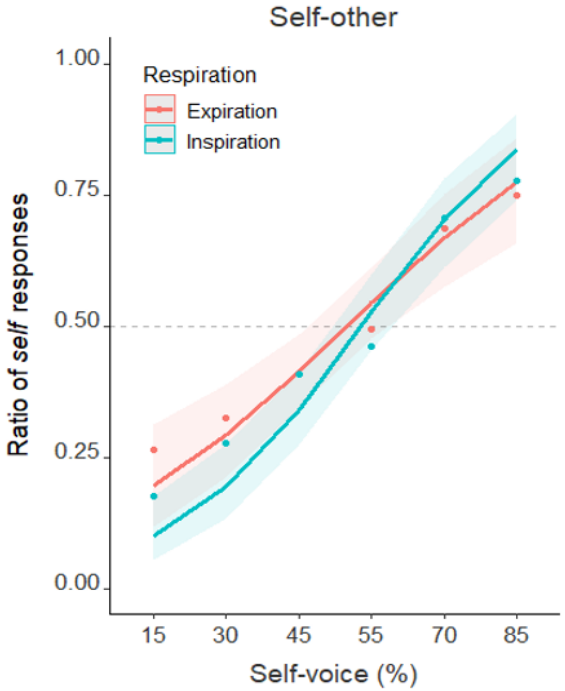




Zelano et al., 2016

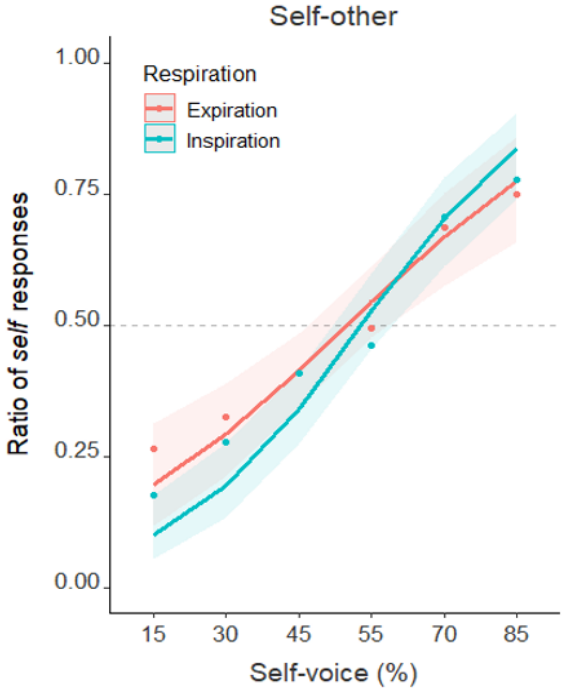
4 cognitive tasks known to be improved during inspiration phase.

