Introduction to neural data

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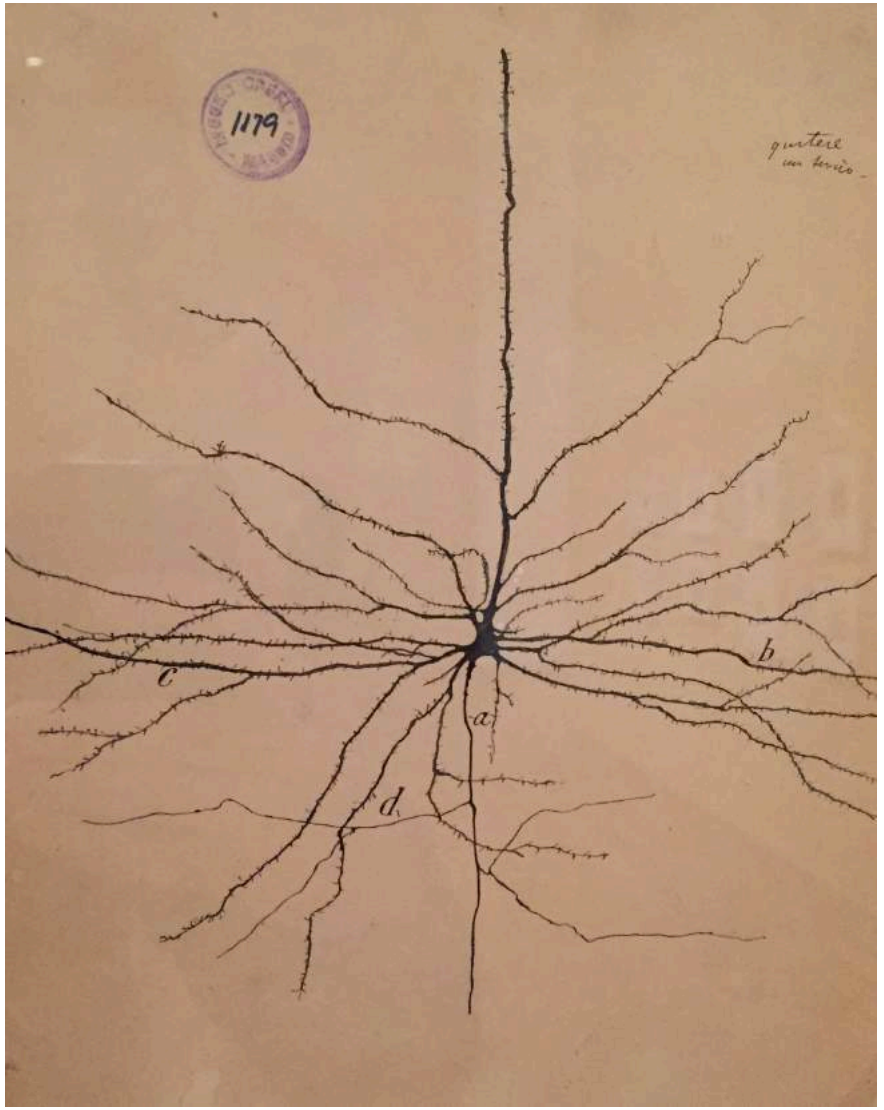
CENTURI Summer School

Comp. Neuro. Project

June 21, 2022

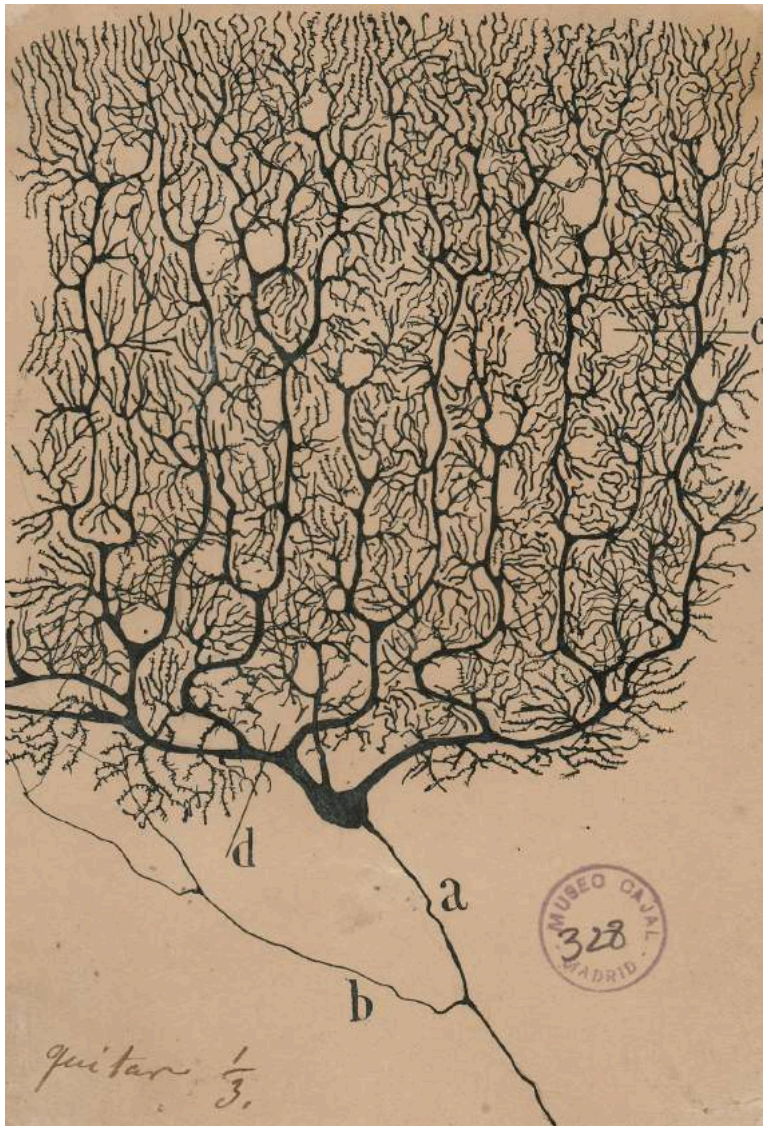
What is a neuron?



Pyramidal neuron

Santiago Ramón y Cajal (1852-1934)

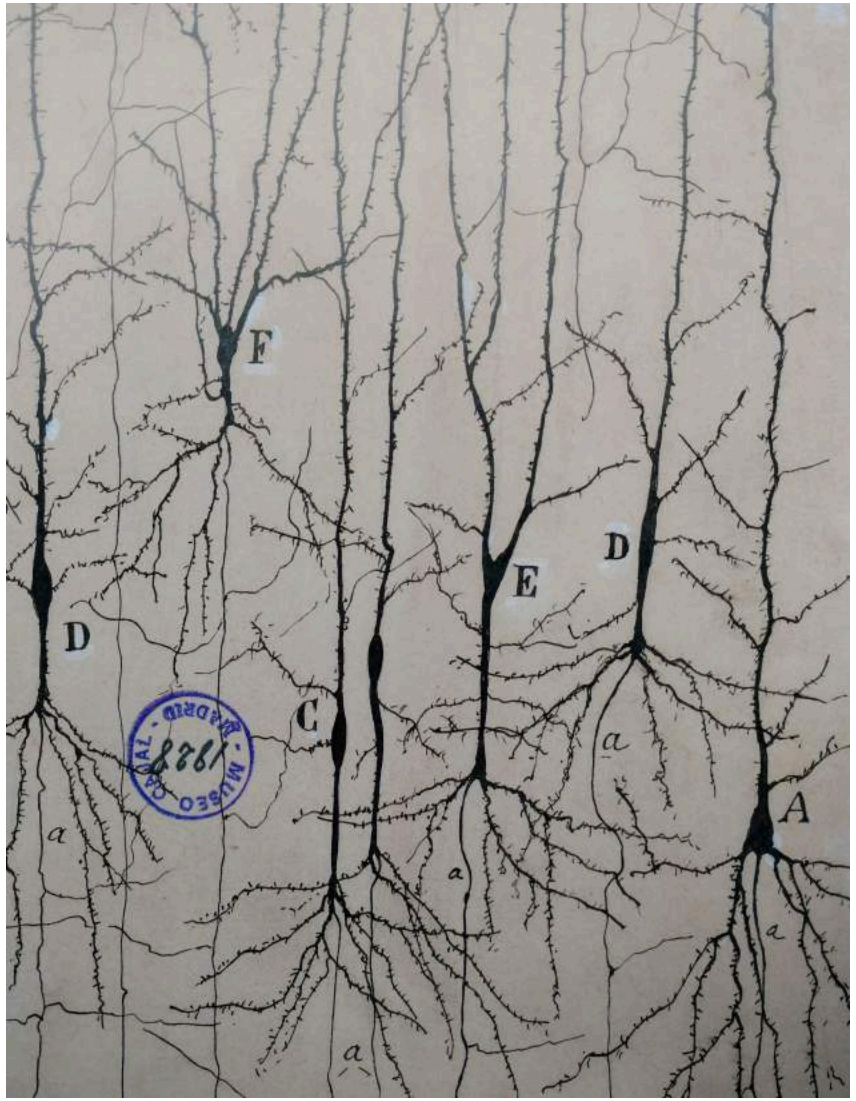
What is a neuron?



Purkinje neuron

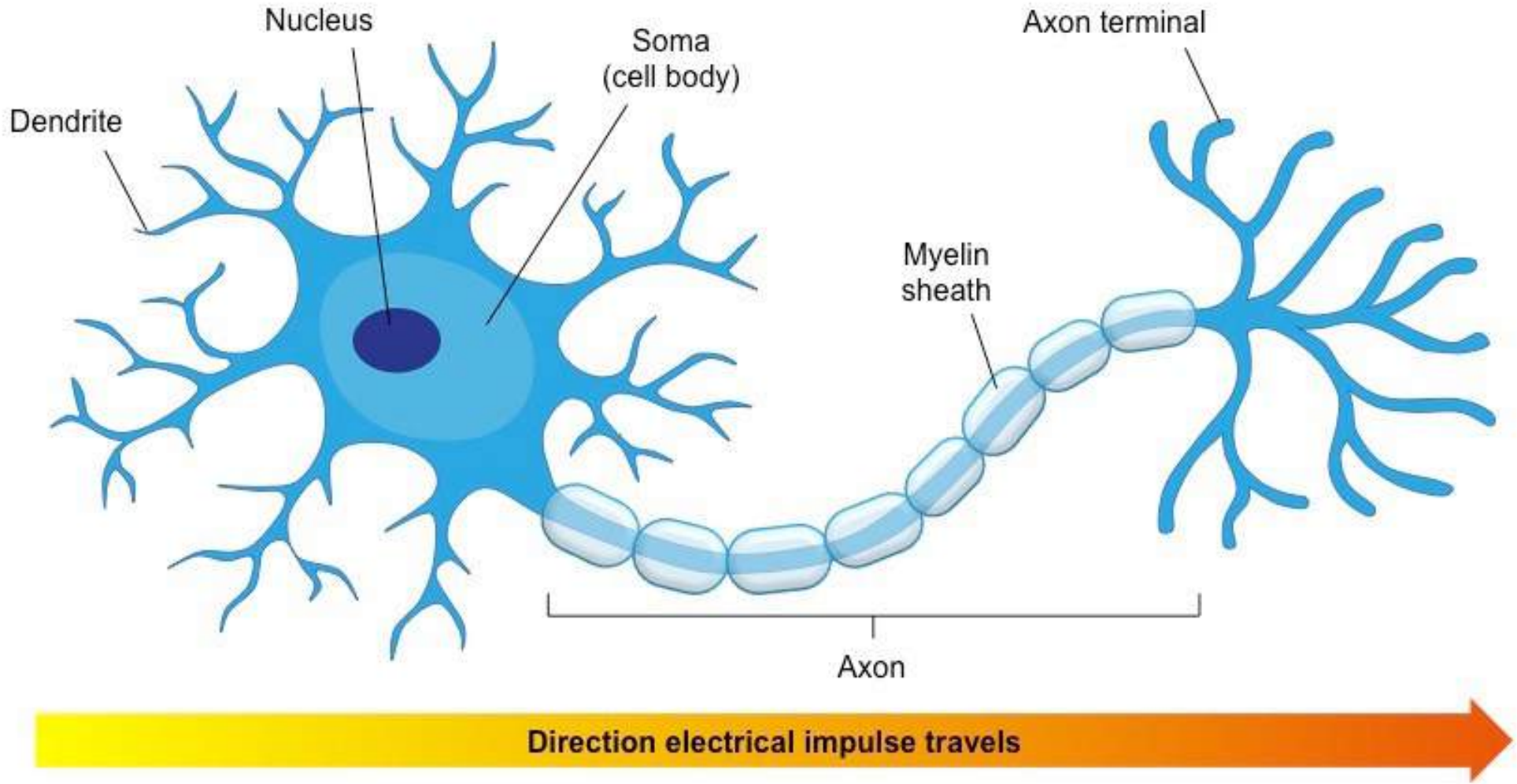
Santiago Ramón y Cajal (1852-1934)

What is a neuron?

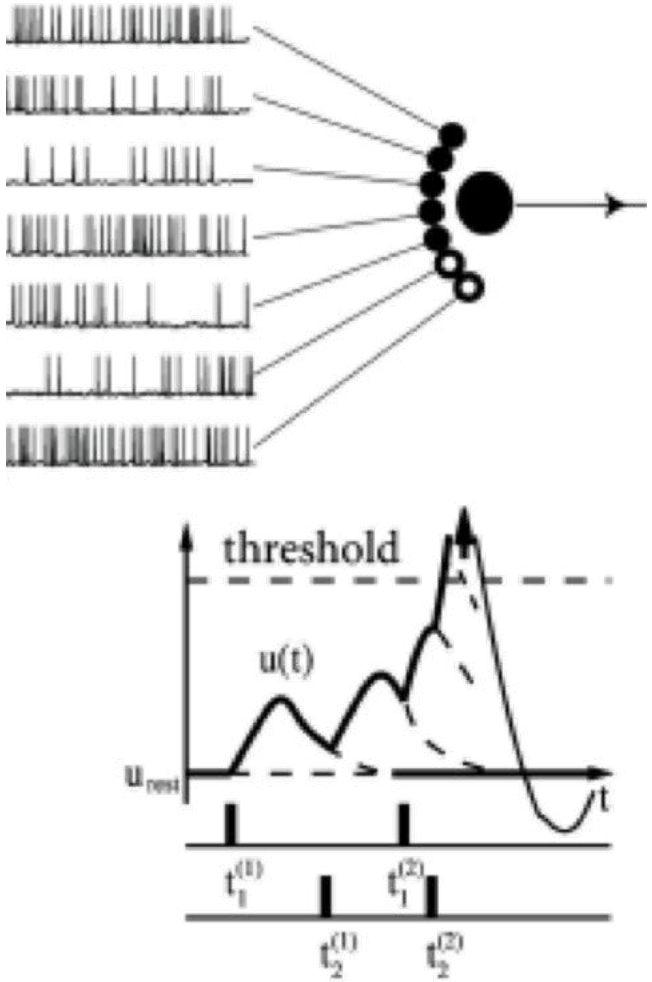


Santiago Ramón y Cajal (1852-1934)

What is a neuron?



Neurons talk to one another via “spikes”



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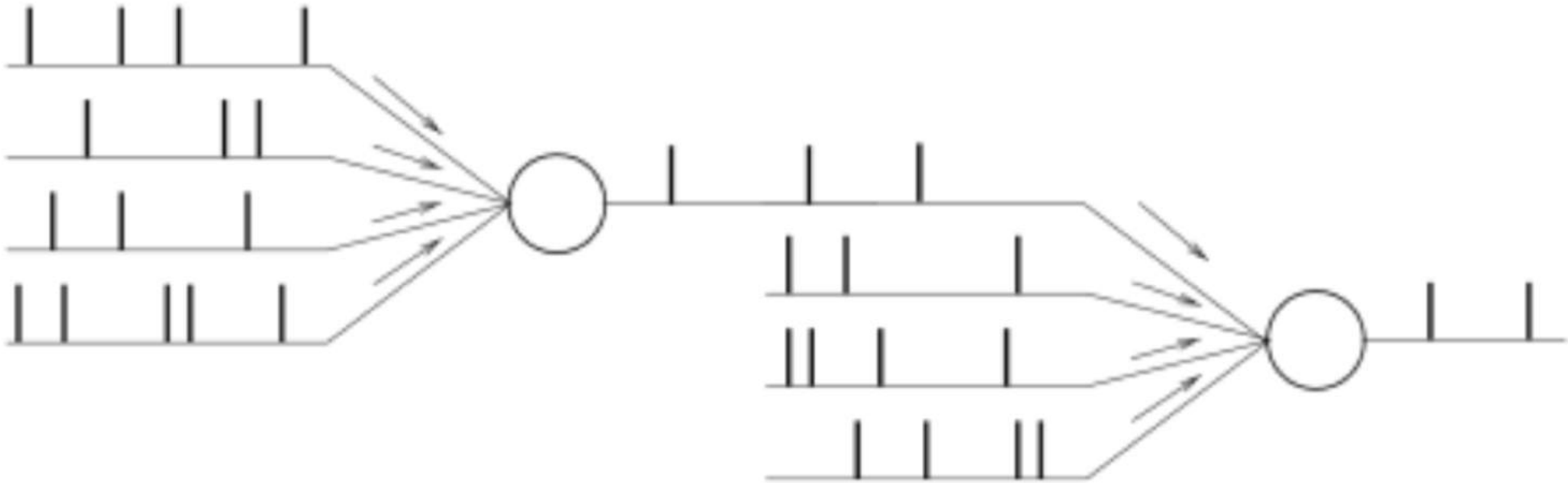
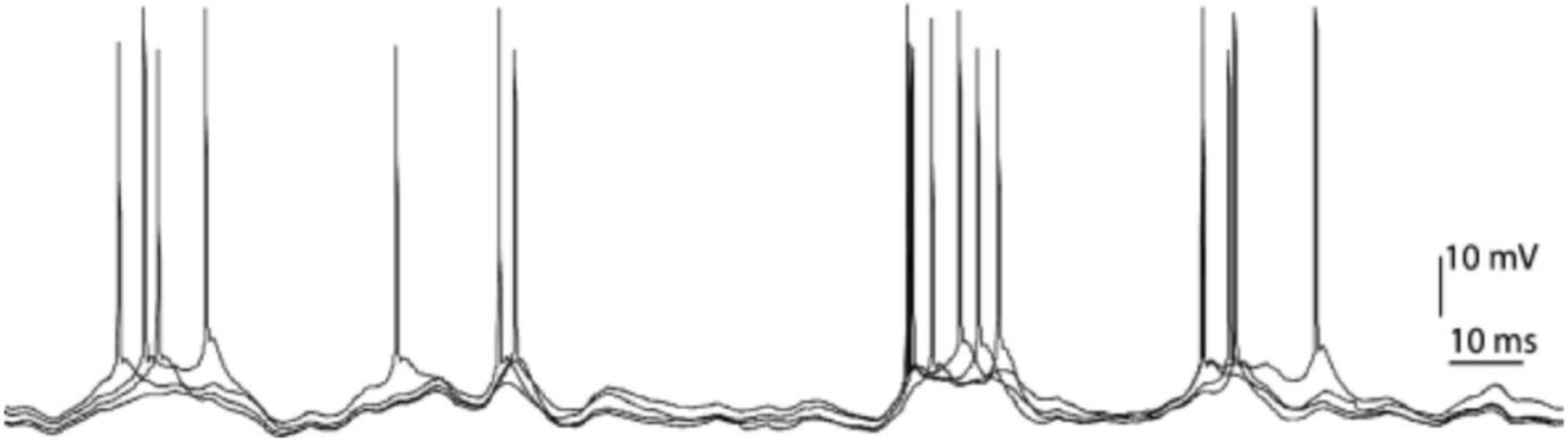
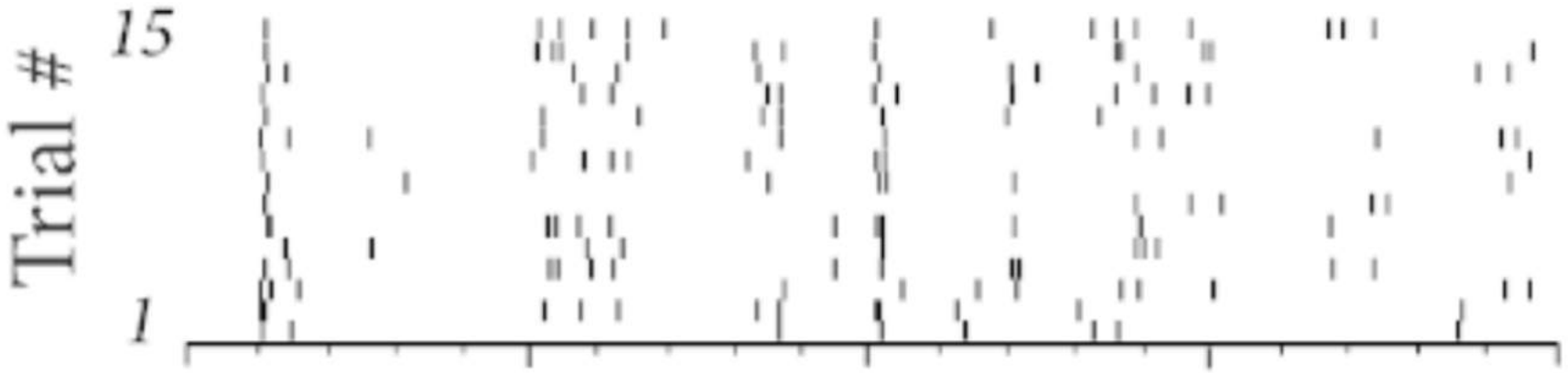


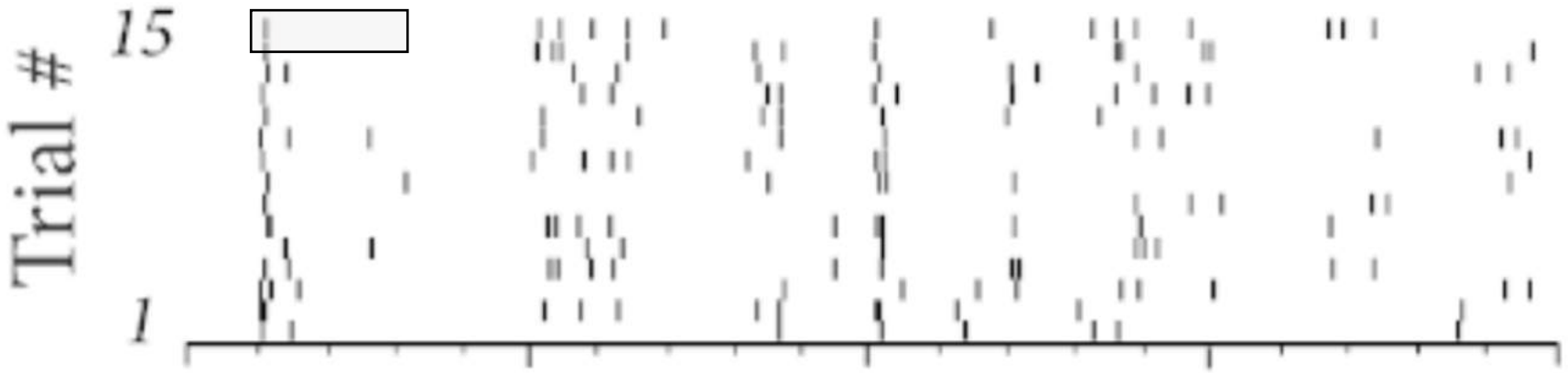
Neurons are “noisy” *in vitro* …



… even more so *in vivo* …



… so we average their activity over time …



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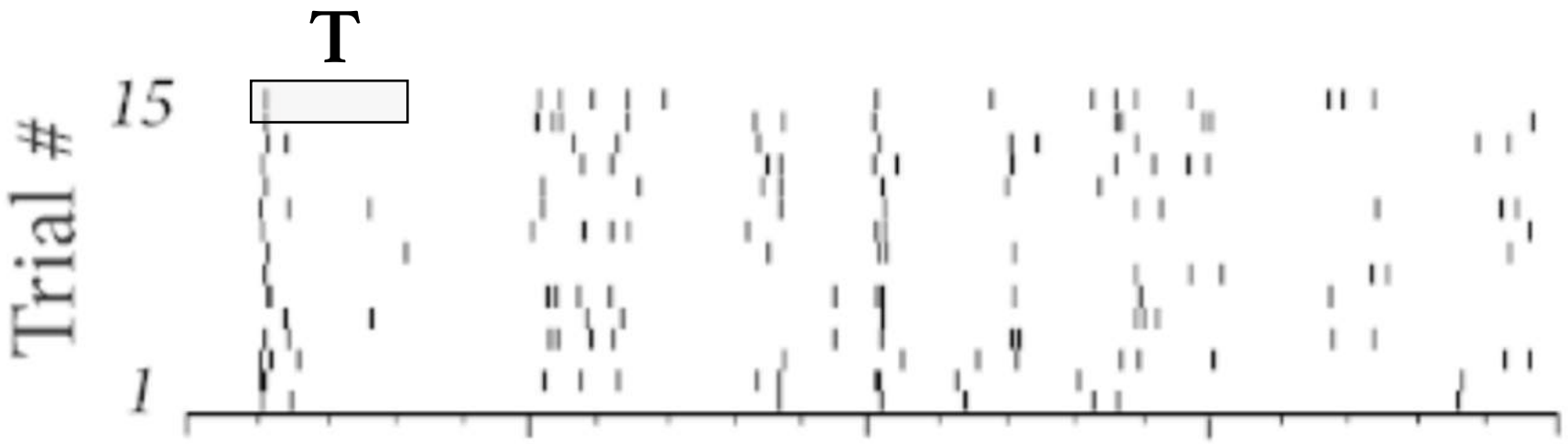
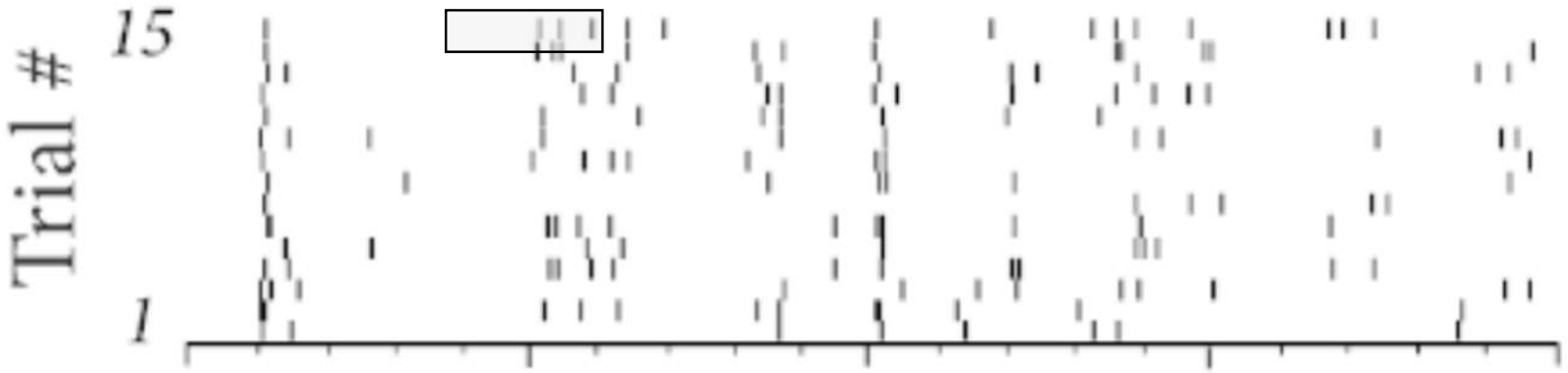


#spikes within T

… so we average their activity over time …



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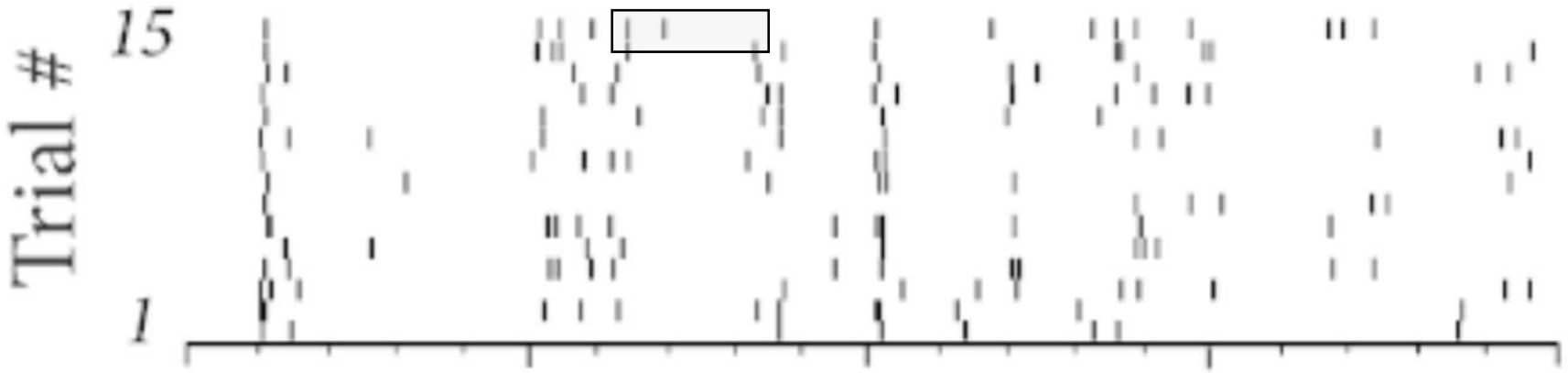

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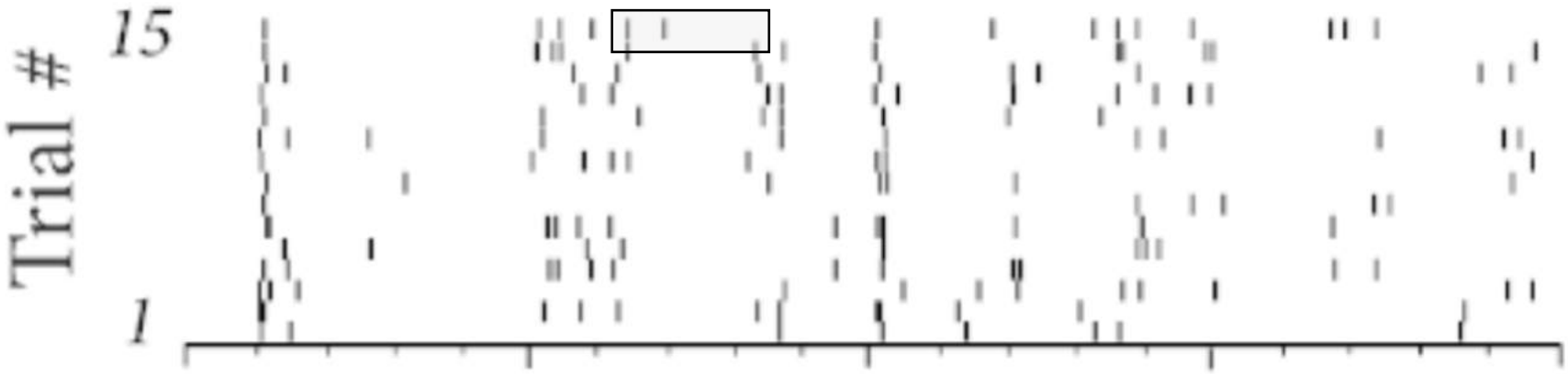
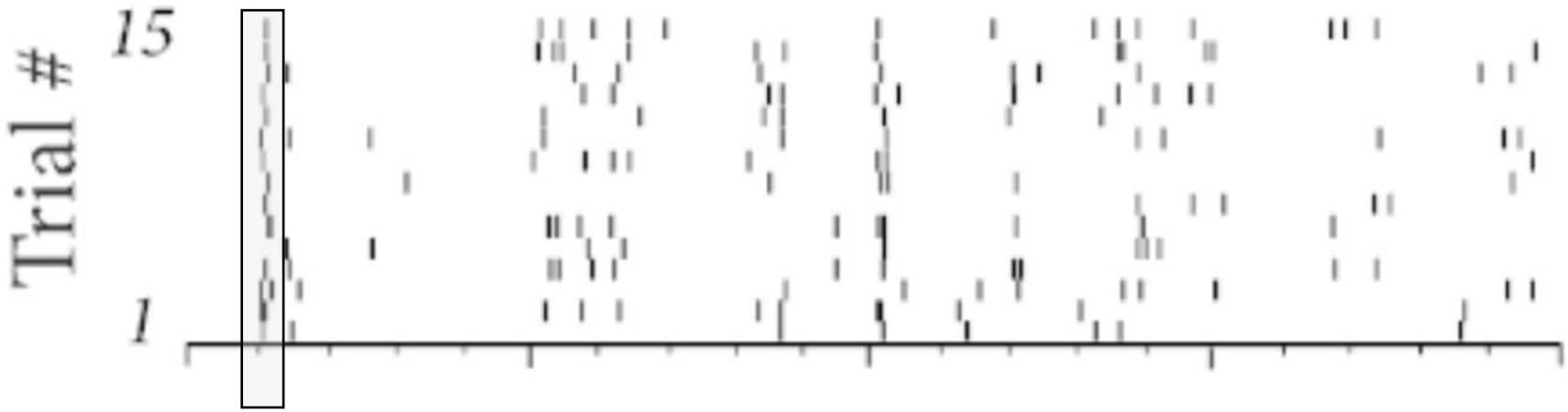
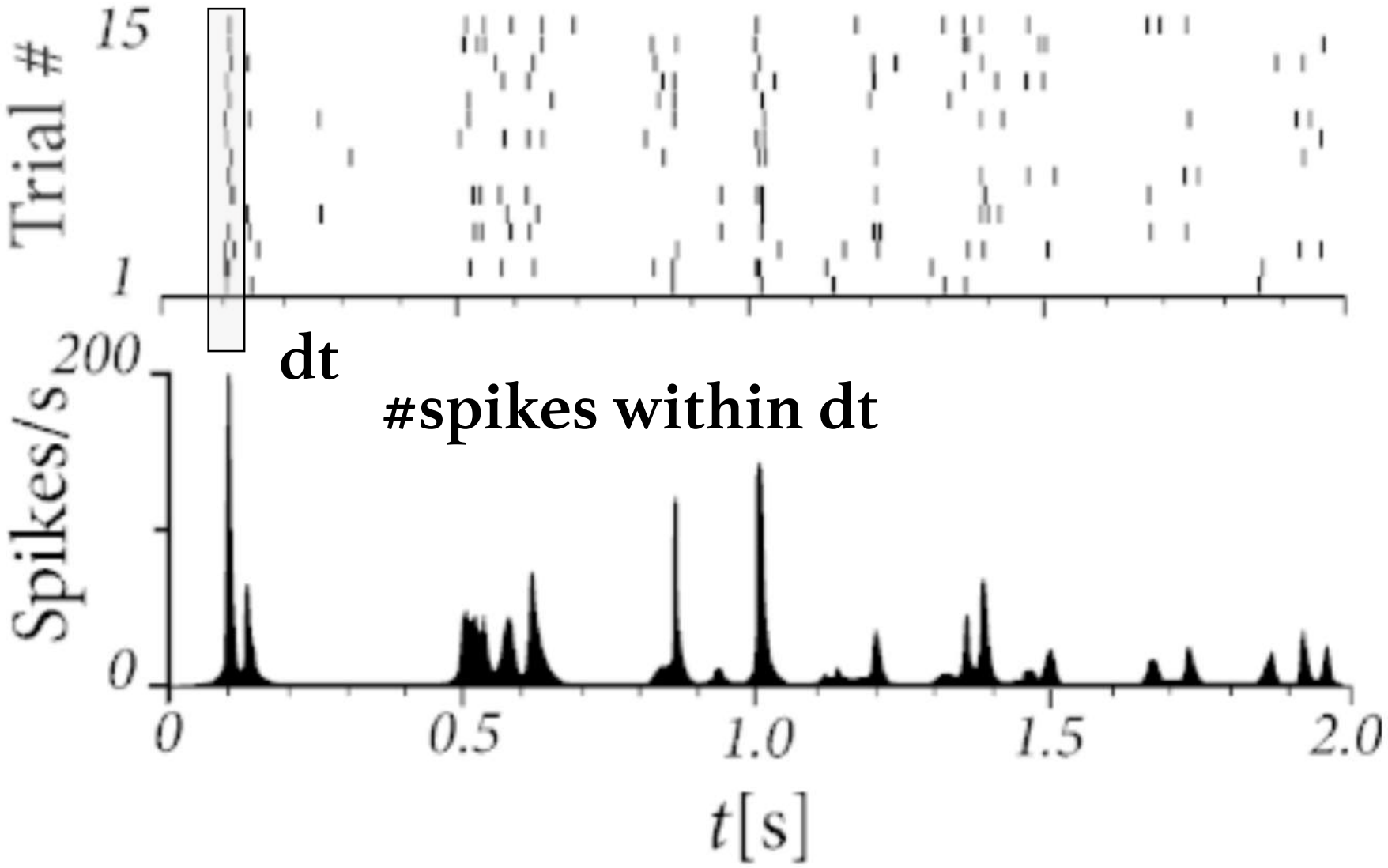


