Structure of Neuronal Correlation: Distance, Dynamics and Depth

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Acknowledgements

- Adam Kohn
- Xiaoxuan Jia
- Amin Zandvakili

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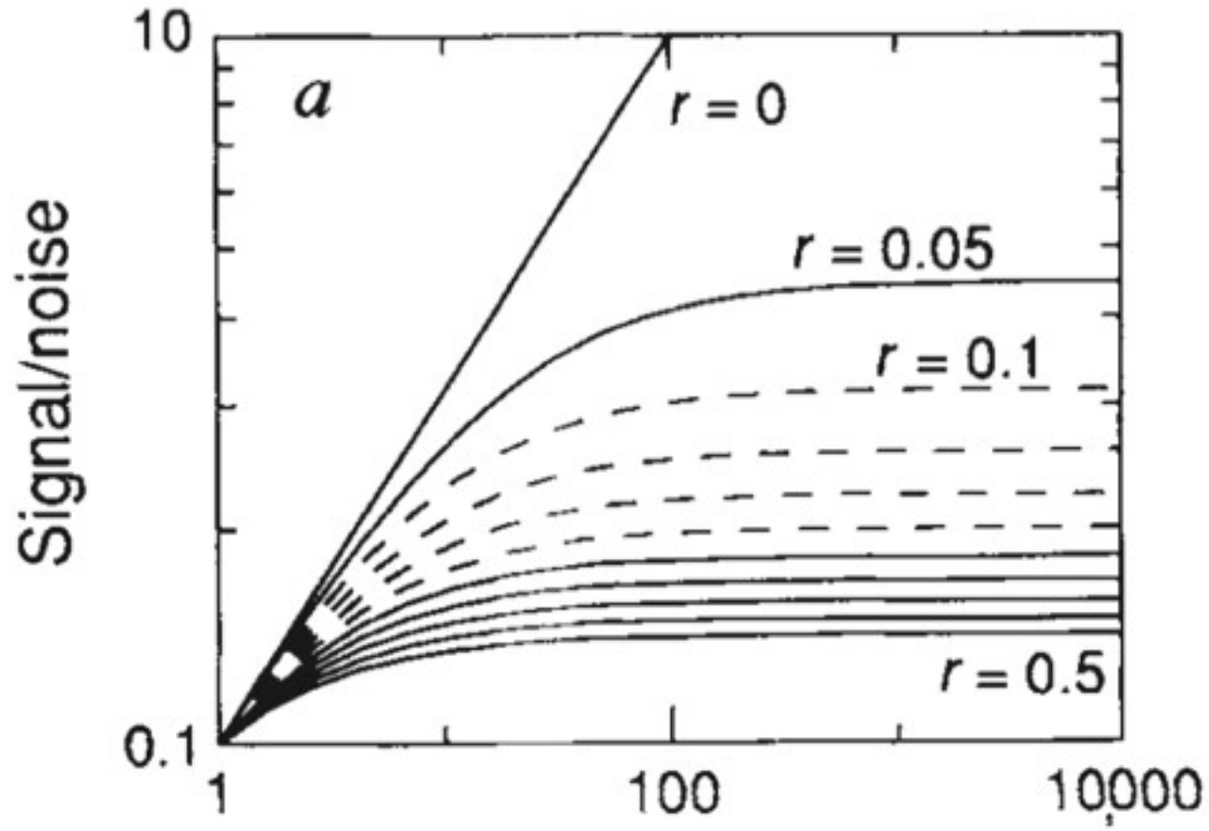
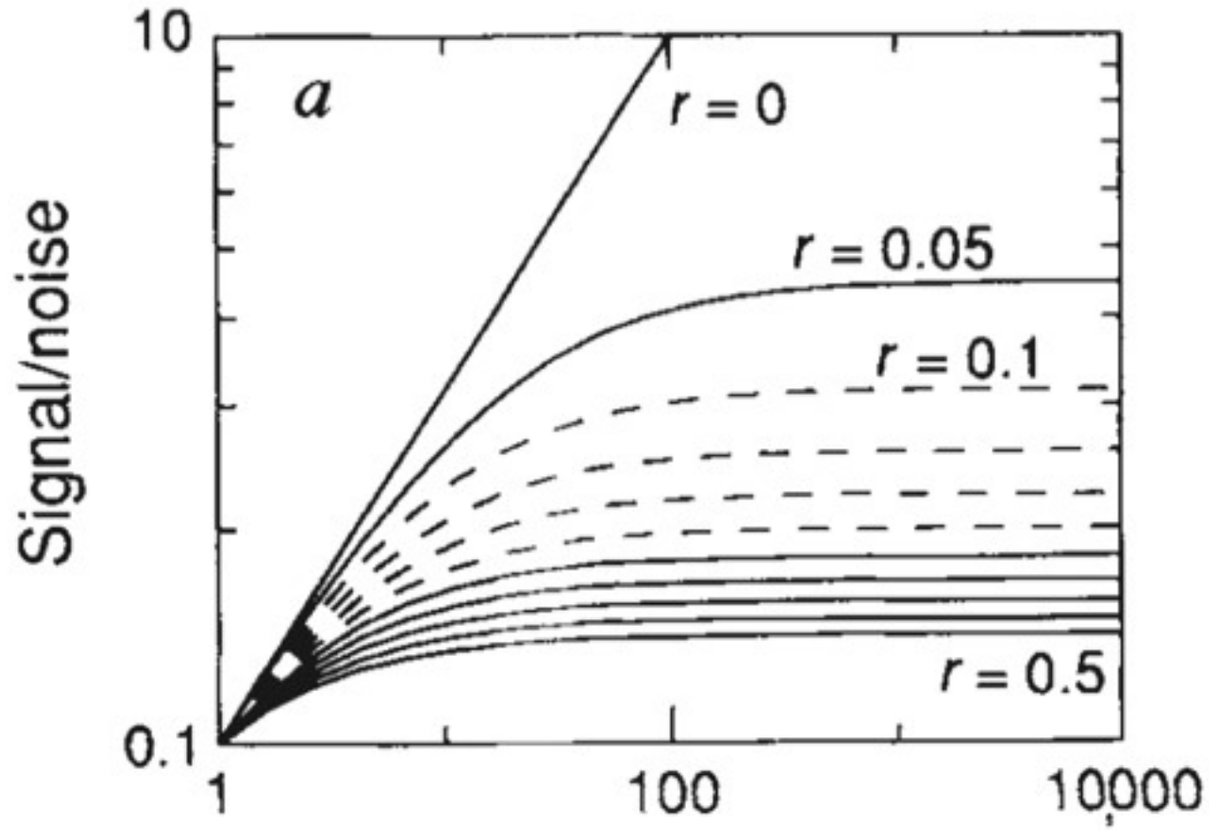


Zohary, Shadlen & Newsome (1994)



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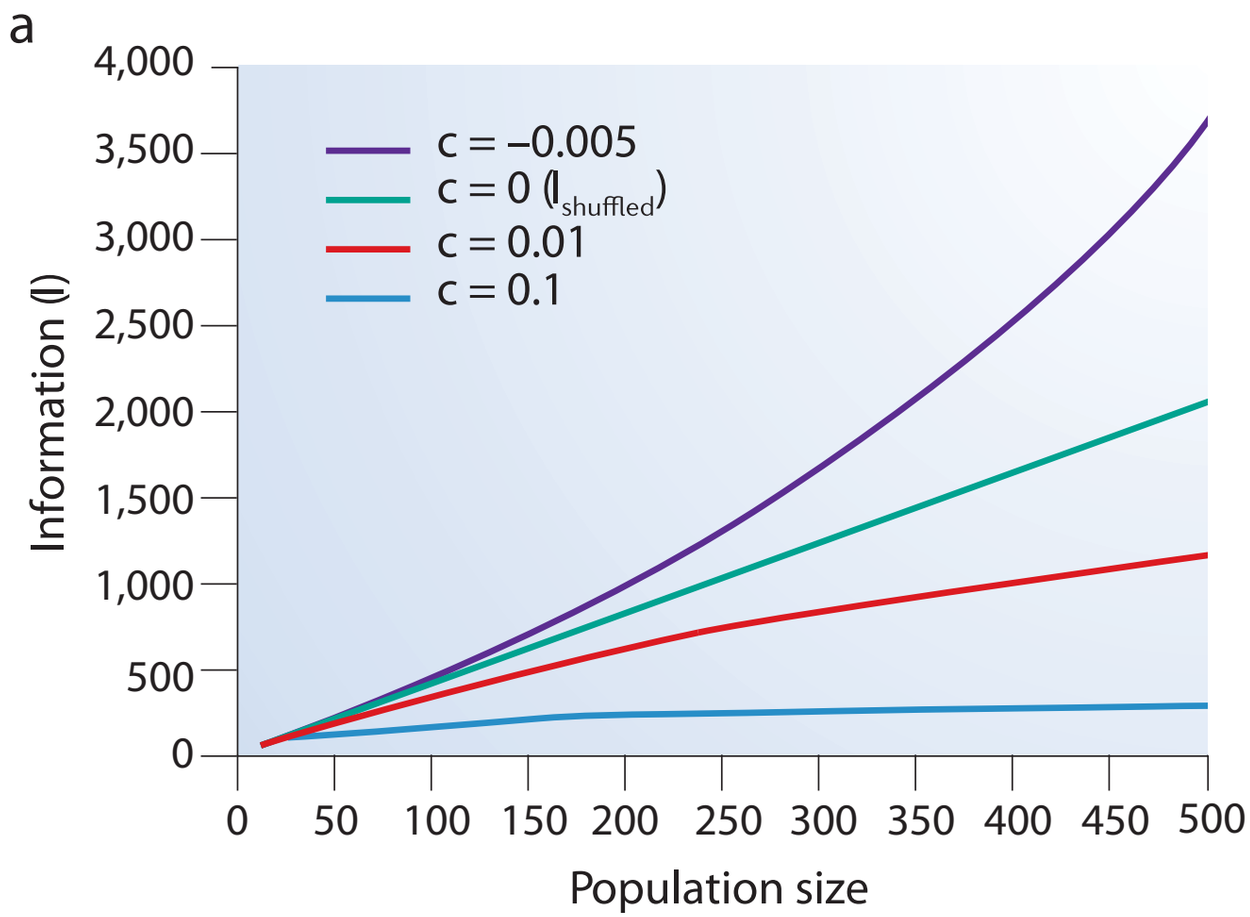

Averbeck, Latham & Pouget (2006)

Structure of neuronal correlation

Structure of neuronal correlation

- Distance

Structure of neuronal correlation

- Distance

  Spatial extent
  Tuning similarity

Structure of neuronal correlation

- Distance

  Spatial extent
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- Dynamics

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  Spontaneous vs Evoked
  Transition between states

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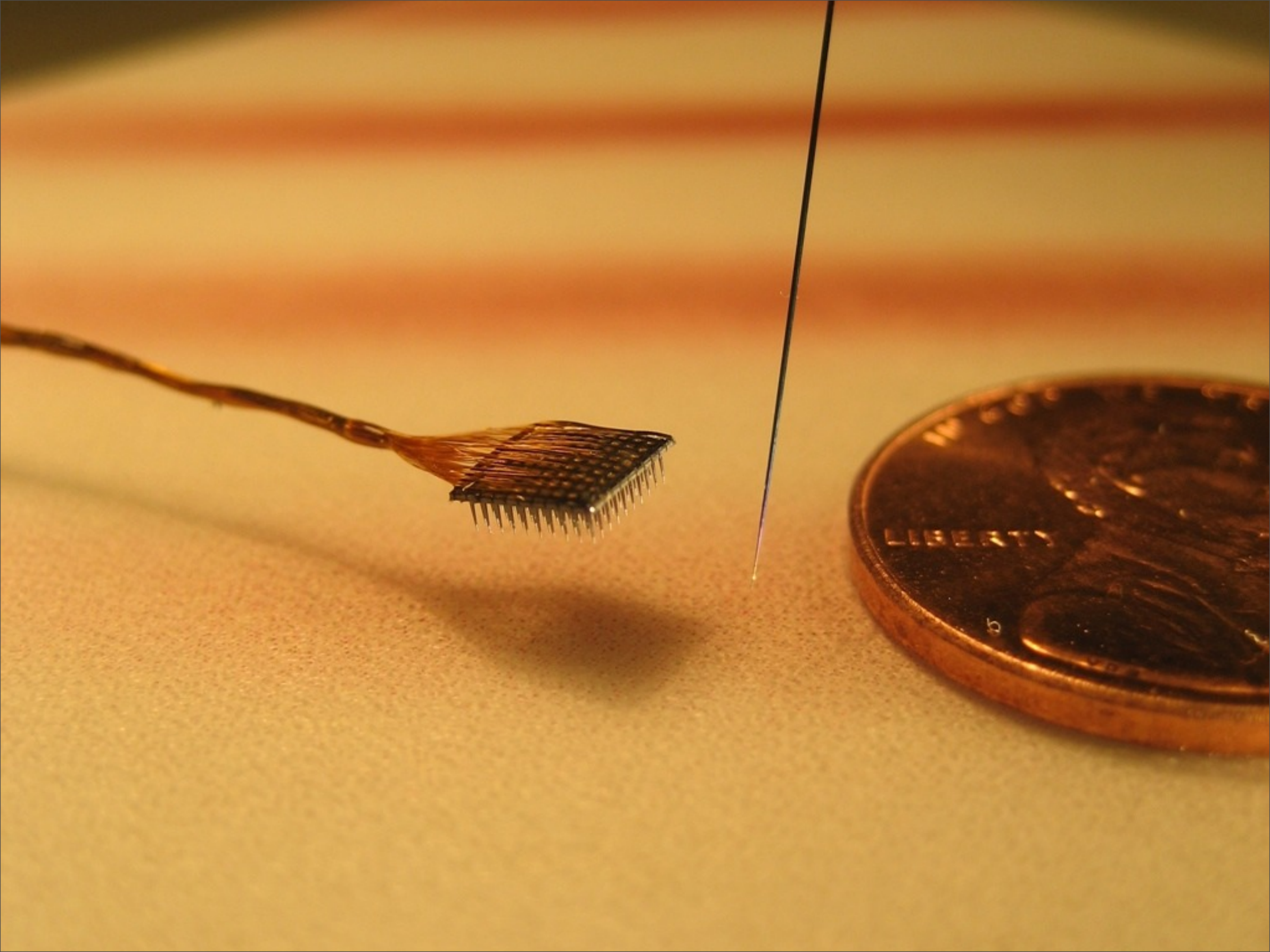
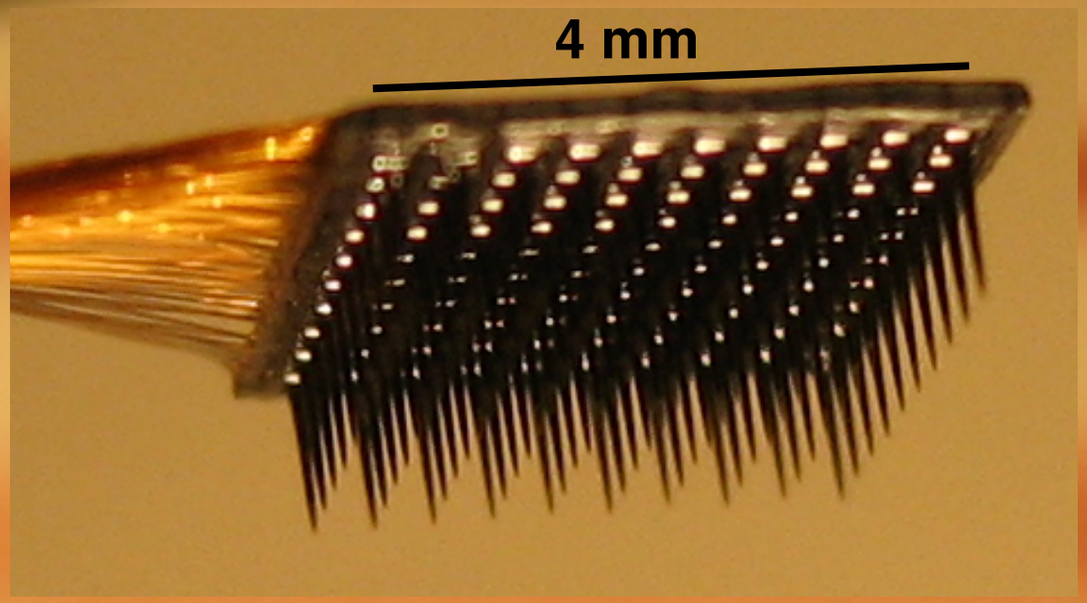

LIBERTY

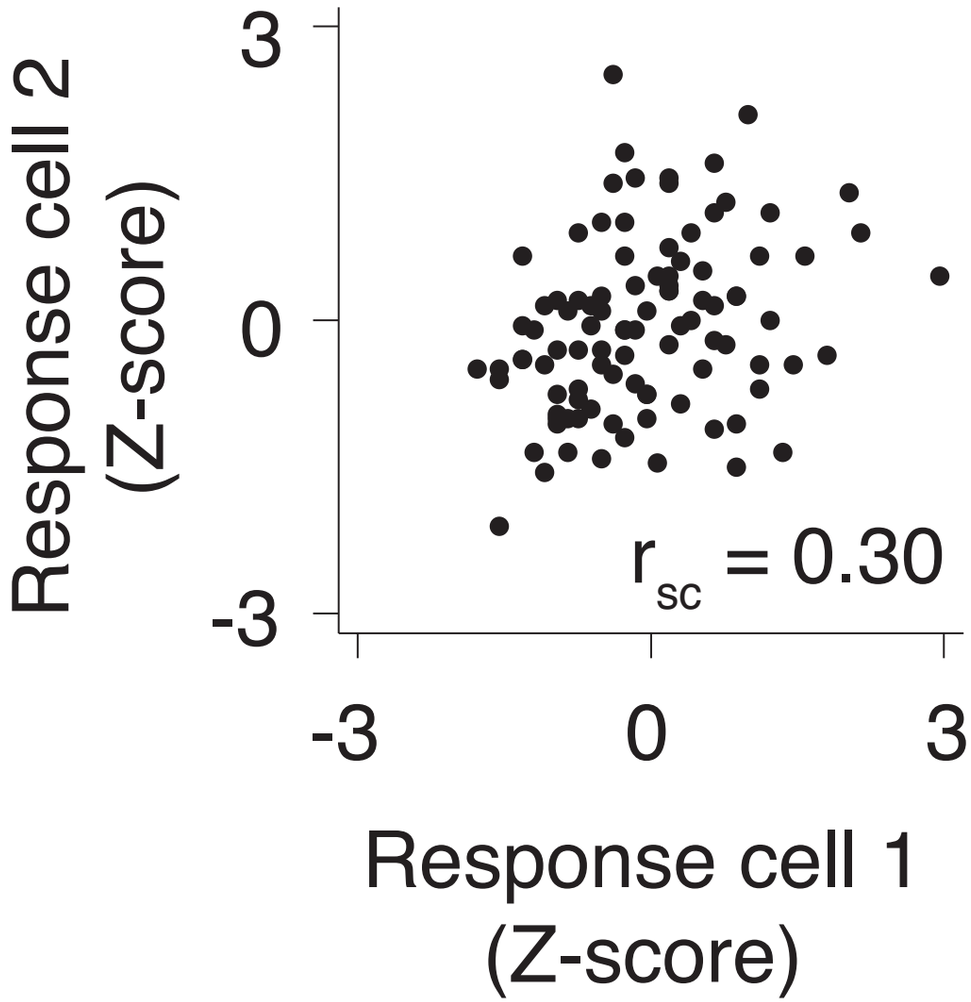

4 mm

Methods

- Opiate-anesthetized, paralyzed macaque monkeys
- V1 array implants
  superficial layer recordings
- Stimulus:
  12 directions
  spatial frequency: 1.3 cpd
  temporal frequency: 6.25 Hz
  size: 8-10 degrees

Spatial scale of functional connections

Slow timescale



Smith & Kohn (2008)

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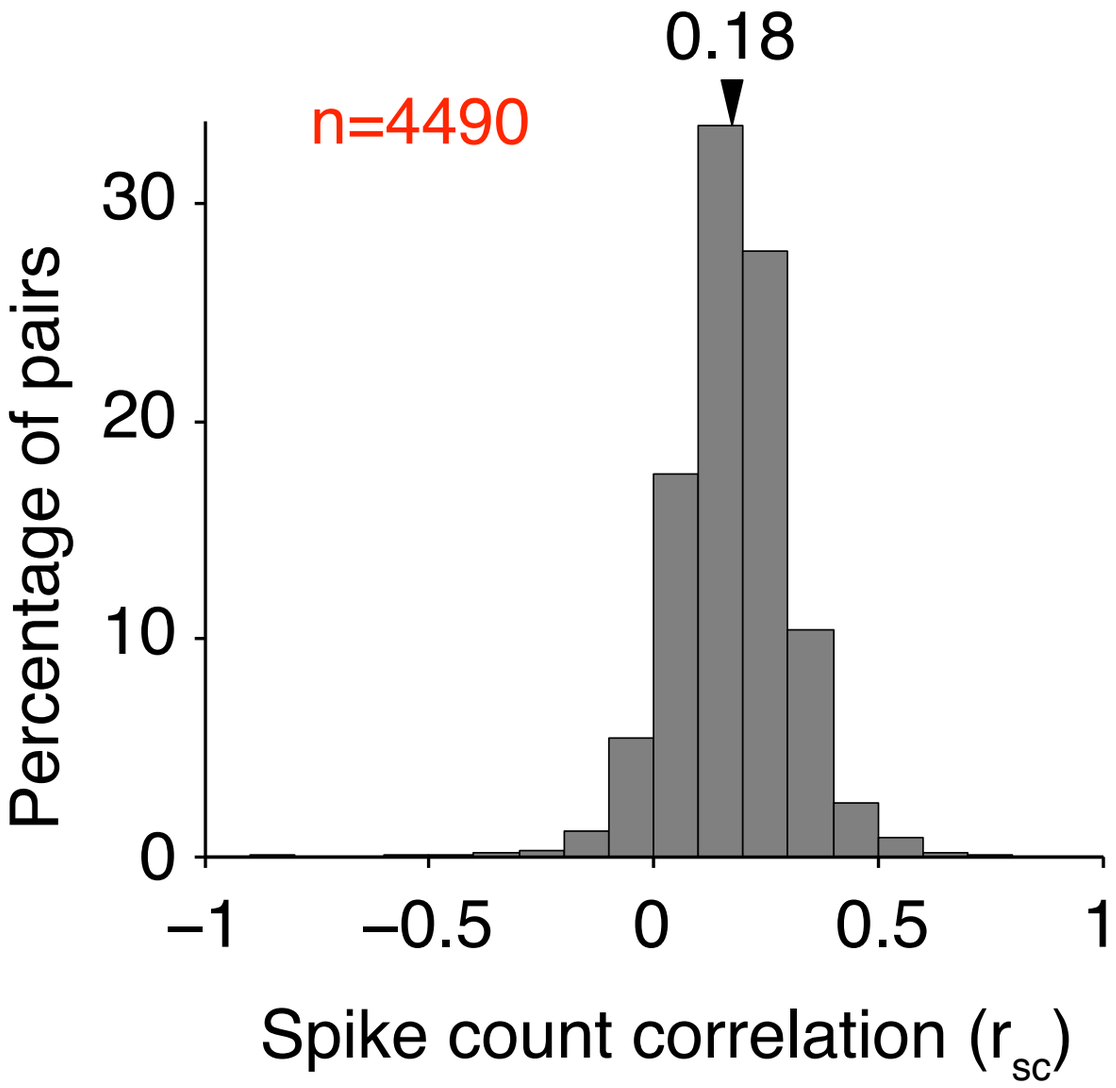

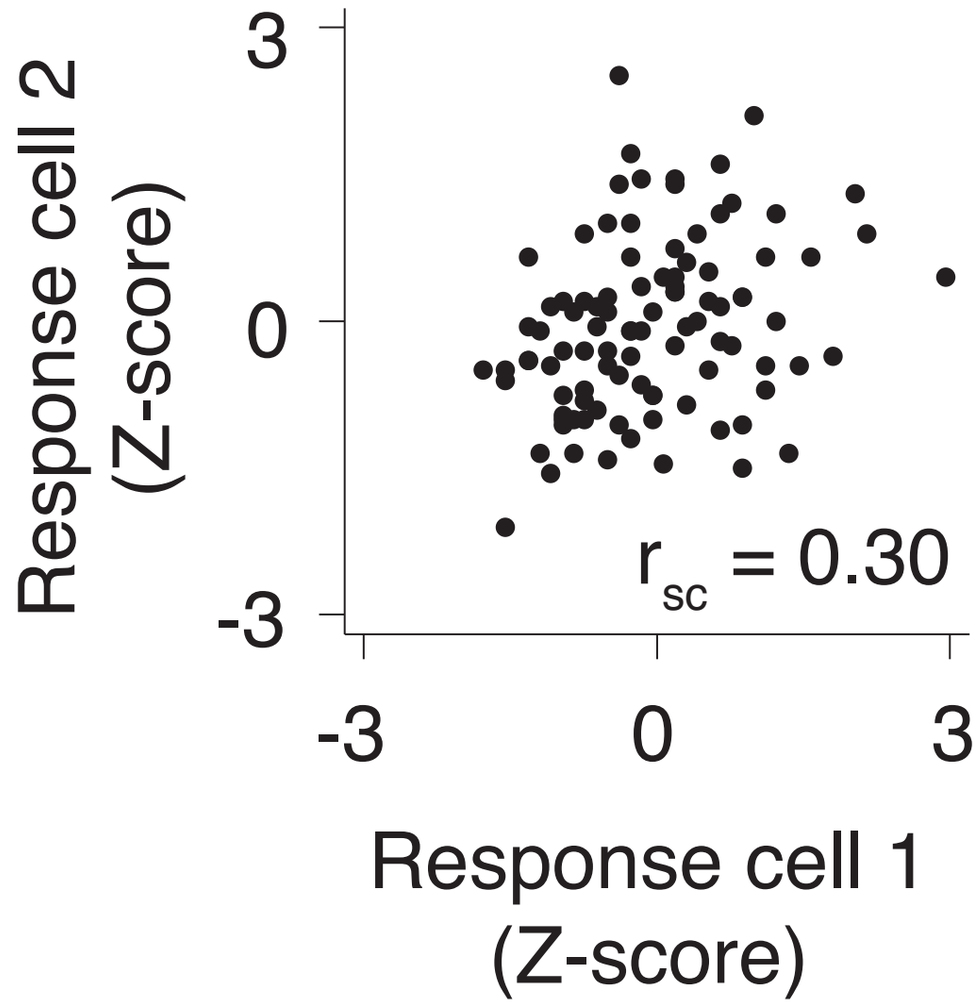

Smith & Kohn (2008)

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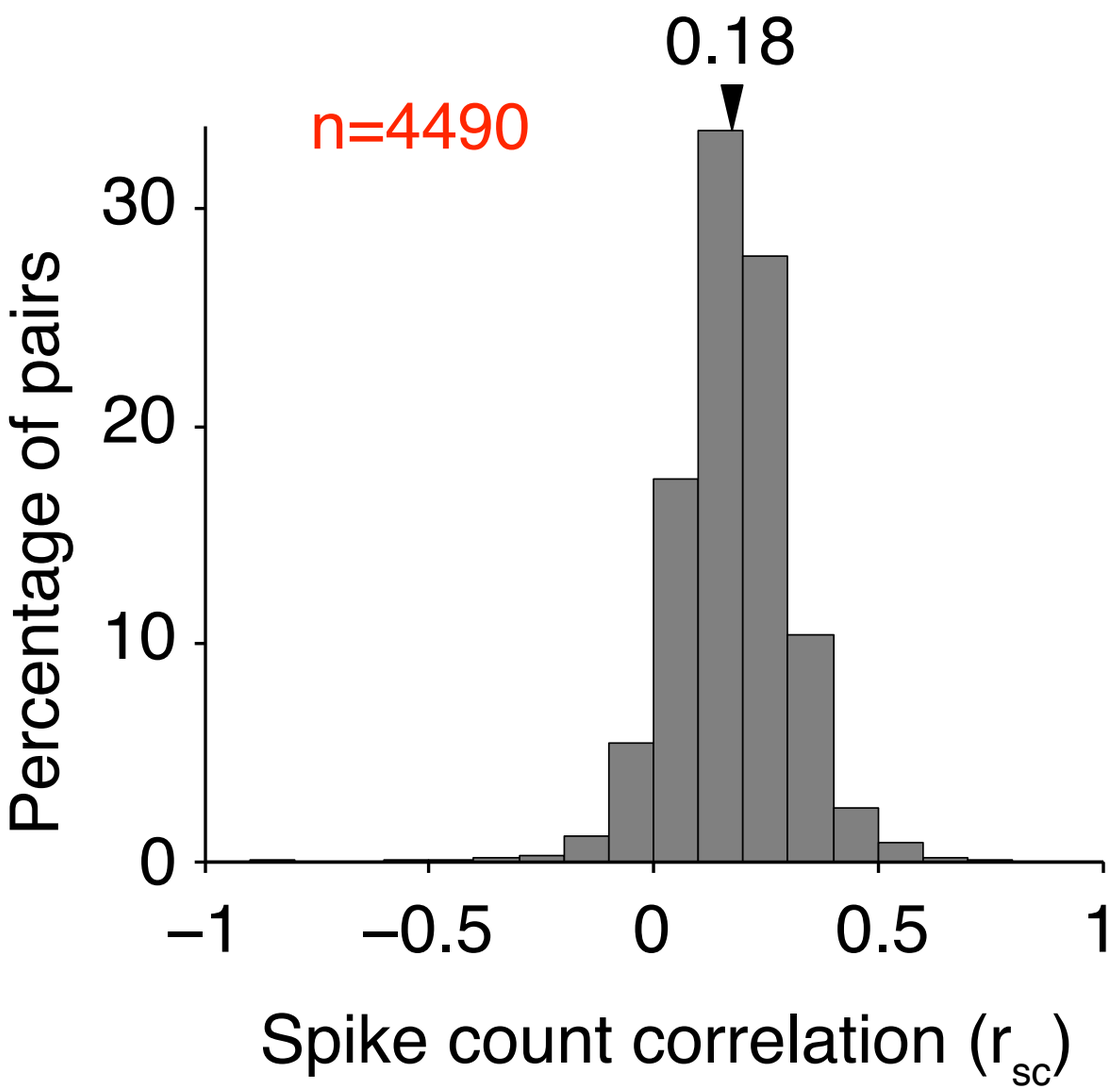
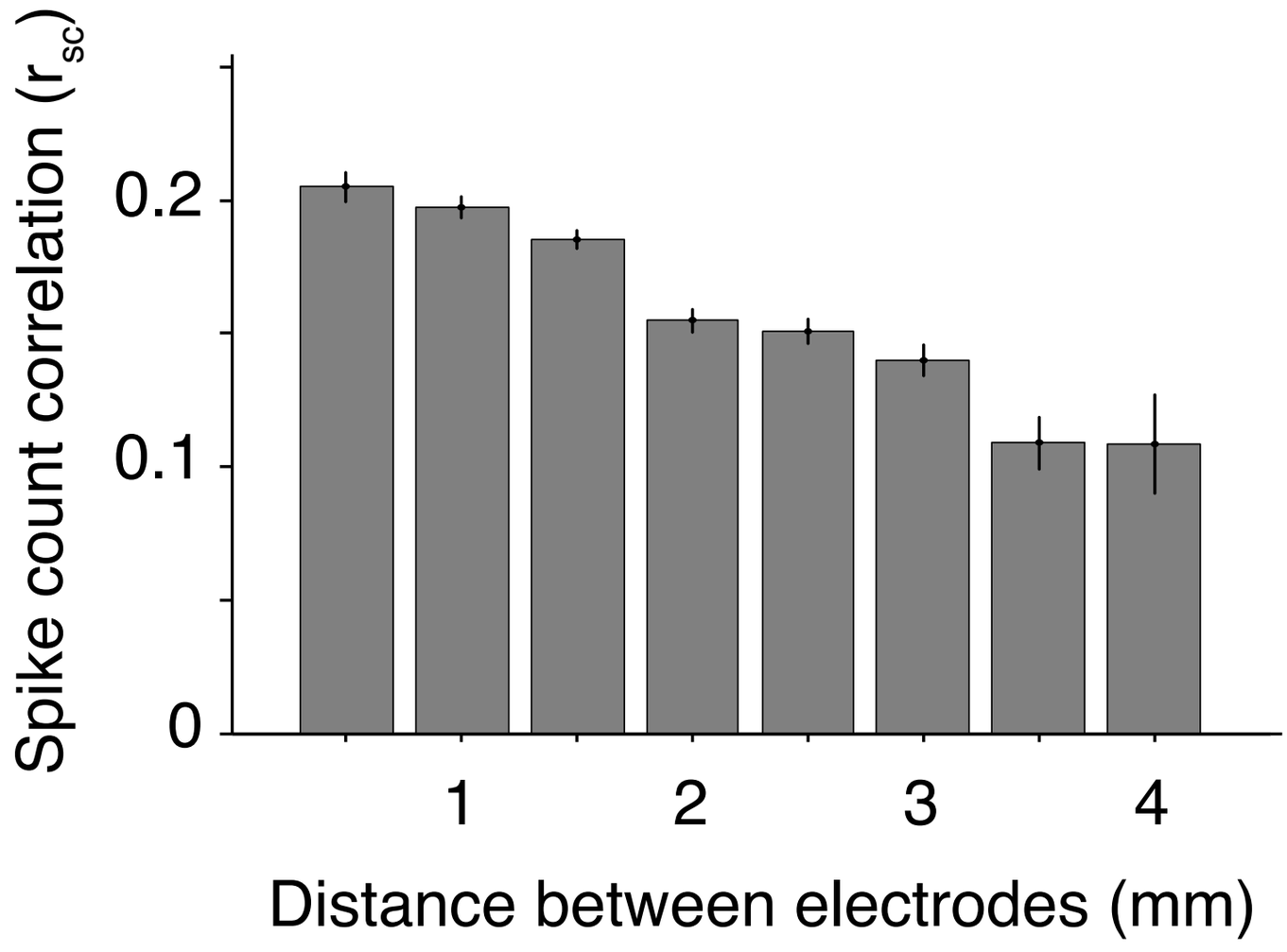
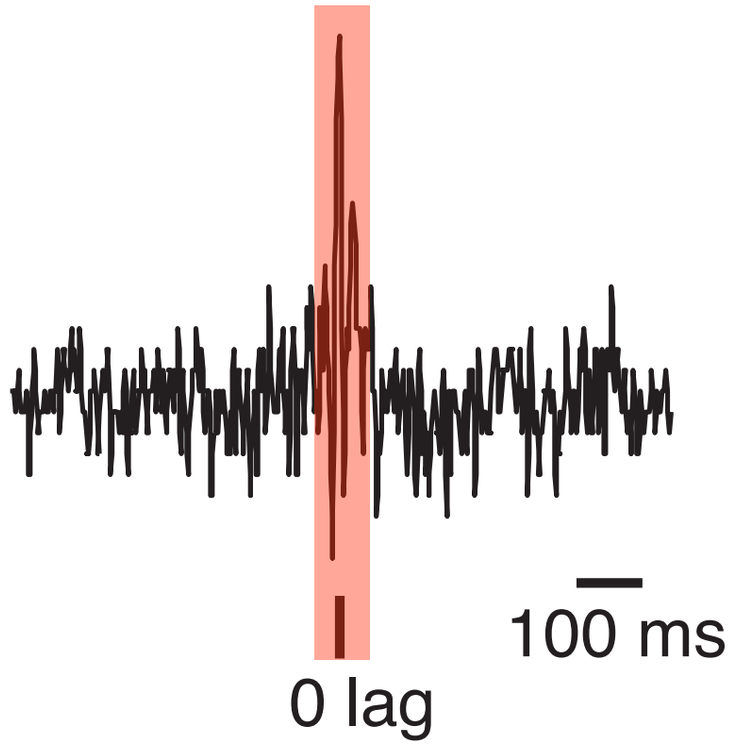