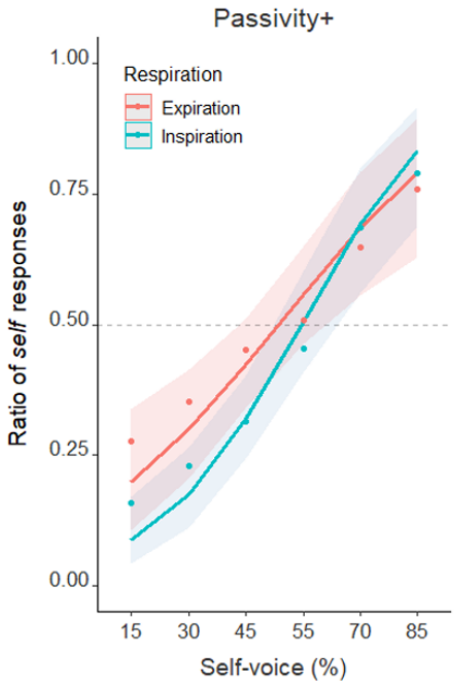
Breathing & self-voice

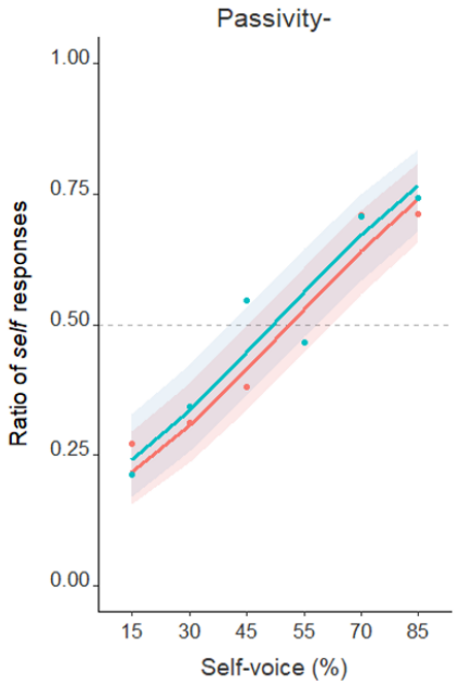


Inspiration improves self-other voice discrimination (SOVD).

Breathing & self-voice & somatic passivity







Inspiration improves SOVD only in participants reporting somatic passivity.

Study 5: Robotically-mediated sensorimotor stimulation induces identity-specific auditory-verbal hallucinations in healthy individuals

Pavo Orepic, Fosco Bernasconi, Melissa Faggella, Nathan Faivre, Olaf Blanke, *In preparation*

