Perceptual Inference and a Computational Nosology of Hallucinations

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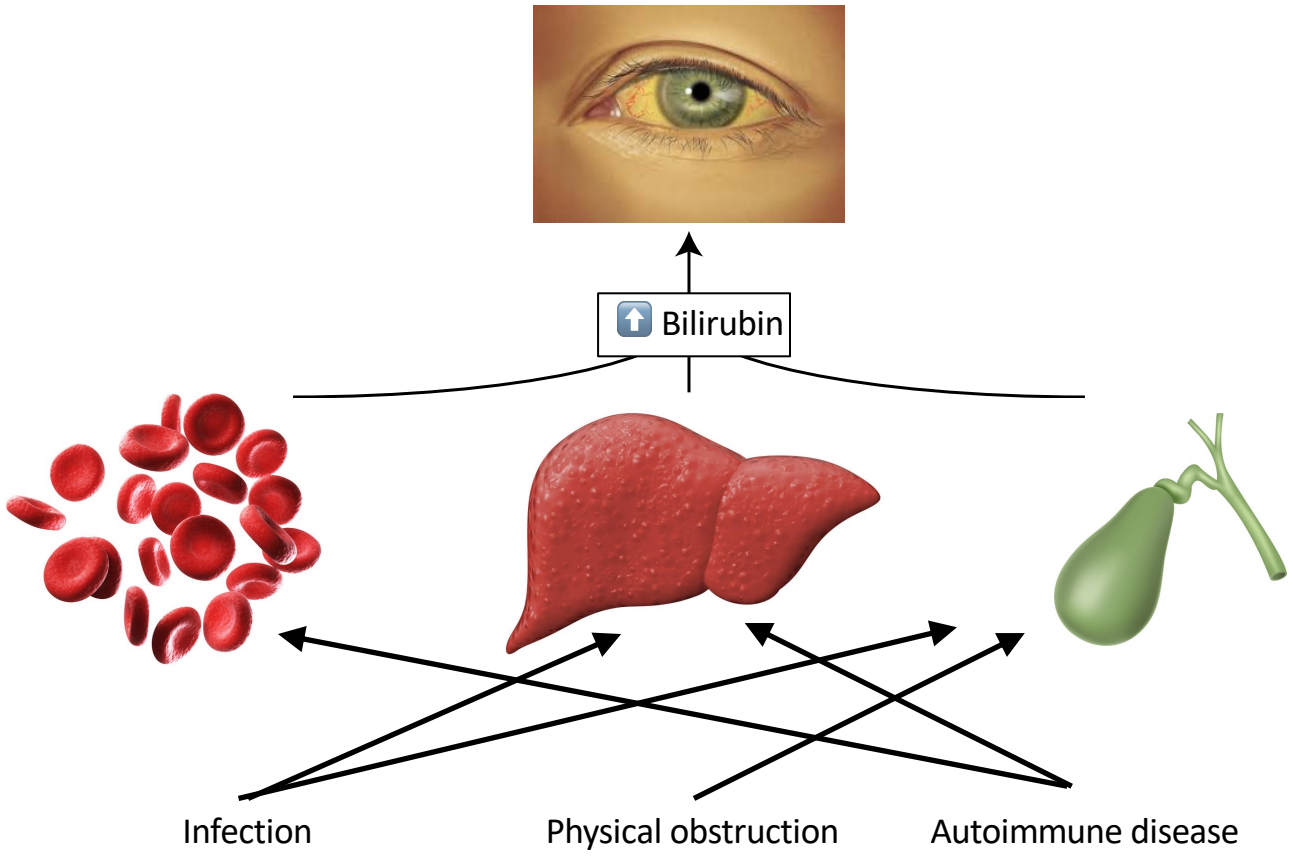
CPC Zürich
September 16, 2022

Outline

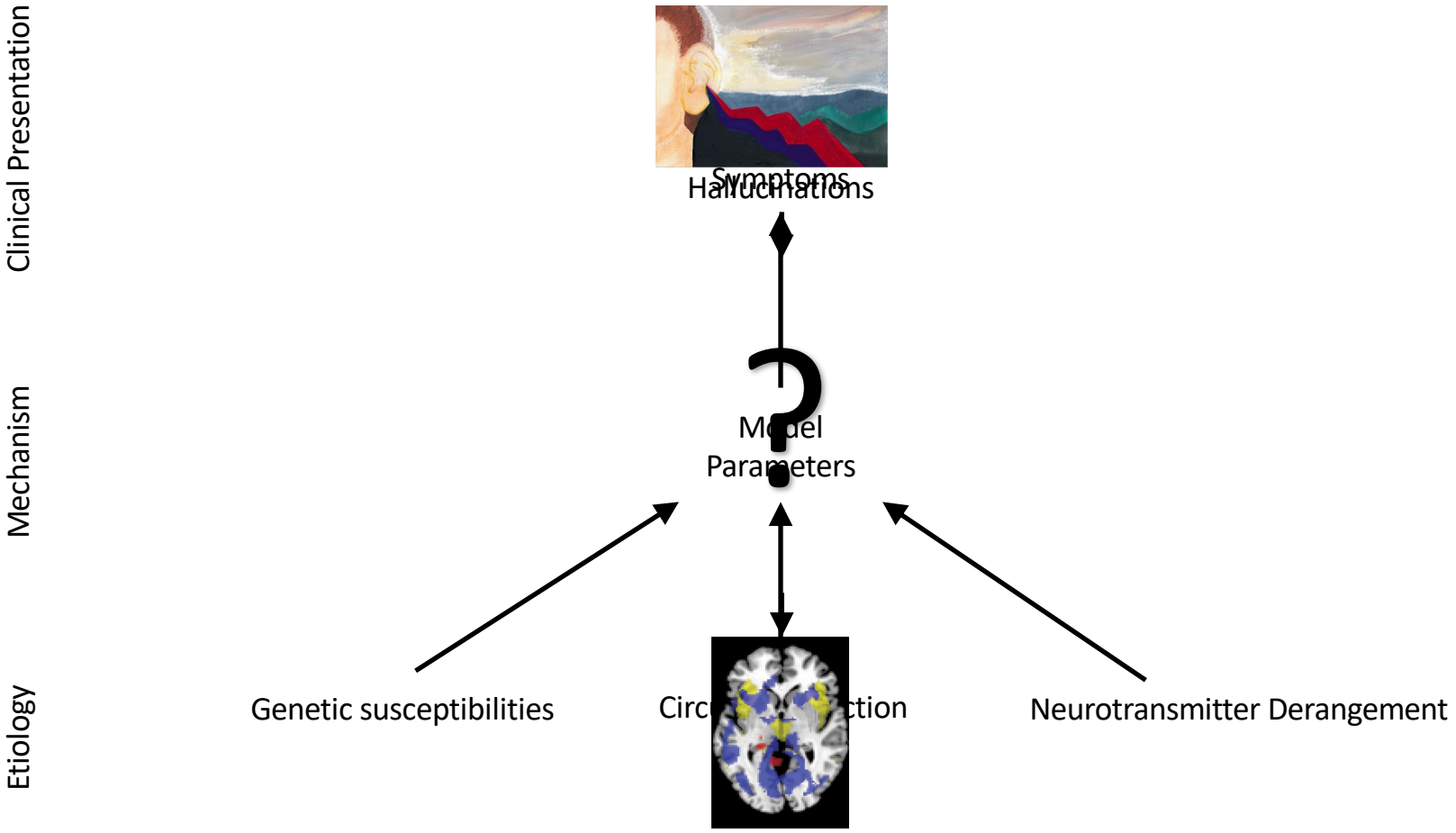
- Recap: medical nosology
- Development of a psychiatric nosology
- Example: auditory hallucinations
- Translation through computation

Medical Nosology



Based on slide from Klaas Enno Stephan

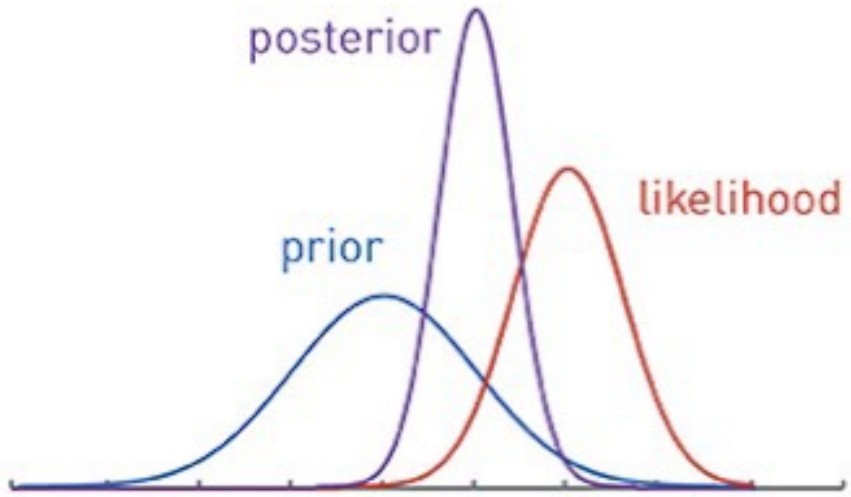
Development of a psychiatric nosology



Unconscious Inference

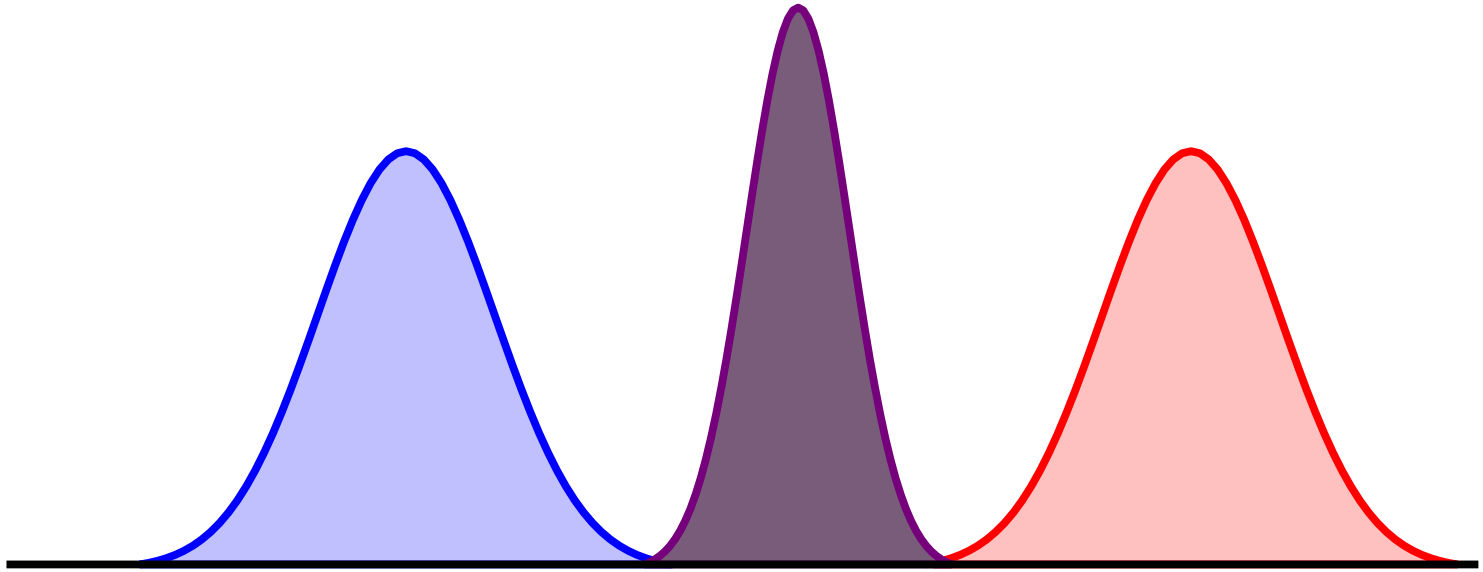
Bayes' Theorem

$$p(x|y,m) = \frac{p(y|x,m)p(x|m)}{p(y|m)}$$



Stephan et al. (2016), Front. Hum. Neurosci., 10:550

Do hallucinations arise from overly precise priors?



