JEANNE CARON GUYON
PI. Anne Kavounoudias – Nicolas Catz
Jean-Luc Anton, Bruno Nazarian, Julien Sein
Laurent Perrinet

How is multisensory motion encoded in the brain ?

FINDING NEURAL « POETRY IN MOTION »

Background Rationale

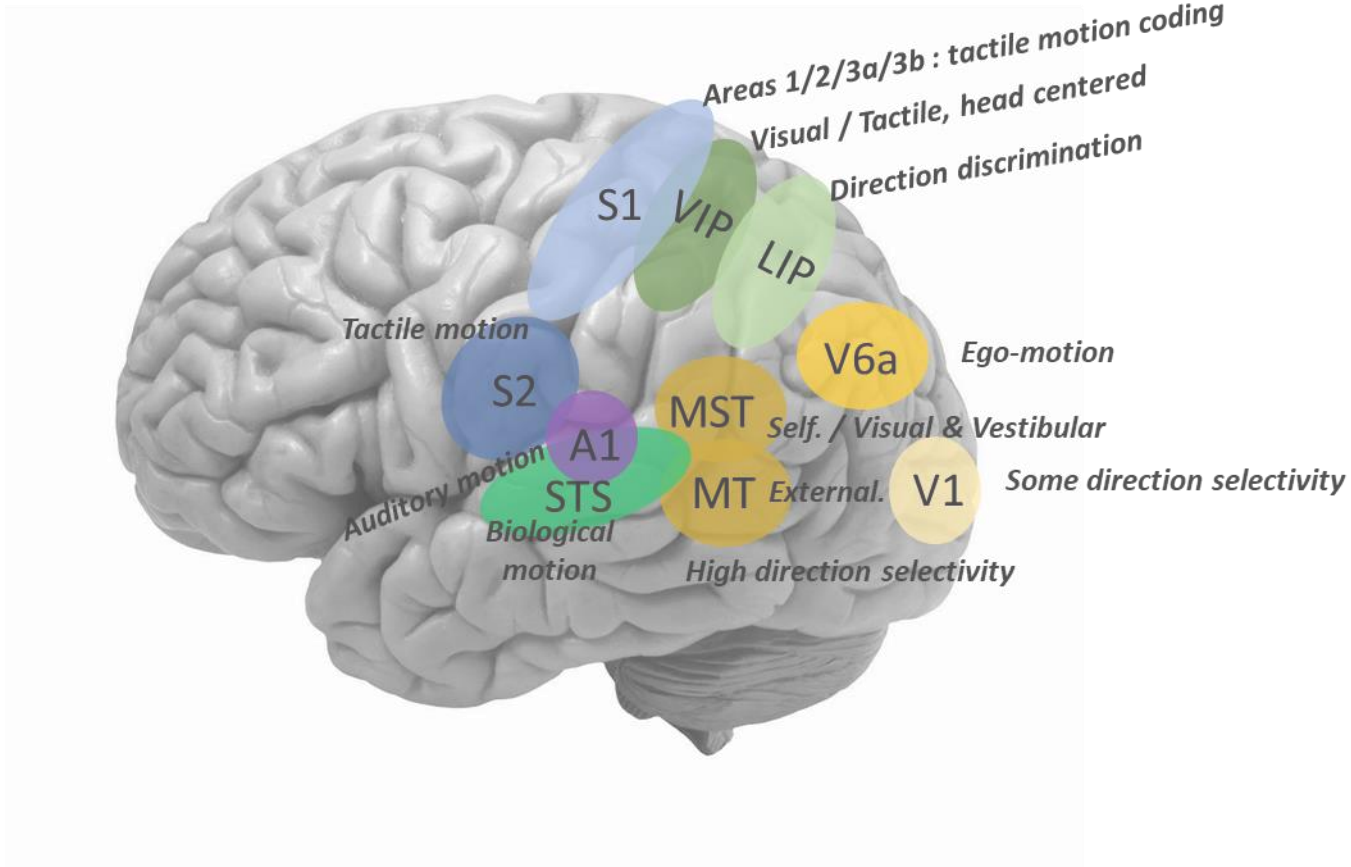
... Motion is most frequently multisensory

... Integrating information from the different senses

→ enhancing and precising perception

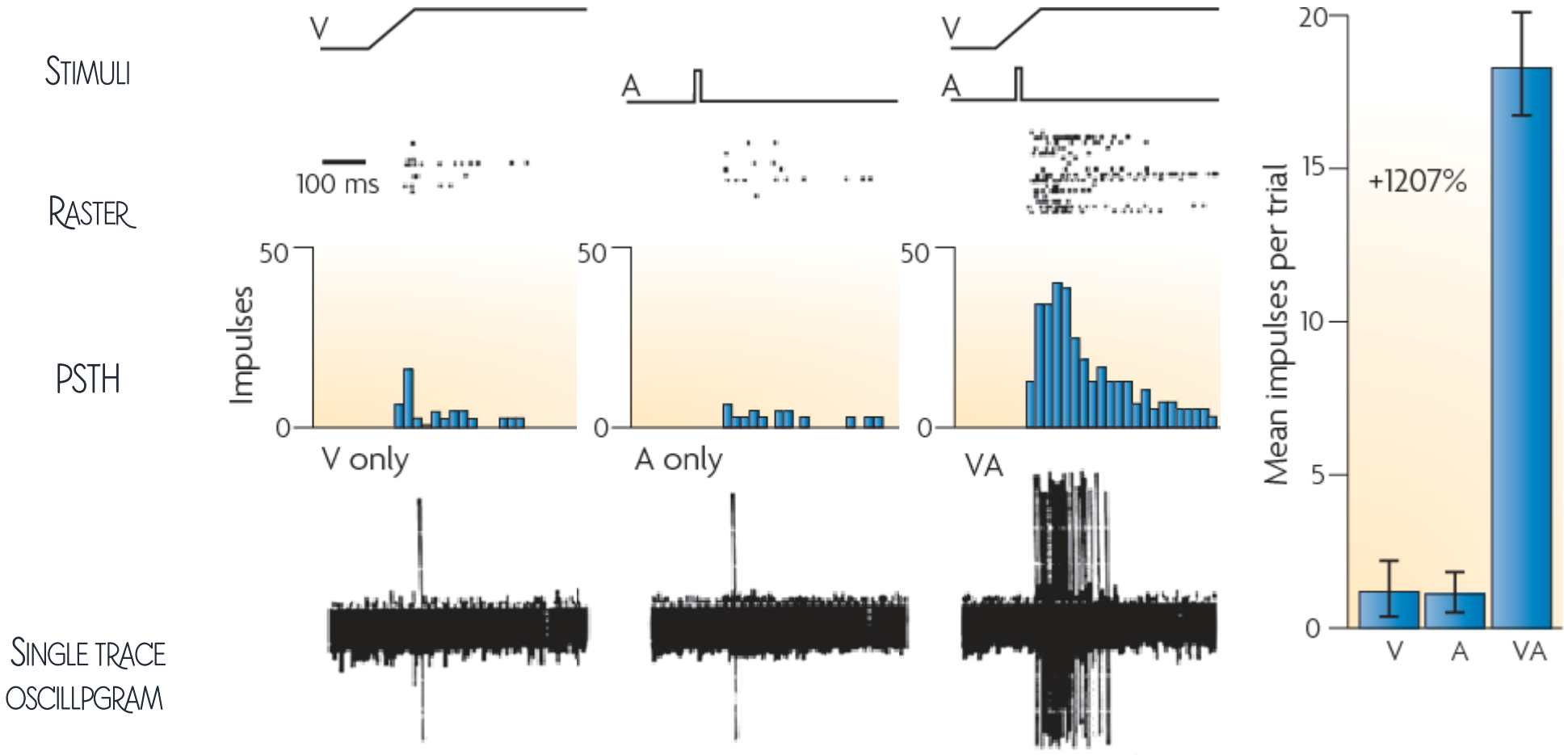
... Multisensory integration is the combination of two or more senses to form a new product

Background Rationale



CLASSICAL ANALYTICAL APPROACHES

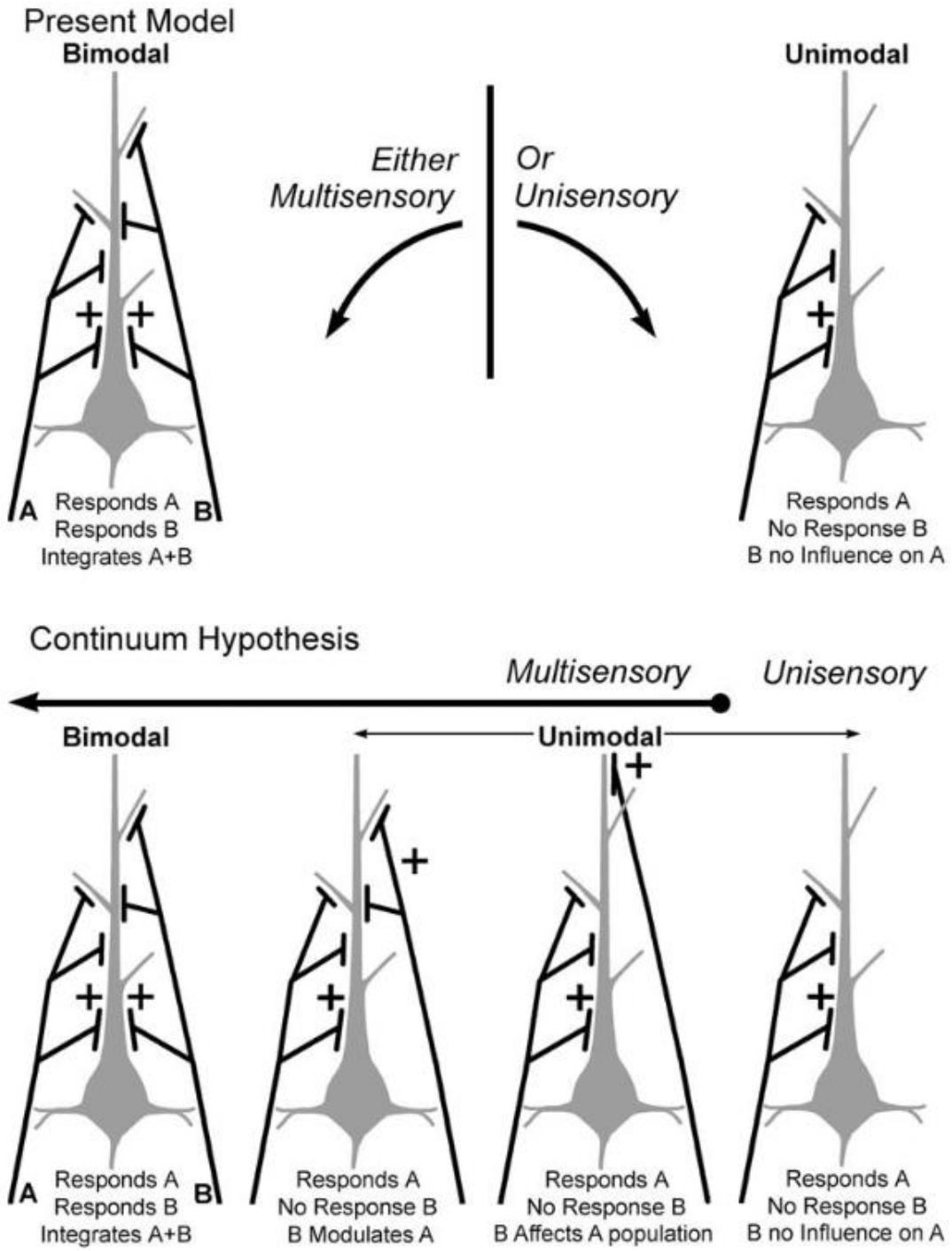
WHAT ARE THE CLASSICAL ANALYTICAL APPROACHES FOR MULITSENSORY INTEGRATION ?