not great for temporal resolution

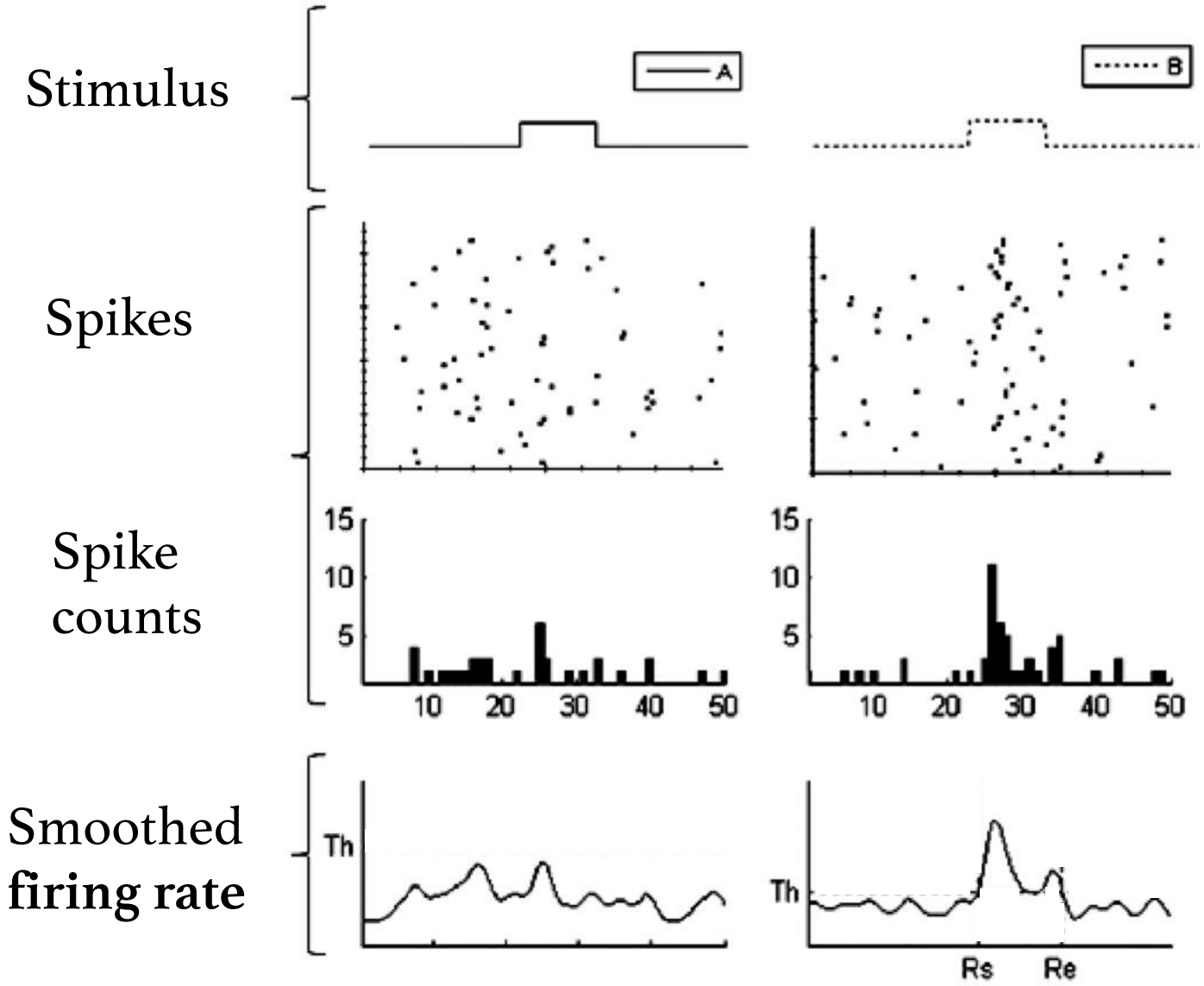
… or we average over repeats

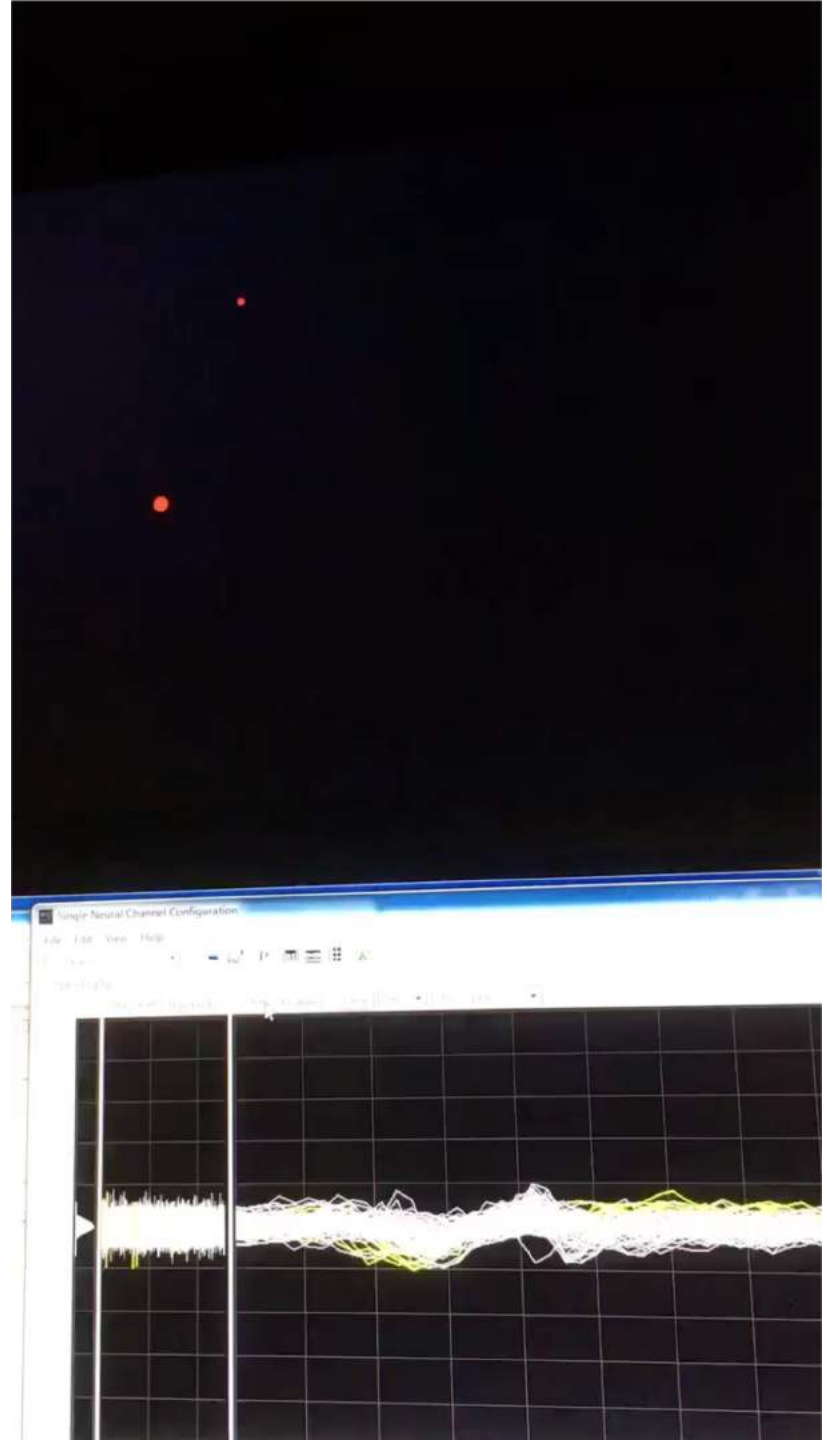


Firing rates: an abstraction

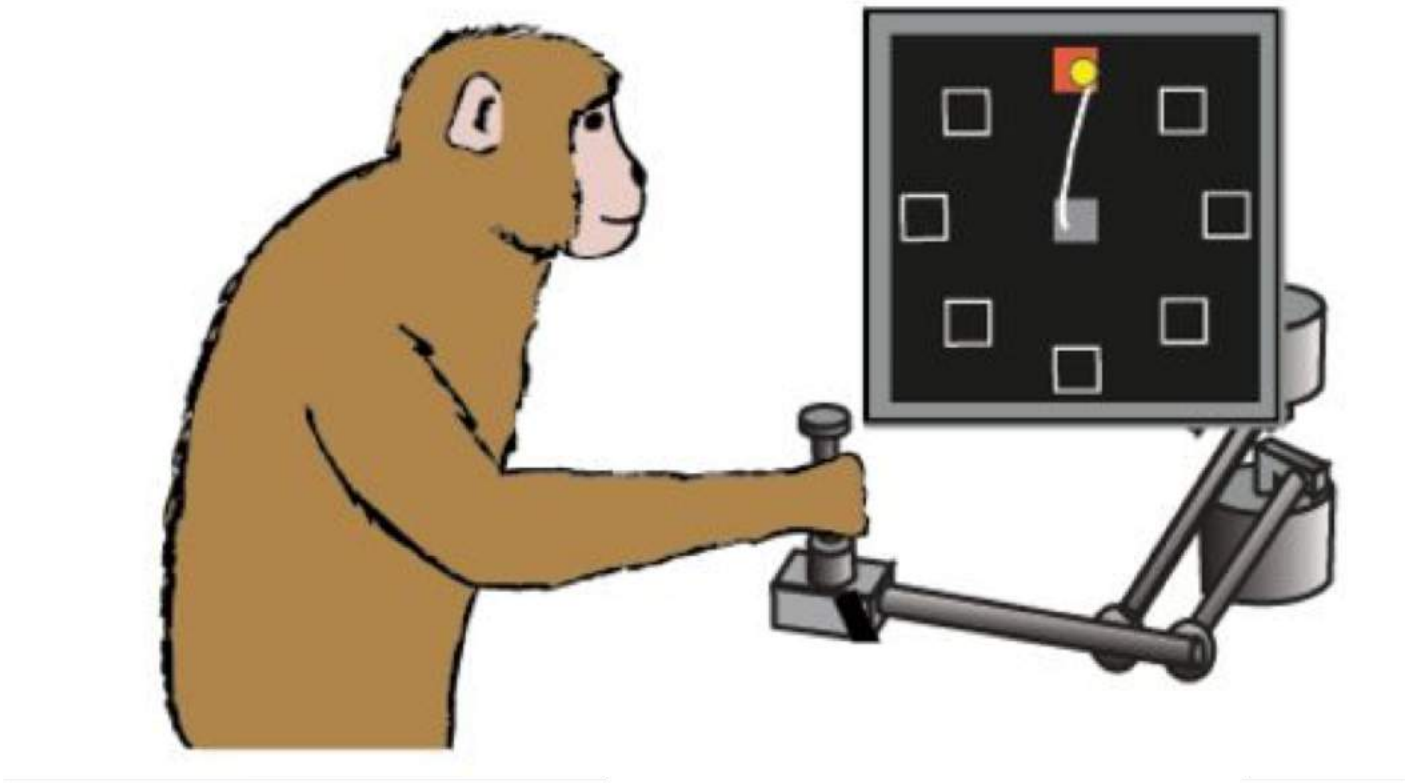


Firing rates: an abstraction




Single Neutral Channel Configuration
File Edit View Help

Dataset #1: center-out task



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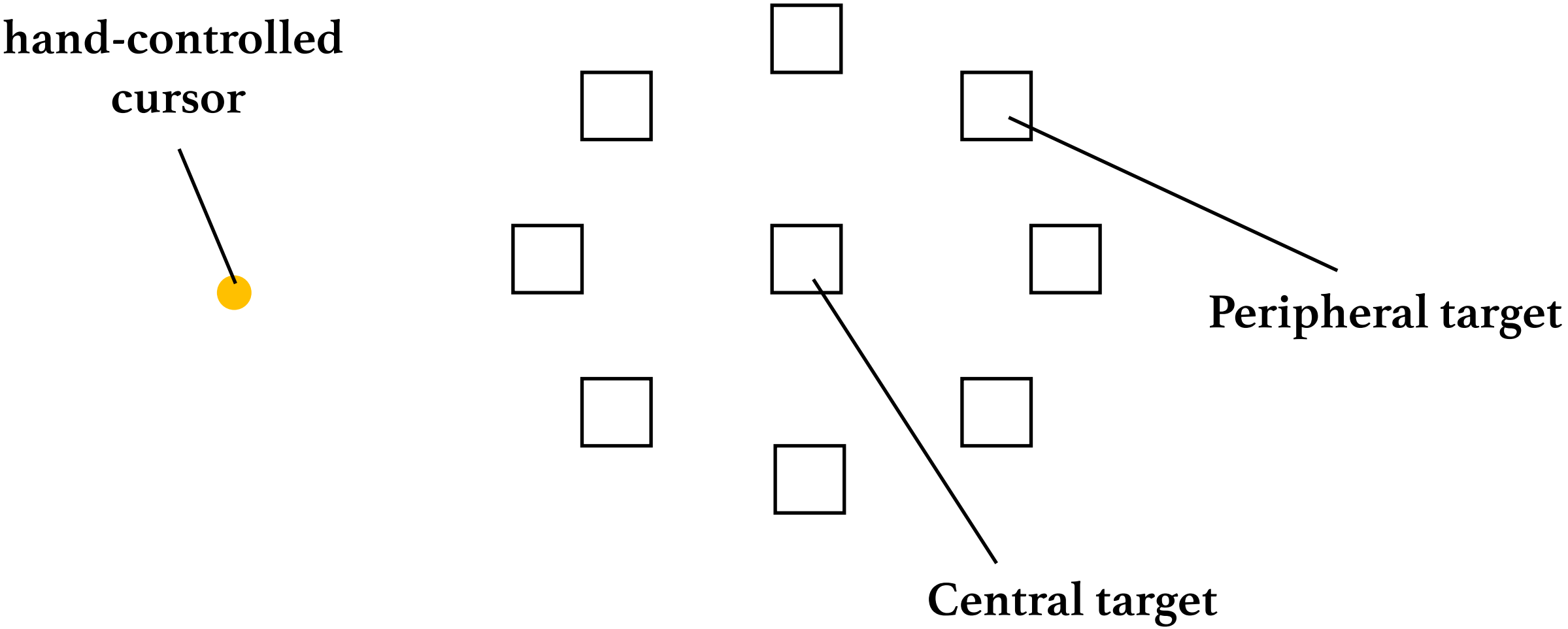

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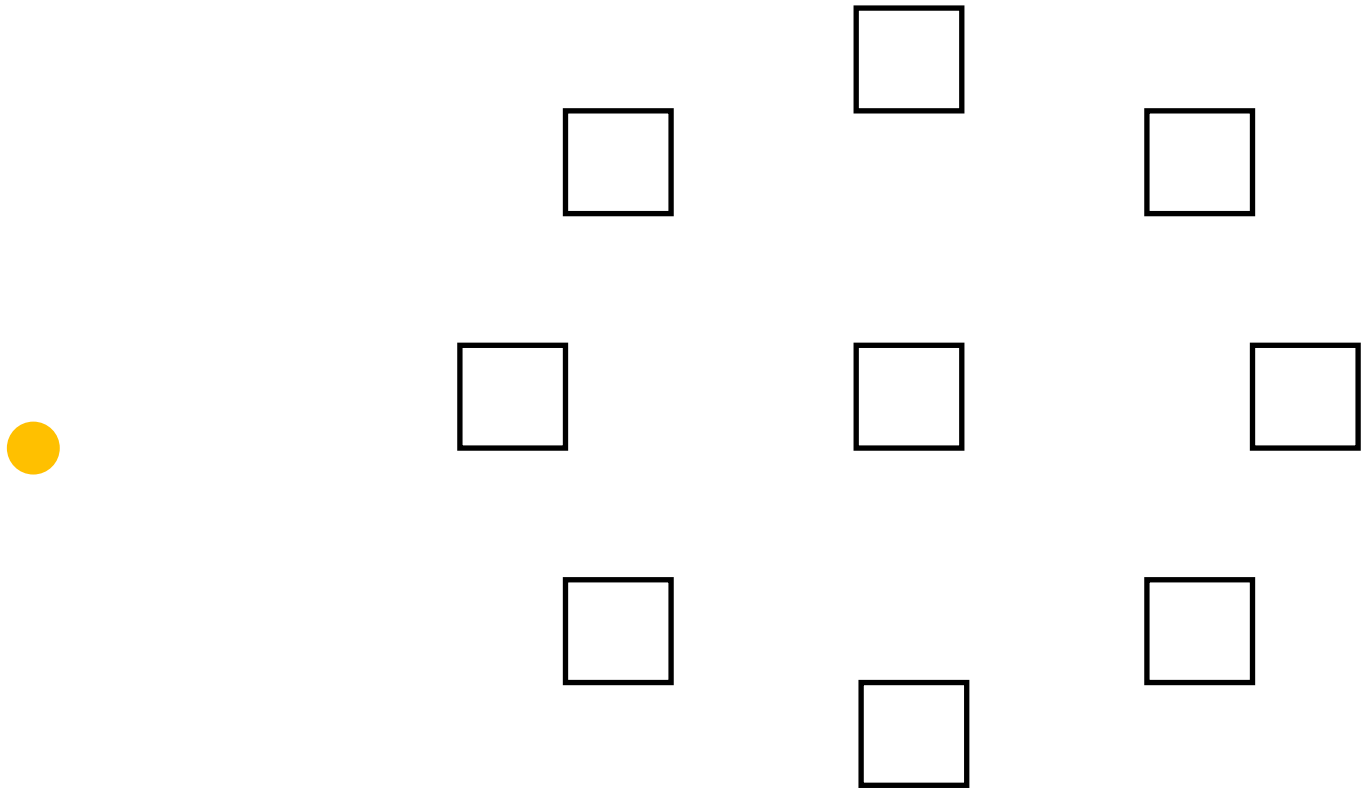
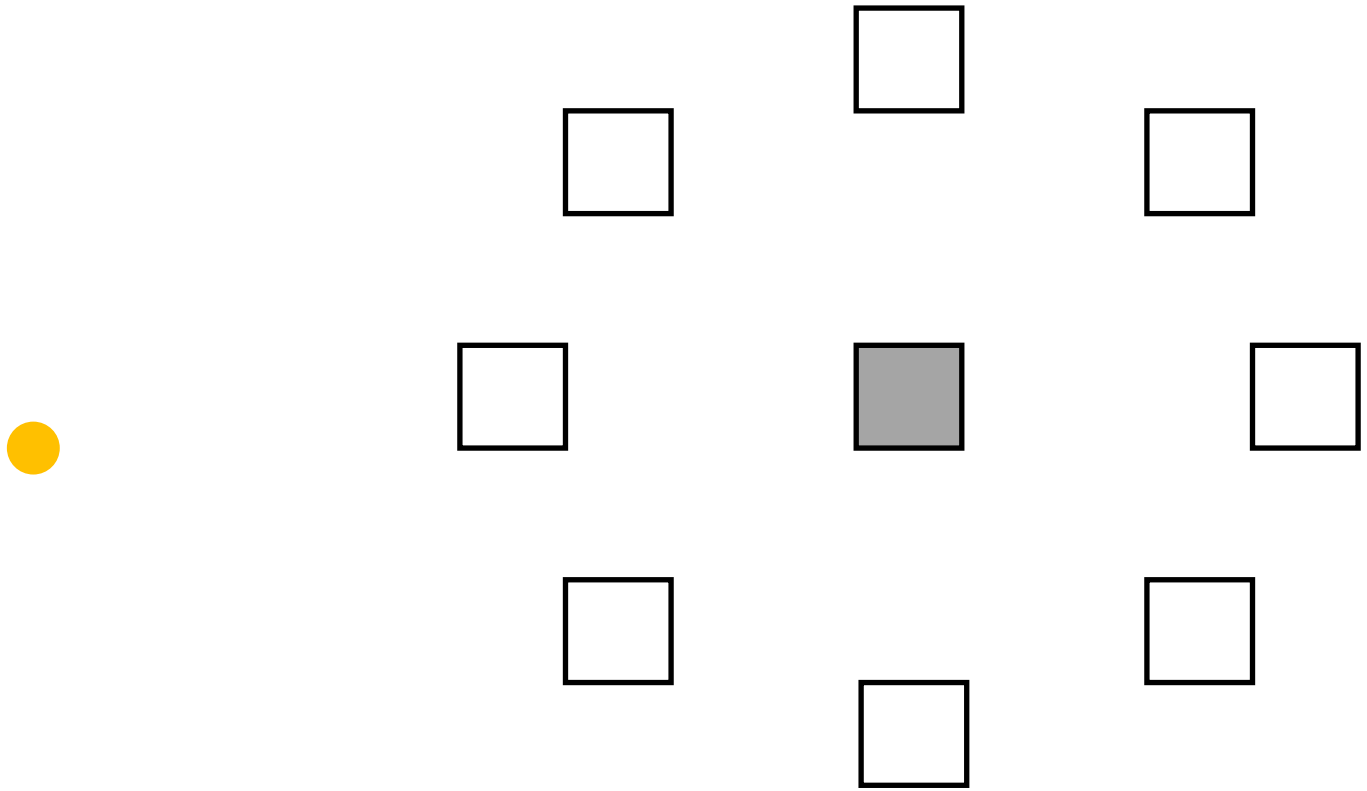


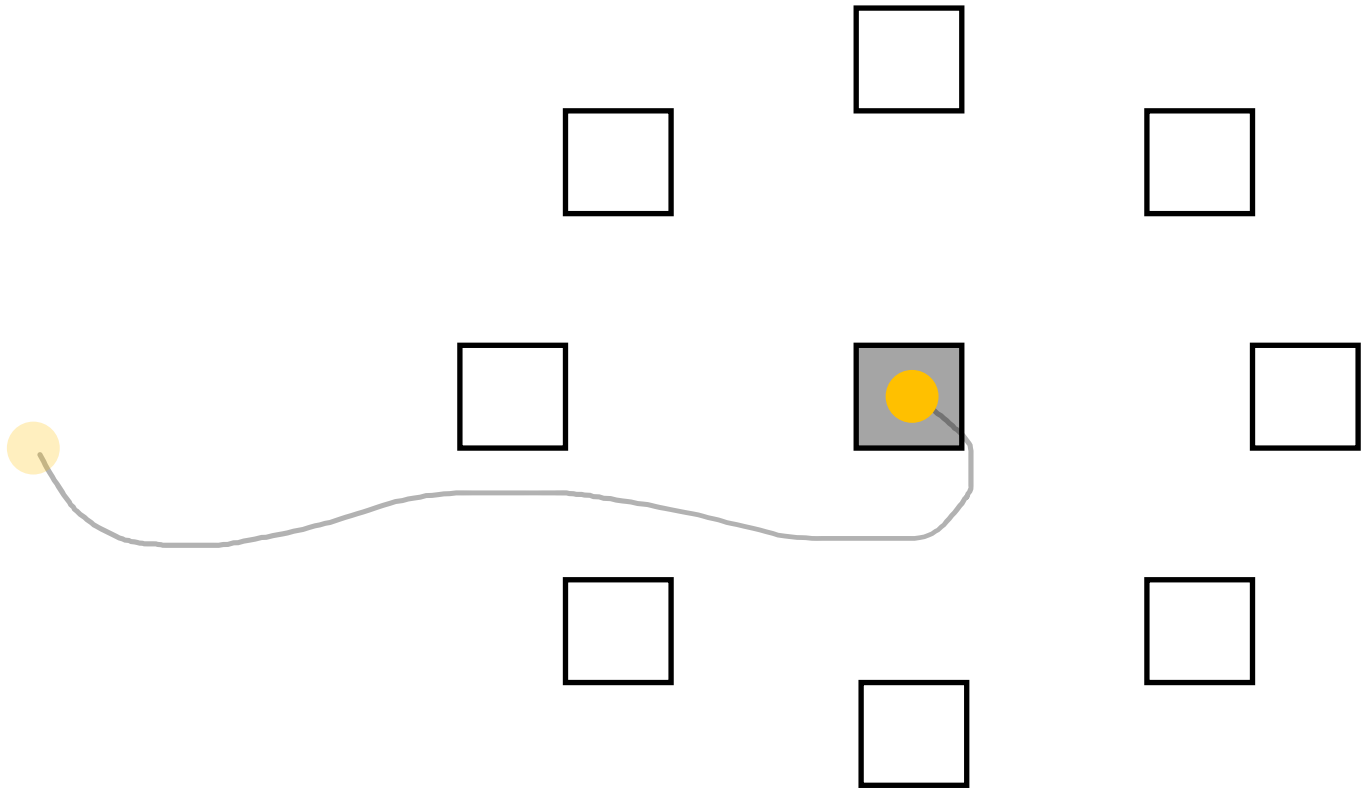
Blank screen

Dataset #1: center-out task



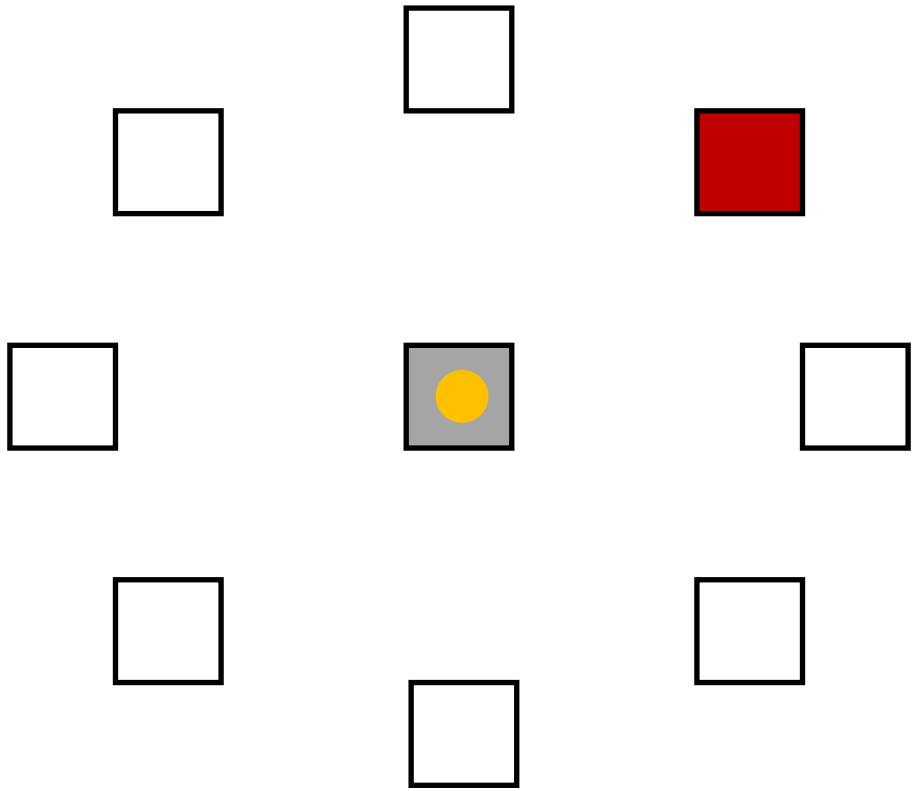
Central target on

Dataset #1: center-out task



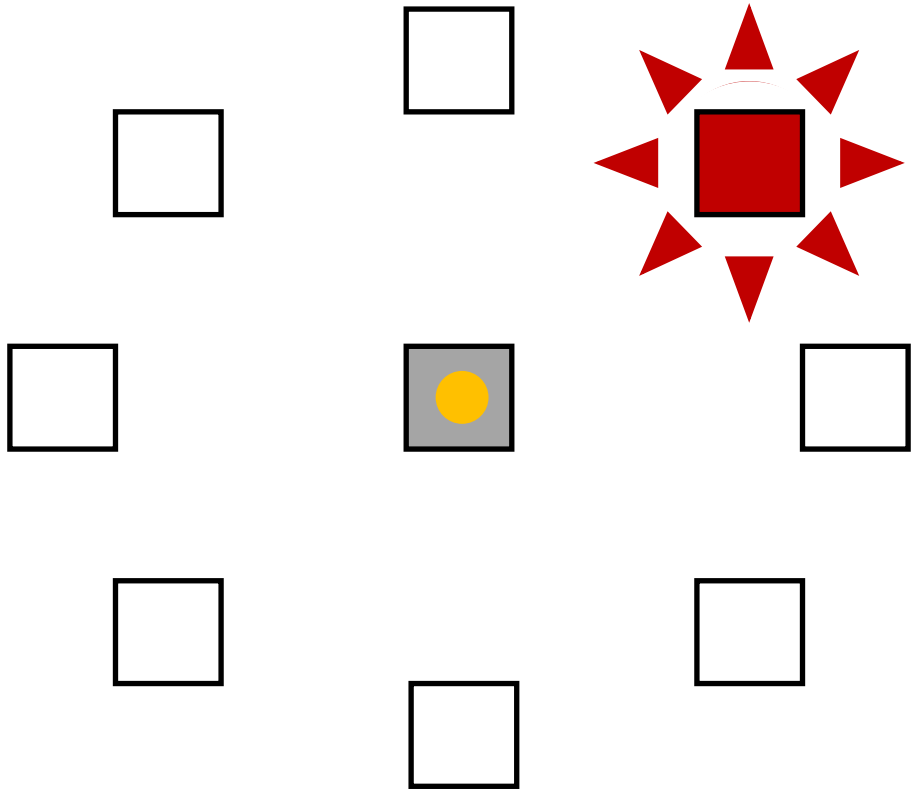
Hand cursor enters central target

Dataset #1: center-out task



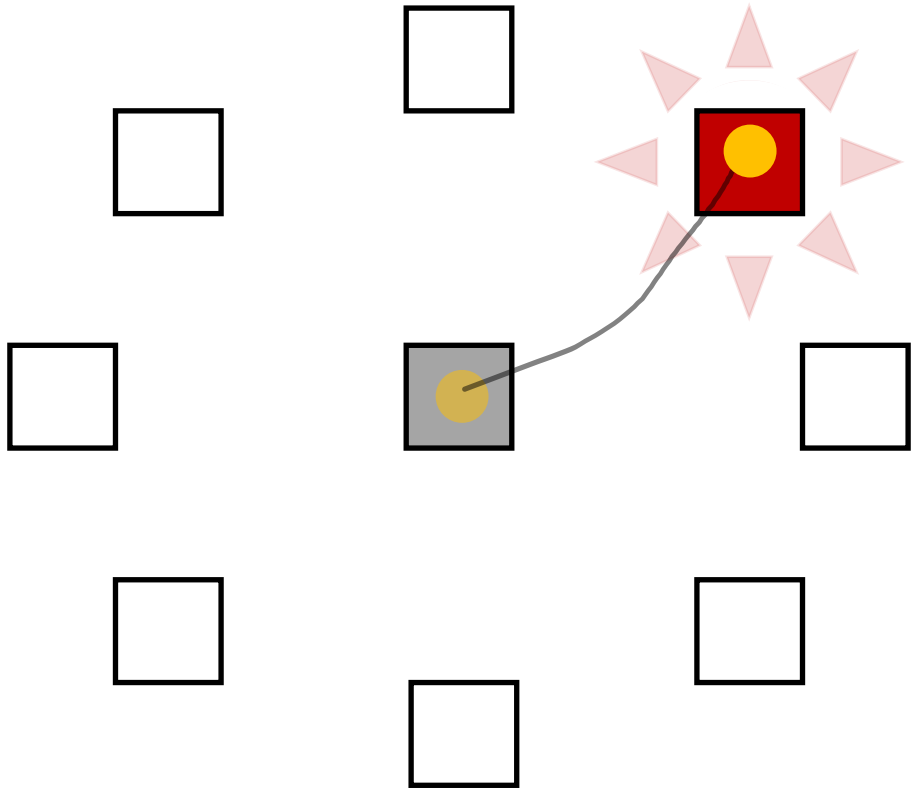
Peripheral target on

Dataset #1: center-out task



Peripheral target starts blinking

Dataset #1: center-out task



Hand moves toward target

Dataset #1: center-out task

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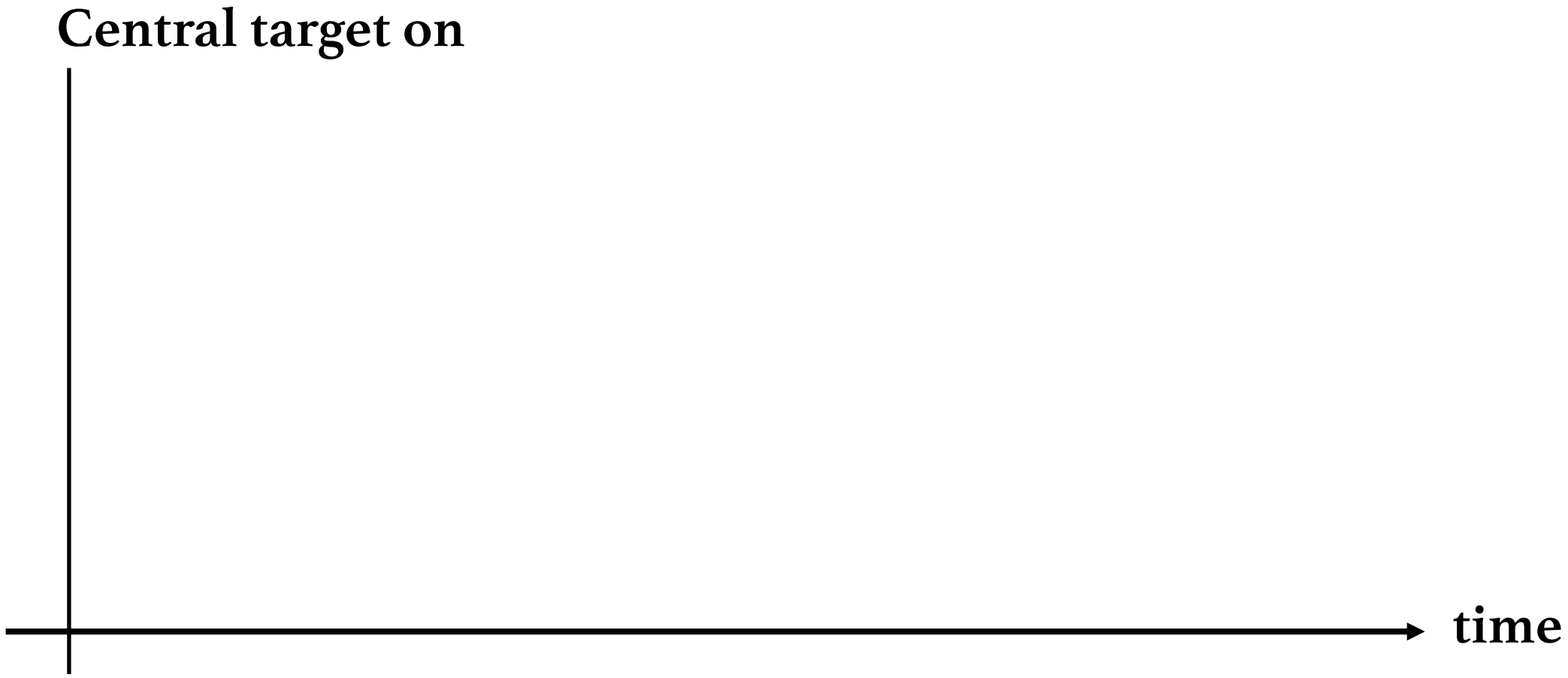

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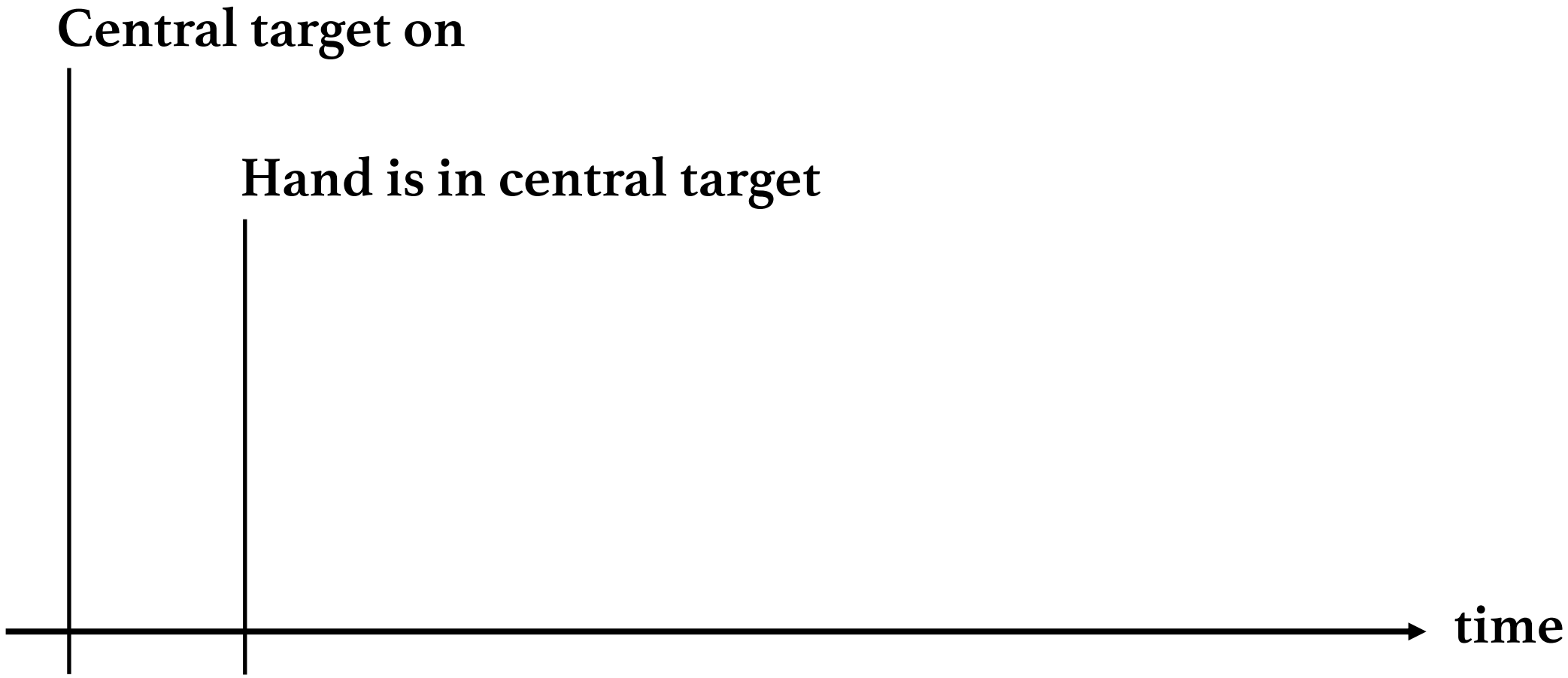

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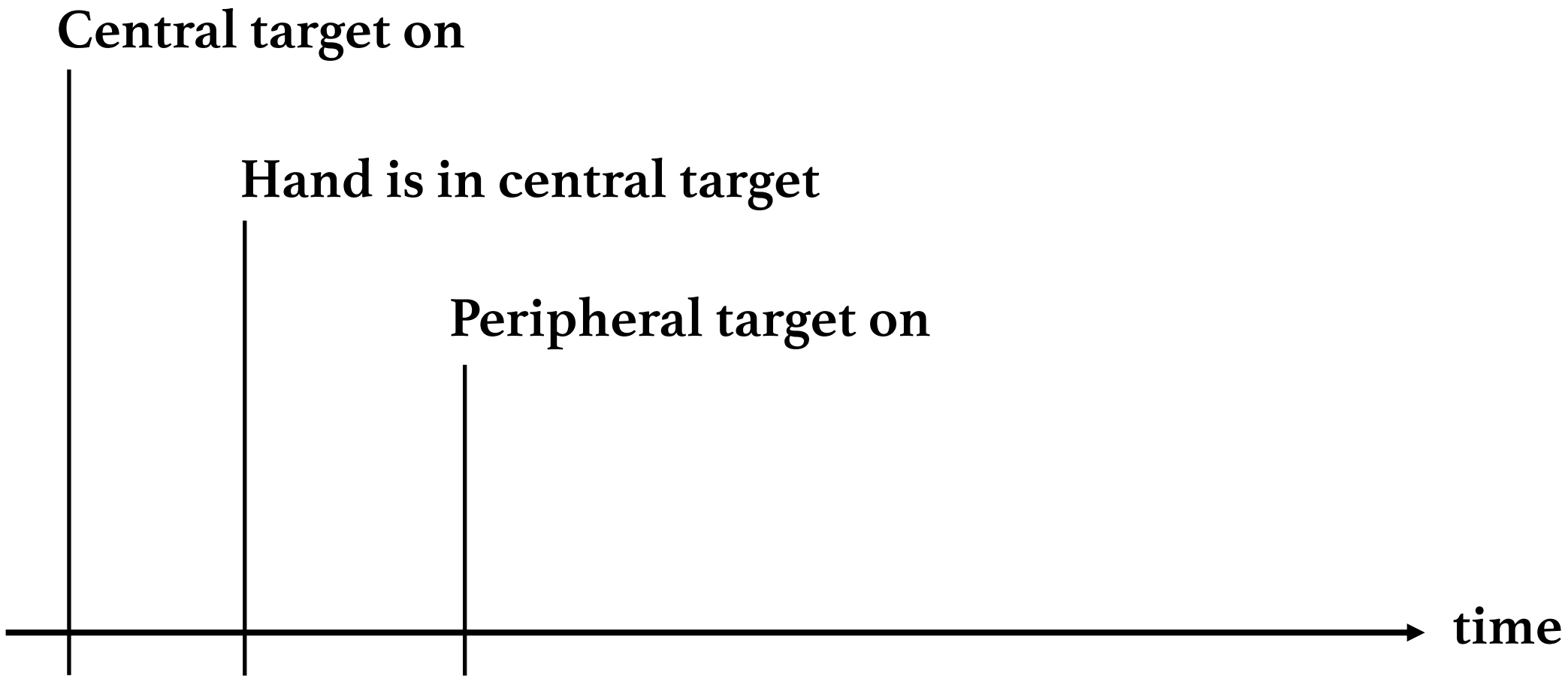