Test:
Can you create hallucinations by making priors more precise?

“Conditioned Hallucinations”

MEASUREMENTS OF ILLUSIONS AND HALLUCINATIONS IN NORMAL LIFE,

BY

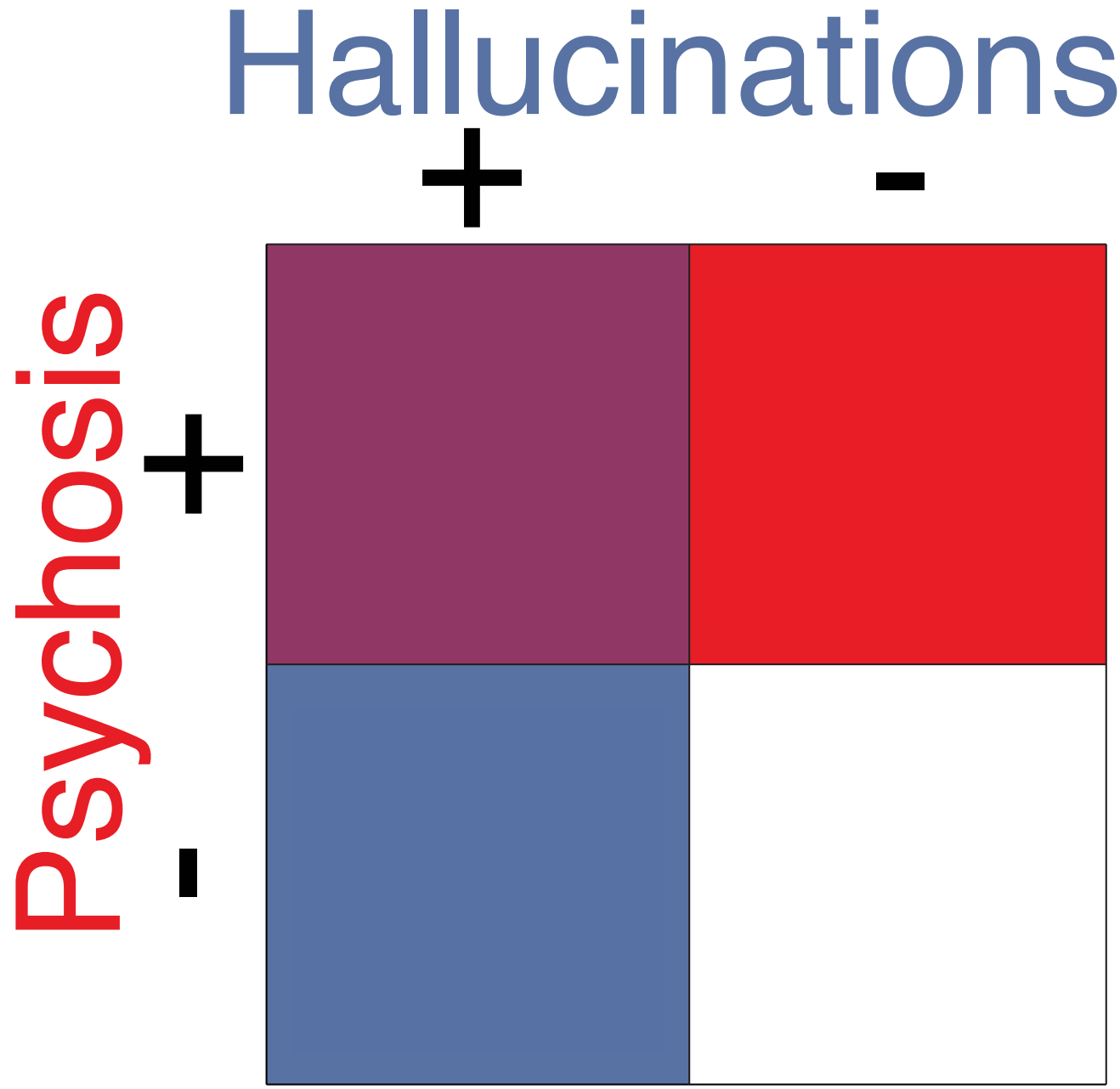
C. E. SEASHORE, PH.D.

PART FIRST.

ILLUSIONS OF WEIGHT: INFLUENCE OF KNOWLEDGE OF SIZE ON JUDGMENT OF WEIGHT.

When an object lifted is found heavier than was expected, it is overestimated, and when it is found lighter than was expected, it is underestimated. The strongest and most frequent illusion of this kind in normal life is perhaps that which is caused by our accustomed associations between the properties of size and weight of objects. The aim in Part First of this research is to investigate the nature and extent of the illusions of weight as caused by knowledge of the size of the body lifted. Illusions of weight from other sources are incidentally considered. The experiments were made between October, 1893, and May, 1895.

The problem is a development from a test made by GILBERT[1] on

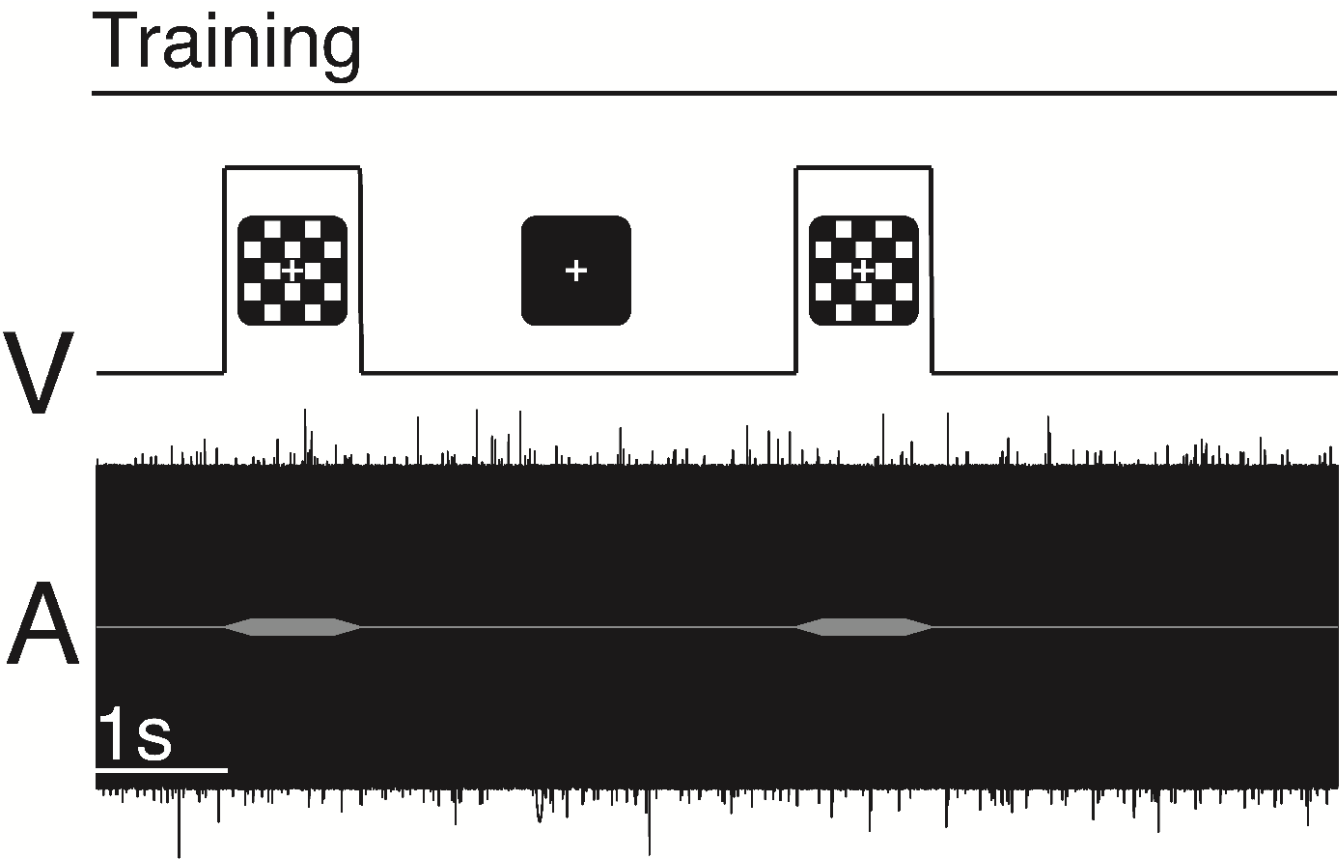

Hallucinations
+
-
Psychosis
+
-

Voice-Hearing in the General Population

Phenomenological Comparison:

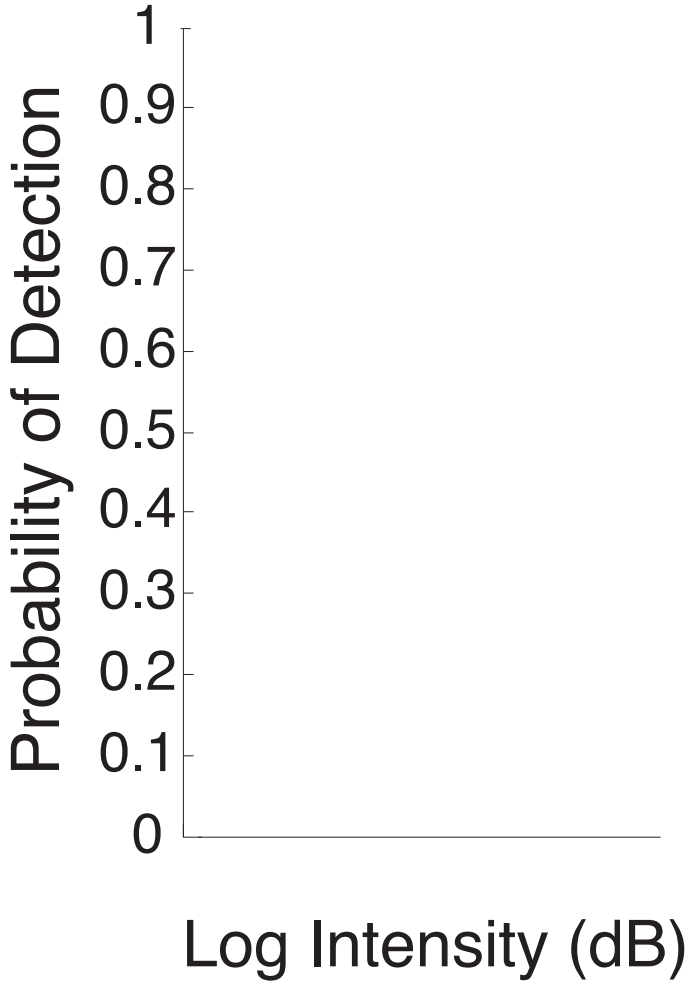
Powers, Kelley, Corlett (2017) *SchizBull*

