

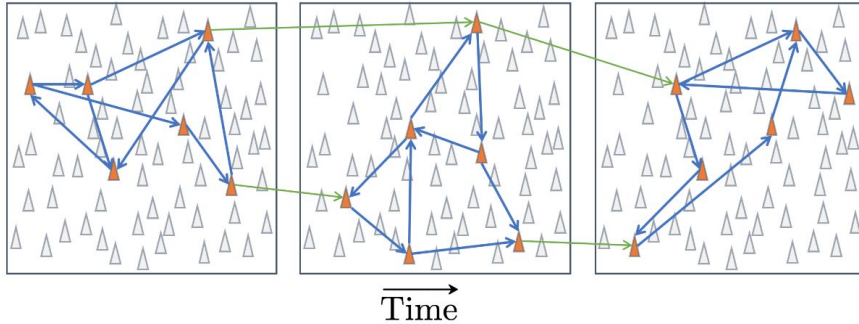
Spatio-temporal patterns in R2G data

Alessandra Stella

05.06.2022, Vision for Action Workshop

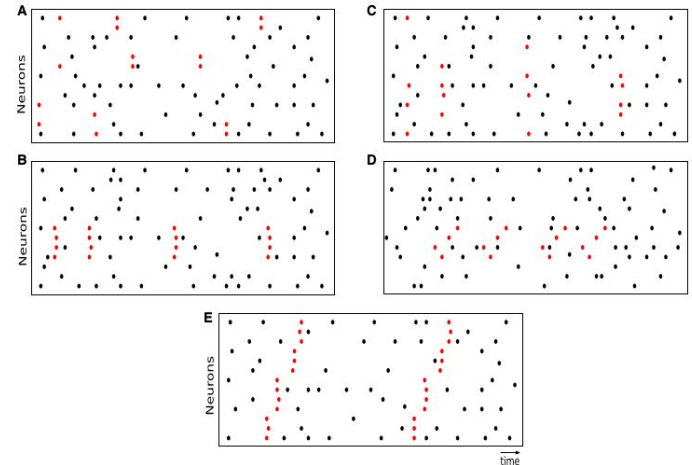
Introduction

Analysis of higher-order structures in parallel spike trains from experimental recordings of monkeys involved in behavioral tasks



Cell assembly hypothesis and temporal coding.

Bouss, *Statistical Evaluation of methods for pattern detection*, Master thesis, 2020

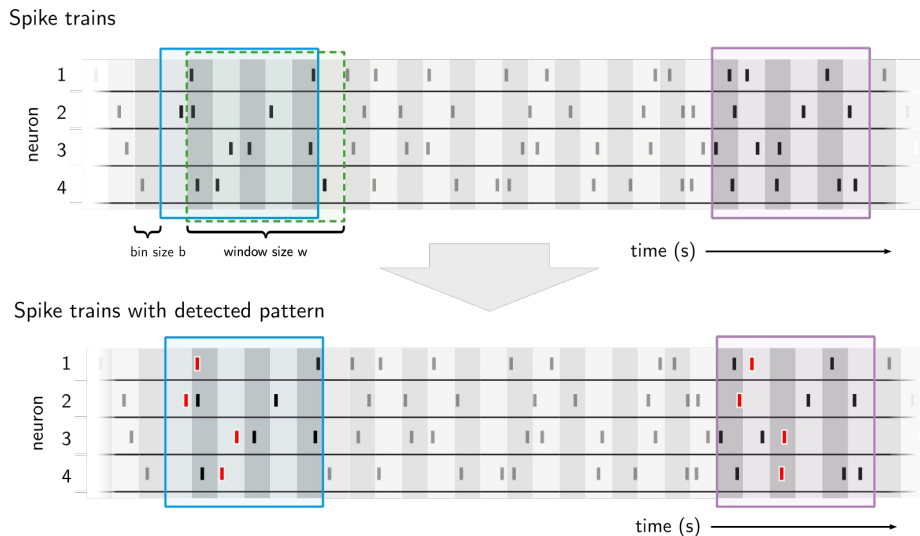


High-order correlation structures in spiking data.

Quaglio, Rostami, Torre, Grün 2018

SPADE method for the detection of spatio-temporal spike patterns

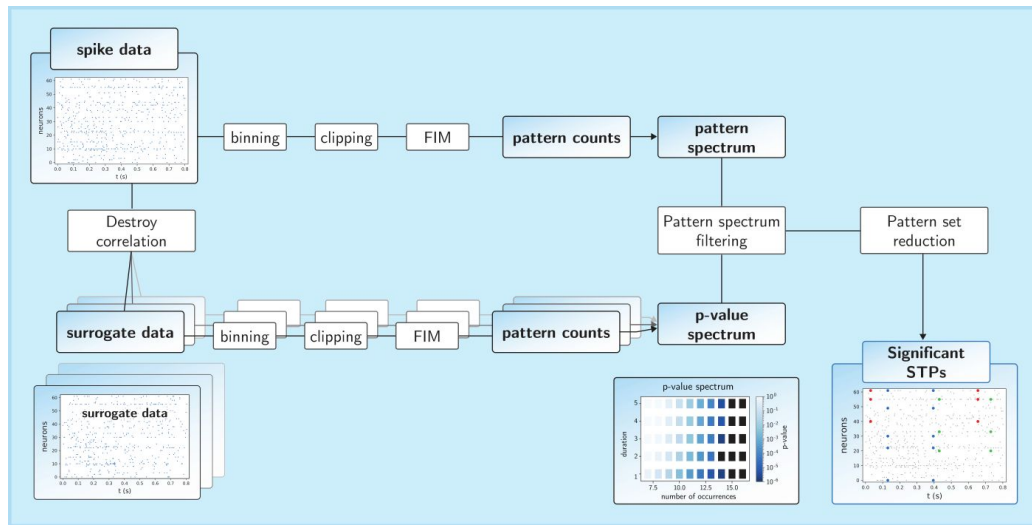
- SPADE **detects Spatio-temporal Spike Patterns** in massively parallel spike trains. (Quaglio et al. 2017)
 - Combines
 - an **optimized pattern mining algorithm**
- together with
- **robust statistical testing** (surrogate generation)