Smith & Kohn (2008)

Spatial scale of functional connections

Fast timescale



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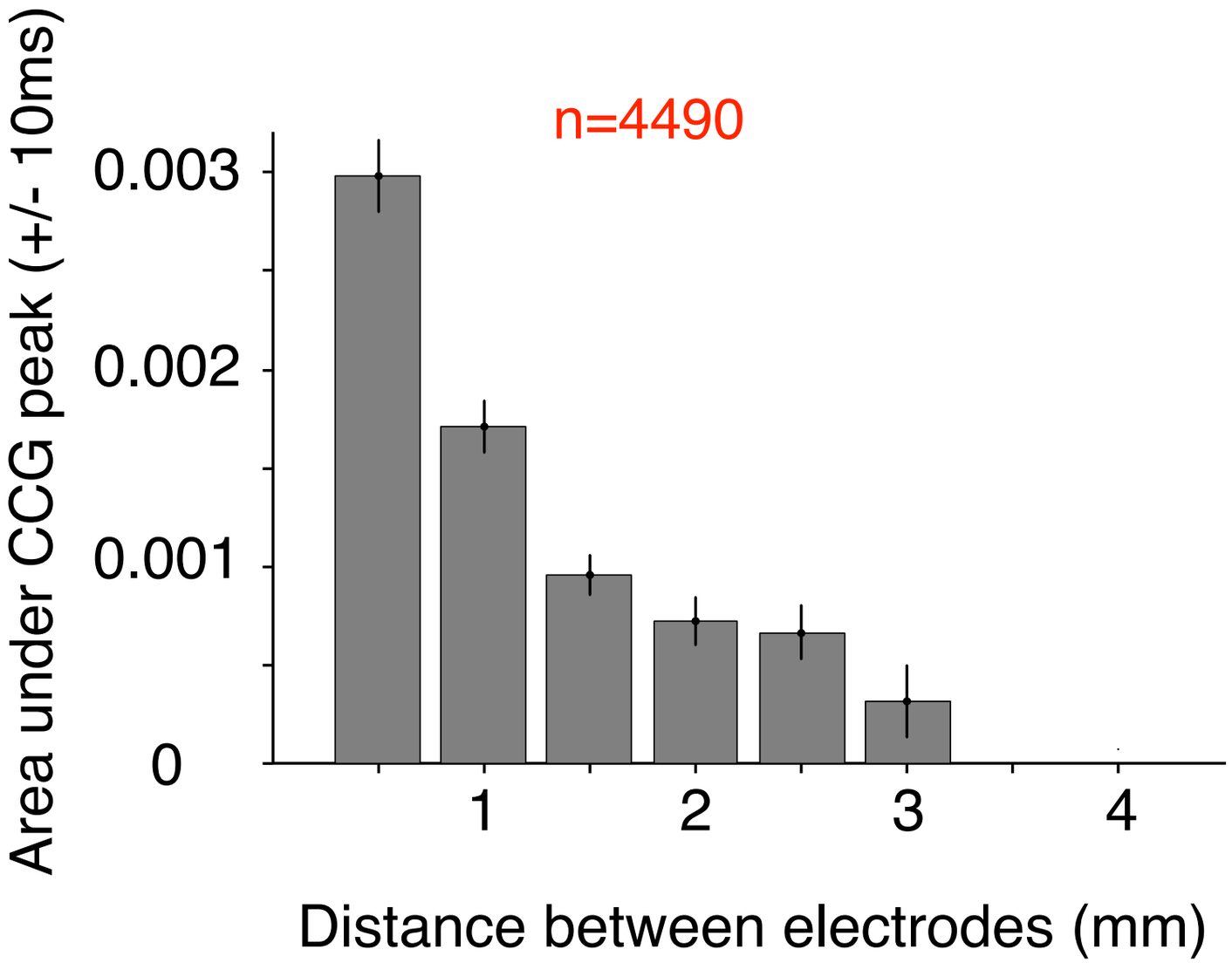

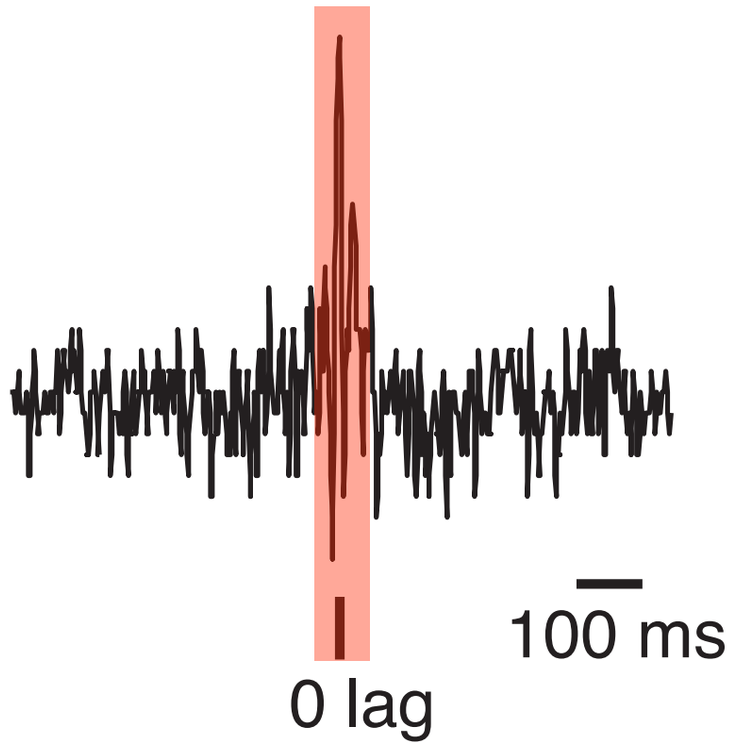

Smith & Kohn (2008)

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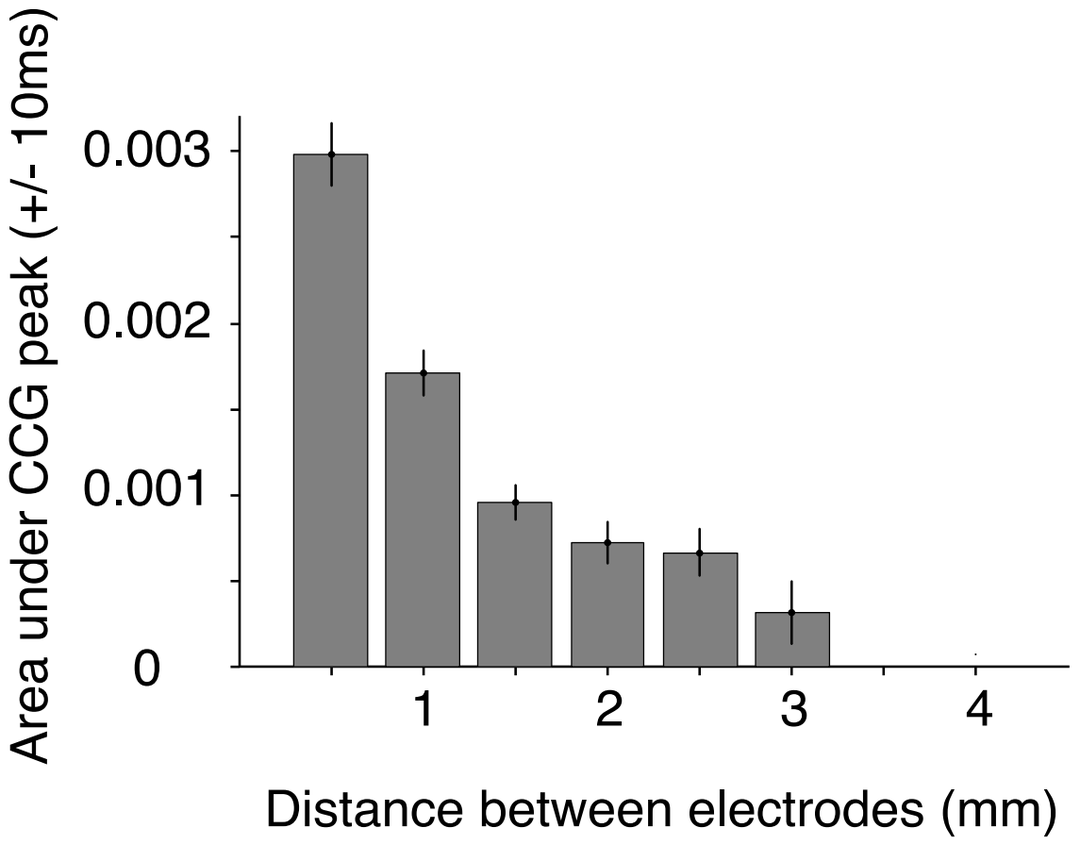
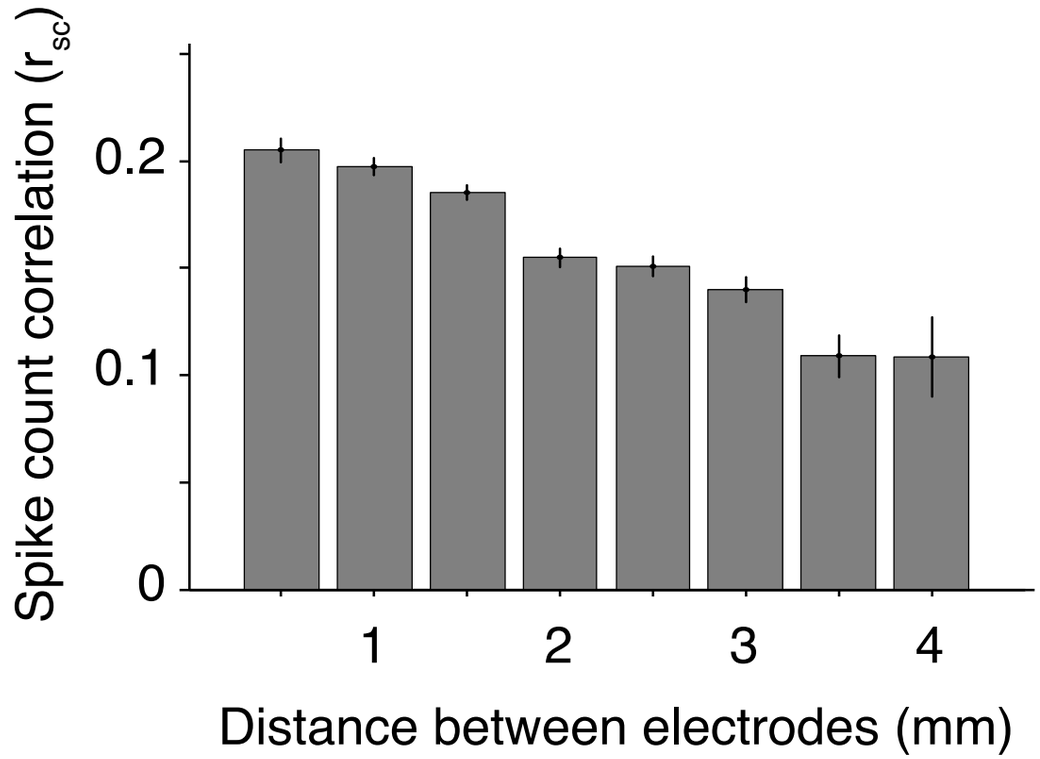
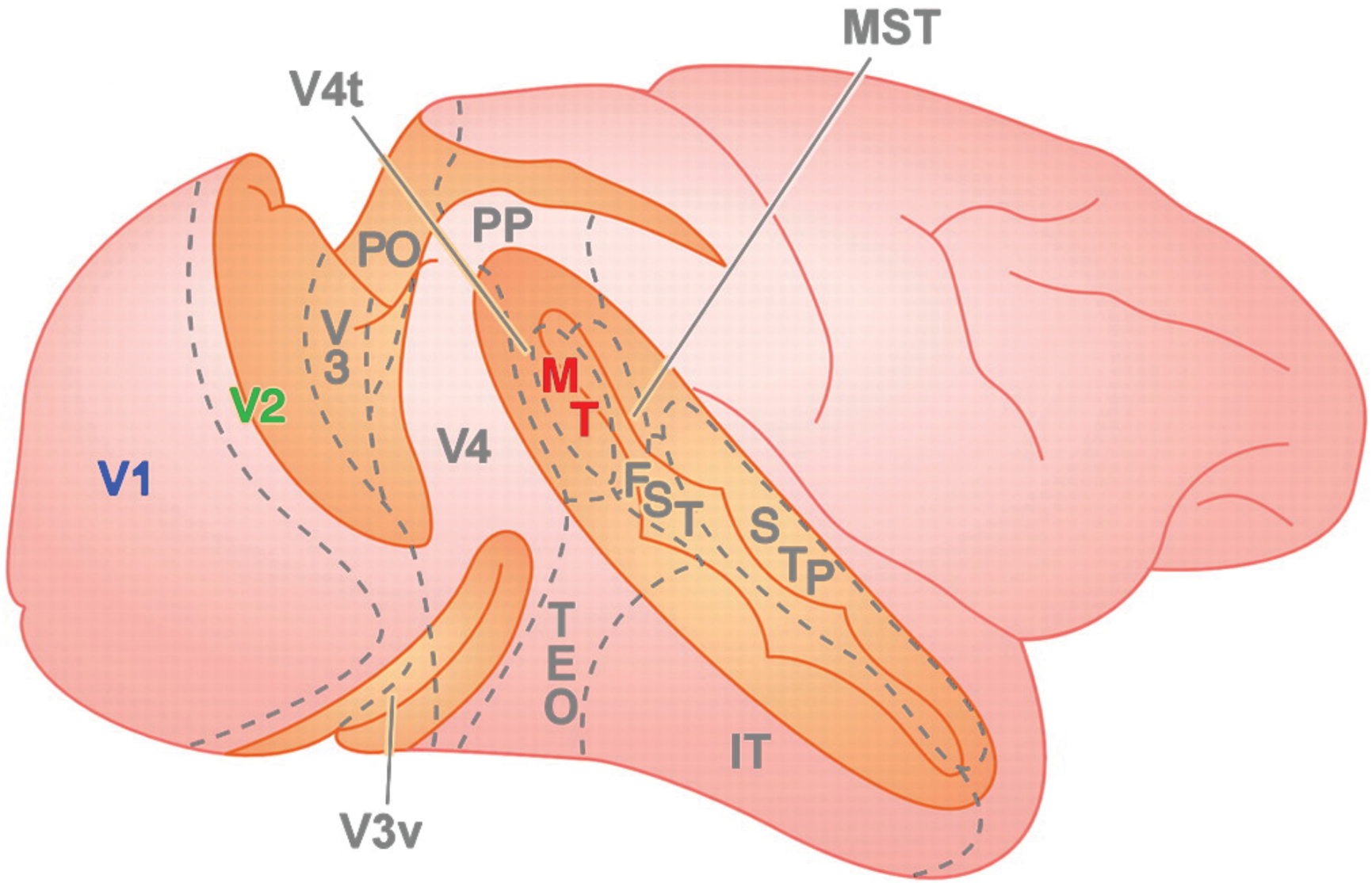




Smith & Kohn (2008)

What about distances > 4 mm?



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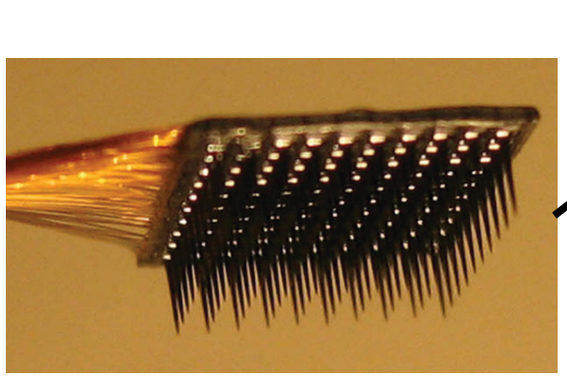
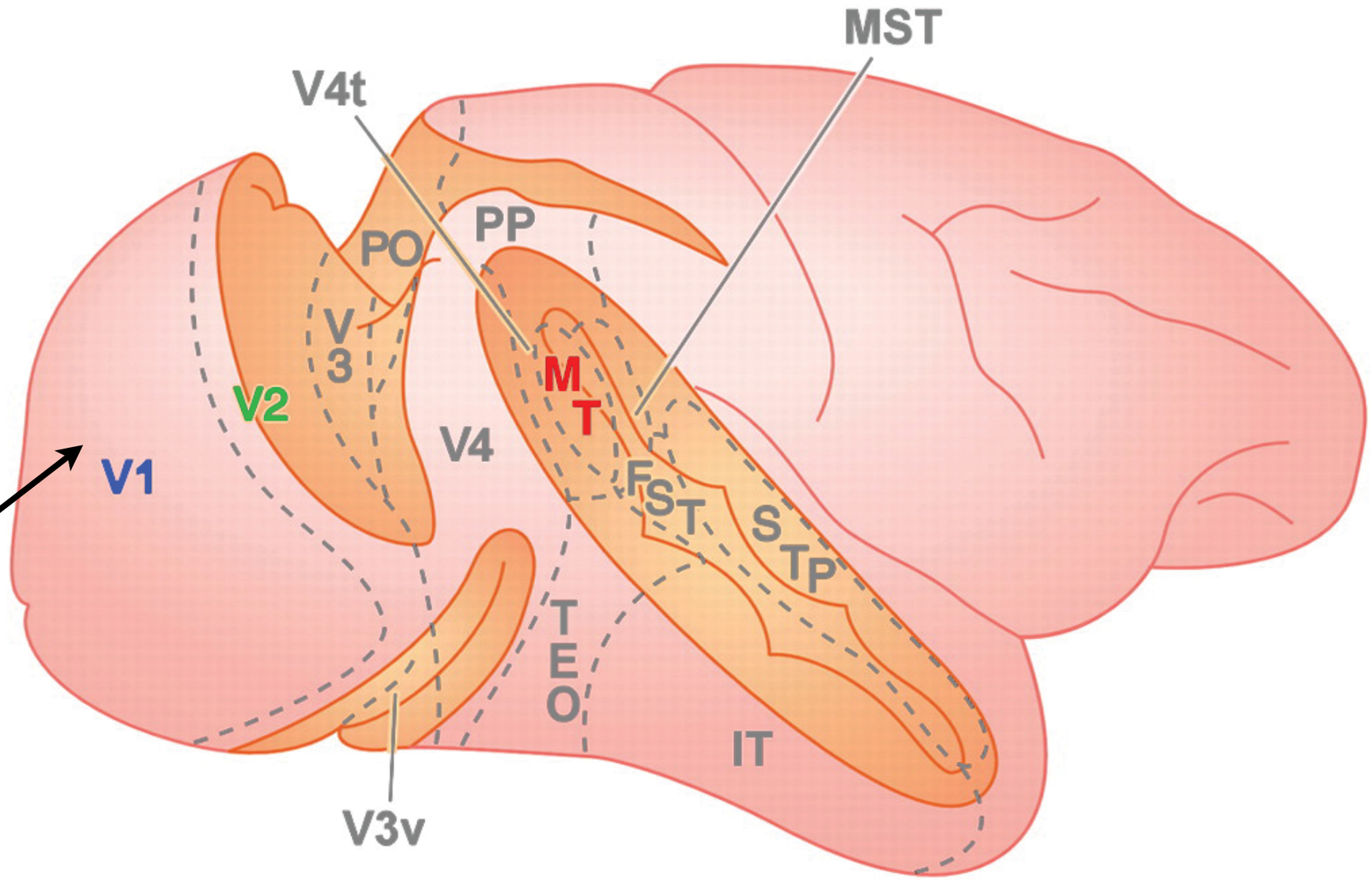


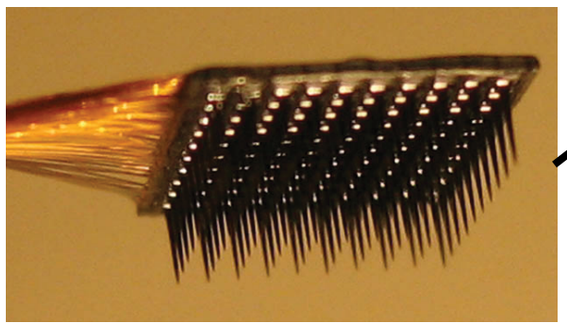


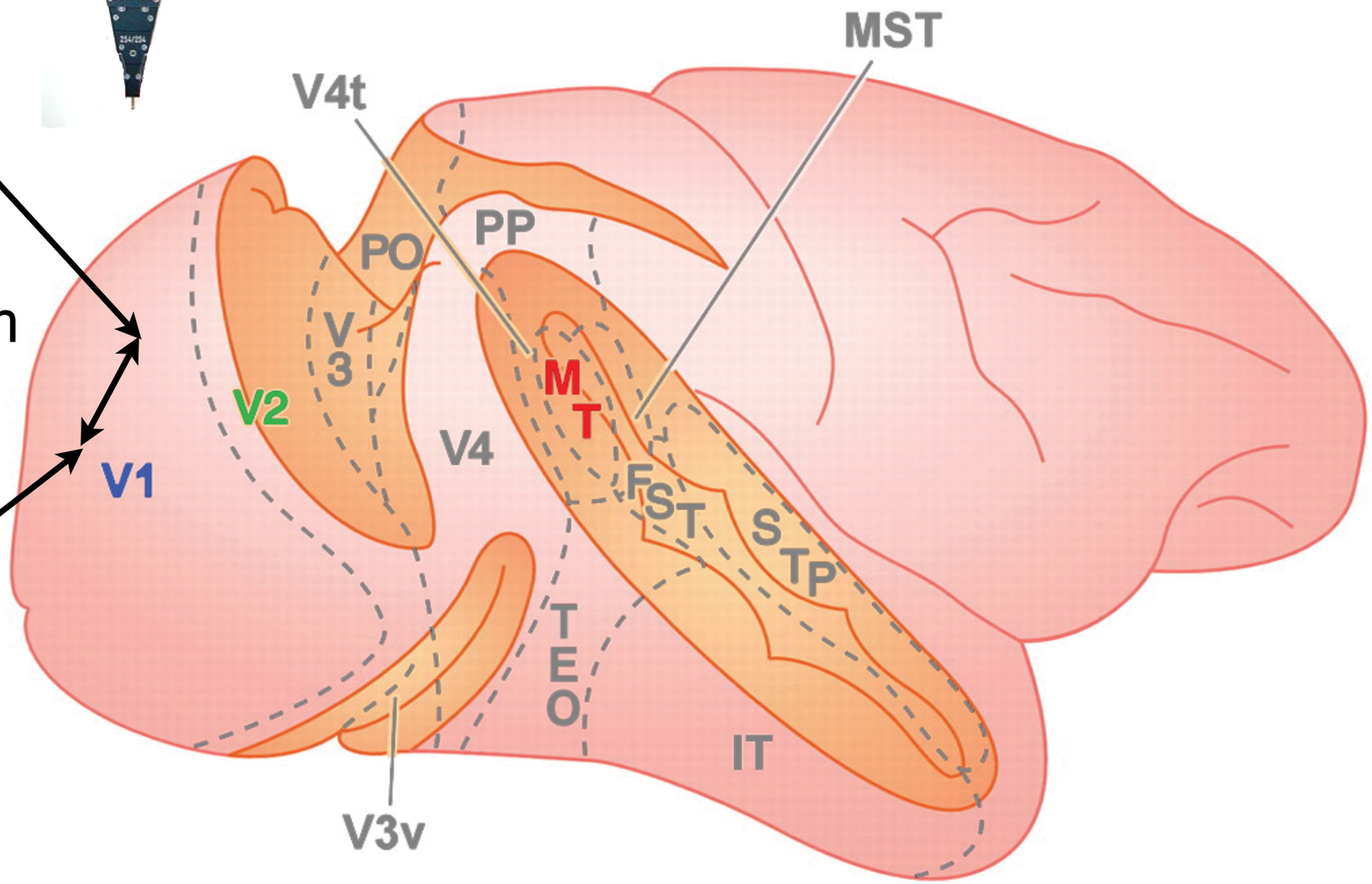
Smith & Kohn (2008)

What about distances > 4 mm?

Thomas recording
7-electrode microdrive

4 mm

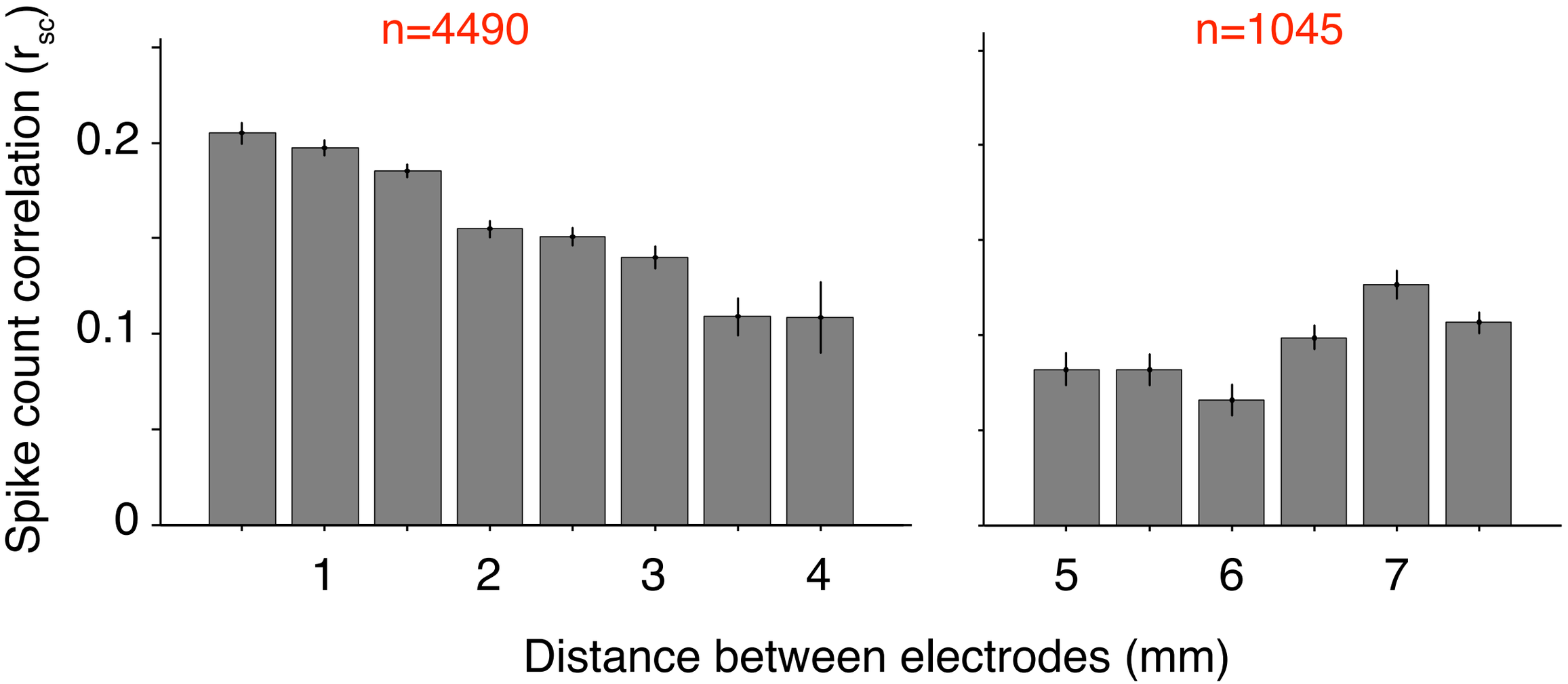




Smith & Kohn (2008)

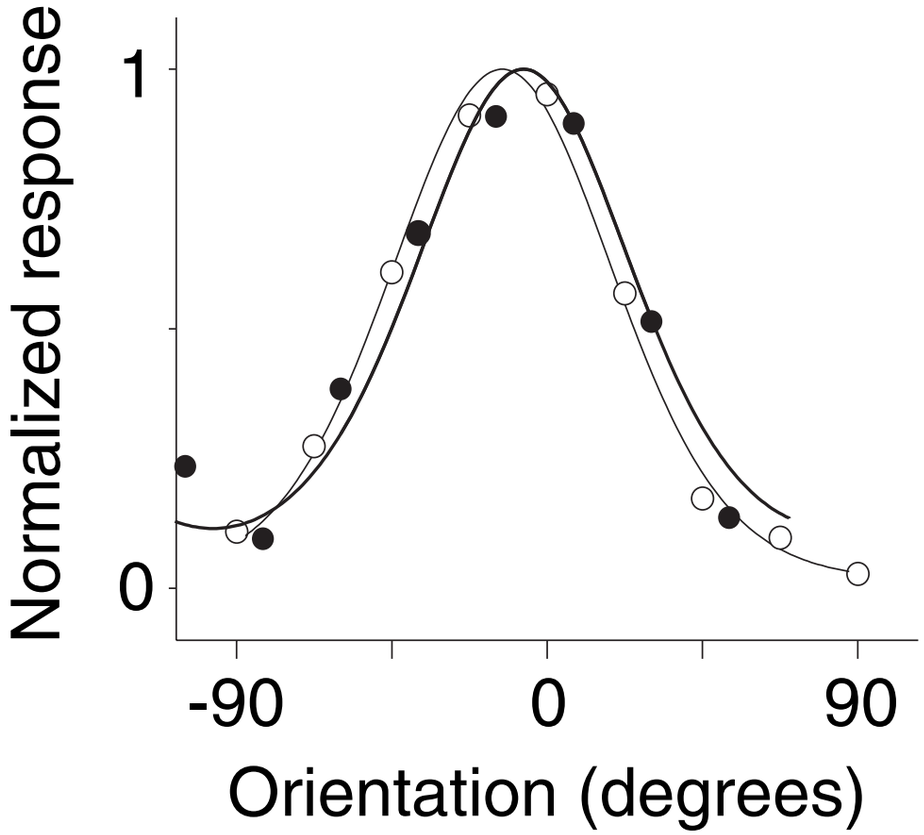
Spatial scale of functional connections

Slow timescale (long distance)



Smith & Kohn (2008)