Conditioned Hallucinations--Revised



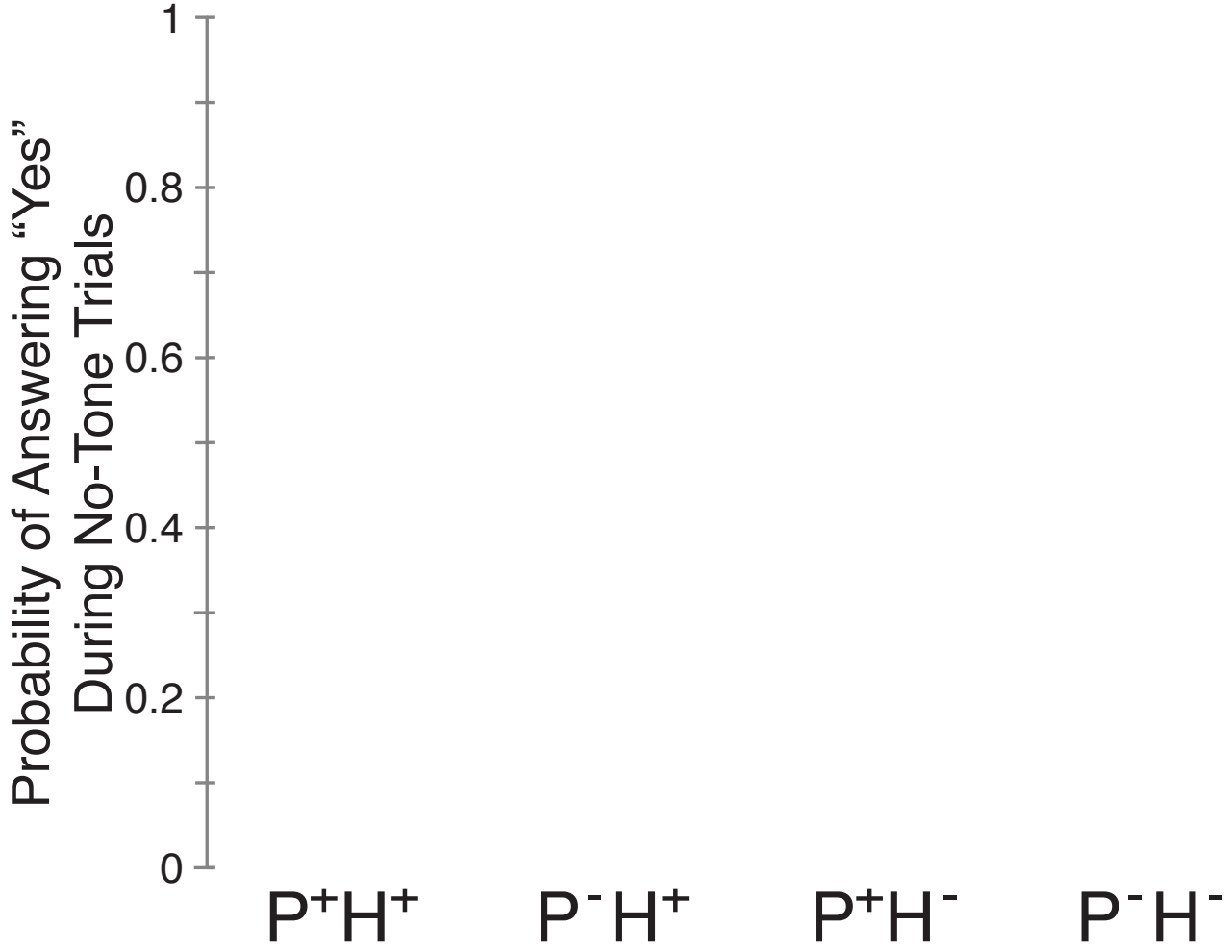
Powers, Mathys, Corlett (2017) *Science*

Trial Structure of Train/Test Sequence



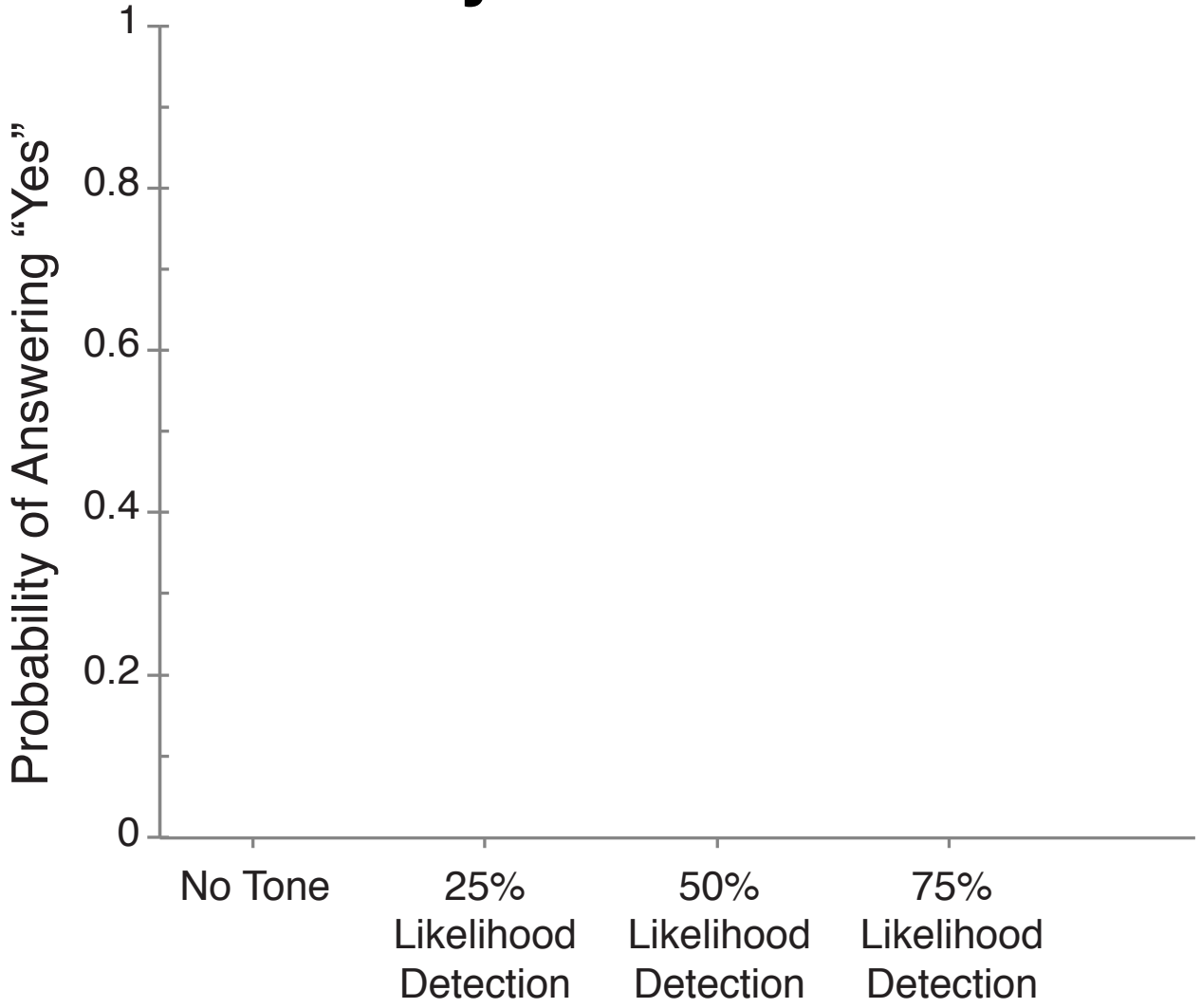
Powers, Mathys, Corlett (2017) *Science*

Likelihood of Conditioned Hallucinations by Group



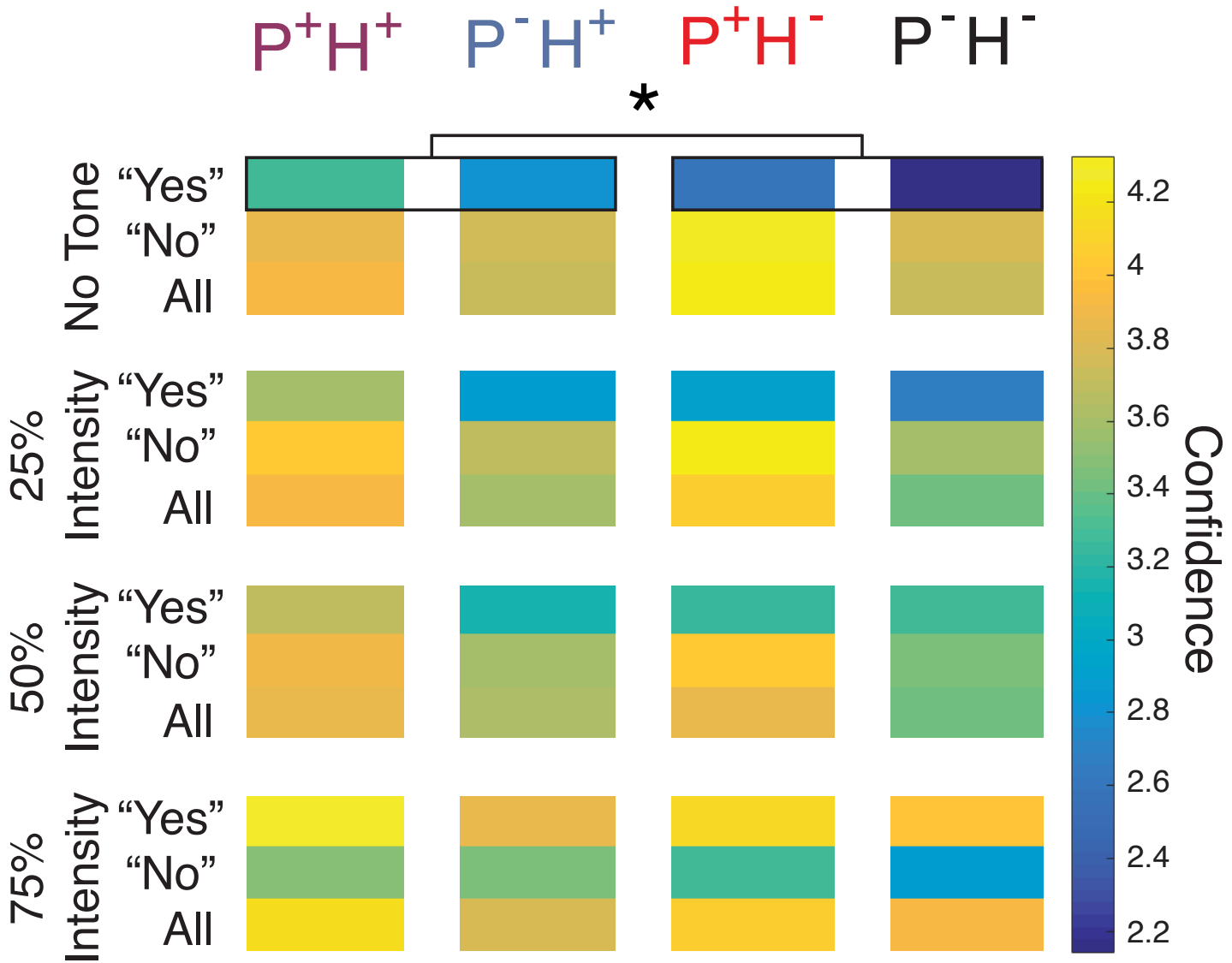
Powers, Mathys, Corlett (2017) *Science*