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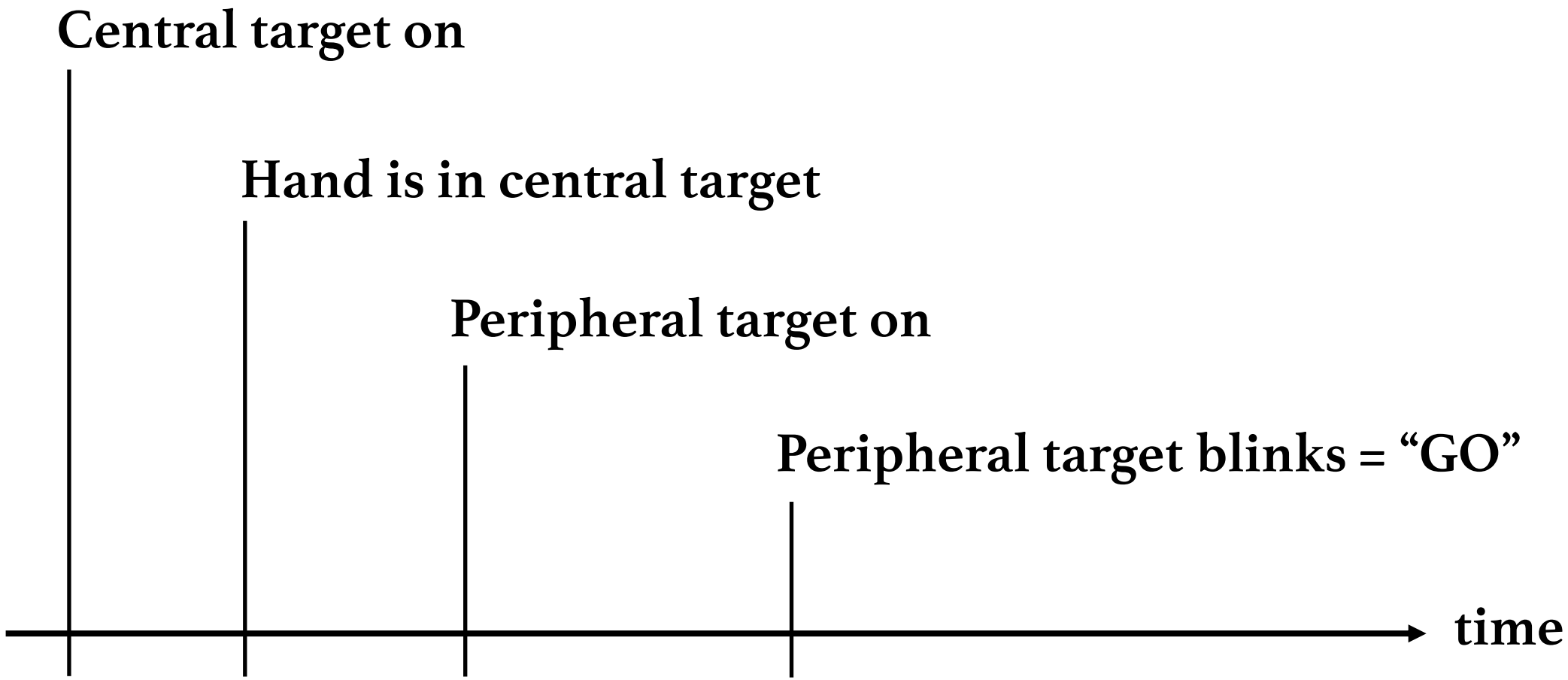

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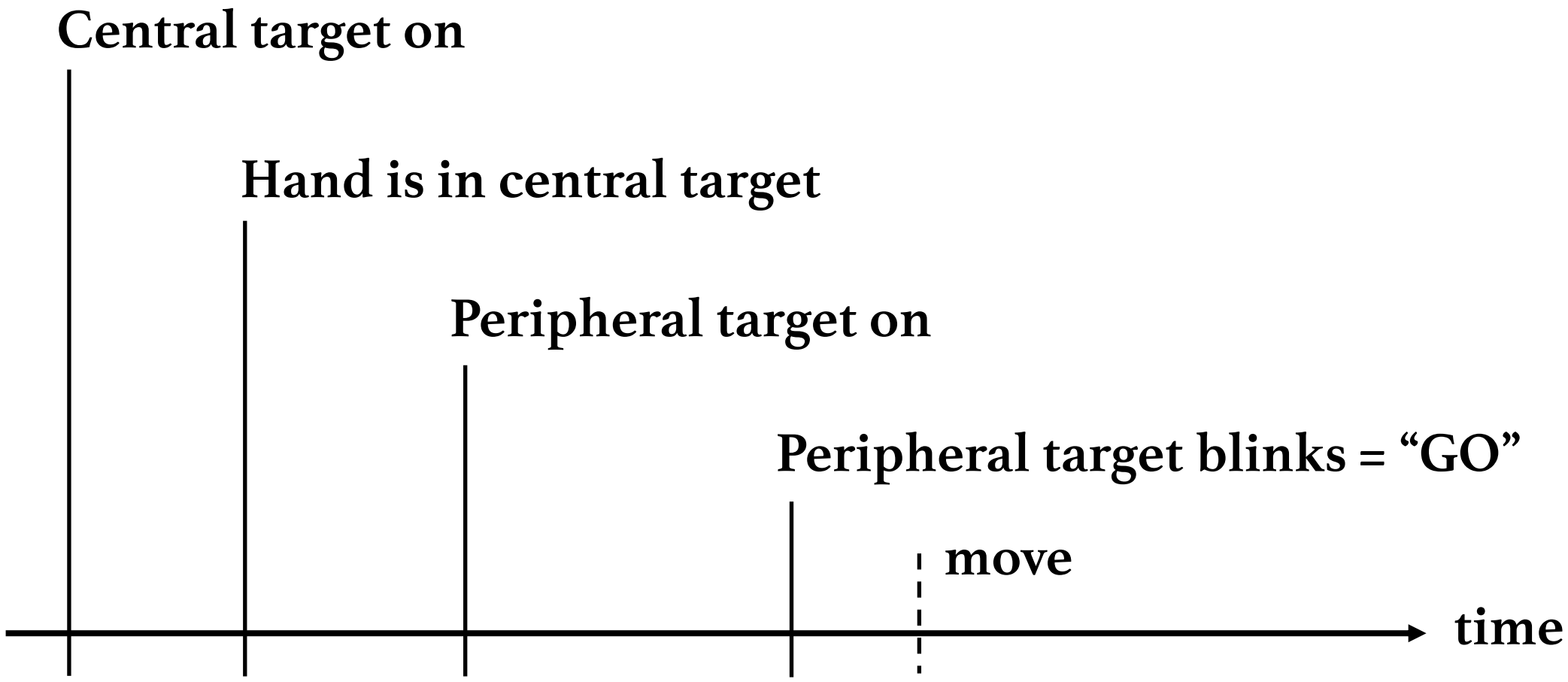

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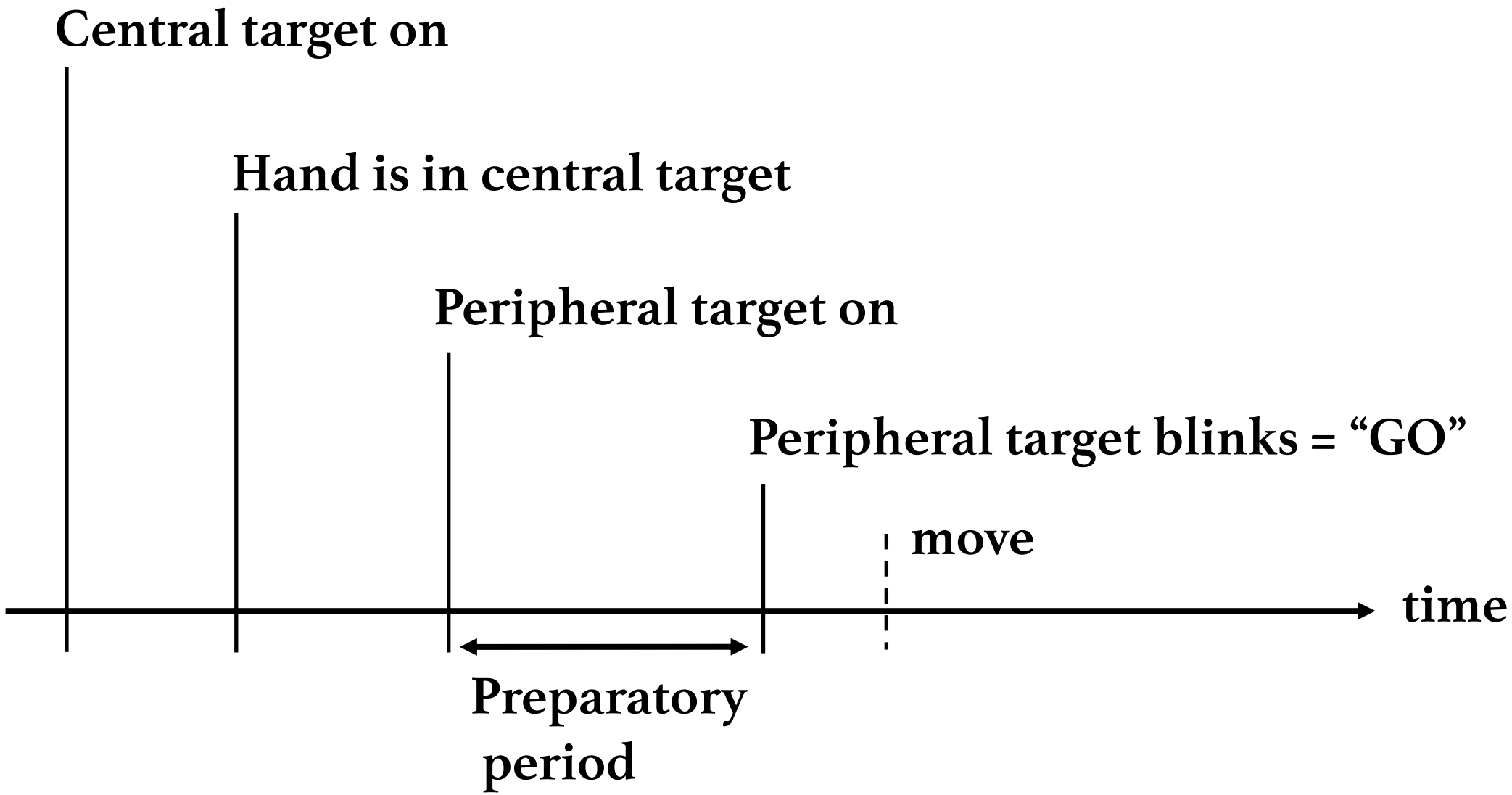

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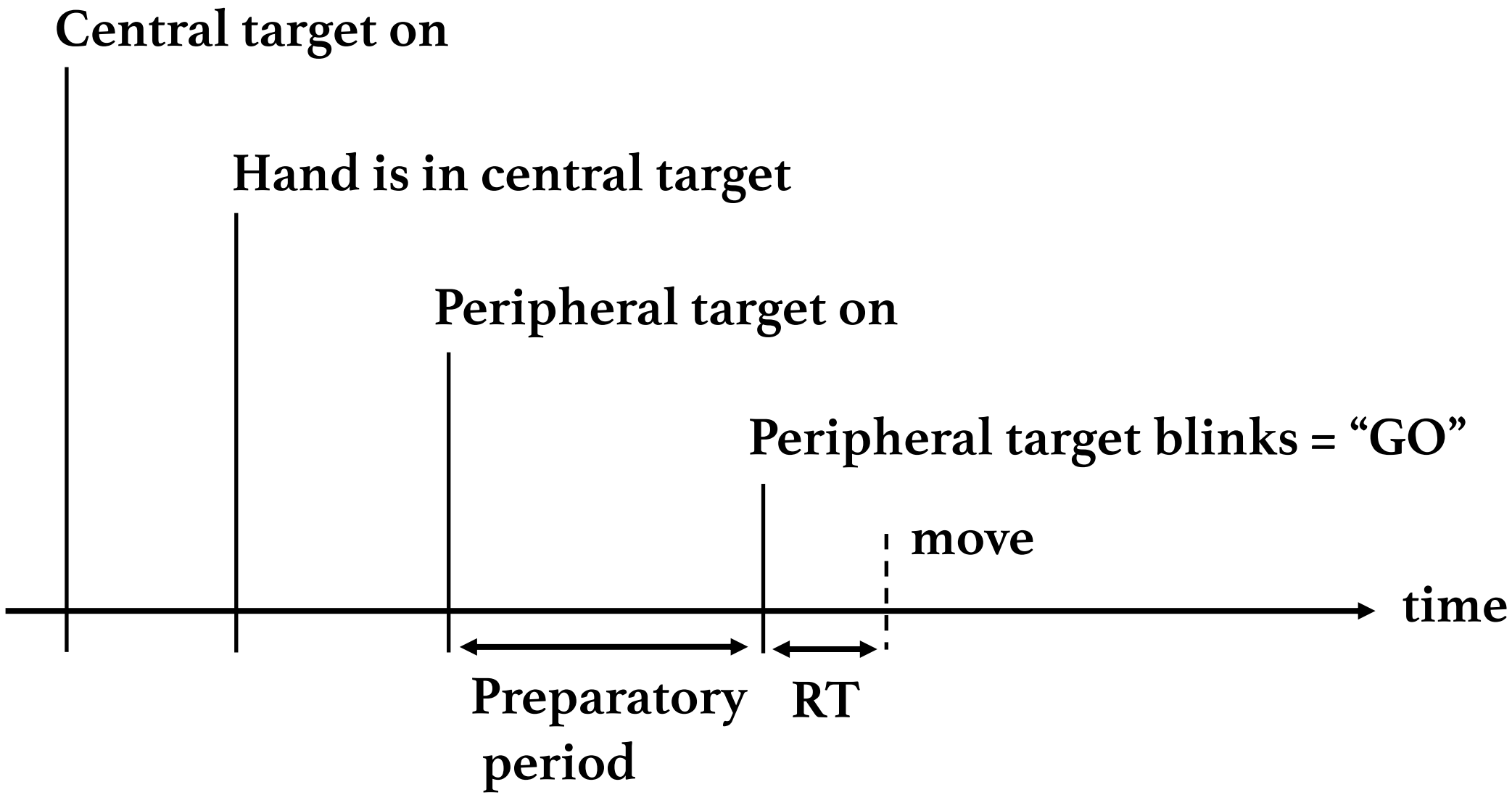

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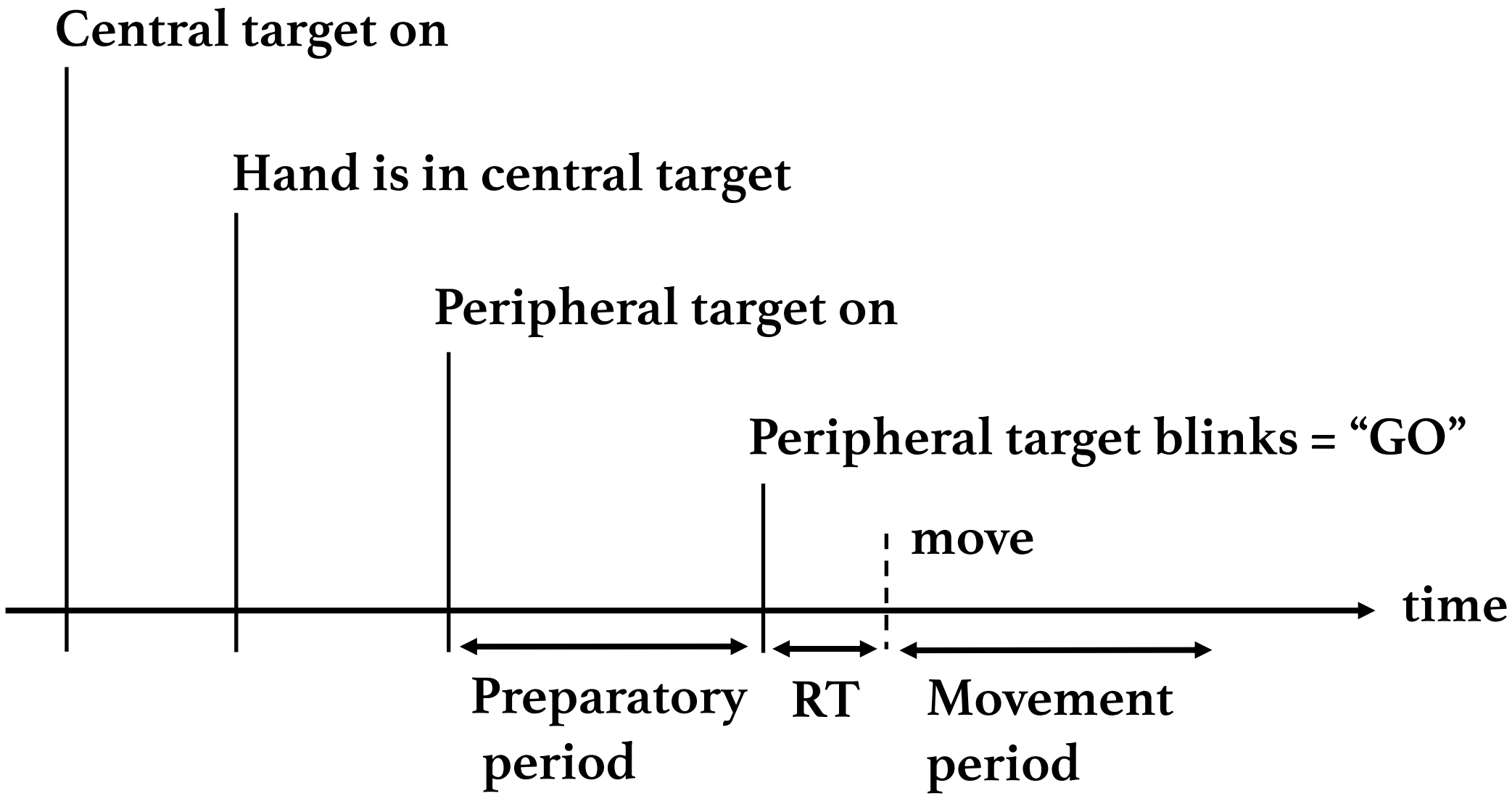

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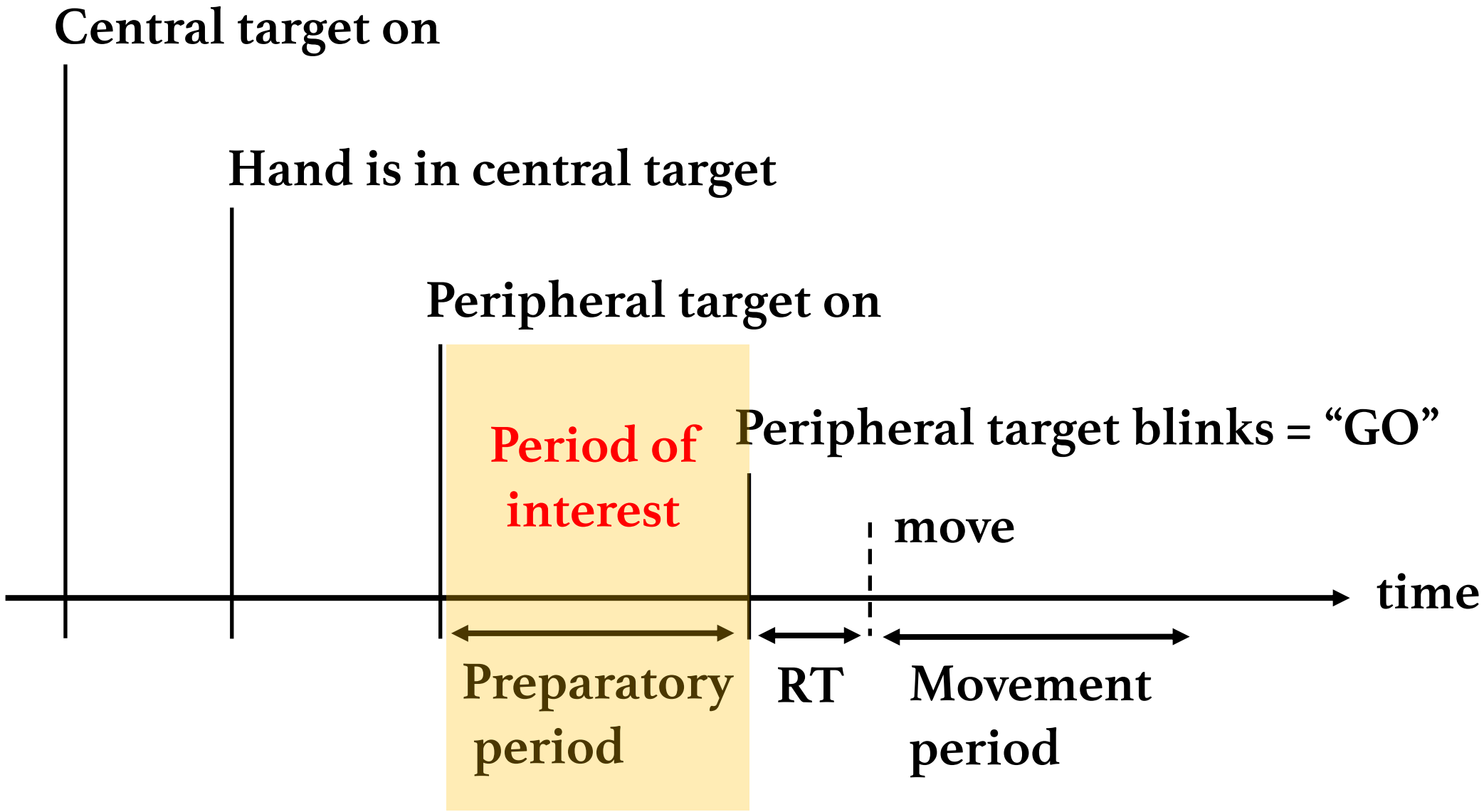

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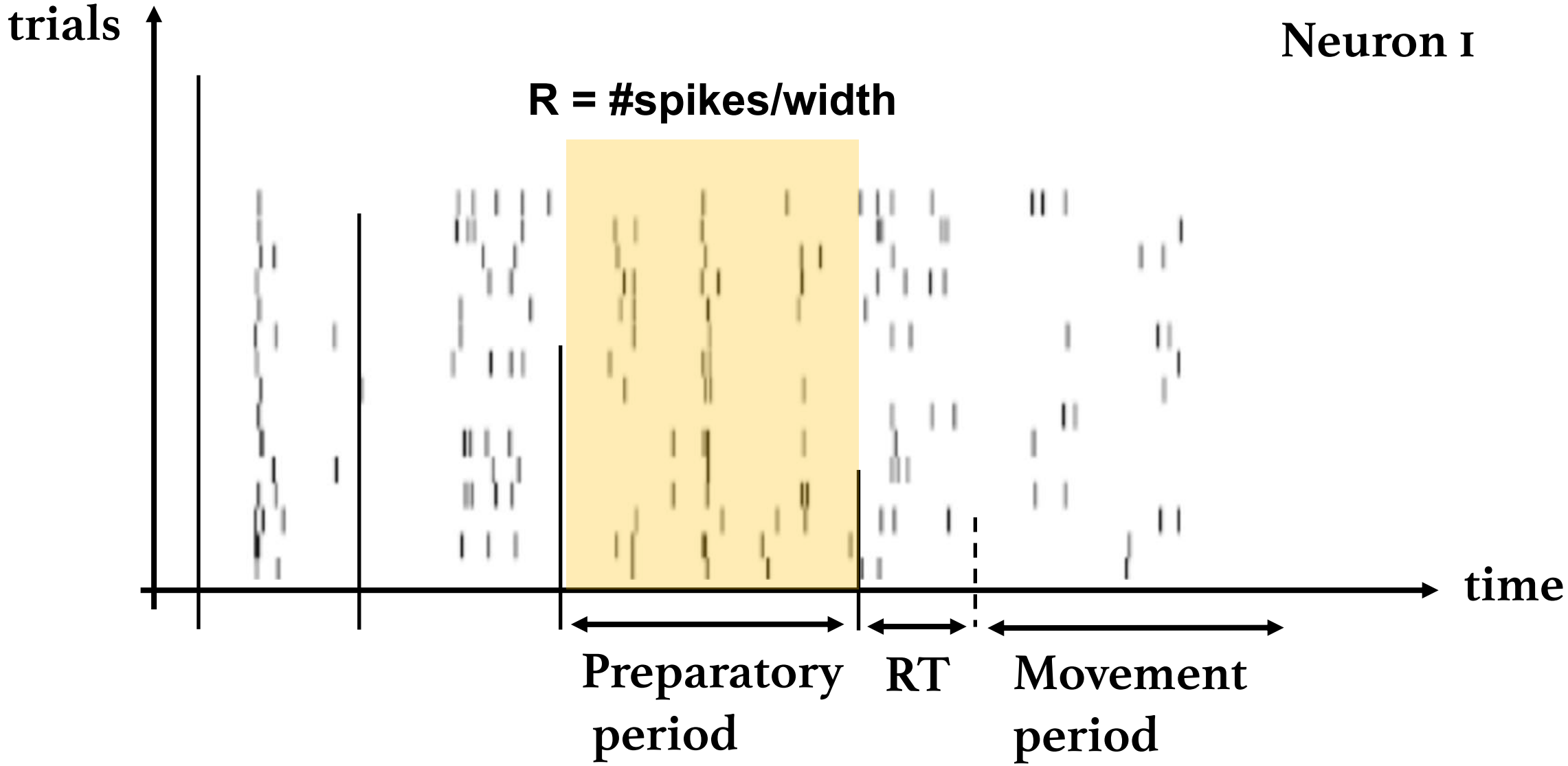

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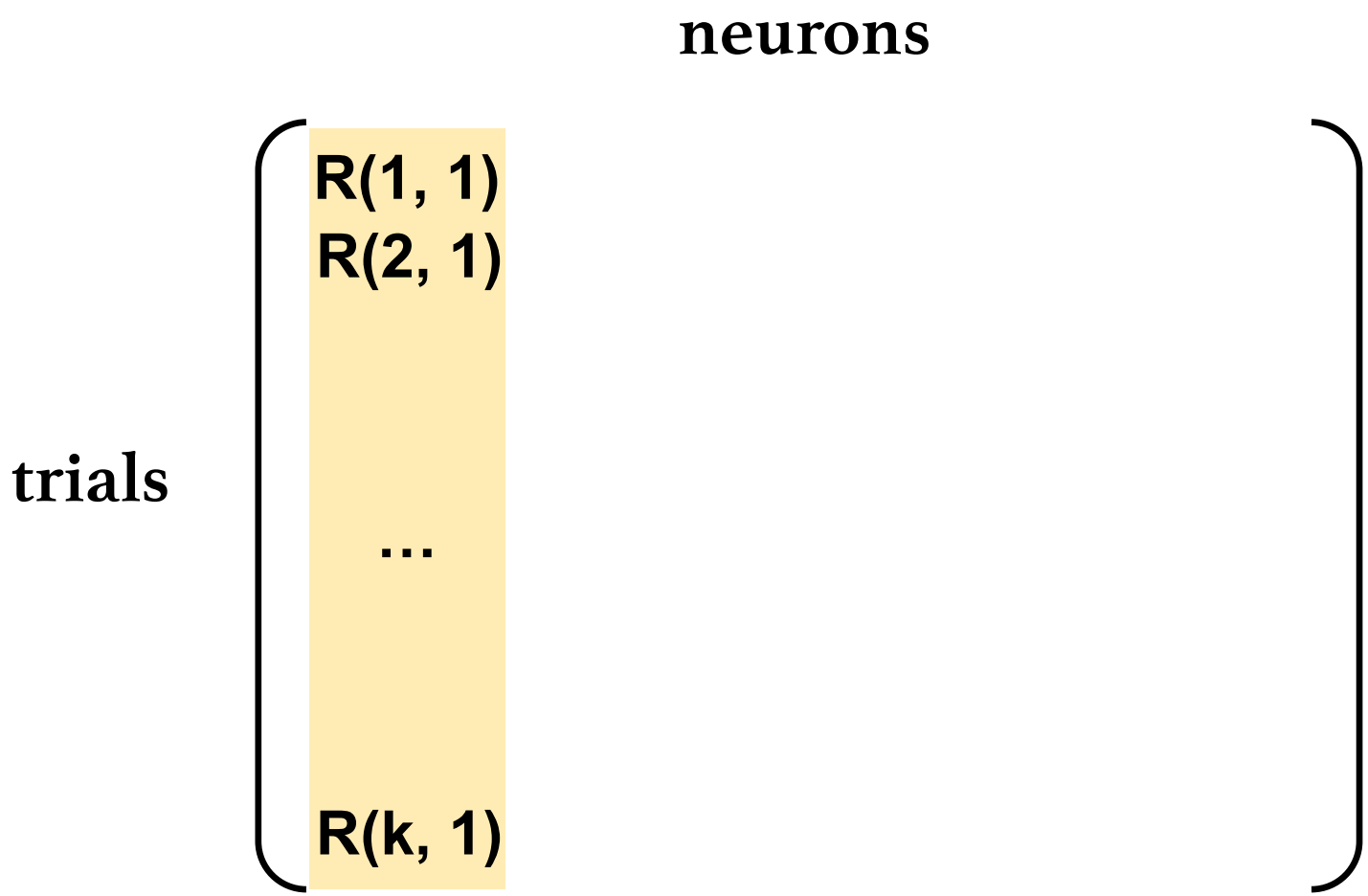

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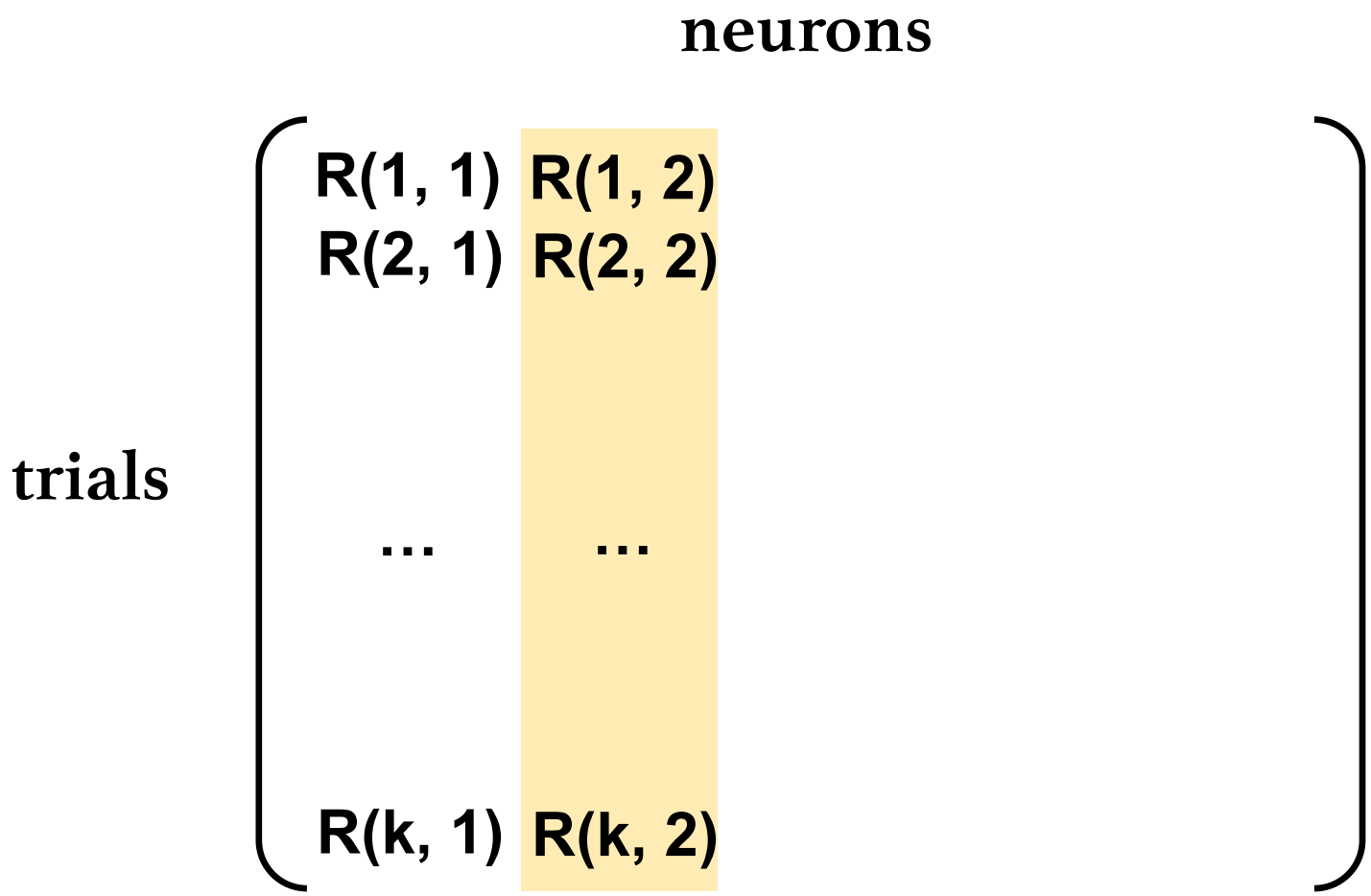

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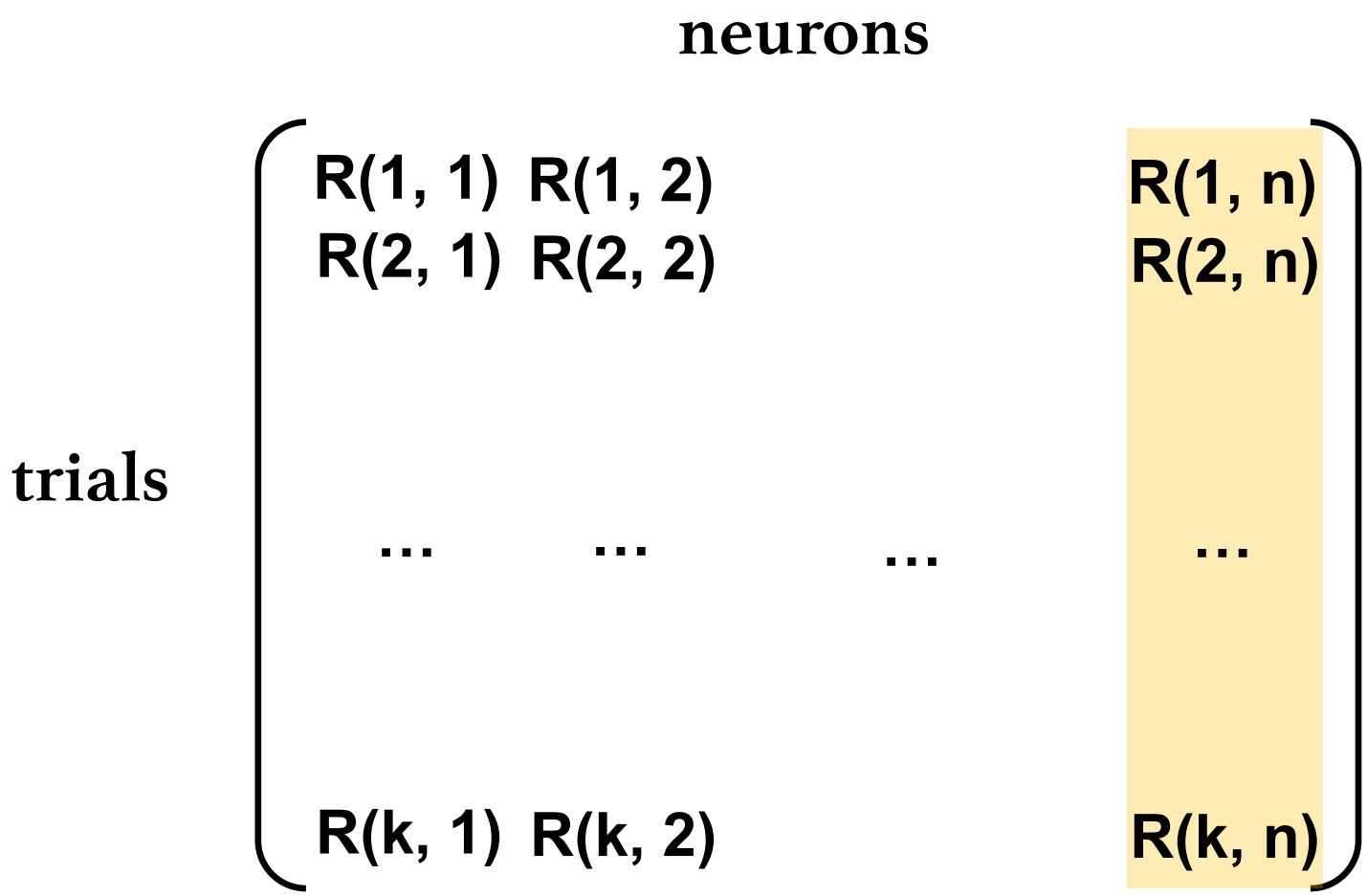


Dataset #1: center-out task

neurons

trials

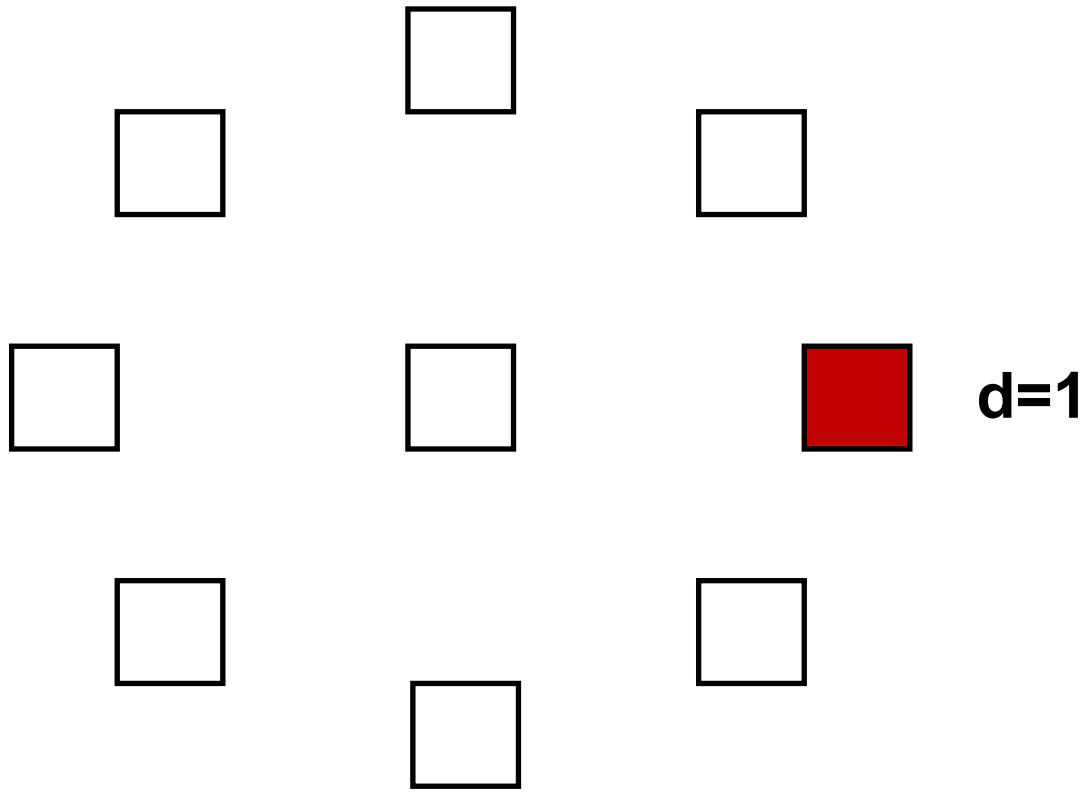
$$\begin{pmatrix} R(1,1) & R(1,2) & \cdots & R(1,n) \\ R(2,1) & R(2,2) & \cdots & R(2,n) \\ \vdots & \vdots & \vdots & \vdots \\ R(k,1) & R(k,2) & \cdots & R(k,n) \end{pmatrix}$$

k = 158 trials

n = 143 neurons

Dataset #1: center-out task

$$\text{Direction} = \begin{pmatrix} d(1) \\ d(2) \\ \\ \cdots \\ \\ \\ d(k) \end{pmatrix}_{(kx1)}$$



