

# Searching the horizon for small targets

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# Background

The Navy wanted models predicting target detection times on workstations controlling remotely piloted boats.

If there was just one target and it could only be detected in the fovea, the search model should be simple.

# Summary

Search task: Find a small target on the horizon.

Model: Random search with a saccade-distance preference distribution and inhibition-of-return.

Lesson learned: Simple inhibition-of-return model predicts mean and standard deviation of search times, but is directly refuted by the data.

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# Stimuli

Screen resolution: 40 pixels per deg

Image size in deg: 32 X 25 (W X H)

Sky is upper half of the display.

Ocean is lower half.

Sky RGB color: 0 128 255 => 45.4 cd/m<sup>2</sup>

Target, ocean: 0 0 128 => 6.62 cd/m<sup>2</sup>

Target size: 1/40 X 1/40 deg

Target in lowest row of sky

Target position random -30:+30 deg

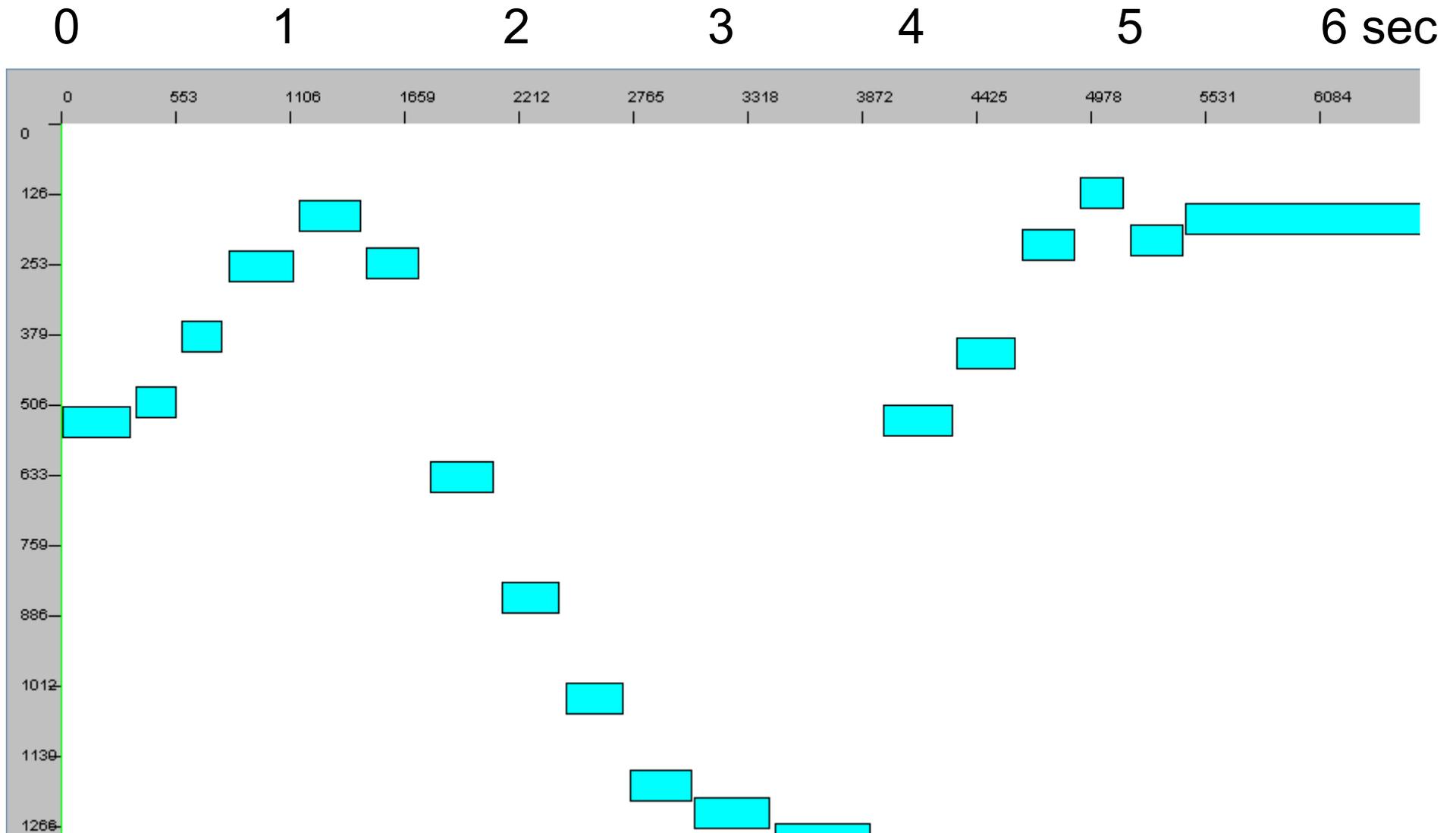
# Eyelink II



# Methods

Eye positions recorded at 250 Hz by an SR Research Eyelink I or II head-mounted tracker. The experiment was controlled by an SR Research Experiment Builder program. A test run had 12 trials, each with a target position chosen at random. Before each 3 trial group a recalibration was performed. The sequence of fixations was extracted by an SR Research Data Viewer program.

# Search data: Test 2 trial 2



# Fixation Results

	runs	ave	std	CV
AA	3	17.4	11.8	0.67
KB	10	24.6	18.0	0.74
JK	4	21.2	14.8	0.68

# Distance and Inhibition Model

Select fixation on horizon near fixation mark

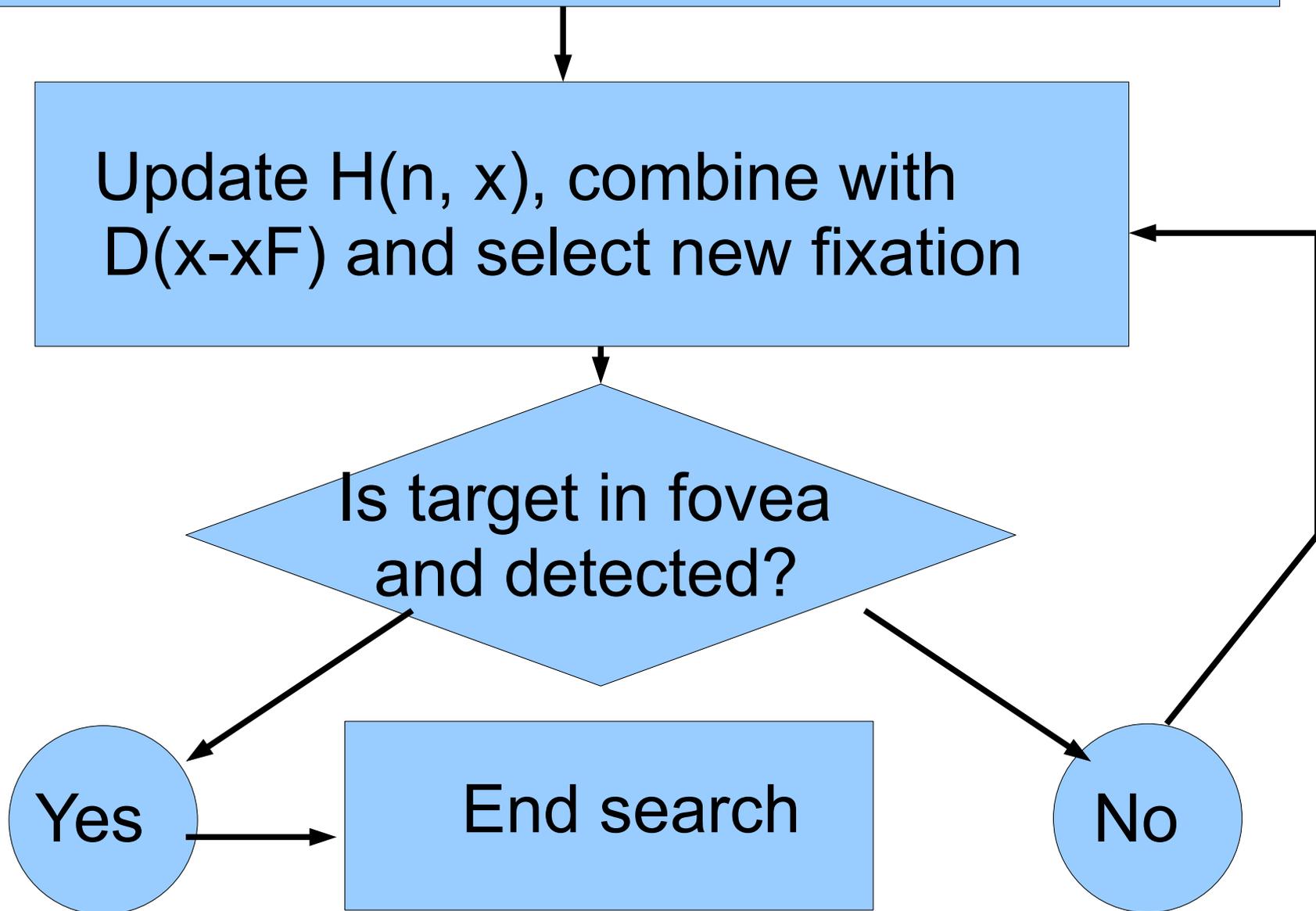
Update  $H(n, x)$ , combine with  $D(x-x_F)$  and select new fixation