Likelihood of Detection By Condition



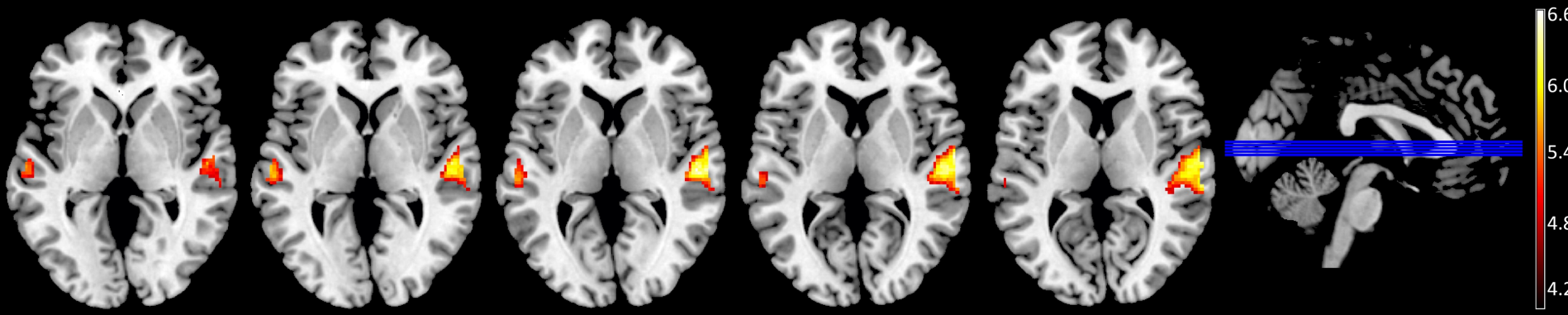
Powers, Mathys, Corlett (2017) *Science*