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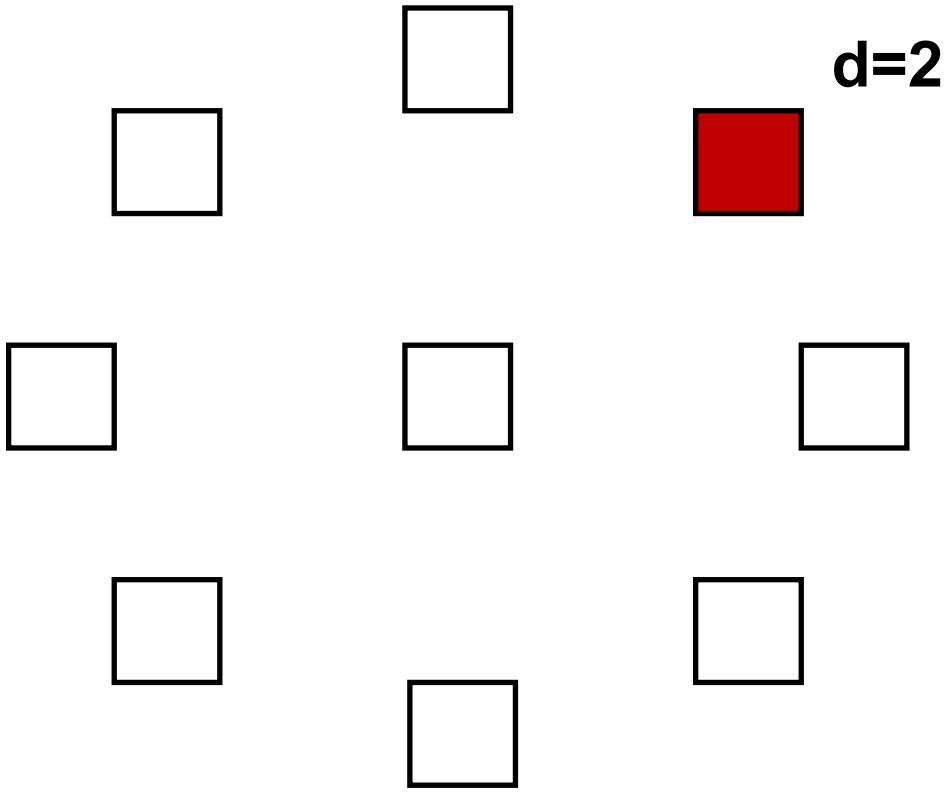

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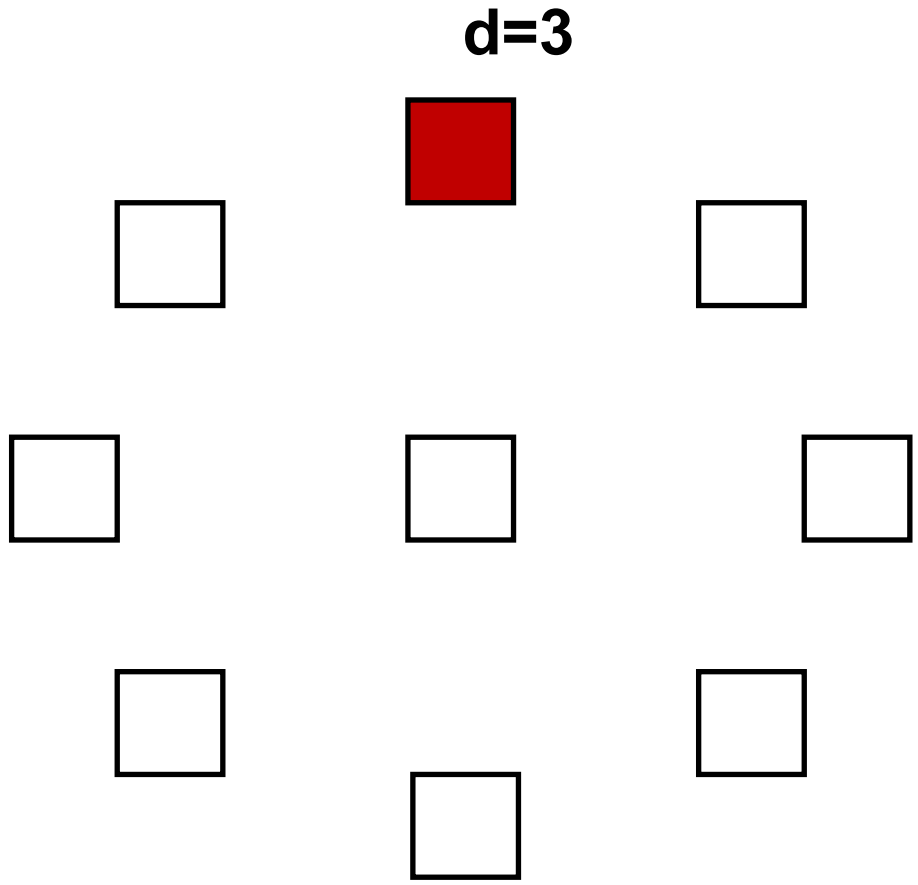

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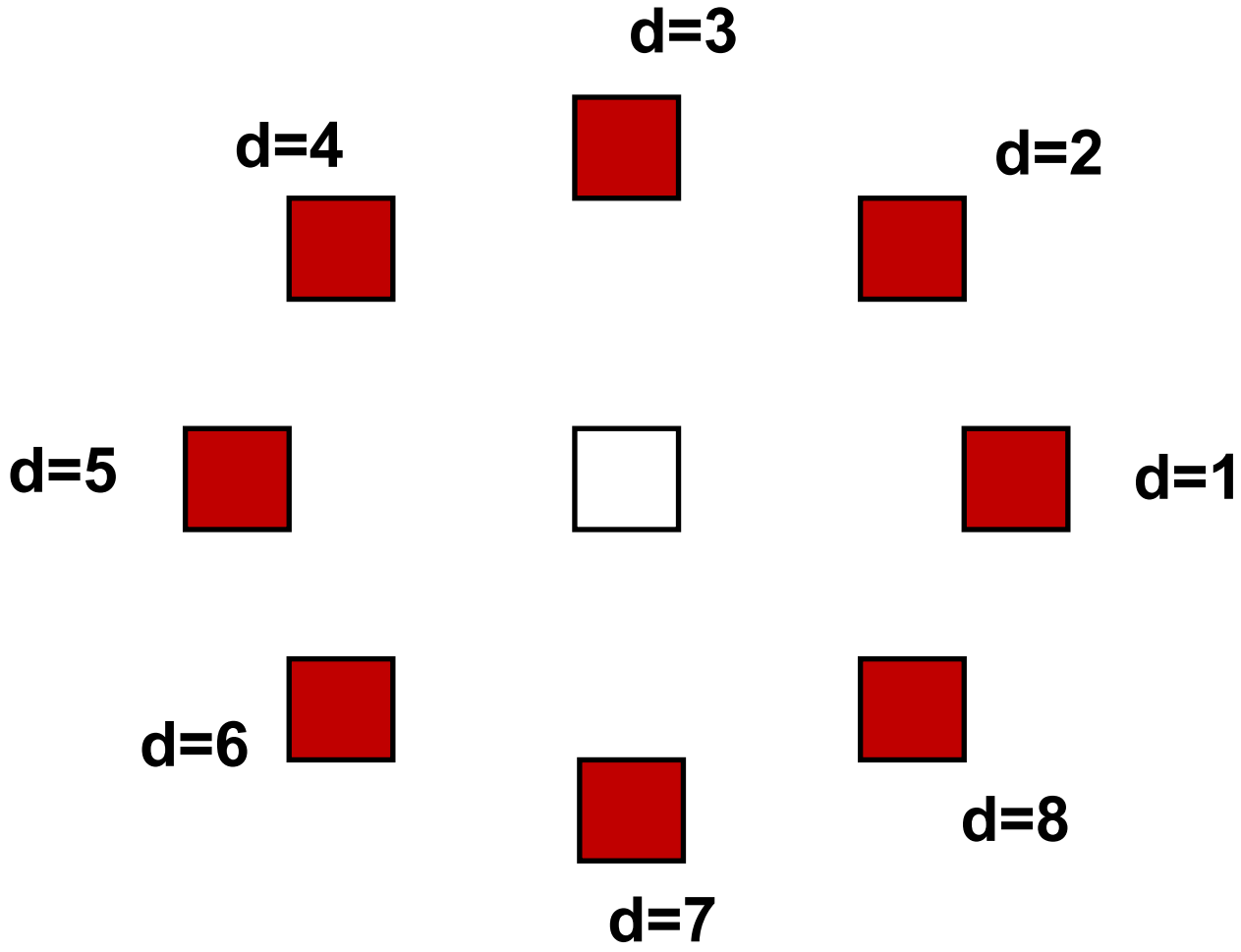
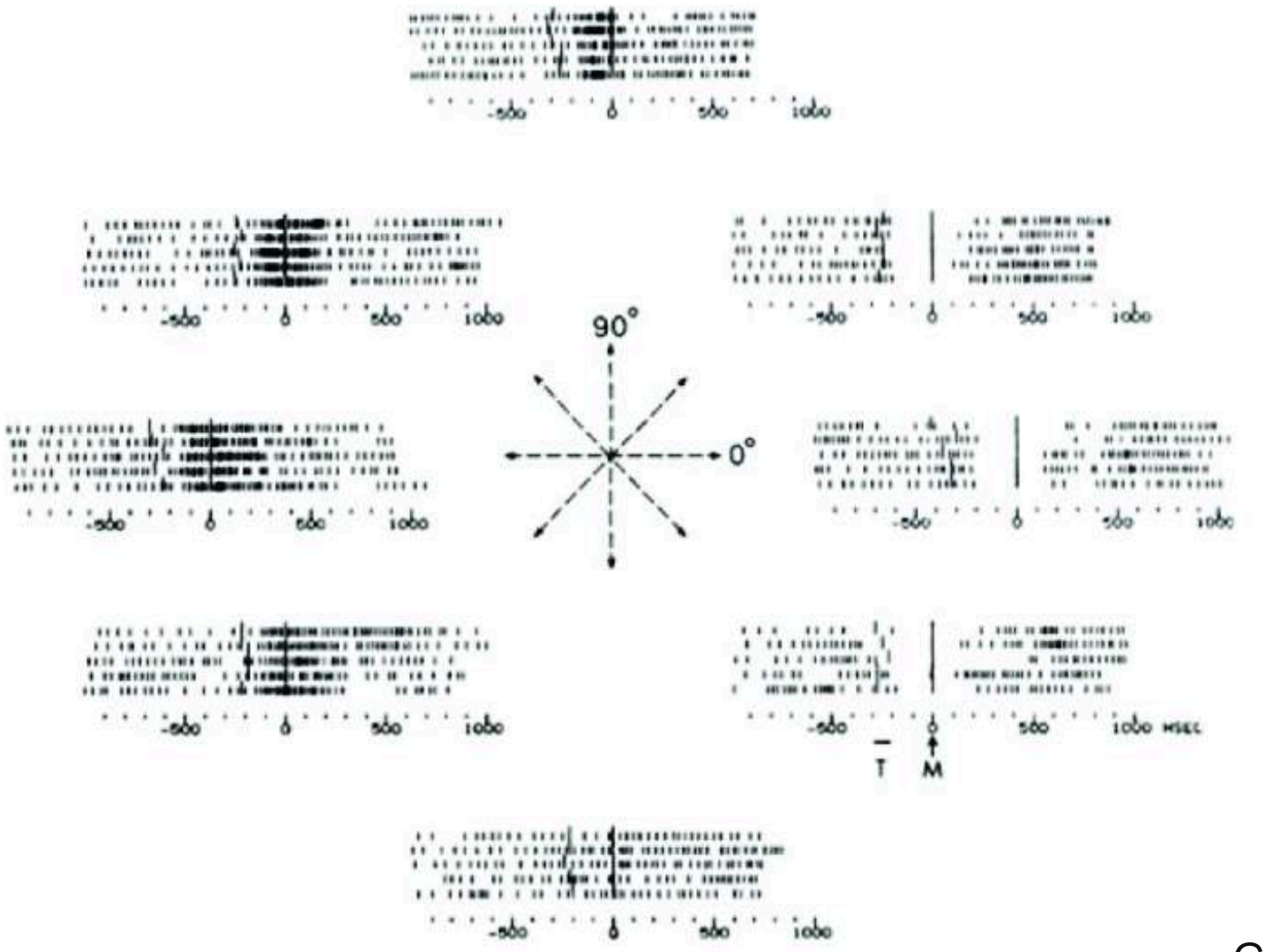
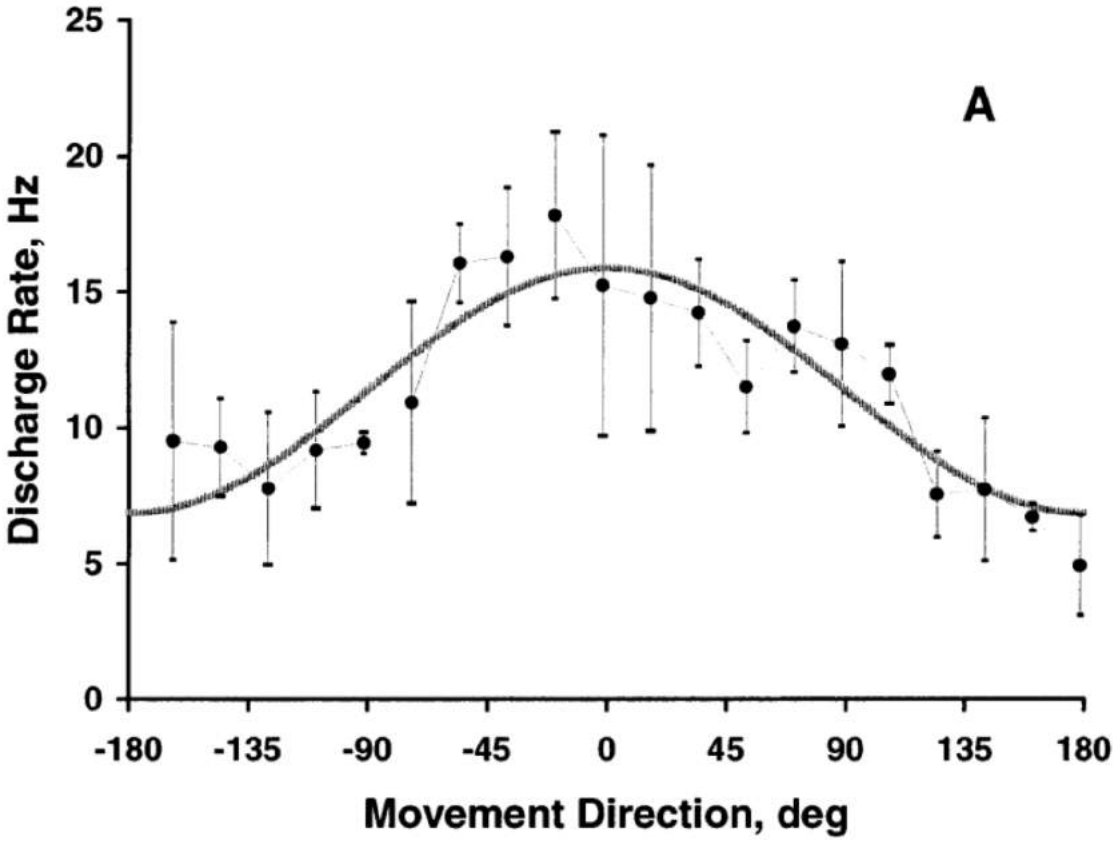


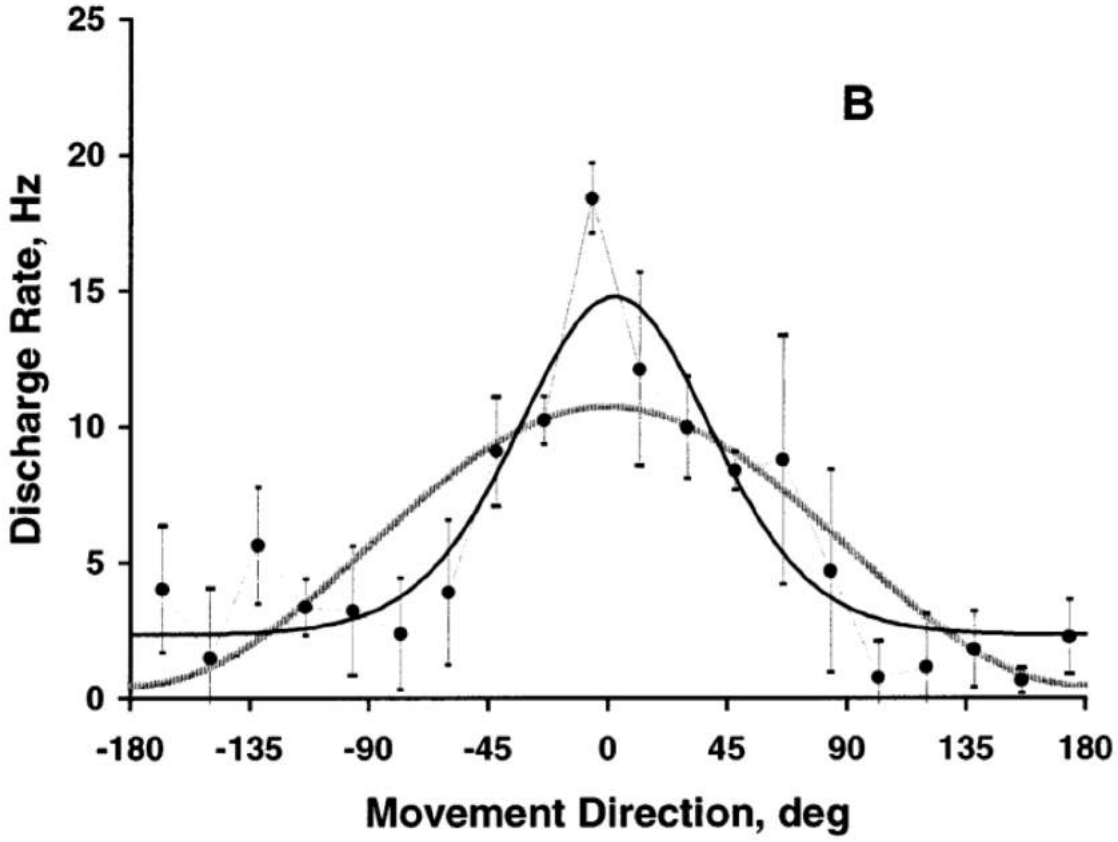
Directional tuning in motor cortex



Georgopoulos et al., 1982

Directional tuning in motor cortex

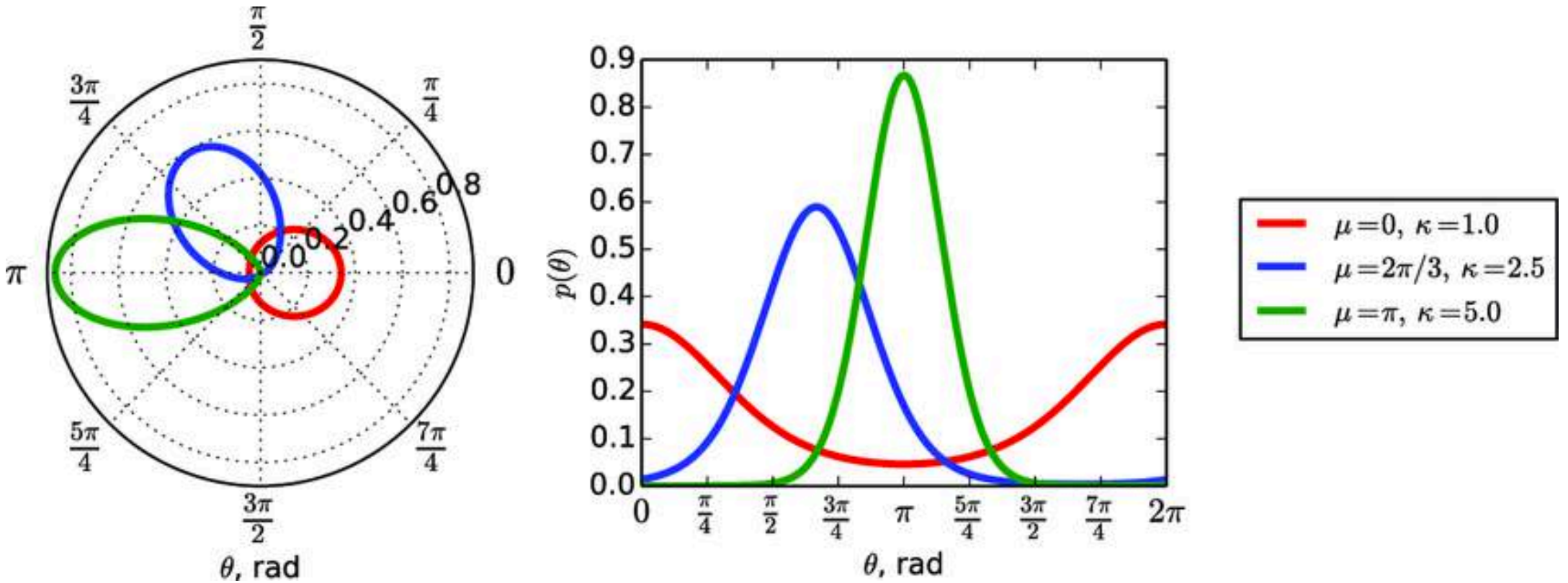




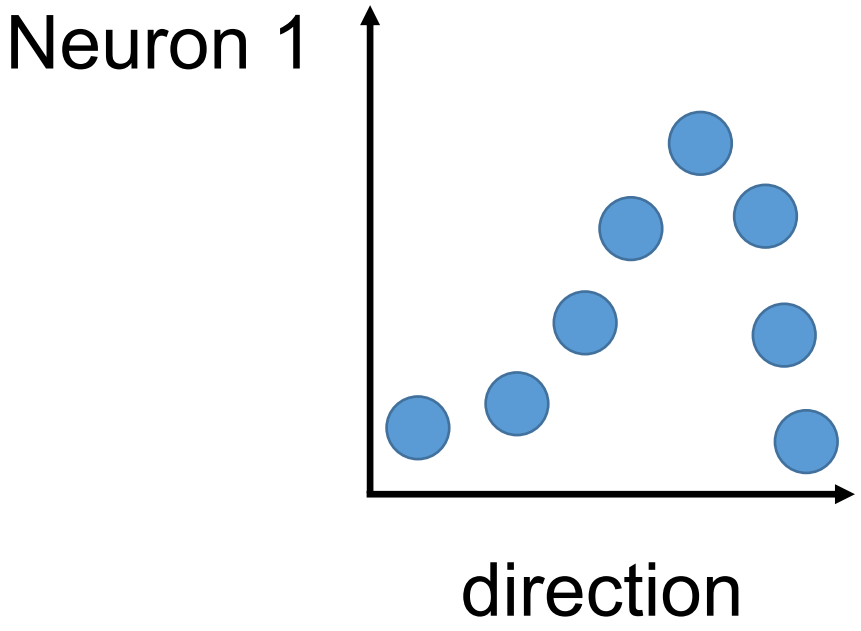
Amirikian & Georgopoulos, 2000

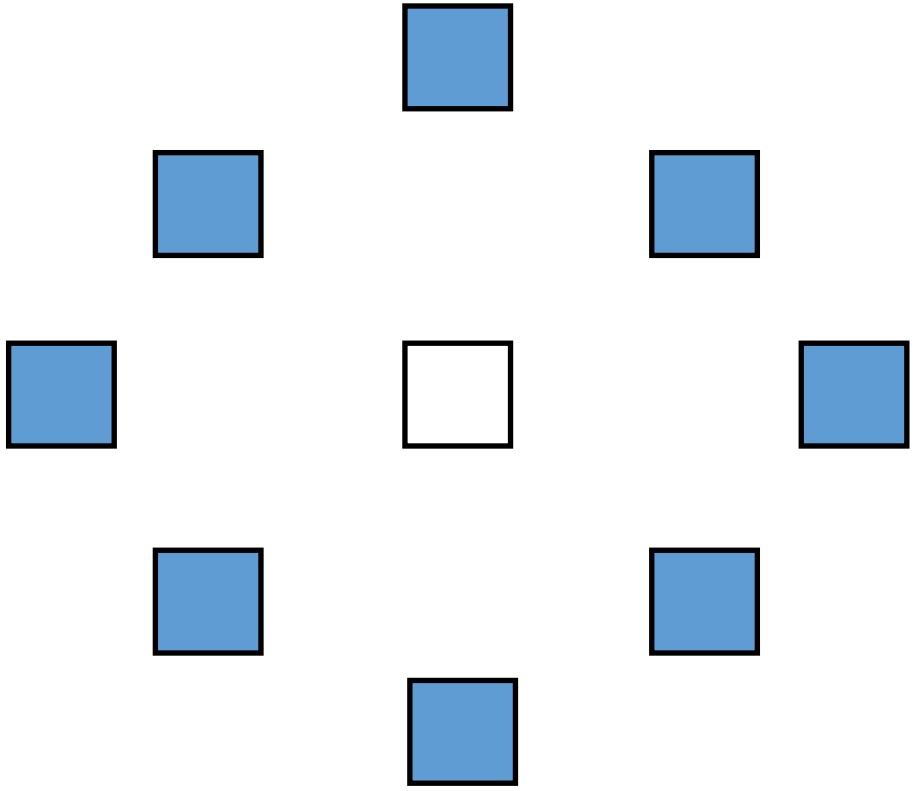
Directional tuning in motor cortex

Von Mises function: $b + k \exp(\kappa \cos(\theta - \mu))$



Principal component analysis





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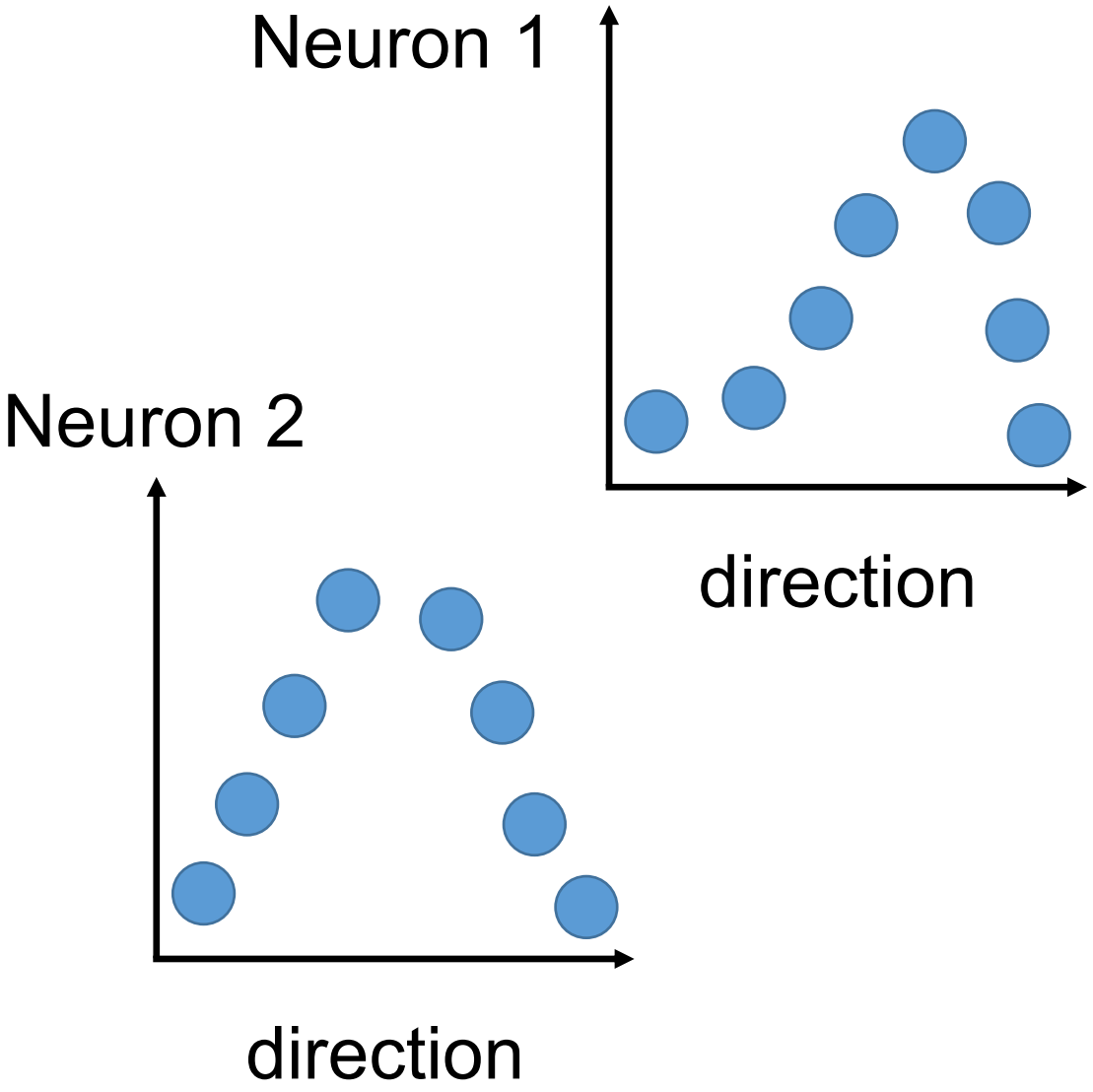

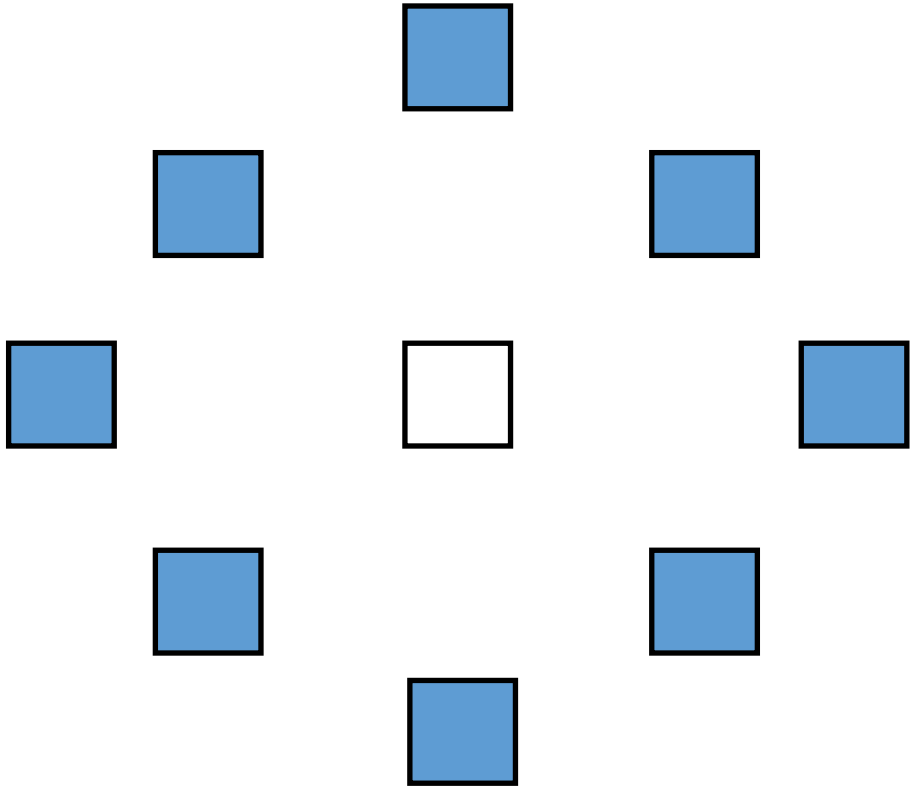

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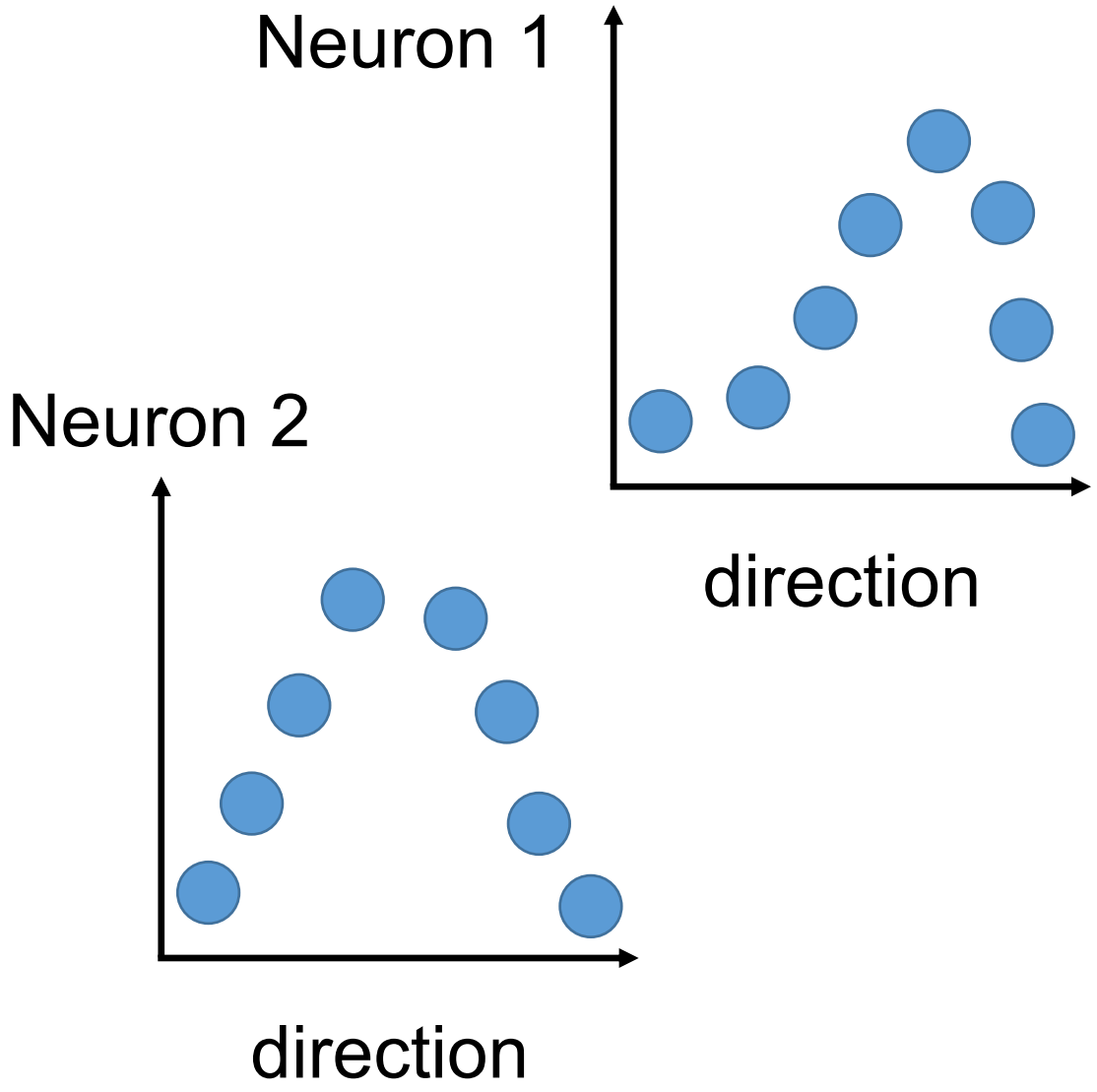