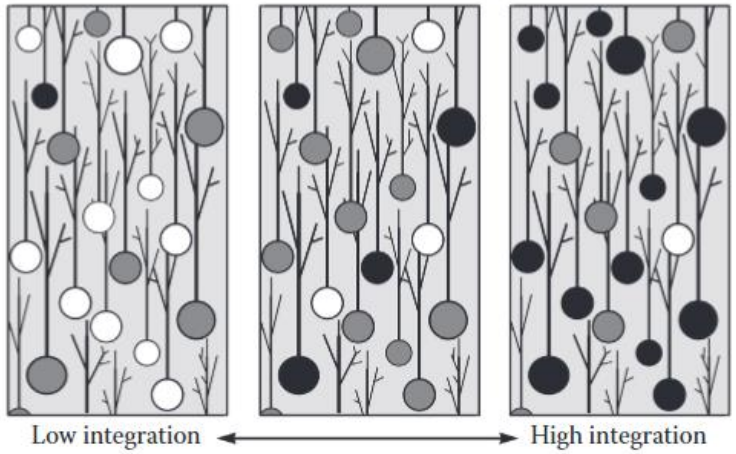
Enhancement of the response (↑)
which is super-additive (> than V+A)

Stein and Stanford, 2008
Original work : Meredith and Stein, 1986

CLASSICAL ANALYTICAL APPROACHES



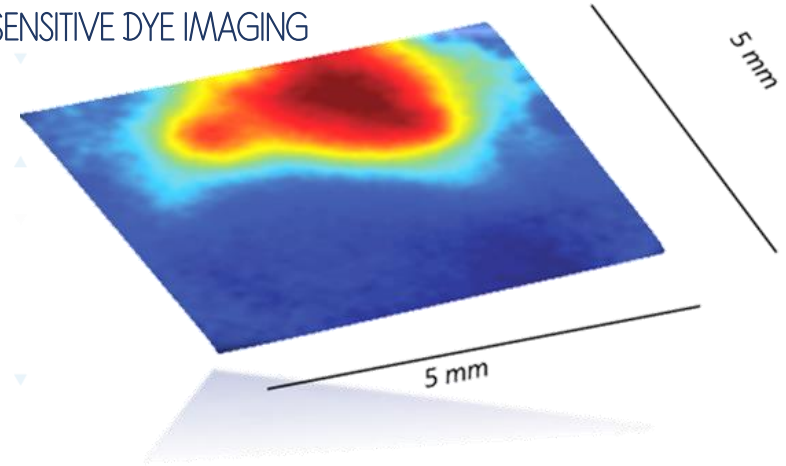
Allman et al., 2009



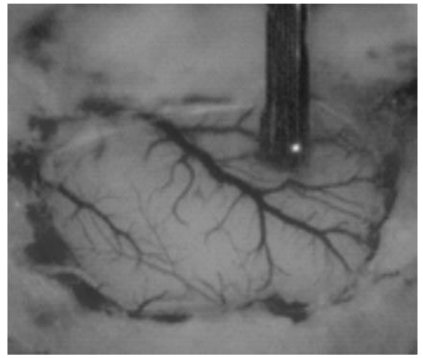
Meredith et al., 2012

Experimental Design

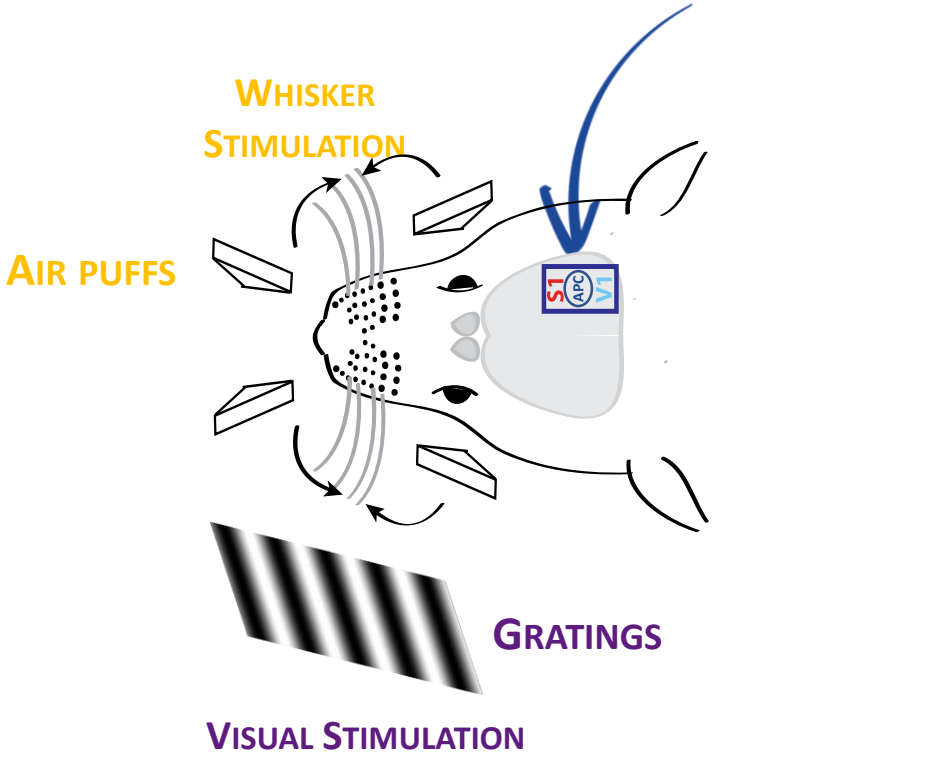
Voltage sensitive dye imaging



Extracellular Electrophysiological recordings

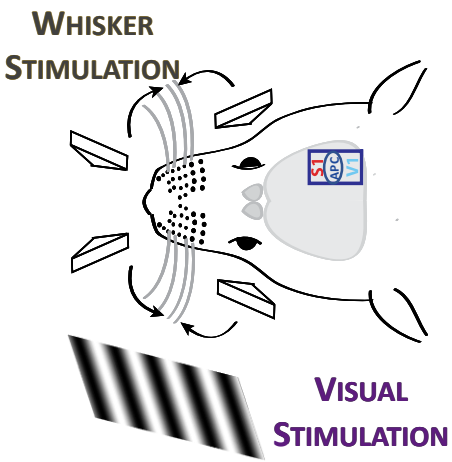


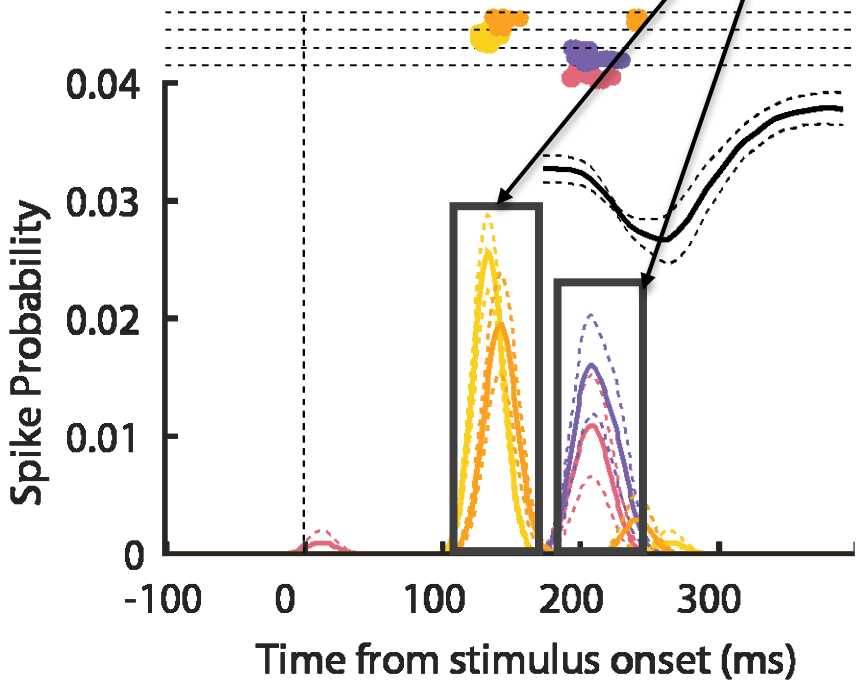
Associative parietal cortex



Caron-Guyon et al., 2019
https://dx.doi.org/10.2139/ssrn.3377643

Analytical Approaches





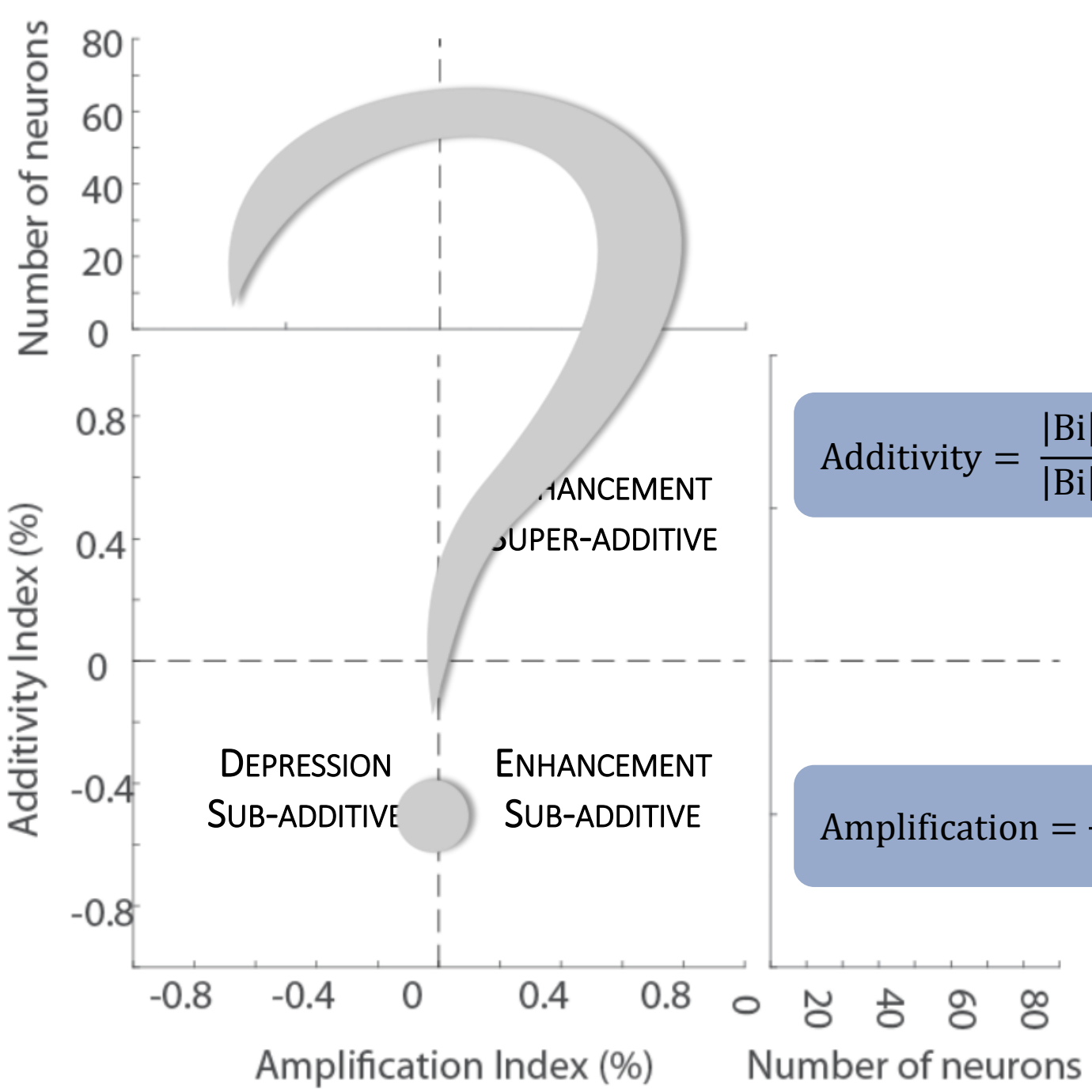
Response latency difference for the two sensory modalities