Confidence

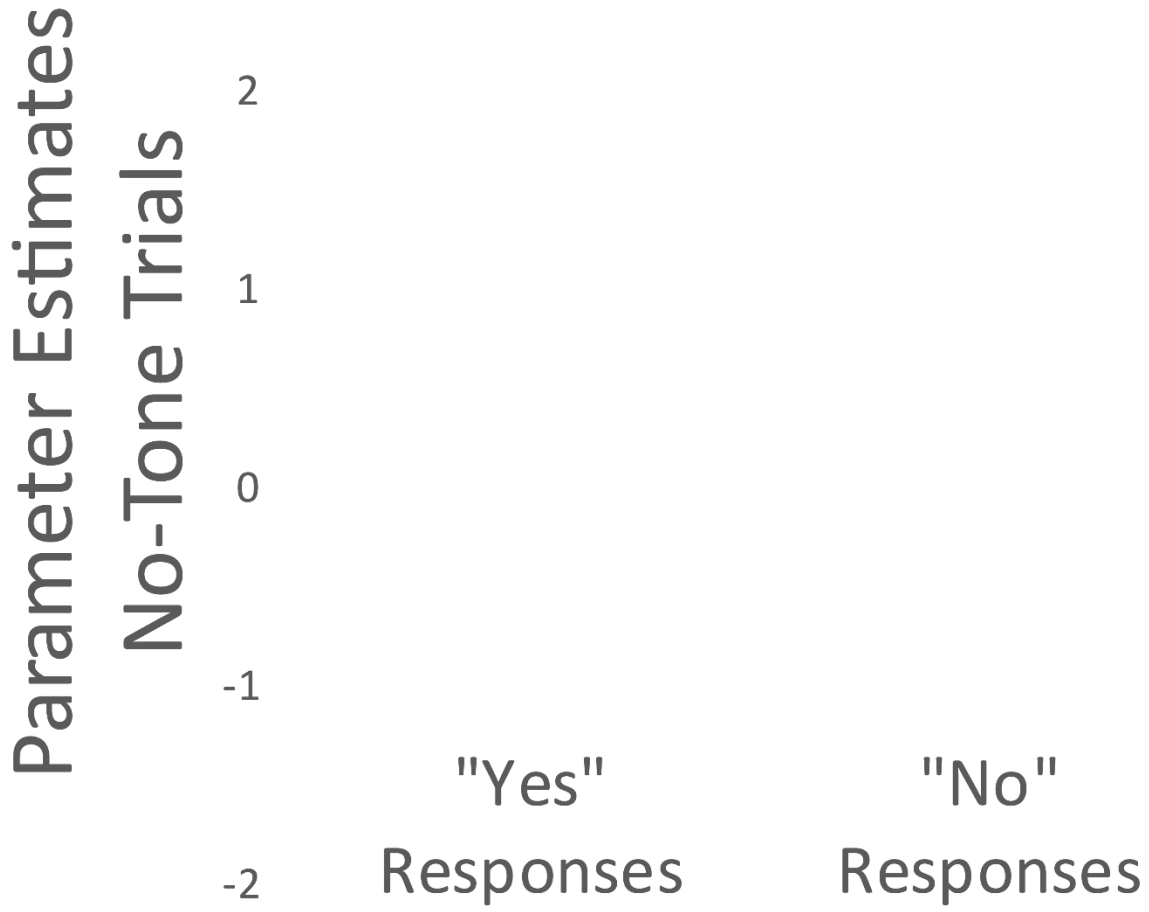


Powers, Mathys, Corlett (2017) *Science*

Imaging Results: Tone-Responsive Region of Interest

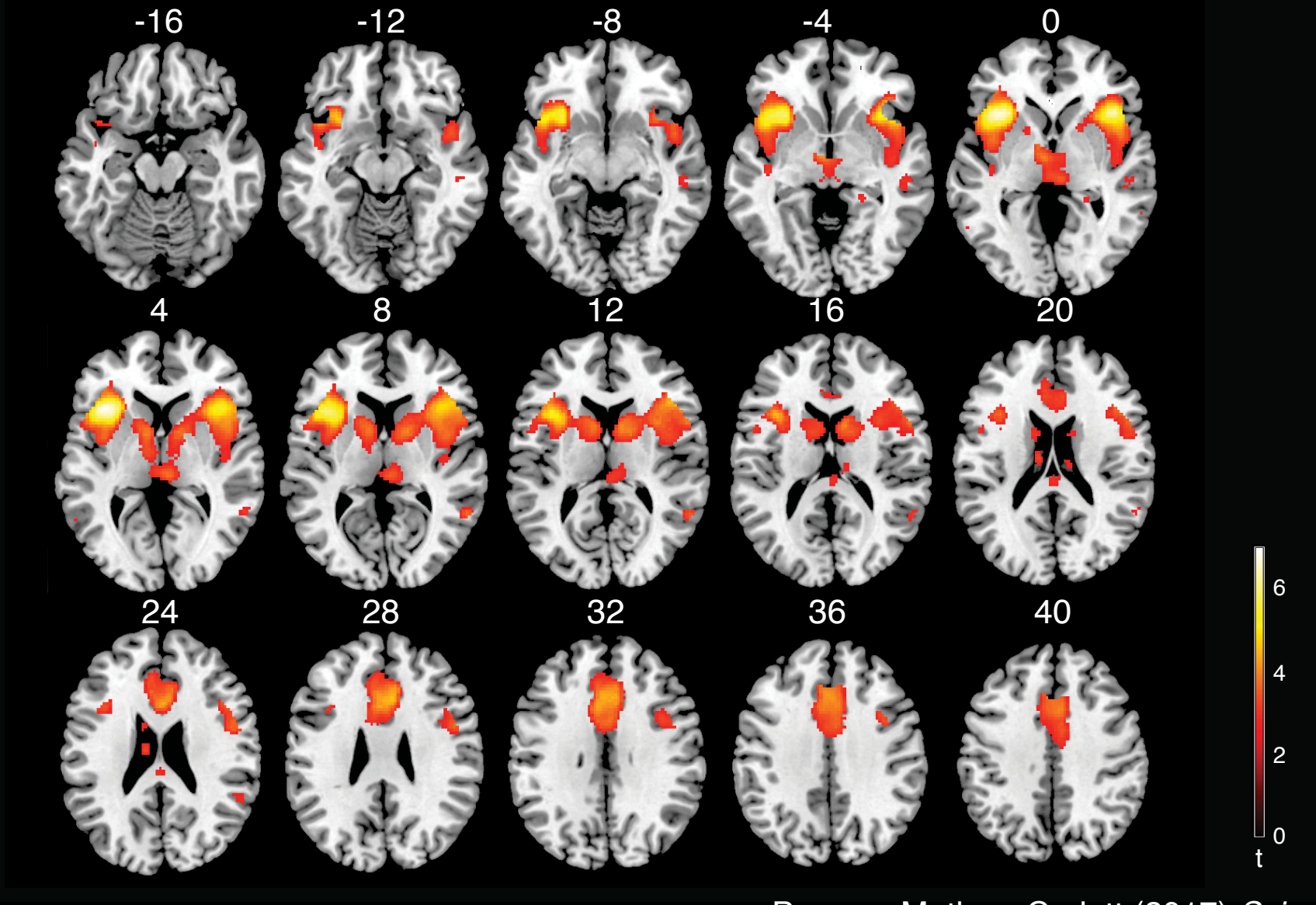


Powers, Mathys, Corlett (2017) *Science*



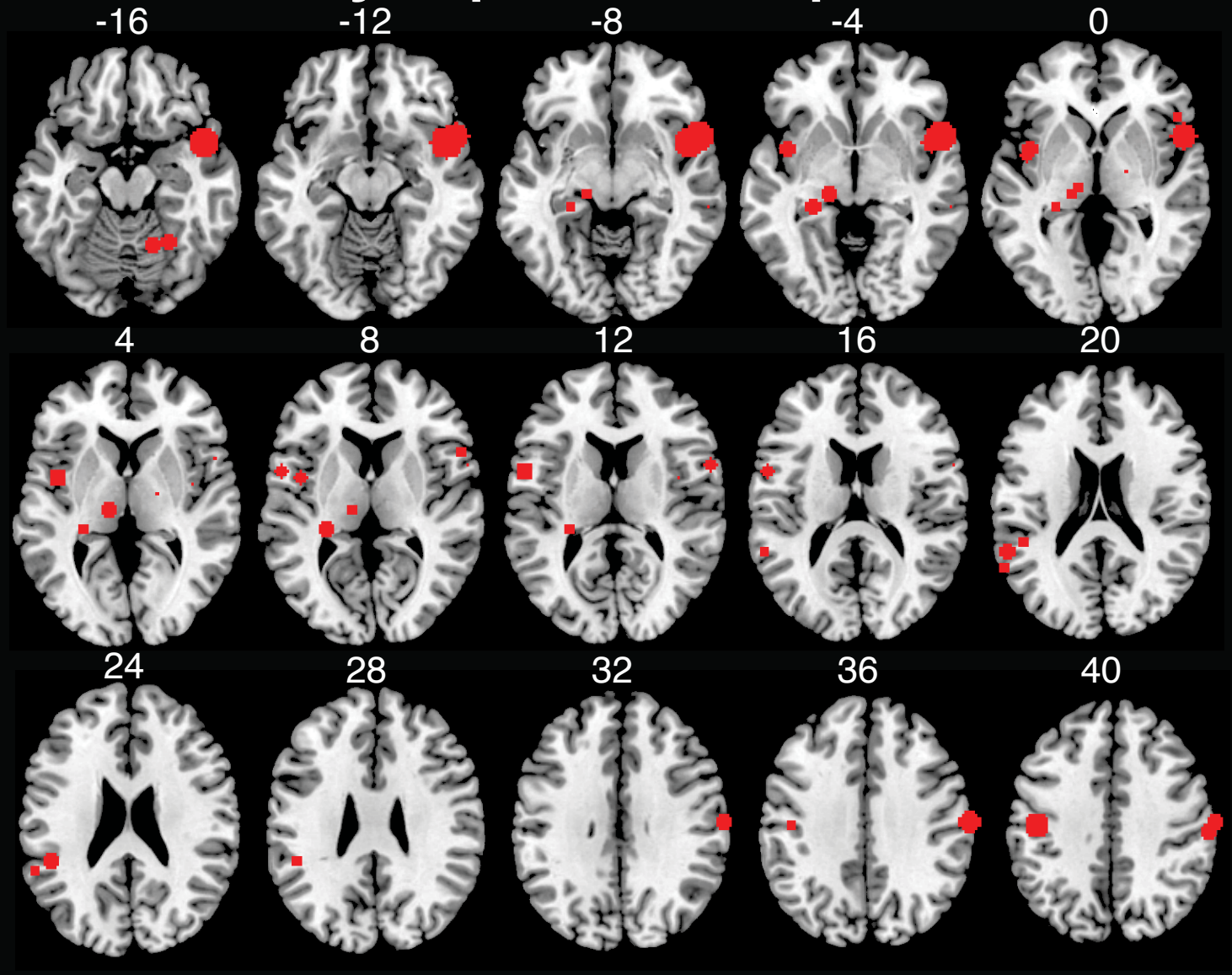
Powers, Mathys, Corlett (2017) *Science*

Whole-Brain Analysis: "Yes" vs "No" on No-Tone Trials



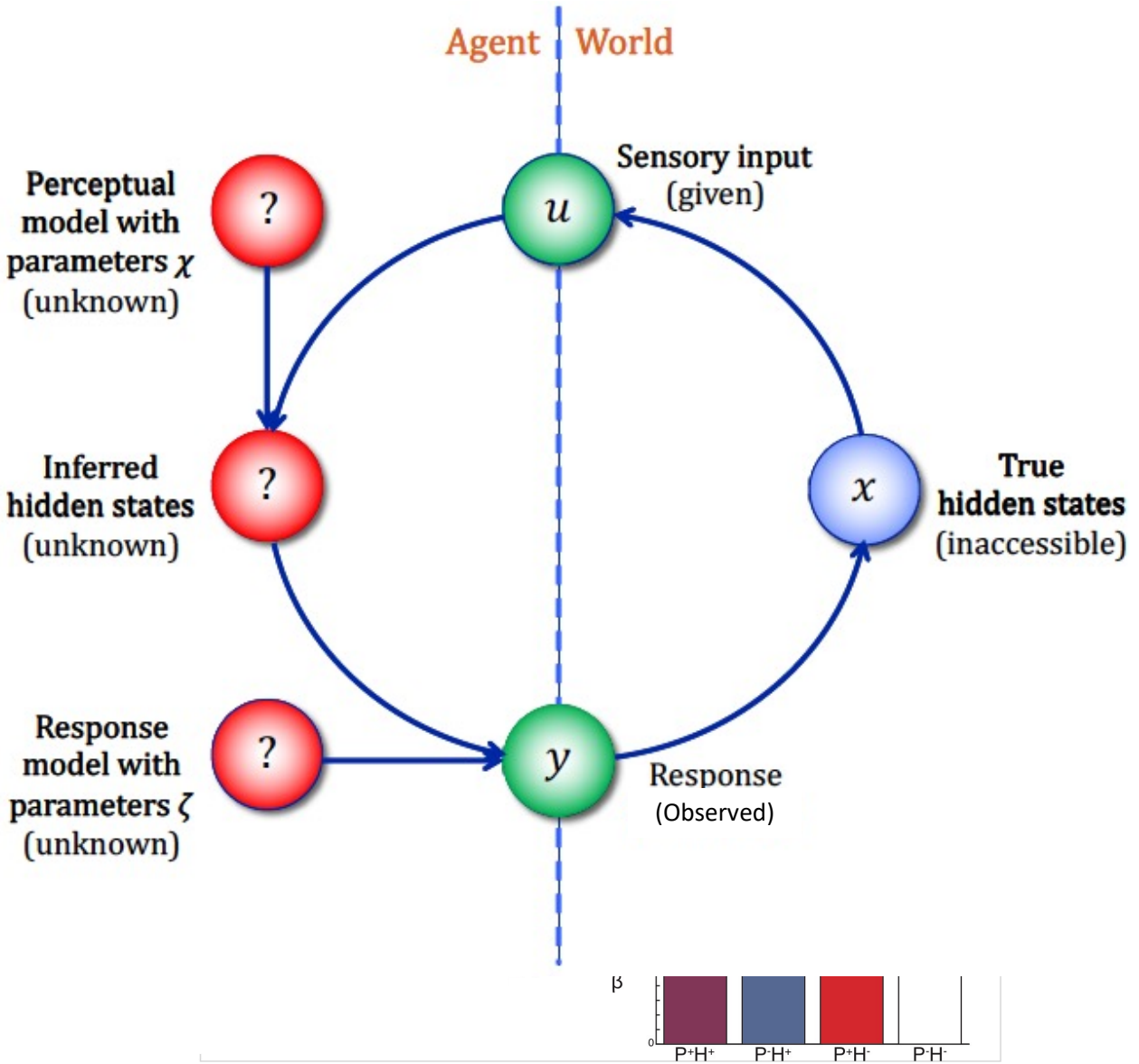
Powers, Mathys, Corlett (2017) *Science*

Regions Involved in Hallucinations: Symptom Capture



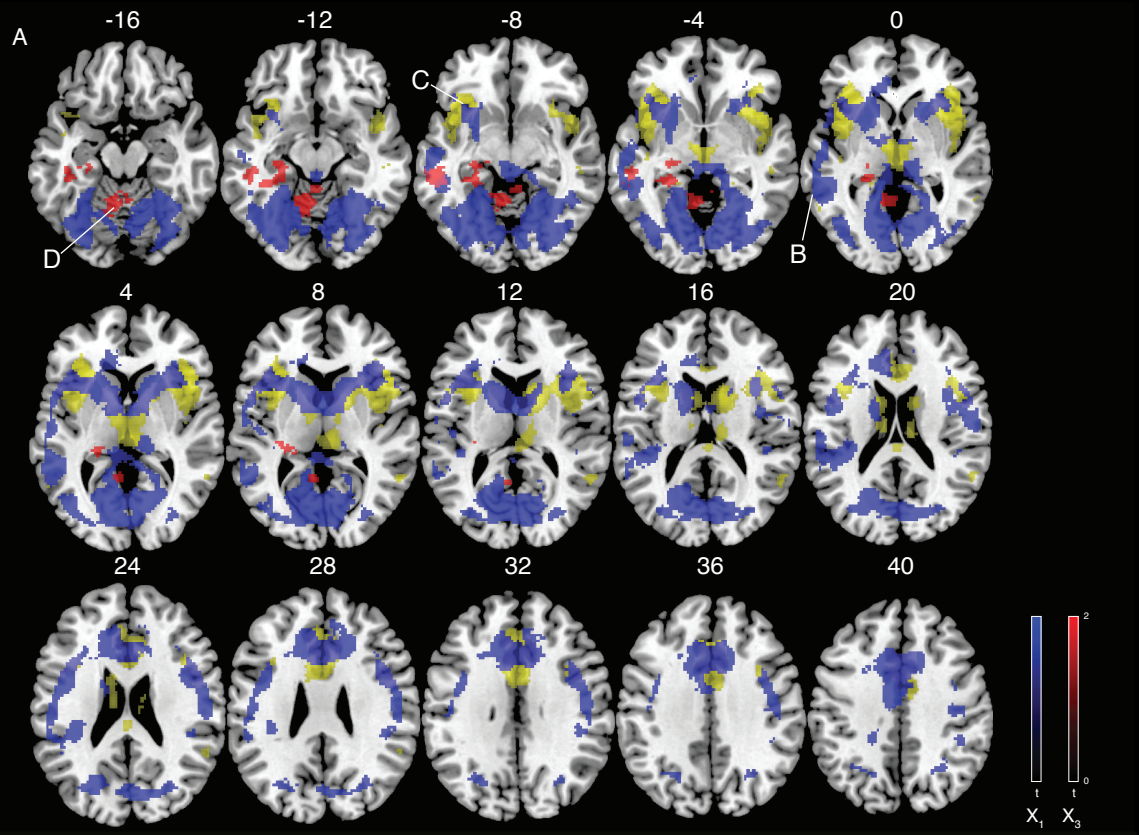
Jardri et al. (2011) *AJP*

Behavioral Measures of Perceptual Belief Differ Among Groups



Powers, Mathys, Corlett (2017) Science 2014

Neural Correlates of Perceptual Belief Differ Among Groups



Powers, Mathys, Corlett (2017) *Science*

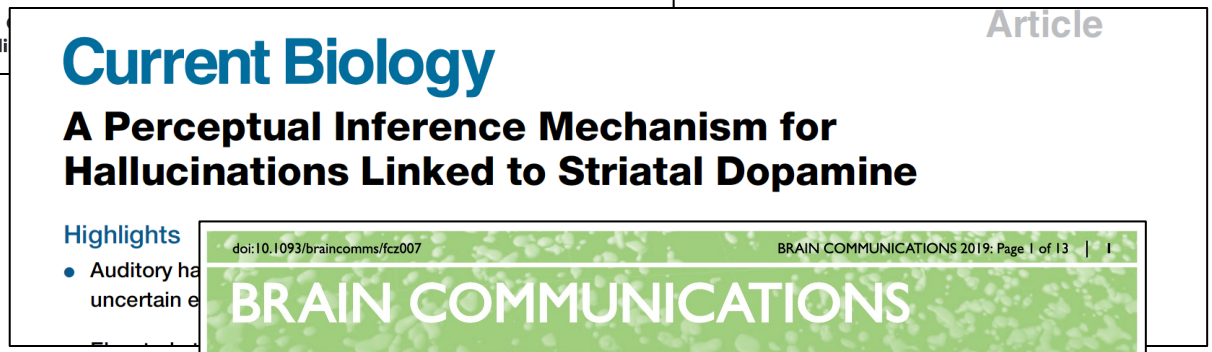
Prior Hyper-precision in Hallucinations

doi:10.1093/brain/awx206 BRAIN 2017: 140; 2475–2489 | 2475

BRAIN
A JOURNAL OF NEUROLOGY

Distinct processing of ambiguous speech in people with non-clinical auditory verbal hallucinations