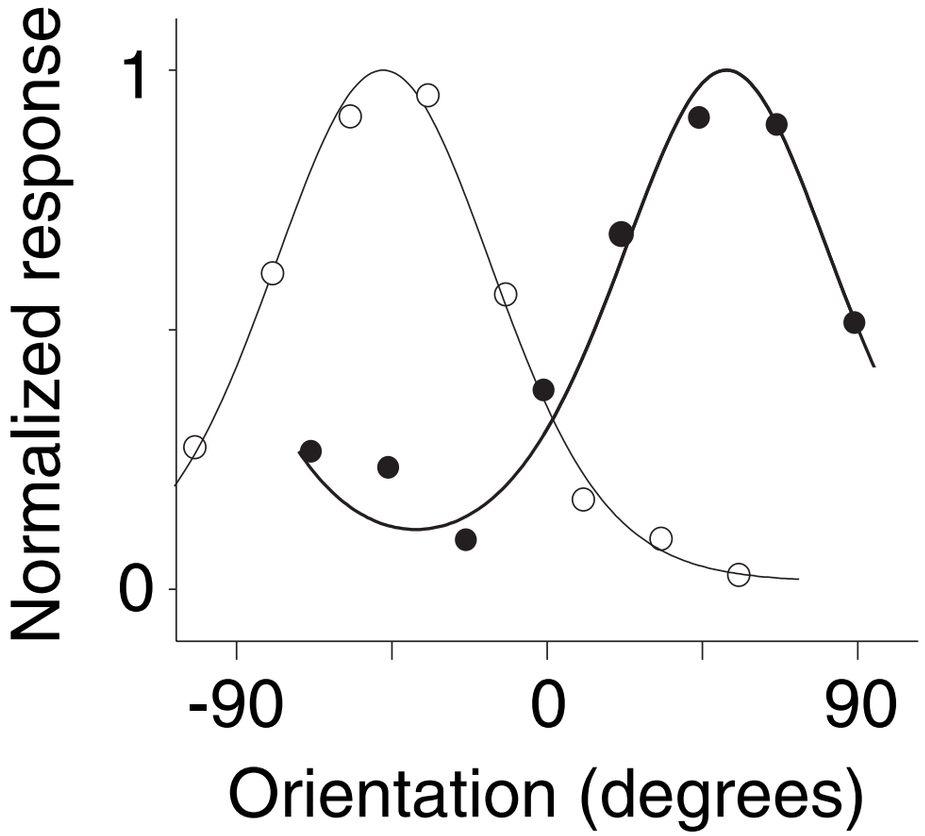
Dependence on tuning similarity (r_{signal})



$r_{signal} \approx 1.0$

(range from -1 to 1)

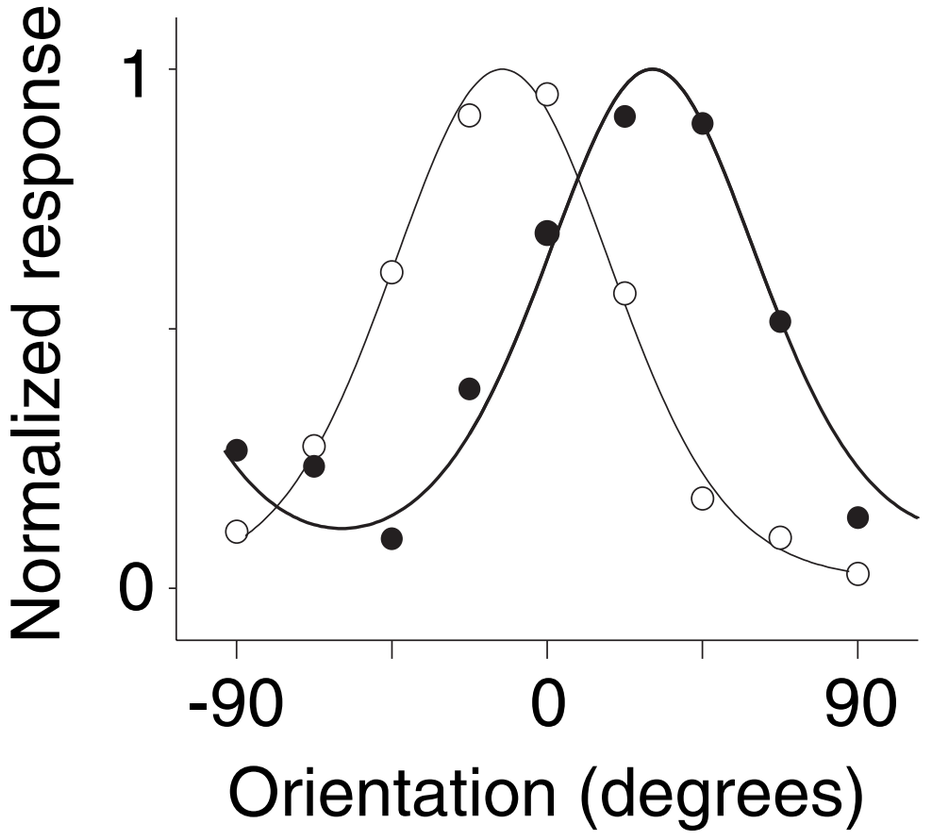
Dependence on tuning similarity (r_{signal})



$r_{signal} \approx -1.0$

(range from -1 to 1)

Dependence on tuning similarity (r_{signal})

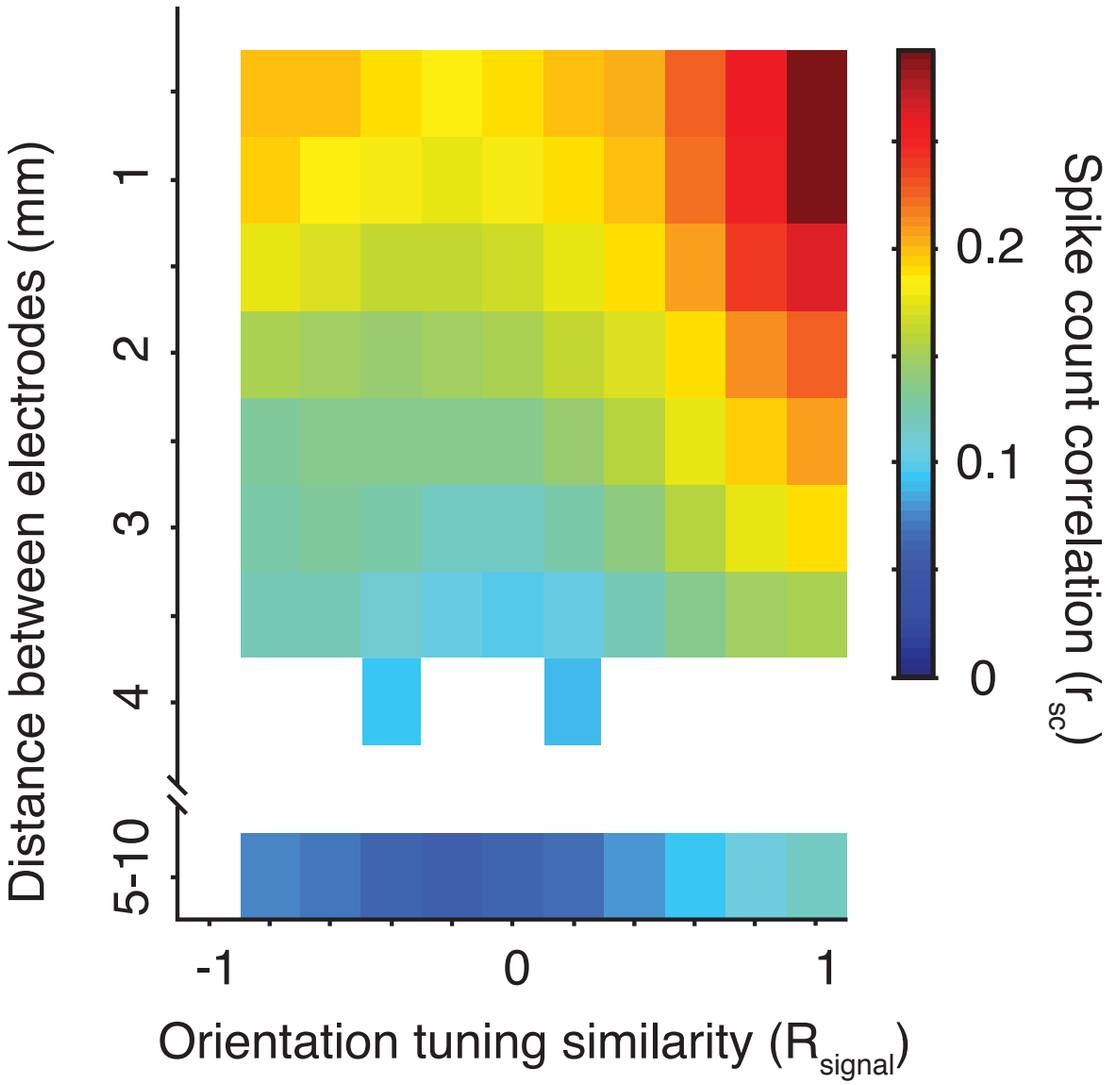


$r_{signal} \approx 0.2$

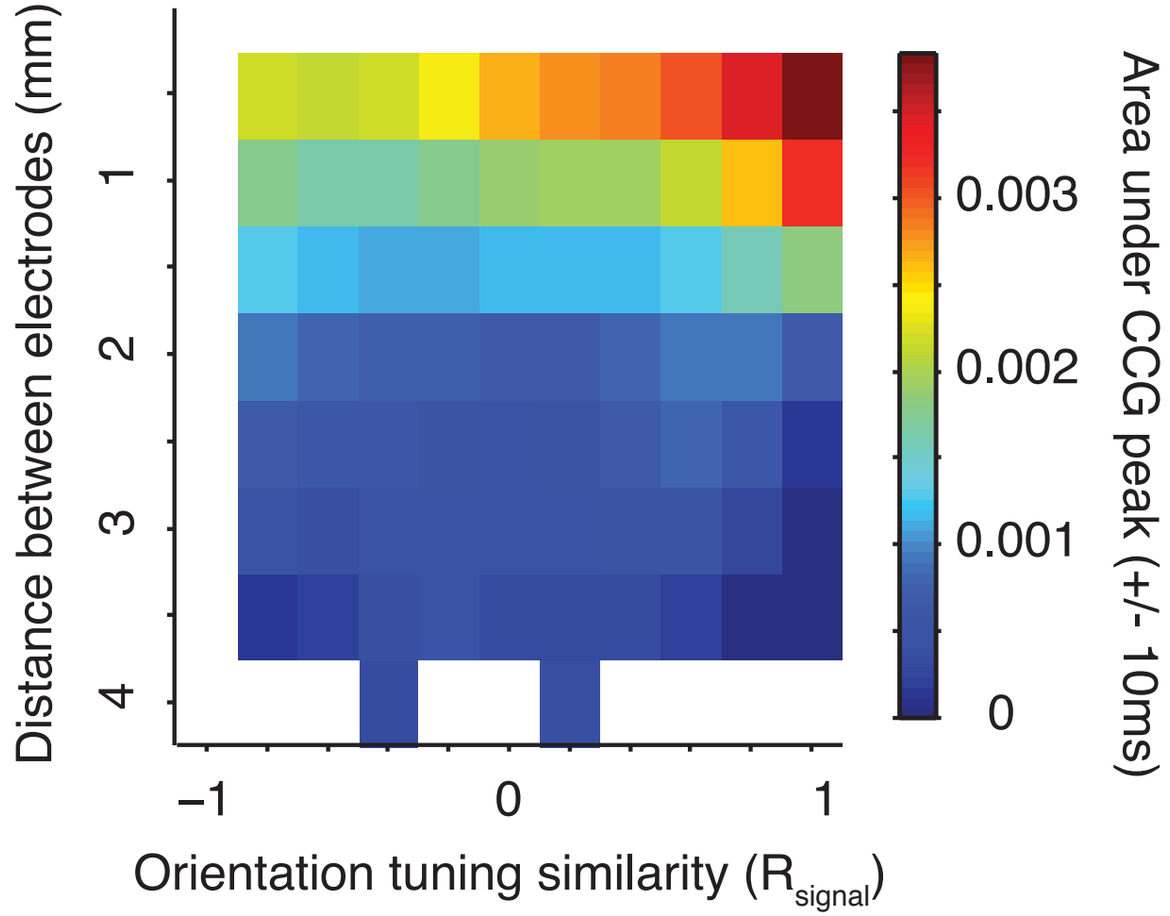
(range from -1 to 1)

Dependence on tuning similarity (r_{signal})

Slow timescale

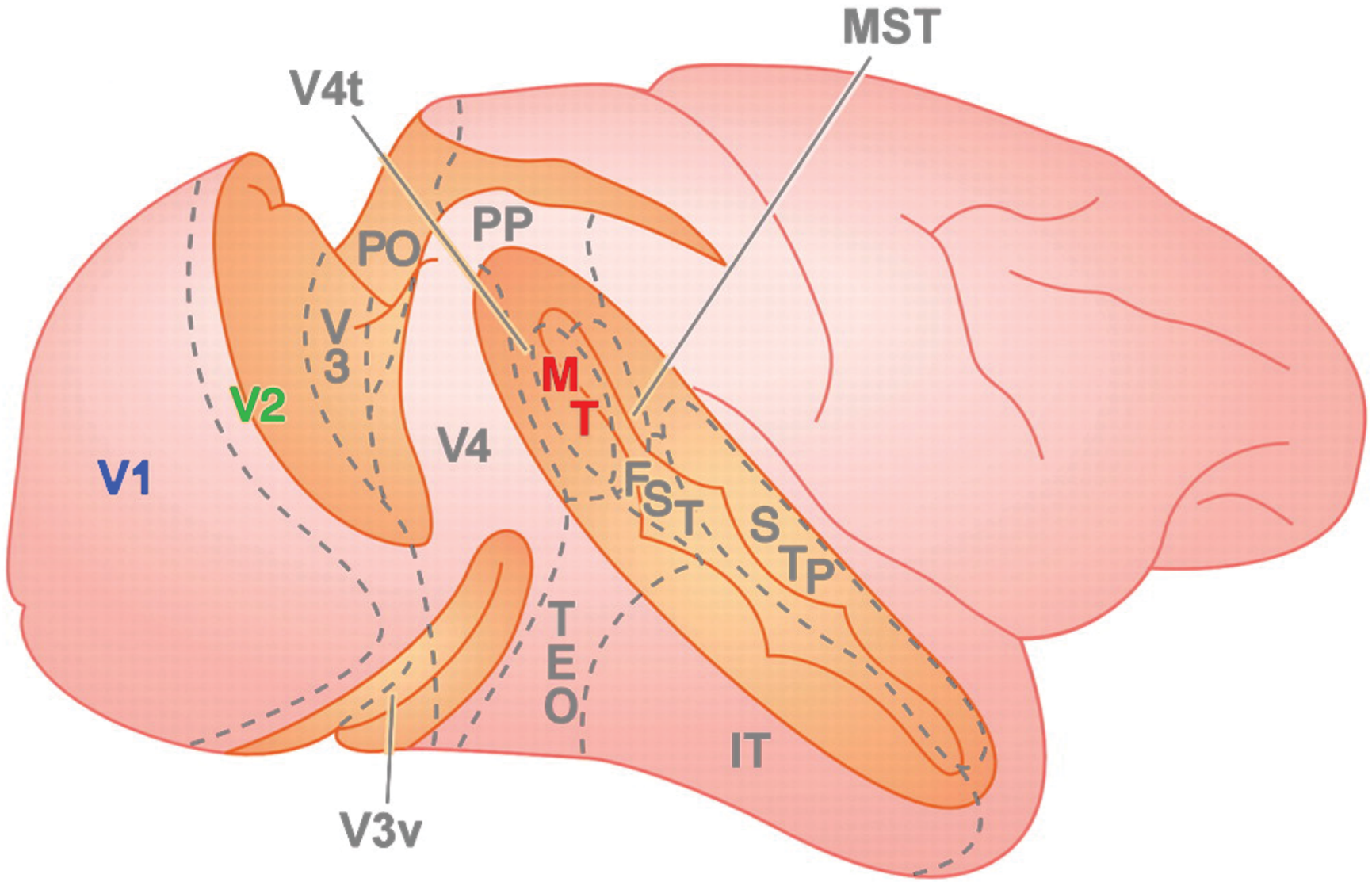


Fast timescale



Smith & Kohn (2008)

Does this structure extend outside V1?



Smith & Sommer (2010, SfN Abstract)

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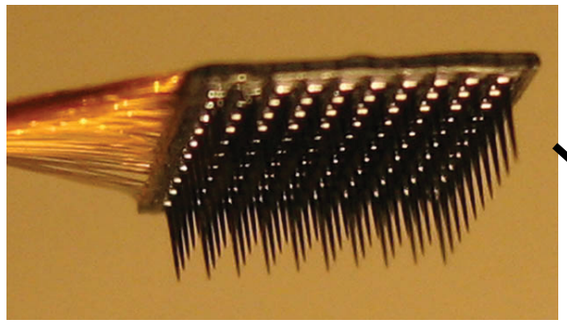
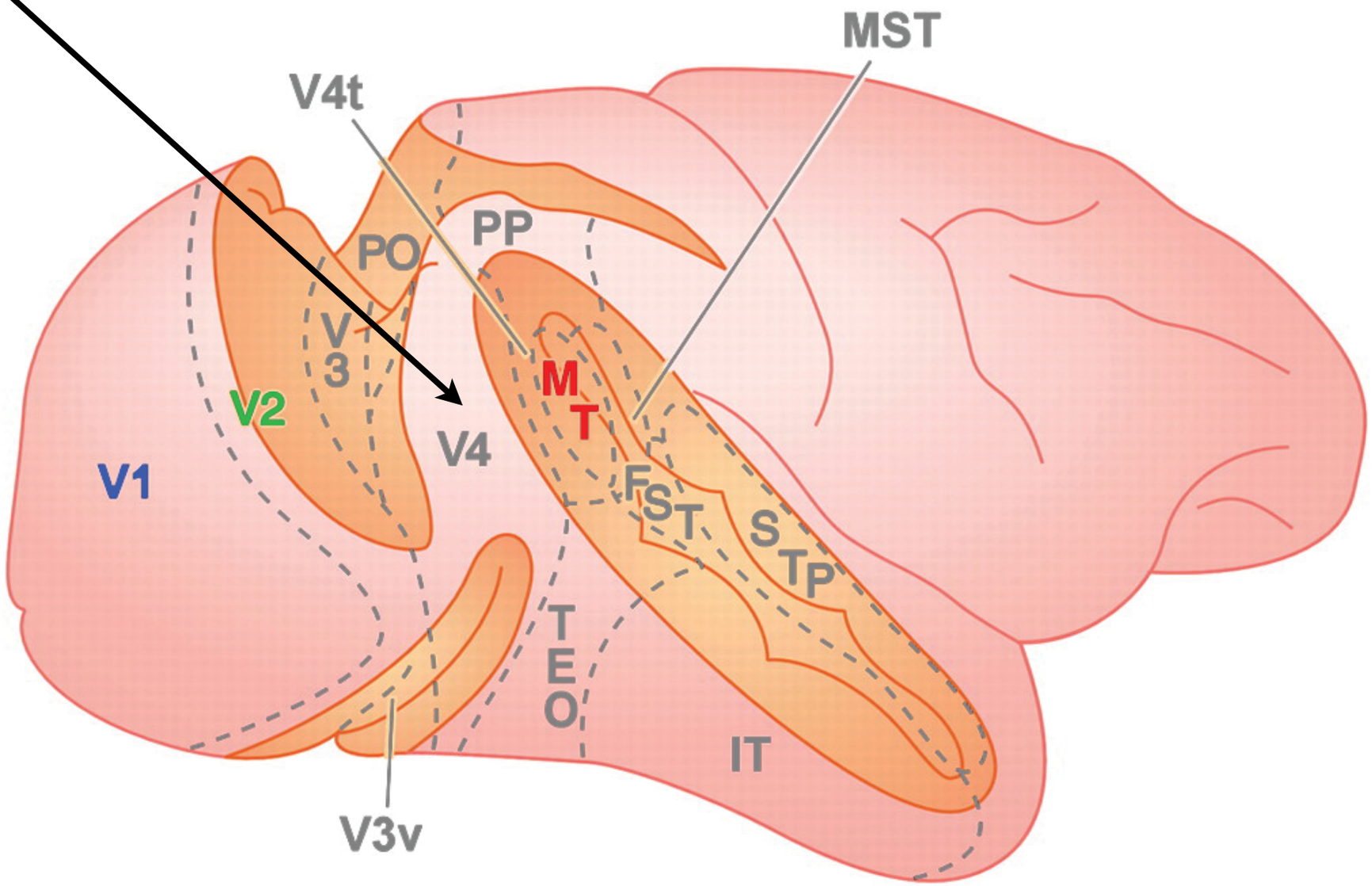


- Awake animals
- V4 array implant
- Fixation task
- Same stimulus



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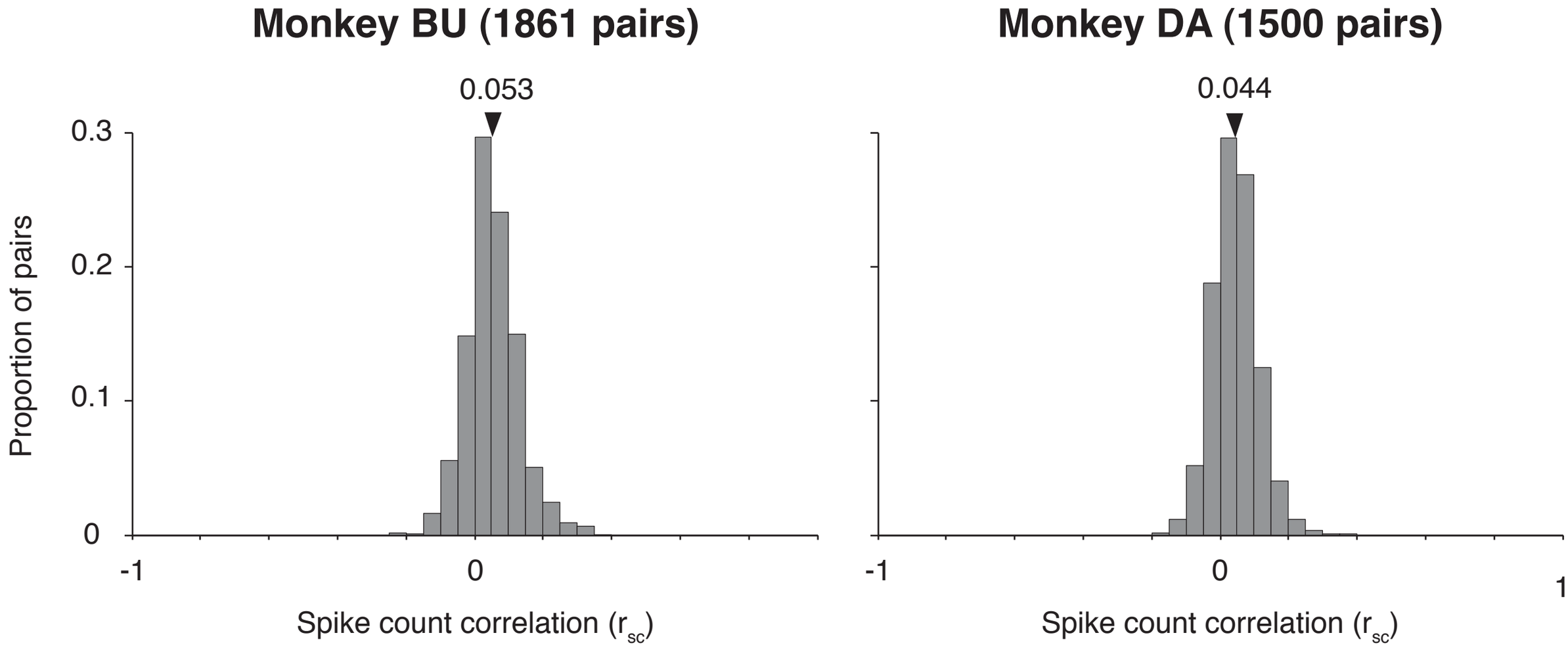

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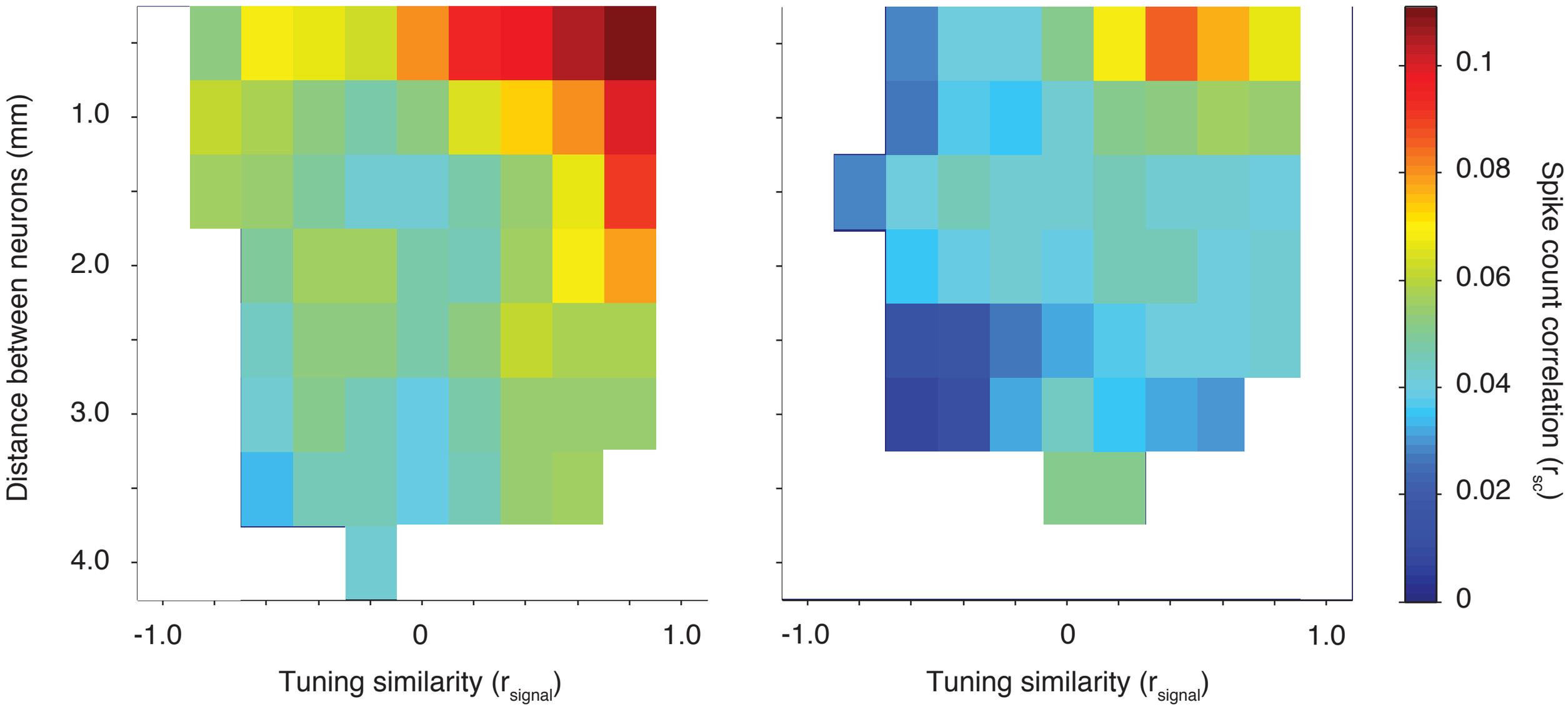

Smith & Sommer (2010, SfN Abstract)

Structure of neuronal correlation

- Distance

- Dynamics

  Spontaneous vs Evoked
  Transition between states

- Depth

  Laminar variation
  Correlation outside V1

Structure of neuronal correlation

- **Distance**
  - r_{sc} extends over long distances; synchrony only short range

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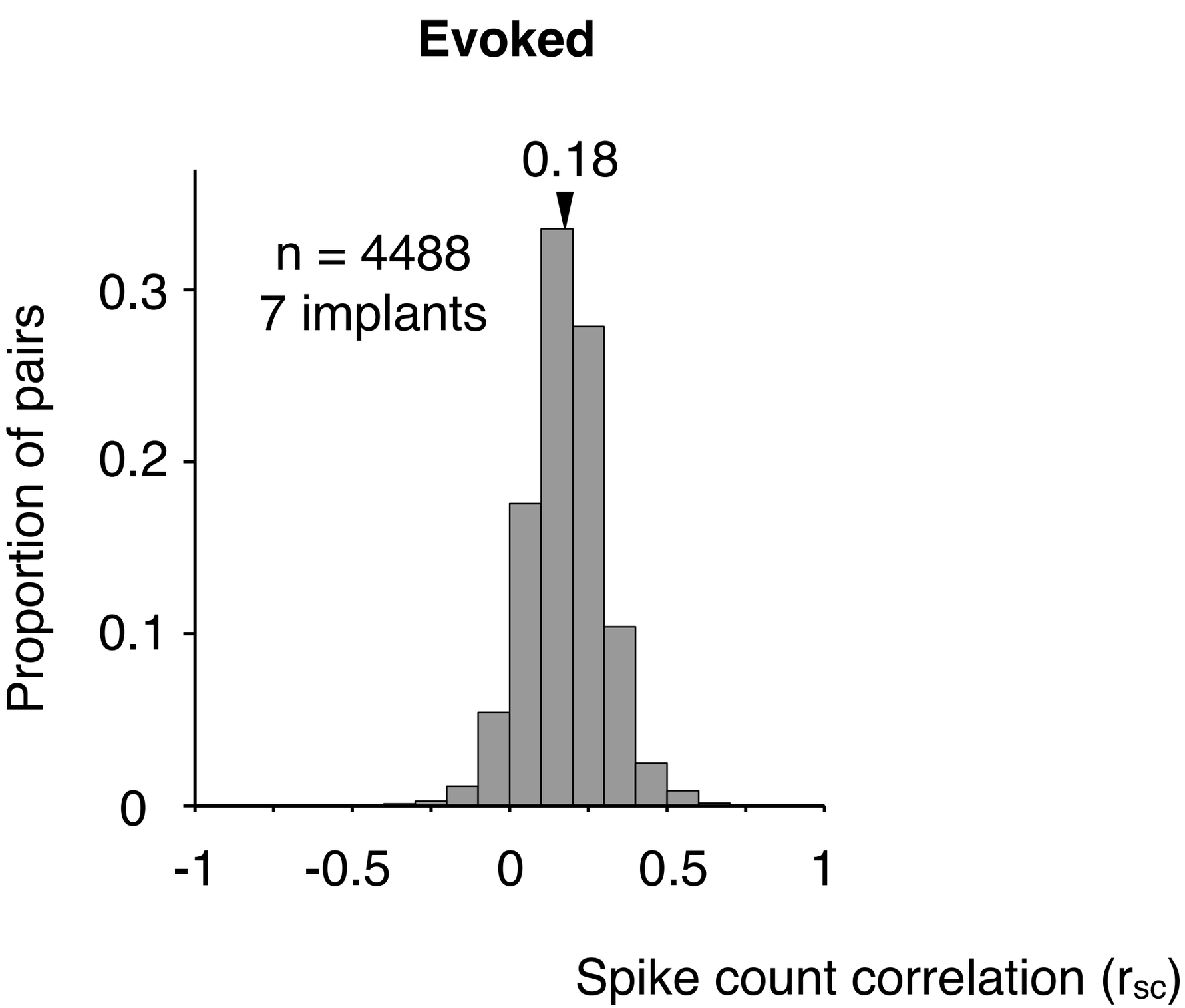

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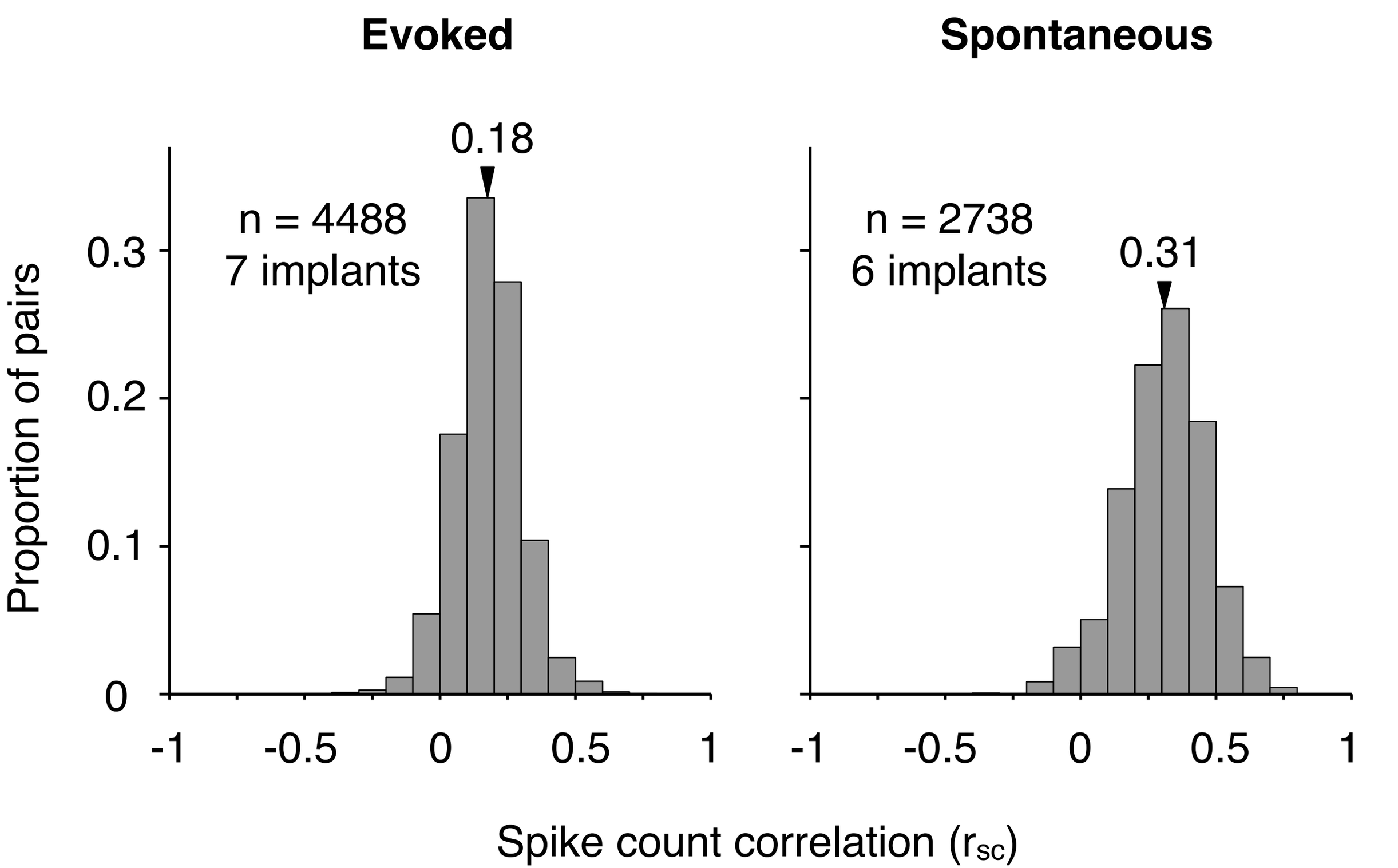