↓

Classical analyses not adapted

Caron-Guyon et al., 2019
https://dx.doi.org/10.2139/ssrn.3377643

Classical Approaches

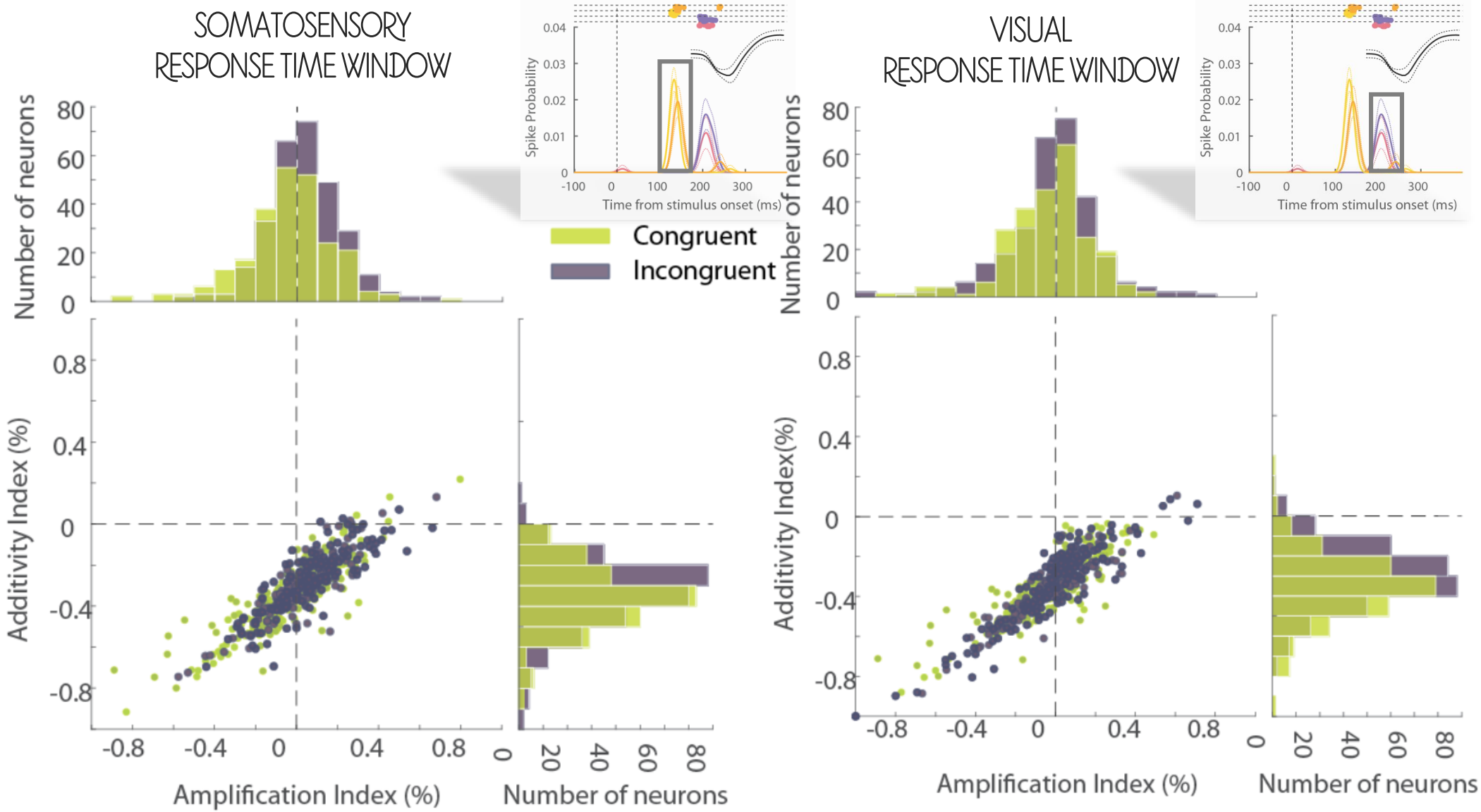


$$\text{Additivity} = \frac{|\text{Bi}| - (|\text{V}| + |\text{T}|)}{|\text{Bi}| + (|\text{V}| + |\text{T}|)} \times 100$$

$$\text{Amplification} = \frac{|\text{Bi}| - |\text{Unimax}|}{|\text{Bi}| + |\text{Unimax}|} \times 100$$

Caron-Guyon et al., 2019
https://dx.doi.org/10.2139/ssrn.3377643

Classical Approaches



Caron-Guyon et al., 2019
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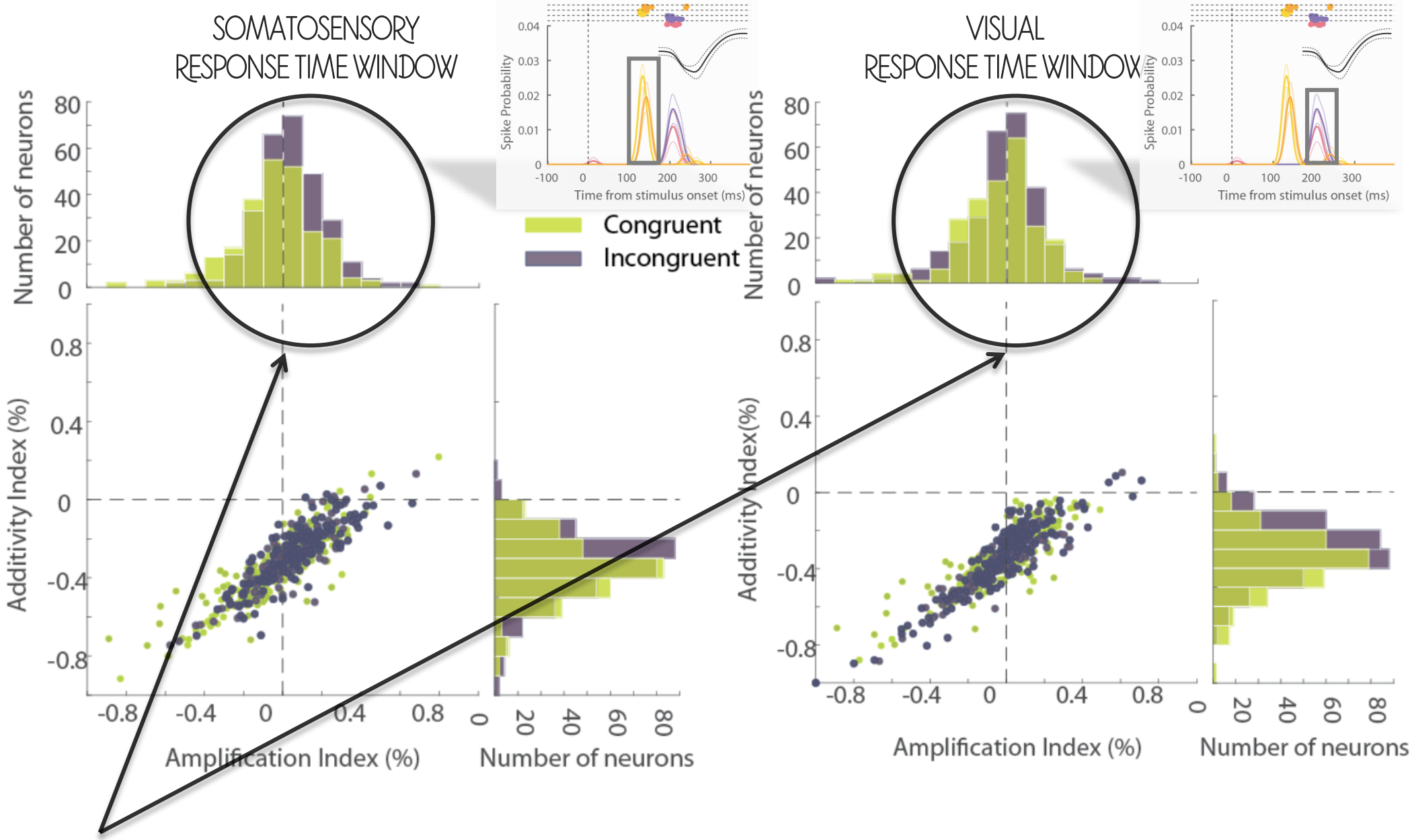
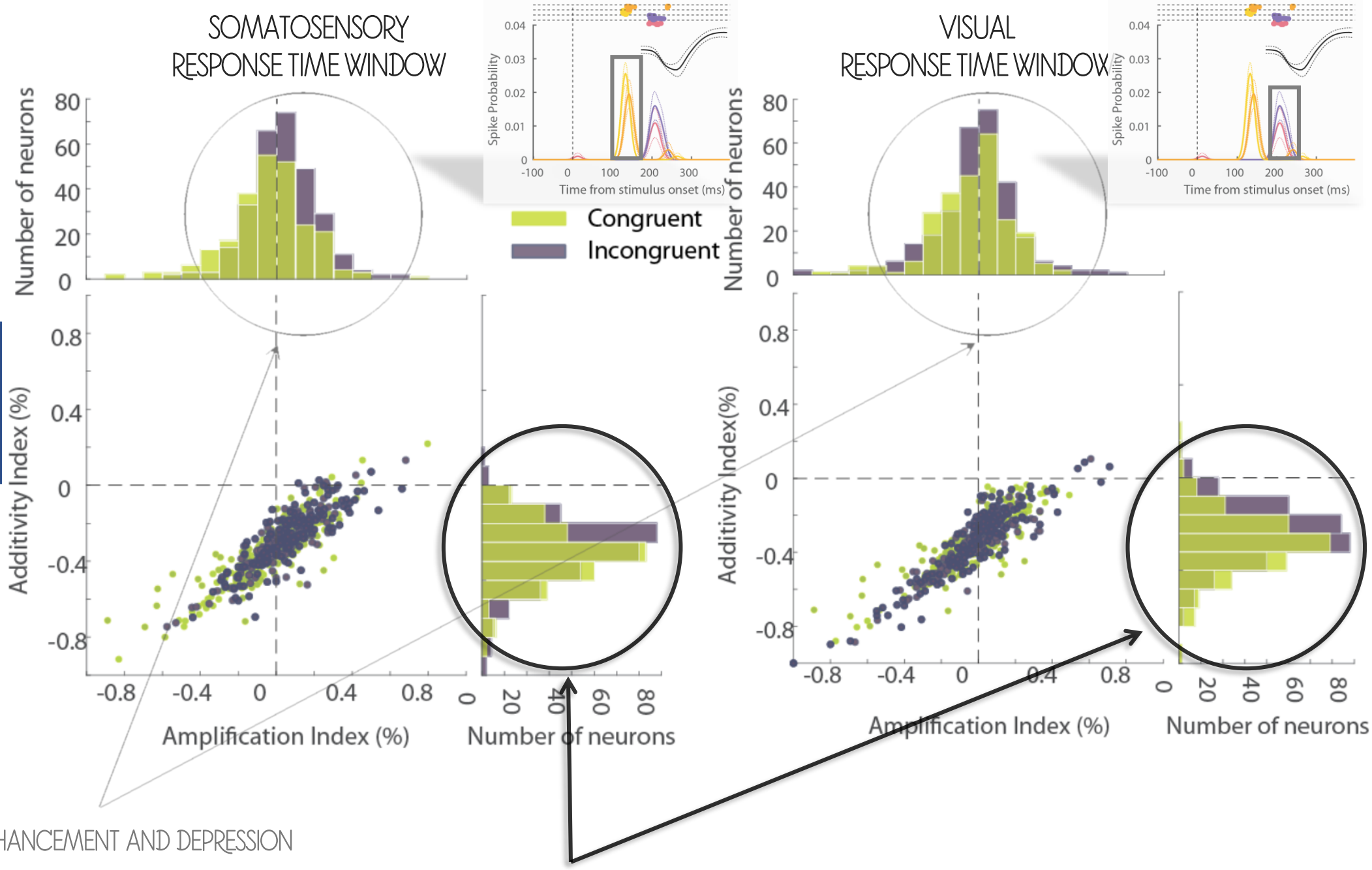
Classical Approaches