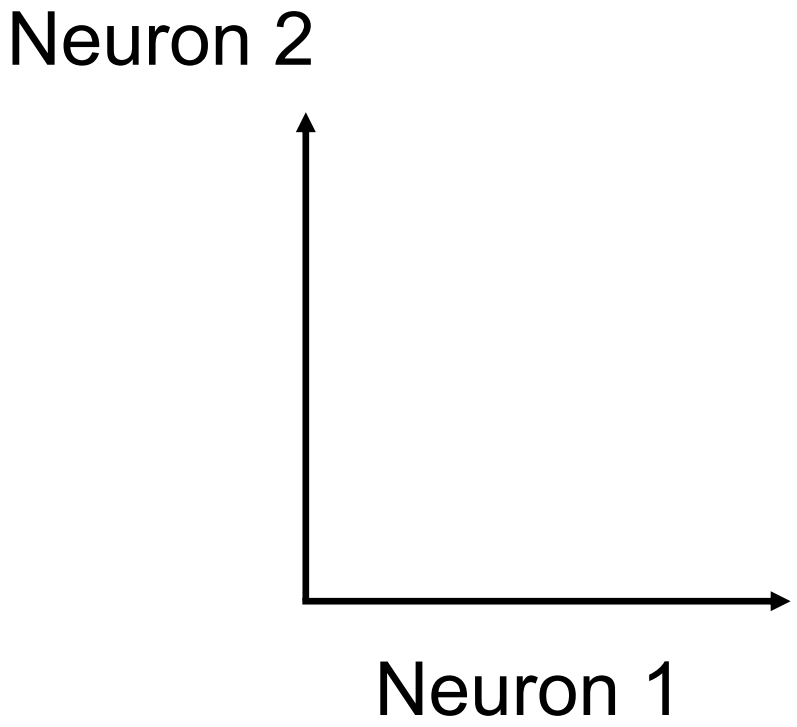

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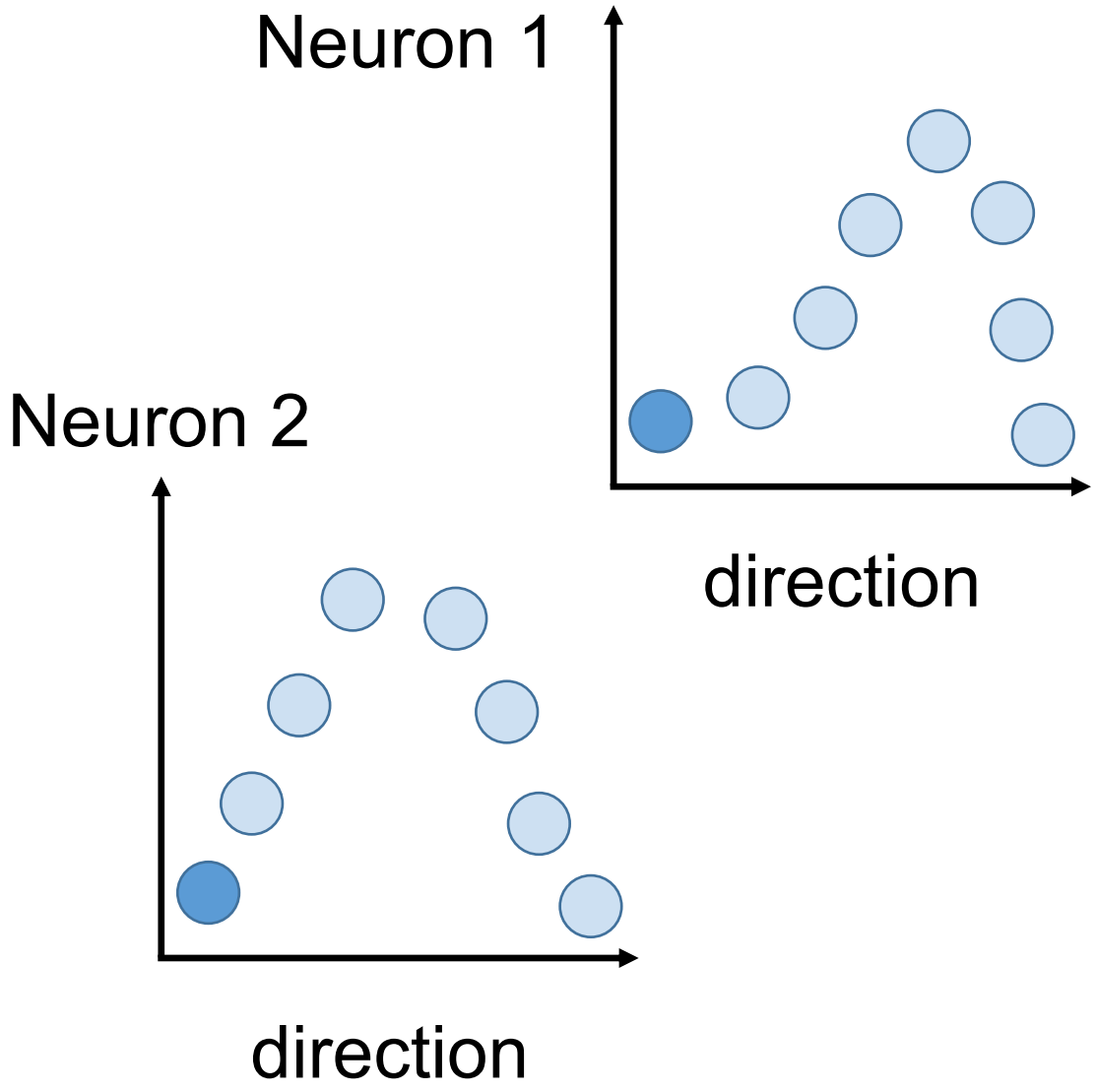
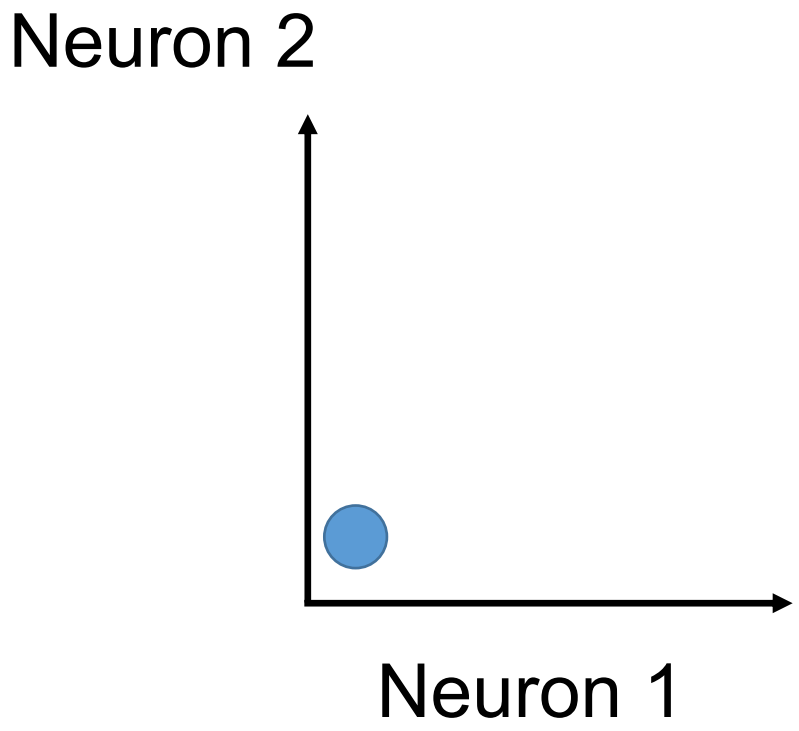
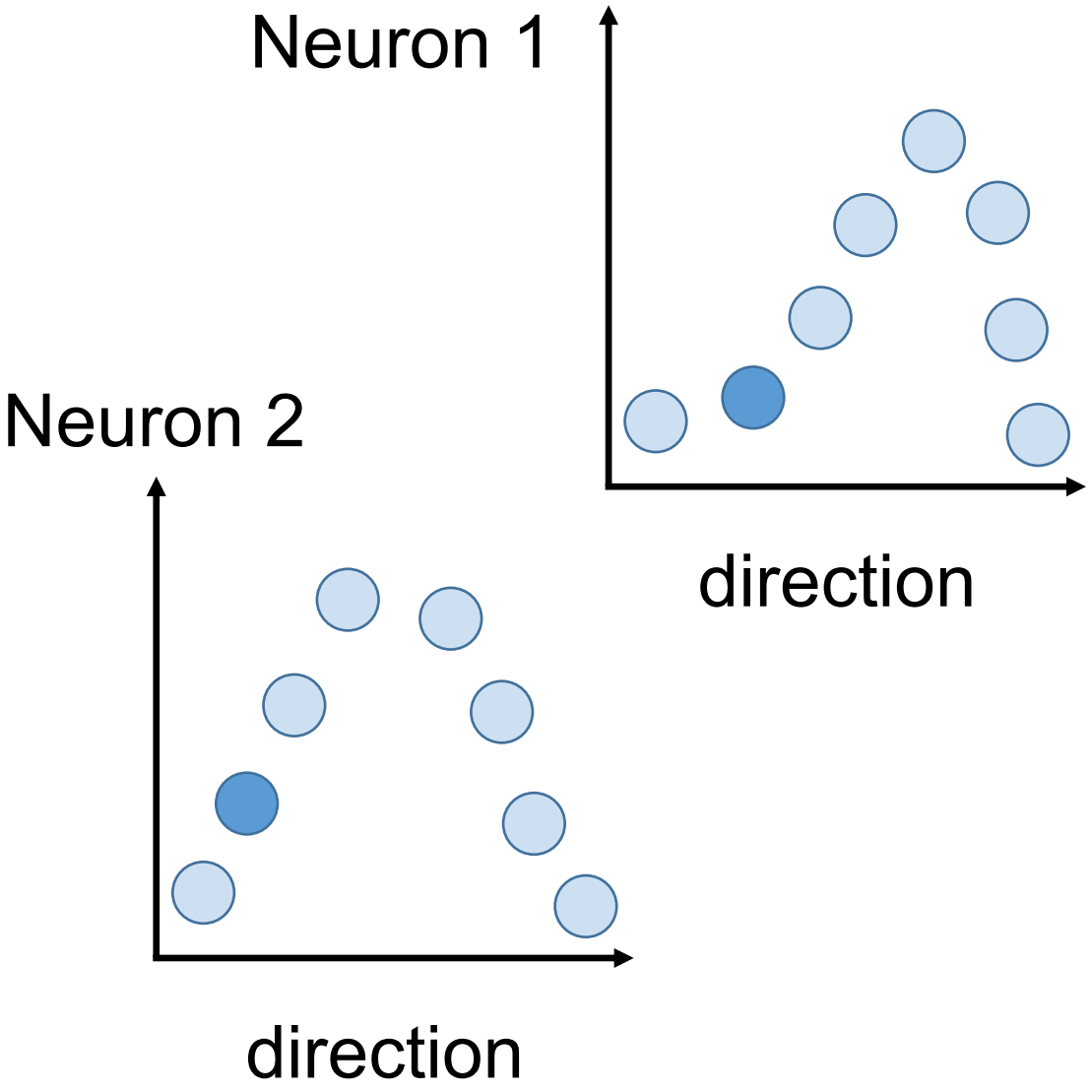
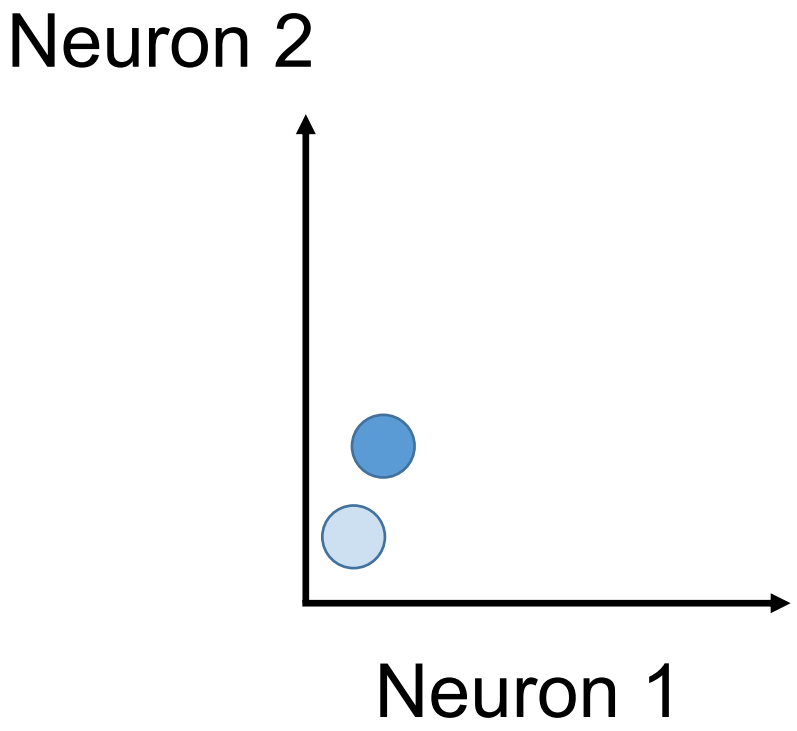