STP detection on parallel spike trains. Adapted from Stella et al. 2019

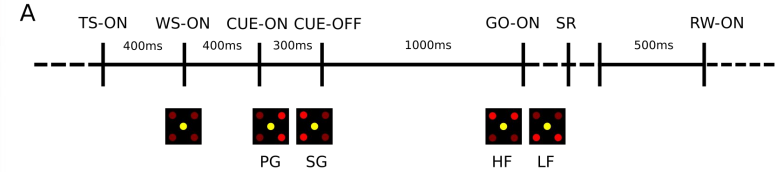
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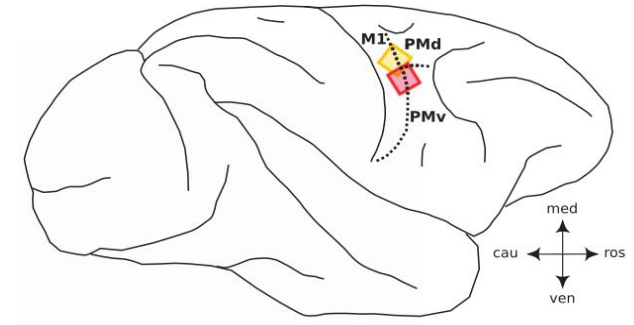


Structure of the SPADE method. Adapted from Stella et al. 2021

The reach-to-grasp experiment



- **Instructed delay reaching and grasping experiment**
- One 10x10 Utah electrode array is inserted in pre-/motor cortex of two macaque monkeys
- Two grip types, two force types
- Simultaneous recordings from ~100 neurons
- References: Riehle et al. 2013, Brochier et al. 2018



Figures adapted from Brochier et al. 2018.

Analysis on the R2G data with SPADE

i.e. **application of SPADE to the R2G data (20 sessions)**

Scientific questions:

- Are there patterns in electrophysiological data?
- Relationship of patterns to behavior
- Relationship of patterns to spatial arrangement of the array
- Which neurons participate prevalently in patterns?
- Are patterns different in structure across behavioral contexts?
- What is different in the results from Torre et al. 2016 (only synchronous patterns)?

Nikos	Lilou
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i140617-001-05	l101013-001-02
i140627-001-05	l101015-001-04
i140701-001-05	l101108-001-03
i140702-001-09	l101110-003-04
i140703-001-05	l101111-002-04
i140704-001-04	l101126-002-02
i140718-001-03	l101210-001-02
i140725-001-06	l110209-001-06

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Bin size	5 ms
Max pattern duration	60 ms
Dither	25 ms
N surrogates	5000
Surrogate method	trial shifting
Alpha level	0.05
Correction	FDR
Psr parameter	[2,2,2]
Firing rate threshold	70Hz
Spread synchrofacts	1
Min SNR	2.5

Analysis on the R2G data with SPADE

Pattern statistics for both monkeys across sessions.

A. Pattern counts across behavioral epochs:

- ~60 patterns per monkey
- patterns occur in all phases of behavior and all trial types