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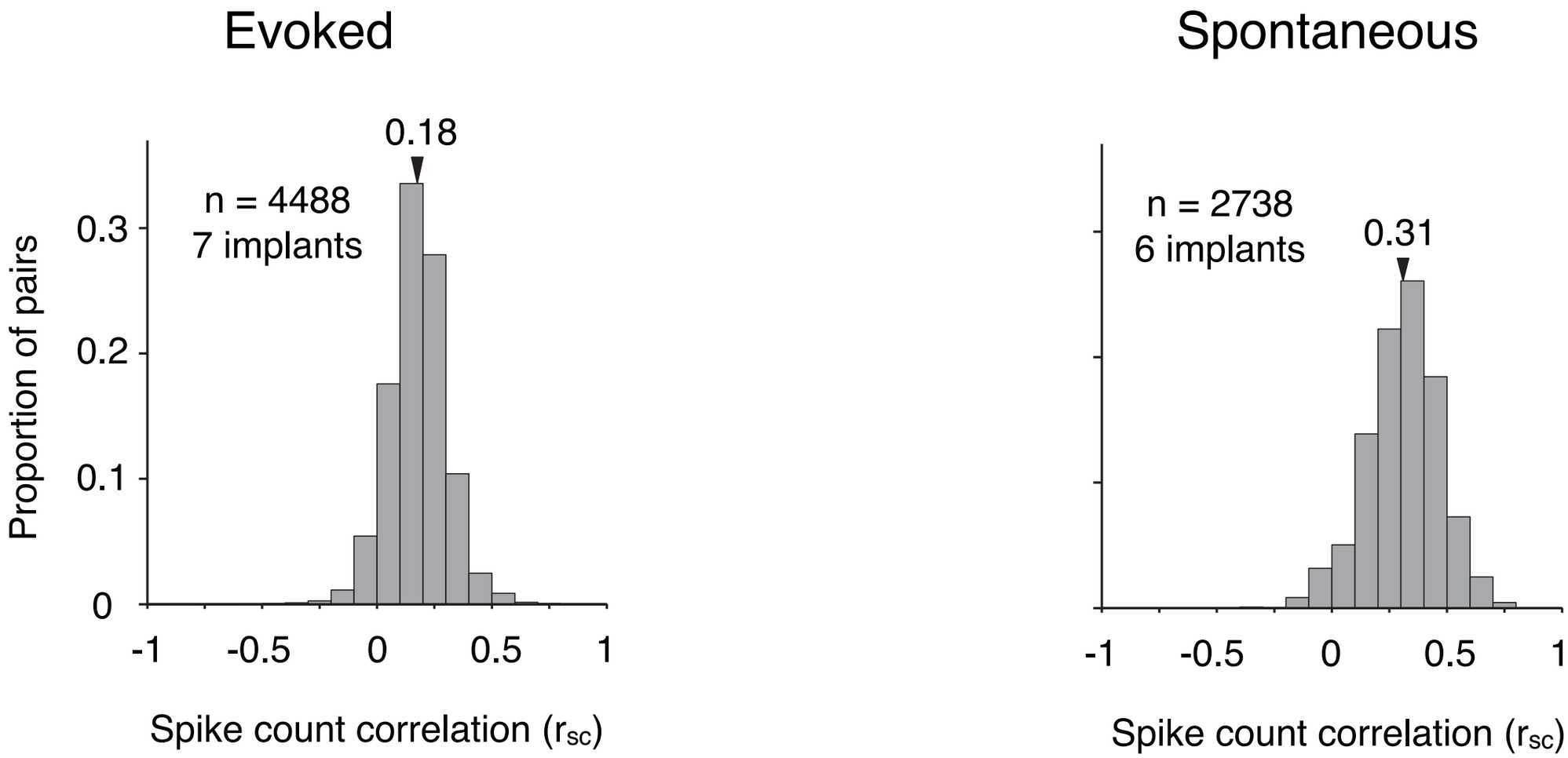
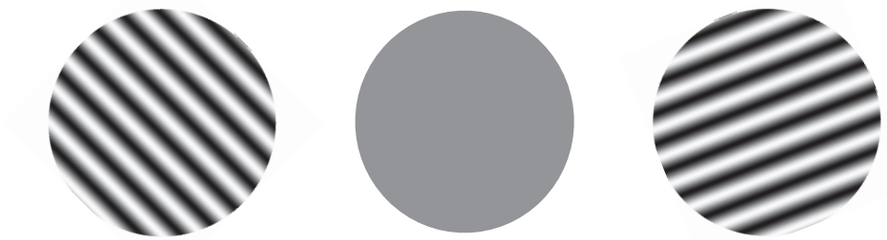
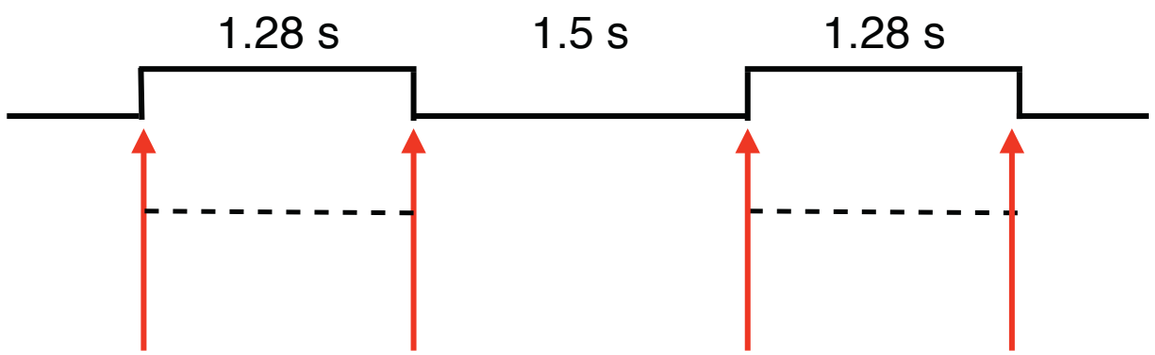
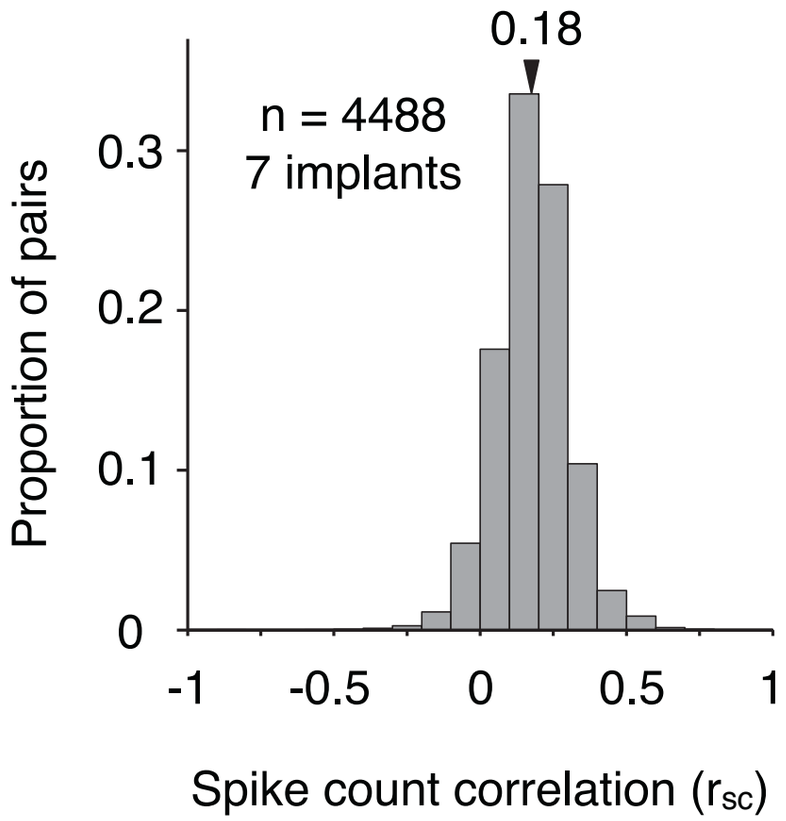

Evoked
Spontaneous
0.18
n = 4488
7 implants
n = 2738
6 implants
0.31
Proportion of pairs
0.3
0.2
0.1
0
-1
-0.5
0
0.5
1
Spike count correlation (r_{sc})
Spike count correlation (r_{sc})

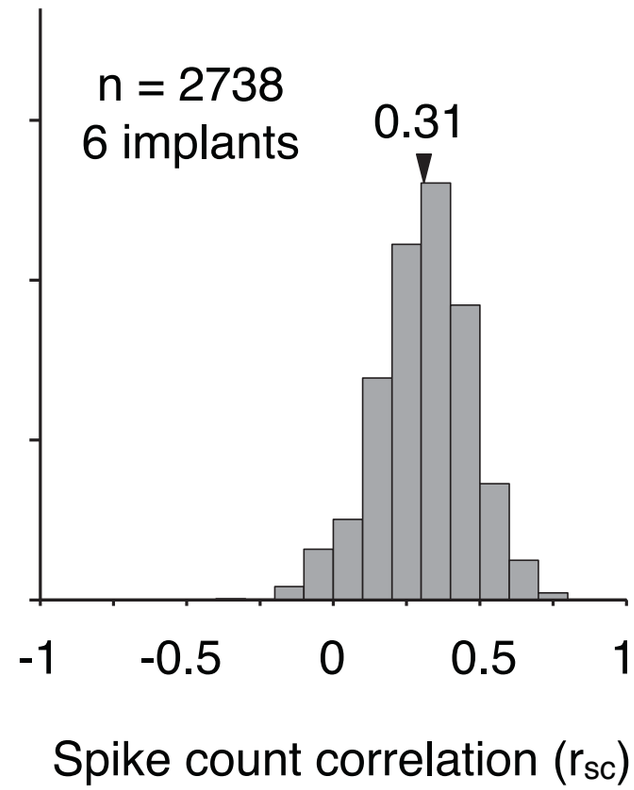
Evoked



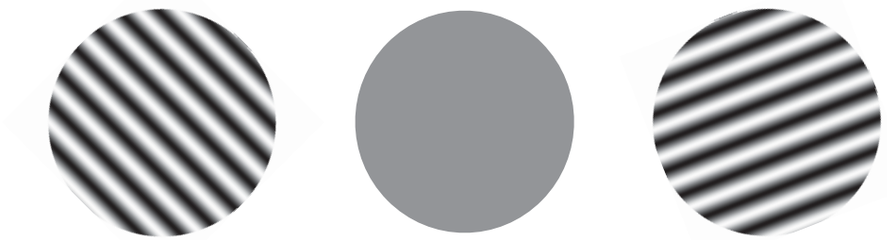




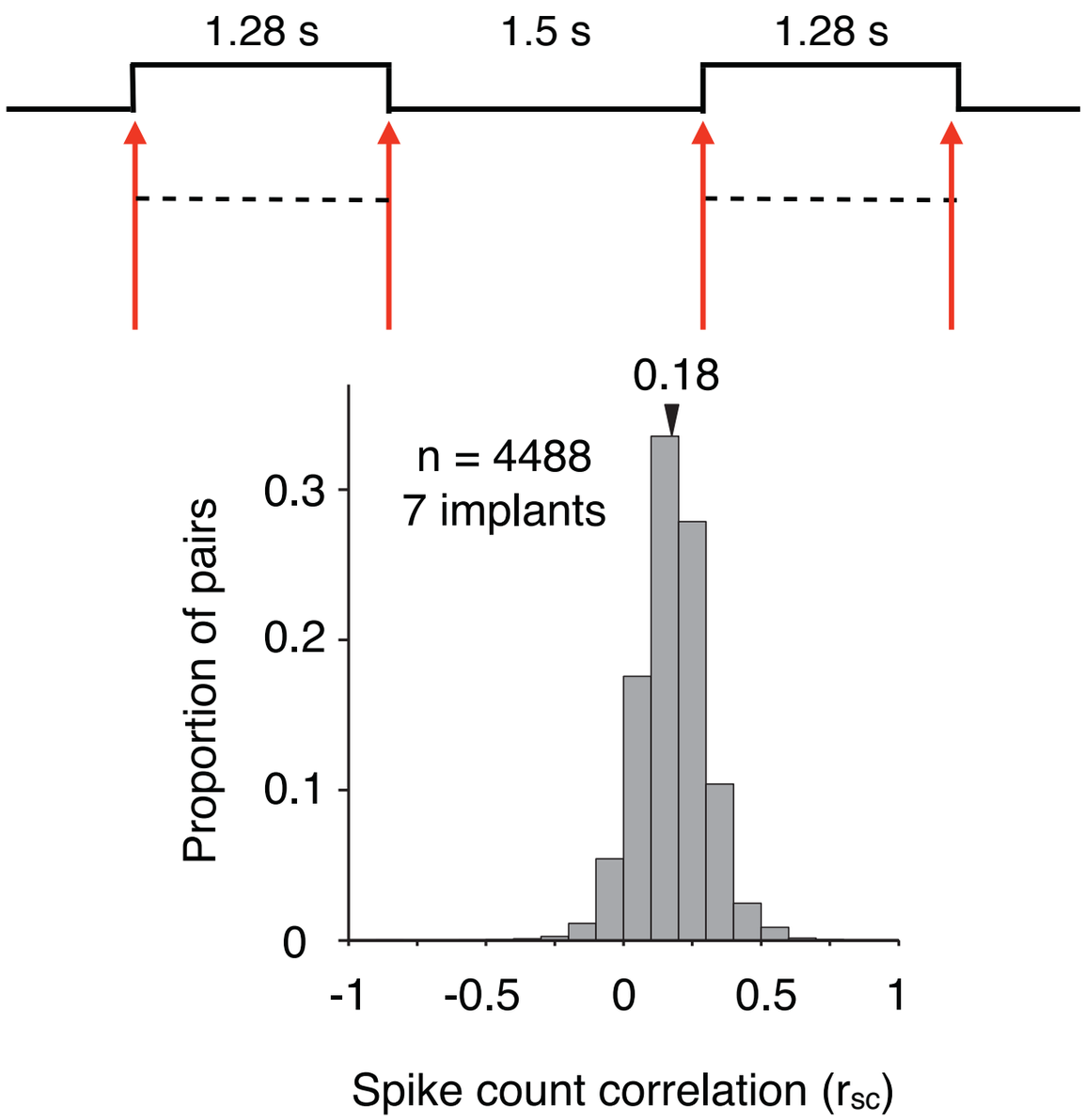
Spontaneous



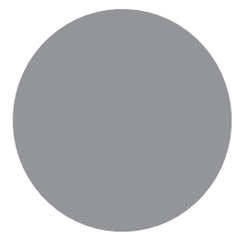
Evoked



1.28 s 1.5 s 1.28 s

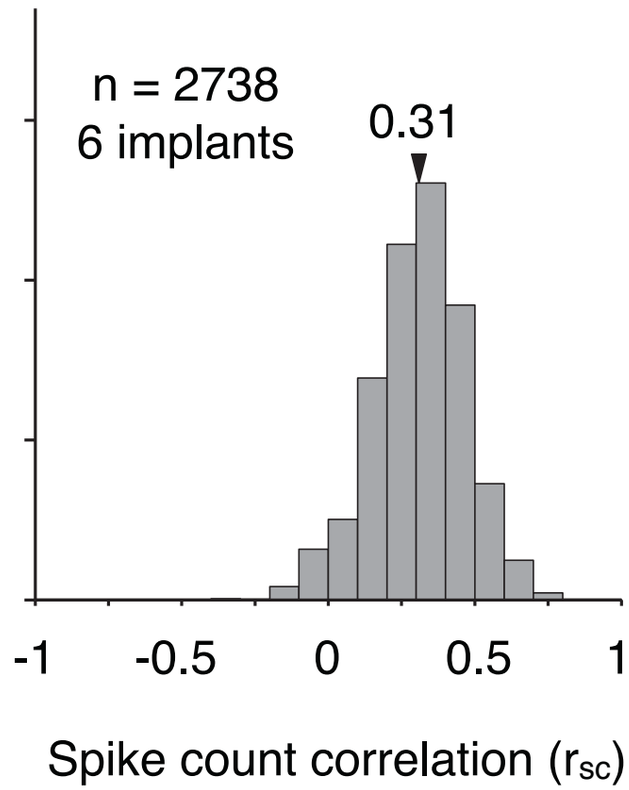


Spontaneous

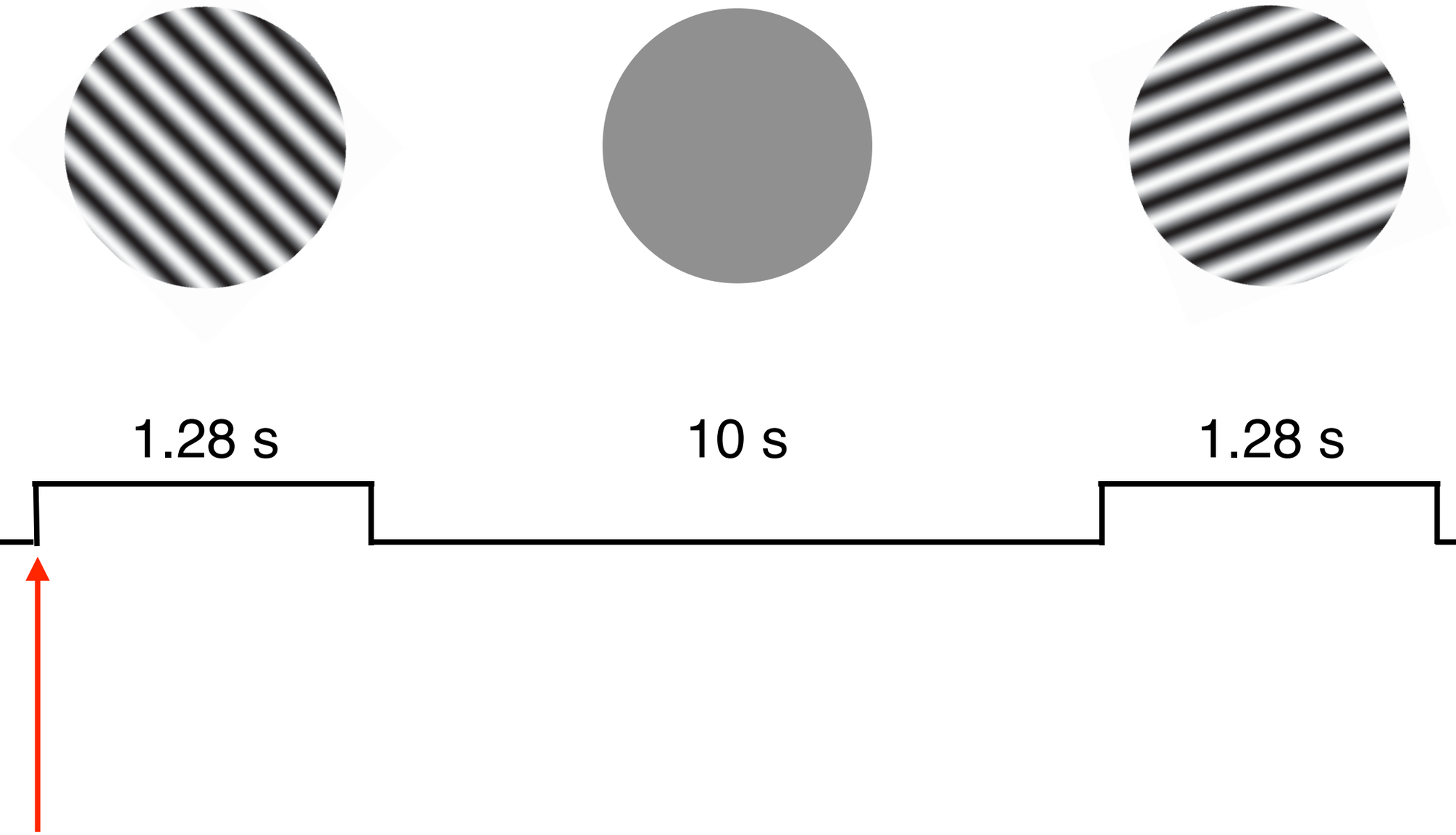


many seconds

1.28 s



Transition from evoked to spontaneous



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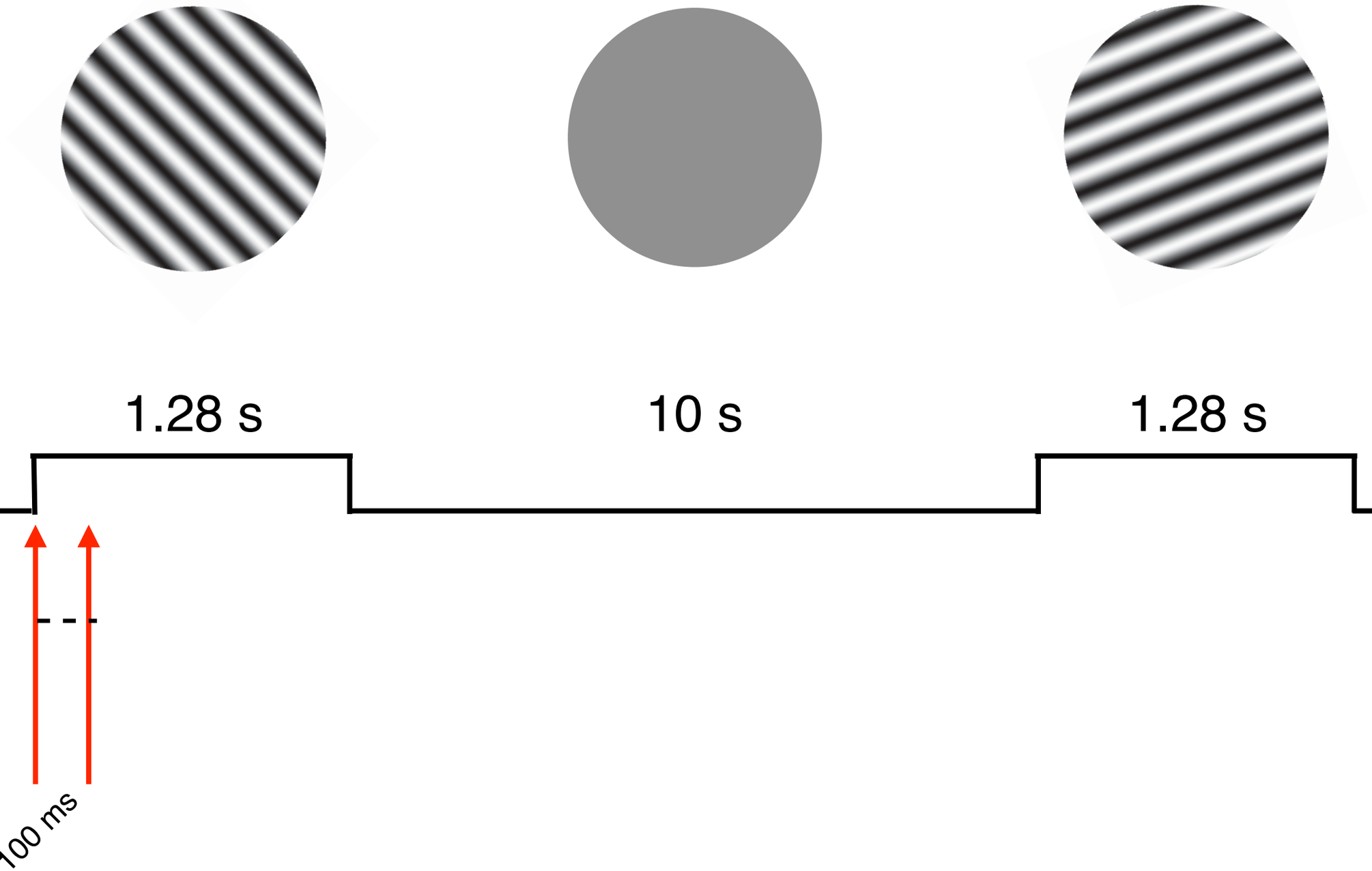

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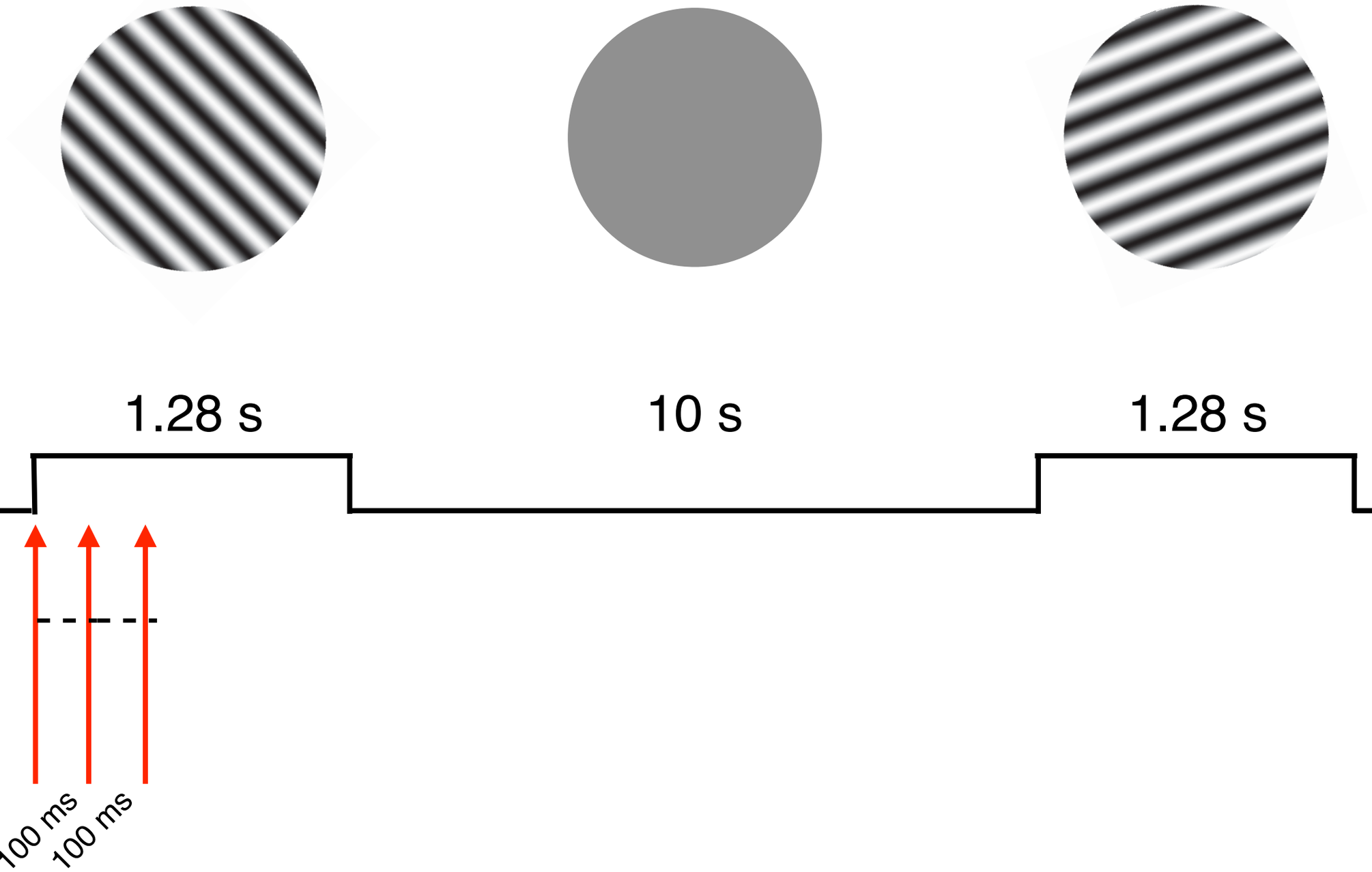

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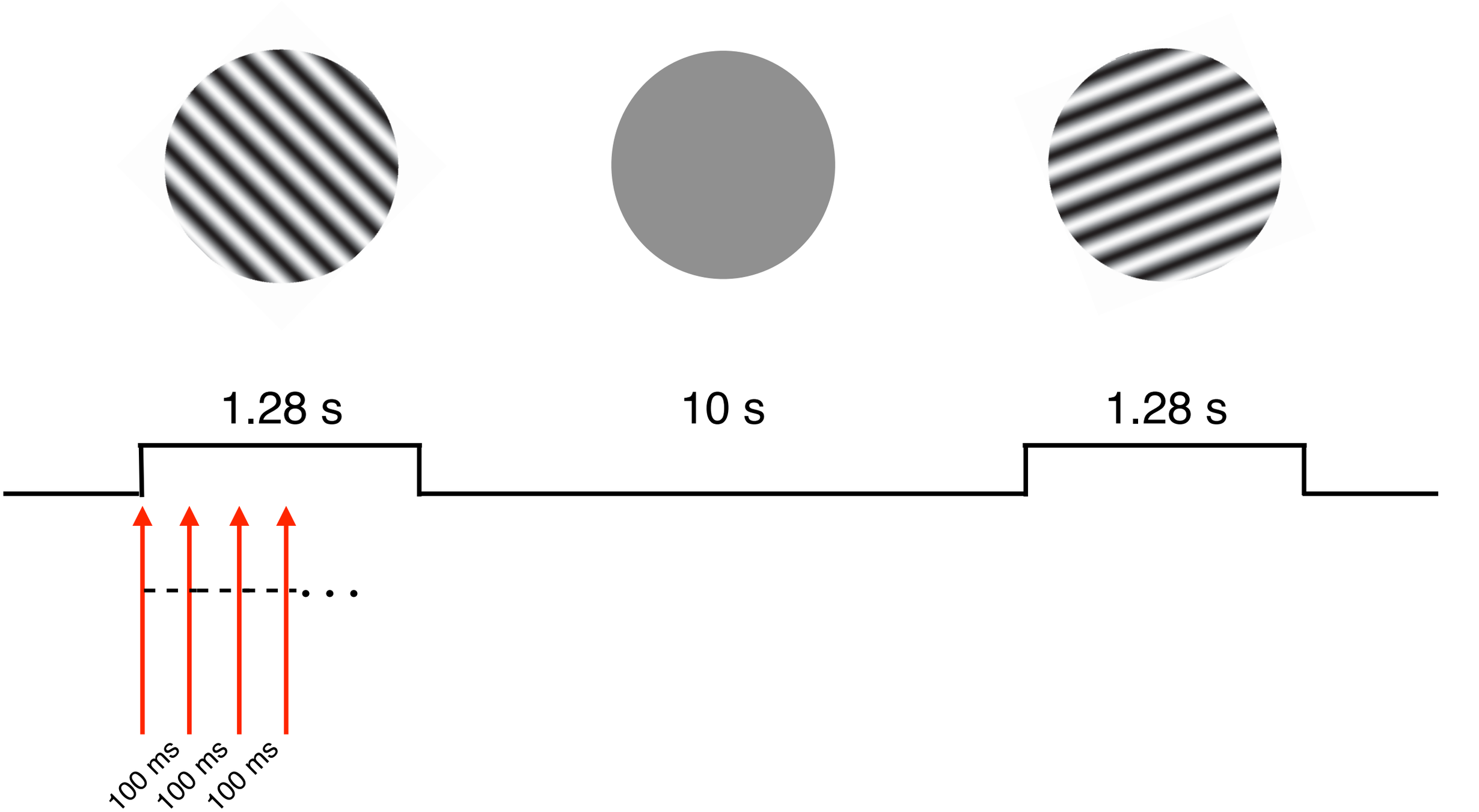
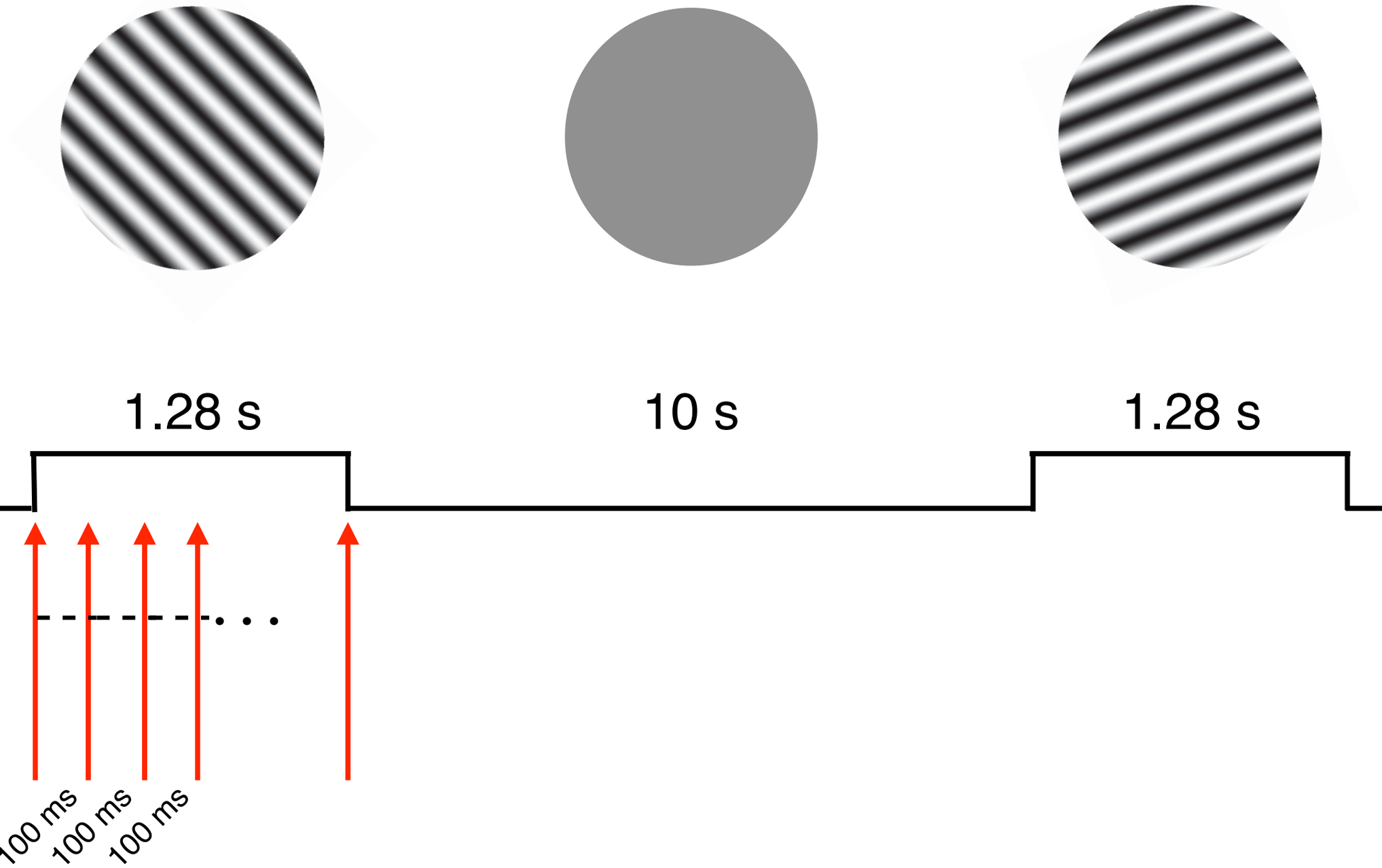