Voice detection

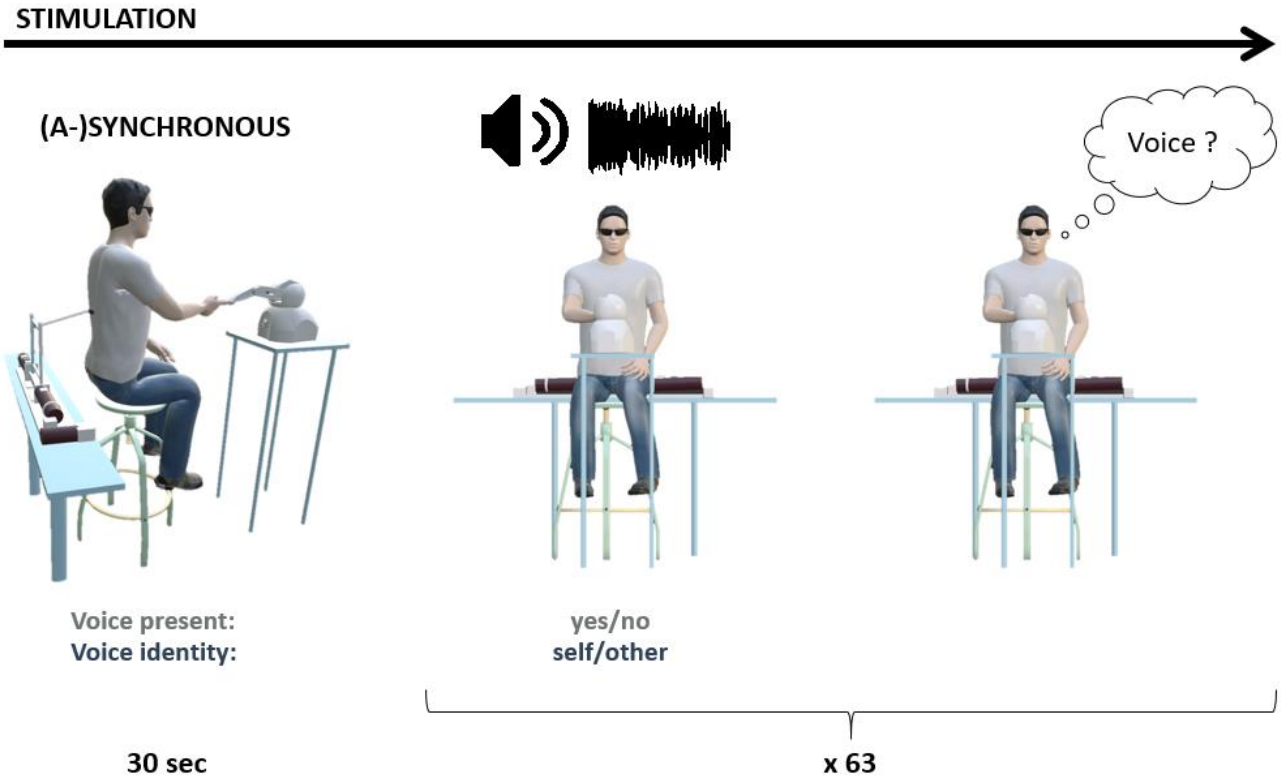
VOICE \ HEARING	YES	NO
PRESENT	HIT	MISS
ABSENT	FALSE ALARM	CORRECT REJECTION

Voice detection

VOICE \ HEARING	YES	NO
PRESENT	HIT	MISS
ABSENT	FALSE ALARM	CORRECT REJECTION

AVH

Task design


STIMULATION
(A-)SYNCHRONOUS
Voice ?
Voice present:
Voice identity:
yes/no
self/other
30 sec
x 63

Hypotheses

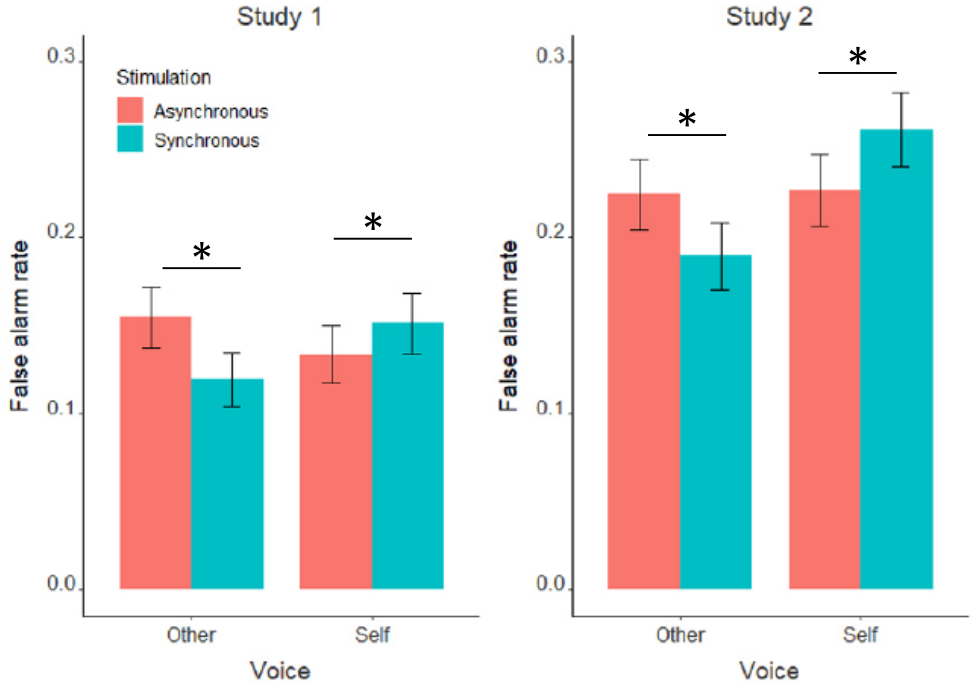
- More false alarms in asynchronous condition
  - Especially for other-voice blocks
- No differences in hits

Hypotheses

- More false alarms in asynchronous condition
  - Especially for other-voice blocks
- No differences in hits

