RECEPTIVE FIELDS

11.2.2020

PROBLEM SET 5

* is posted!

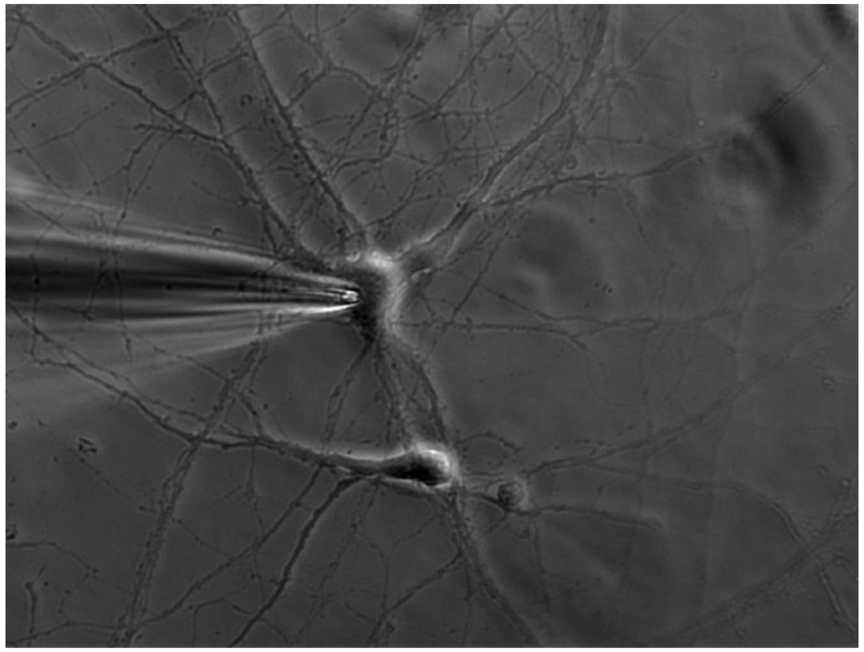
* due in ~three weeks (11/20)

VISUAL EXPERIMENT

* suppose we've placed an electrode into primary visual cortex (V1) to record spikes from a single neuron

* we can choose what visual stimuli to display, and know where our subject is fixating

* how do we figure out what this neuron is doing?



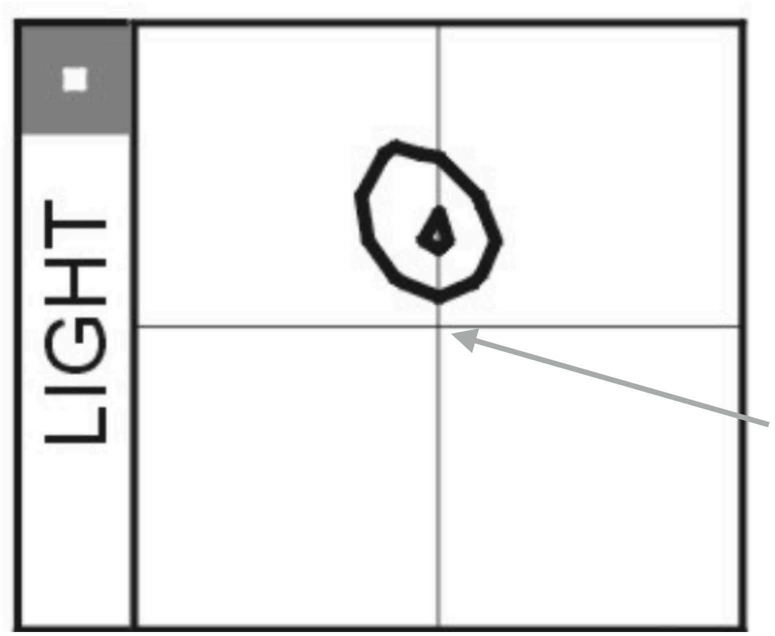
Video of Hubel & Wiesel experiment:

https://www.youtube.com/watch?v=8VdFf3egwfg

VISUAL EXPERIMENT

* each neuron in V1 has a **receptive field**
    * this is the region of visual space where stimuli cause the neuron to fire

an example receptive field



fixation point

RECEPTIVE FIELDS

* the same idea applies to other sensory neurons

  * in *somatosensory cortex*, each neuron has a receptive field localized somewhere on the body (e.g. the top of the left pinky finger)

  * in *auditory cortex*, each neuron has (typically) a spectral receptive field, meaning it only responds to certain frequencies of sound

RECEPTIVE FIELDS

* this leads to a more general definition of a receptive field:

  * a receptive field is the part of a “sensory space” that can elicit neural responses when stimulated

* so what is a “sensory space”? how is it different from, e.g., visual space?