Transition from evoked to spontaneous



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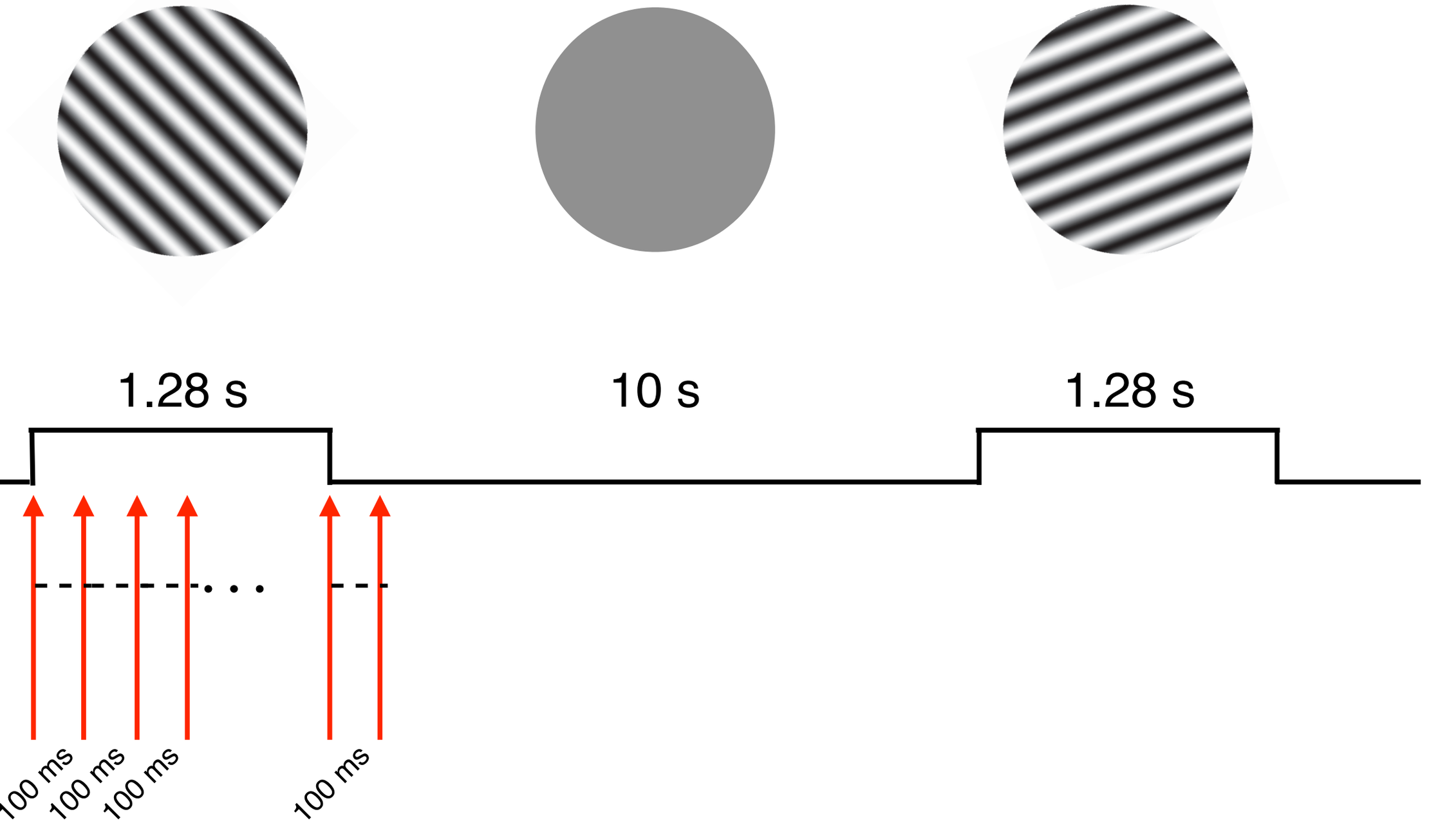

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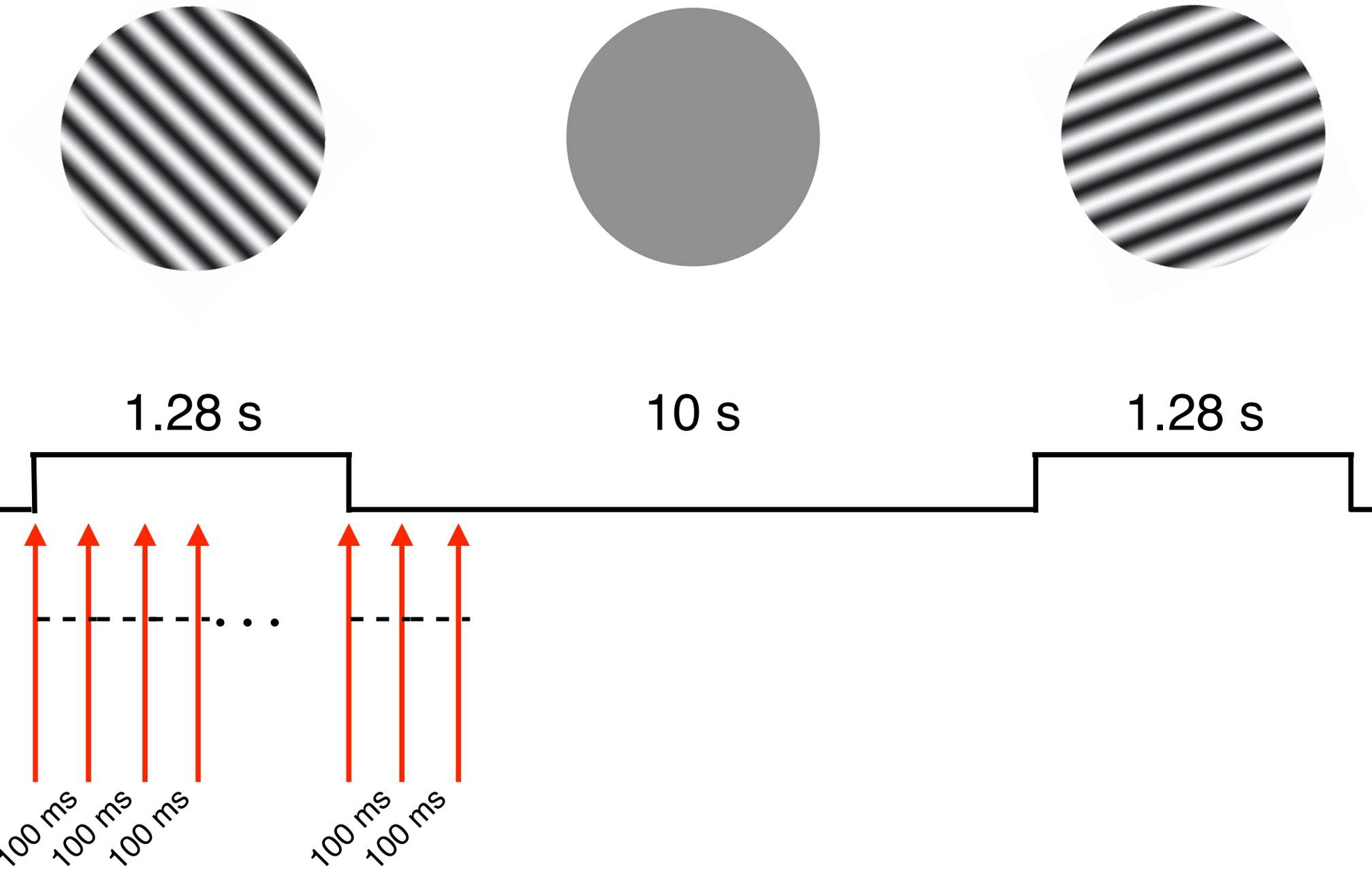
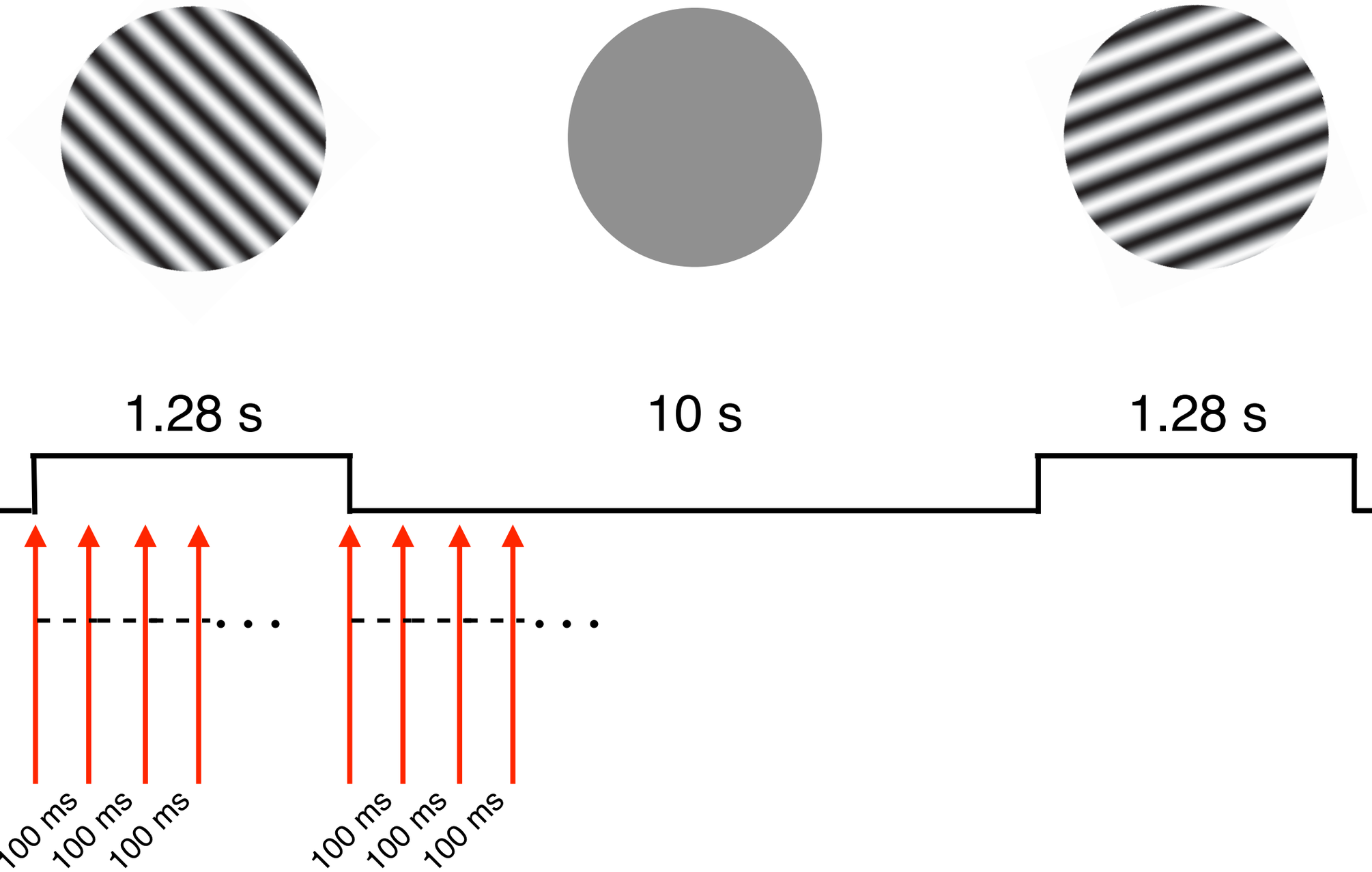
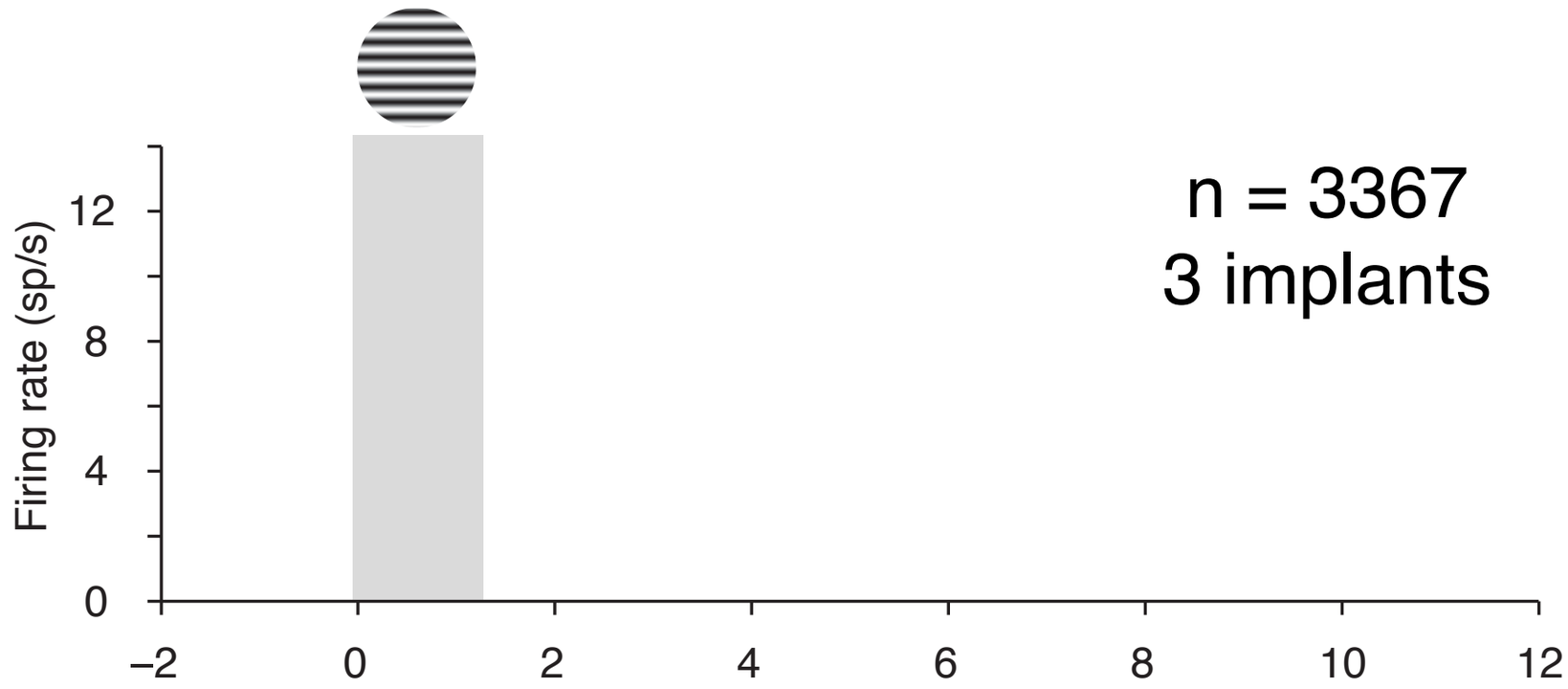
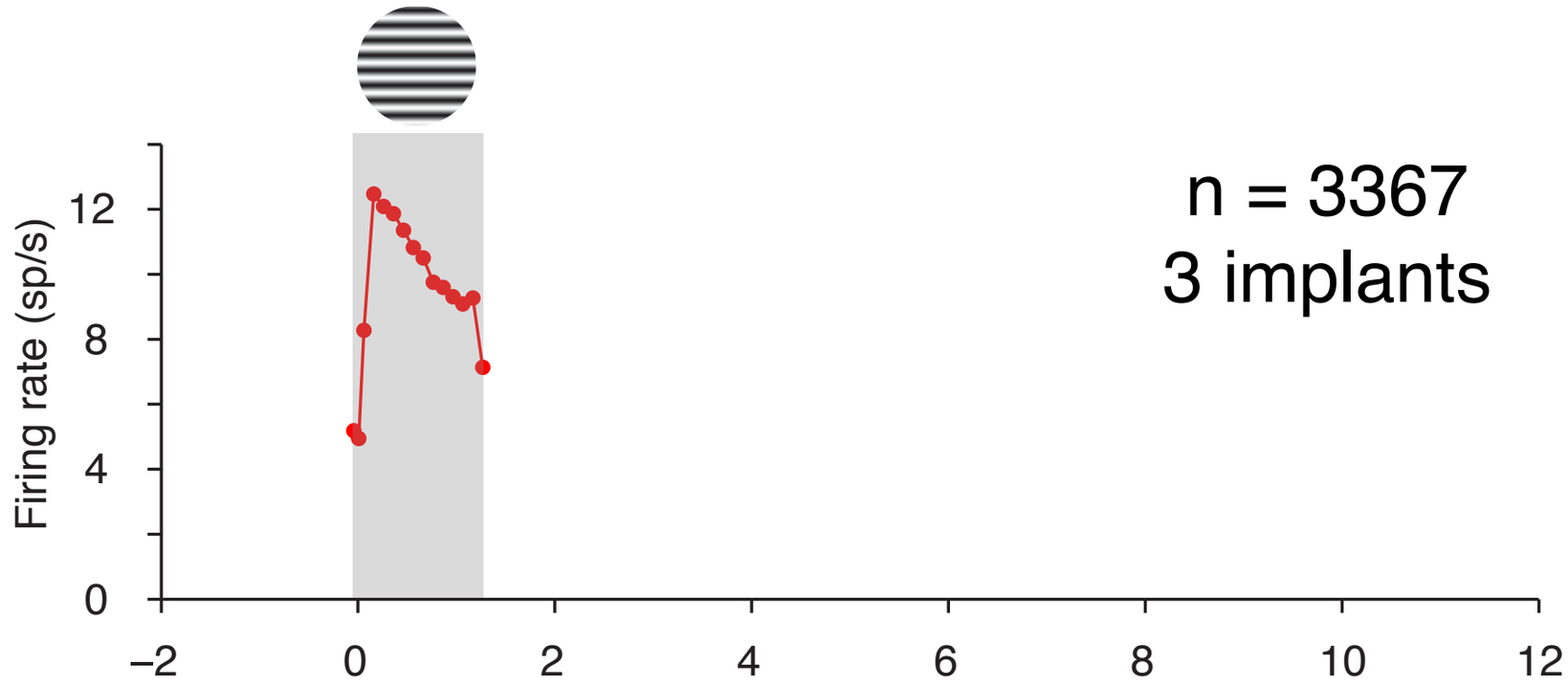
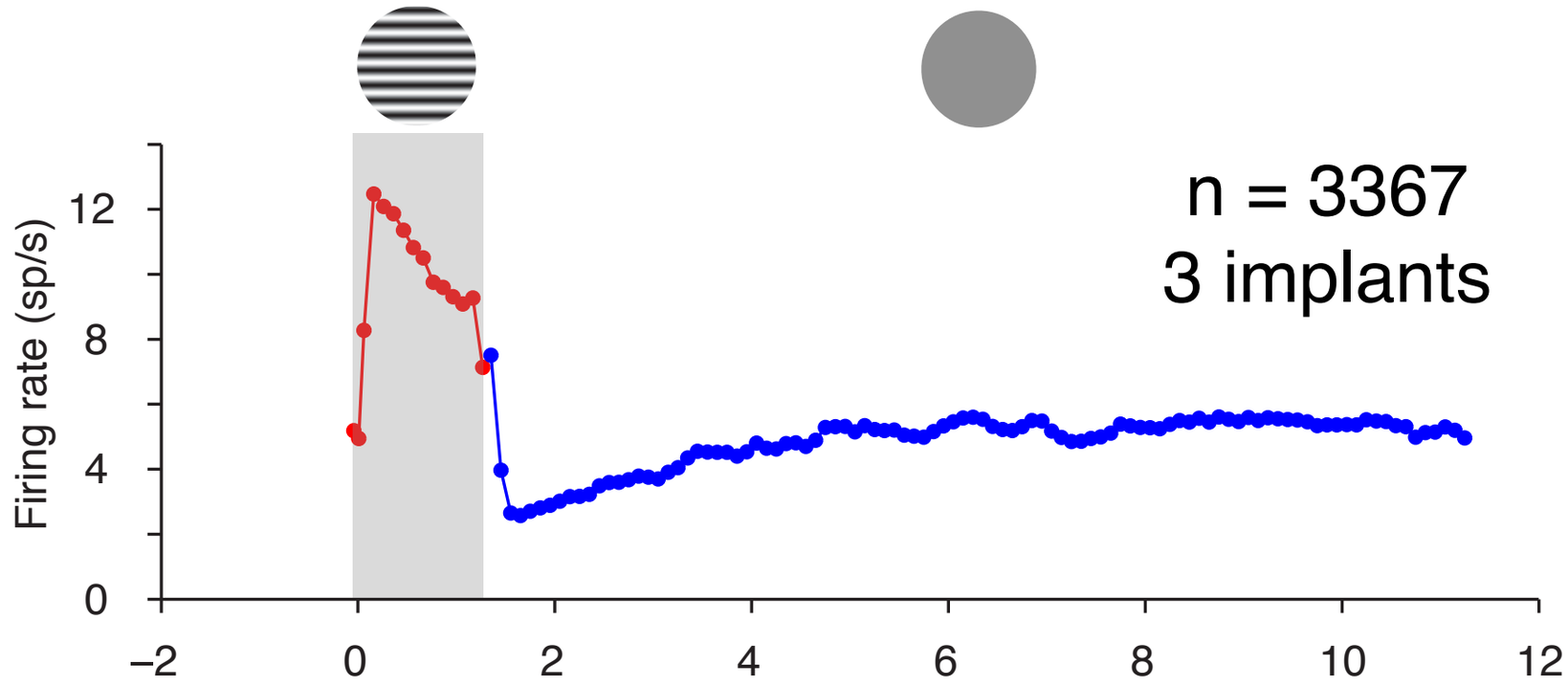


Transition from evoked to spontaneous




Firing rate (sp/s)
0
4
8
12
–2
0
2
4
6
8
10
12
n = 3367
3 implants
Time (seconds)


Firing rate (sp/s)
0
4
8
12
–2
0
2
4
6
8
10
12
n = 3367
3 implants
Time (seconds)


n = 3367
3 implants
Firing rate (sp/s)
0
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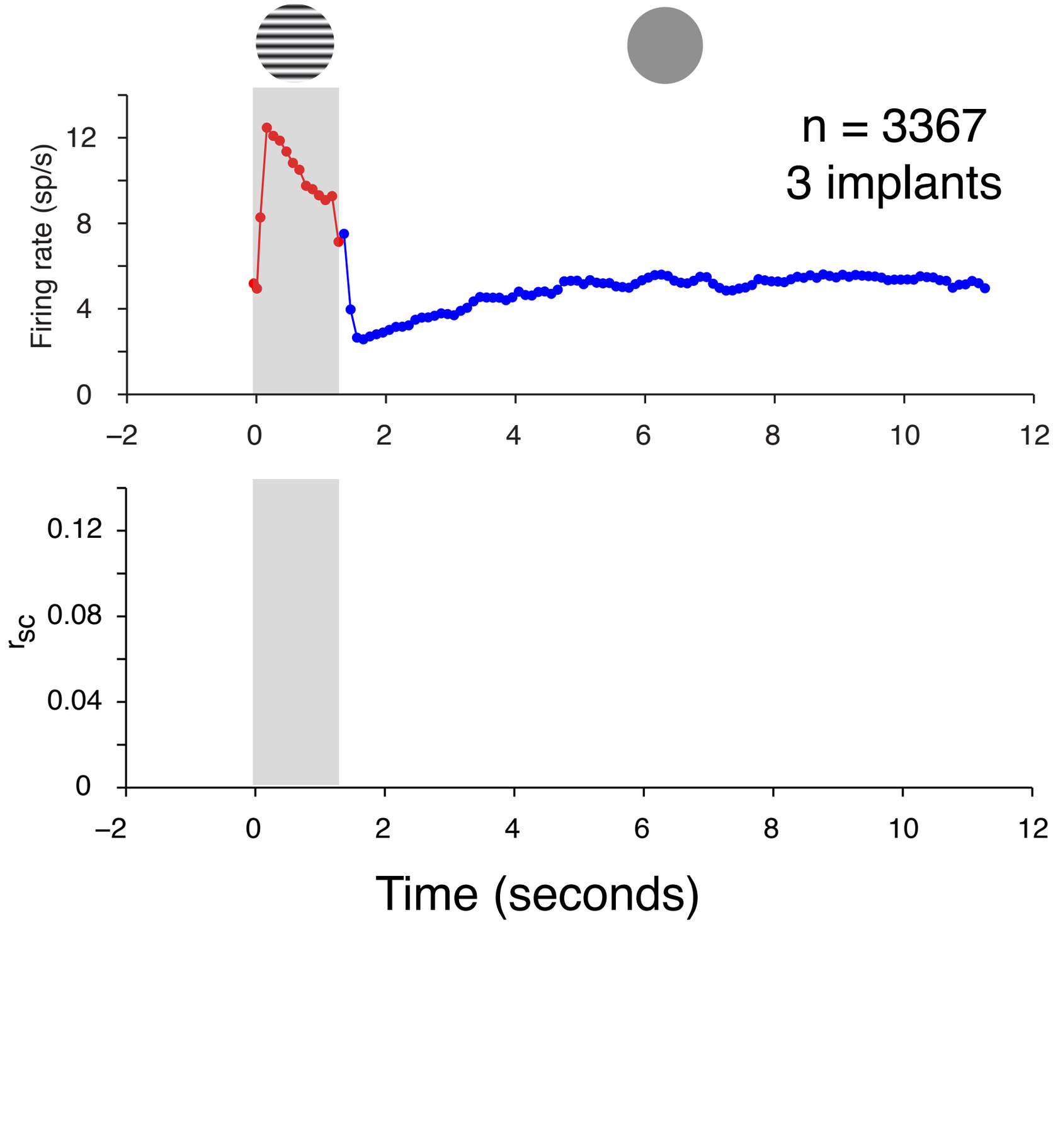
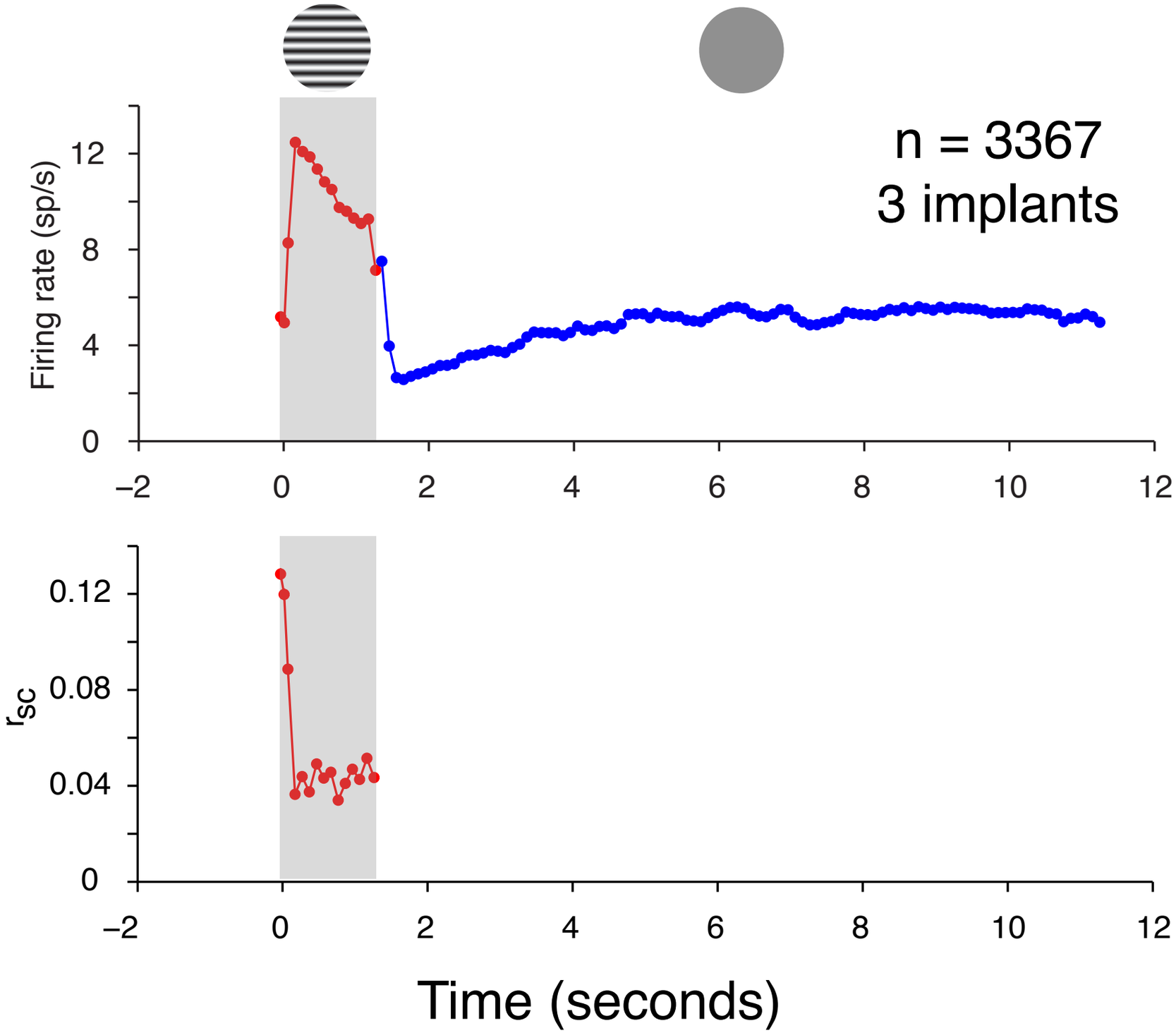