B. Pattern size:

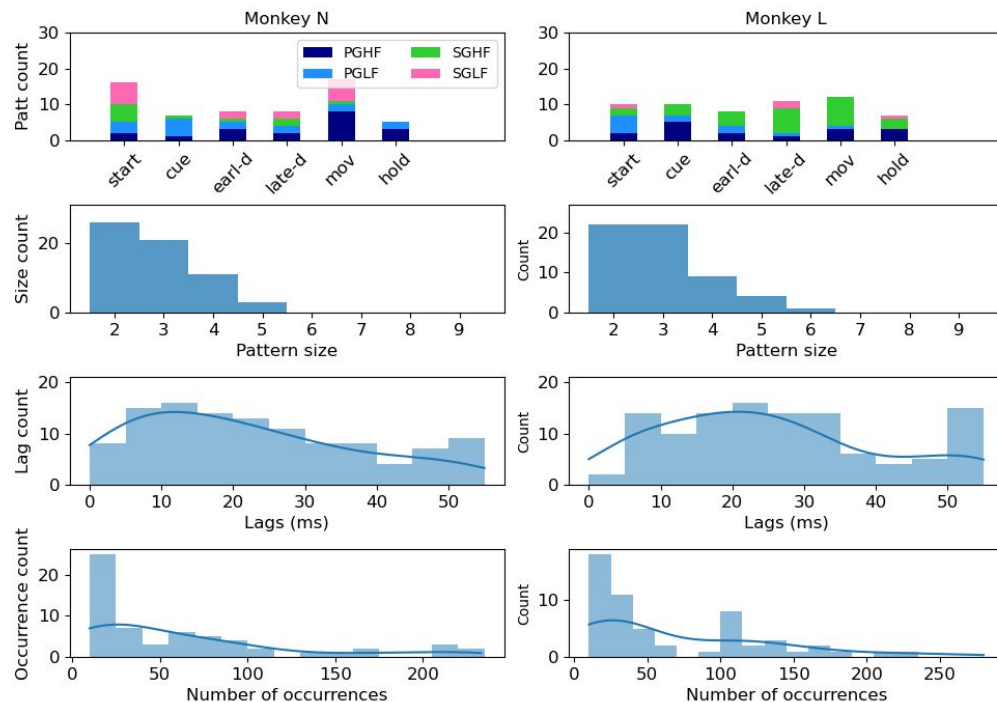
- 2-5 neurons per pattern

C. Pattern lags:

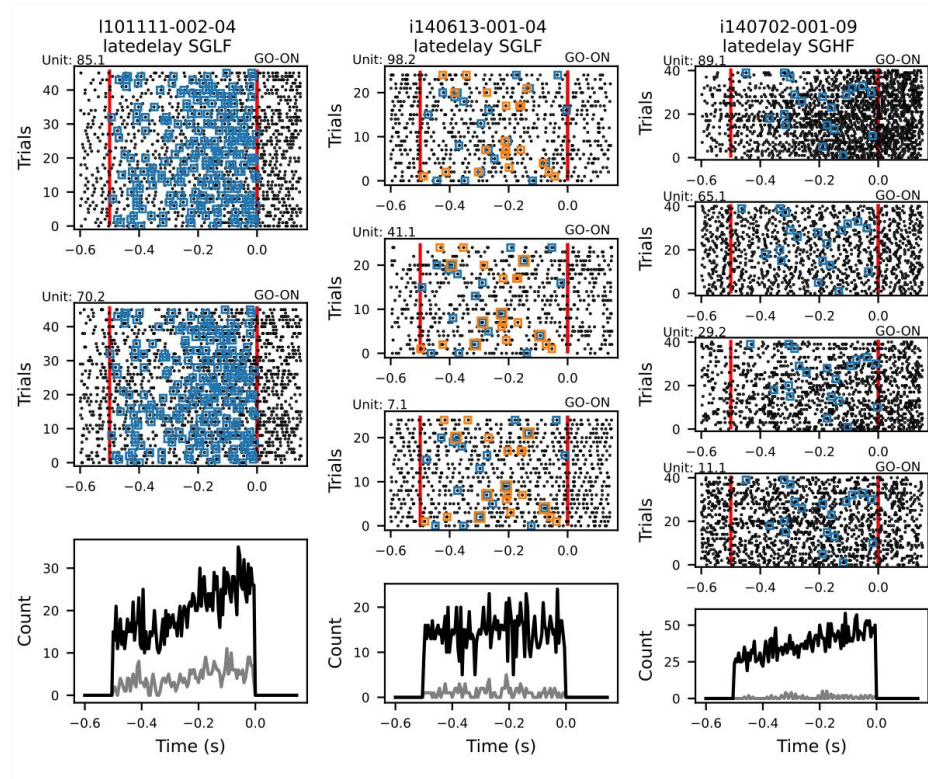
- max temporal duration = 60ms

D. Number of pattern repetitions:

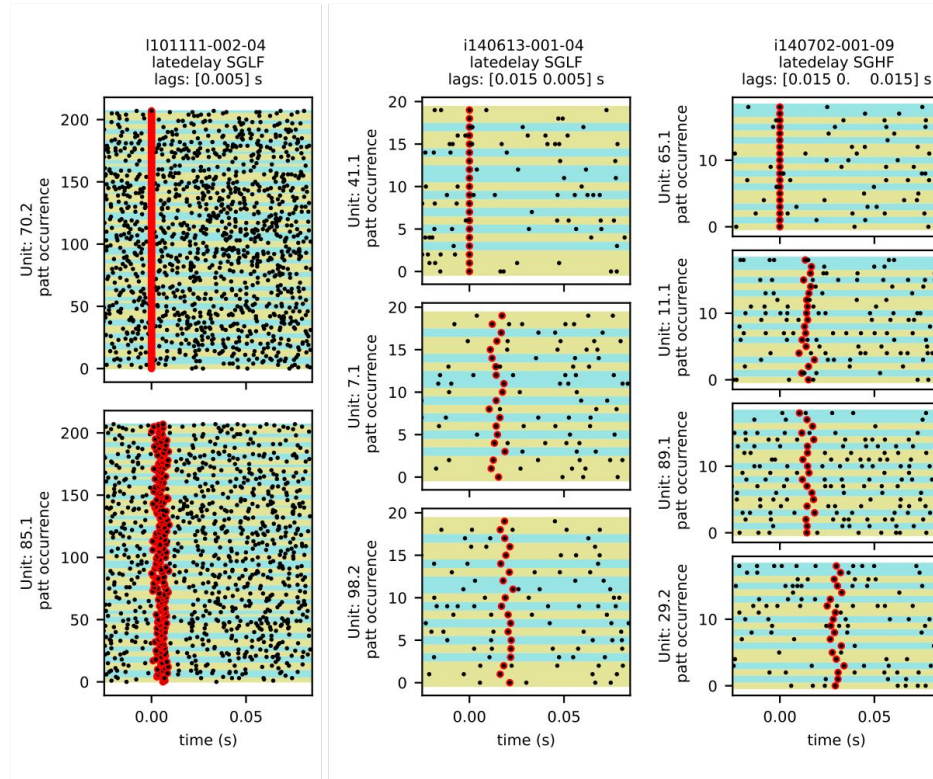
- min: 10 to max. 250 occurrences, depending on size