- 2 studies with the same procedure
  - $N_1 = N_2 = 24$

False alarm (FA) rate



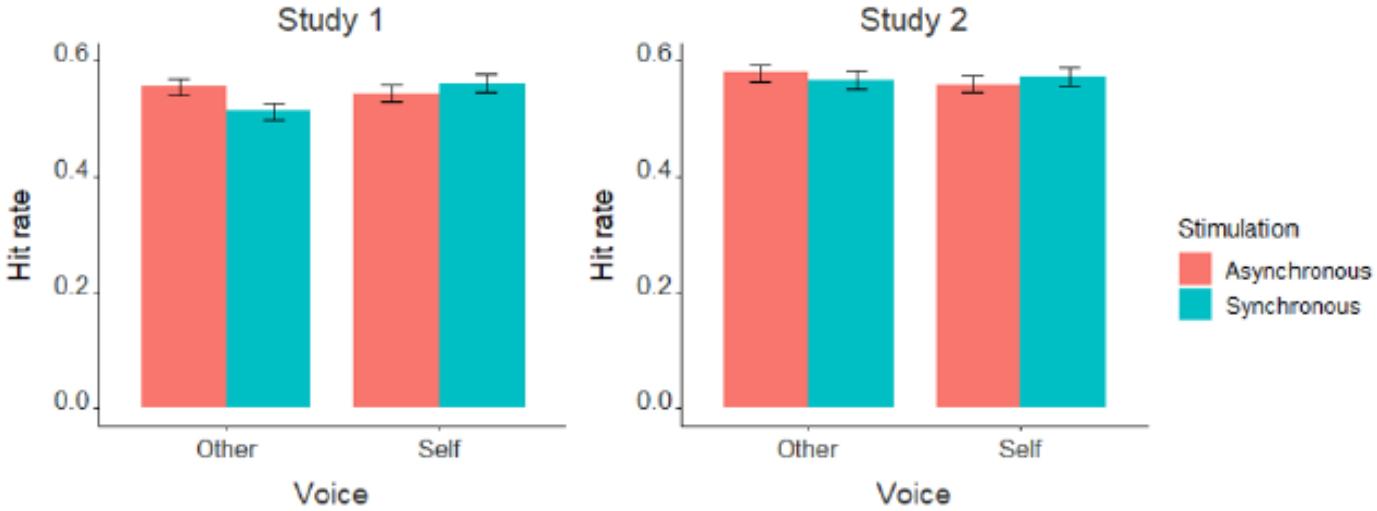
$N_1 = N_2 = 24$

FA- **Stimulation** * Voice (A > S)
$p_1 = 0.039$
$p_2 = 0.027$

FA- **Stimulation * Voice**
$p_1 = 0.013$
$p_2 = 0.003$

Asynchronous stimulation increased other-voice FAs, and synchronous self-voice FAs.

Hit rate

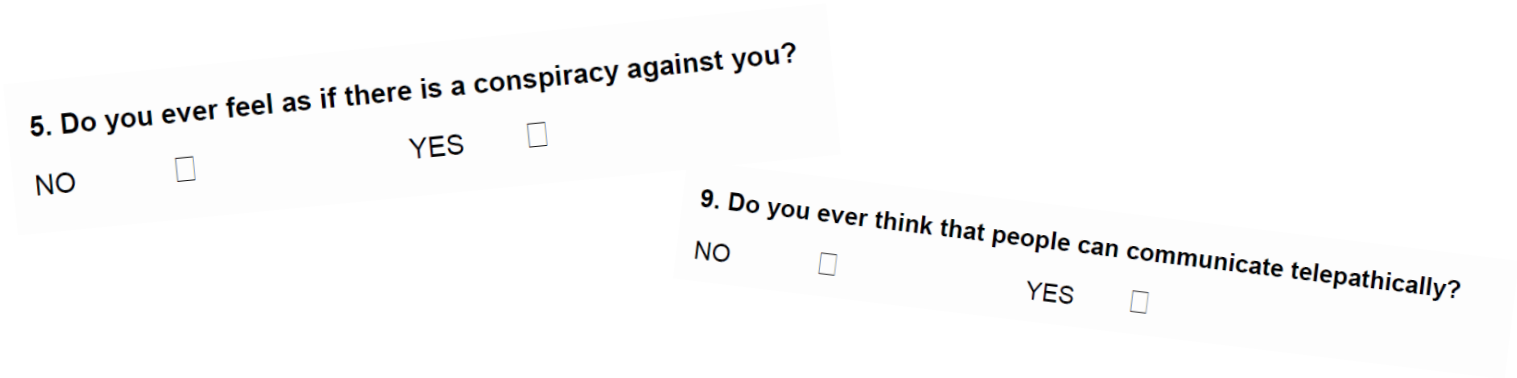


$N_1 = N_2 = 24$
$p_1 > 0.05$
$p_2 > 0.05$

Hit rate was unaffected by experimental manipulation.