n = 3367
3 implants
Firing rate (sp/s)
12
8
4
0
–2
0
2
4
6
8
10
12
0.12
0.08
0.04
0
r_{sc}
Time (seconds)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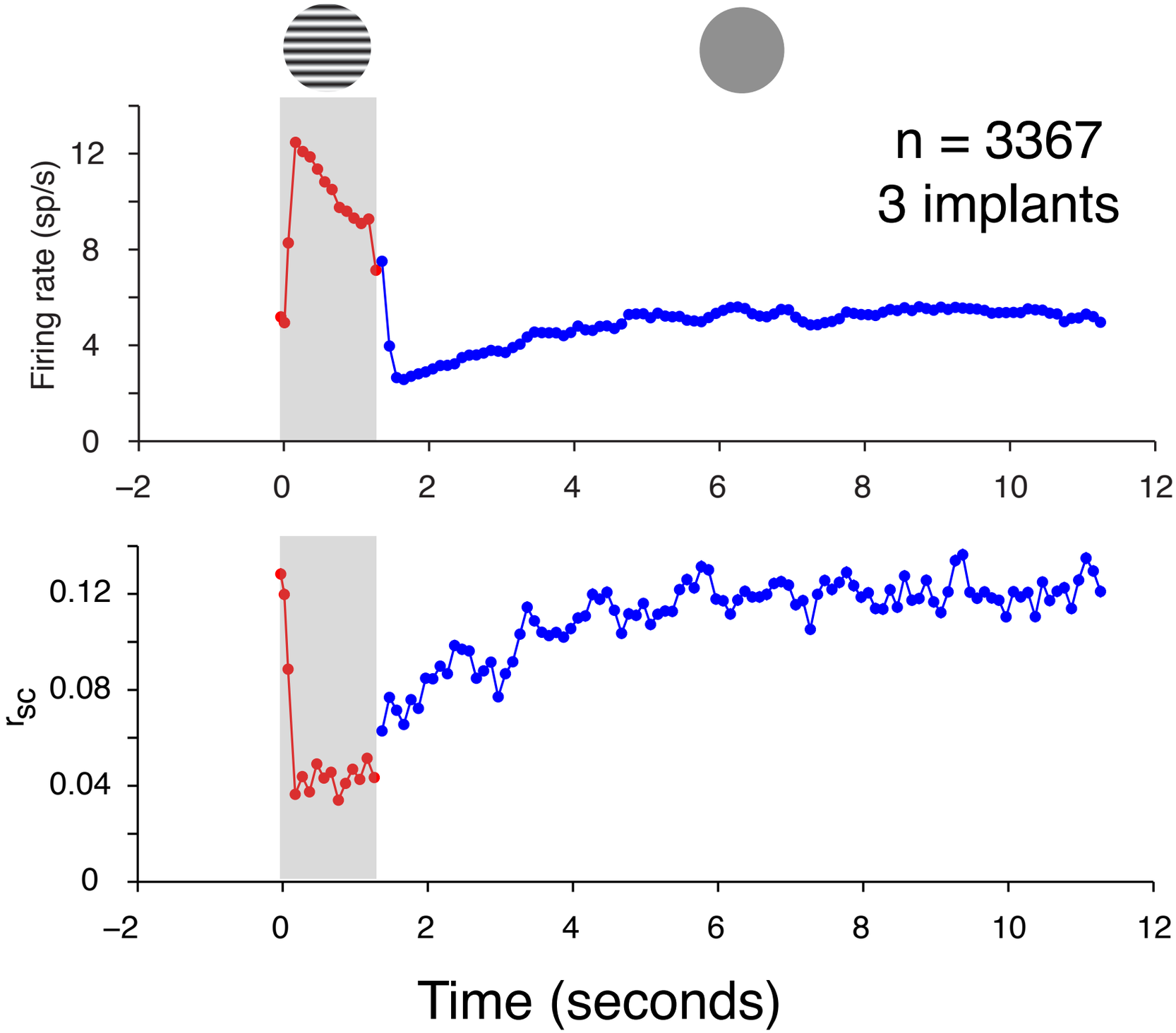
12
r_{sc}
0
0.04
0.08
0.12
–2
0
2
4
6
8
10
12
Time (seconds)


n = 3367
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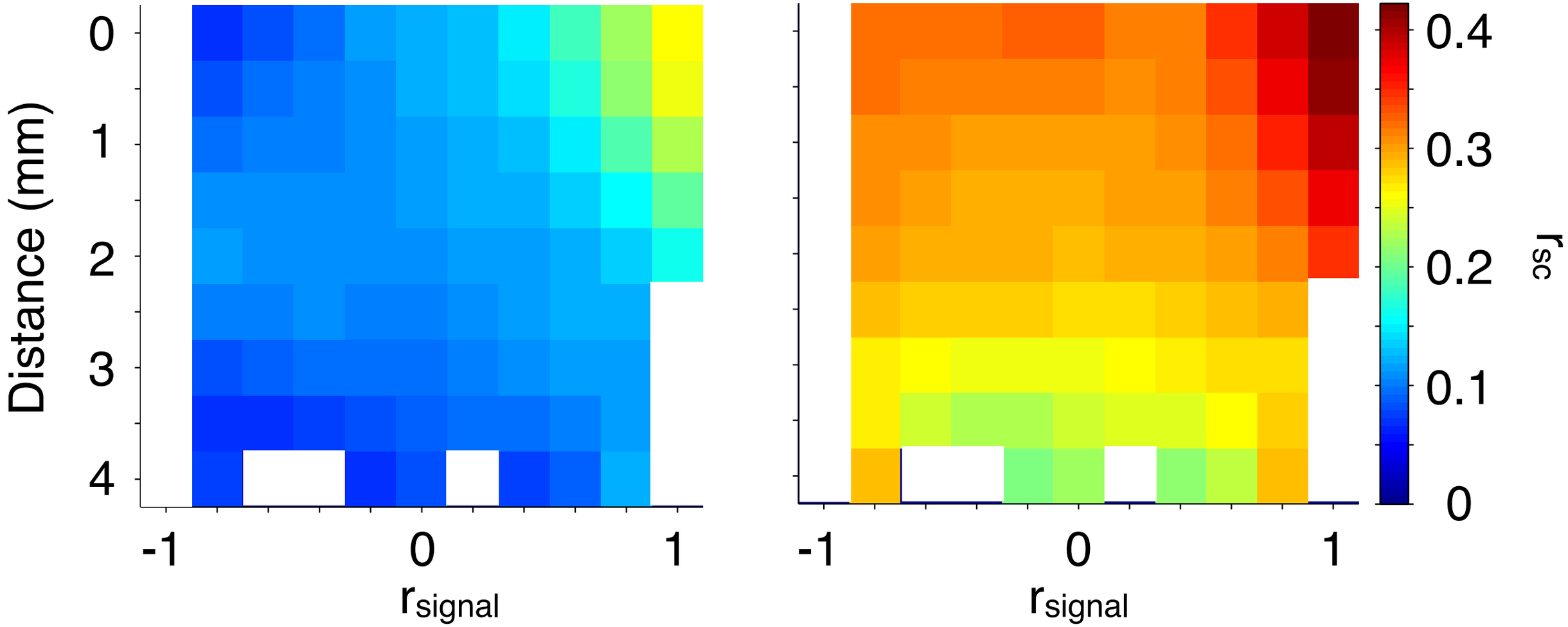
8
4
0
–2
0
2
4
6
8
10
12
0.12
0.08
0.04
0
r_{sc}
Time (seconds)

Evoked

Spontaneous



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  Laminar variation
  Correlation outside V1

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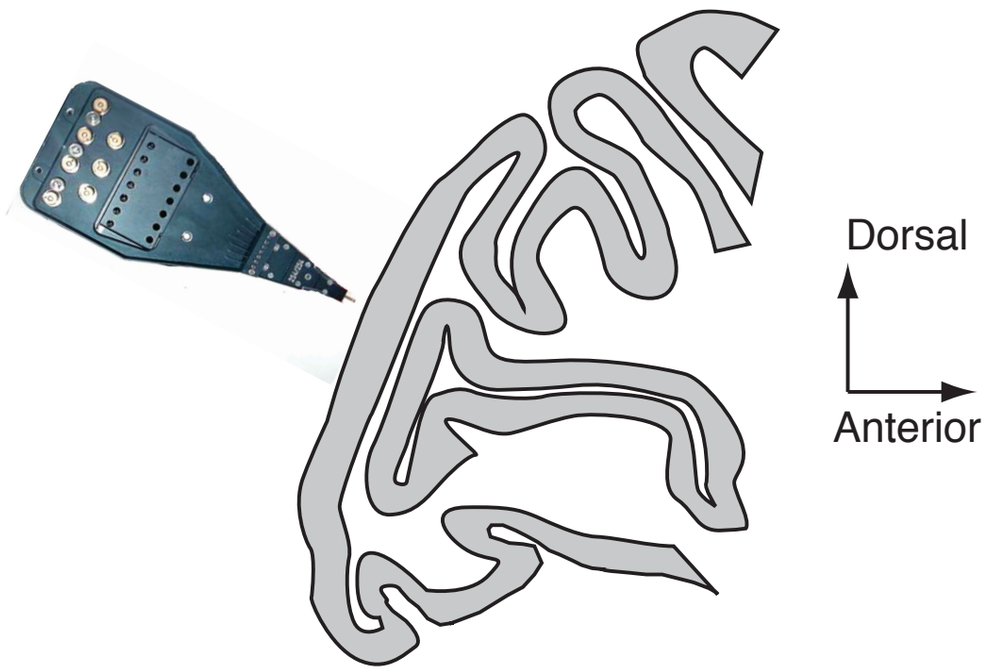
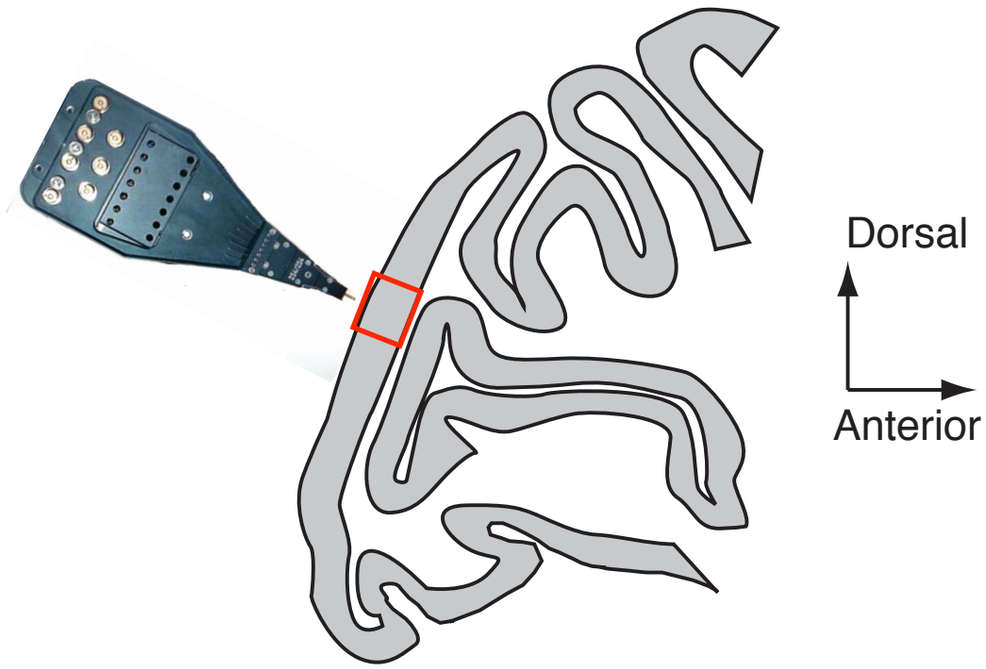
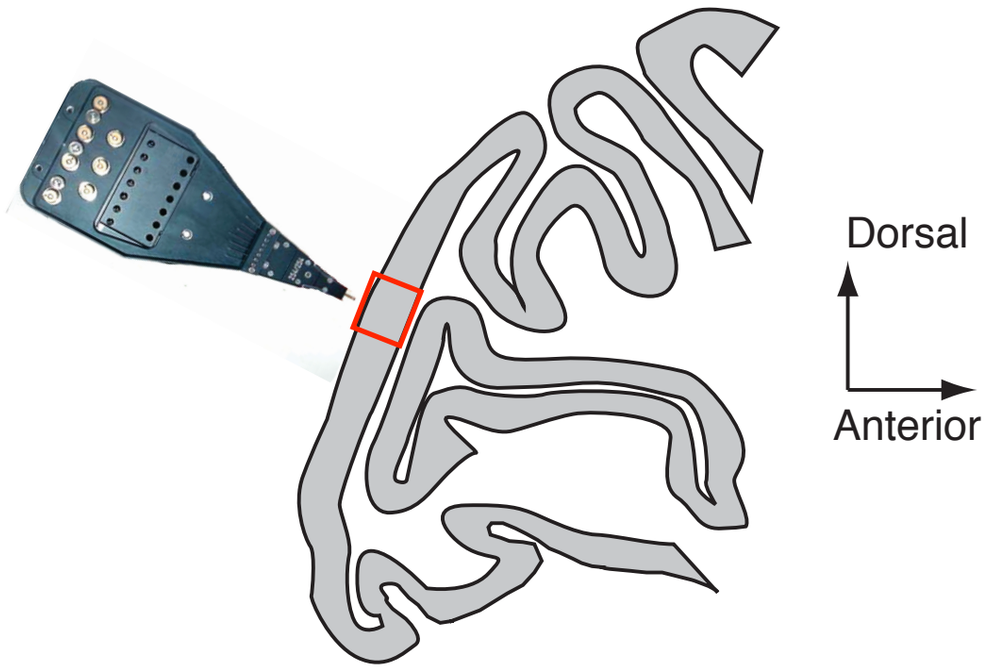


Smith & Kohn (2009, SfN Abstract)



Smith & Kohn (2009, SfN Abstract)



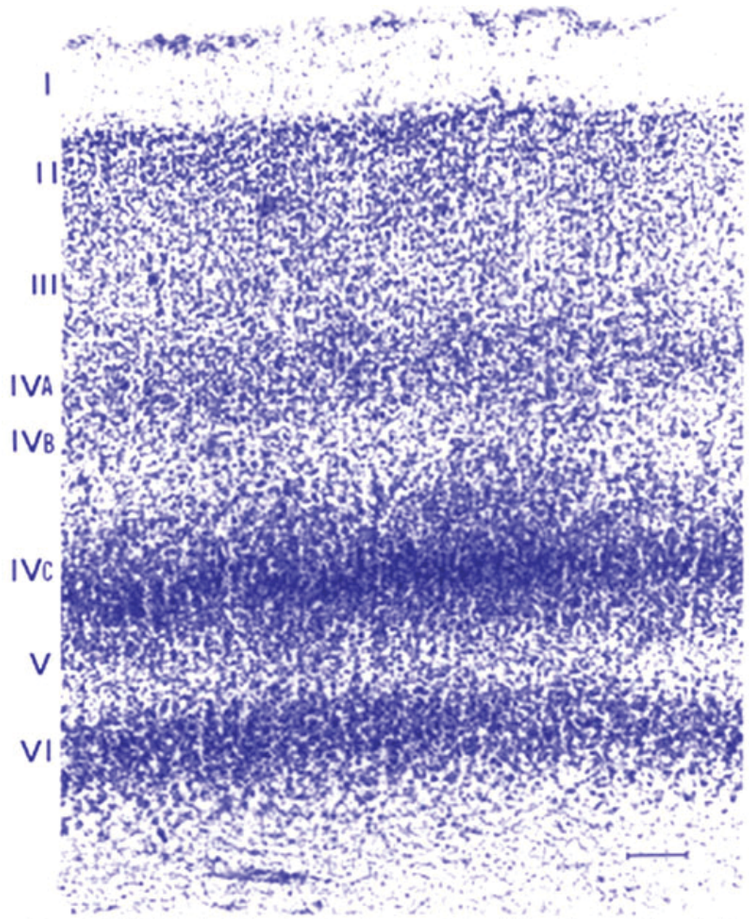
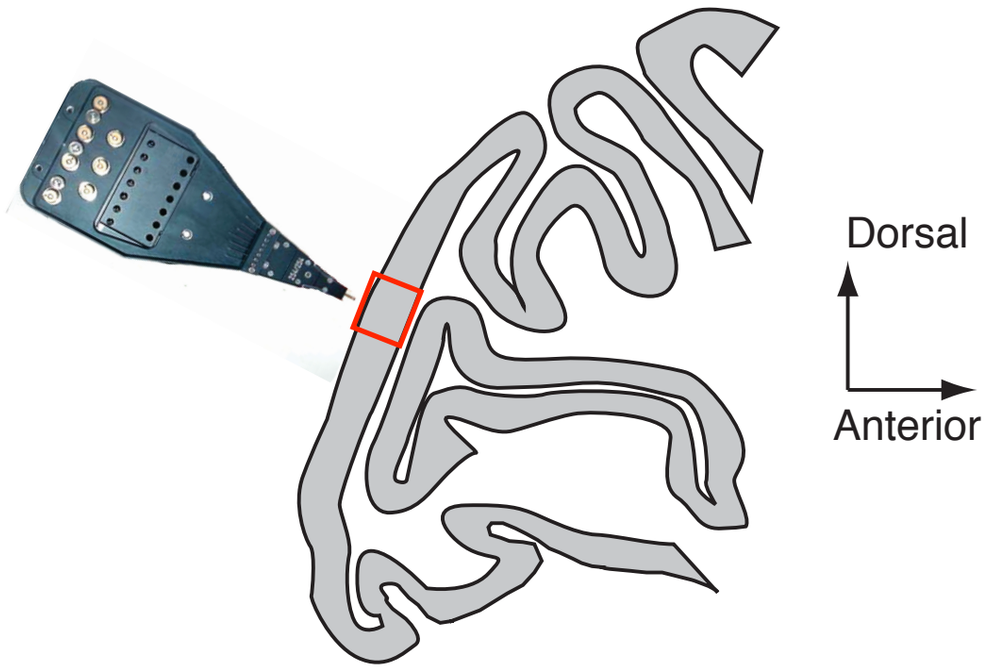
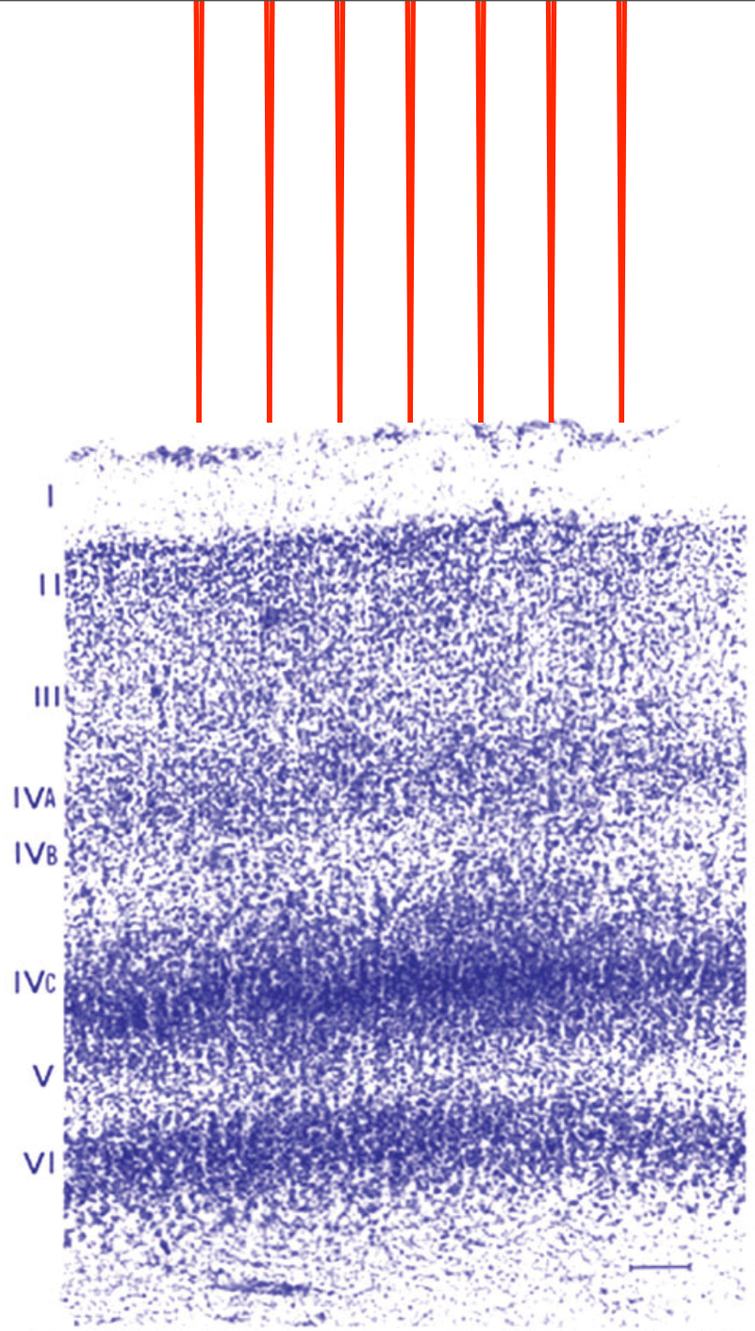


Figure 13. Nissl stain of the visual cortex reveals the different layers I through VI quite clearly.

Smith & Kohn (2009, SfN Abstract)





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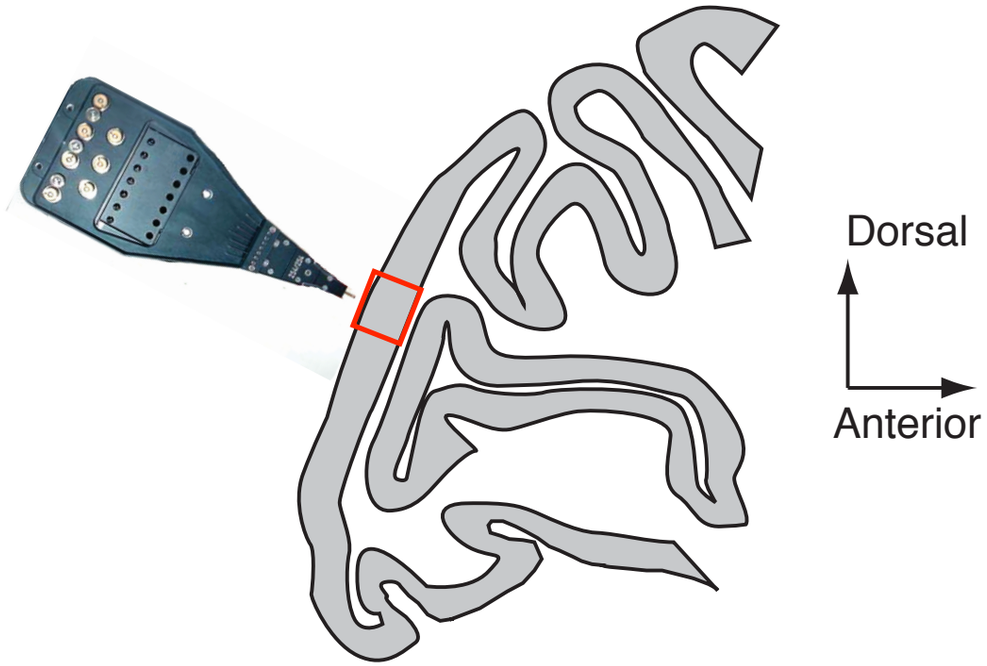

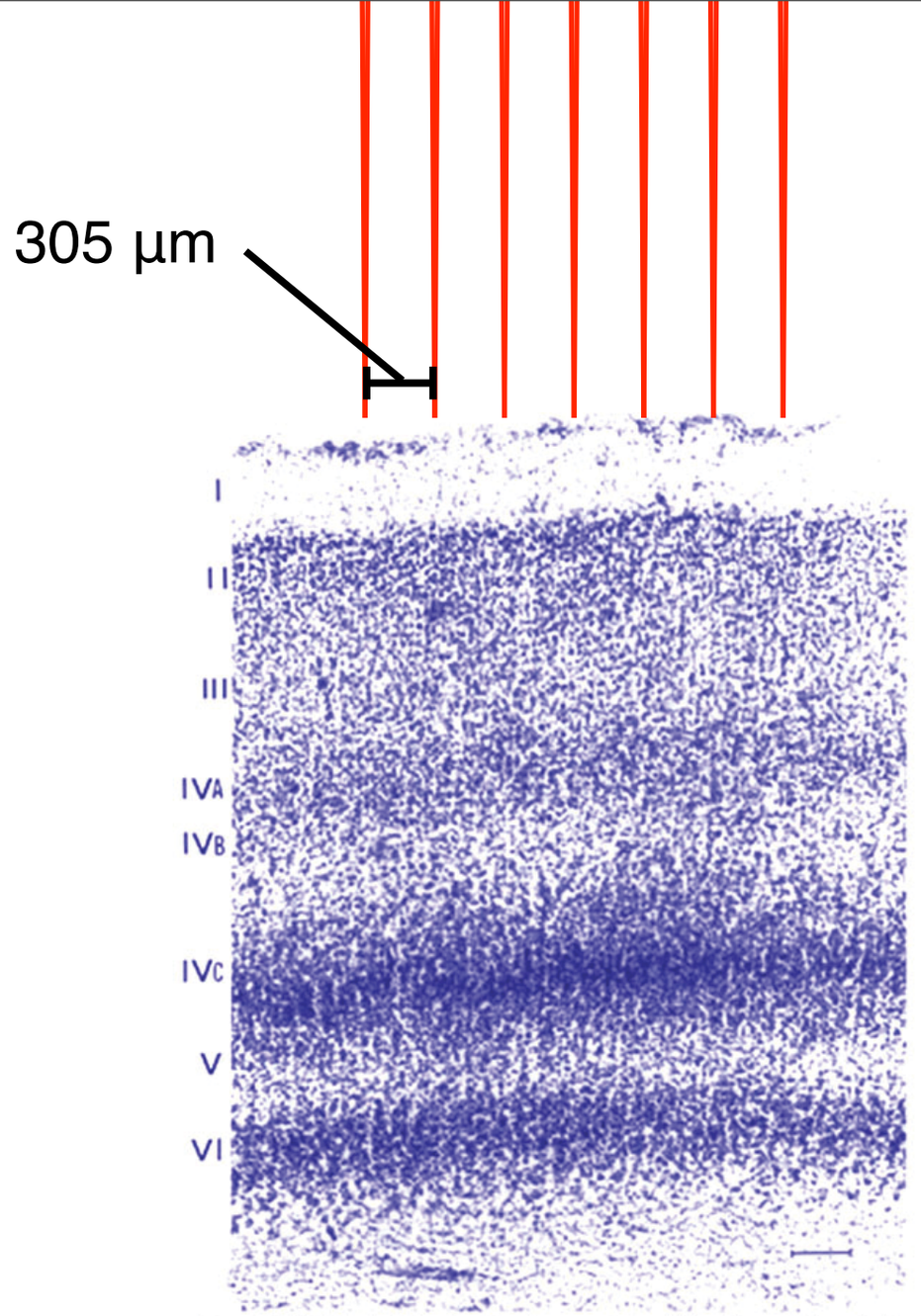

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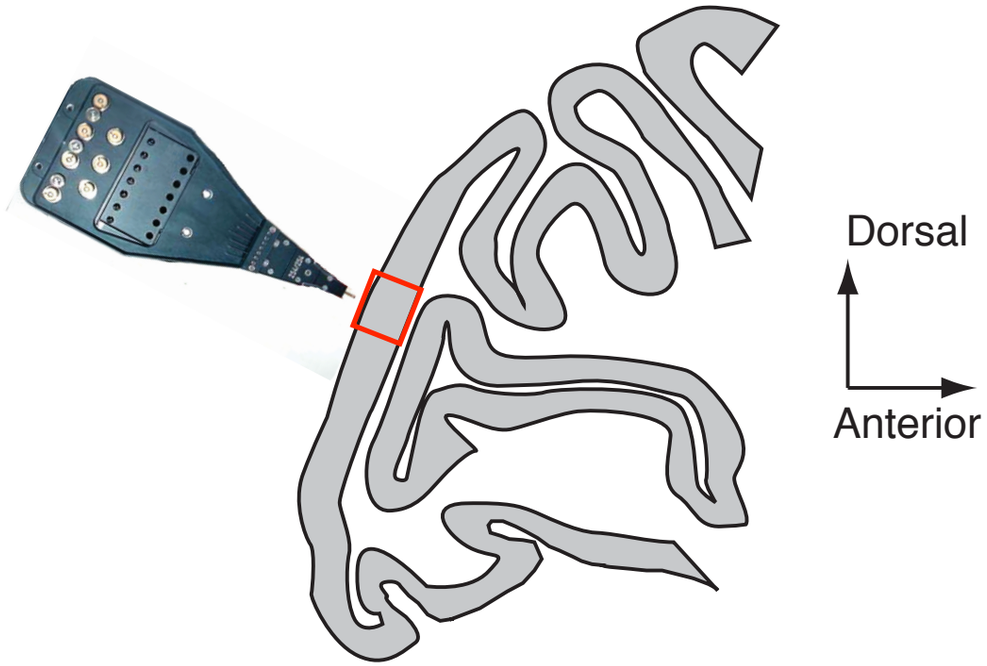

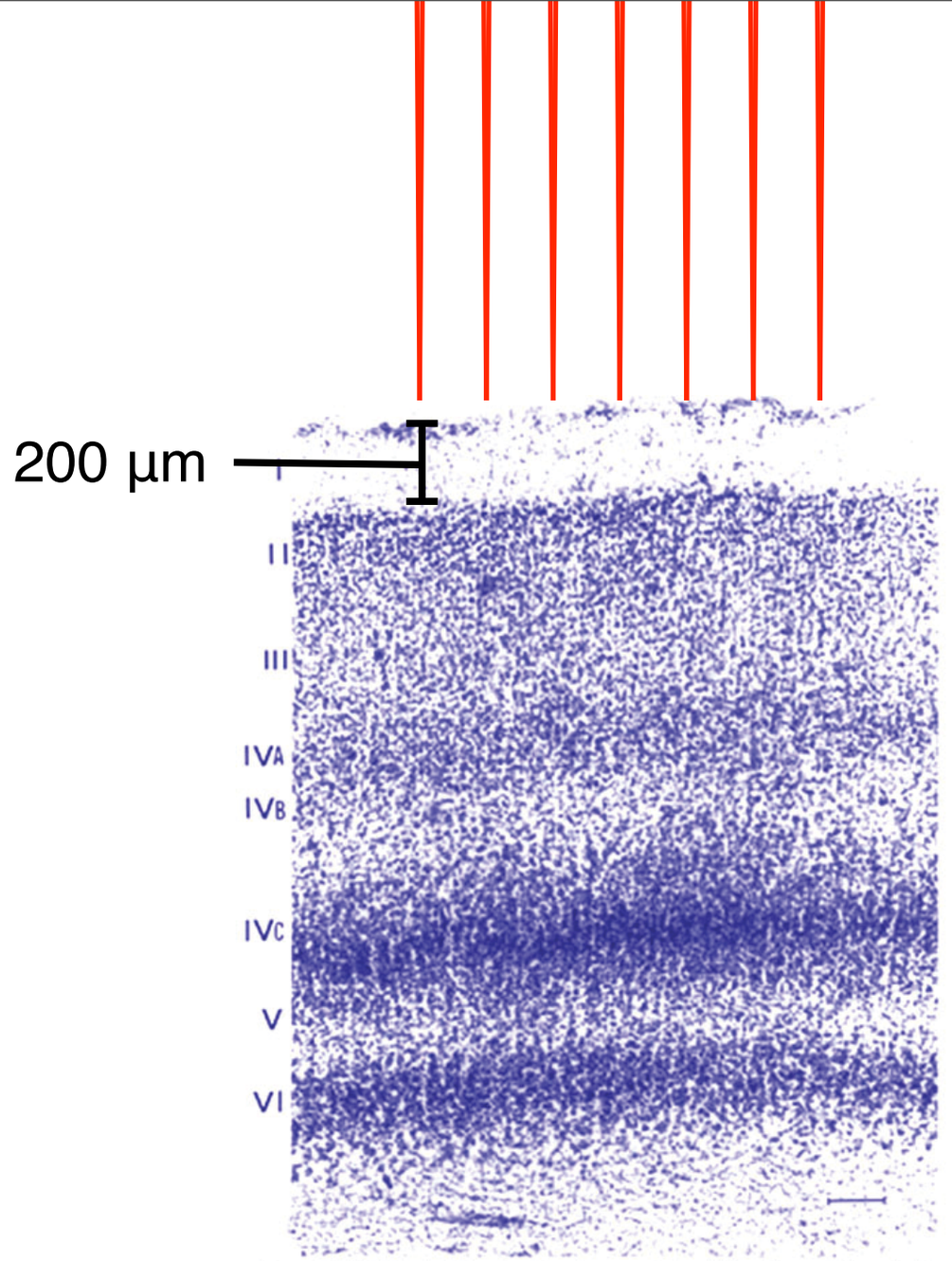

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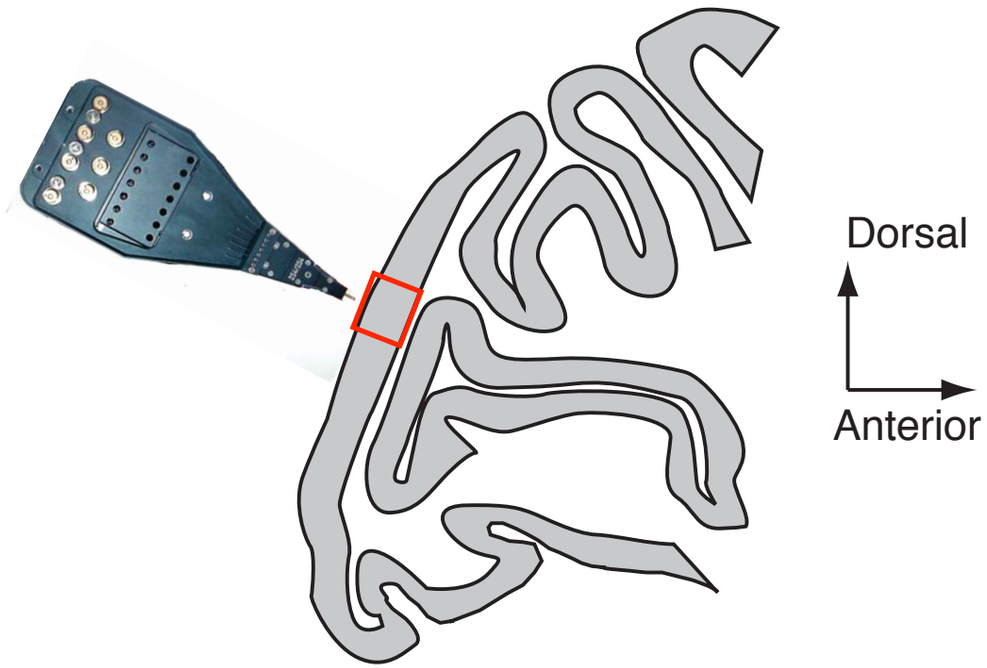