VISUAL SENSORY SPACE

* what are some other visual “features” that are important components of the visual sensory space?

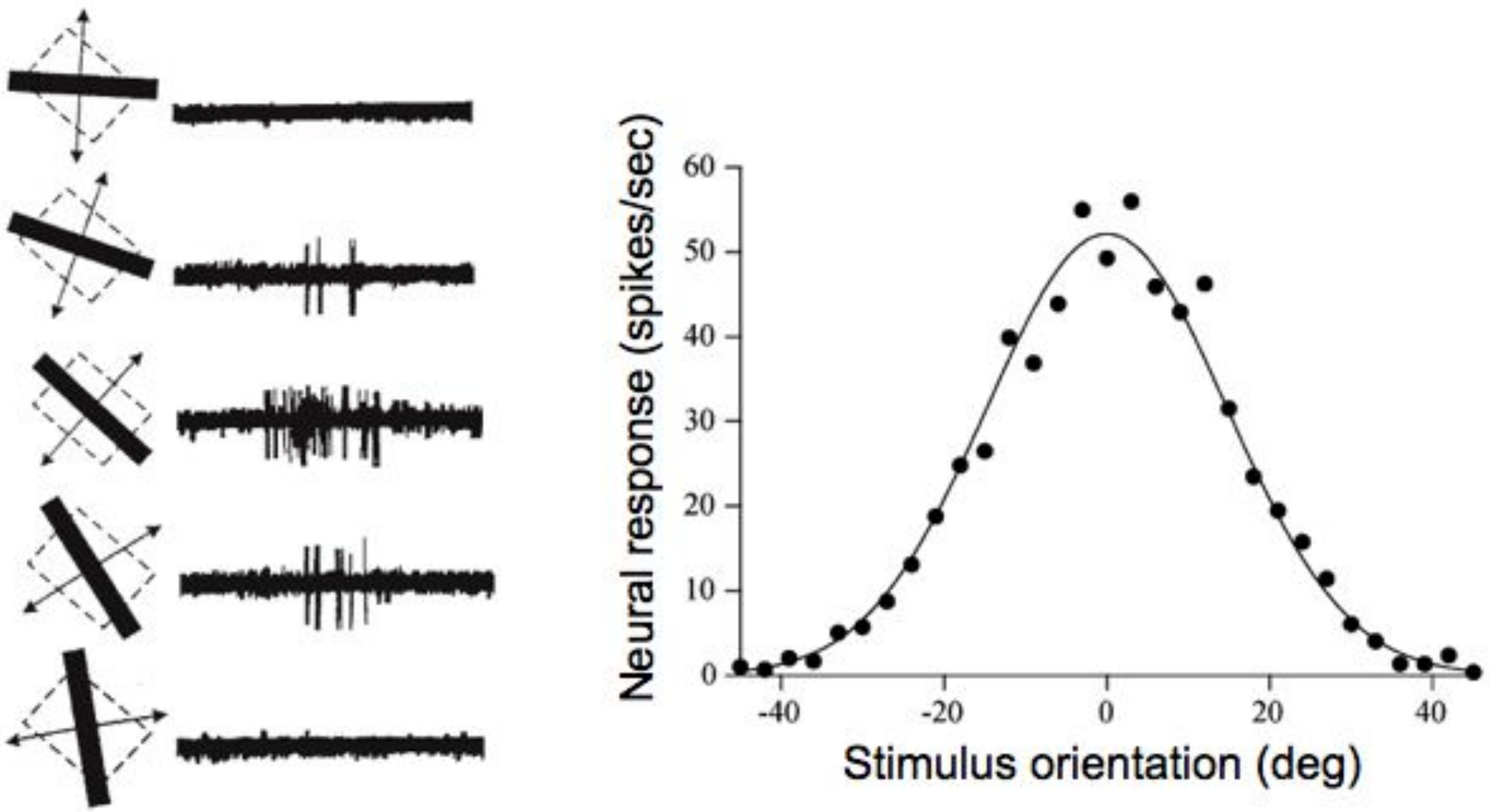
VISUAL SENSORY SPACE

* suppose we choose some other dimension of visual sensory space, like orientation