Is target in fovea  
and detected?

Yes

End search

No



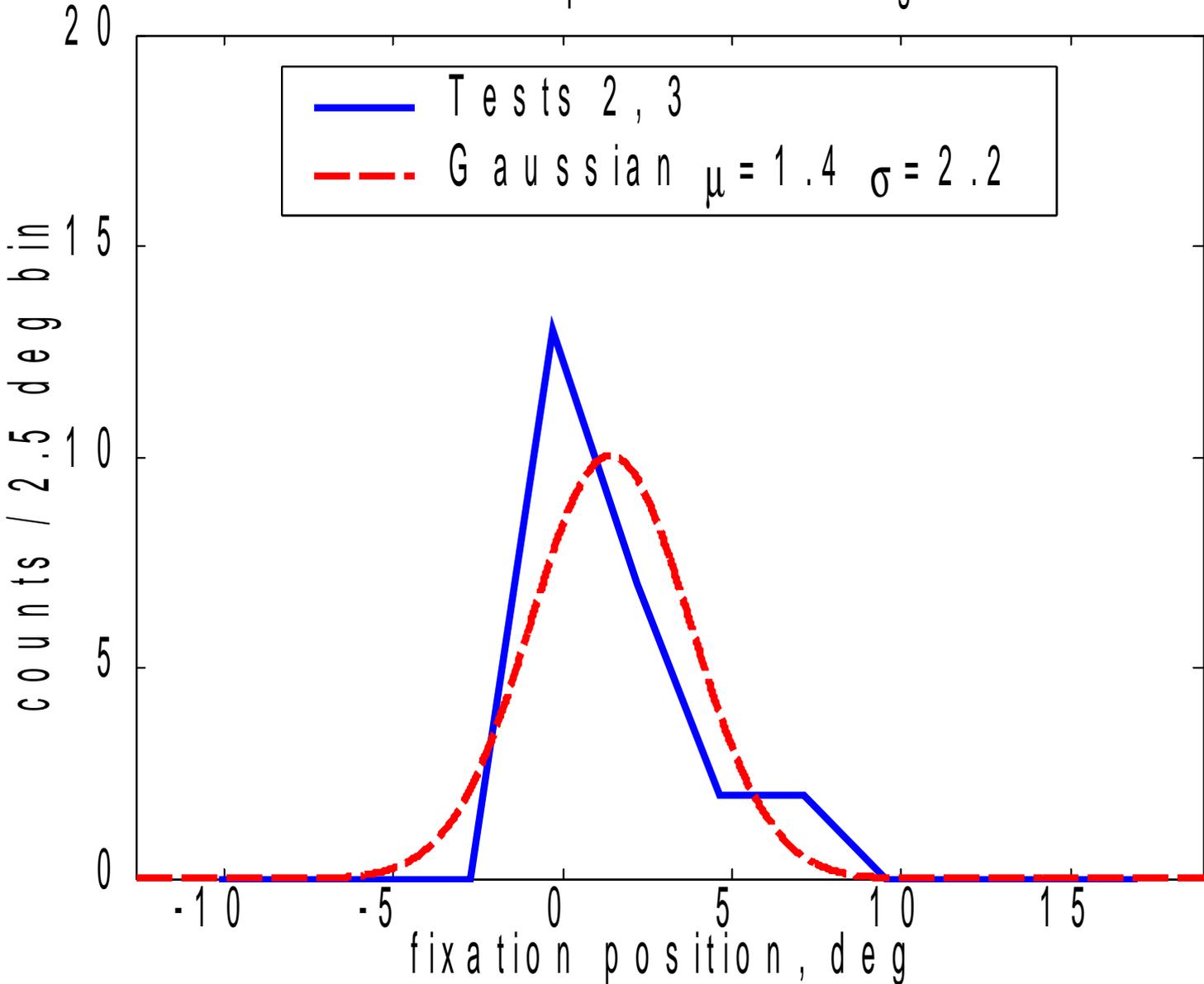
# Distance preference distribution

Let  $D(x)$  be the probability density distribution of the position of next fixation