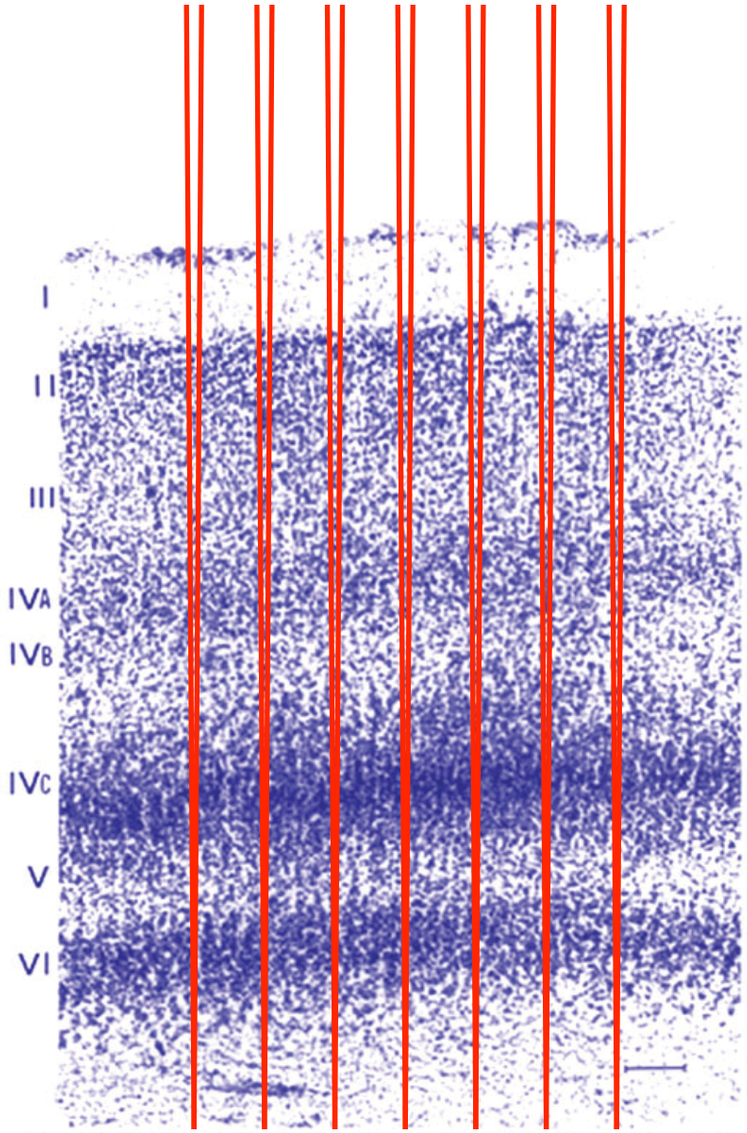

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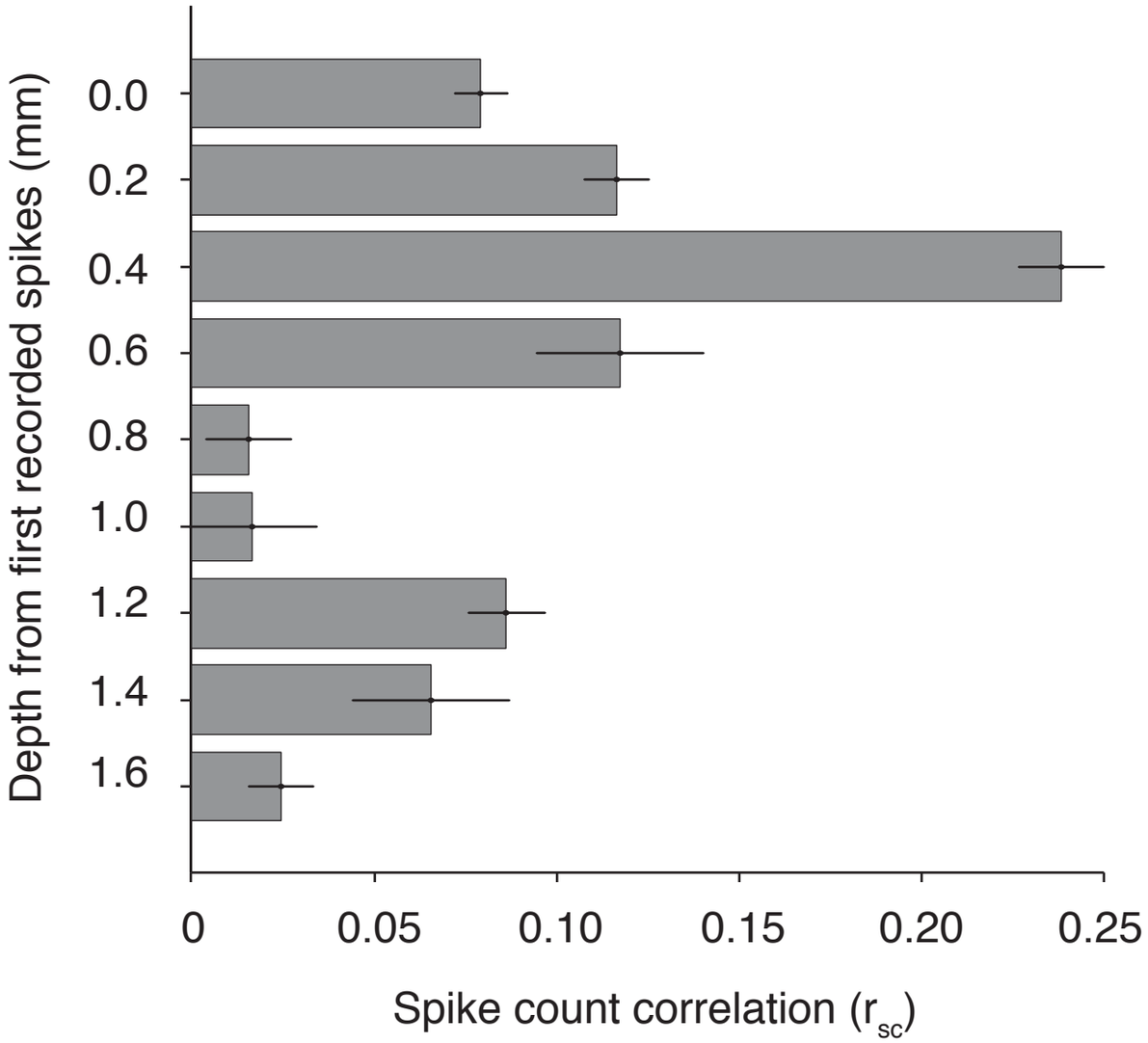

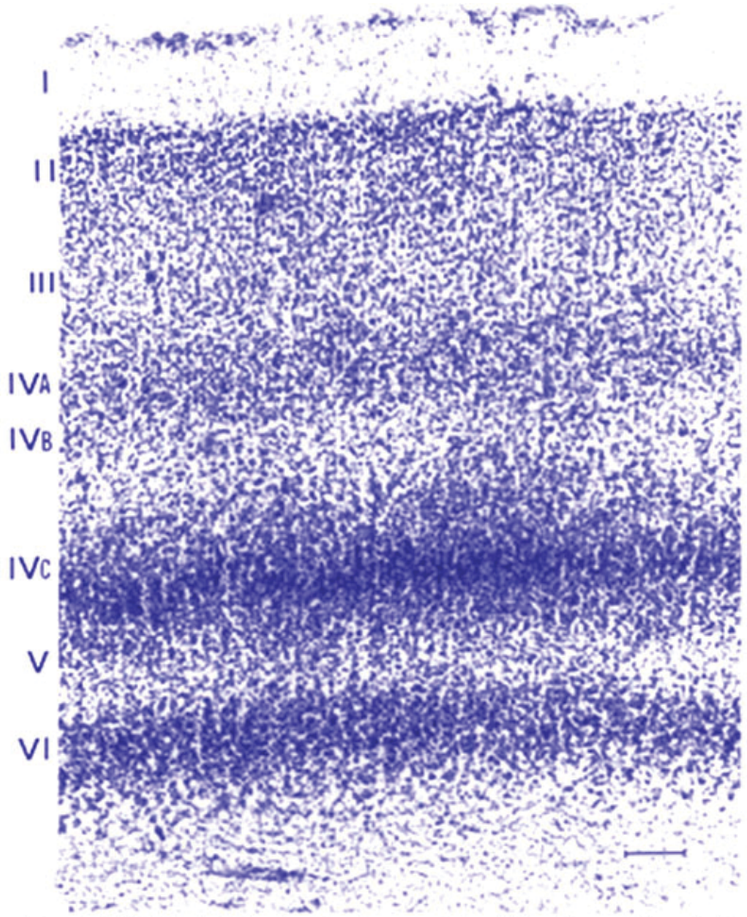

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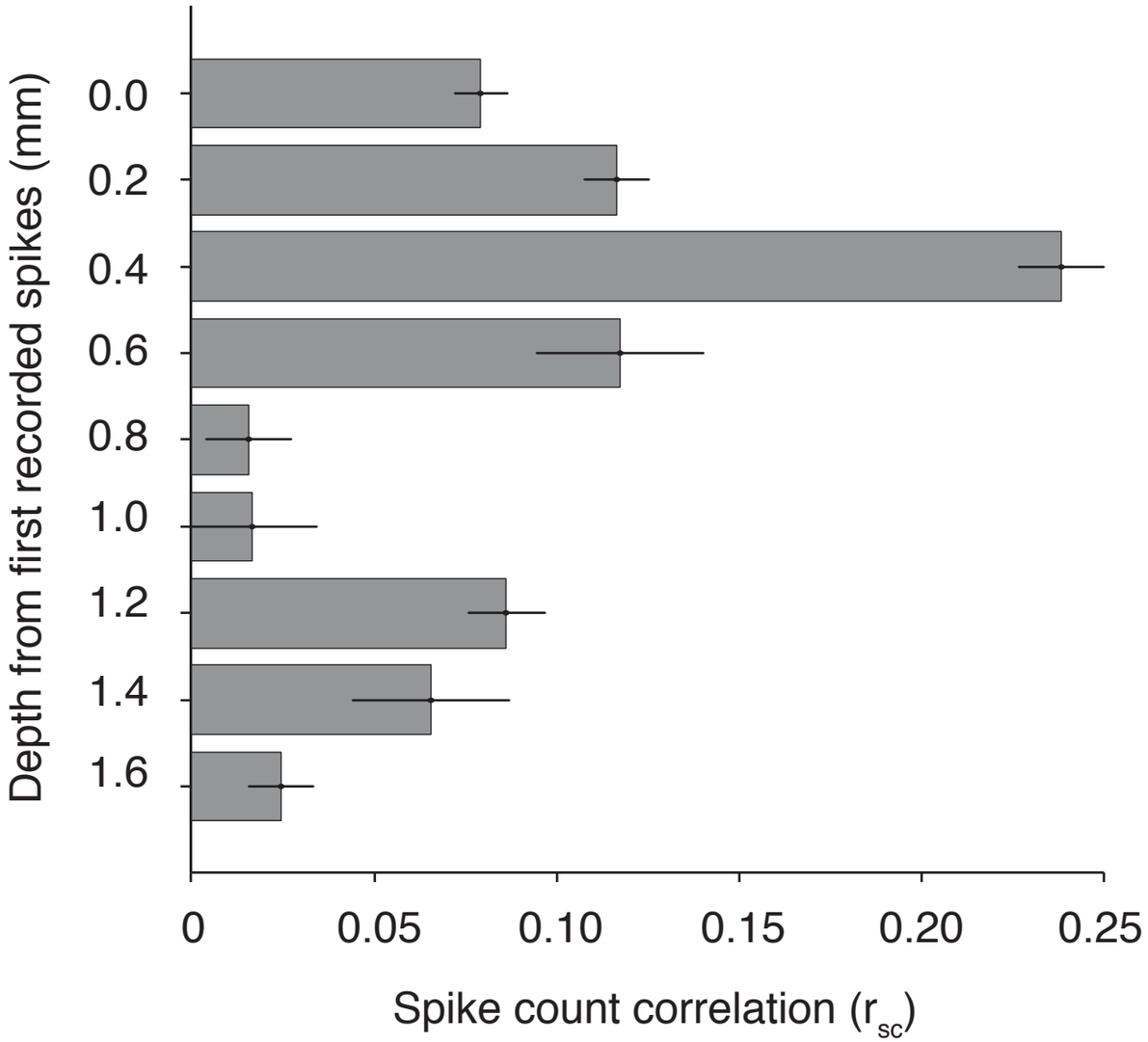
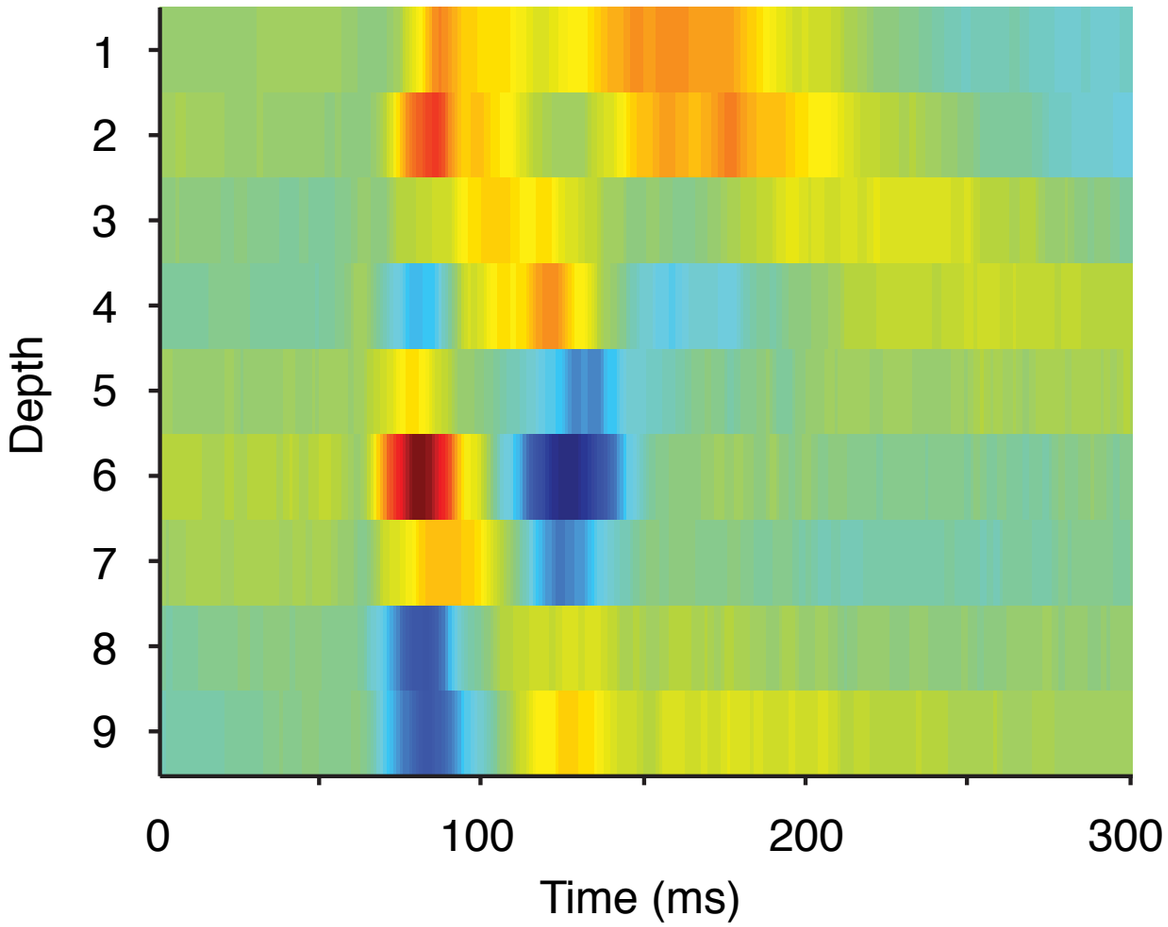


Smith & Kohn (2009, SfN Abstract)

Current Source Density



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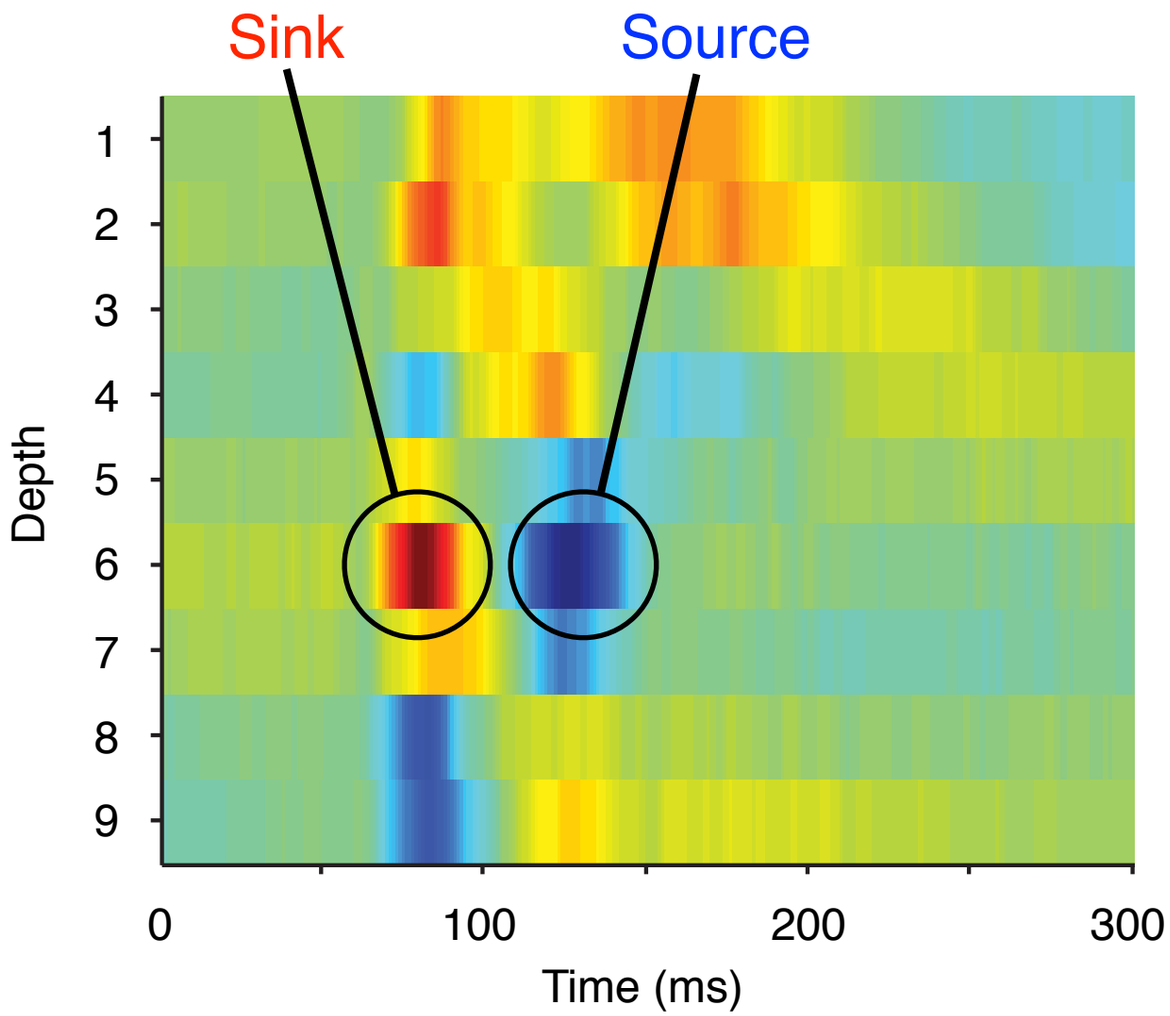
Current Source Density



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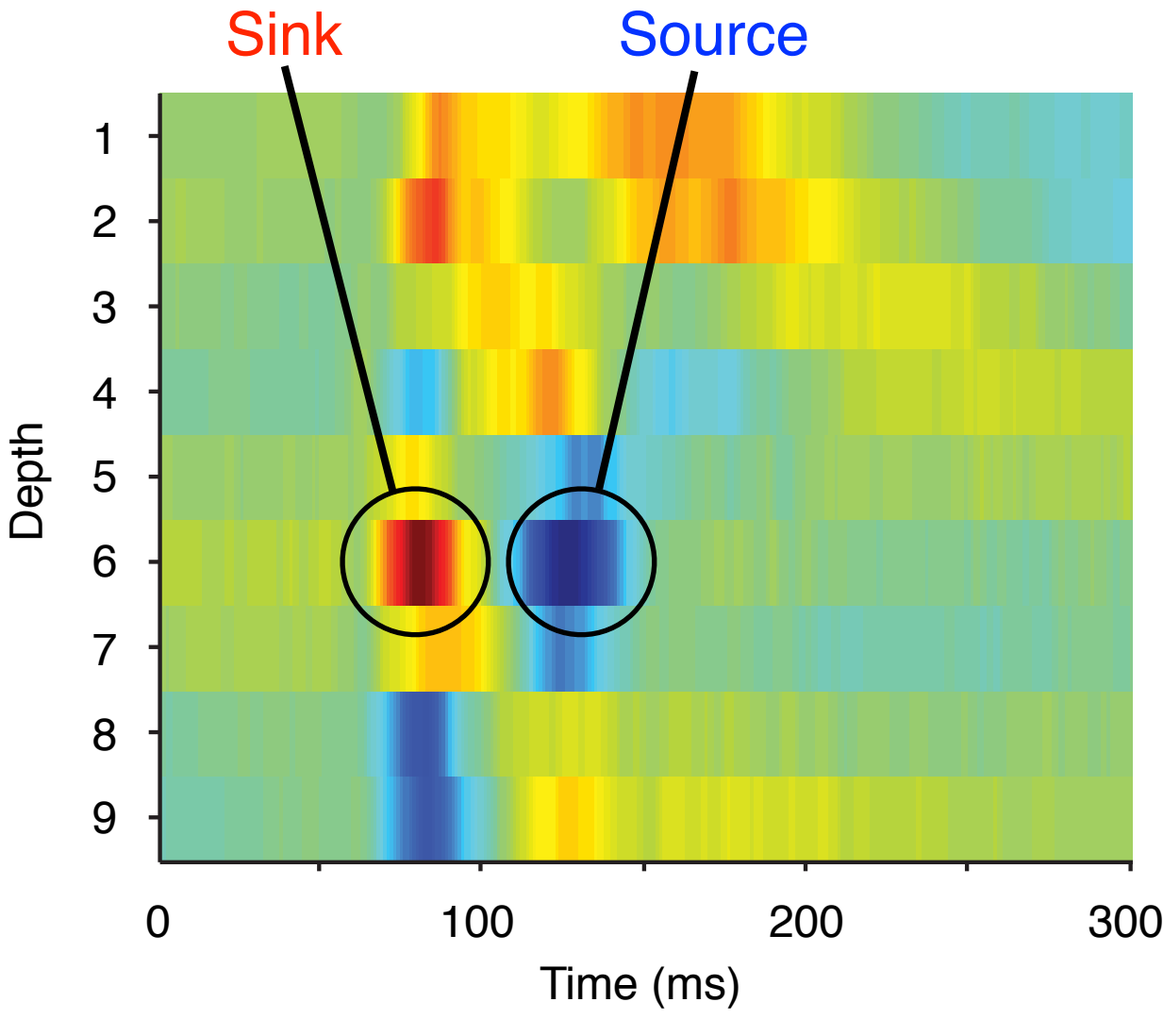
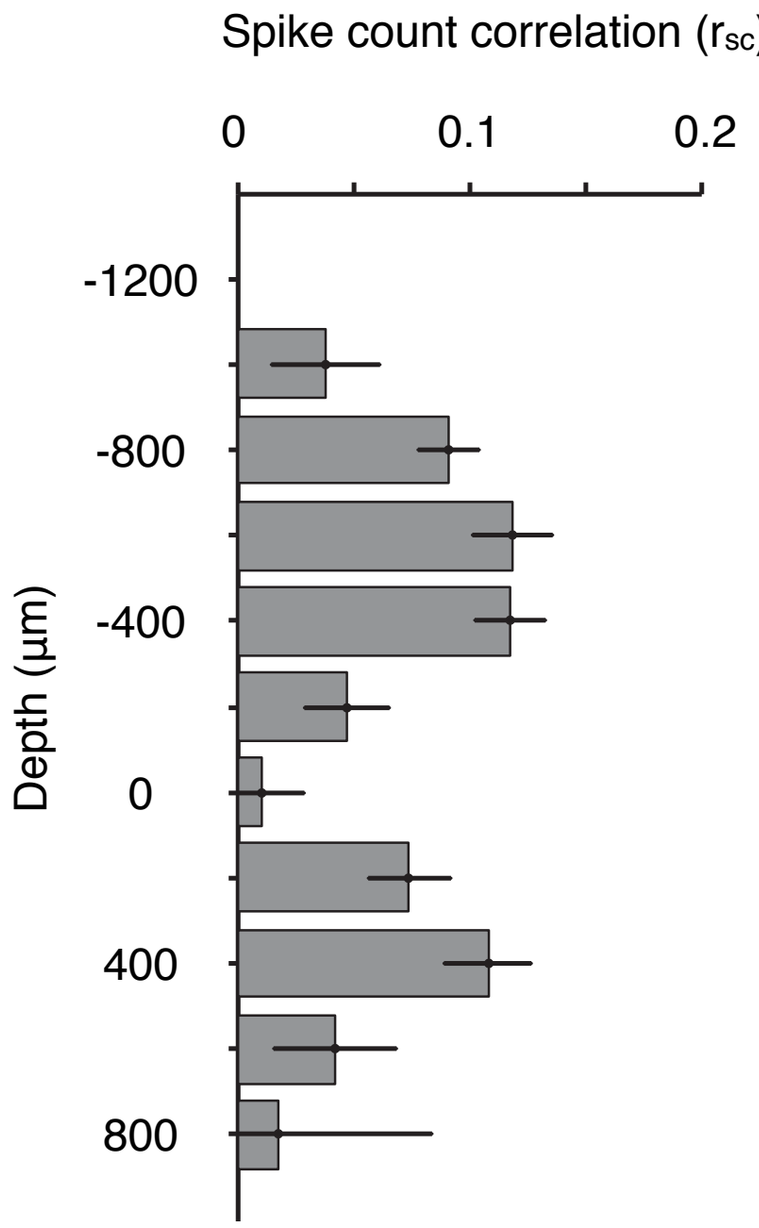


Average of 4 penetrations



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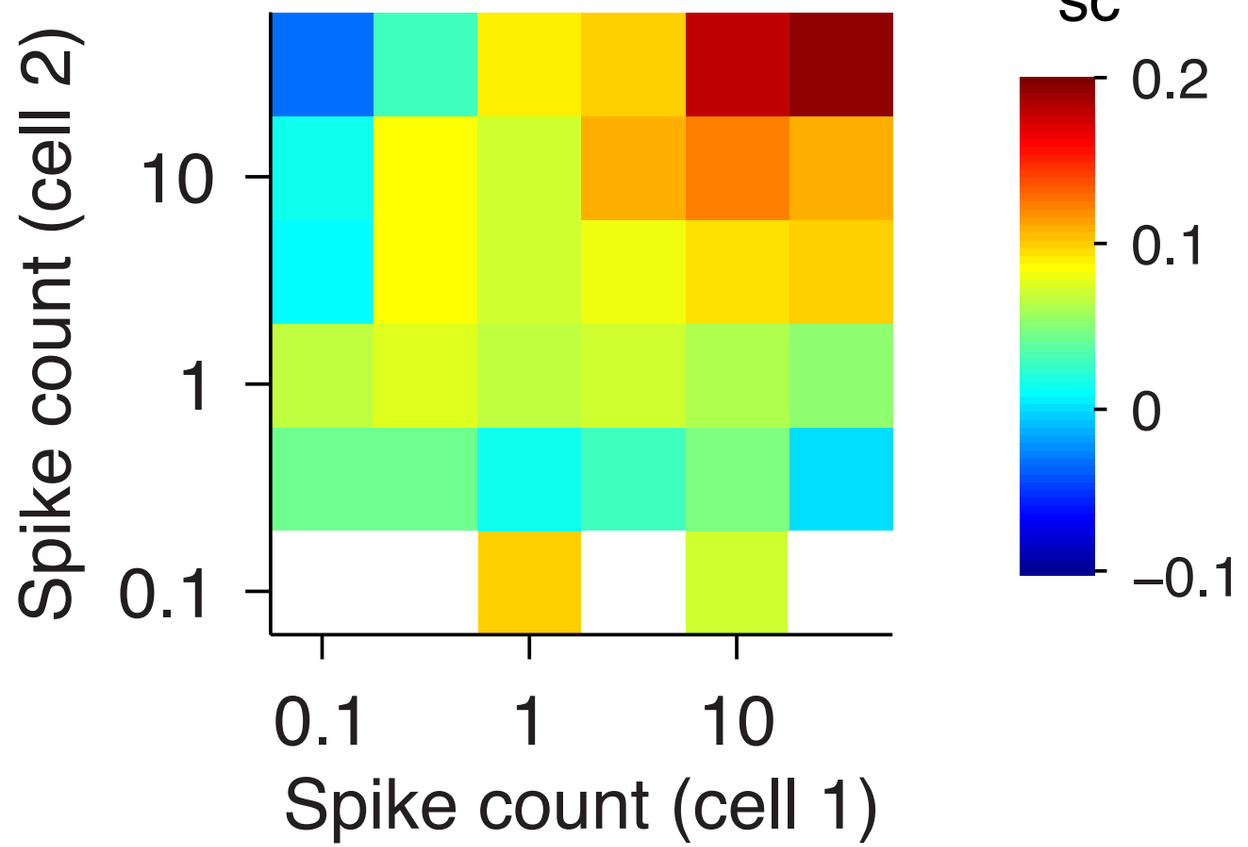

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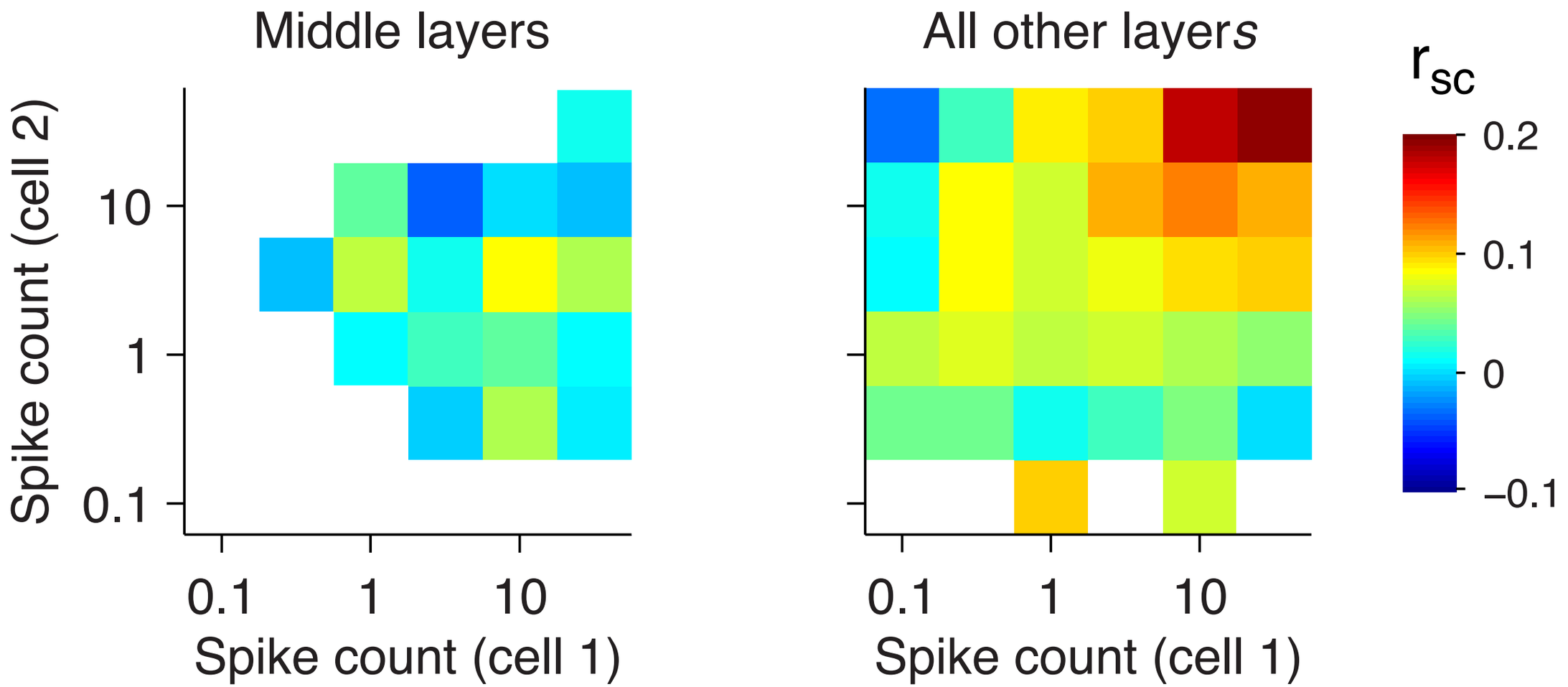