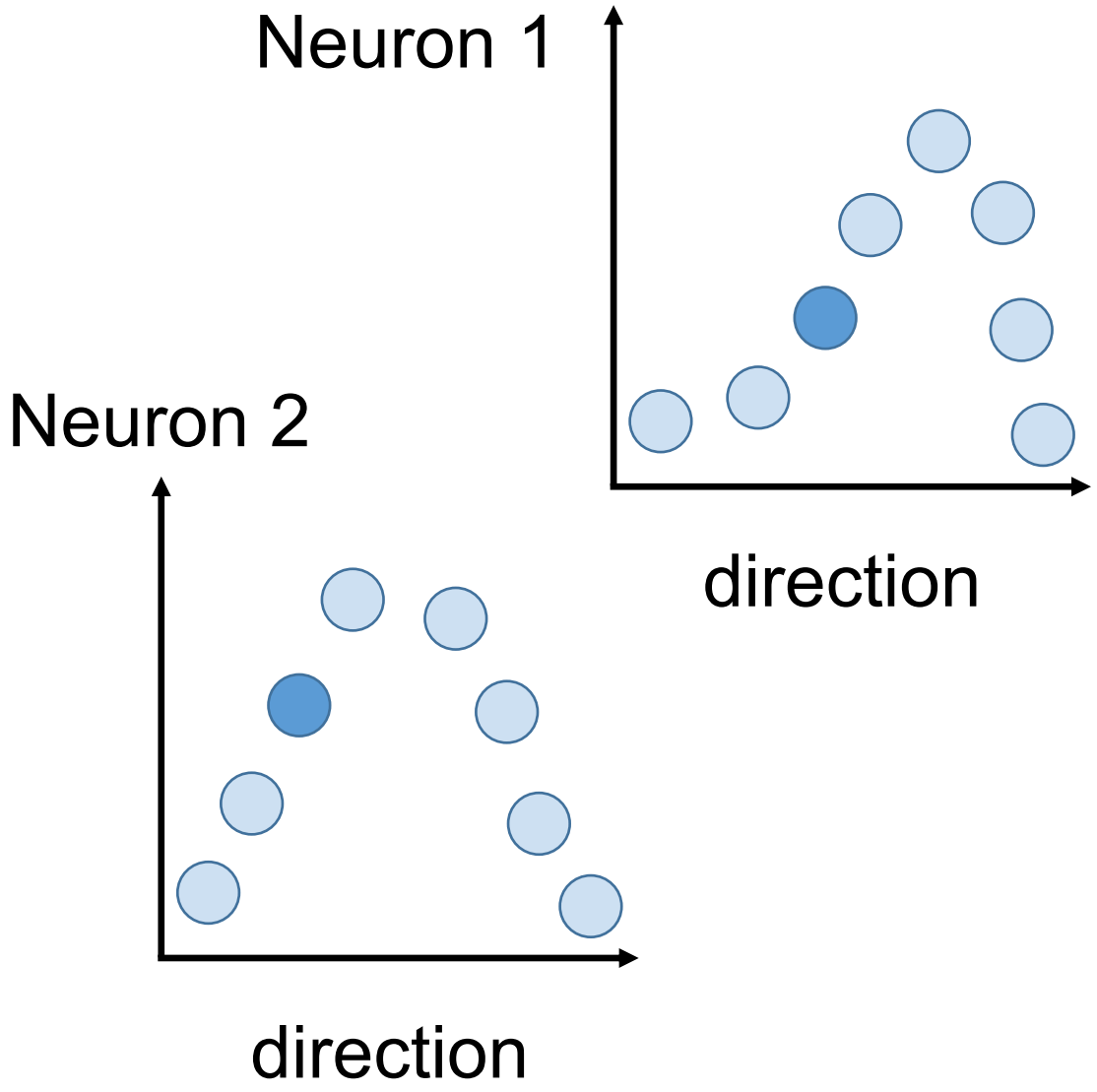


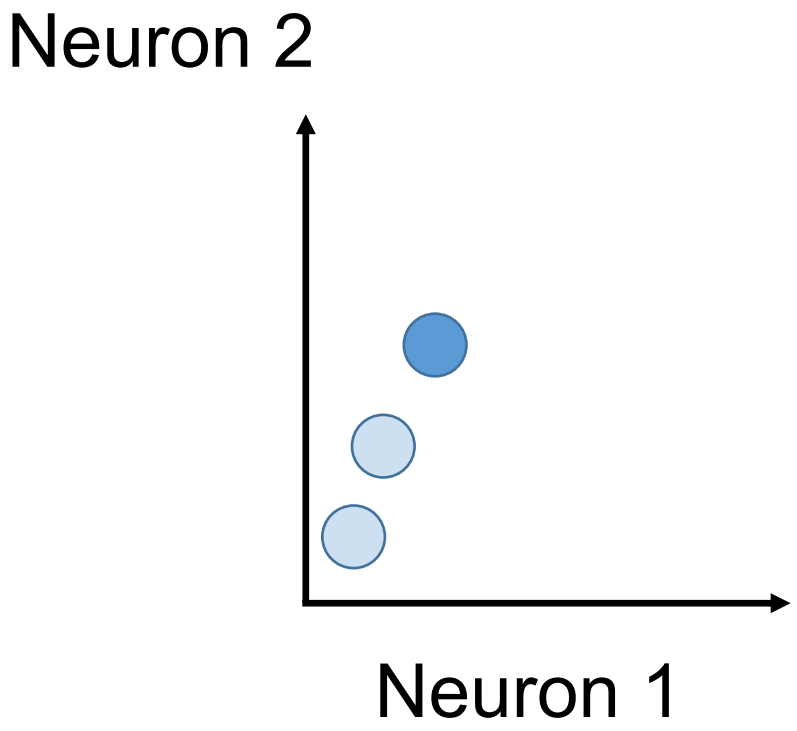
Principal component analysis



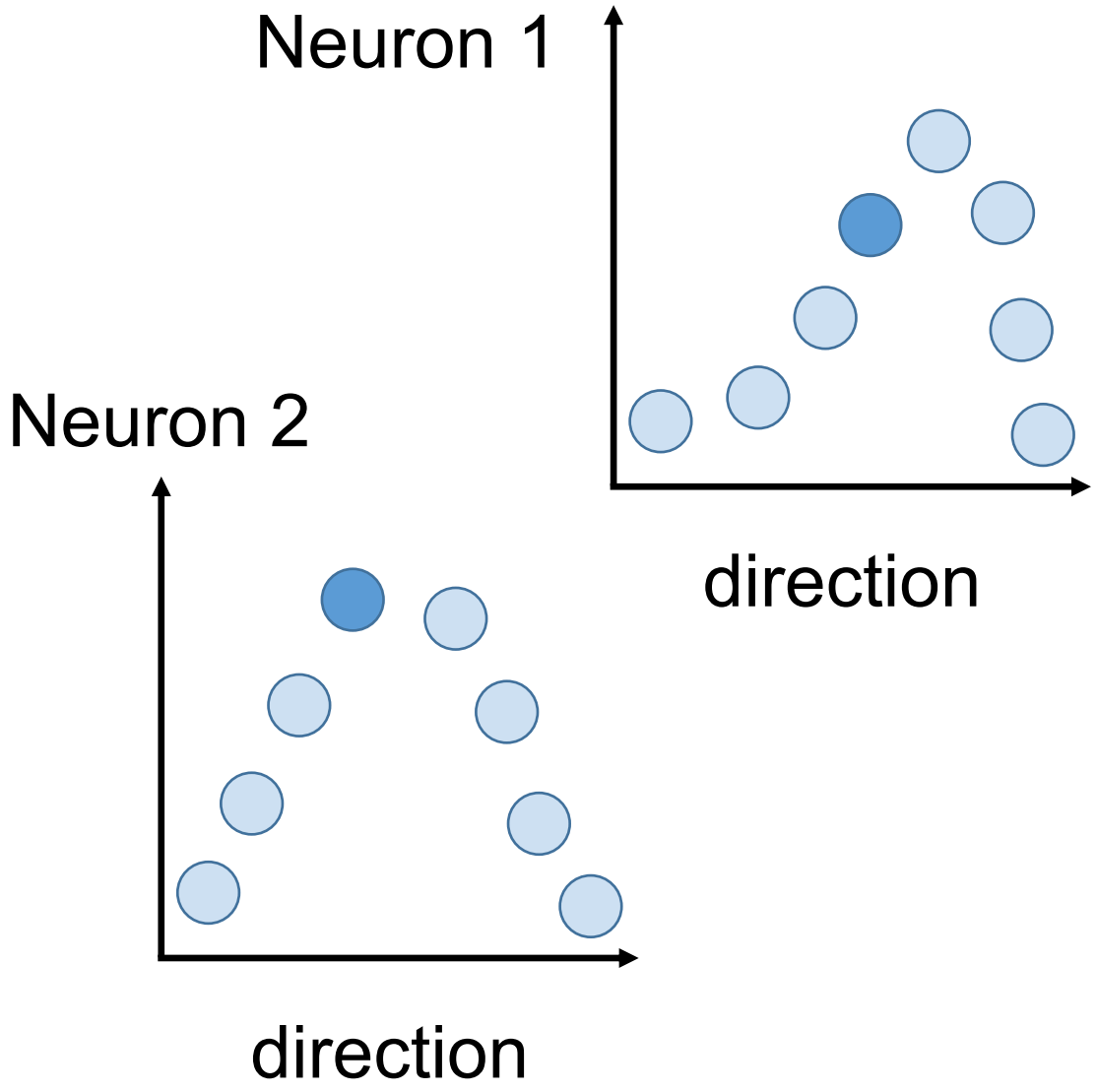


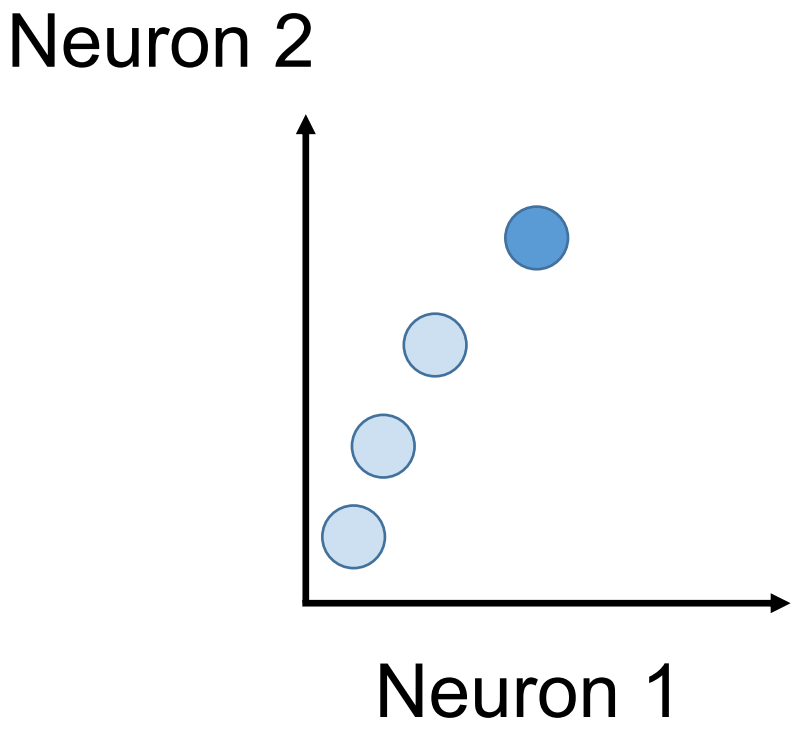
Principal component analysis



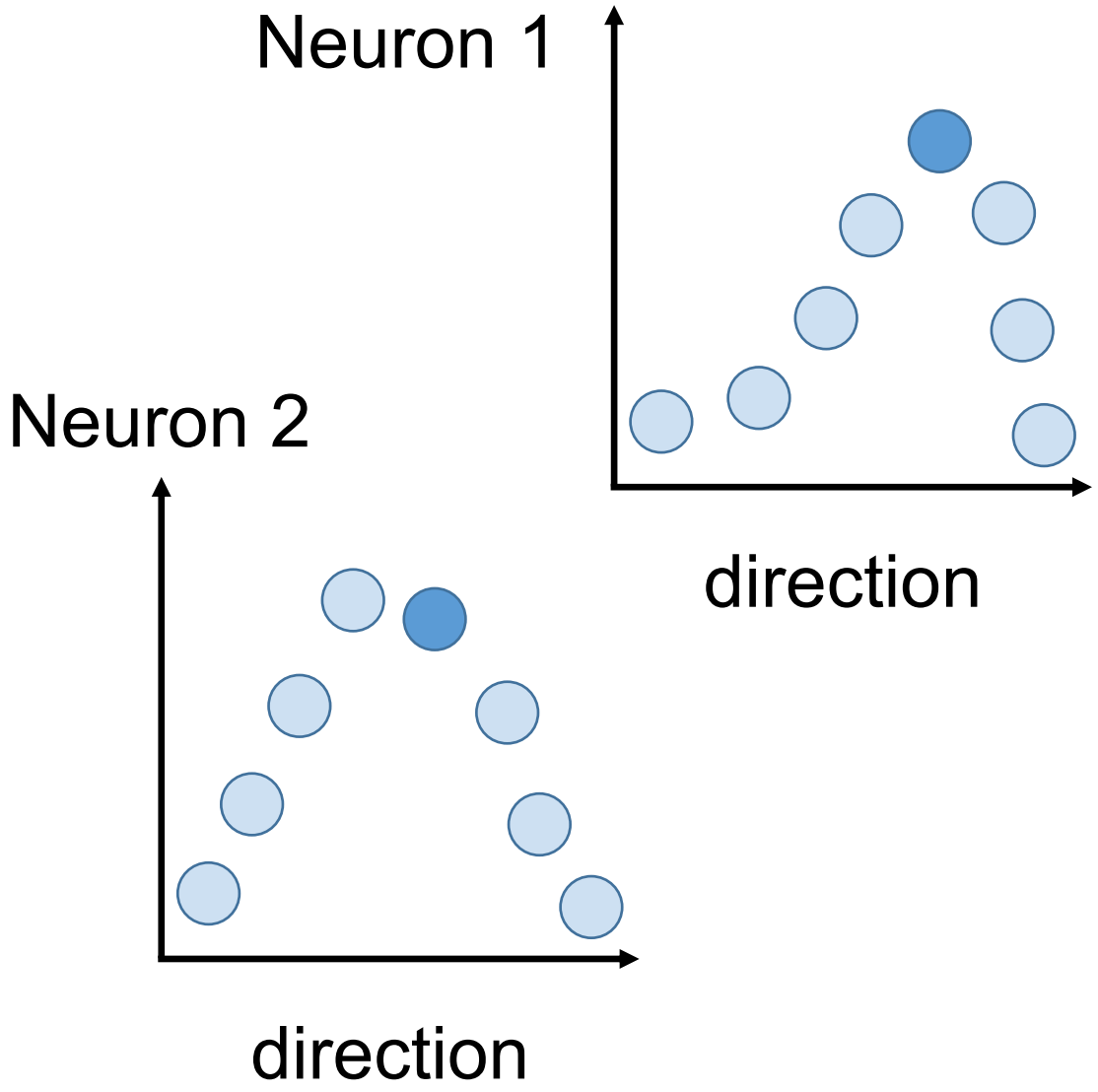


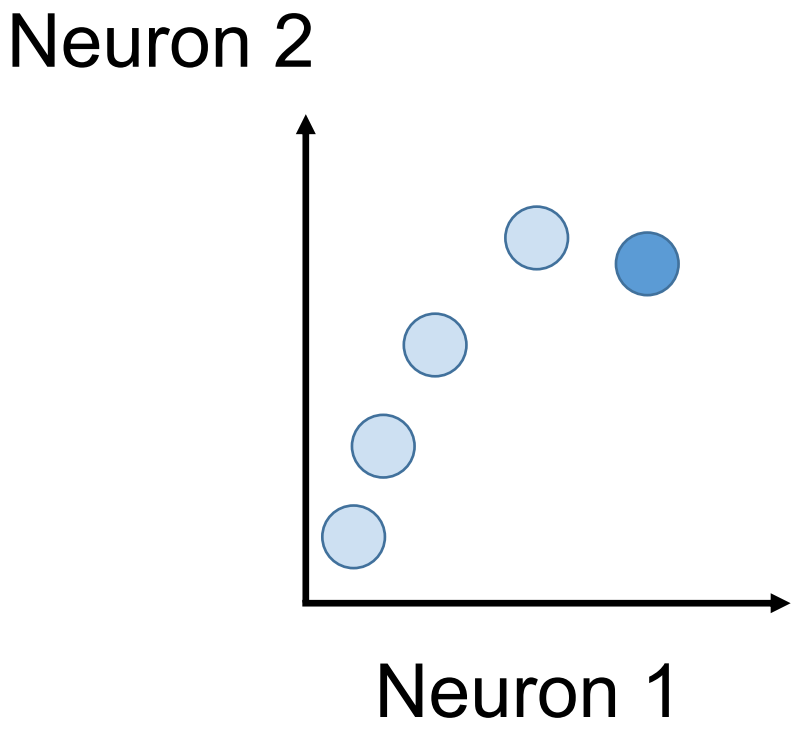
Principal component analysis



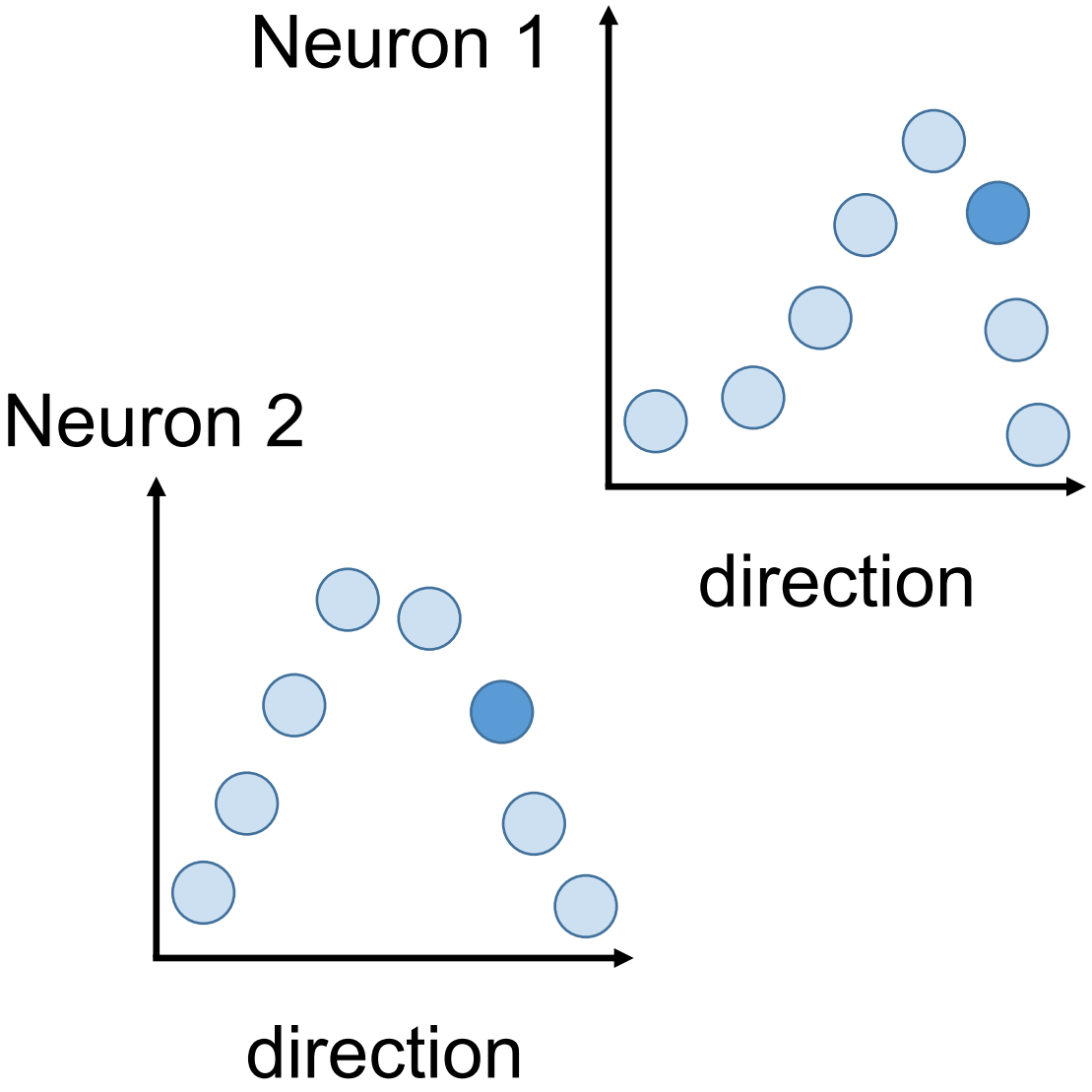


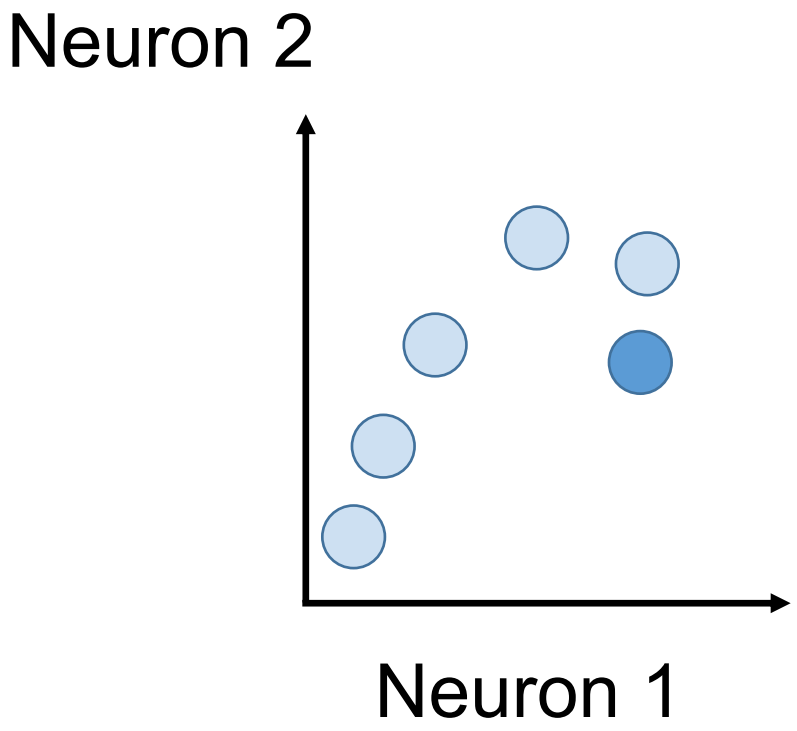
Principal component analysis



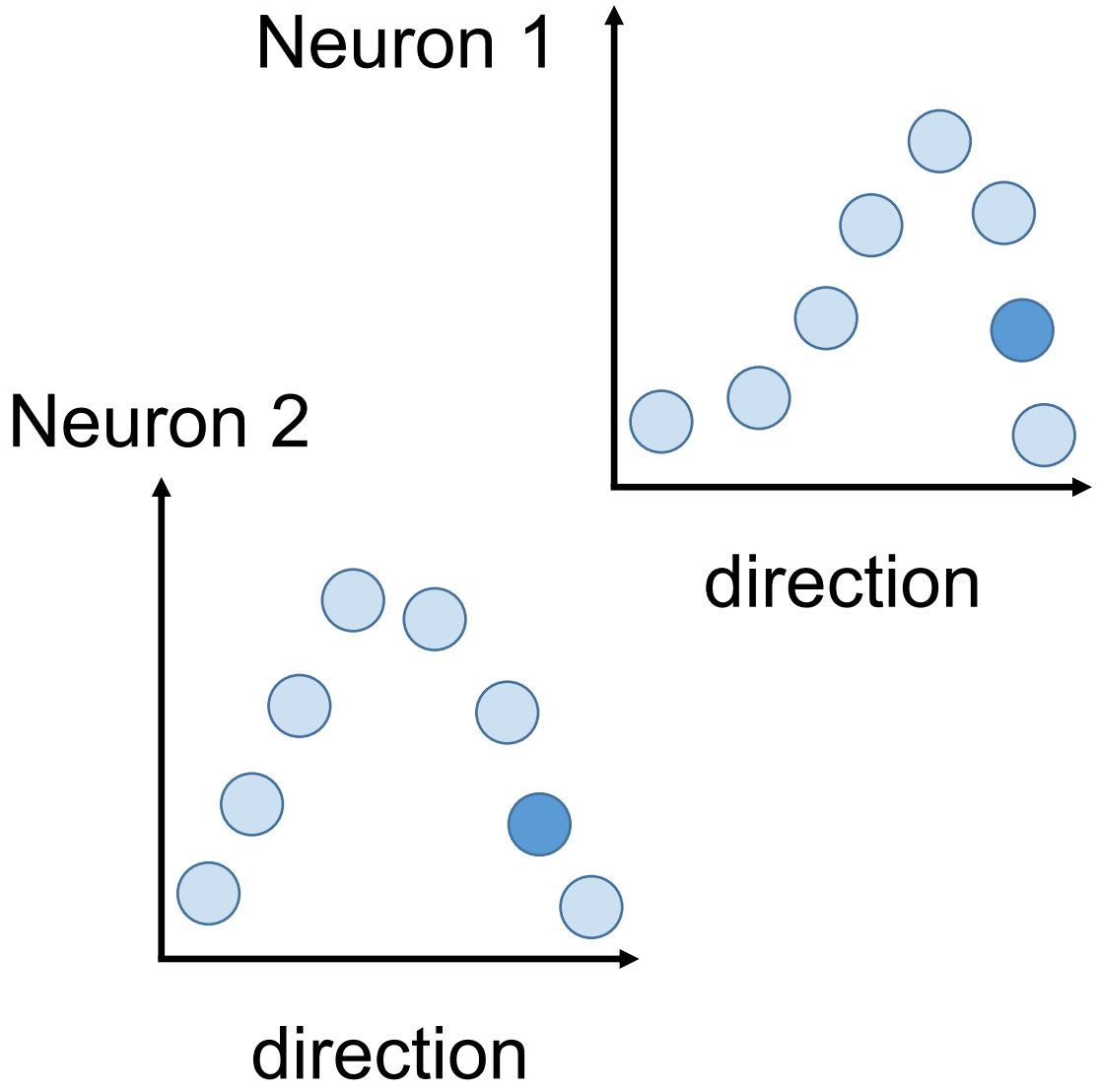


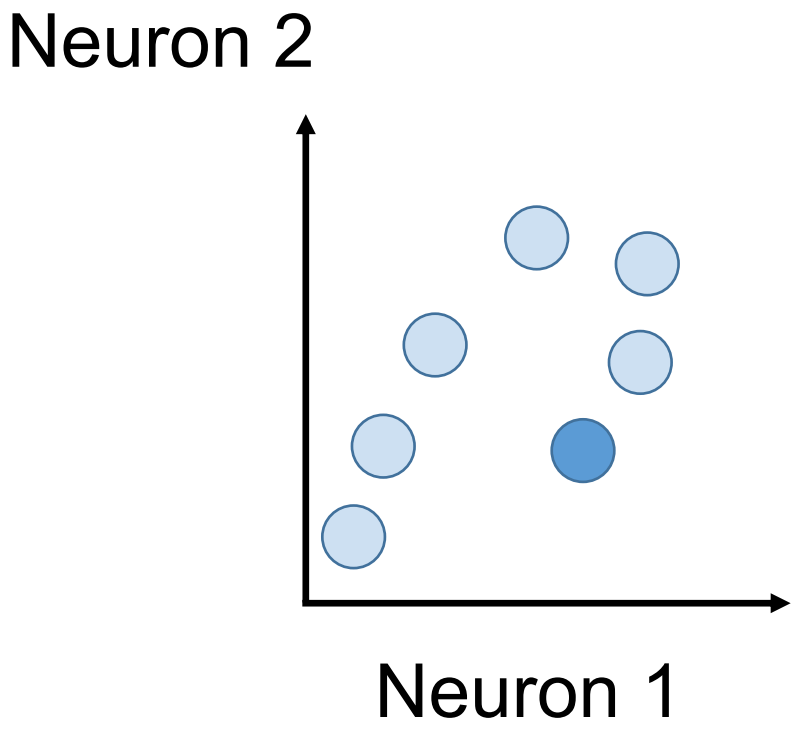
Principal component analysis



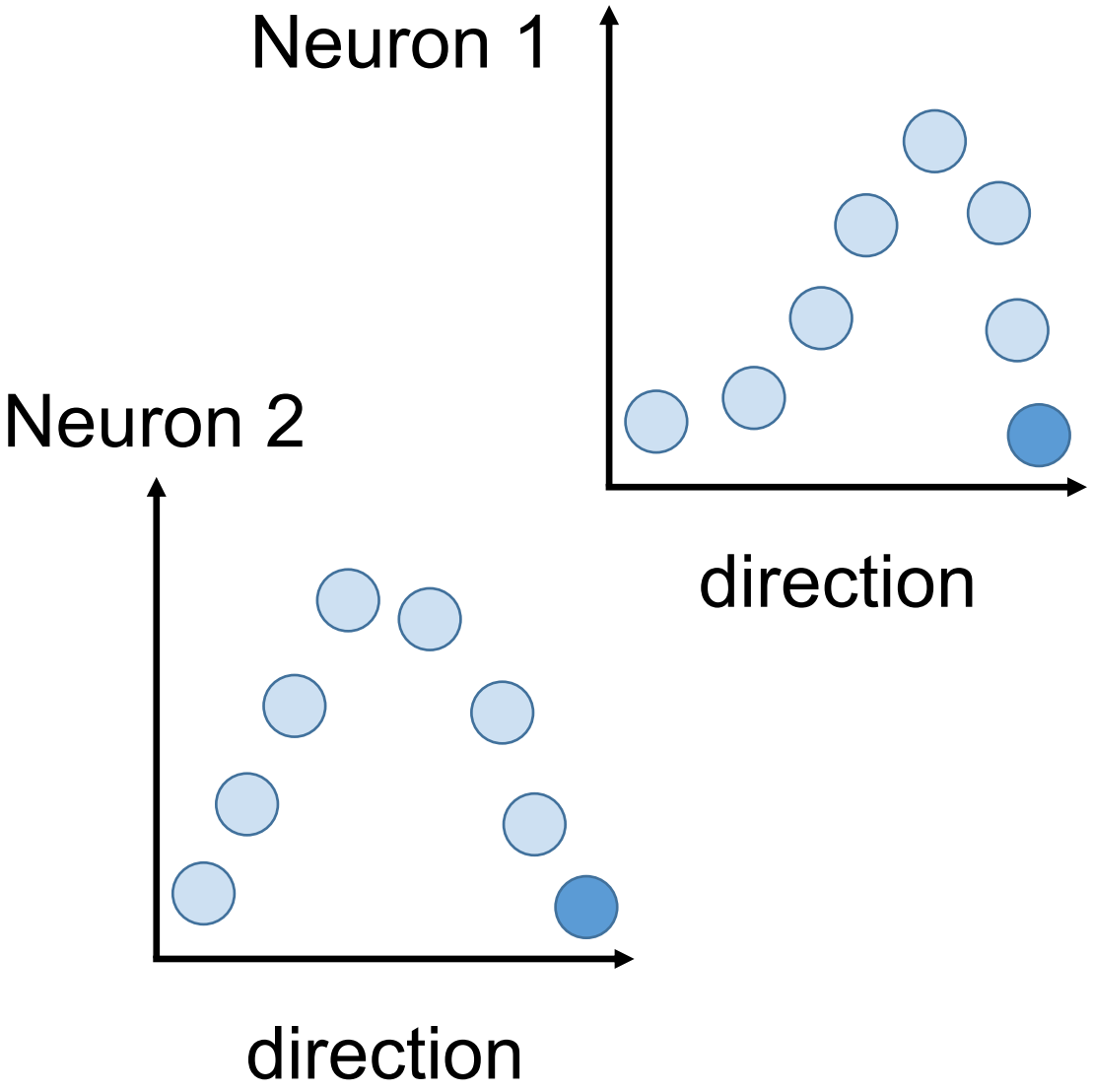


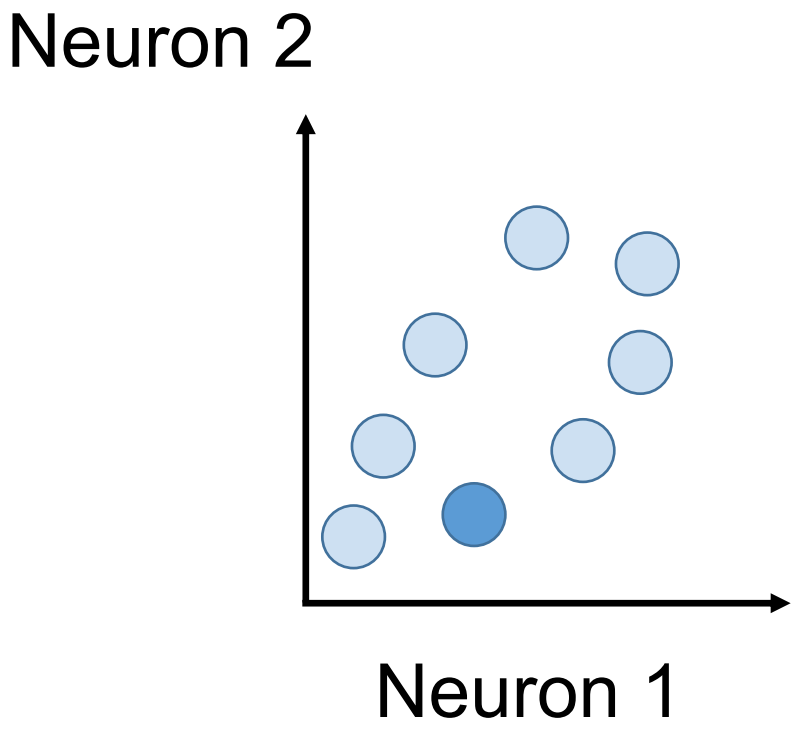
Principal component analysis



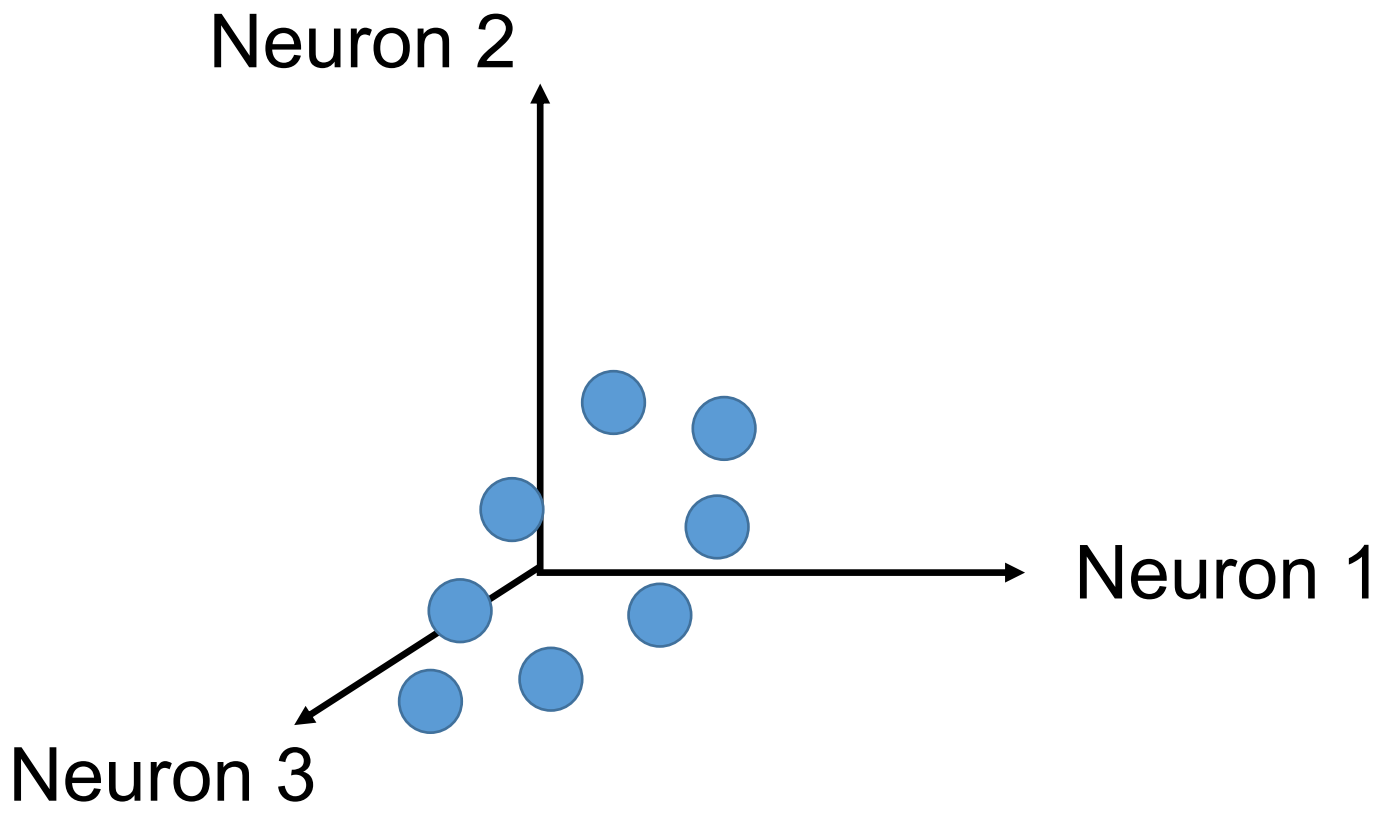


Principal component analysis

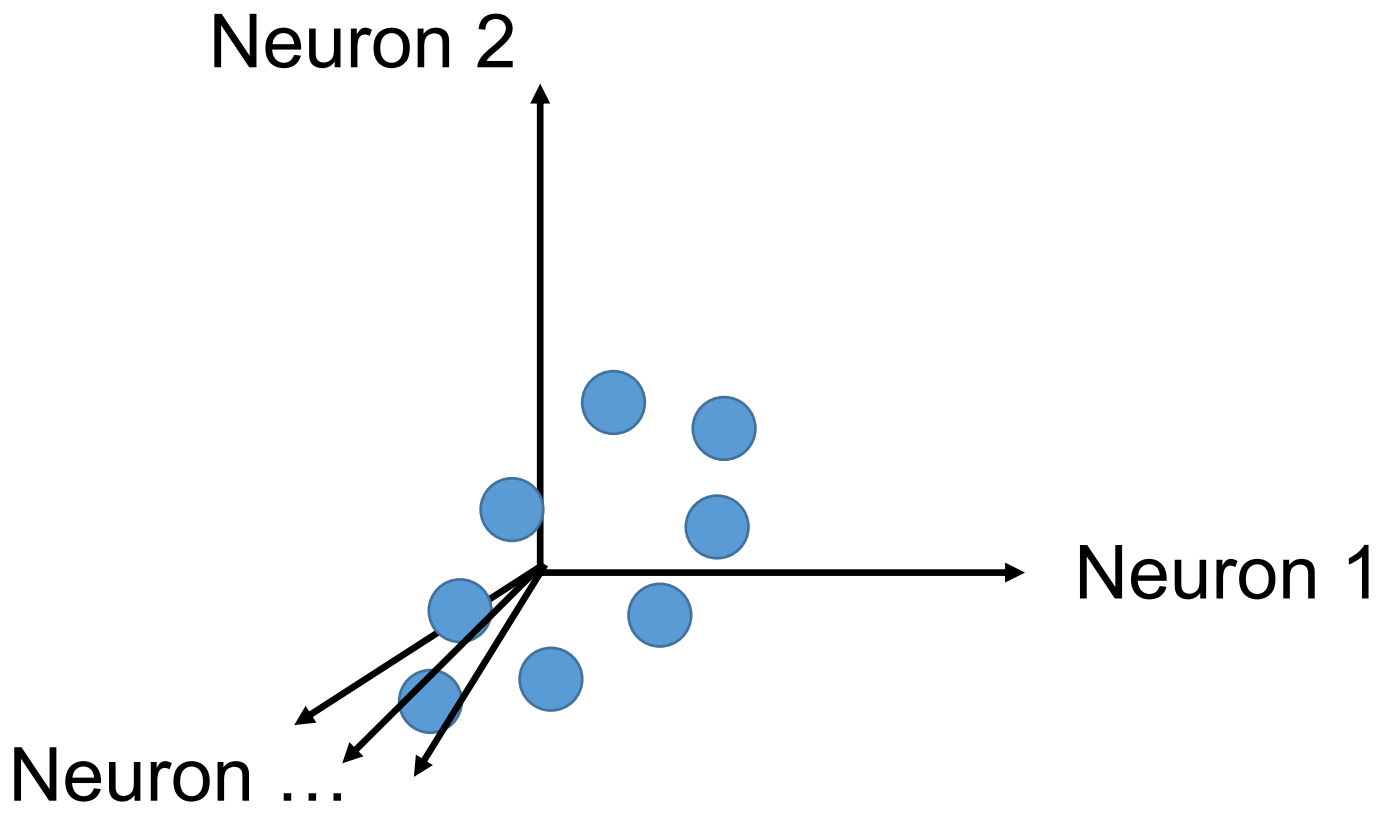




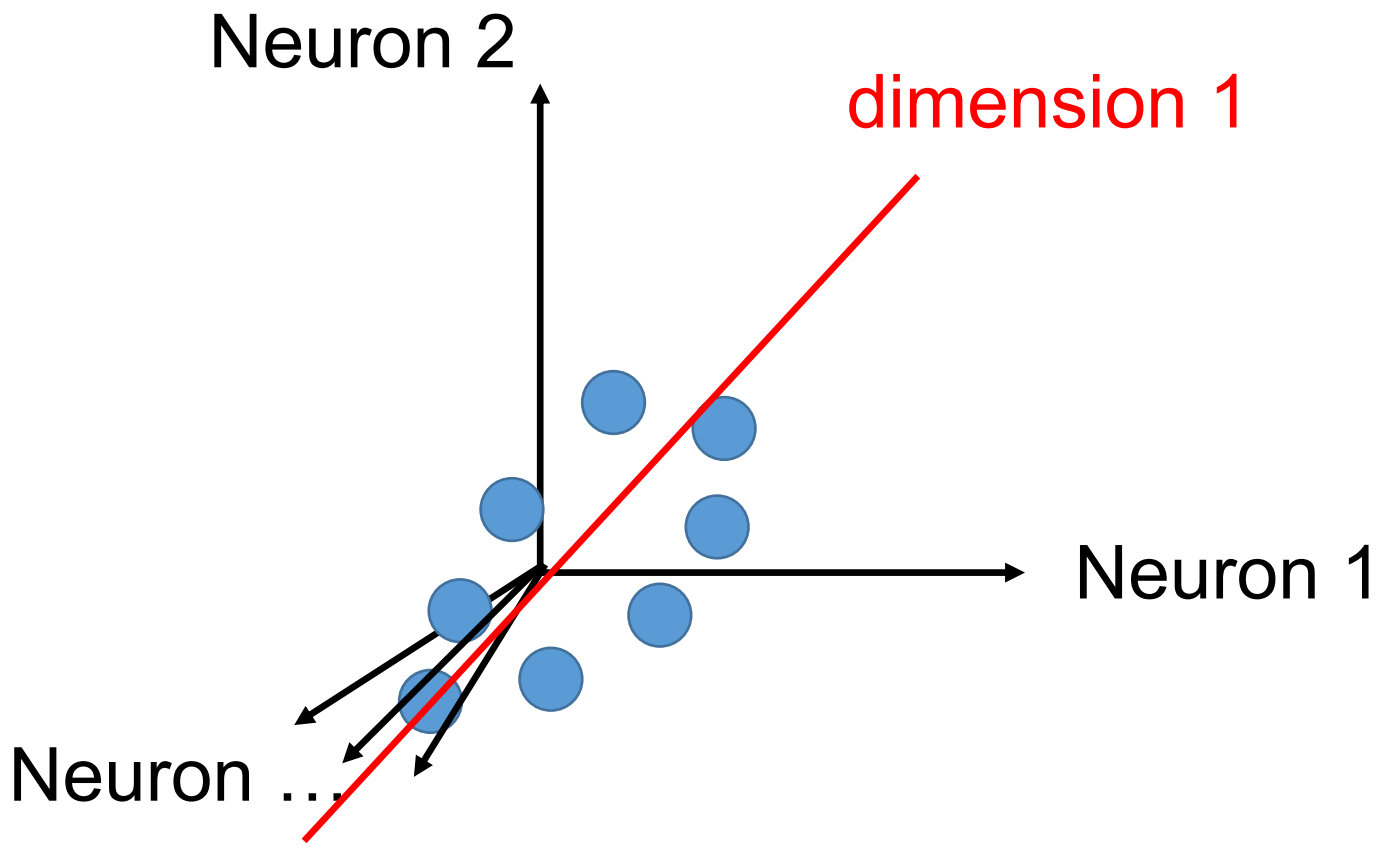
Principal component analysis



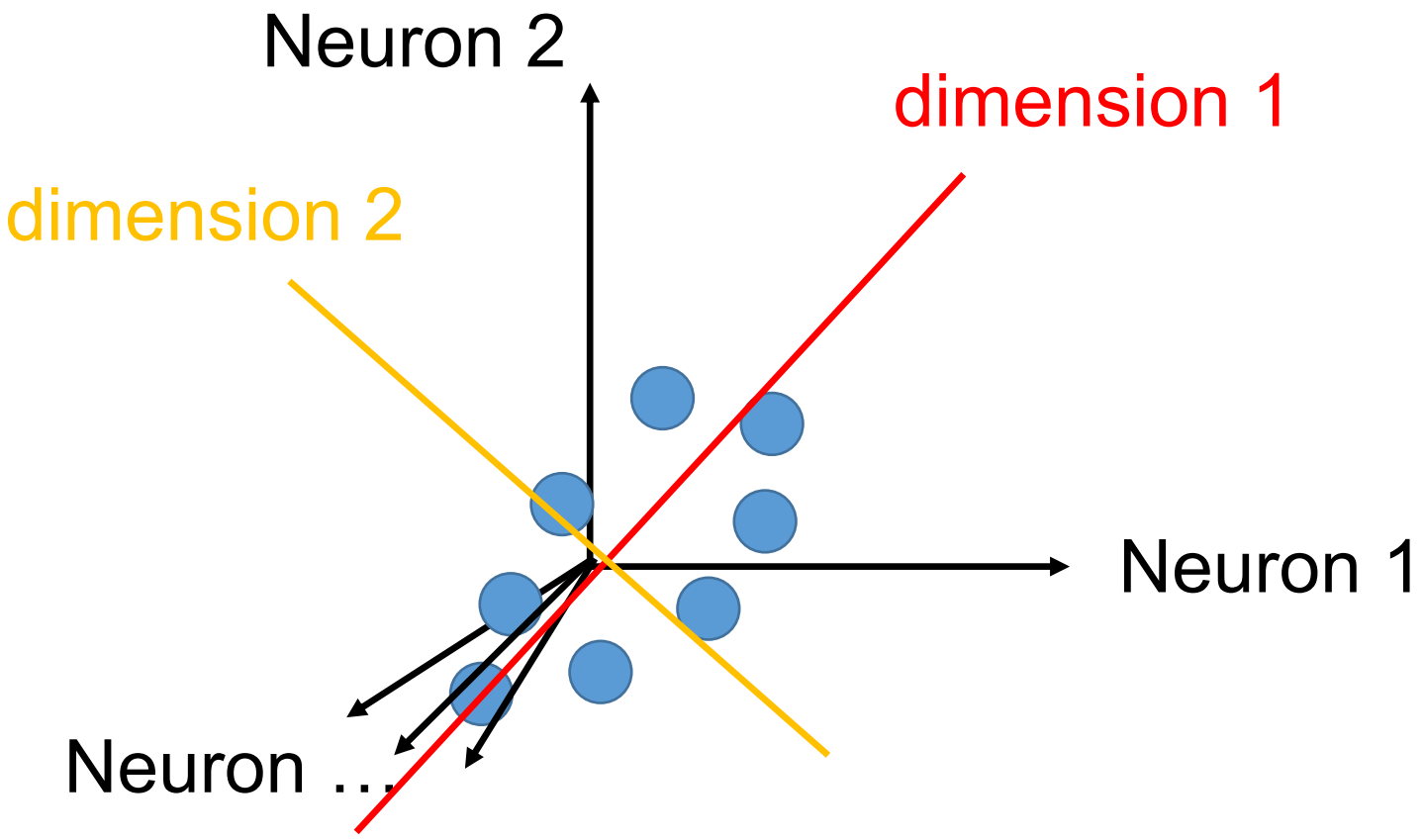
Principal component analysis



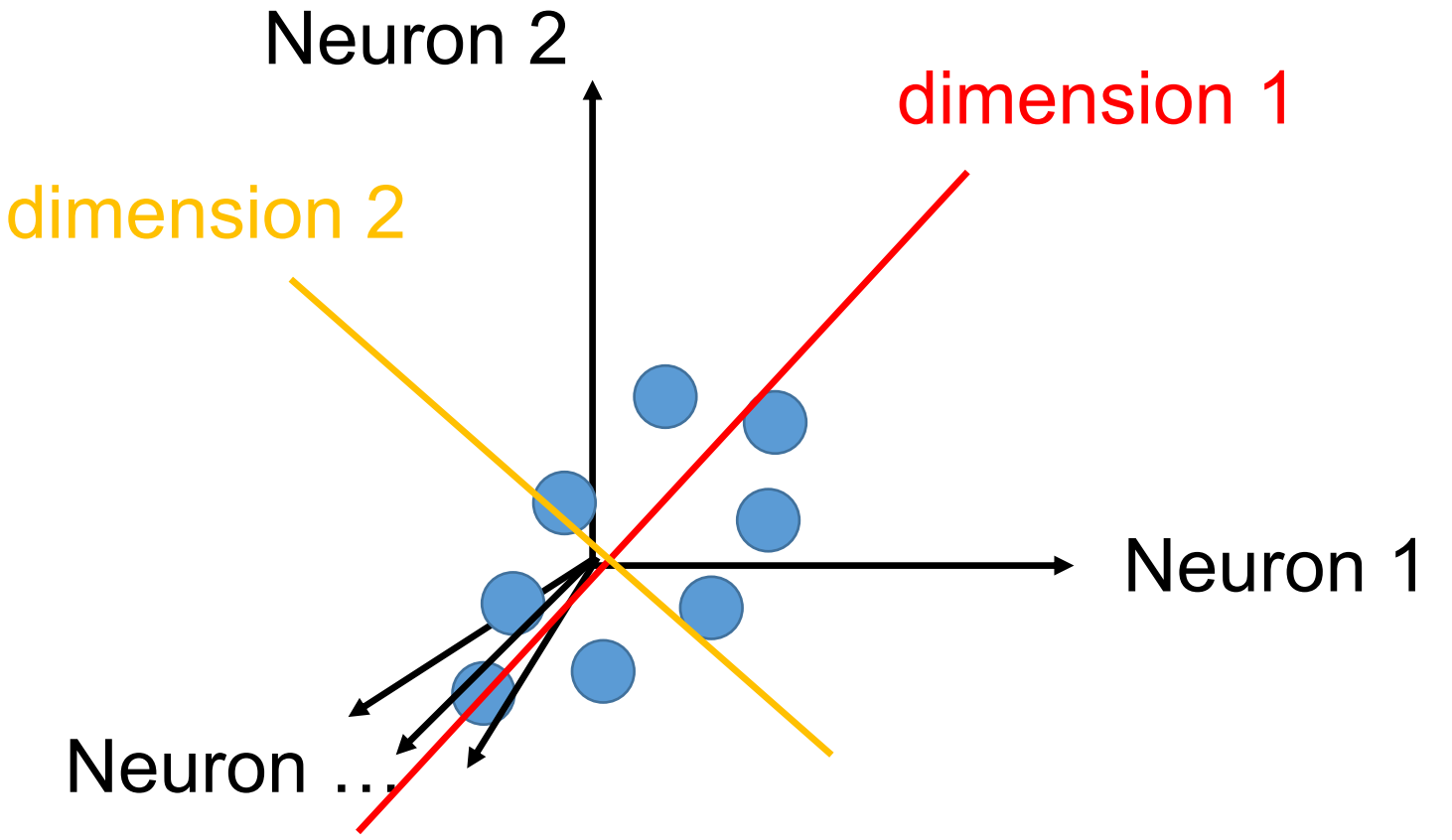
Principal component analysis

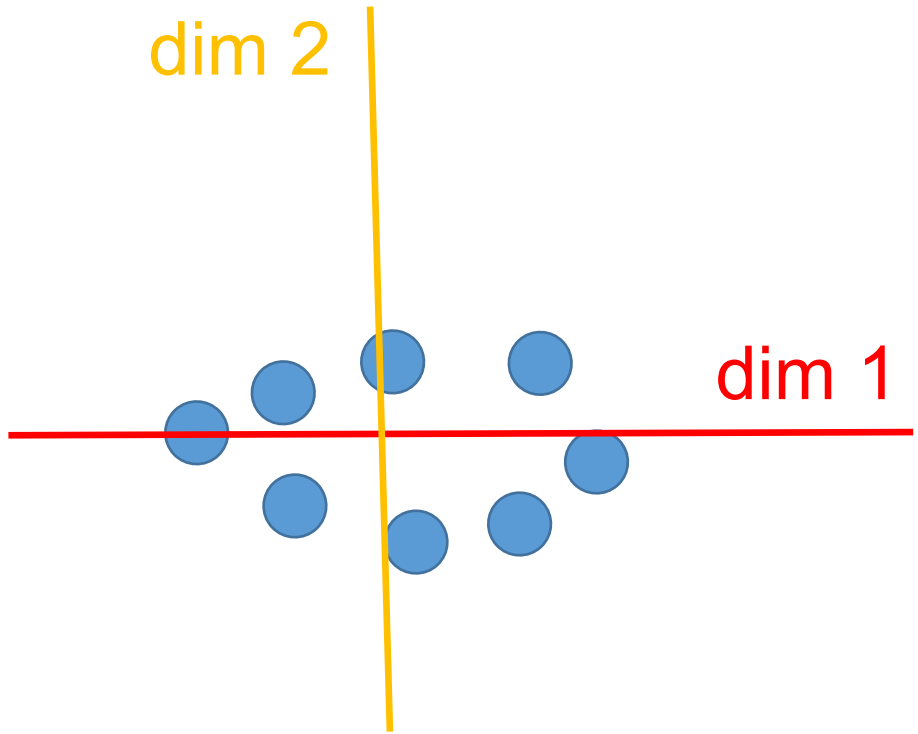


Principal component analysis

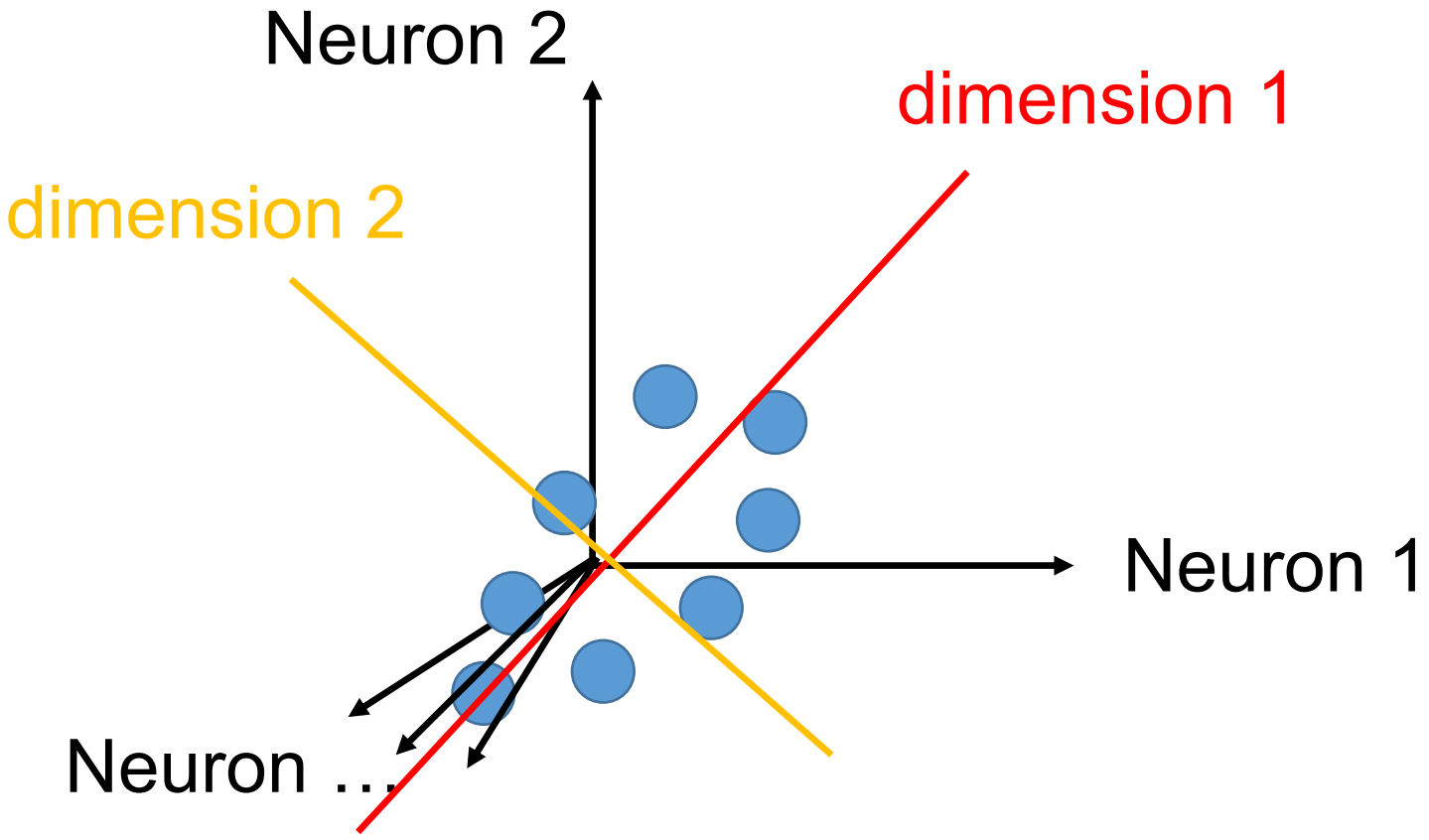


Principal component analysis

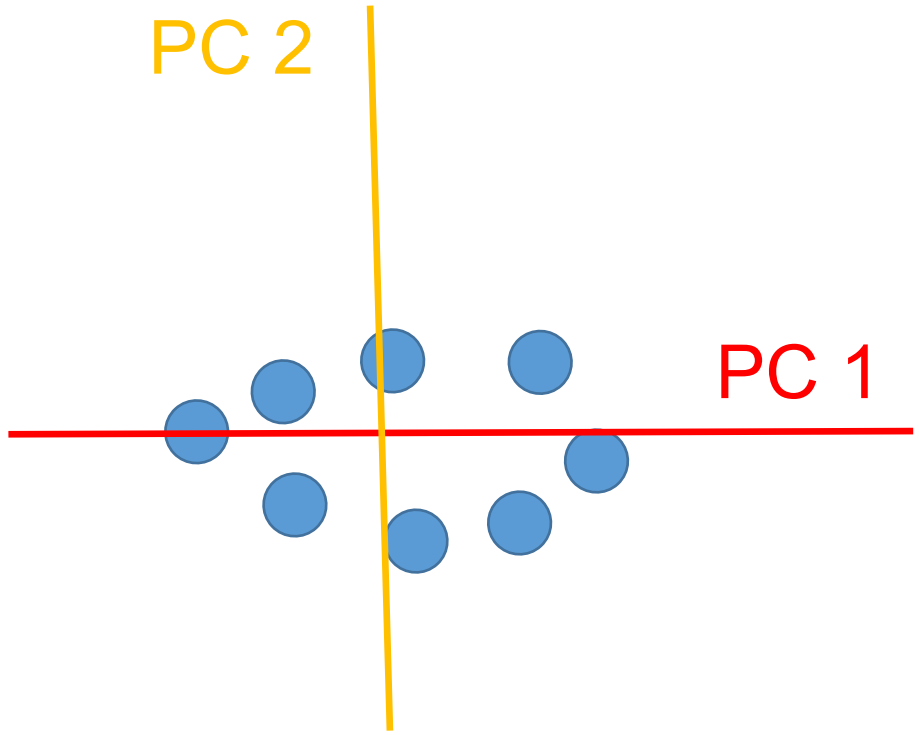




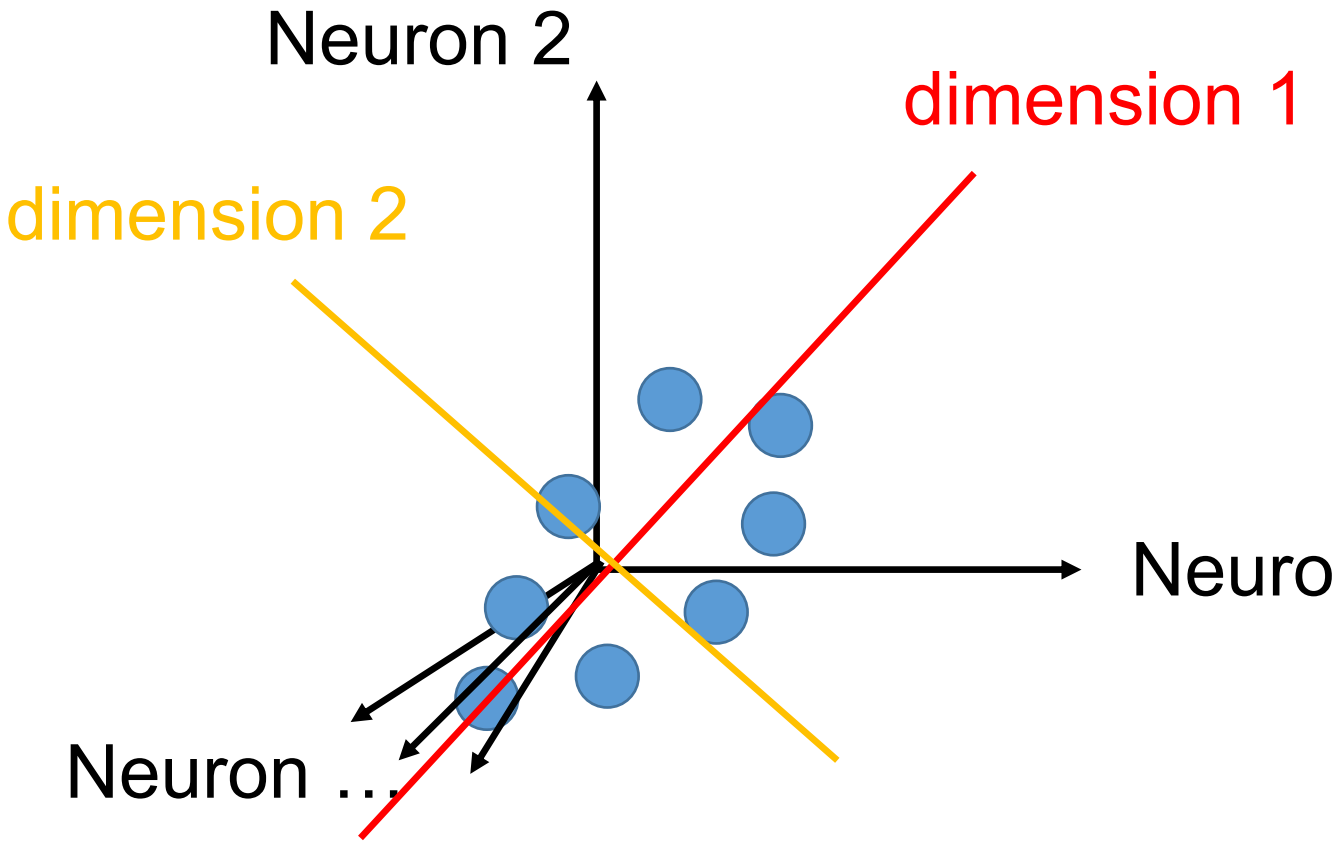
Principal component analysis



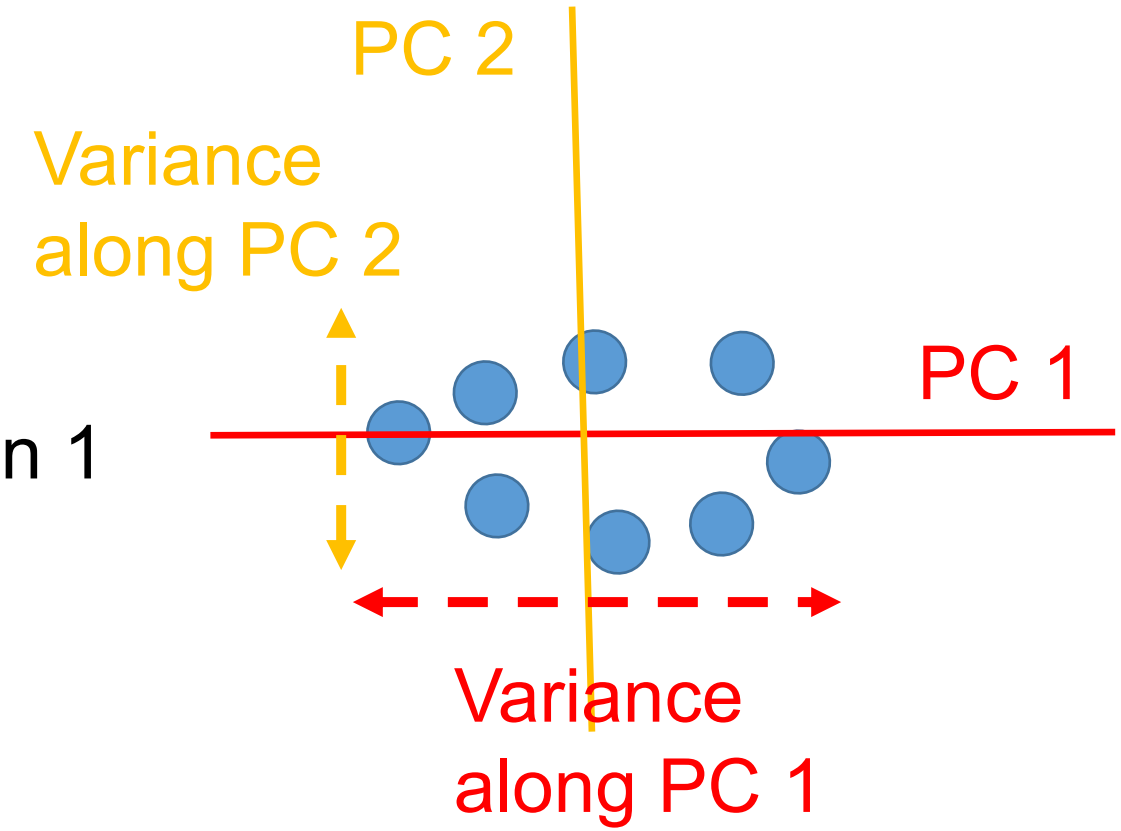