given that the current fixation is at zero eccentricity and there is no Inhibition of Return.

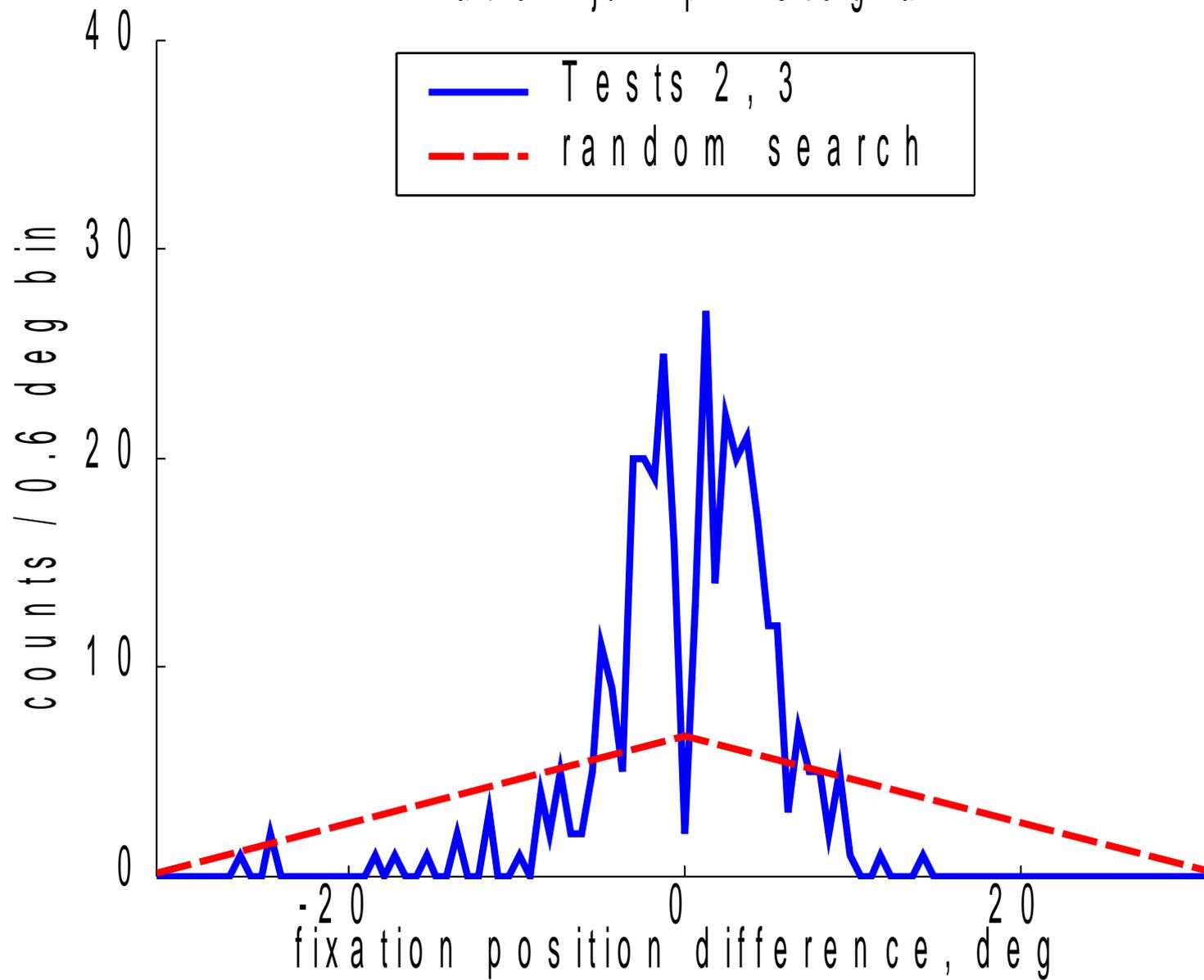
Let  $x_0$  and  $x_1$  be the ends of the horizon and  $x_C$  be the center of fixation