Both enhancement and depression

Caron-Guyon et al., 2019
https://dx.doi.org/10.2139/ssrn.3377643

Classical Approaches



Both enhancement and depression

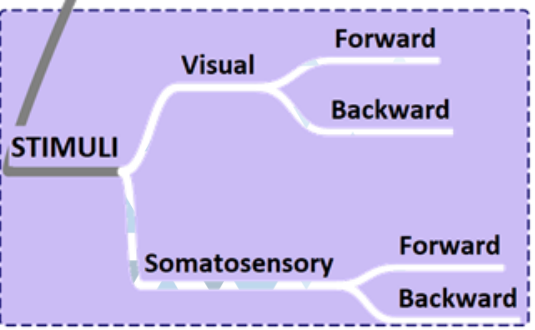
Mainly sub additive

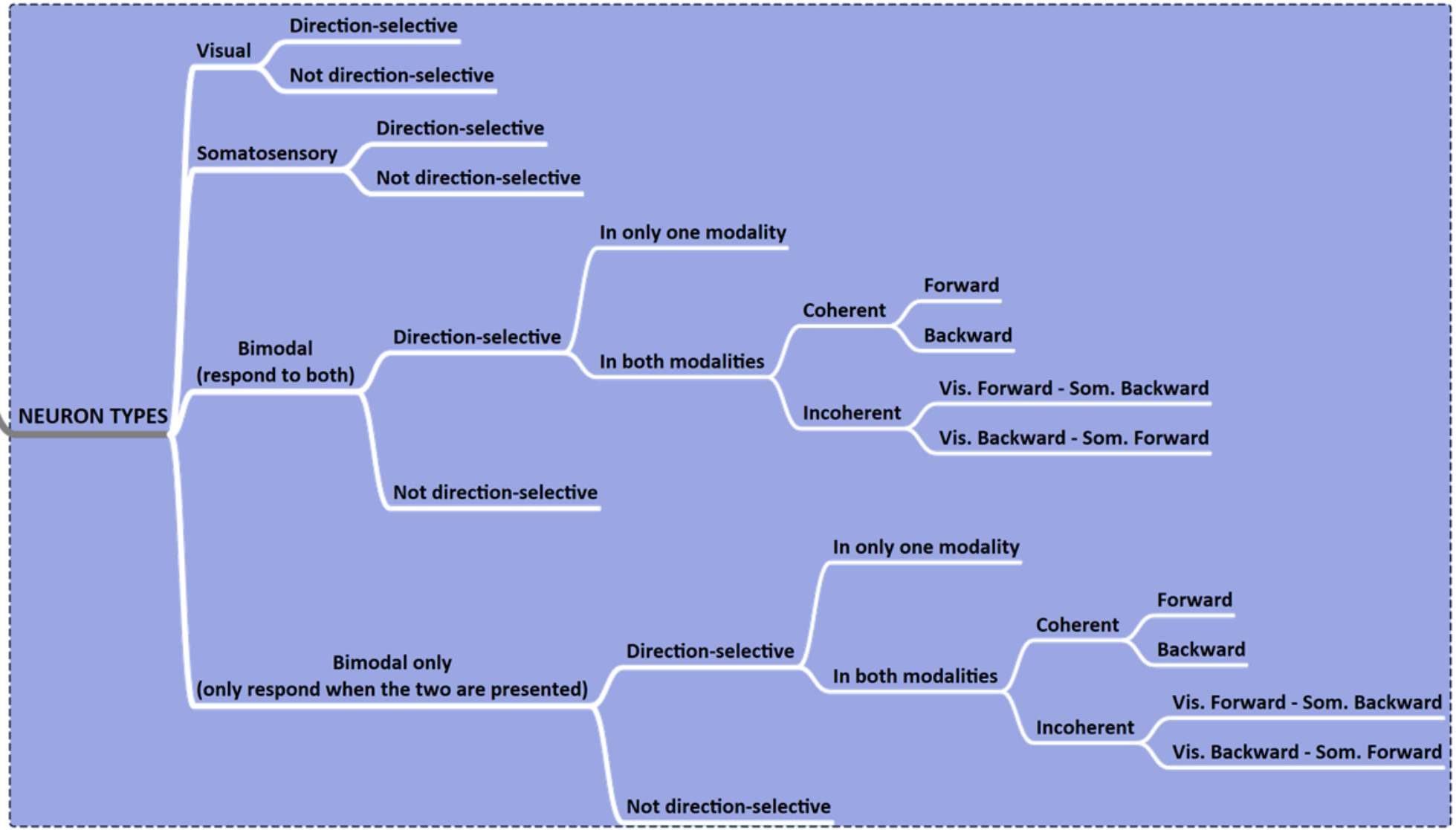
Caron-Guyon et al., 2019
https://dx.doi.org/10.2139/ssrn.3377643

A GLANCE AT THE COMPLEXITY OF IT ALL...

2 MAIN FACTORS : STIMULI & NEURON TYPES, WITH THEIR OWN SUB-CATEGORIES

NEURONAL ACTIVITY IN THE ASSOCIATIVE PARIETAL CORTEX





A GLANCE AT THE COMPLEXITY OF IT ALL…

2 MAIN FACTORS : STIMULI & NEURON TYPES, WITH THEIR OWN SUB-CATEGORIES

WHICH CATEGORY « MAKES SENSE » FOR THE NEURONS ?

… STILL UNANSWERED

frontiers in NEUROINFORMATICS

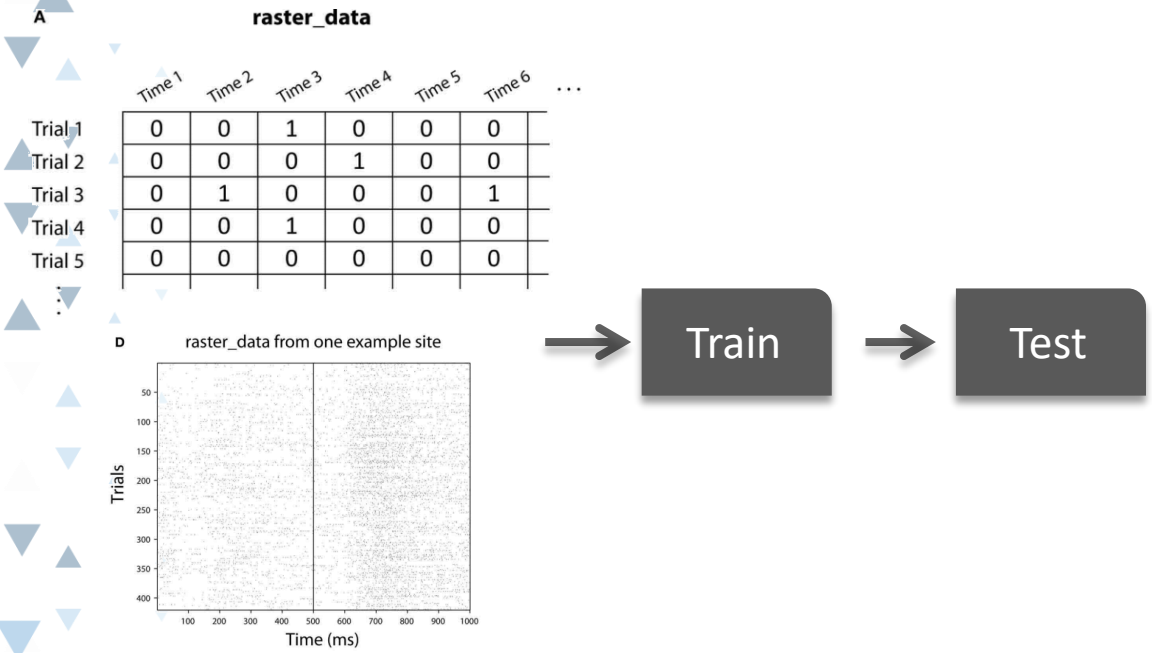
METHODS ARTICLE
published: 22 May 2013
doi: 10.3389/fninf.2013.00008

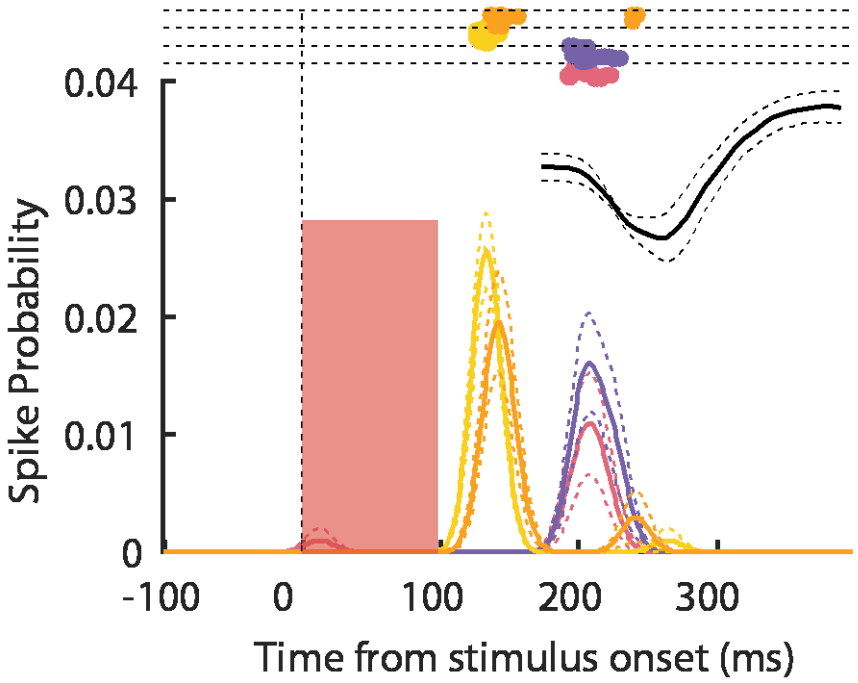
The neural decoding toolbox

Ethan M. Meyers*

Department of Brain and Cognitive Sciences, McGovern Institute, Massachusetts Institute of Technology, Cambridge, MA, USA

Decoding Approach





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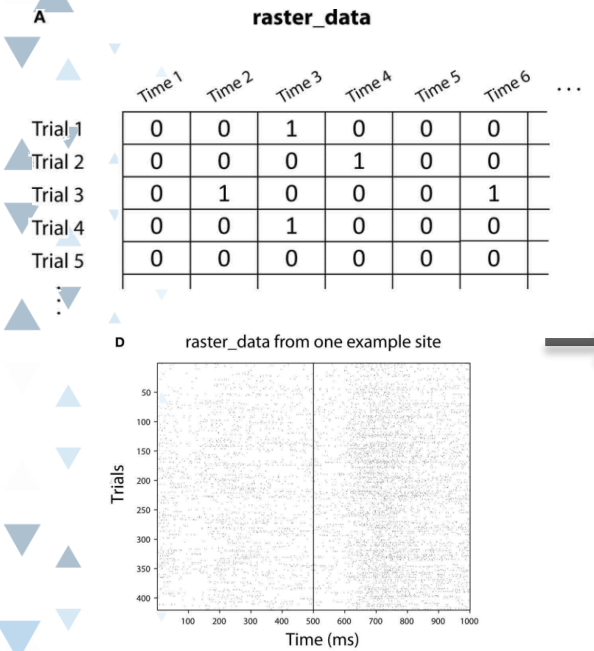
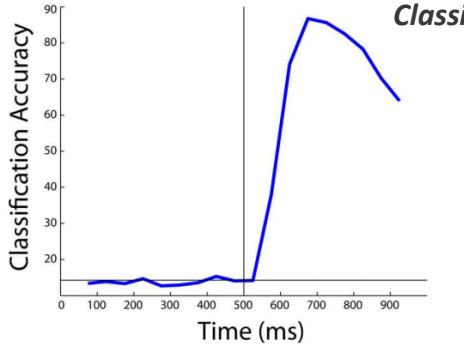
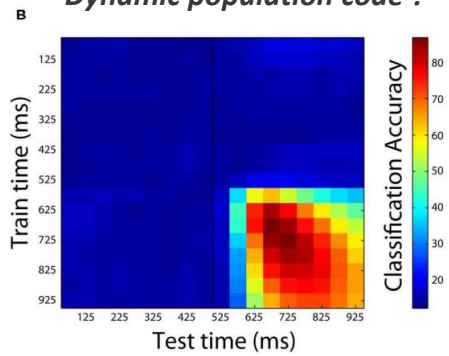


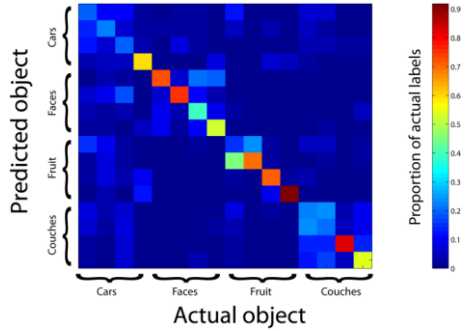
Train → Test → Results

Classification accuracy over time



Dynamic population code ?