Ben Alderson-Day,[1,*]
Pradheep Shanmugali



Article

Current Biology

A Perceptual Inference Mechanism for Hallucinations Linked to Striatal Dopamine

Highlights

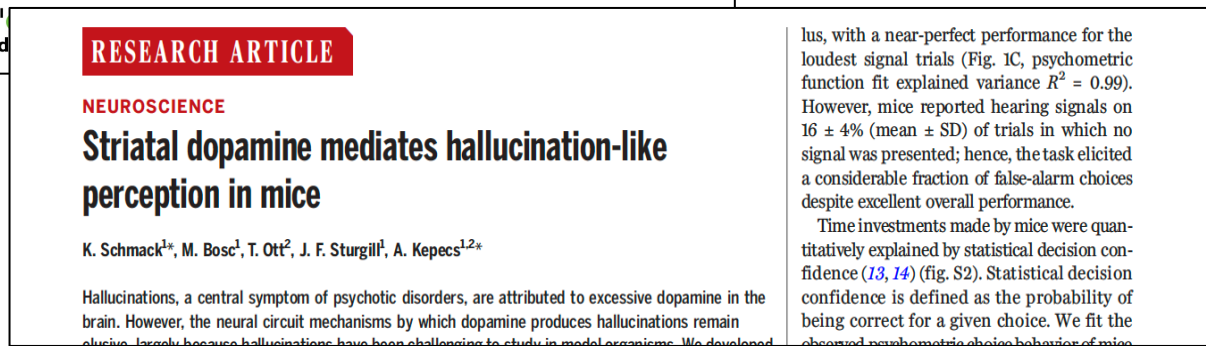
- Auditory ha
uncertain e

doi:10.1093/braincomms/fcz007 BRAIN COMMUNICATIONS 2019: Page 1 of 13 | 1

BRAIN COMMUNICATIONS

Increased weighting on prior knowledge in Lewy body-associated visual hallucinations

Angeliki Zarkali,[1]
Geraint Rees[5,6] and



RESEARCH ARTICLE

NEUROSCIENCE

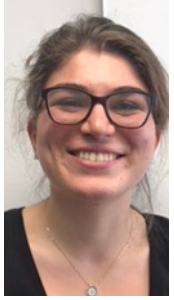
Striatal dopamine mediates hallucination-like perception in mice

K. Schmack[1]*, M. Bosc[1], T. Ott[2], J. F. Sturgill[1], A. Kepecs[1,2]*

Hallucinations, a central symptom of psychotic disorders, are attributed to excessive dopamine in the brain. However, the neural circuit mechanisms by which dopamine produces hallucinations remain

lus, with a near-perfect performance for the loudest signal trials (Fig. 1C, psychometric function fit explained variance R^2 = 0.99). However, mice reported hearing signals on 16 ± 4% (mean ± SD) of trials in which no signal was presented; hence, the task elicited a considerable fraction of false-alarm choices despite excellent overall performance.

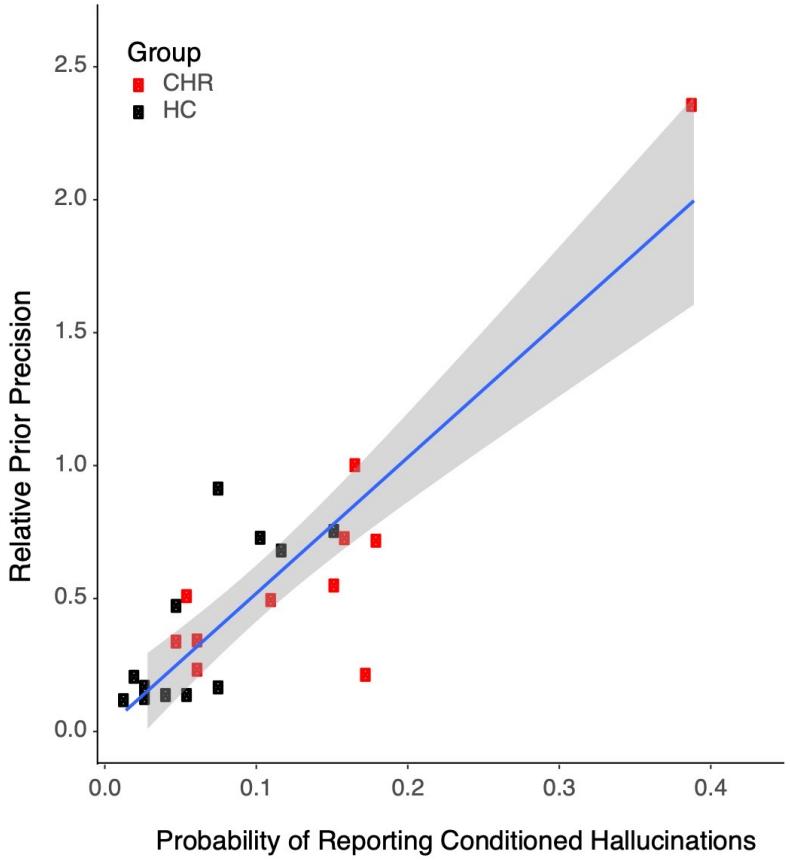
Time investments made by mice were quantitatively explained by statistical decision confidence (*13*, *14*) (fig. S2). Statistical decision confidence is defined as the probability of being correct for a given choice. We fit the



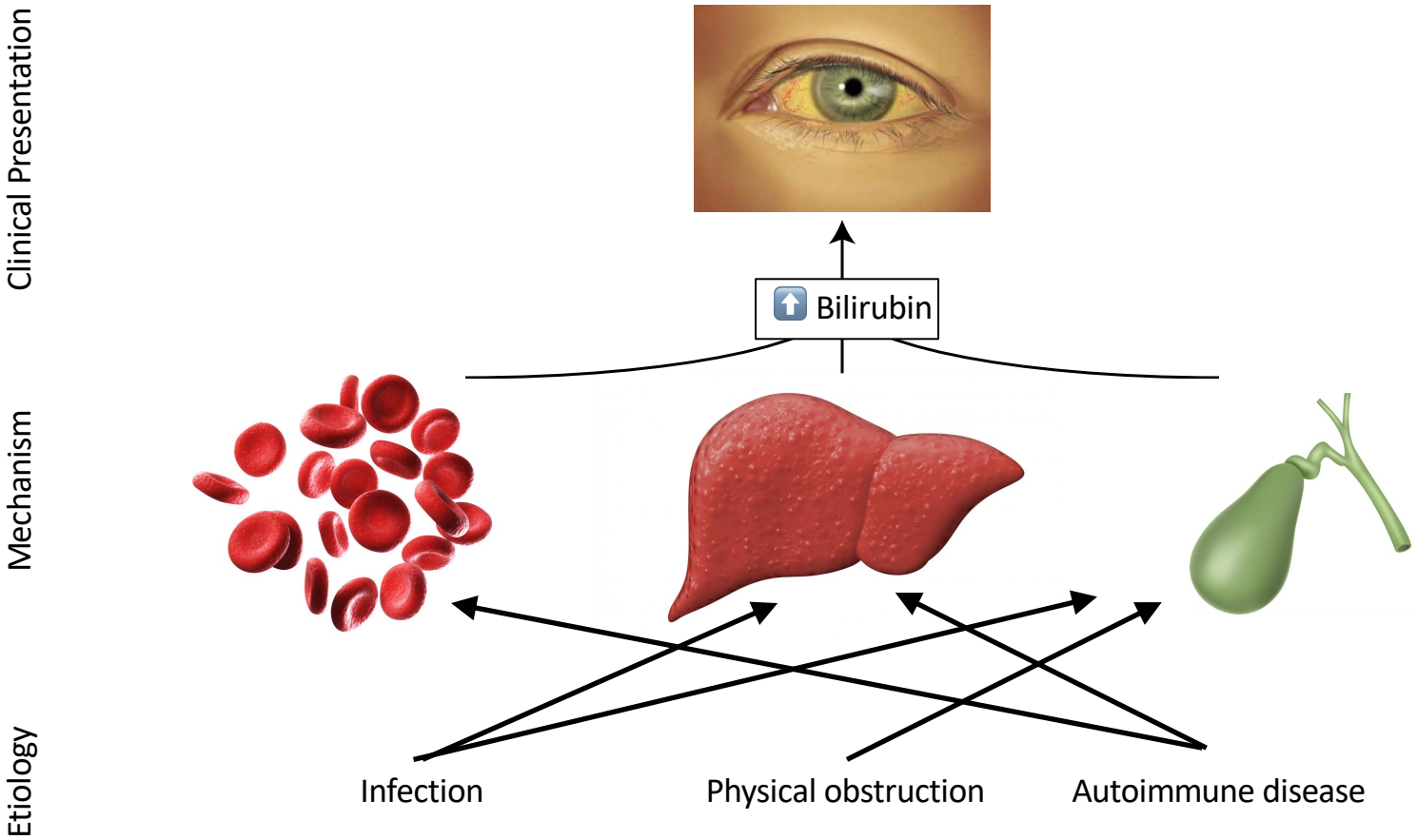
Measures of prior precision correlate

Eren Kafadar

a



Kafadar et al (2020), *SchizRes*



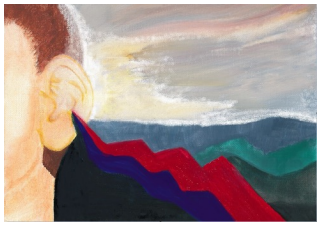
Based on slide from Klaas Enno Stephan

How close is prior hyper-precision to symptom expression?