The the un-normalized distance penalty is  
 $D(x-x_C)$ ,  $x_0 < x < x_1$

Fixation 1 position histogram



# Fixation jump histogram



# Inhibition of Return

$H(n, x)$  is Inhibition on fixation  $n$  at position  $x$

$$H(1, x) = 0$$

$F(n, x) = 1$  if  $x$  is in the fovea on trial  $n$ ,  
 $= 0$  otherwise

Update rule:

$$H(n, x) = \min(1, h H(n-1, x) + F(n, x))$$

Usage: un-normalized distribution is

$$(1-H(n, x)) D(x-x_C)$$

# Model Parameters

initial distribution:  $m = 1$  deg,  $s = 2$  deg

distance preference distribution:  $s = 5$  deg

inhibition persistence factor:  $h = 0.99$

foveal width: 1 deg

# Fixation Results

	runs	ave	std	CV
AA	3	17.4	11.8	0.67
KB	10	24.6	18.0	0.74
JK	4	21.2	14.8	0.68
model	25	18.2	13.3	0.73

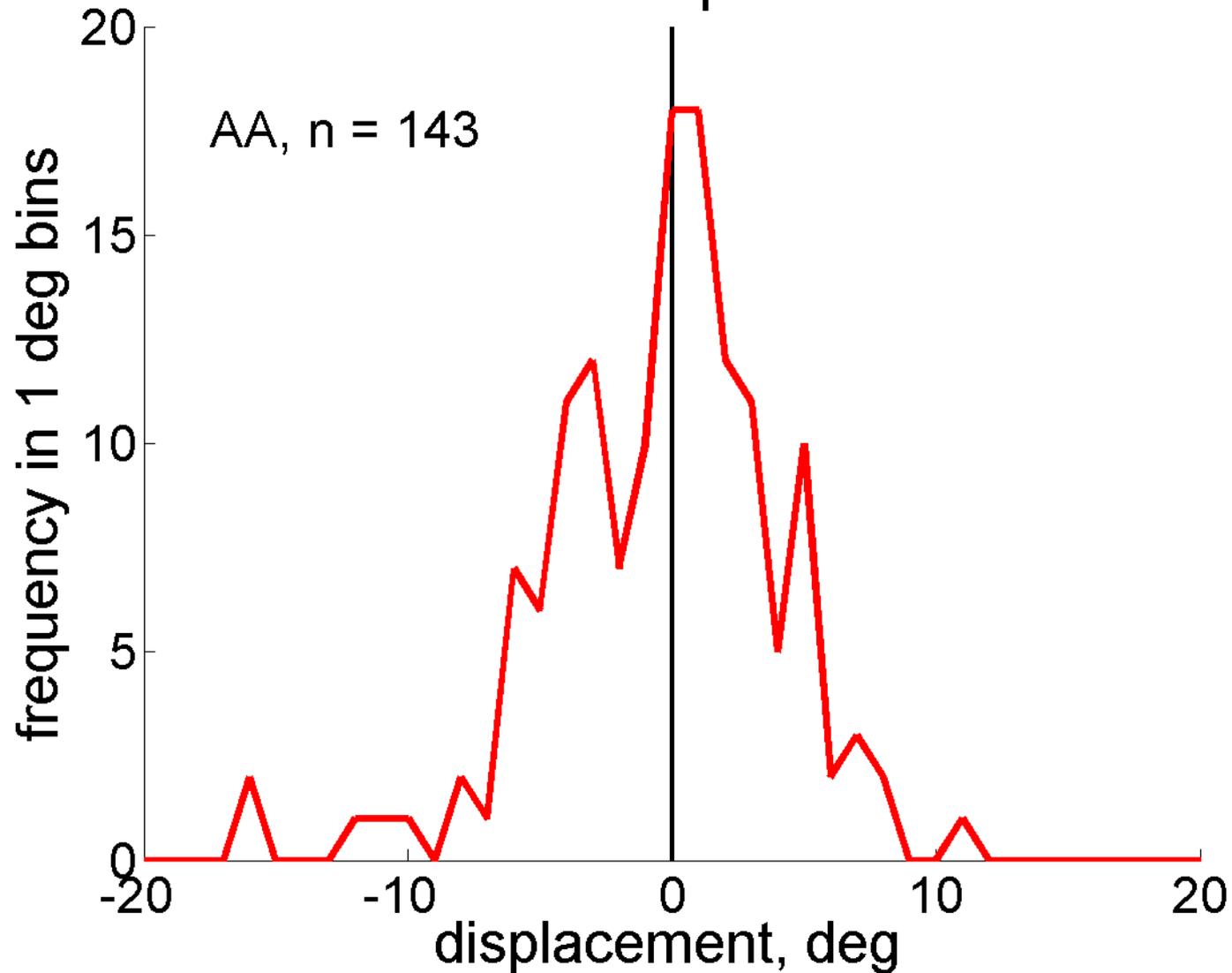
# Are Prior Fixation Locations Avoided?