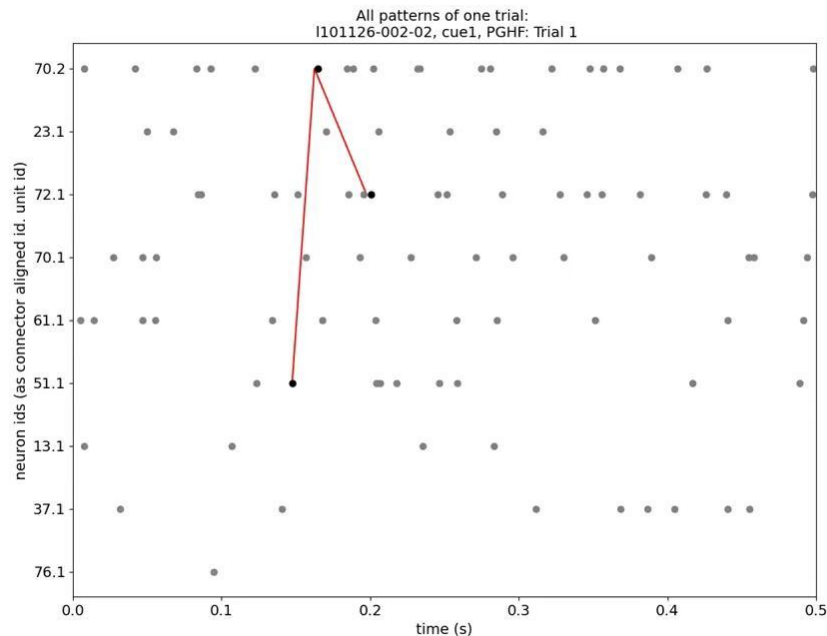
Spatio-temporal patterns may share individual spikes