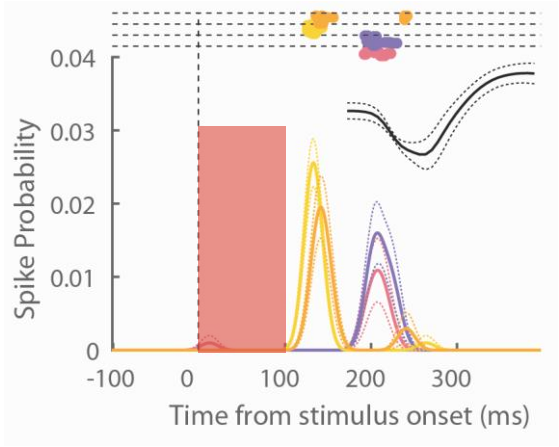




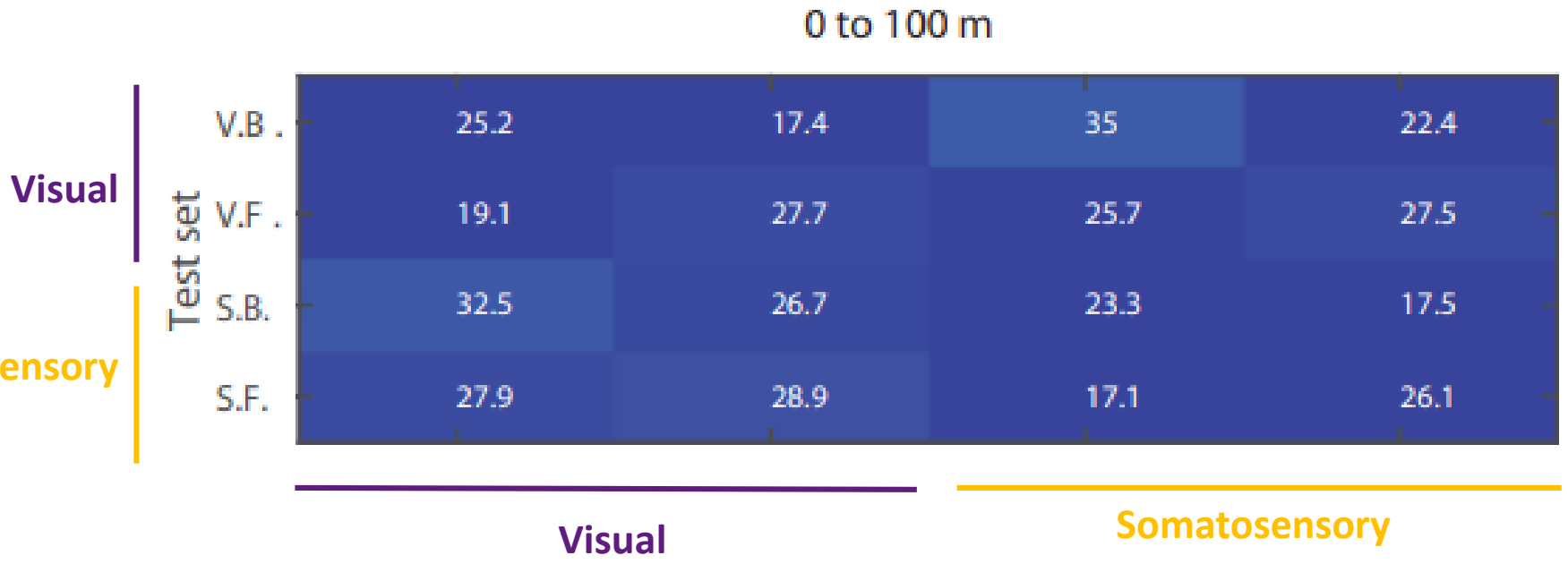
Confusion matrices

ARE SENSORY MODALITY AND DIRECTION OF THE STIMULUS ENCODED ?

Sensory modality and Motion direction coding ?



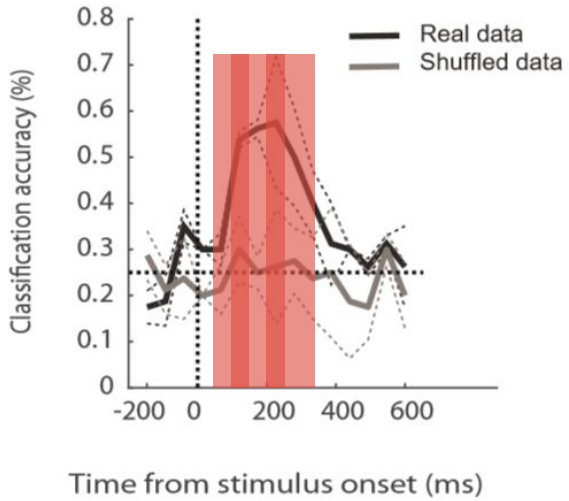
Decoding Results



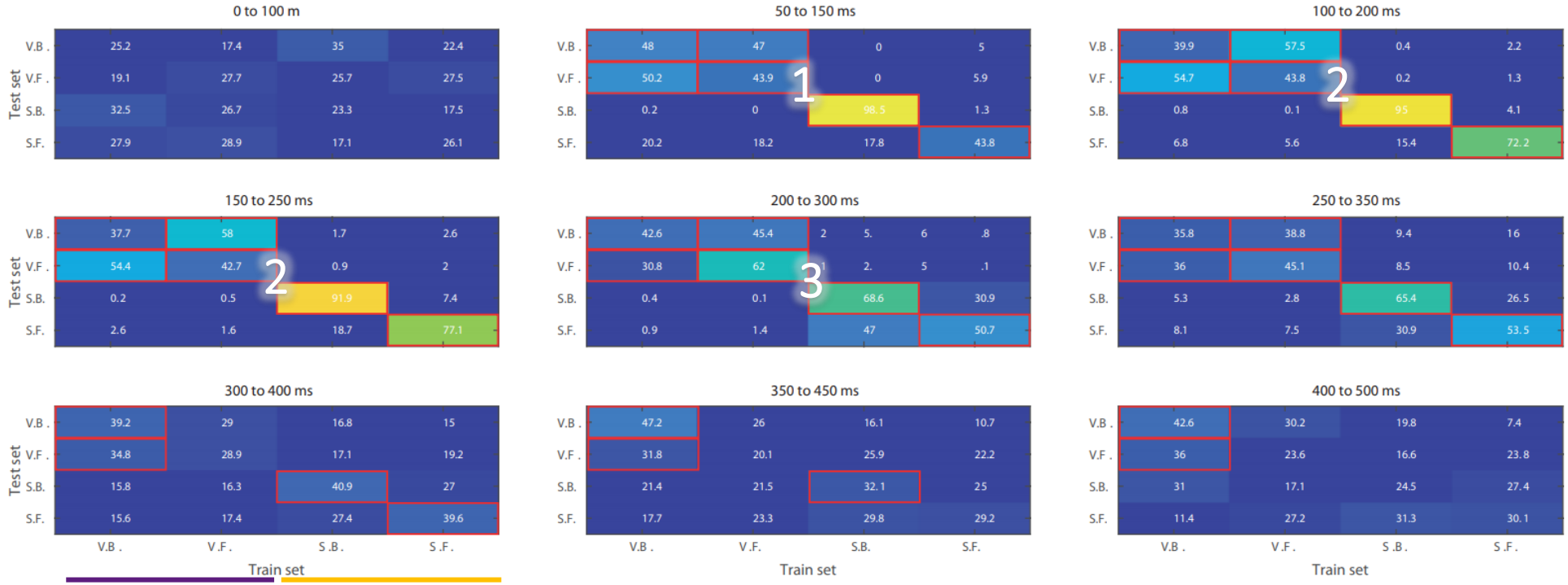
Caron-Guyon et al., 2019
https://dx.doi.org/10.2139/ssrn.3377643

Sensory modality and Motion direction coding ?

Decoding Results



1. **Decodes the modality (50-150ms)**
2. **Also decodes the somatosensory direction (100-250)**
3. **Also decodes the visual direction (200-300ms)**



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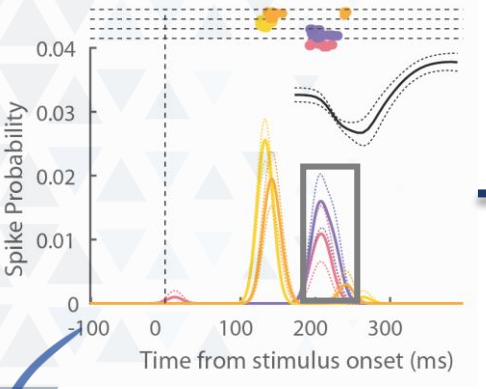
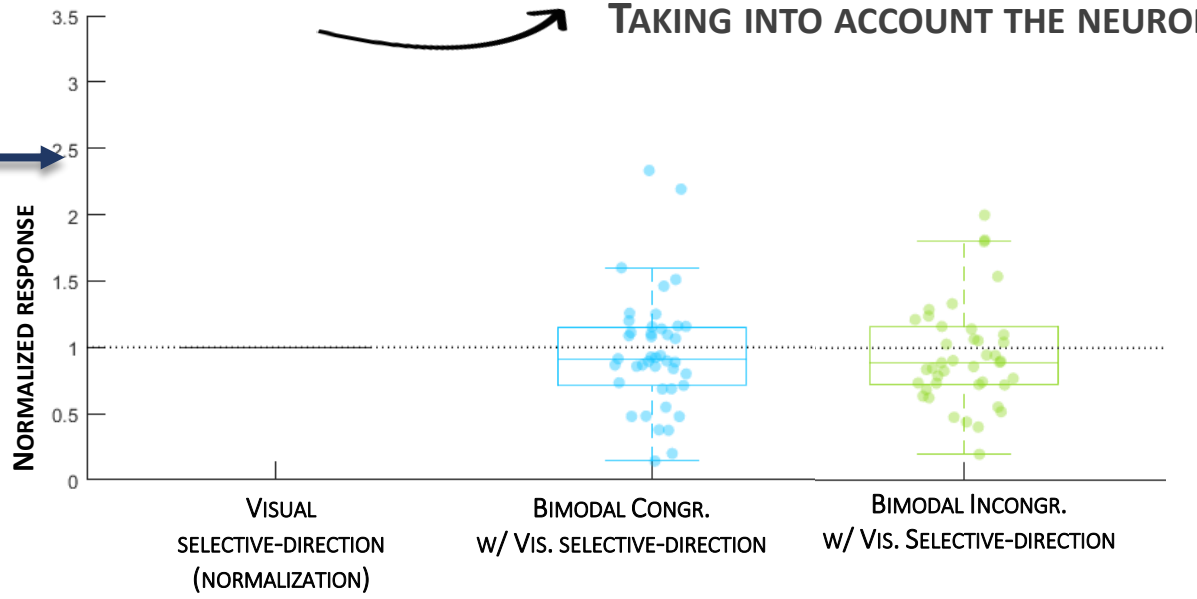
MULTISENSORY DIRECTION CONGRUENCY CODING ?



(NOT SO)–CLASSICAL APPROACHES VS. DECODING

TAKING INTO ACCOUNT THE NEURONS' DIRECTION SELECTIVITY



MULTISENSORY INTEGRATION ?

Caron-Guyon et al., 2019
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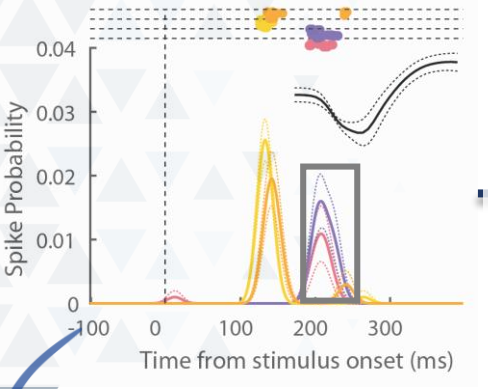

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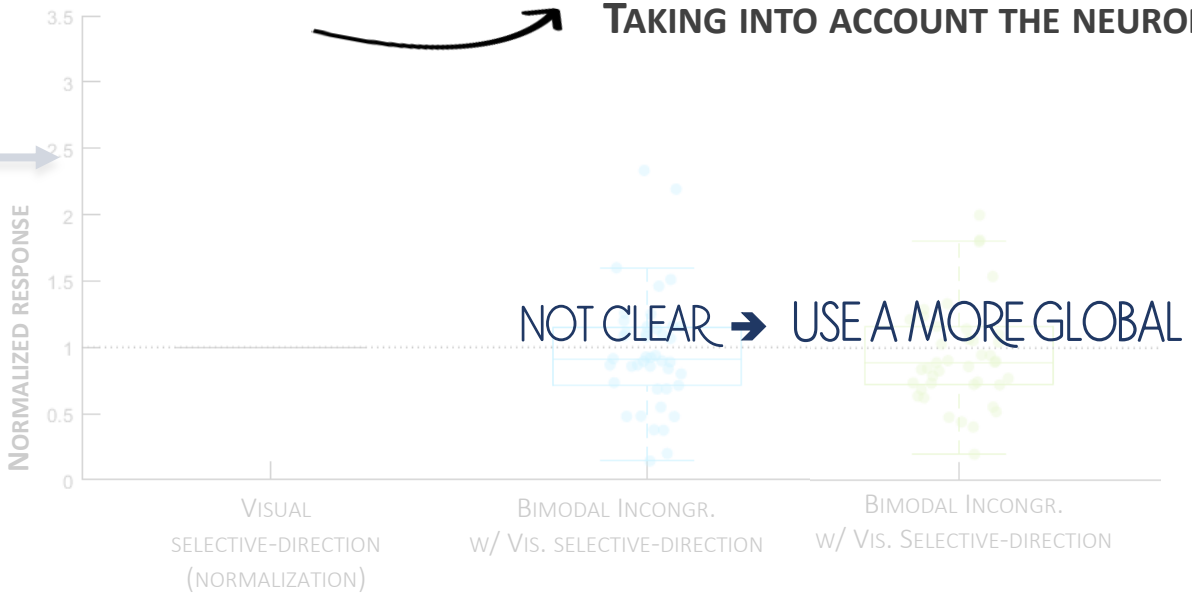


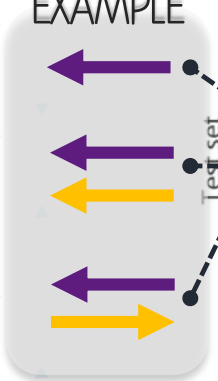
MULTISENSORY INTEGRATION ?