* we can measure the response of a V1 neuron to each orientation of a stimulus

* this gives us an “orientation tuning curve”

VISUAL EXPERIMENT



Hubel & Wiesel, 1968

VISUAL SENSORY SPACE

* now it’s getting a bit complicated. neurons in V1 have:

  * a visual receptive field

  * an orientation tuning curve

  * ocular dominance

  * “simple” or “complex” behavior (response to moving stimuli)

GENERALIZED RECEPTIVE FIELDS

* we can summarize all of these properties as a *function*

* suppose that Y is the firing rate of our neuron & X is the stimulus

* we can relate the two through a function,

$$f(X) = Y,$$

  where f is a function that predicts the response of the neuron to any stimulus

GENERALIZED RECEPTIVE FIELDS

* we can think of this function as a more general version of the “receptive field” of our neuron

* what is the form of this function?

* how do we parameterize the stimulus?

GENERALIZED RECEPTIVE FIELDS

* we can assume that the function *f* is determined by a set of parameters *p*

* these parameters could describe, e.g., the location of the visual receptive field, the orientation selectivity, and so on

* estimating the parameters from a set of (stimulus, response) pairs is called *system identification*

GENERALIZED RECEPTIVE FIELDS

* the simplest form that this function could take is *linear*

* this means that the response Y is a linear function of the stimulus features

  * $Y = \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots$

* we will write this form of model using matrix multiplication notation: $Y = X\beta$