Spatio-temporal patterns have precise timing

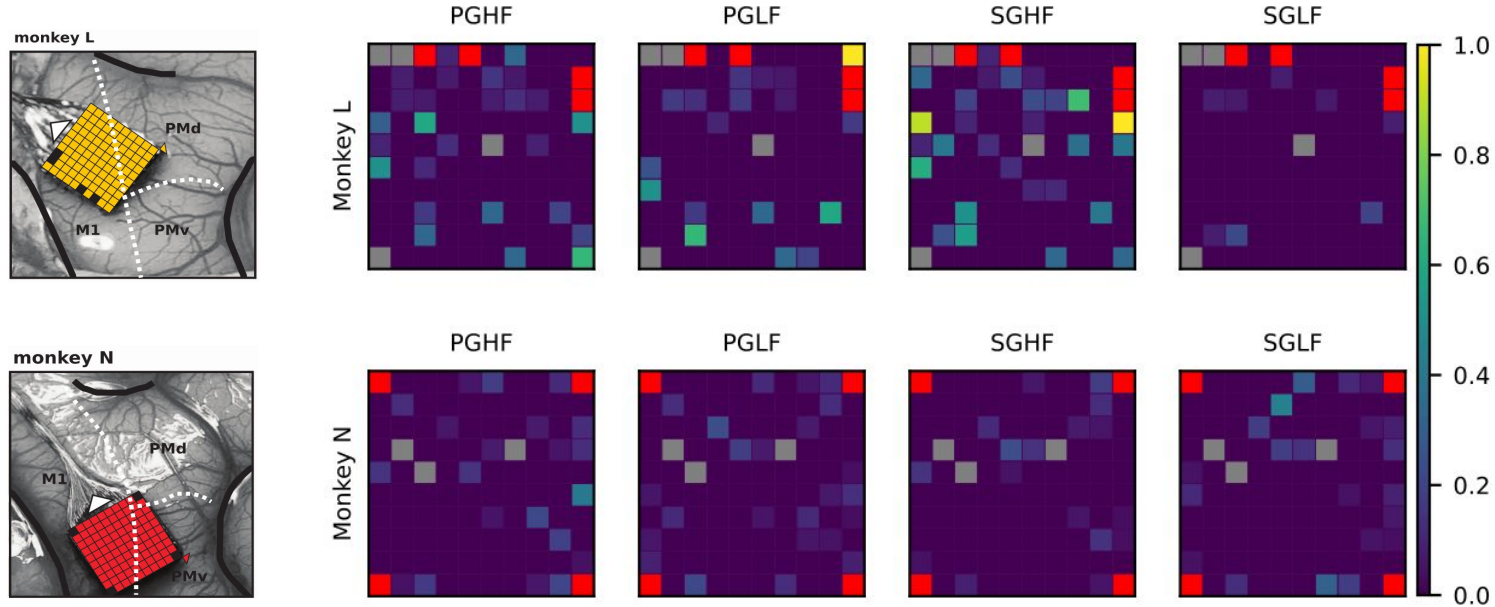


Pattern specificity to behavior



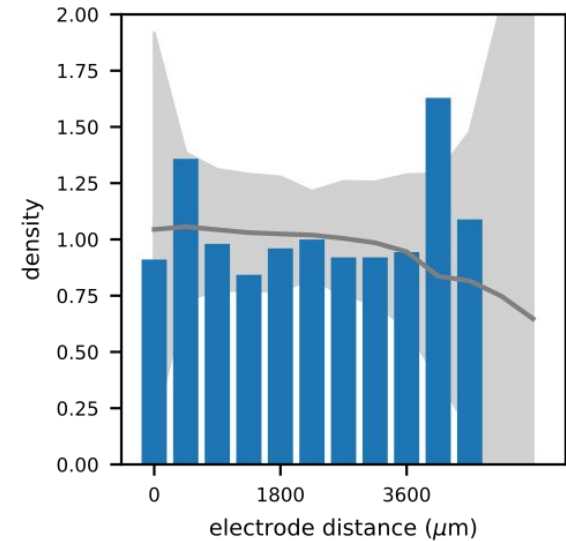
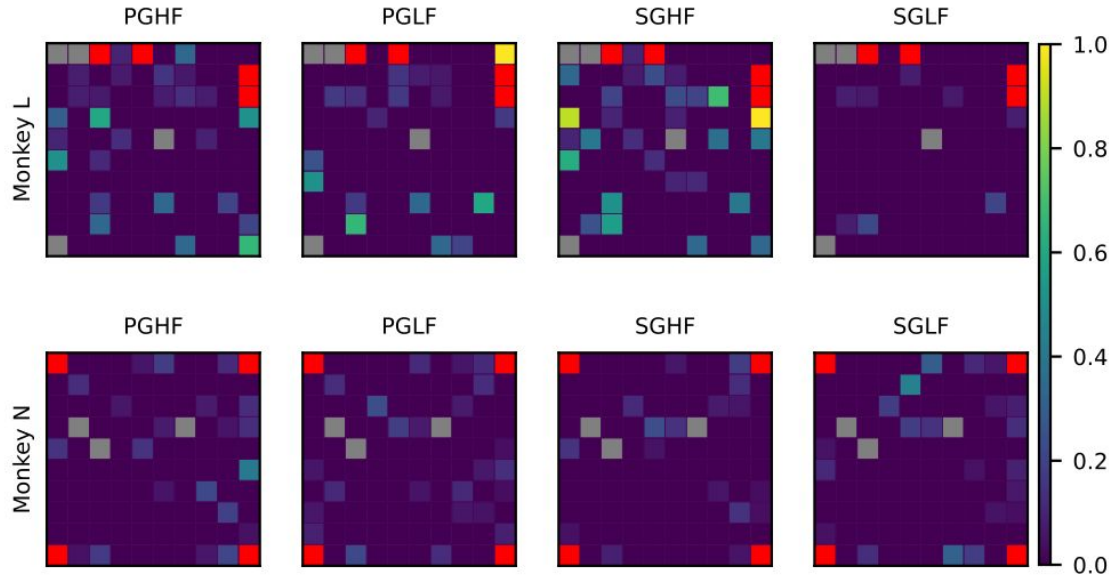
- Shown: neurons involved in patterns. Video shows single trials in succession
 - Patterns are **strictly specific** to the specific condition
 - Different neuronal compositions and different lags
- **STPs are specific to behavior**