This is what PCA does



Principal component analysis



This is what PCA does



Principal component analysis

$$\mathbf{R} = \begin{pmatrix} & \\ & \\ & \end{pmatrix}$$

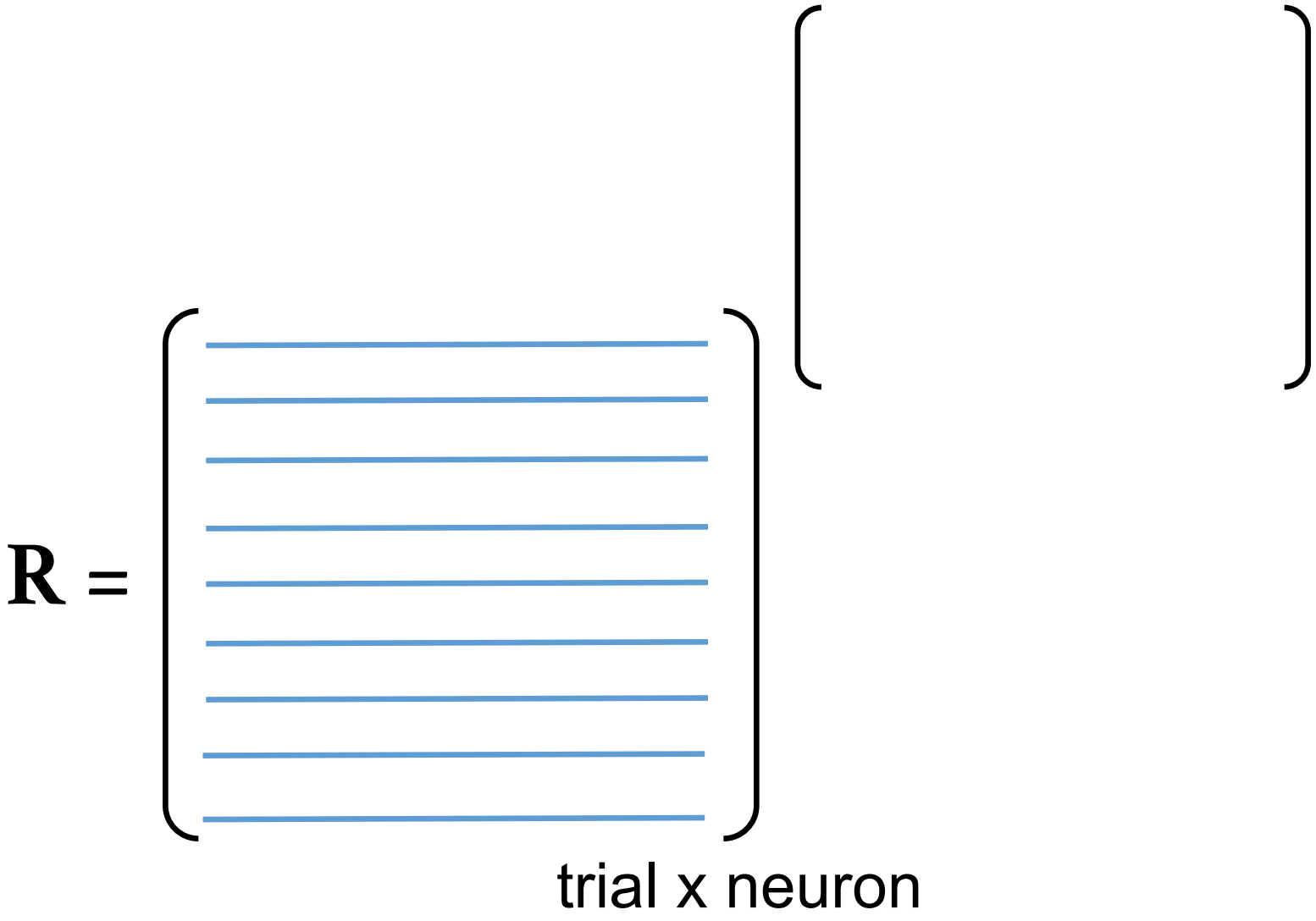
trial x neuron

Principal component analysis

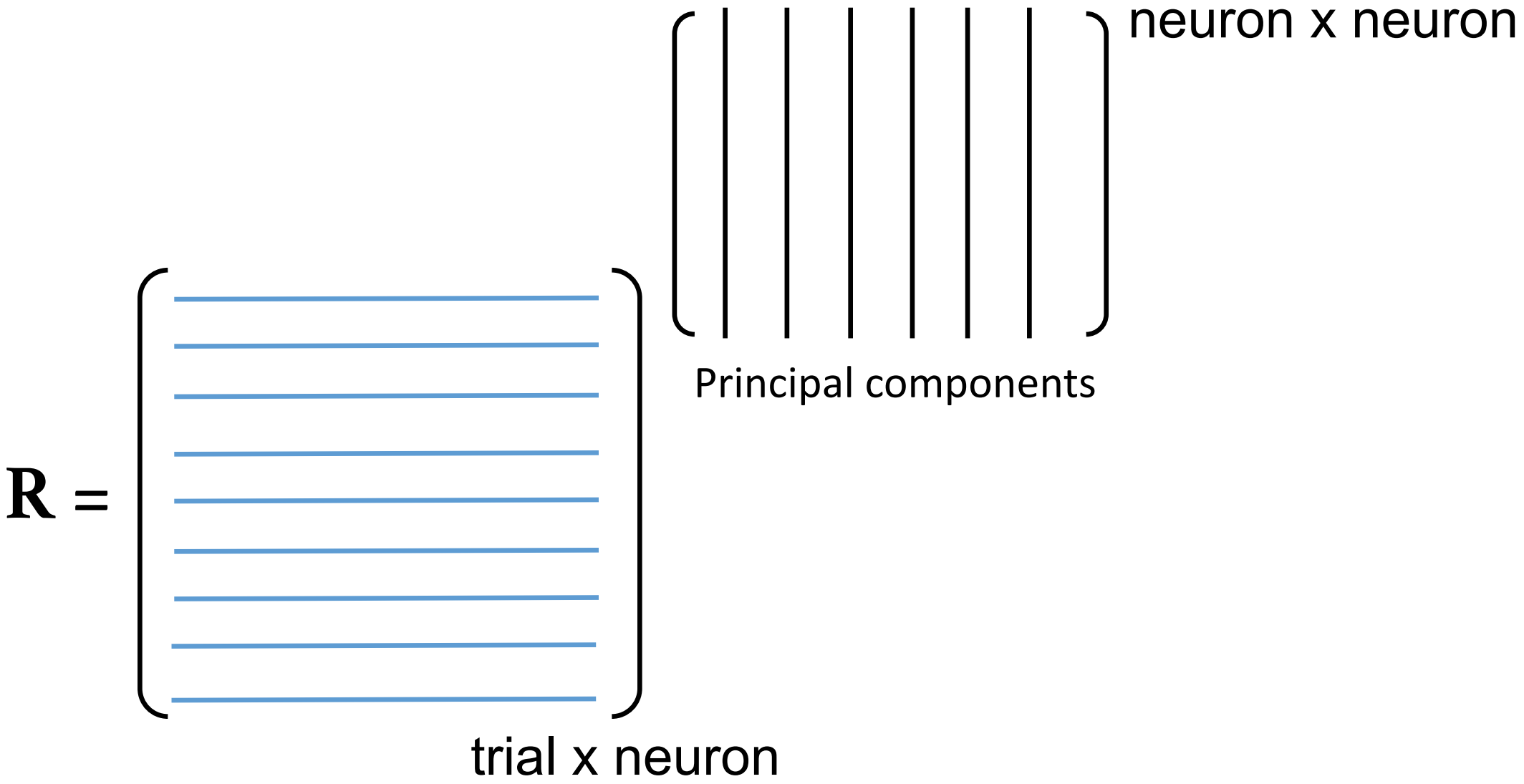
$$R = \begin{pmatrix} \\ \\ \\ \\ \\ \\ \\ \\ \end{pmatrix}$$

trial x neuron

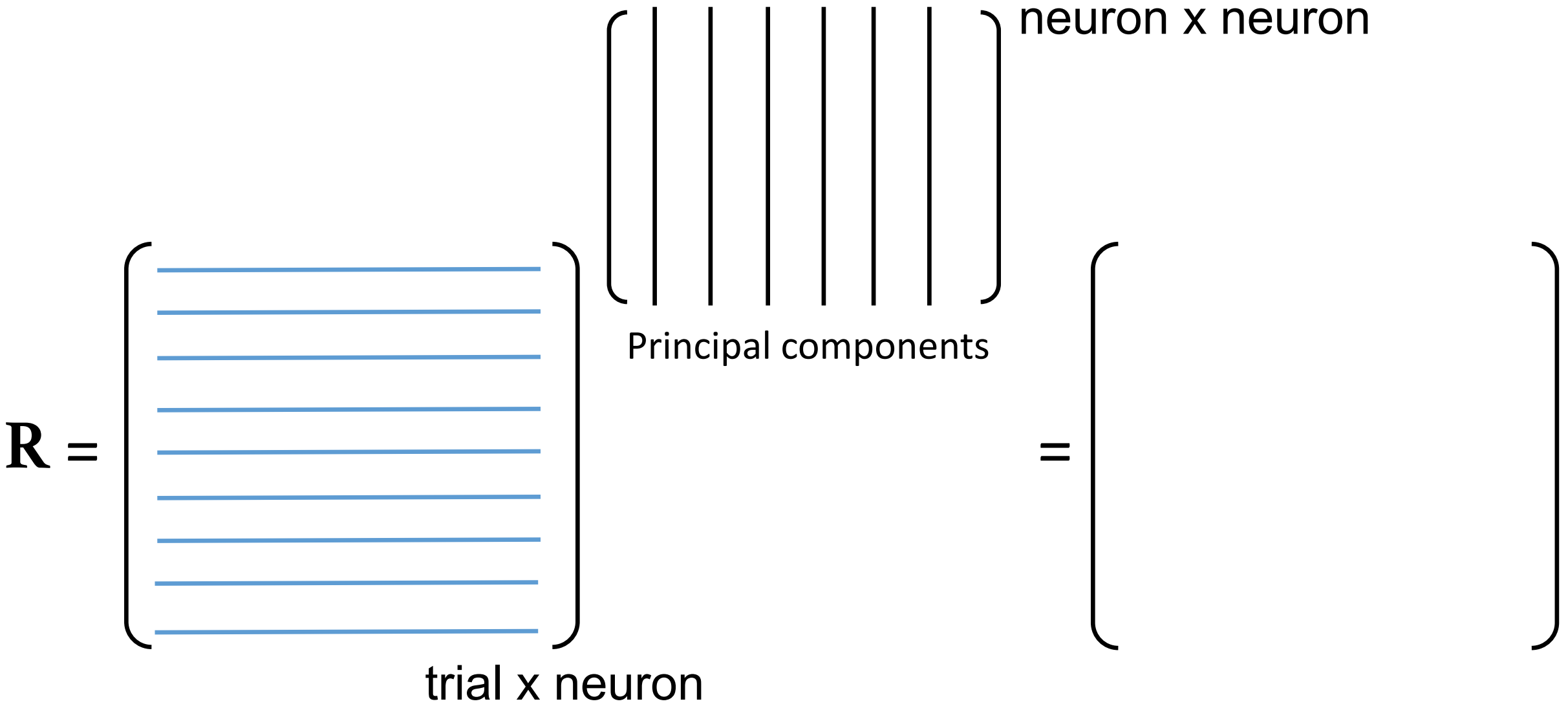
Principal component analysis



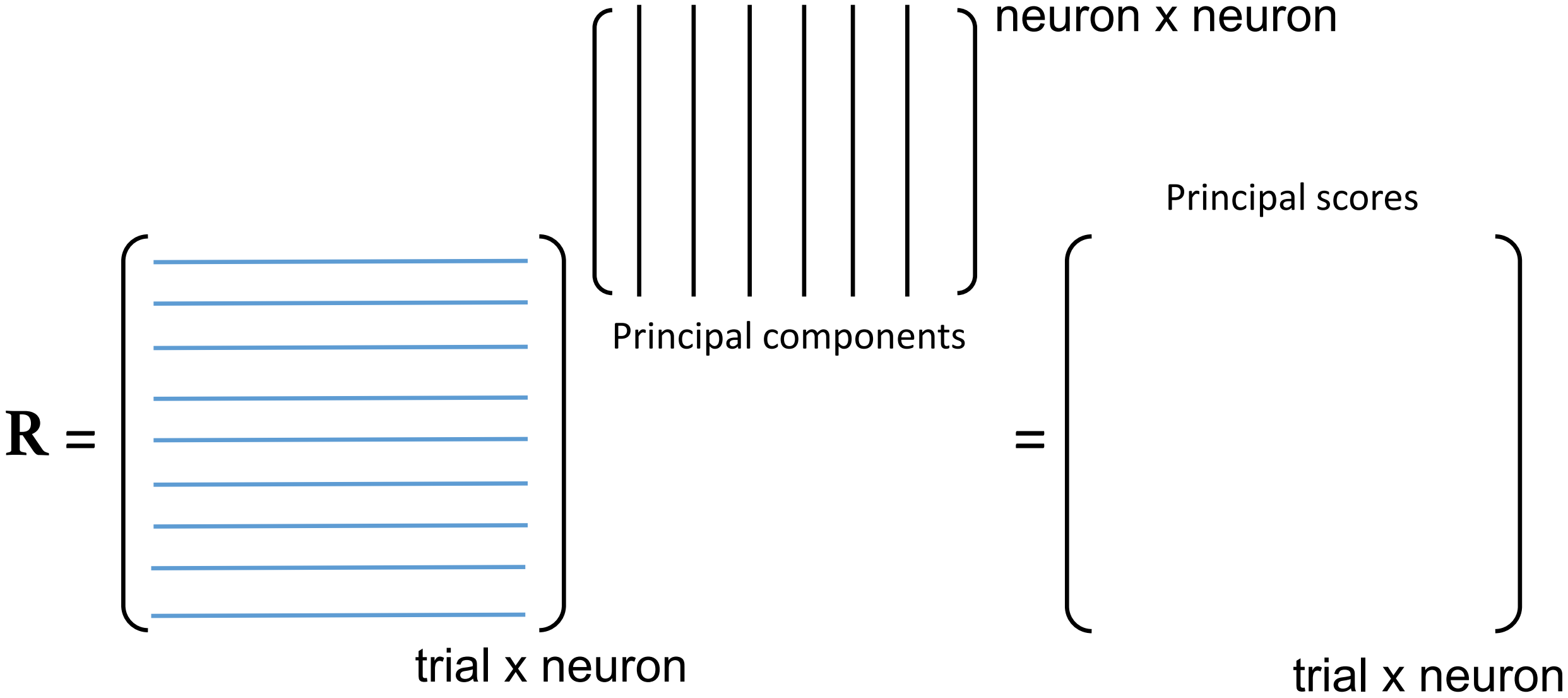
Principal component analysis



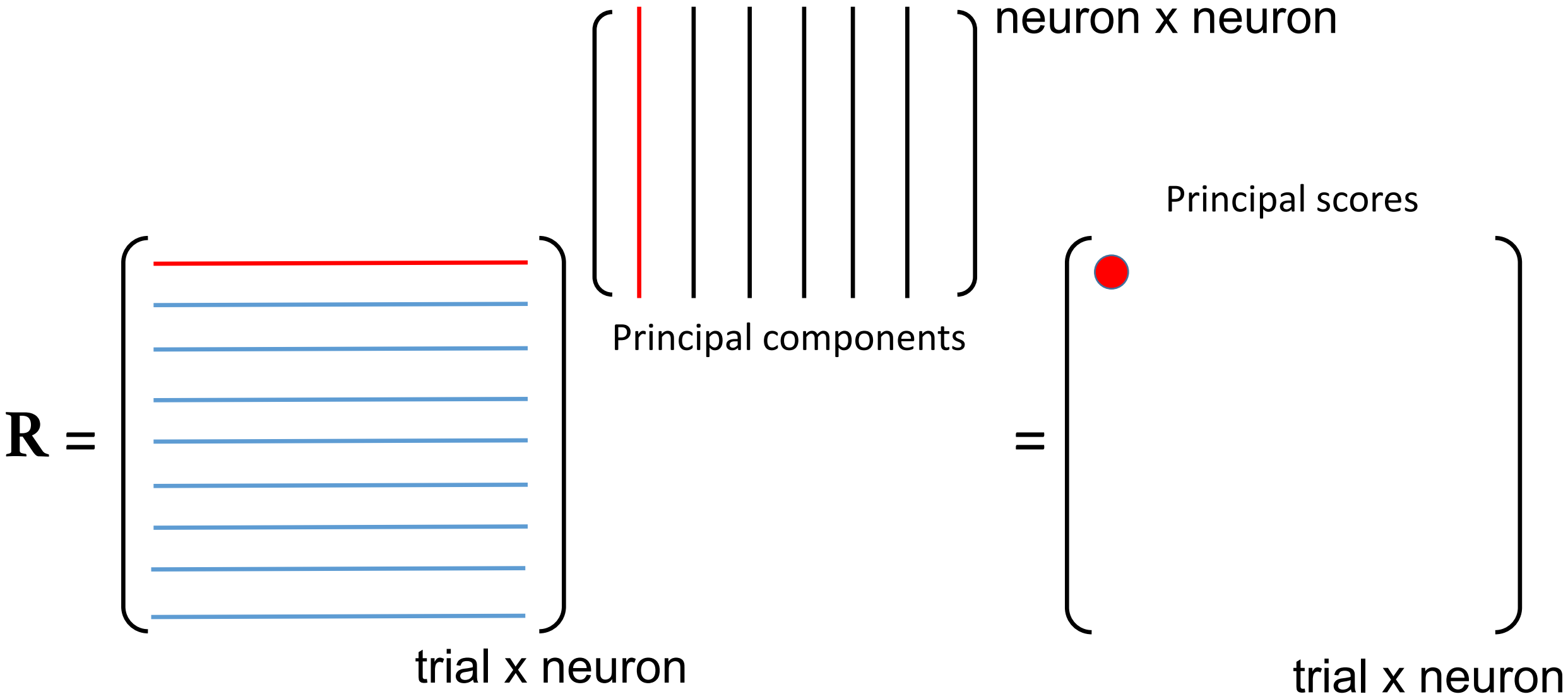
Principal component analysis



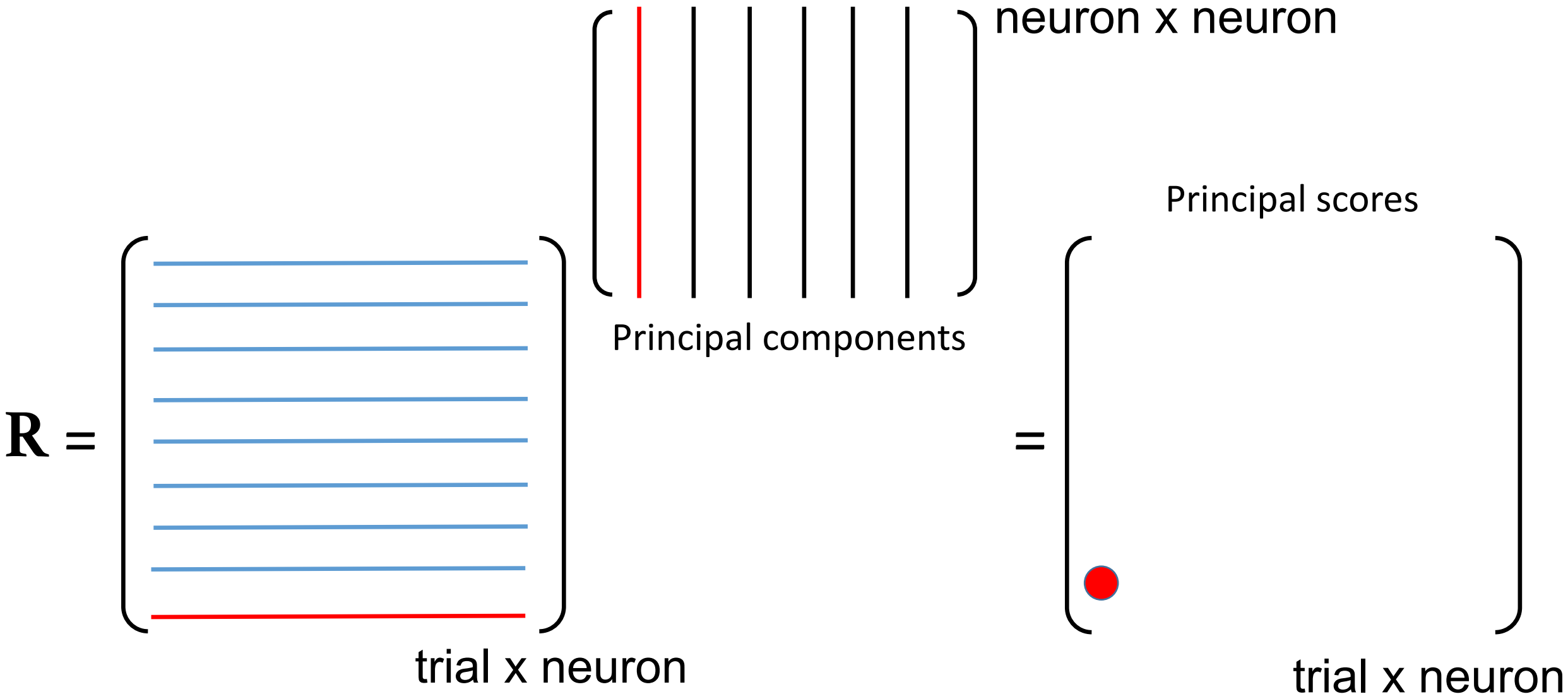
Principal component analysis



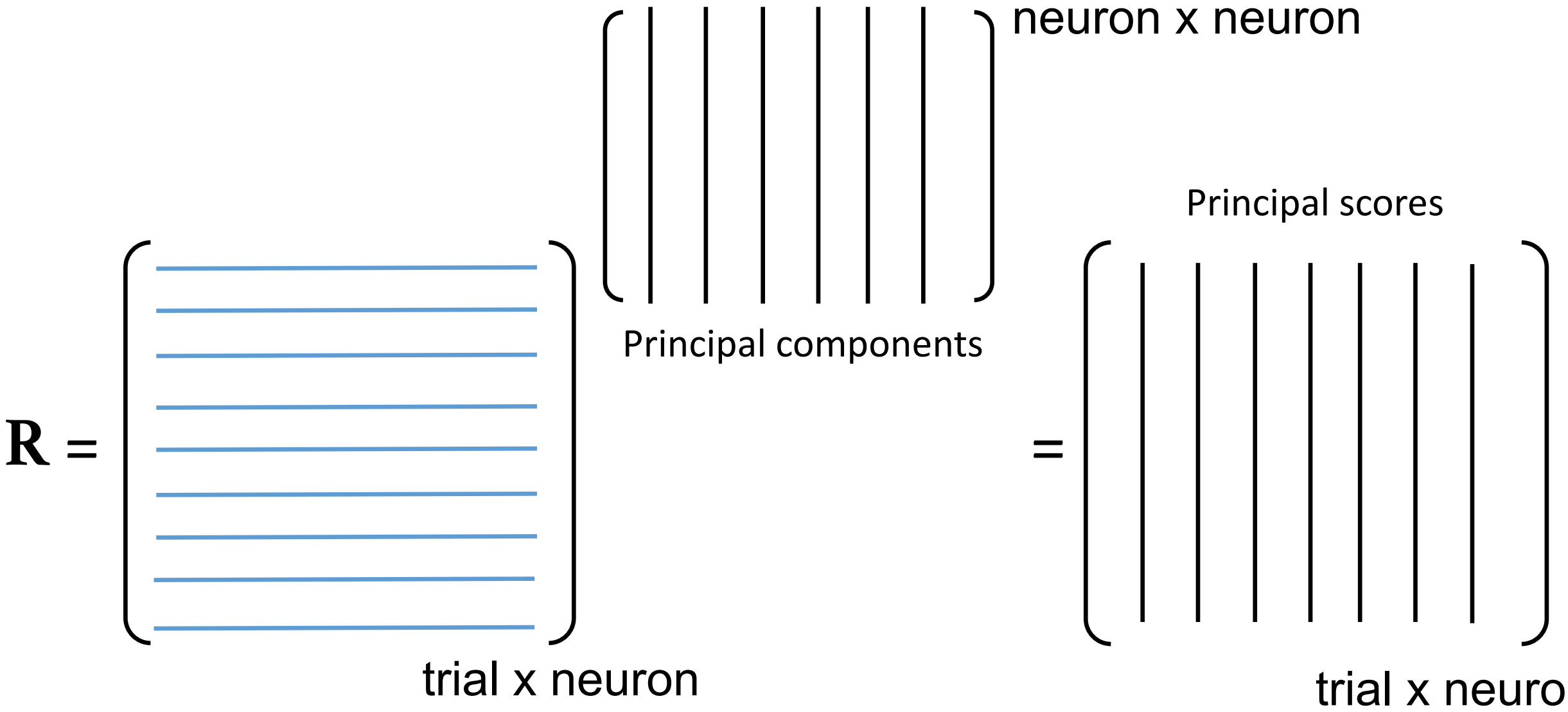
Principal component analysis



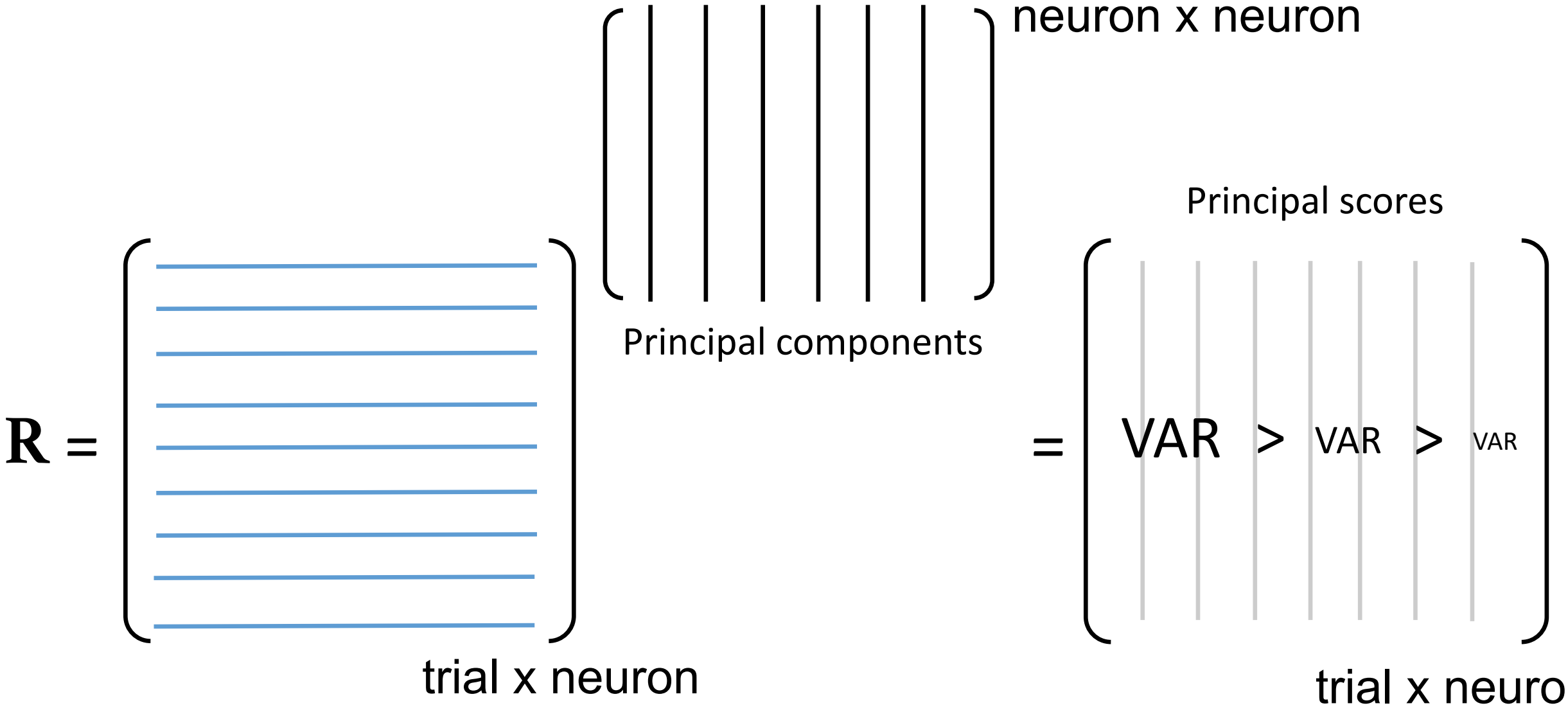
Principal component analysis



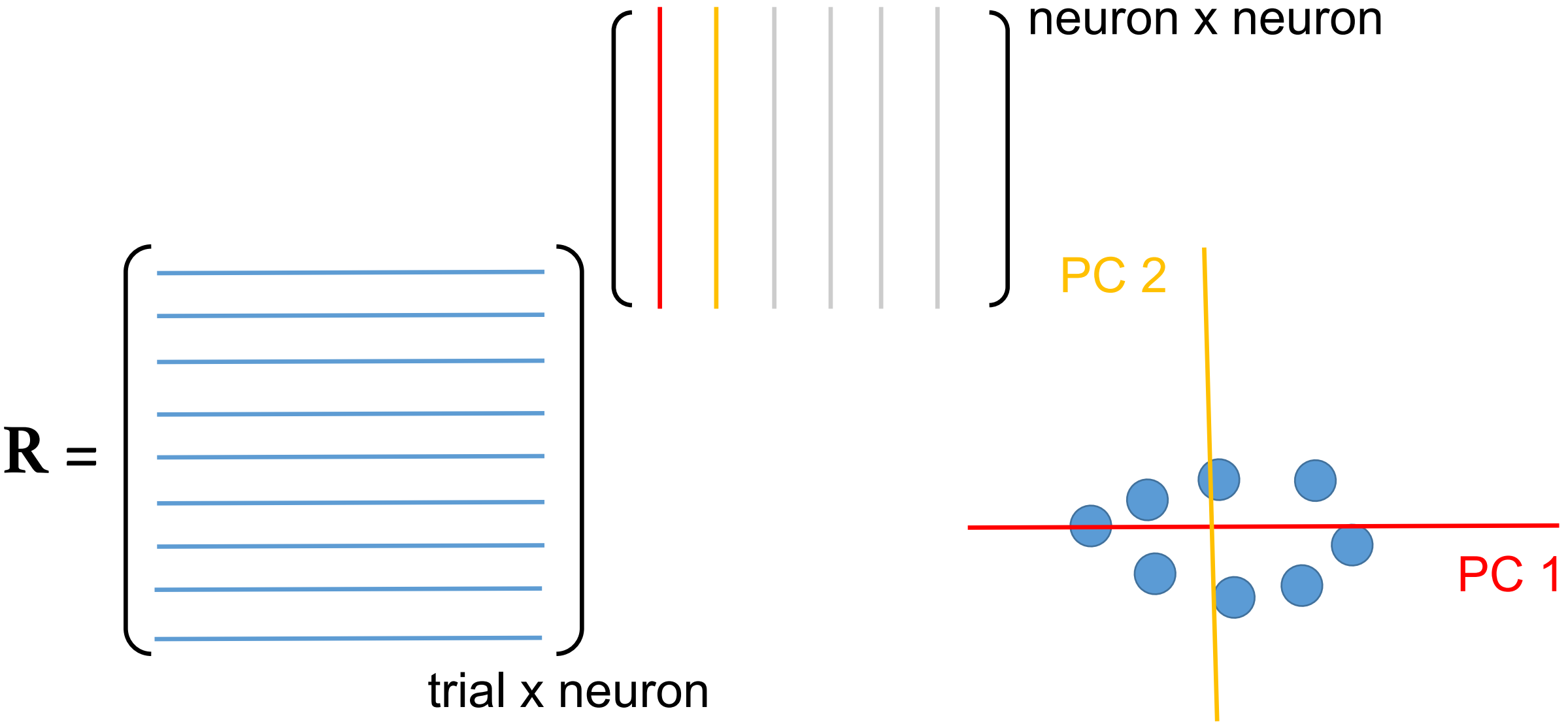
Principal component analysis



Principal component analysis



Principal component analysis

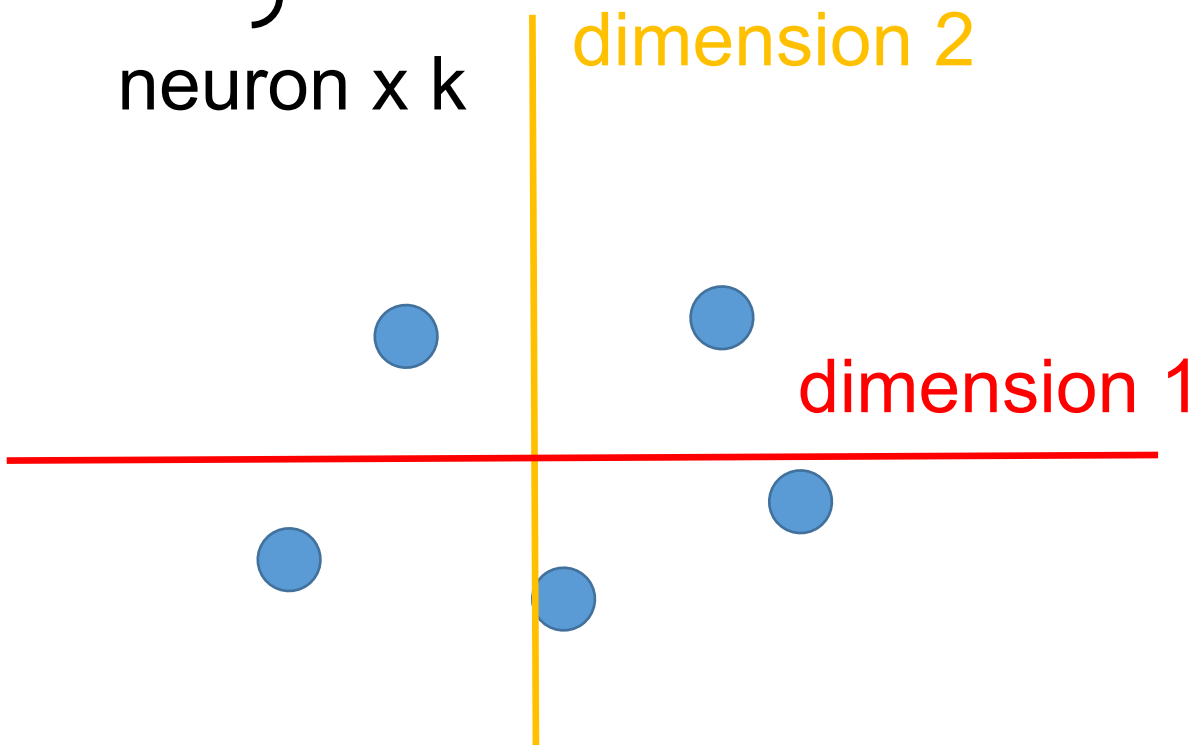


Principal component analysis

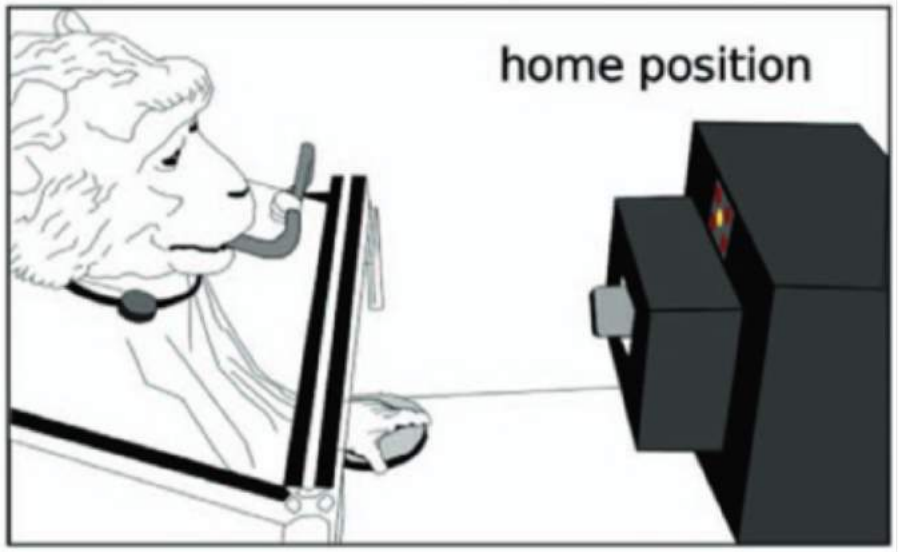
$$R = \begin{bmatrix} R \end{bmatrix} \begin{bmatrix} C^{-1} \end{bmatrix}$$

trial x neuron

neuron x k



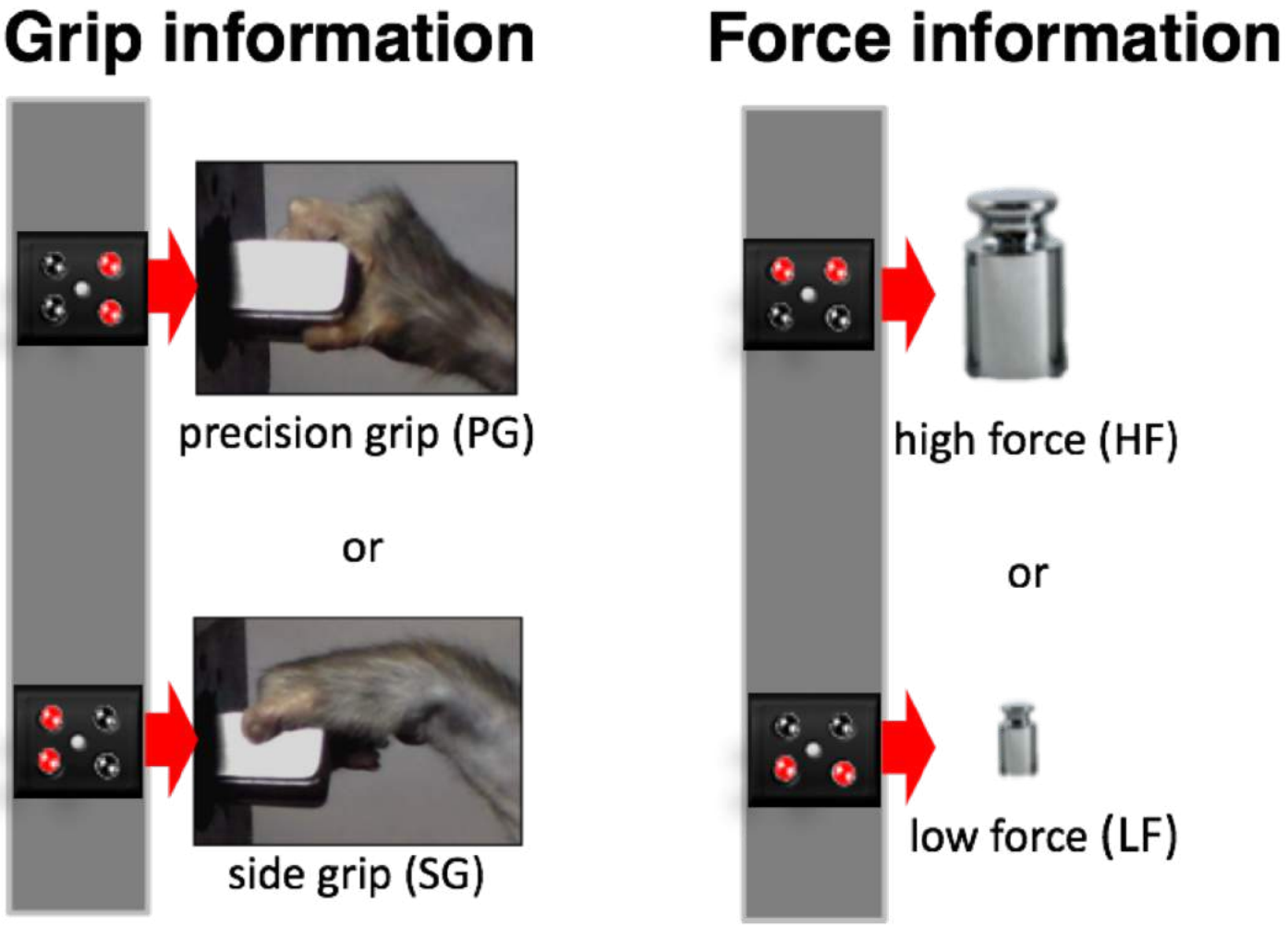
Dataset #2



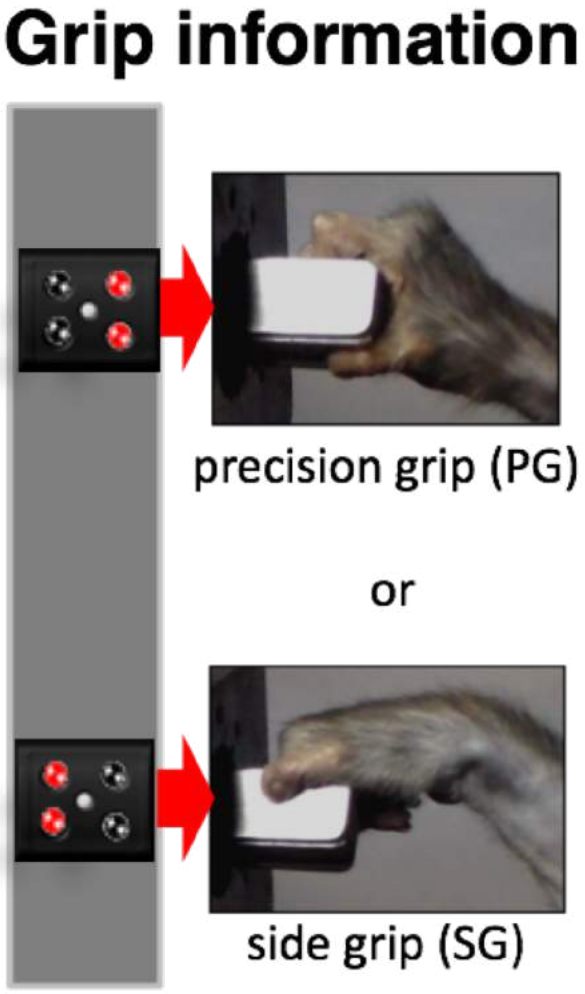
Context-dependent reach-to-grasp task:
2 grip types, 2 force levels