The optimal search model and the inhibition-of-return models predict that the observer should not revisit a place that was just visited.

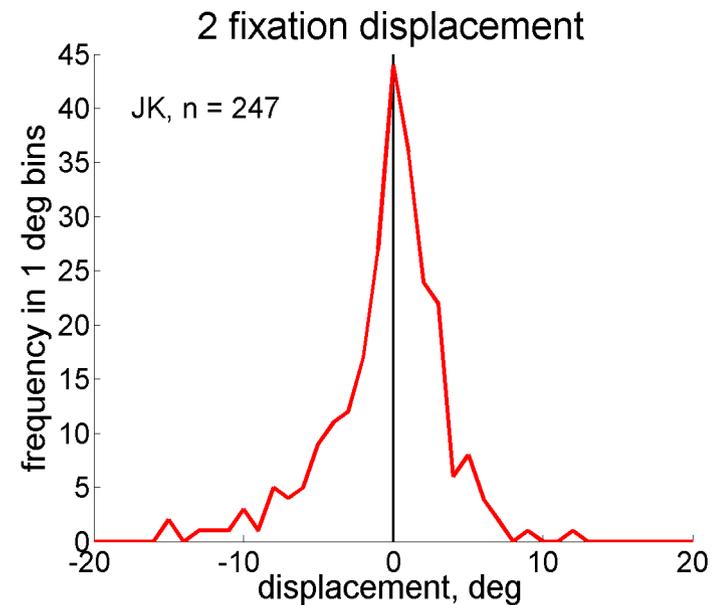
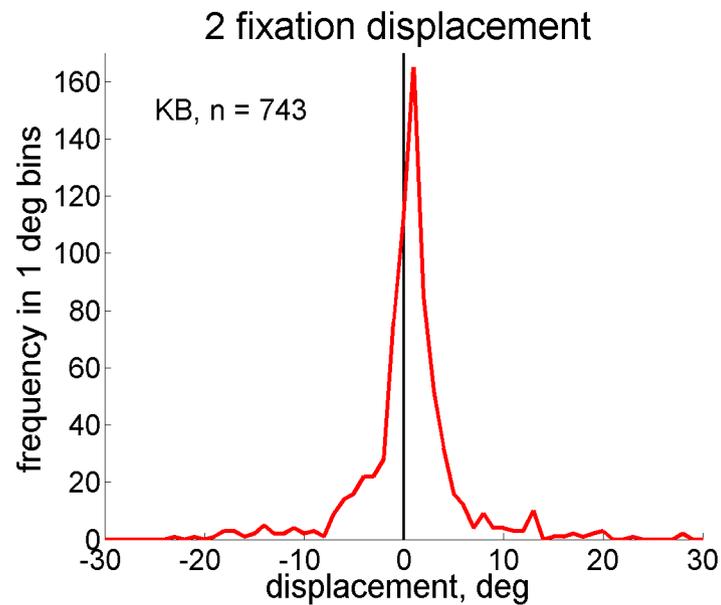
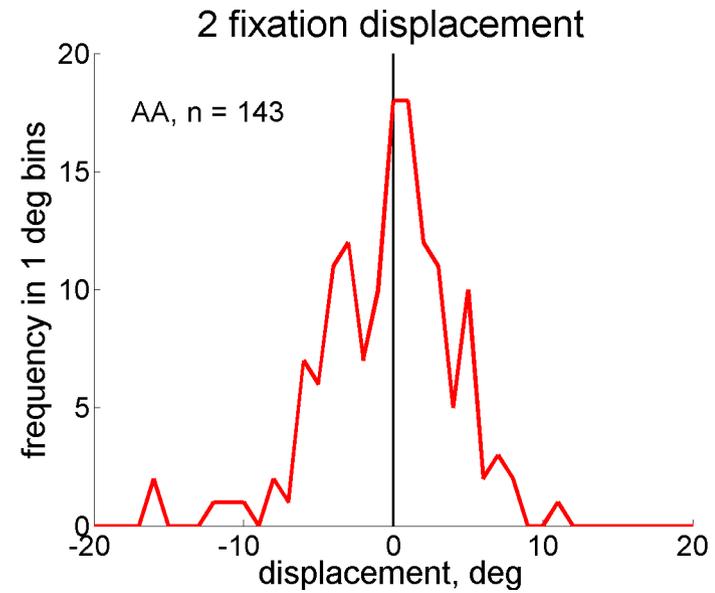
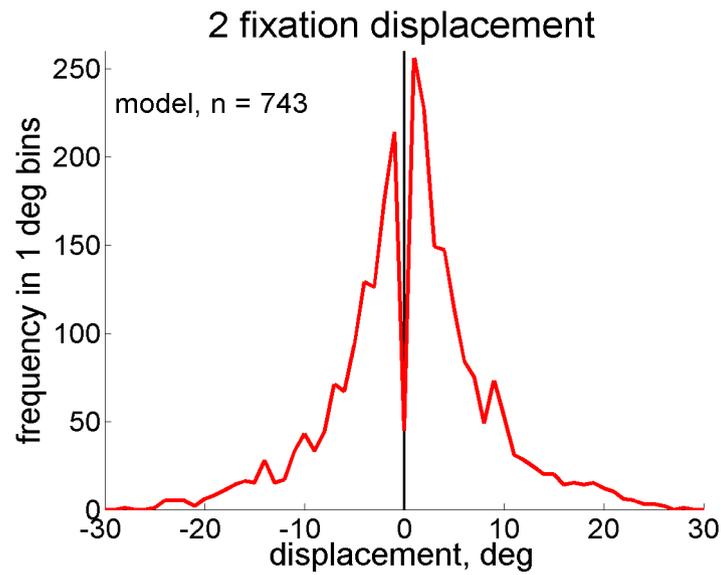
We plotted the location of fixations relative to the location of the fixation two fixations back.

# Previous Fixation Location Not Avoided

2 fixation displacement



# Previous Fixation Location Not Avoided



# Summary

Search task: Target on horizon in uniform sky above a uniform ocean

Model: Random search with a saccade-distance preference distribution and inhibition-of-return.

Lesson learned: Simple inhibition-of-return model predicts mean and standard deviation of search times, but is directly refuted by the data.

# Suggestion

Eye position recorders are usually calibrated with a simple “follow the spot” procedure.

A short “horizon” search and could help calibrate the distance preference parameter before expectations and stimulus attractors are included.