NOT CLEAR → USE A MORE GLOBAL ANALYTICAL FRAMEWORK

Multisensory decoding due to the difference in somatosensory direction

MULTISENSORY CONGRUENCY DECODING

EXAMPLE



VISUAL PREFERRED DIRECTION

B

50-150 ms

Test set \ Train set	Visual	Congr.	Incongr.
Visual	55.05	23.85	21.1
Congruent	24.75	55.25	20
Incongruent	20	24.15	55.85

Somatosensory response time window

100 - 200 ms

	Visual	Congr.	Incongr.
Vis.	54.2	18.9	26.9
Congr.	21.9	39.95	38.15
Incongr.	22.8	35.75	41.45

150 - 250 ms

	Visual	Congr.	Incongr.
Vis.	50.05	26	23.95
Congr.	25.85	59.25	14.9
Incongr.	17.4	16.1	66.5

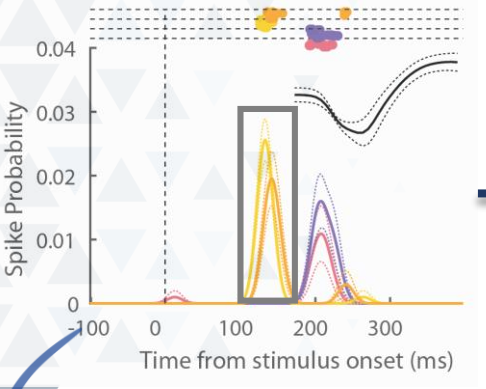
Visual response time window

200 - 300 ms

	Visual	Congr.	Incongr.
Vis.	48.8	29.3	21.9
Congr.	26.95	39.1	33.95
Incongr.	18.7	33.4	47.9

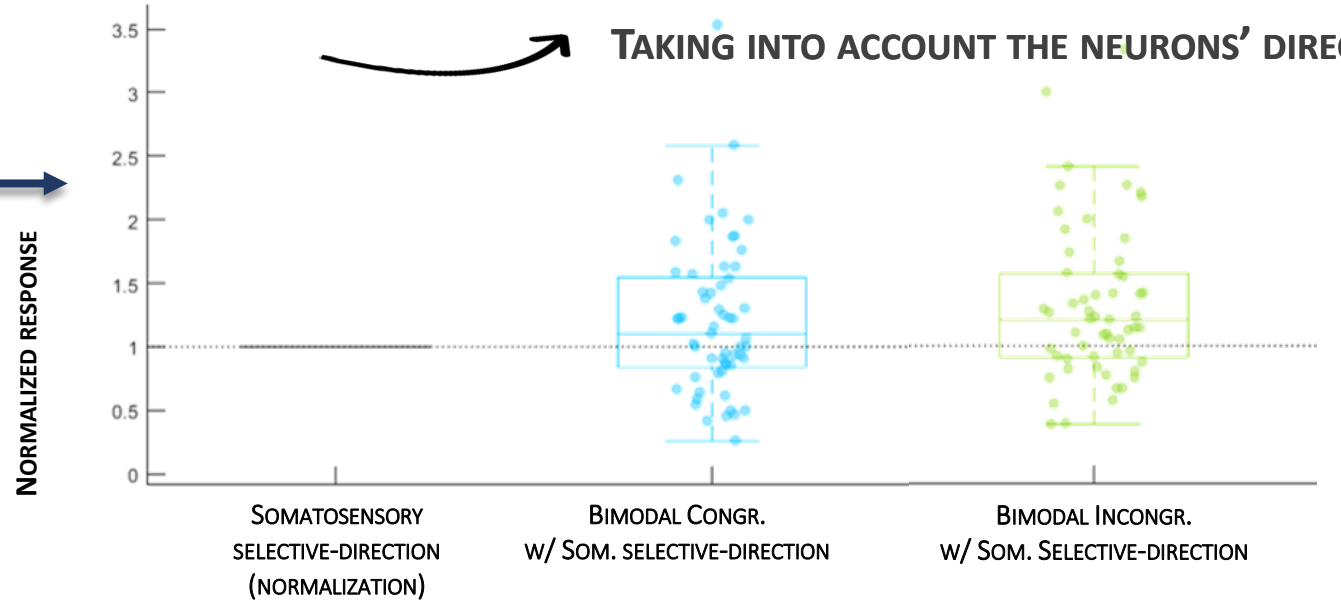
Train set

Caron-Guyon et al., 2019
https://dx.doi.org/10.2139/ssrn.3377643



(NOT SO)–CLASSICAL APPROACHES VS. DECODING

TAKING INTO ACCOUNT THE NEURONS' DIRECTION SELECTIVITY



MULTISENSORY INTEGRATION ?

Multisensory decoding due to the difference in visual direction

E

SOMATOSENSORY PREFERRED DIRECTION

50-150 ms

	Somat.	Congr.	Incongr.
Somat.	32.5	33.65	33.85
Congruent	35.4	29.8	34.8
Incongruent	37.4	31.8	30.8

Somat. Congr. Incongr. — Train set

100 - 200 ms

	Somat.	Congr.	Incongr.
Somat.	39.9	27.9	32.2
Congr.	32	35.8	32.2
Incongr.	37.15	33.85	29

Somat. Congr. Incongr. — Train set

150 - 250 ms

	Somat.	Congr.	Incongr.
Somat.	70.75	20.05	9.2
Congr.	26.2	40.45	33.35
Incongr.	15.65	27.5	56.85

Somat. Congr. Incongr. — Train set

200 - 300 ms

	Somat.	Congr.	Incongr.
Somat.	73.65	14.4	11.95
Congr.	23.2	31.85	44.95
Incongr.	17.15	41.8	41.05

Somat. Congr. Incongr. — Train set

Somatosensory response time window

Visual response time window

Caron-Guyon et al., 2019
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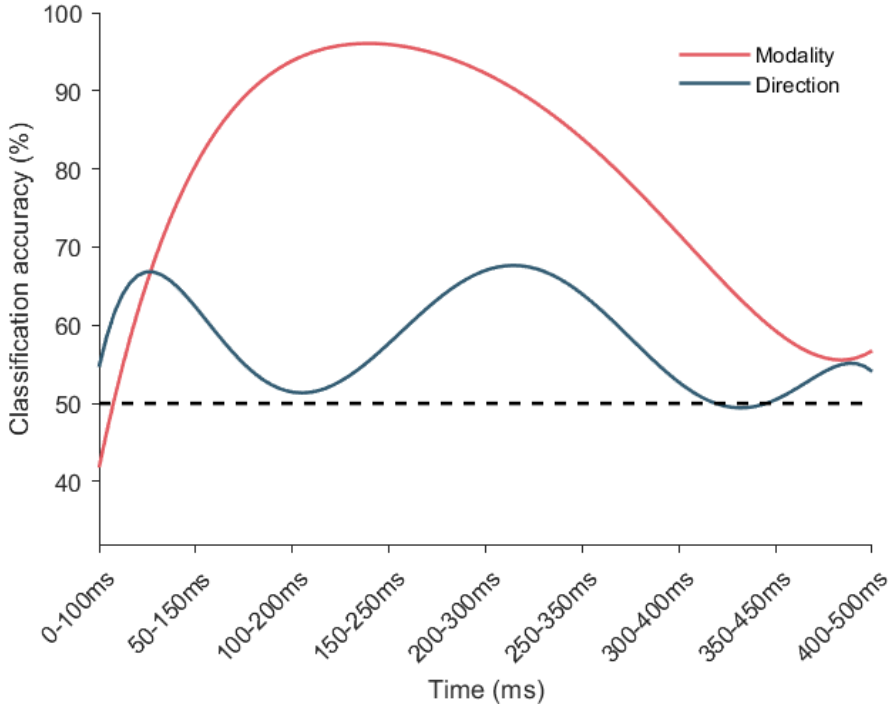
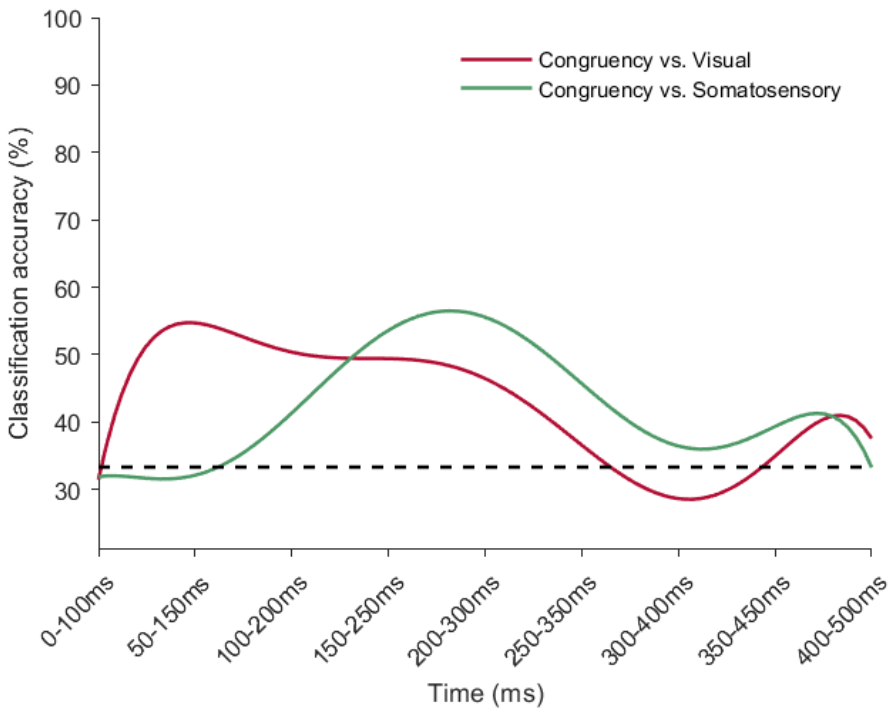
Decoding
So what?

Modality and Direction



Congruency vs. Prefered unimodal direction



- ⮡ There are differences in the signal that are sufficient for the algorithm to decode : motion direction, sensory modality, and motion direction congruency.
- ⮡ APC is a multisensory integrative motion-processing area
- ⟲ However : does not tell us which neuron category contributes most to that decoding

Caron-Guyon et al., 2019
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WHY DECODING ?