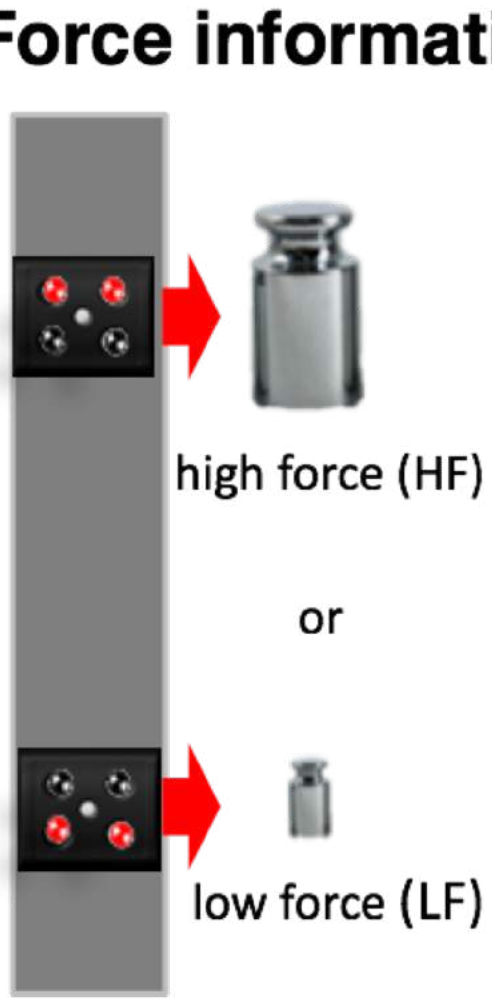
Original data from Thomas Brochier and Alexa Riehle

Dataset #2


Grip information
precision grip (PG)
or
side grip (SG)
Force information
high force (HF)
or
low force (LF)

Dataset #2

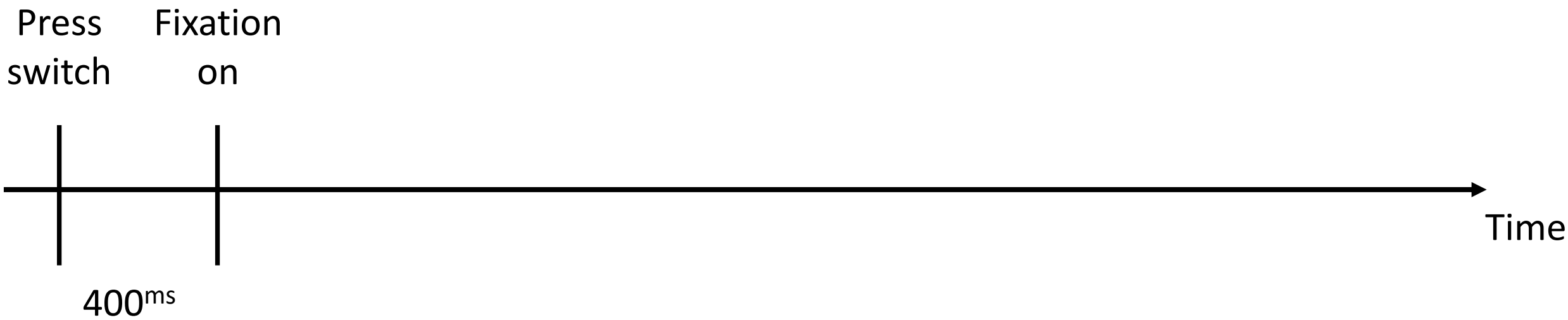




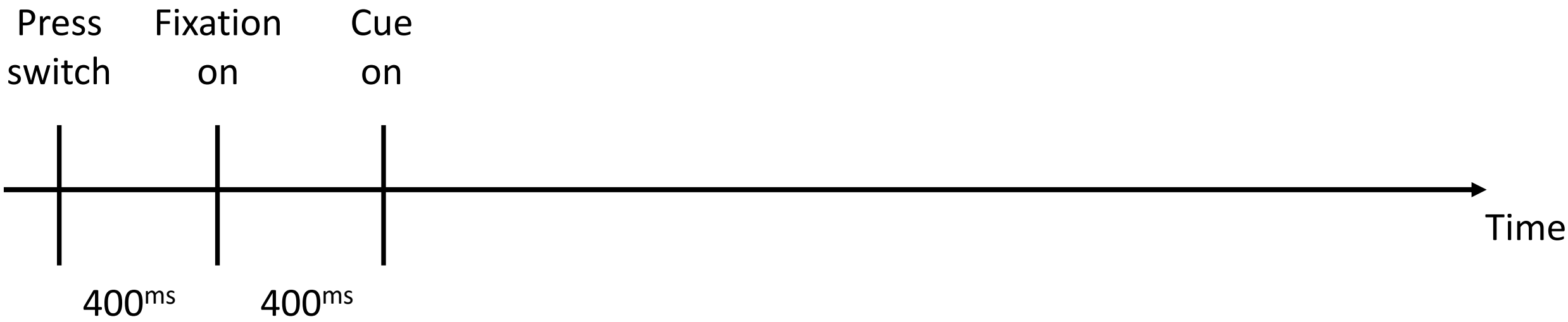
4 trial types
PG/HF
PG/LF
SG/HF
SG/LF

Dataset #2

Dataset #2



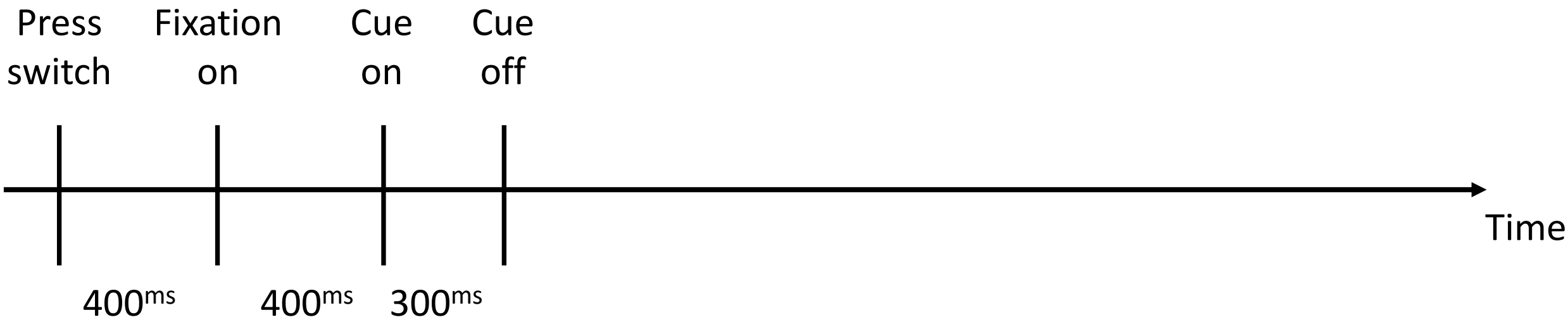
Dataset #2



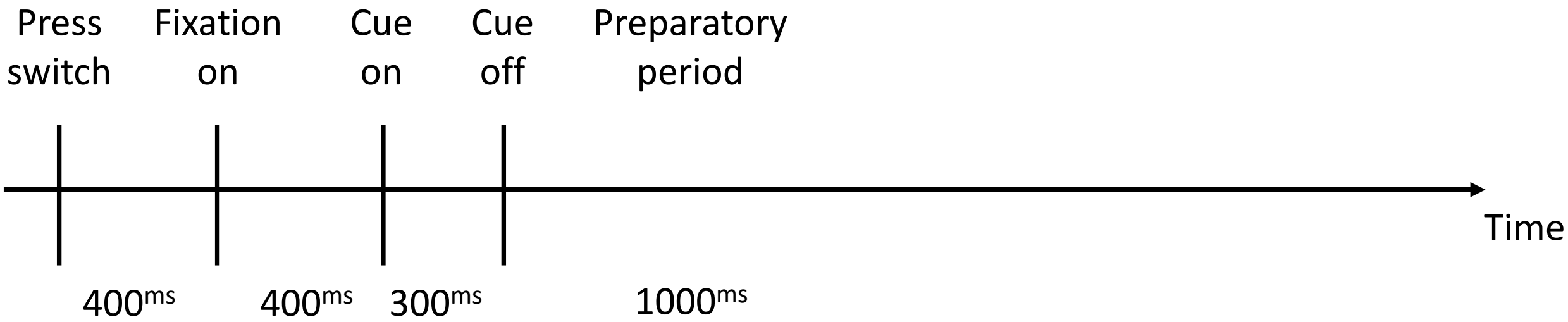
Dataset #2


Press switch
Fixation on
Cue on
400ms
400ms
precision grip (PG)
or
side grip (SG)
Time

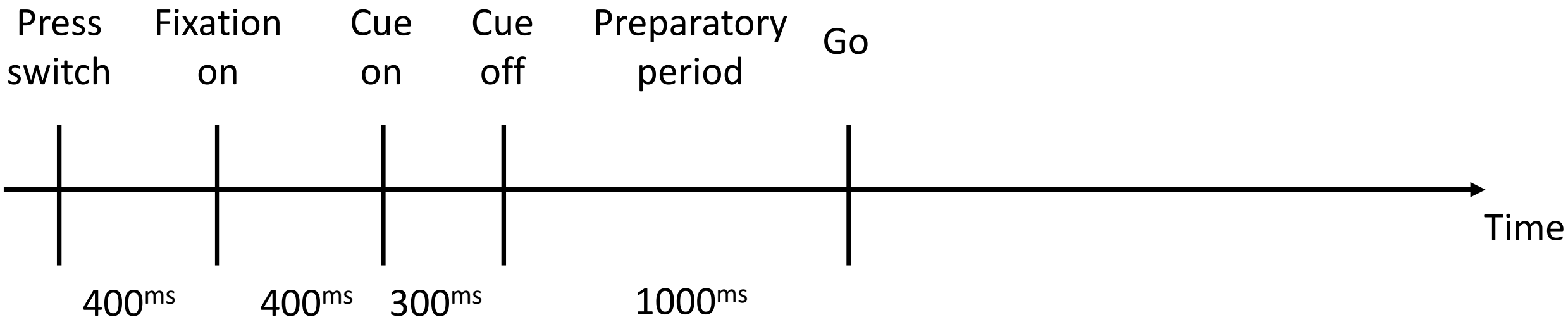
Dataset #2


Press switch
Fixation on
Cue on
Cue off
Time
400ms
400ms
300ms

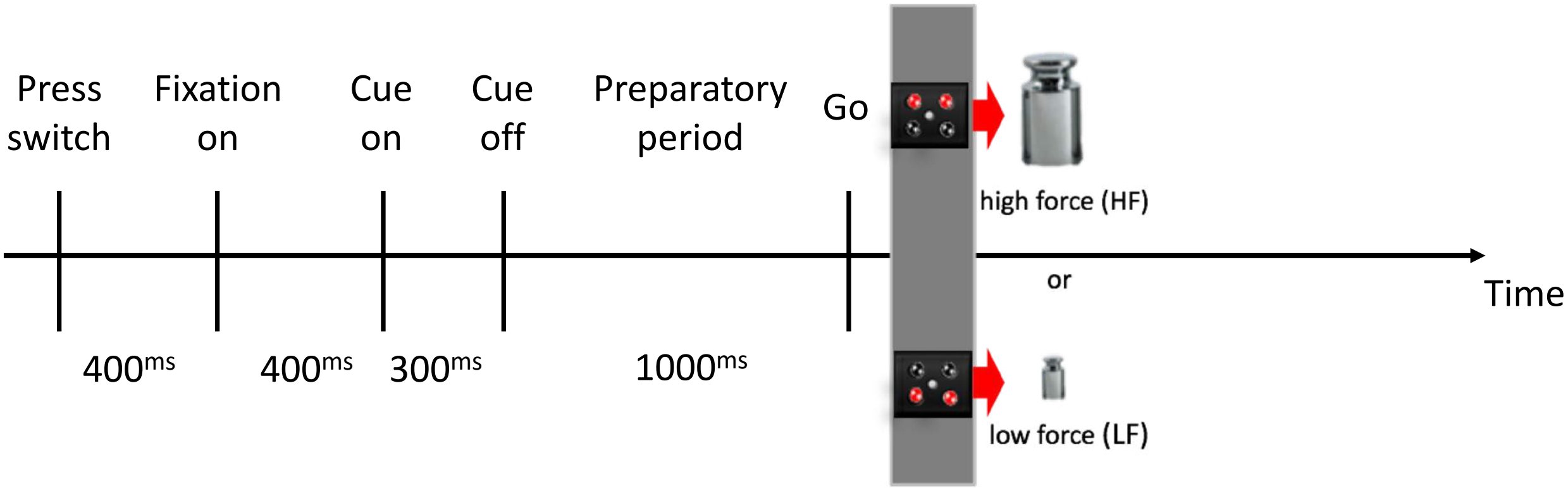
Dataset #2


Press switch
Fixation on
Cue on
Cue off
Preparatory period
Time
400ms
400ms
300ms
1000ms

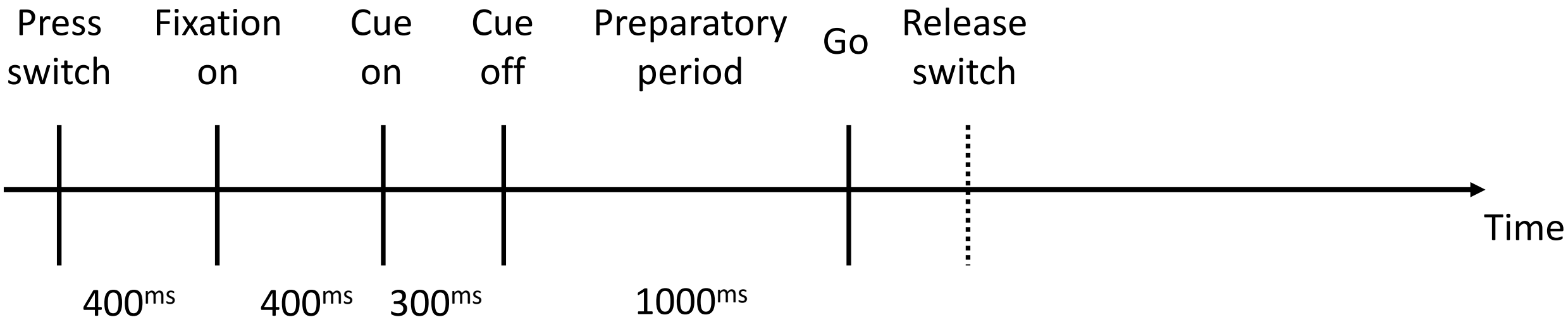
Dataset #2


Press switch
Fixation on
Cue on
Cue off
Preparatory period
Go
Time
400ms
400ms
300ms
1000ms

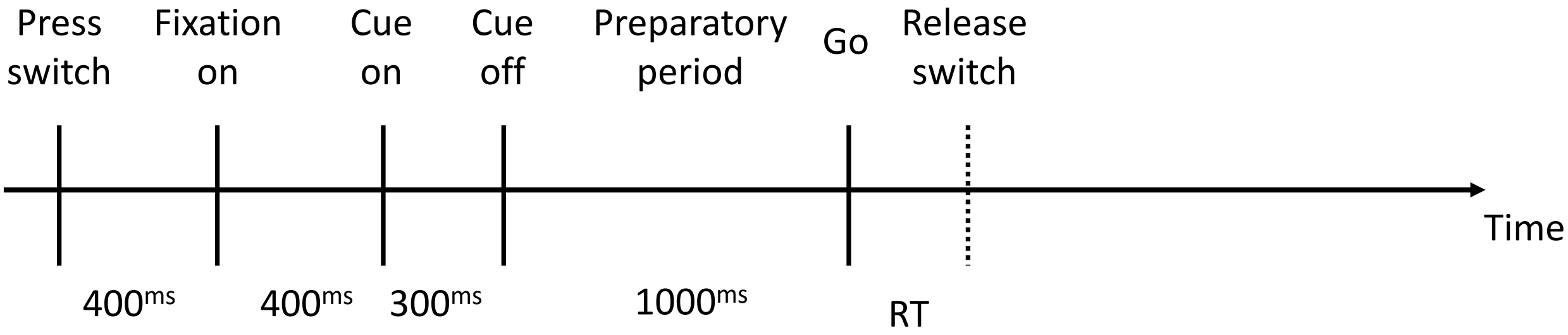
Dataset #2


Press switch
Fixation on
Cue on
Cue off
Preparatory period
Go
400ms
400ms
300ms
1000ms
high force (HF)
or
low force (LF)
Time

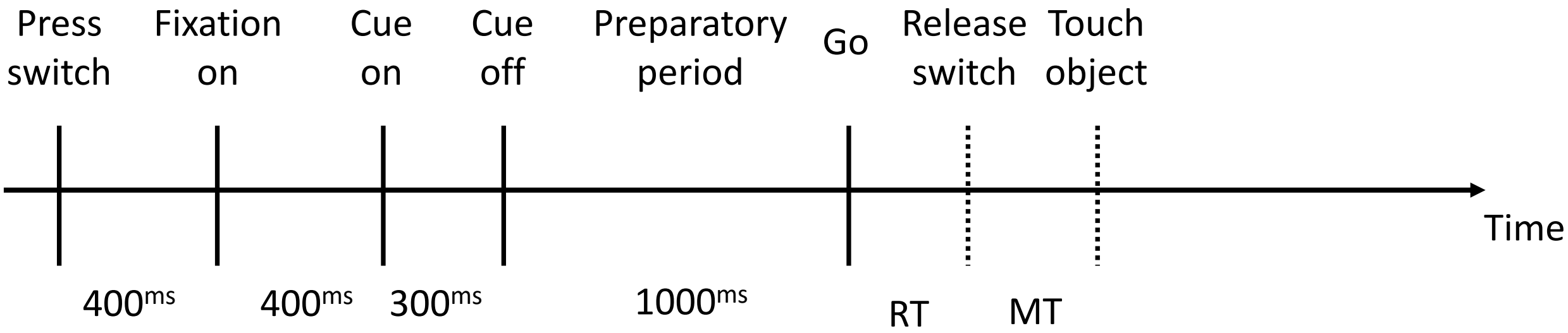
Dataset #2


Press switch
Fixation on
Cue on
Cue off
Preparatory period
Go
Release switch
Time
400ms
400ms
300ms
1000ms

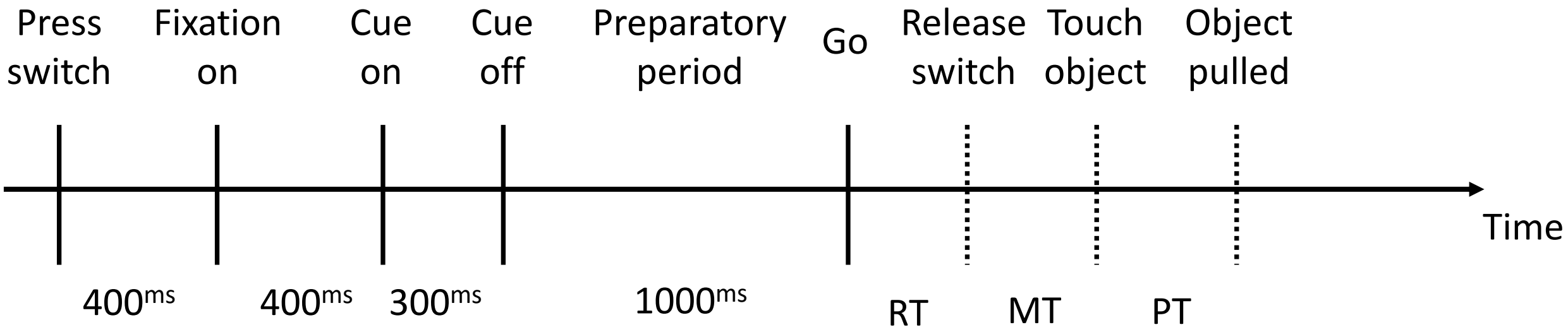
Dataset #2


Press switch
Fixation on
Cue on
Cue off
Preparatory period
Go
Release switch
Time
400ms
400ms
300ms
1000ms
RT

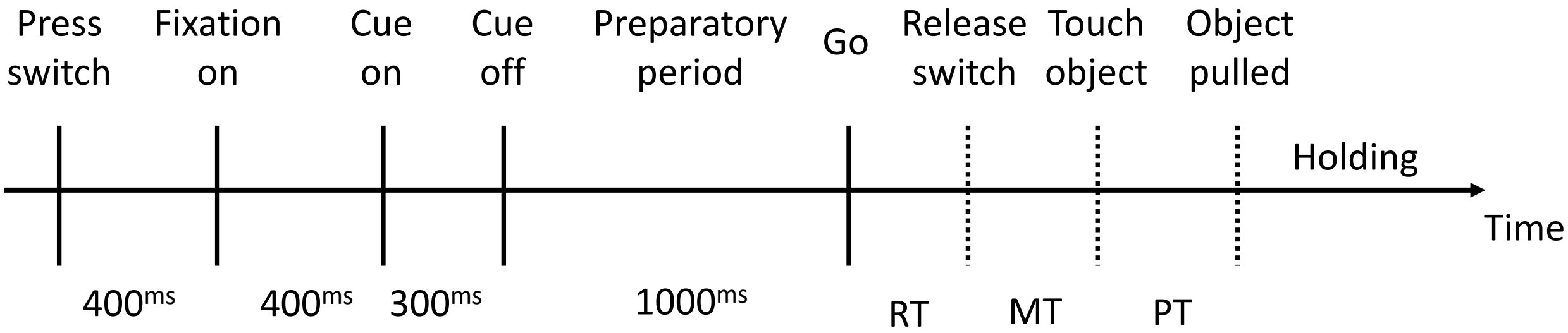
Dataset #2


Press switch
Fixation on
Cue on
Cue off
Preparatory period
Go
Release switch
Touch object
Time
400ms
400ms
300ms
1000ms
RT
MT

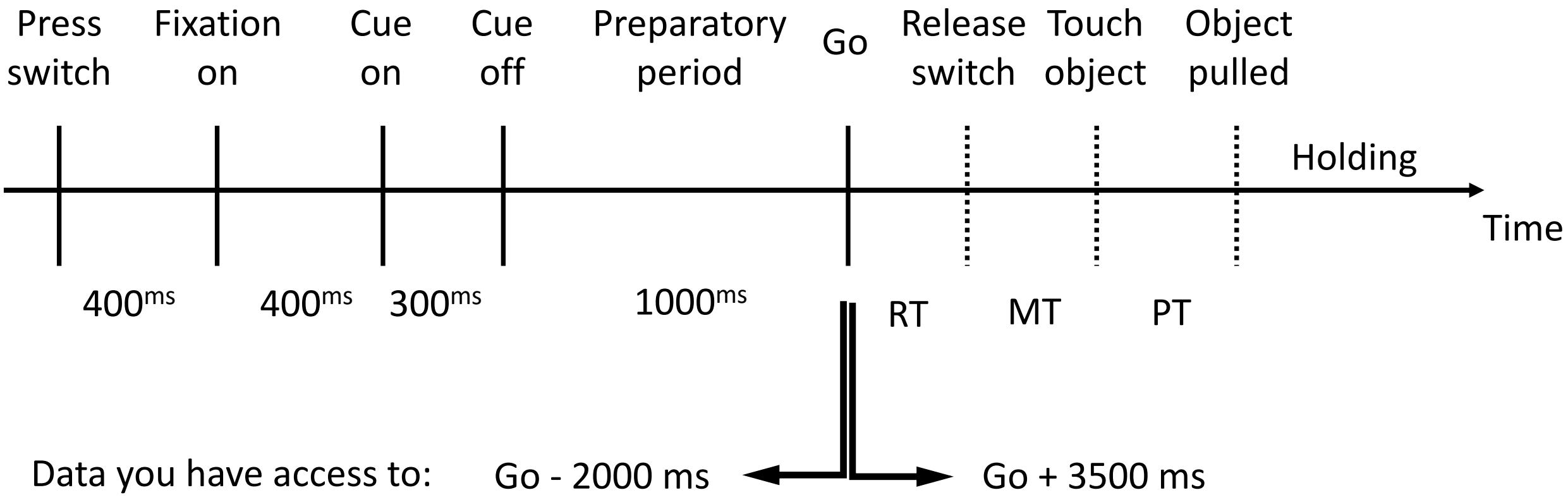
Dataset #2


Press switch
Fixation on
Cue on
Cue off
Preparatory period
Go
Release switch
Touch object
Object pulled
Time
400ms
400ms
300ms
1000ms
RT
MT
PT

Dataset #2


Press switch
Fixation on
Cue on
Cue off
Preparatory period
Go
Release switch
Touch object
Object pulled
Holding
Time
400ms
400ms
300ms
1000ms
RT
MT
PT

Dataset #2



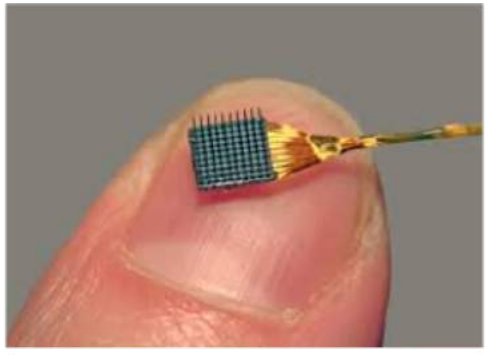
Data you have access to: Go - 2000 ms Go + 3500 ms

Dataset #2

Two data structures, called *monkeyL* and *monkeyN*

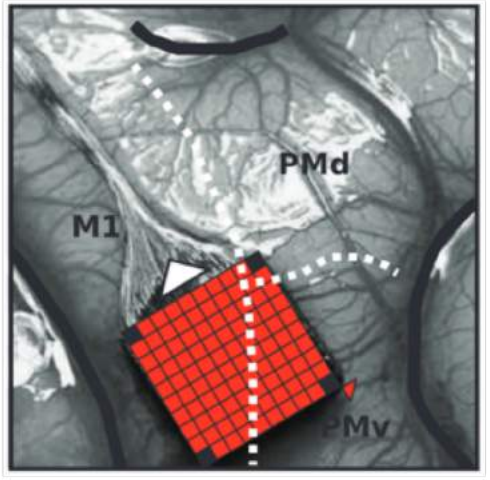
Dataset #2

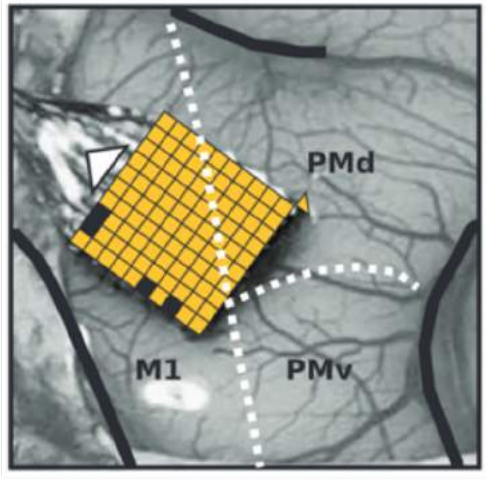
Two data structures, called *monkeyL* and *monkeyN*



100 electrodes Utah array
(*Blackrock Microsystems*
Salt Lake City, USA)

Monkey N





Monkey L

Dataset #2

Two data structures, called *monkeyL* and *monkeyN*

Dataset #2

Two data structures, called *monkeyL* and *monkeyN*
Each structure contains 7 fields:

Dataset #2

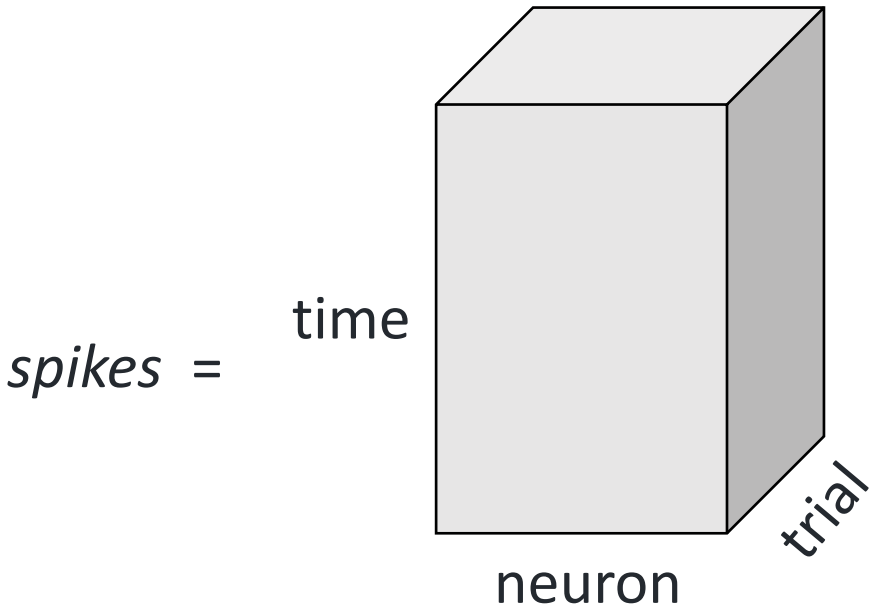
Two data structures, called *monkeyL* and *monkeyN*
Each structure contains 7 fields:

• *spikes* is a 3-D tensor [*T*x*N*x*K*] containing the spiking activity of *N* neurons, across *K* trials and *T* times points. Spikes are binned in a 1-ms window (why do you think 1-ms?) and include data between Go – 2000 ms and Go + 3500 ms.

Dataset #2

Two data structures, called *monkeyL* and *monkeyN*
Each structure contains 7 fields:

• *spikes* is a 3-D tensor [*T*x*N*x*K*] containing the spiking activity of *N* neurons, across *K* trials and *T* times points. Spikes are binned in a 1-ms window (why do you think 1-ms?) and include data between Go – 2000 ms and Go + 3500 ms.



Dataset #2

Two data structures, called *monkeyL* and *monkeyN*
Each structure contains 7 fields:

- *spikes* is a 3-D tensor [*T*x*N*x*K*] containing the spiking activity of *N* neurons, across *K* trials and *T* times points. Spikes are binned in a 1-ms window (why do you think 1-ms?) and include data between Go – 2000 ms and Go + 3500 ms.
- *grip* is vector [*K*x1] containing the grip information for each trial (1 for SG, 2 for PG)

Dataset #2

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Each structure contains 7 fields:

- *spikes* is a 3-D tensor [*T*x*N*x*K*] containing the spiking activity of *N* neurons, across *K* trials and *T* times points. Spikes are binned in a 1-ms window (why do you think 1-ms?) and include data between Go – 2000 ms and Go + 3500 ms.
- *grip* is vector [*K*x1] containing the grip information for each trial (1 for SG, 2 for PG)
- *force* is vector [*K*x1] containing the force information for each trial (1 for HF, 2 for LF)

Dataset #2

Two data structures, called *monkeyL* and *monkeyN*
Each structure contains 7 fields:

- *spikes* is a 3-D tensor [*T*x*N*x*K*] containing the spiking activity of *N* neurons, across *K* trials and *T* times points. Spikes are binned in a 1-ms window (why do you think 1-ms?) and include data between Go – 2000 ms and Go + 3500 ms.
- *grip* is vector [*K*x1] containing the grip information for each trial (1 for SG, 2 for PG)
- *force* is vector [*K*x1] containing the force information for each trial (1 for HF, 2 for LF)
- *RT* is a vector [*K*x1] containing the reaction time on each trial (between Go and the switch release)

Dataset #2

Two data structures, called *monkeyL* and *monkeyN*
Each structure contains 7 fields:

- *spikes* is a 3-D tensor [*T*x*N*x*K*] containing the spiking activity of *N* neurons, across *K* trials and *T* times points. Spikes are binned in a 1-ms window (why do you think 1-ms?) and include data between Go – 2000 ms and Go + 3500 ms.
- *grip* is vector [*K*x1] containing the grip information for each trial (1 for SG, 2 for PG)
- *force* is vector [*K*x1] containing the force information for each trial (1 for HF, 2 for LF)
- *RT* is a vector [*K*x1] containing the reaction time on each trial (between Go and the switch release)
- *MT* is a vector [*K*x1] containing the movement time on each trial (between the switch release and the object touch)

Dataset #2

Two data structures, called *monkeyL* and *monkeyN*
Each structure contains 7 fields:

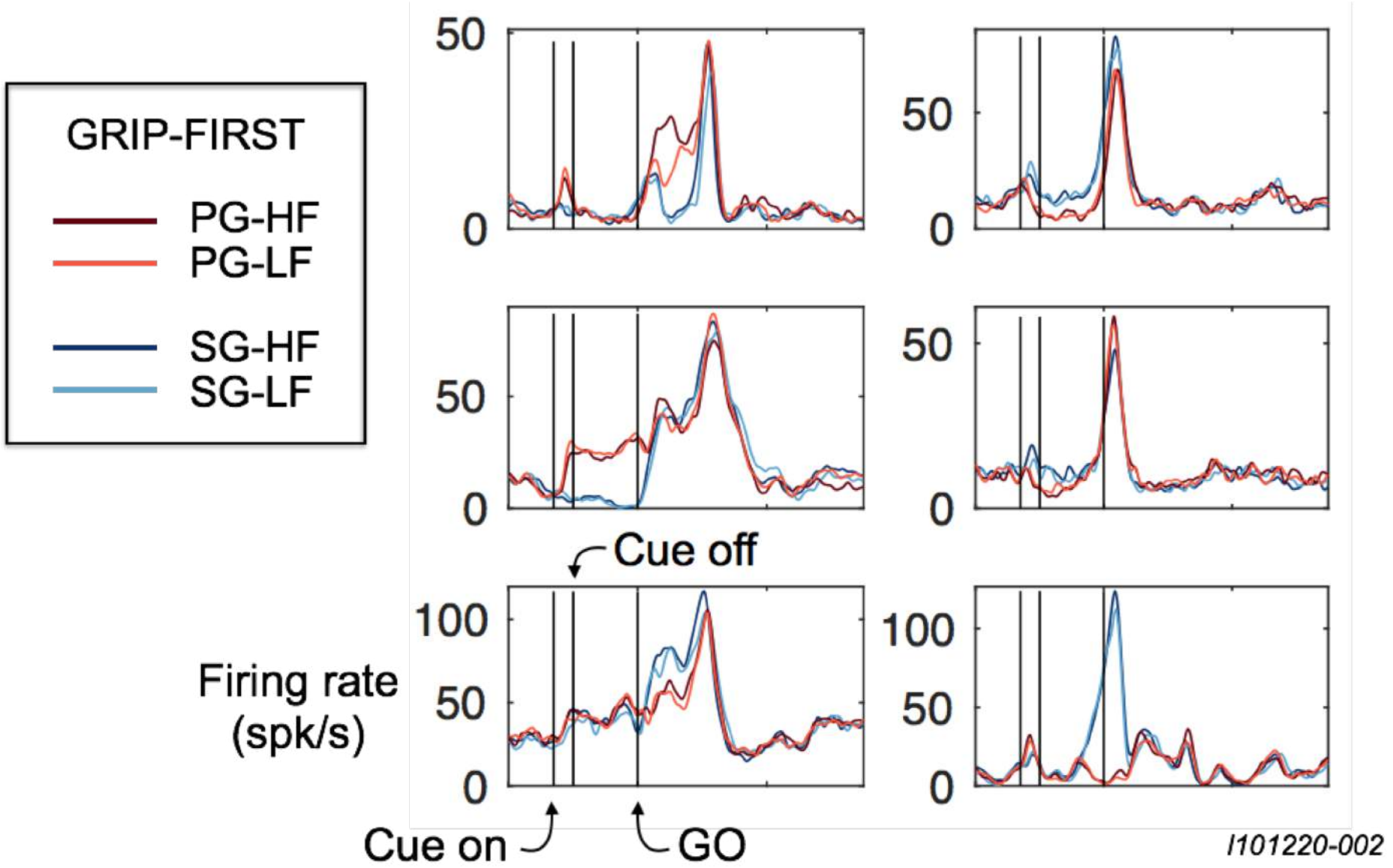
- *spikes* is a 3-D tensor [*T*x*N*x*K*] containing the spiking activity of *N* neurons, across *K* trials and *T* times points. Spikes are binned in a 1-ms window (why do you think 1-ms?) and include data between Go – 2000 ms and Go + 3500 ms.
- *grip* is vector [*K*x1] containing the grip information for each trial (1 for SG, 2 for PG)
- *force* is vector [*K*x1] containing the force information for each trial (1 for HF, 2 for LF)
- *RT* is a vector [*K*x1] containing the reaction time on each trial (between Go and the switch release)
- *MT* is a vector [*K*x1] containing the movement time on each trial (between the switch release and the object touch)
- *PT* is a vector [*K*x1] containing the pulling time on each trial (between the object touch and the object pulled)

Dataset #2

Two data structures, called *monkeyL* and *monkeyN*
Each structure contains 7 fields:

- *spikes* is a 3-D tensor [*T*x*N*x*K*] containing the spiking activity of *N* neurons, across *K* trials and *T* times points. Spikes are binned in a 1-ms window (why do you think 1-ms?) and include data between Go – 2000 ms and Go + 3500 ms.
- *grip* is vector [*K*x1] containing the grip information for each trial (1 for SG, 2 for PG)
- *force* is vector [*K*x1] containing the force information for each trial (1 for HF, 2 for LF)
- *RT* is a vector [*K*x1] containing the reaction time on each trial (between Go and the switch release)
- *MT* is a vector [*K*x1] containing the movement time on each trial (between the switch release and the object touch)
- *PT* is a vector [*K*x1] containing the pulling time on each trial (between the object touch and the object pulled)
- *neuron* is a vector [*N*x1] containing the ID of each neuron.

Dataset #2


GRIP-FIRST
PG-HF
PG-LF
SG-HF
SG-LF
50
0
50
0
50
0
50
0
Cue off
100
50
0
100
50
0
Firing rate
(spk/s)
Cue on
GO
I101220-002