LINEAR MODELS

$$Y = X\beta$$

image pixels

X1, Y=0.7

X2, Y=0.3

X3, Y=0.0

LINEAR MODELS

$$Y = X\beta$$

image pixels

X

14	100	120	121
12	58	103	107
8	32	78	99
10	14	62	102
3	32	56	81

…

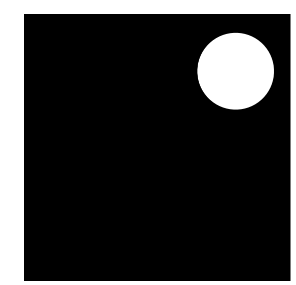
⋮

unravel

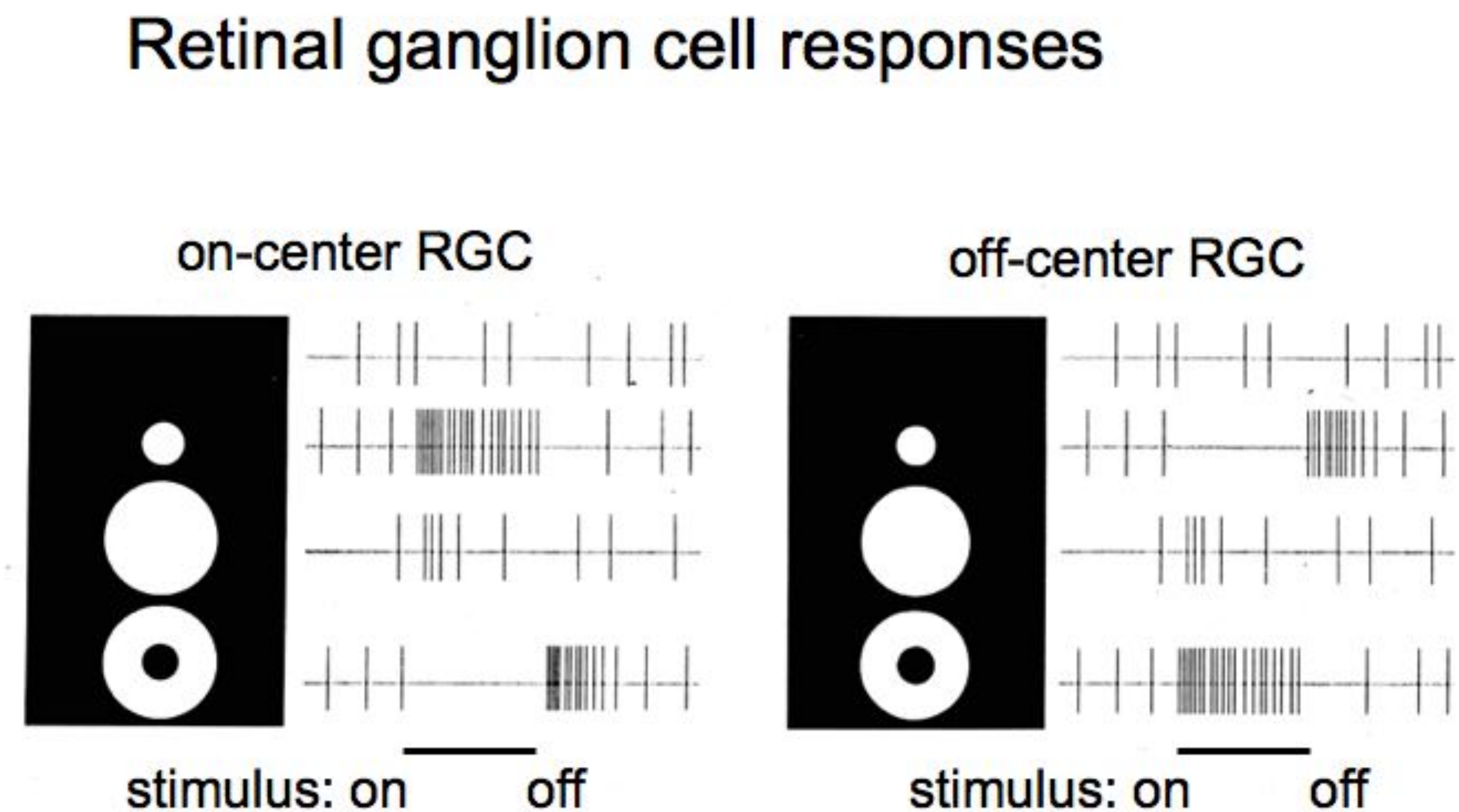
Y = X · B

X	B
14	1
12	1
8	1
10	1
3	1
100	0
58	0
32	0
14	0
32	0
120	0
103	0
78	0
62	0
56	0
121	0
107	0
99	0
102	0
81	0
⋮	⋮

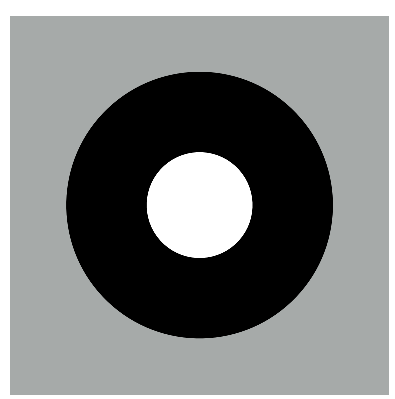
"filter"



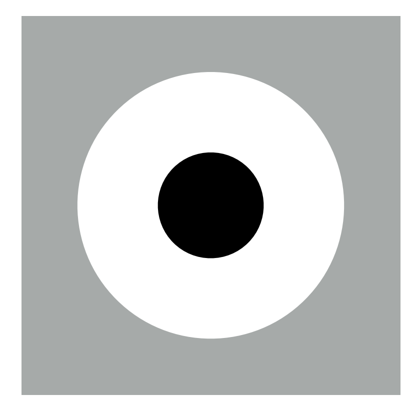
LINEAR MODELS



Beta
(on-center)



Beta
(off-center)



http://www.cns.nyu.edu/~david/courses/perception/lecturenotes/ganglion/ganglion.html

FITTING LINEAR MODELS

* suppose we have a bunch of (X,Y) pairs (i.e. the response of the neuron to many images)

* how do we figure out what β is?