UNIVARIATE ANALYSIS CAVEAT

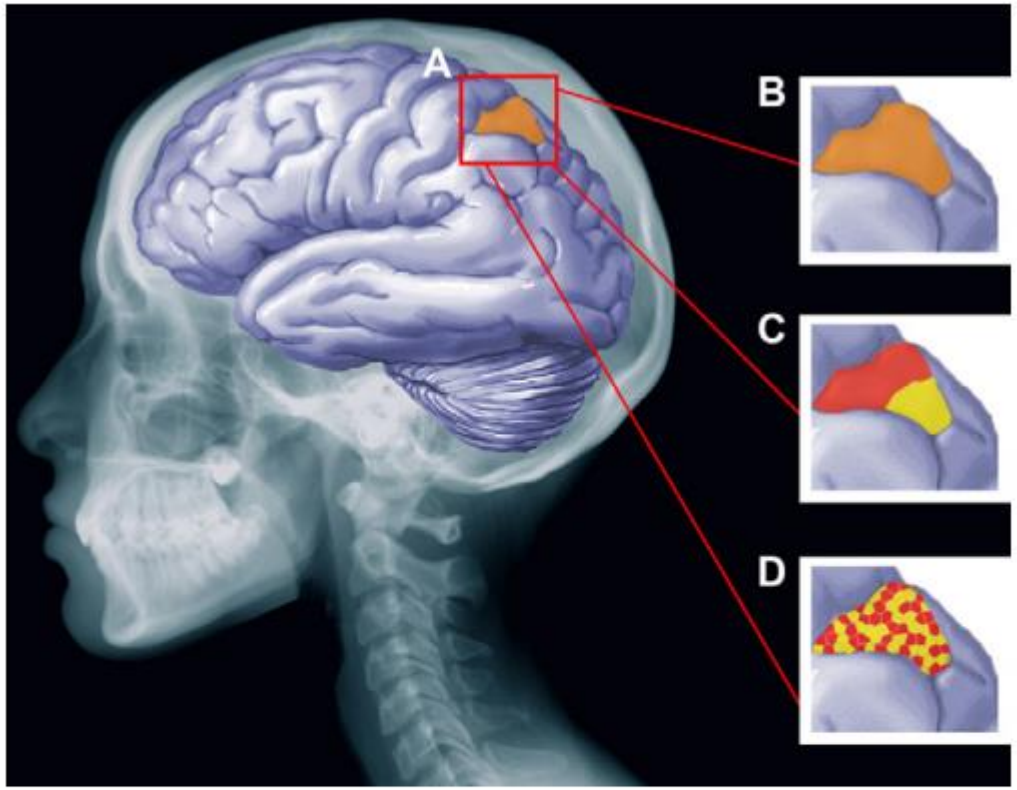


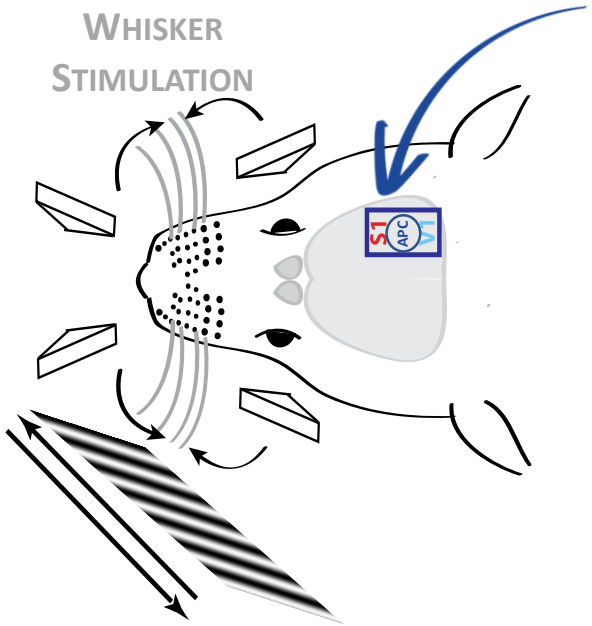
Fig. 1. Different causes of presumed supramodal activation. (A) Stimulating either sensory modality A, sensory modality B, or both modalities results in the observation of a common brain activation using fMRI. (B) The observed activity could be caused by activation of a truly supramodal brain area. (C) Alternative 1: area X and area Y are functionally distinct, but lie in such close spatial proximity that conventional univariate fMRI analysis cannot distinguish between areas X and Y. Both areas co-activate each other, however, the co-activated area does not perform any functionally *necessary* processing. (D) Alternative 2: small, functionally distinct neural populations, which are spatially intermingled, may also be mistaken for homogenous supramodal activation.

Klemen & Chambers, 2012

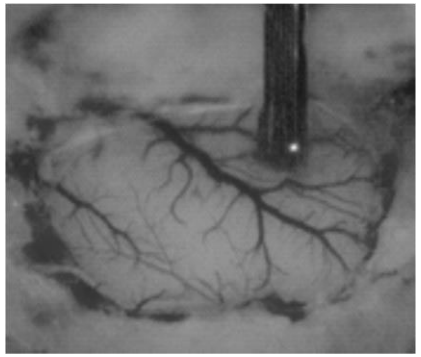
SOLUTION

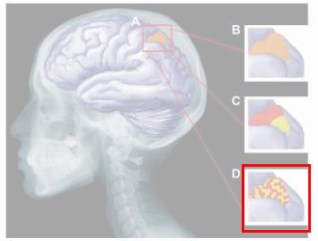
MULTIVARIATE PATTERN ANALYSIS

How does it work at the level of neurons in the associative parietal cortex ?



Associative parietal cortex



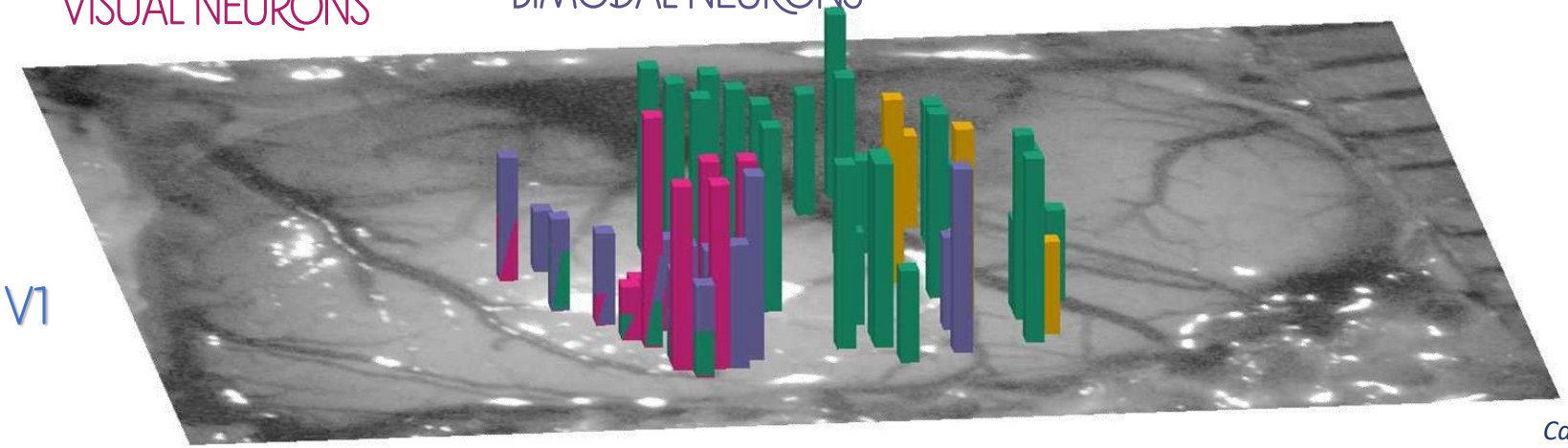


Integrative neurons

Visual neurons

Bimodal neurons

Somatosensory neurons



Caron-Guyon et al., 2019
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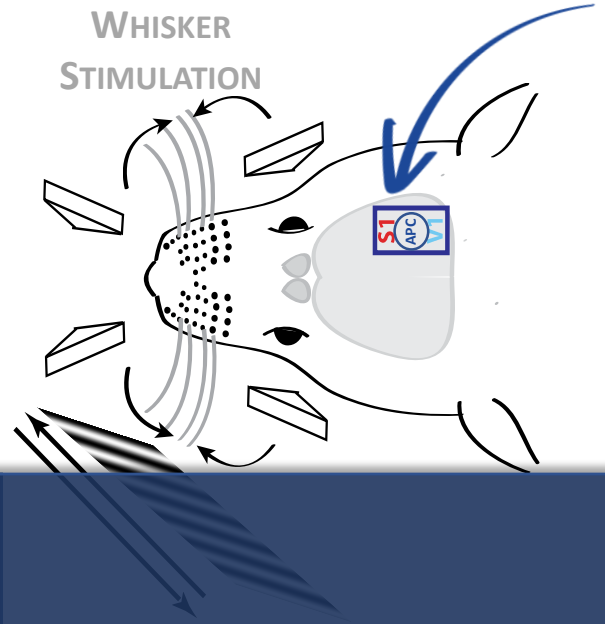
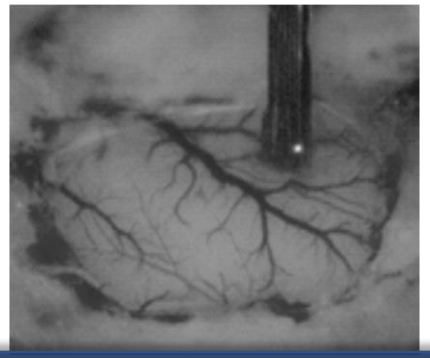
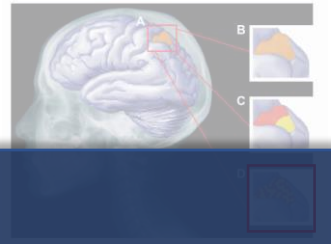
Whisker Stimulation



Visual Stimulation

Associative Parietal Cortex





How does it work at the level of neurons in the associative parietal cortex ?