Spatial distribution of patterns on the array

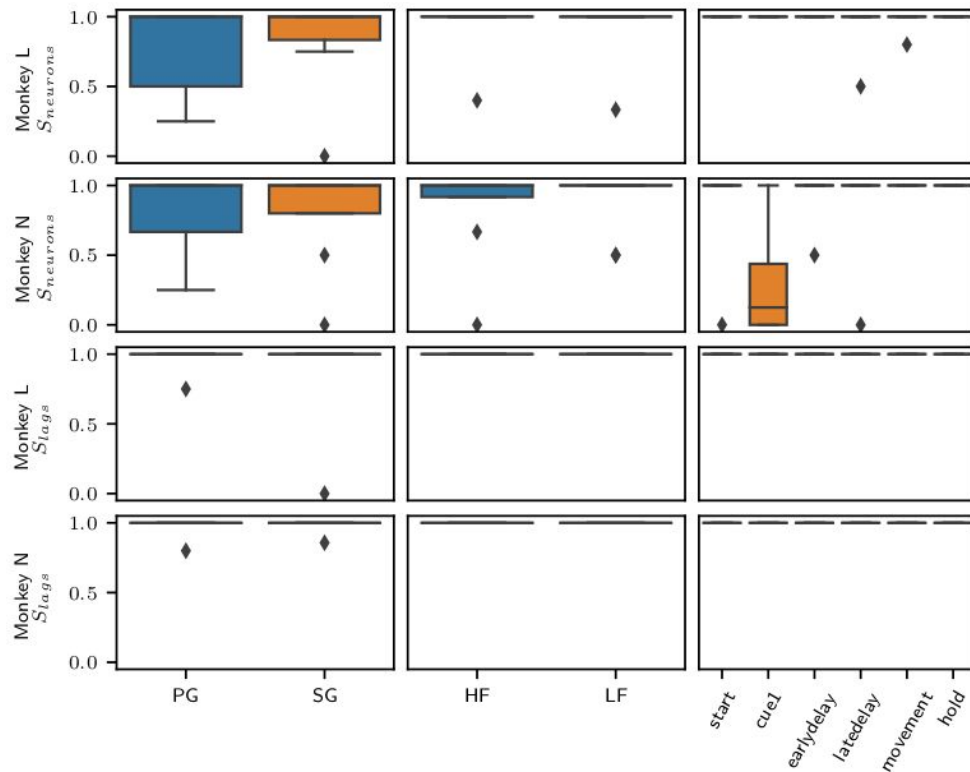


Utah electrode arrays implanted in
Monkey L and N. Figure adapted from
Brochier et al. 2018

Spatial distribution of patterns on the array



Pattern specificity to behavior

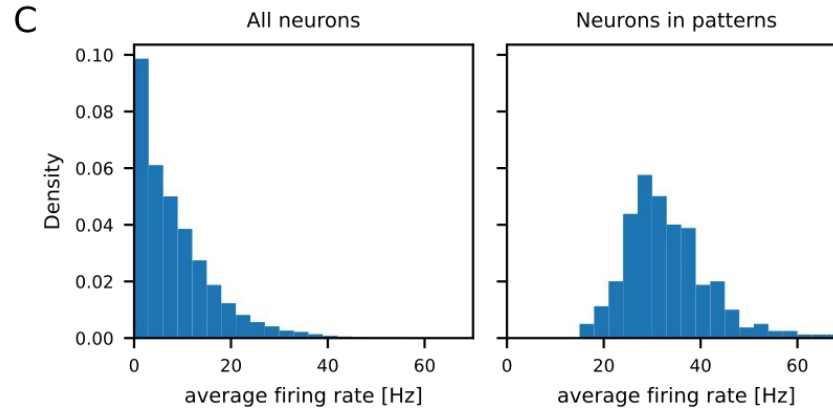
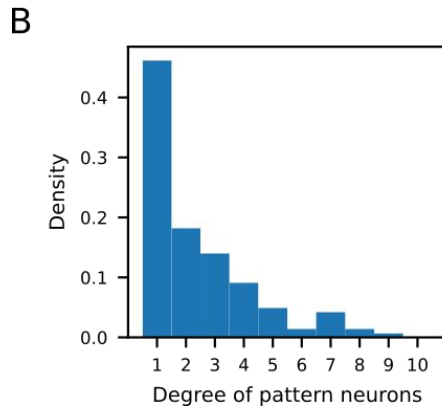
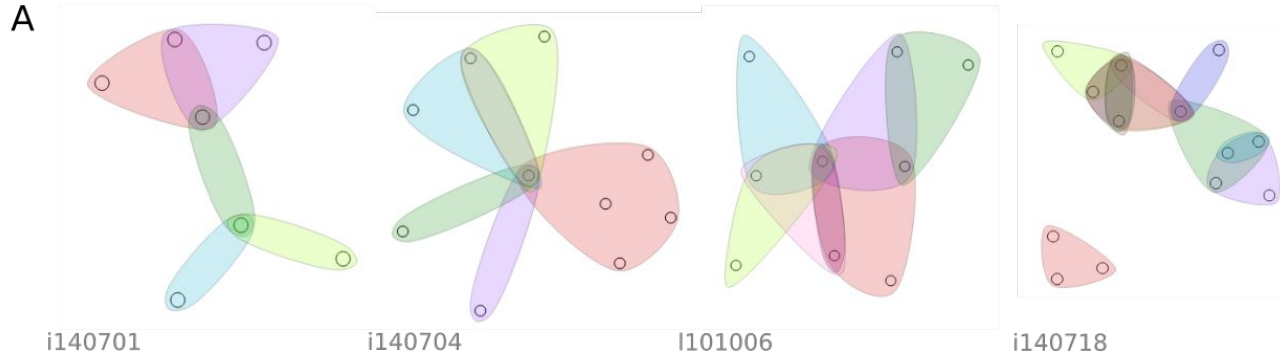


$$S_i = \frac{|P_i \setminus (\cup_{j \neq i} P_j)|}{|P_i|}.$$

Specificity of patterns for different behaviors.

The specificity index takes values in the range [0, 1]: it is equal to 1 whenever all patterns detected in a certain instance are not present in any other instance of the same context, and it is 0 whenever all patterns of all instances completely overlap.