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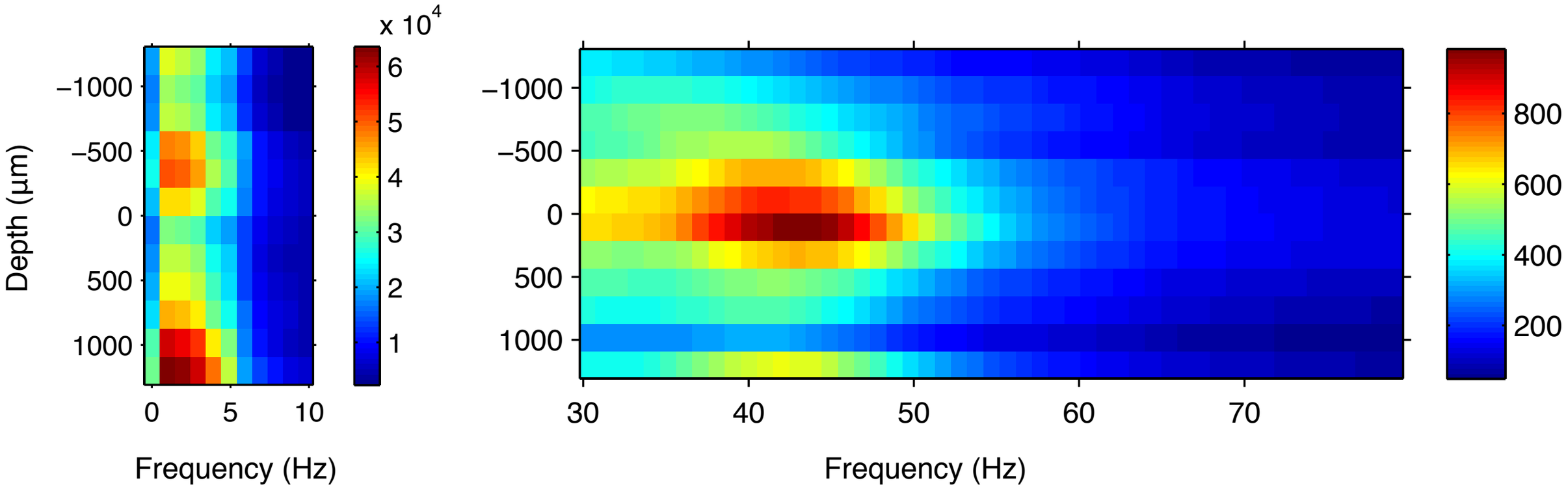

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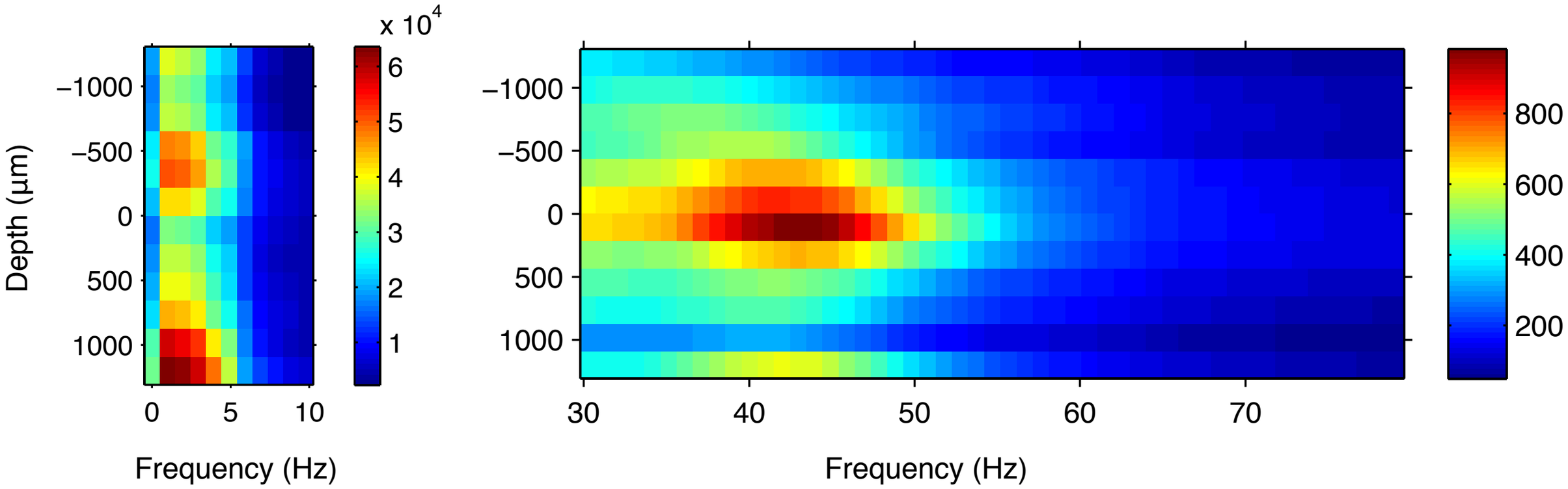
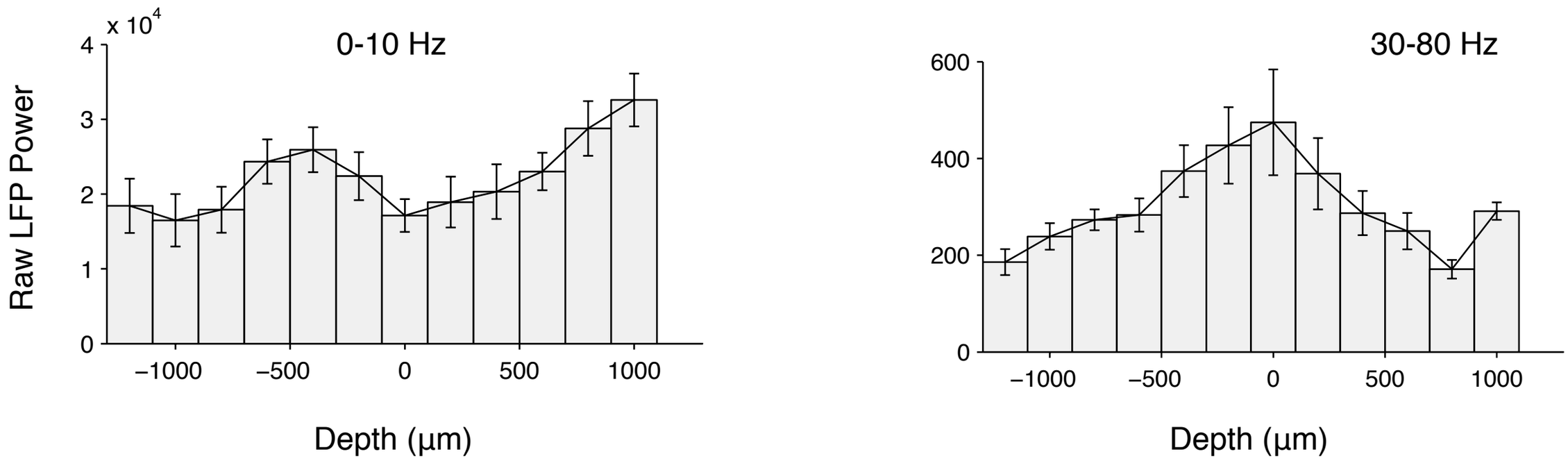
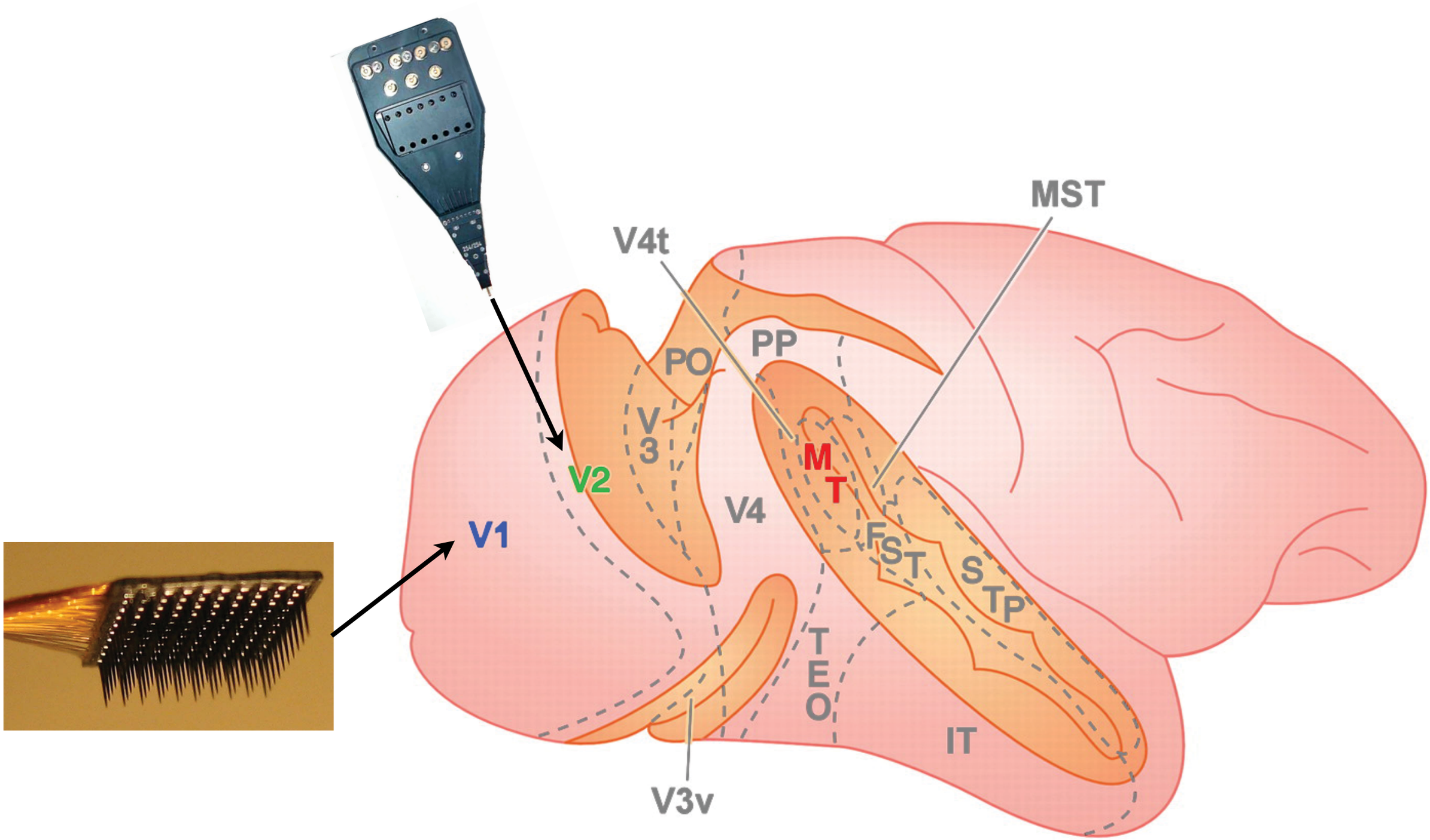


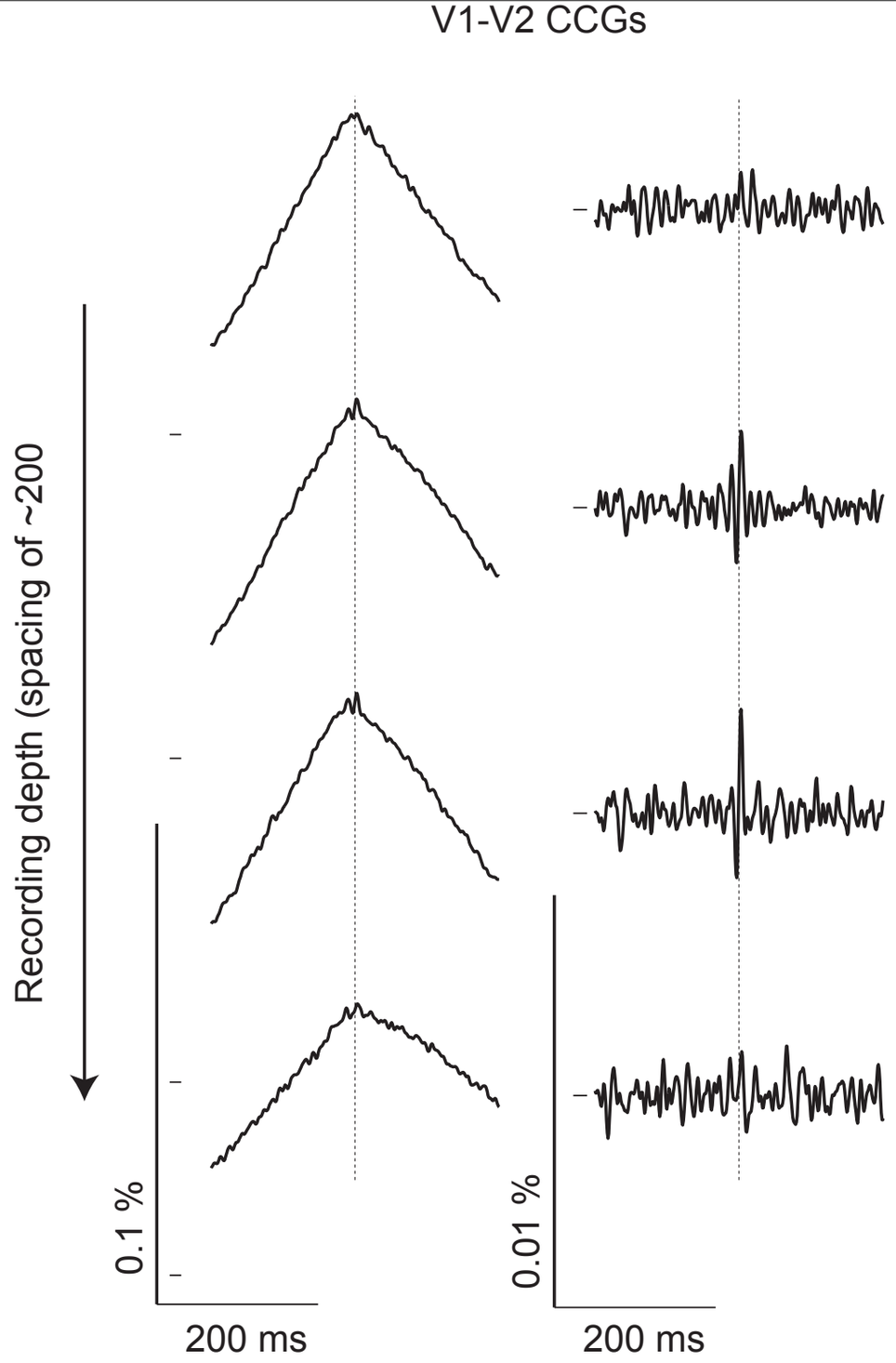


Smith & Kohn (2009, SfN Abstract)

Are the input layers of V1 special?



Smith & Kohn (2009, SfN Abstract)



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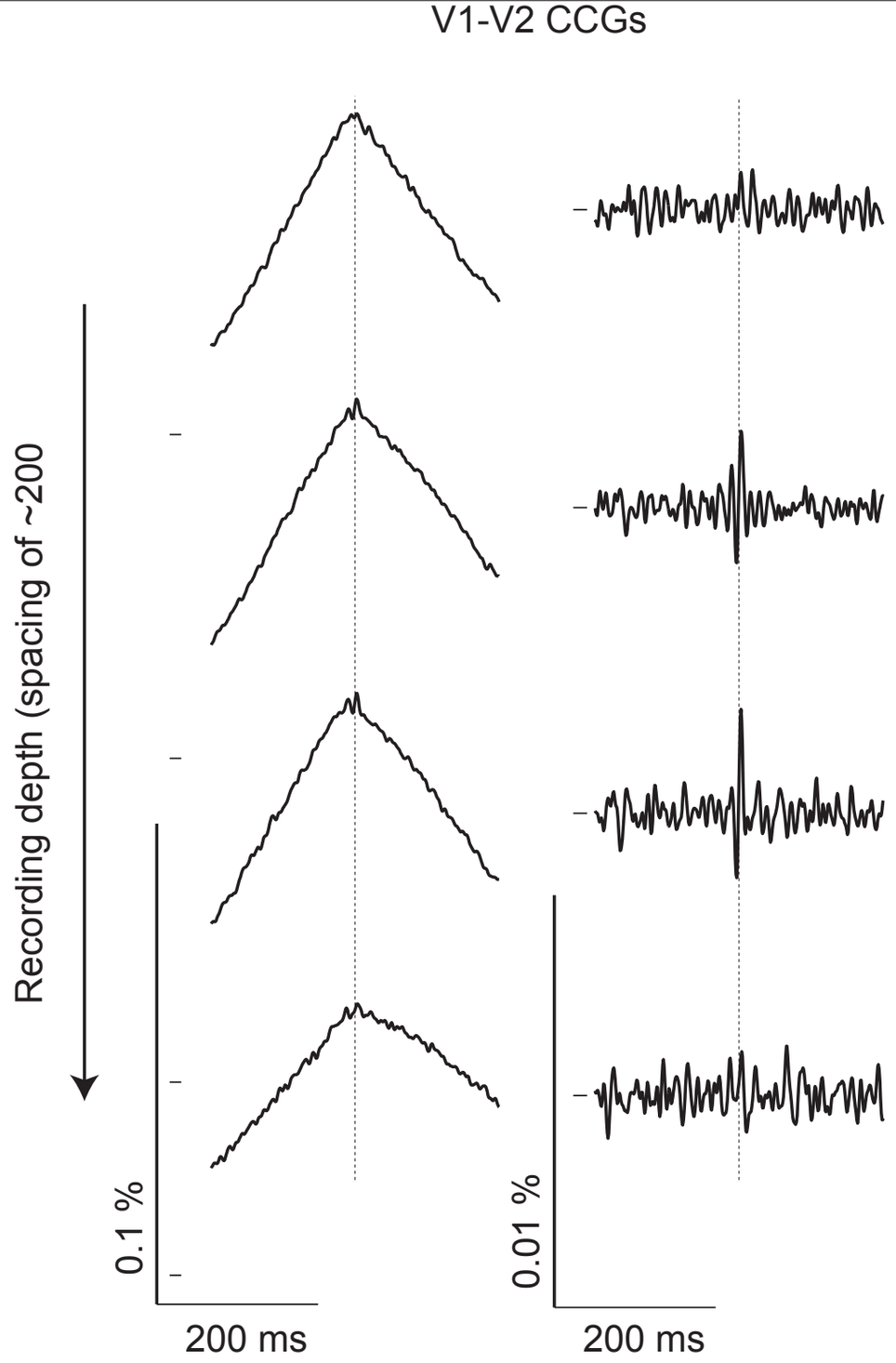

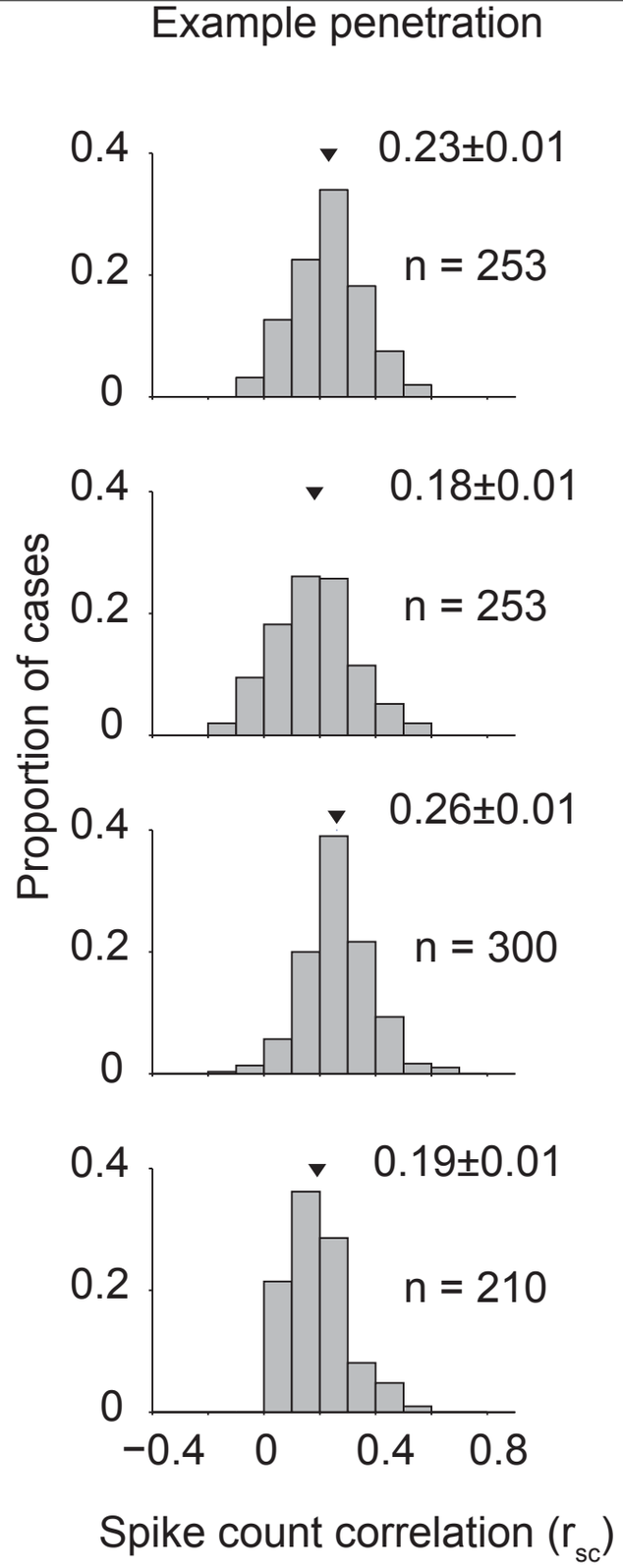

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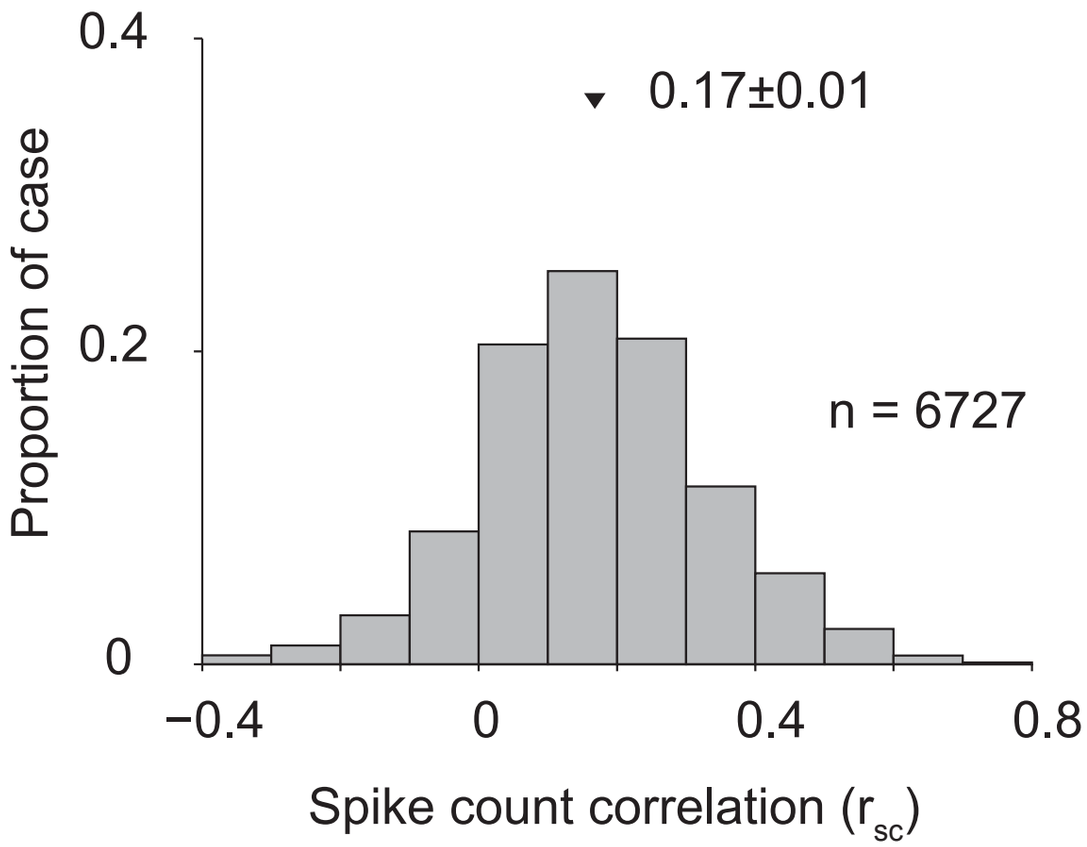
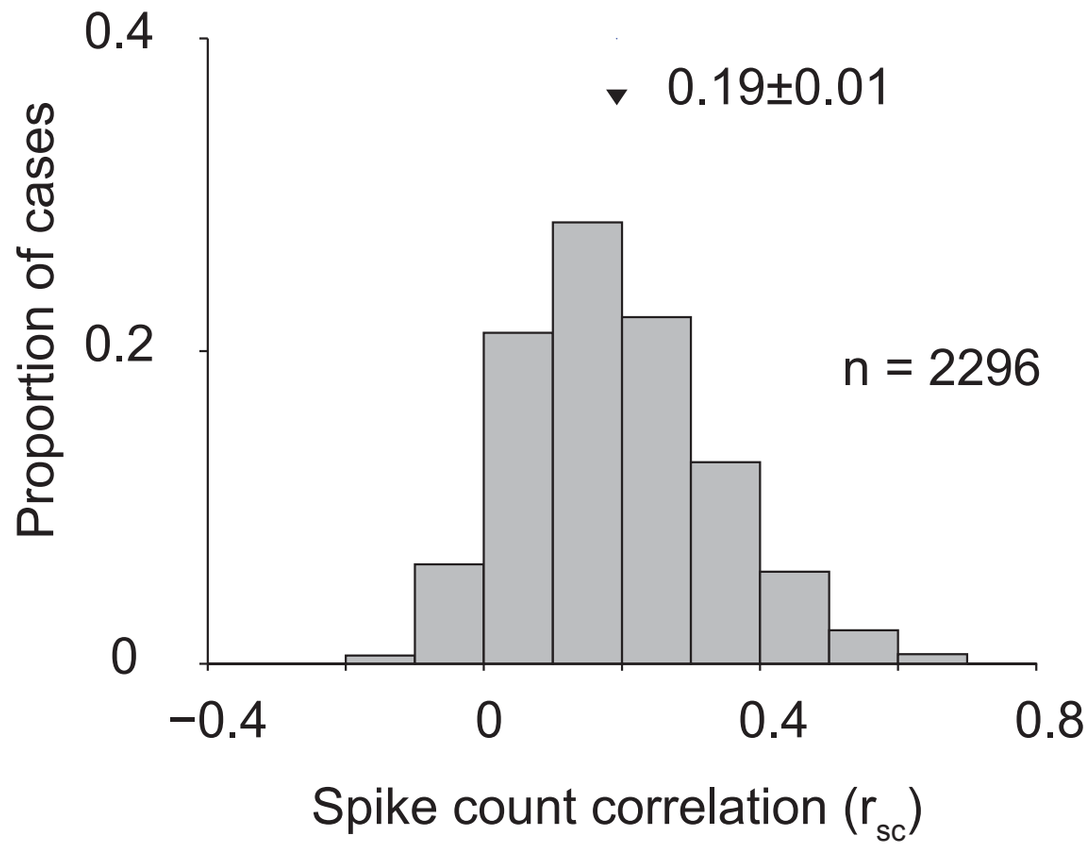
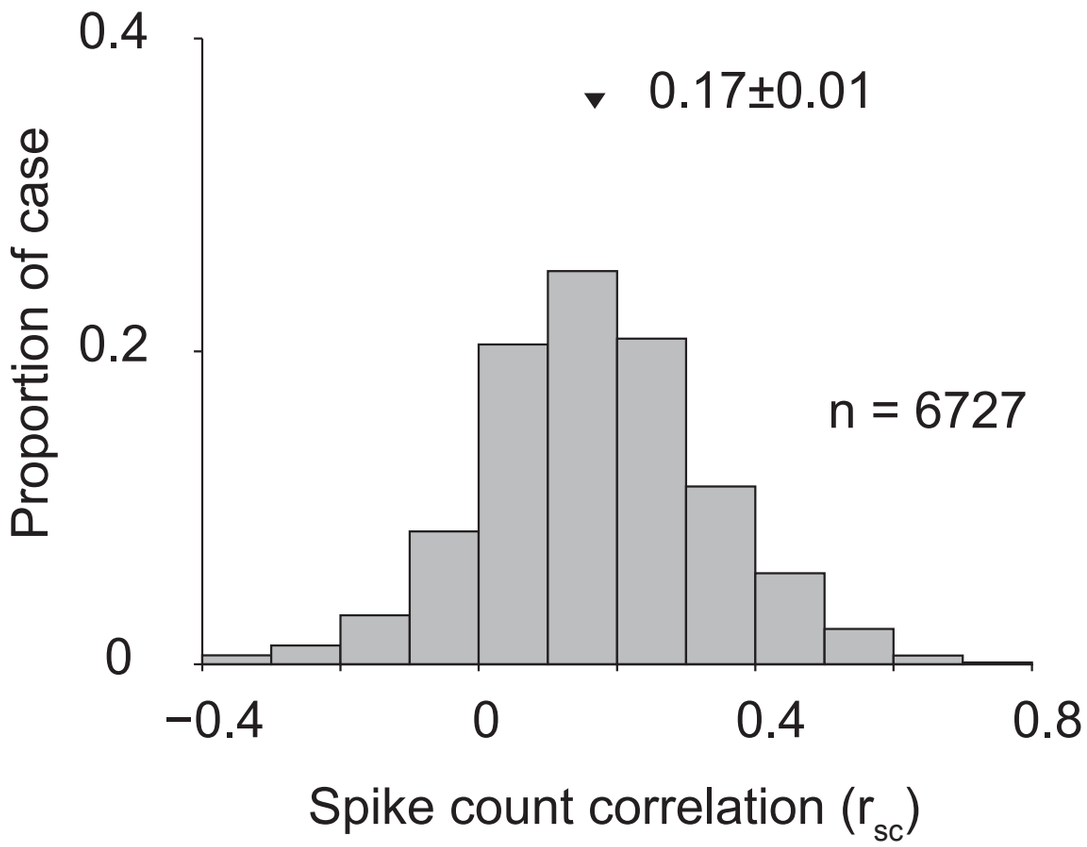


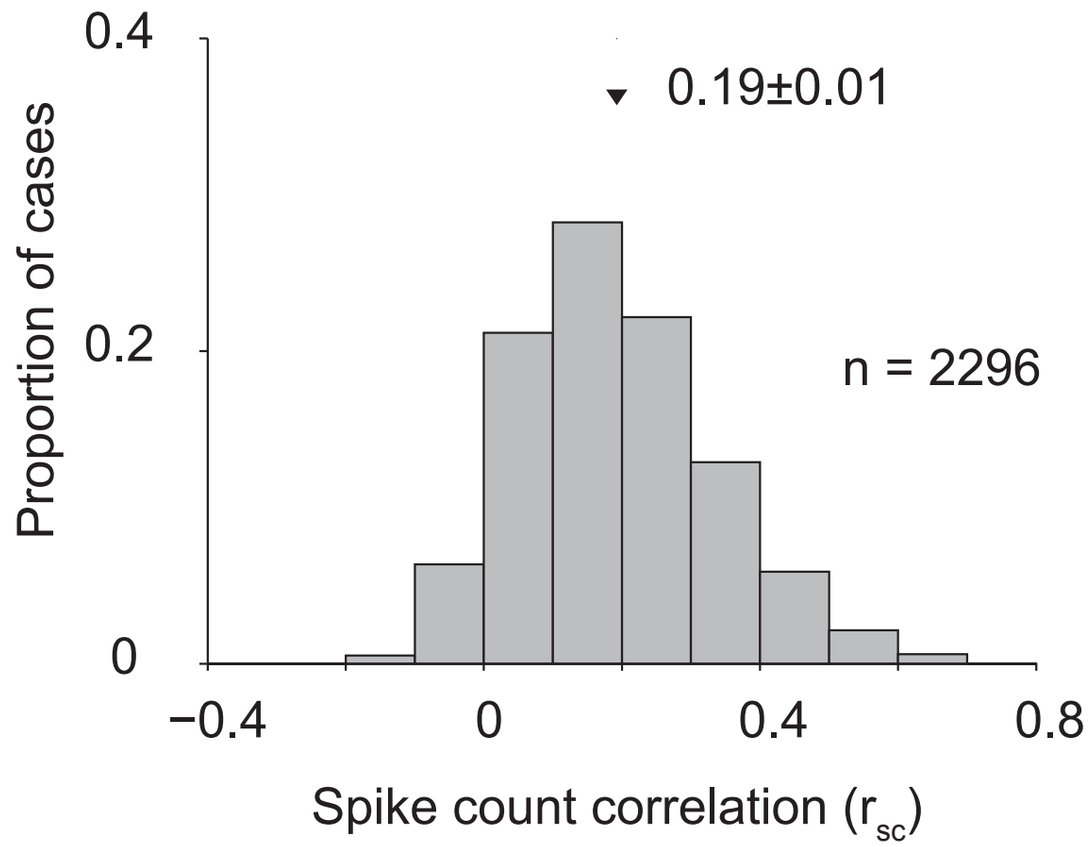


Smith & Kohn (2009, SfN Abstract)

Input layers



Not input layers



Smith & Kohn (2009, SfN Abstract)

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  - No evidence for such drastic layer differences in V2

Conclusions

- Correlation has different properties on different time scales
- Correlation in spontaneous activity exceeds evoked
- Correlation varies dramatically with layer in V1, but not V2
- Similar structure exists in V4

Funding

- Adam Kohn (NIH EY016774)
- Matt Smith (NIH EY018894)