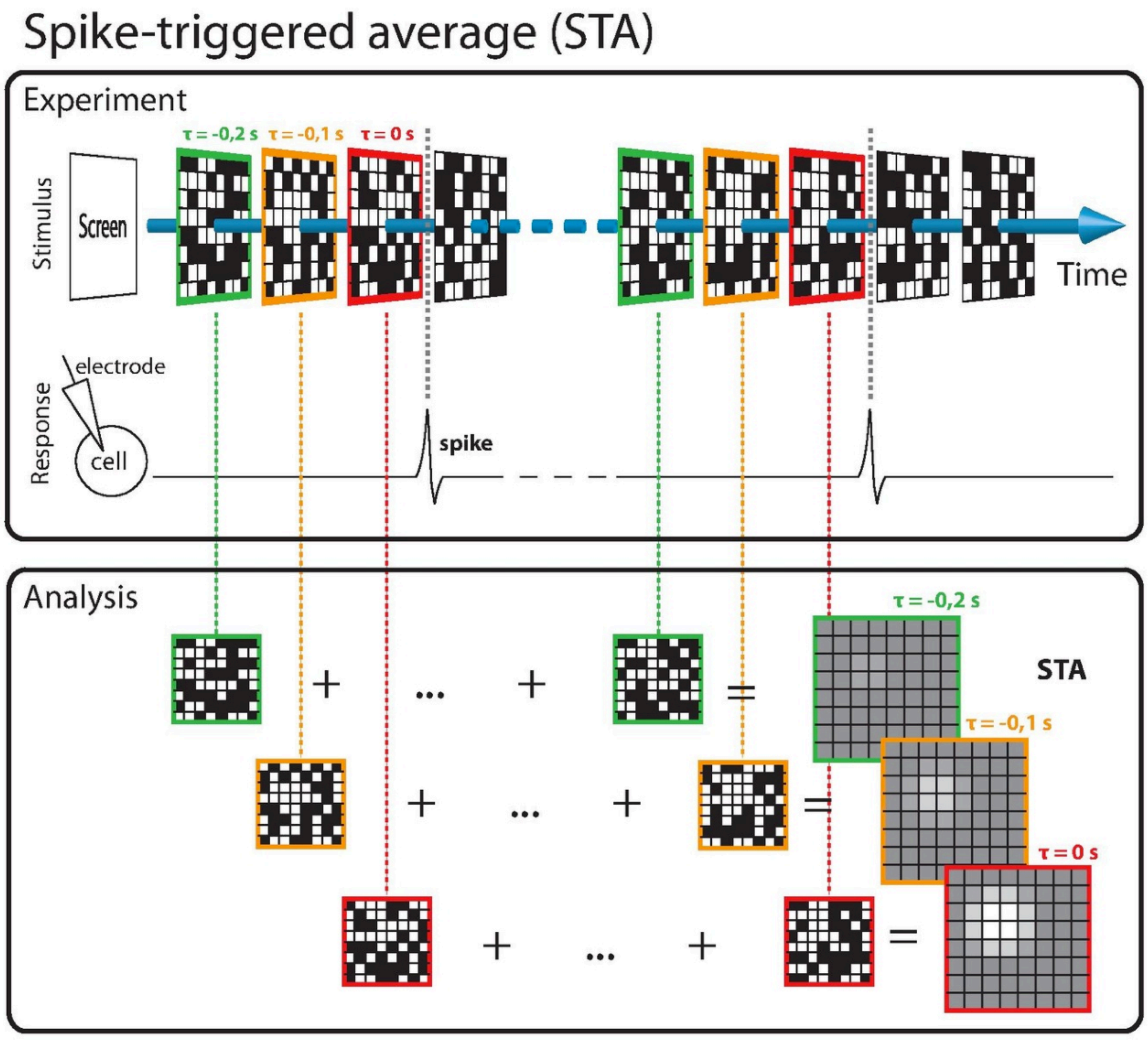
FITTING LINEAR MODELS

* one way is **spike-triggered average** (STA)

* in STA, we assume that each stimulus either elicited a spike or did not (responses are 1 or 0)

* then we take the average of all the stimuli that elicited a spike

FITTING LINEAR MODELS



FITTING LINEAR MODELS

* this method is really bad unless we designed our experiment specifically to use STA

* because it doesn’t account for *correlations* among the stimulus channels

FITTING LINEAR MODELS

* e.g. imagine this is the data:

* $Y = [1,1,0,1,0]$
  $X_1 = [1,1,0,1,0]$
  $X_2 = [1,0,0,1,0]$

* STA would say that $beta_1=1$, and $beta_2=0.66$

* but a simpler explanation would be that $beta_2=0$, since X_1 already explains everything about Y

FITTING LINEAR MODELS

* the solution? regression!

END