Clustering of neurons in patterns



Conclusions

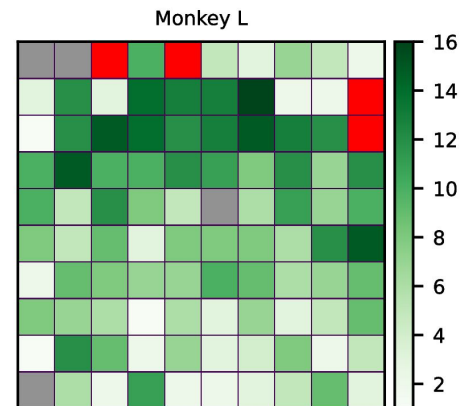
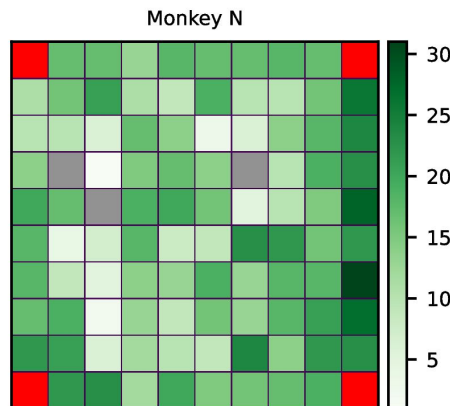
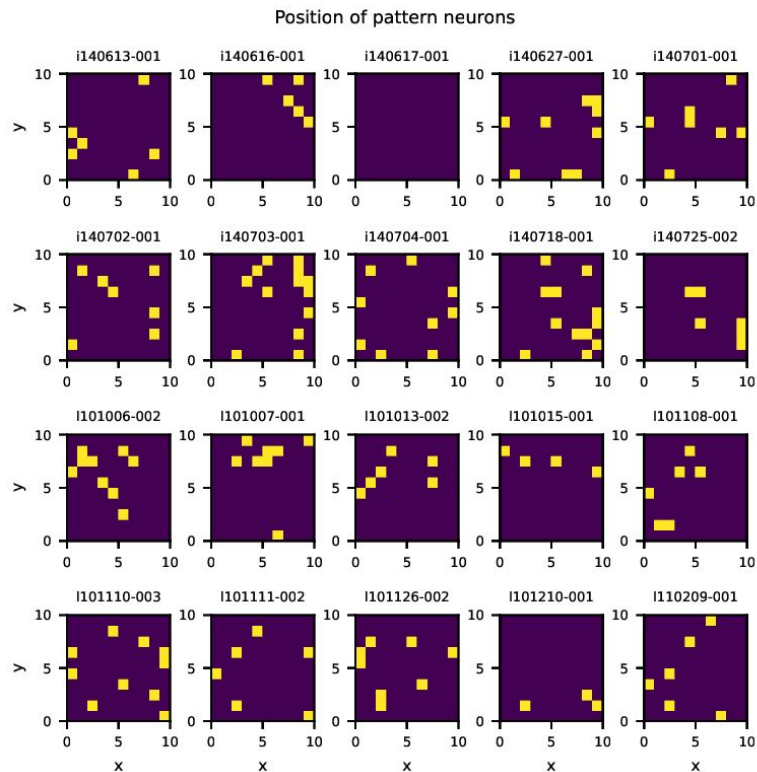
- We hypothesize that assembly activity is expressed by the occurrence of **precise spatio-temporal patterns of spikes** emitted by neurons that presumably are members of an assembly
- We **developed a method, called SPADE, detecting significant spatio temporal patterns** in massively parallel spike trains
- We **analyzed N=20 experimental sessions** with SPADE consisting of about 100 parallel spike trains recorded by a 10x10-electrode Utah array in the pre-/motor cortex of two macaque monkeys performing a reach-to-grasp task
- Our results show that **spatio temporal patterns occur in all phases of the behavior**
- Patterns are specific to a behavioral condition, suggesting that **different assemblies are activated for each specific behavioral context**



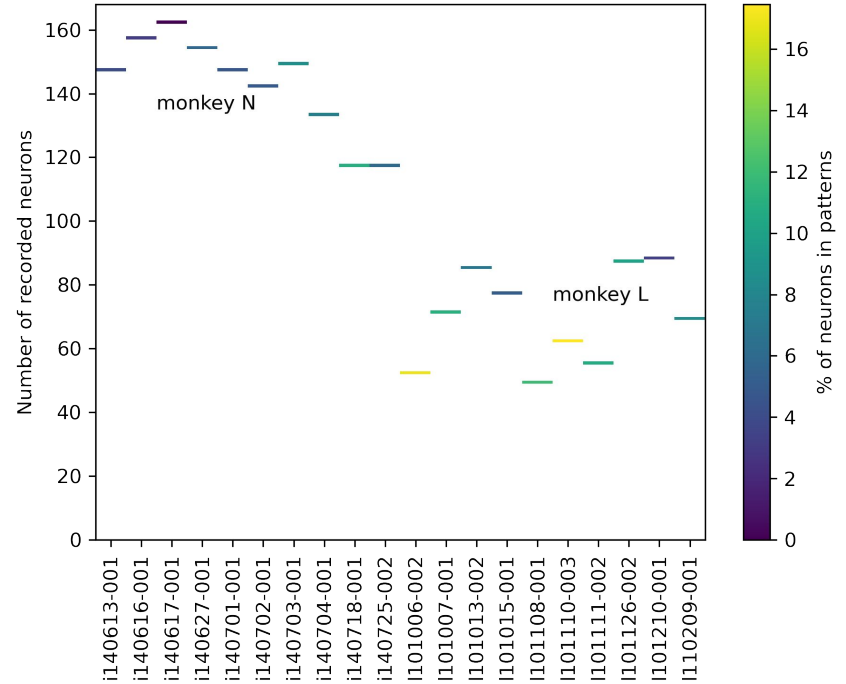
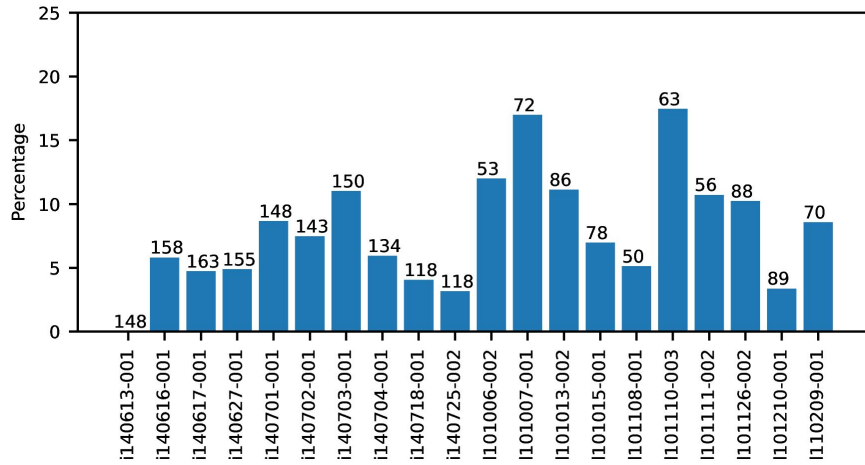
Thank you