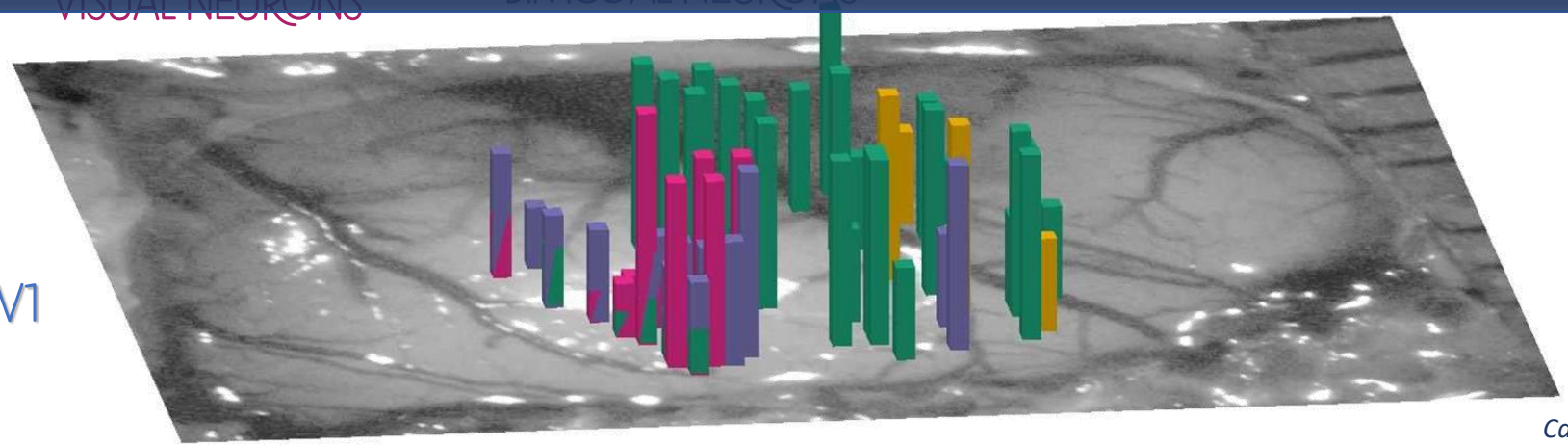
Distributed populations across the area

Integrative neurons

Somatosensory neurons

Visual neurons

Bimodal neurons



V1

S1

Caron-Guyon et al., 2019
https://dx.doi.org/10.2139/ssrn.3377643

Decoding Approaches

CATEGORIES

Leftward motion

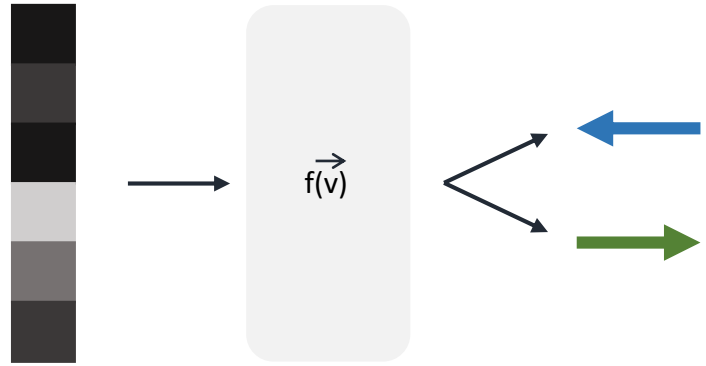
Rightward motion

SIGNAL

VOXELS

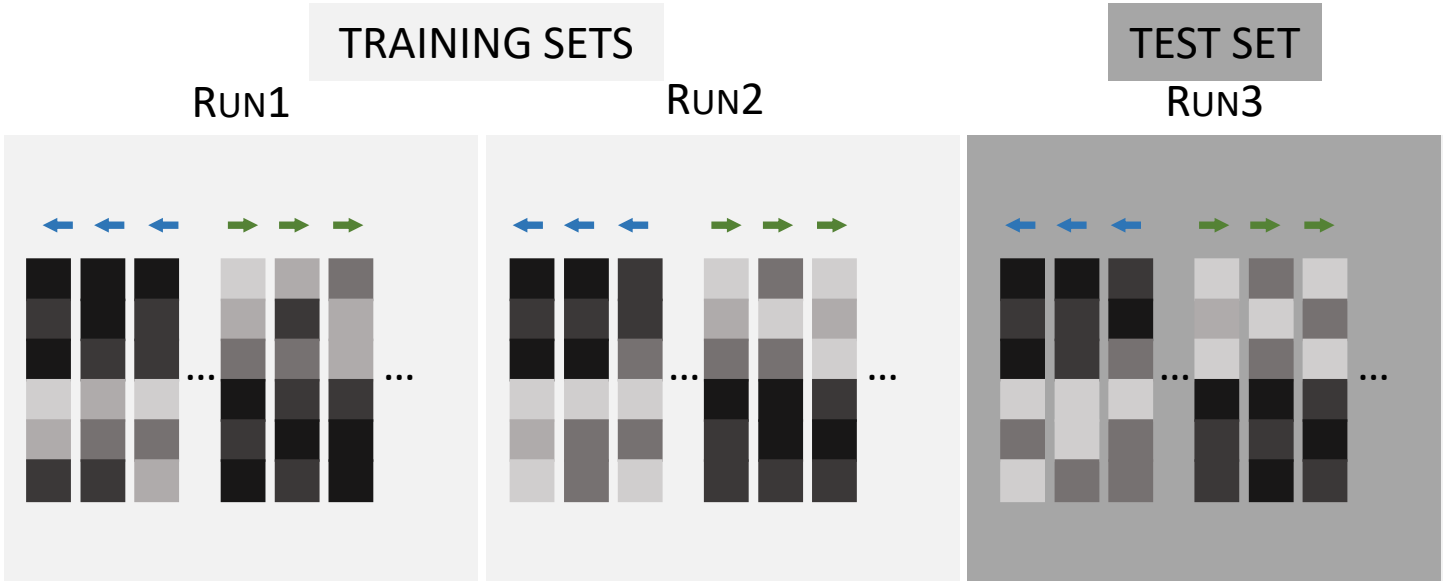
Learns in which direction the stimulus was going. Here : left.

Decoding



Input — Classification — Decision

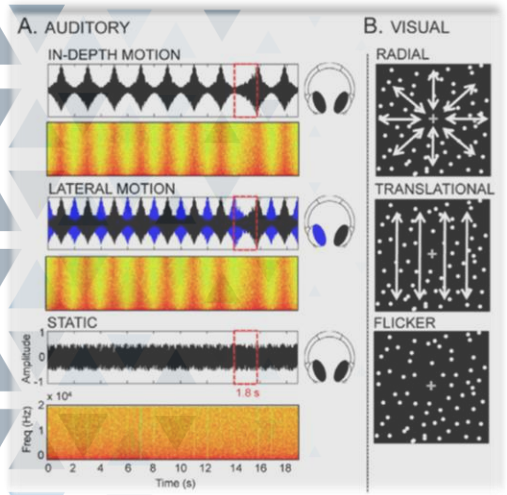
« Leave one run out»

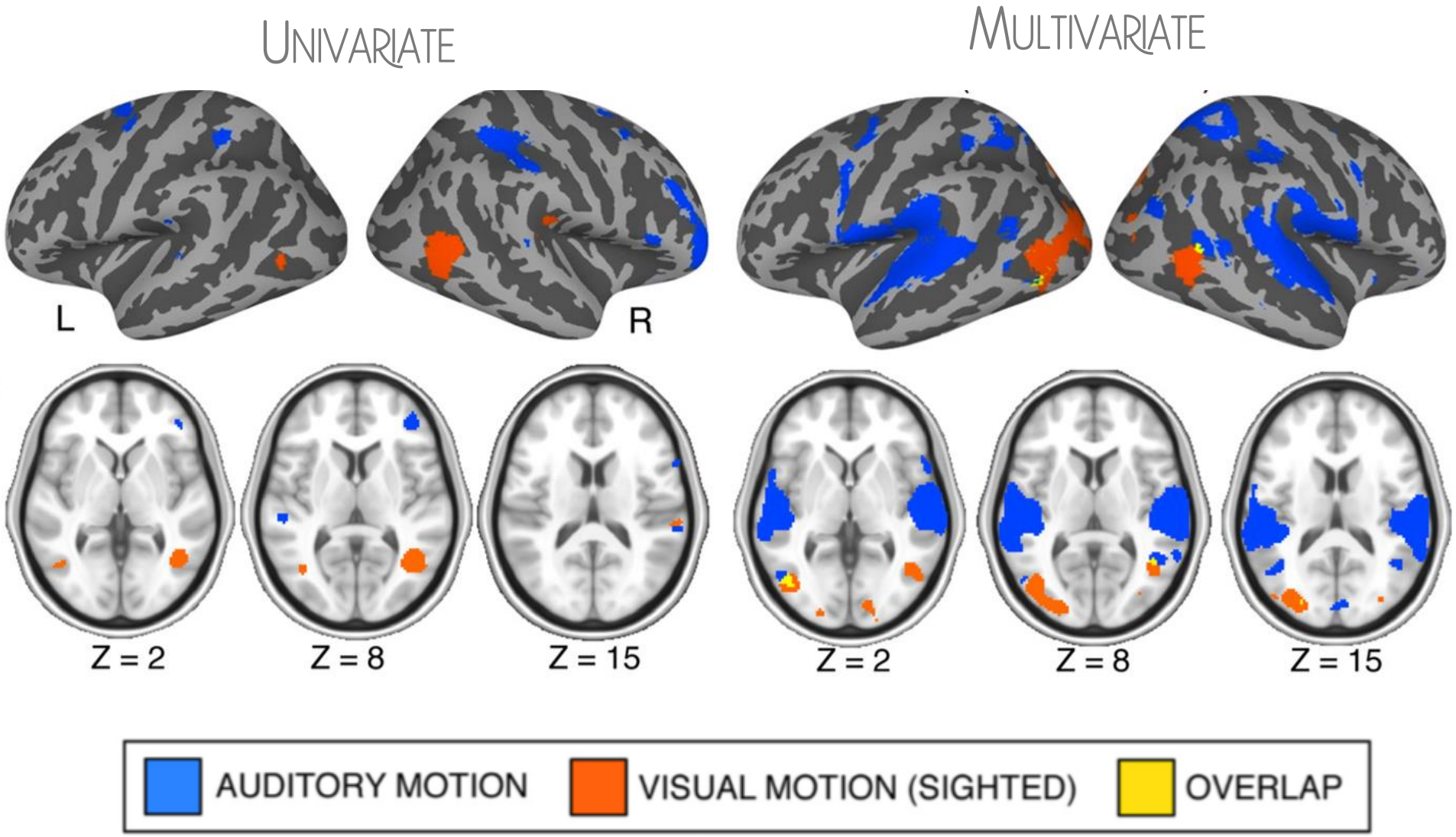


Performance

Classification accuracy (%)

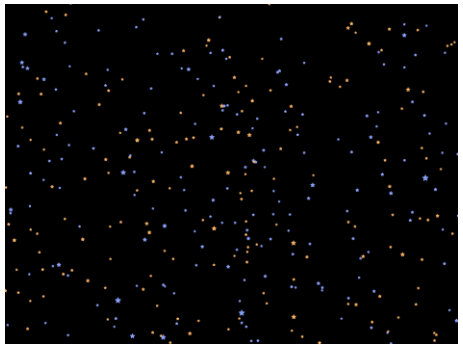
Study on motion Using MVPA





Dormal et al., 2016

Our study on visuotactile motion in humans



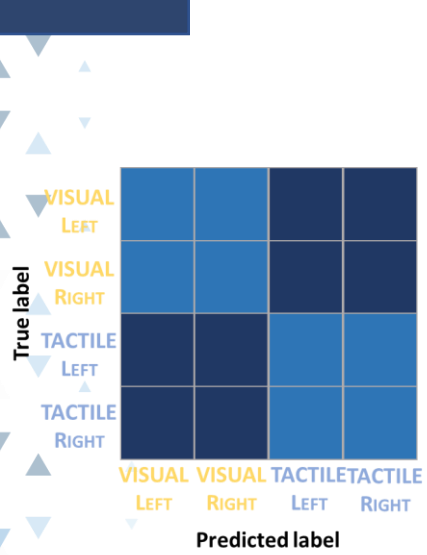
... Using air puffs (TACTILE) & 3D moving dots (VISUAL)

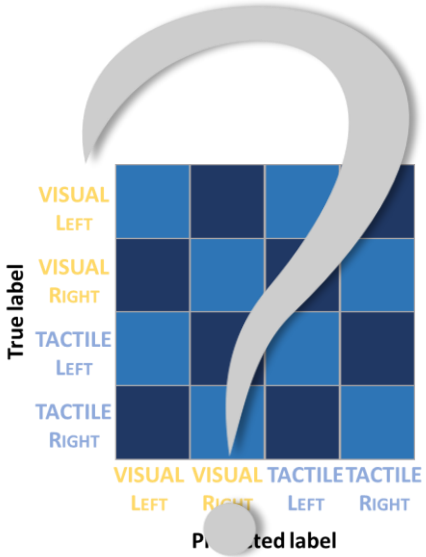
... Coherent spatially, temporally and semantically

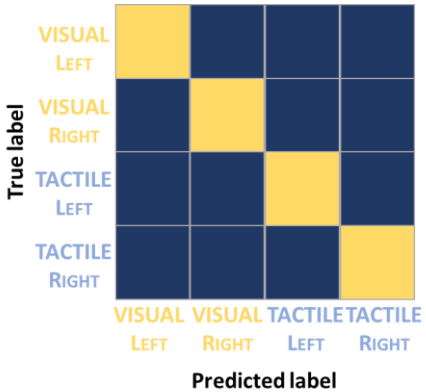
... What do regions encode ? (Modality, Direction, Both ?)

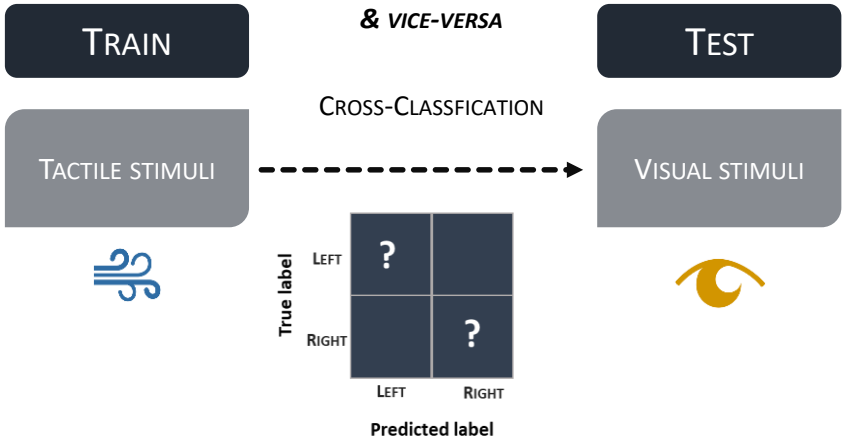
... Cross-classification : training in one modality – testing in the other

... *in progress*









Acknowledgements

MRL Dream Team

Jean Luc Anton
Bruno Nazarian
Julien Sein

Super-Vision

Anne Kavounoudias
Nicolas Catz

VSDI Team

Christian Xerri
Yoh'i Azennou Zogui

Visual Stimulations

Laurent Perrinet

Technical Support

Ali Gharbi
Joel Baurberg