Delusional ideation

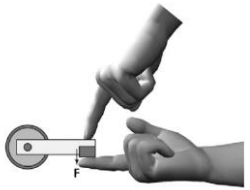
- PDI is a self-rating questionnaire that measures delusion proneness in a healthy population



Peters et al., 2004; Teufel et al., 2010; Whitford et al., 2017

Delusional ideation

- PDI is a self-rating questionnaire that measures delusion proneness in a healthy population
- Related to self-monitoring deficits



5. Do you ever feel as if there is a conspiracy against you?

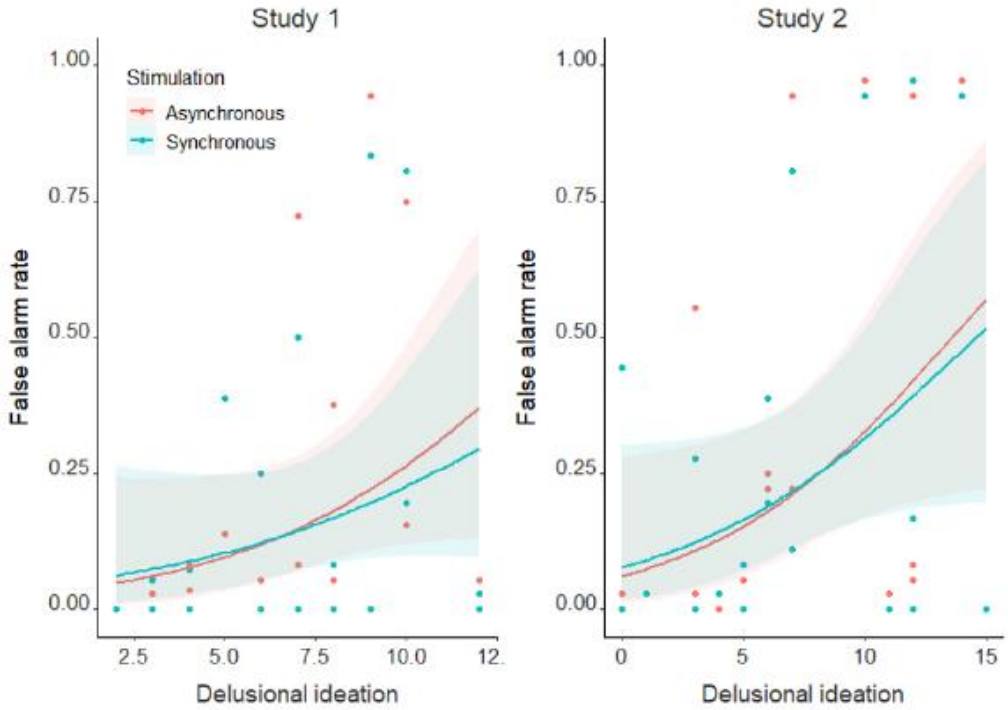
NO ☐ YES ☐

9. Do you ever think that people can communicate telepathically?

NO ☐ YES ☐

Peters et al., 2004; Teufel et al., 2010; Whitford et al., 2017

Delusional ideation



$N_1 = N_2 = 24$

FA~ Stimulation * **PDI**

$p_1 = 0.049$

$p_2 = 0.032$

FA~ **Stimulation * PDI**

$p_1 = 0.036$

$p_2 = 0.058$

FA increase associated with delusion proneness.

Study 5: Discussion

- AVH (FA) in a controlled laboratory environment
  - Prevoius work: conditioning paradigms
- Identity (self/other) reflected in the type of stimulation
  - Asynchronous -> otherness -> other-voice FAs
- Link to delusional ideation
  - suggestive of top-down effects

Part II: Summary

- Robotically-mediated sensorimotor stimulation that impairs bodily self-monitoring
- ...can cause a cross-modal effect on voice perception (Study 3)
- ...which is related to breathing (Study 4)
- ...and lead to identity-specific AVH (Study 5)

Impact

- Methodological
  - Increasing auditory self-identification
  - Inducing AVH in controlled environment
- Scientific
  - Elucidating self-voice phenomenon
  - Associating sensorimotor processing, self-voice perception and interoception
- Clinical
  - Post-surgical personality alterations
  - Addressing AVH etiology

Outlook

- Active self-voice perception (voice production)
- Computational modeling
- Self-voice perception & network in voice-hearers

OLAF BLANKE

NATHAN FAIVRE

GIULIO ROGNINI

OLIVER ALAN KANNAPE

GIANNINA RITA IANNOTTI

FOSCO BERNASCONI

HYEONG-DONG PARK

Thank you!

Questions?