Point Sublime, Gorges du Verdon, France
August 2020

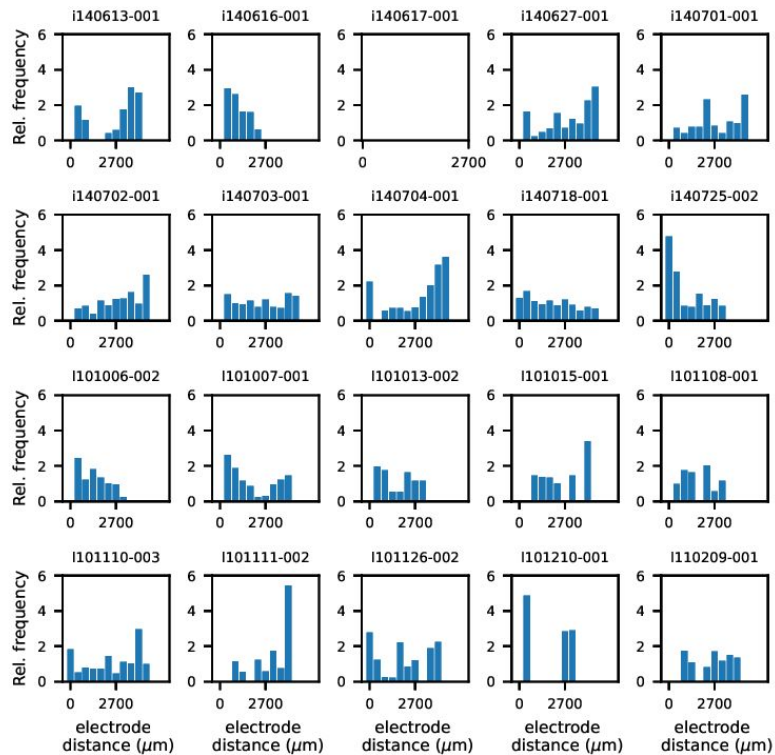
Supplementary material



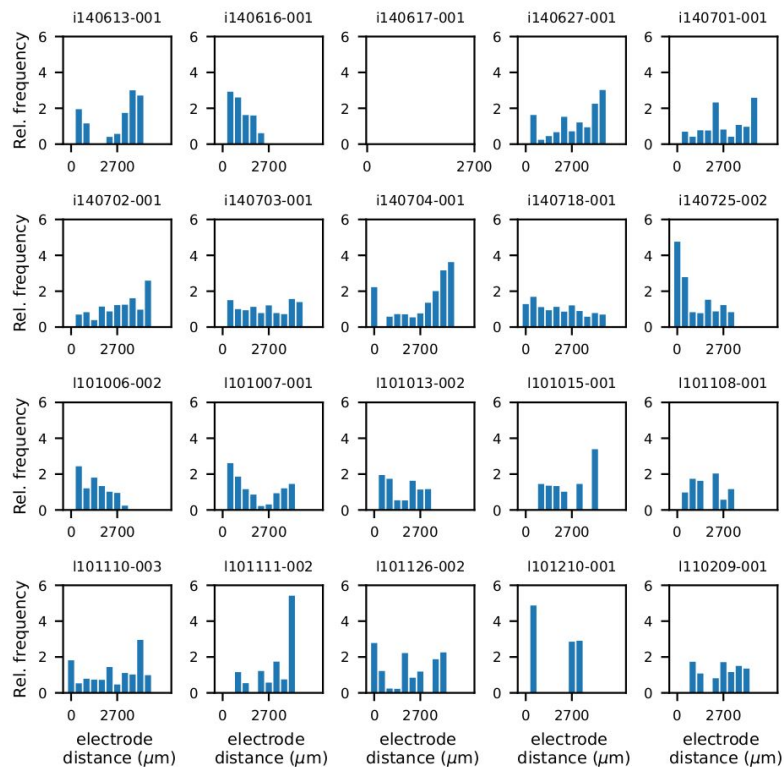
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