Clinical Presentation

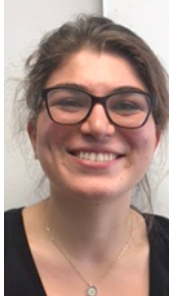
Mechanism

Etiology



Hallucinations

↑ (Relative) Prior Precision

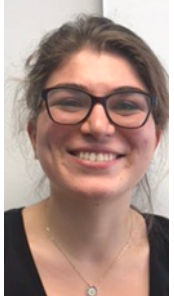


Prior hyper-precision is state-sensitive

Eren Kafadar

Tori Fisher

Kafadar & Fisher et al. (In Press), *Biological Psychiatry*



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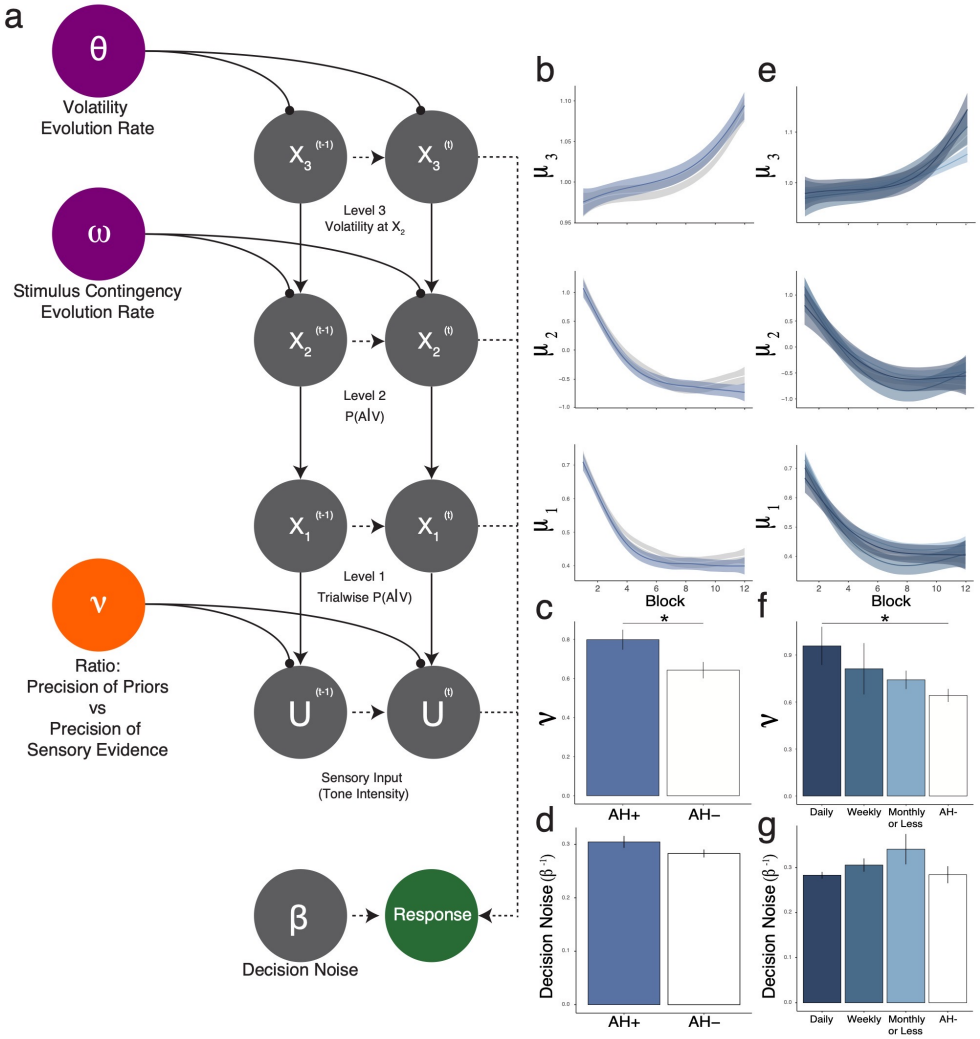
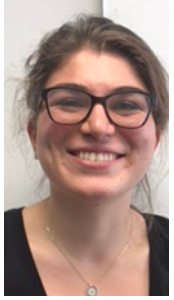


Kafadar & Fisher et al. (In Press), *Biological Psychiatry*



Eren Kafadar

Prior hyper-precision is state-sensitive

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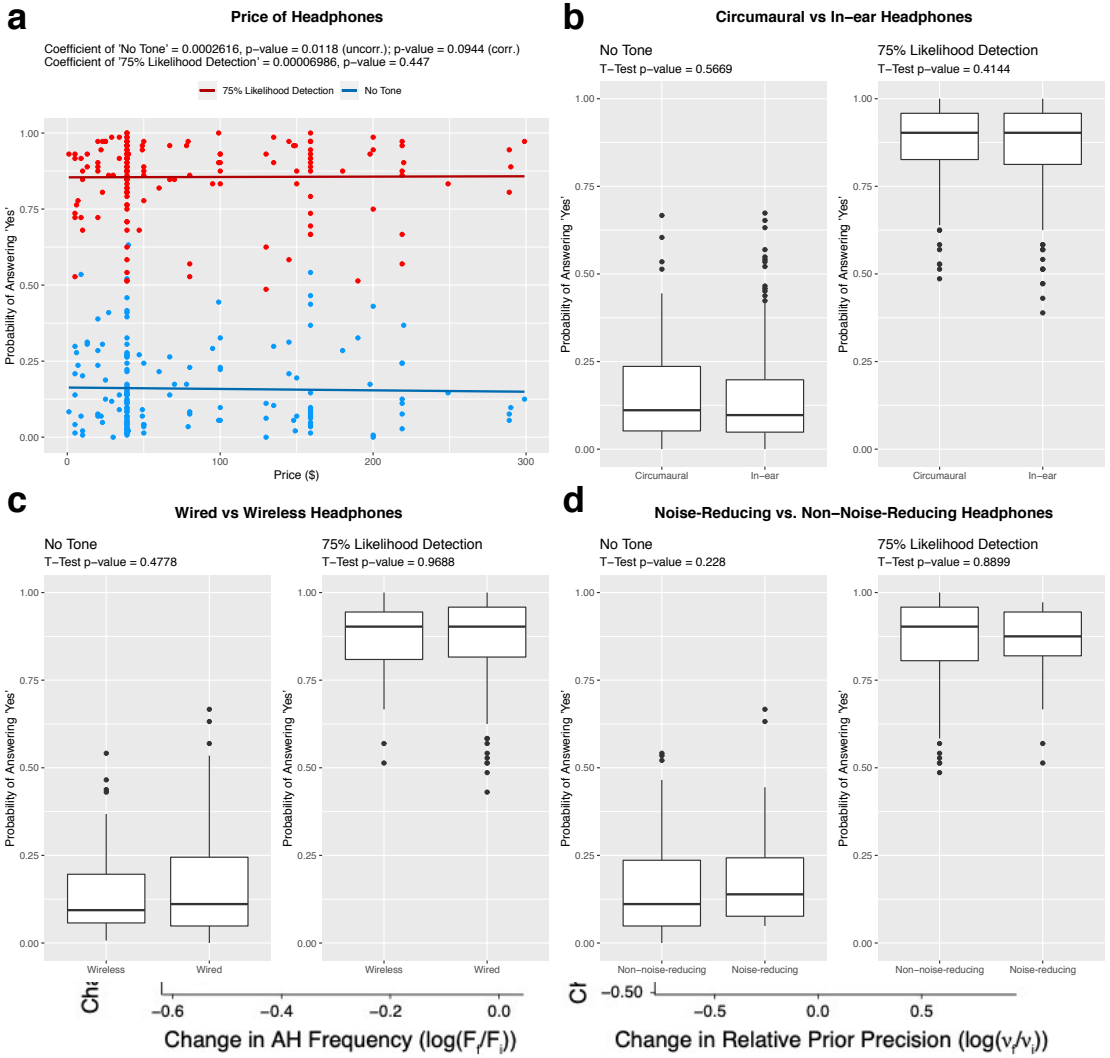
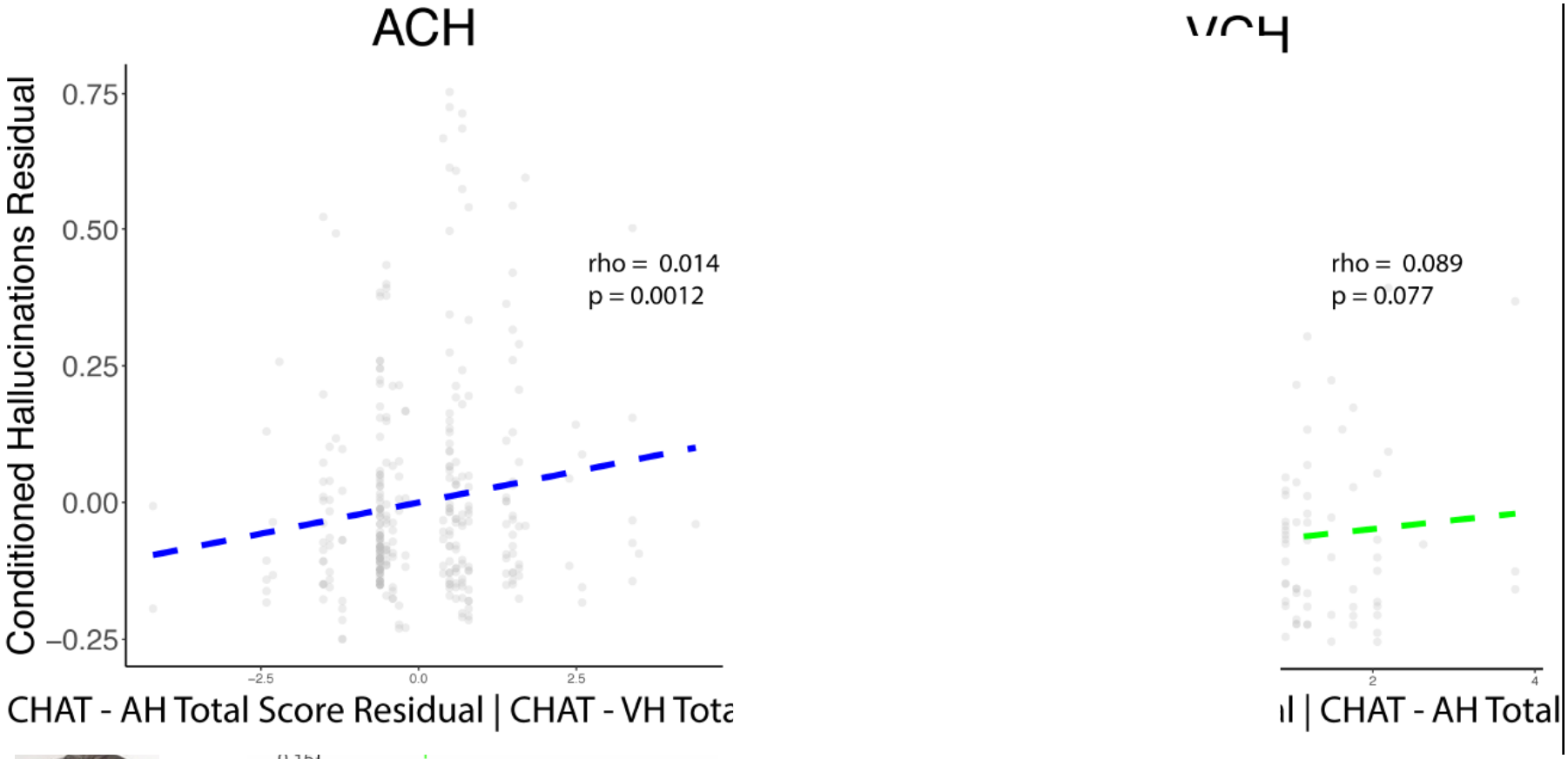
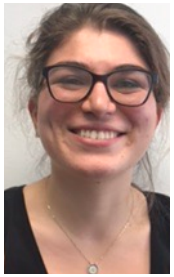


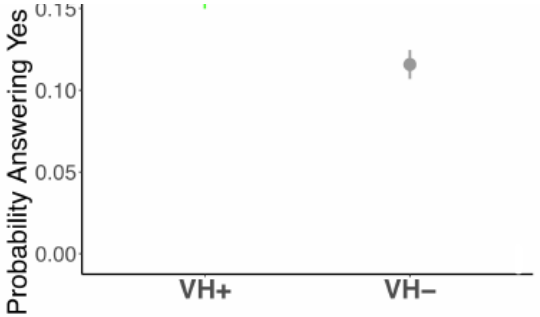
Kafadar & Fisher et al. (In Press), *Biological Psychiatry*

Prior hyper-precision is (partly) modality-specific





Eren Kafadar



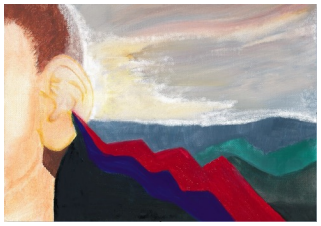
Kafadar et al. (in prep)

A Nosology of Hallucinations

Clinical Presentation

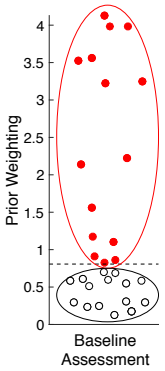
Mechanism

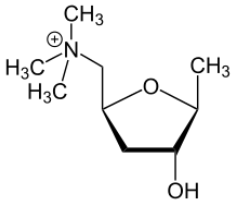
Etiology



Hallucinations

(Relative) Prior Precision





RESEARCH ARTICLE

Pharmacological Fingerprints of Contextu
Uncertainty

Louise Marshall[1*], Christoph Mathys[2,3*], Diane Ruge[1,4], Archy O. de Berker[1,2], Peter Dayan[5], Klaas E. Stephan[2,6,7], Sven Bestmann[1]

1º Hyper-precision?

2º (Compensatory) Hyper-precision?

Genetic High Risk
Risk Factors for Psychosis
Hallucination Development in Other Disorders

Sheldon et al. 2022, *SchizRes*

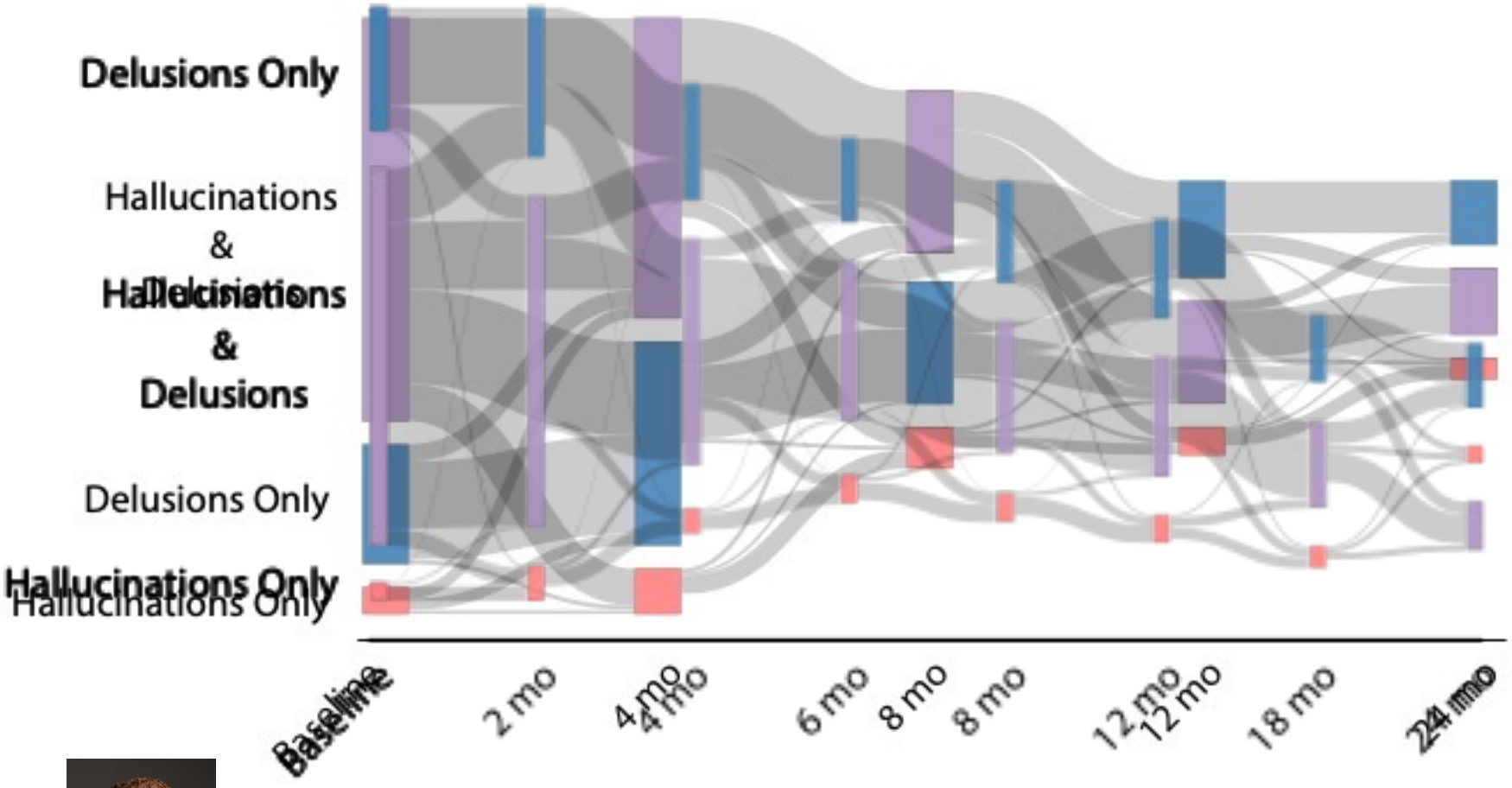
Risk Factors for Psychosis: Cannabis Use

Tori Fisher

Fisher & Hammer et al. (in prep)

NAPLS 3

N = 710 subjects with CHR-P



Catalina Mourgues

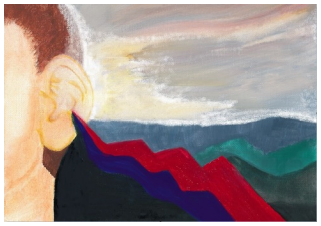
Mourgues et al. (in prep)

Computation as Translation

Clinical Presentation

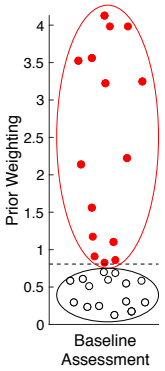
Mechanism

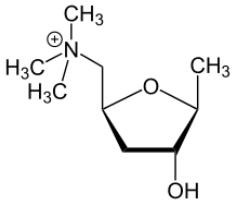
Etiology



Hallucinations

(Relative) Prior Precision





1º Hyper-precision?

2º (Compensatory) Hyper-precision?

Genetic High Risk
Risk Factors for Psychosis
Hallucination Development in Other Disorders

Thank You
Klaas Enno Stephan
Team TNU
CPC Zürich

Powers Lab

- Catalina Mourgues
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- Drew Sheldon
- David Benrimoh
- Elizabeth Aslinger
- Rashina Seabury
- Henrique Oliva

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- Brain & Behavior Research Foundation
- Yale Department of Psychiatry
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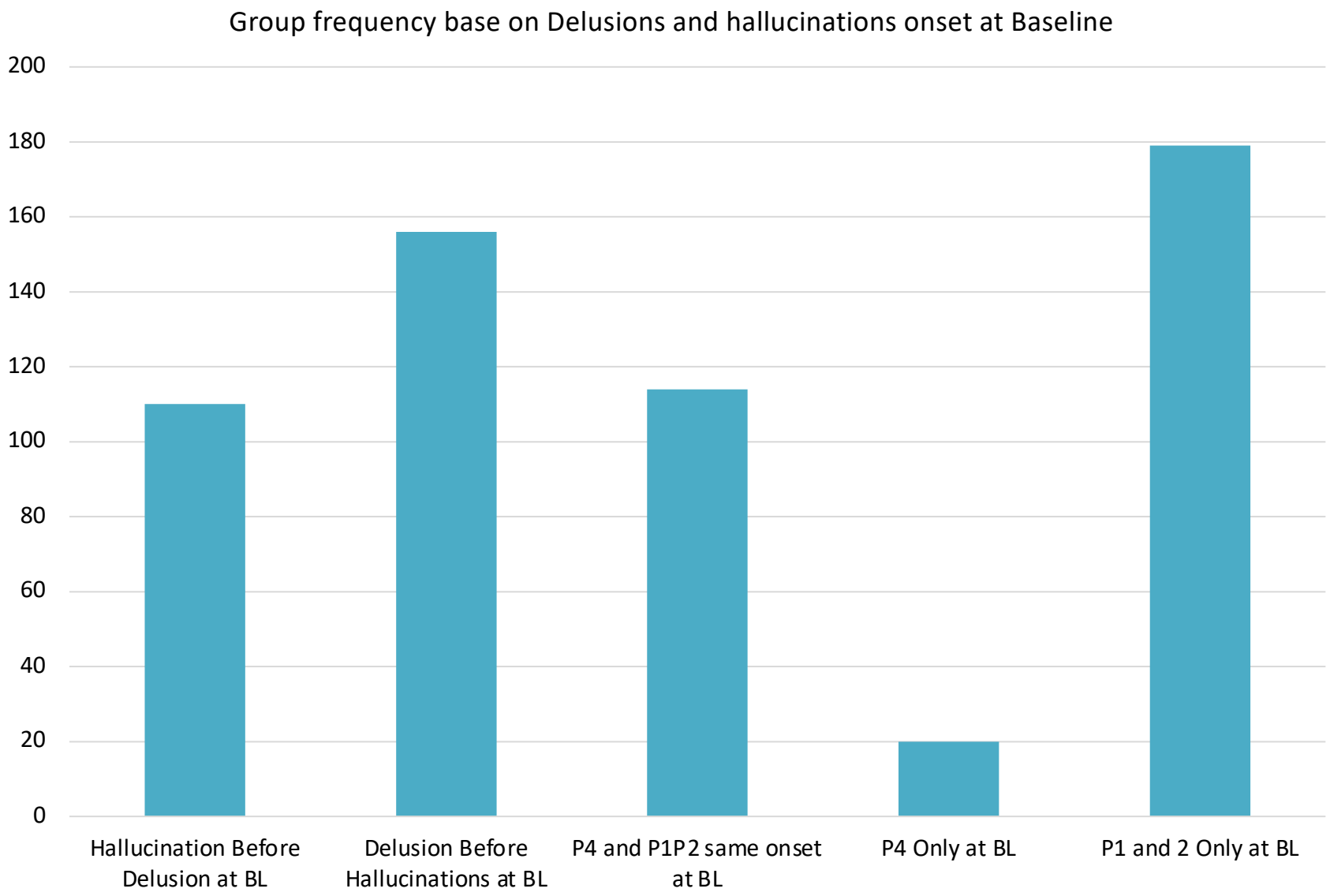
- Burroughs-Wellcome Fund (CAMS)
- Ludwig Family Foundation


Group frequency base on Delusions and hallucinations onset at Baseline
200
180
160
140
120
100
80
60
40
20
0
Hallucination Before Delusion at BL
Delusion Before Hallucinations at BL
P4 and P1P2 same onset at BL
P4 Only at BL
P1 and 2 Only at BL