Simulated quantum sampling of Sloan optotypes

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Purpose

Previous research into letter visibility of under-sampled letters has used predominantly regularly sampled letters.

e.g. Legge 2007

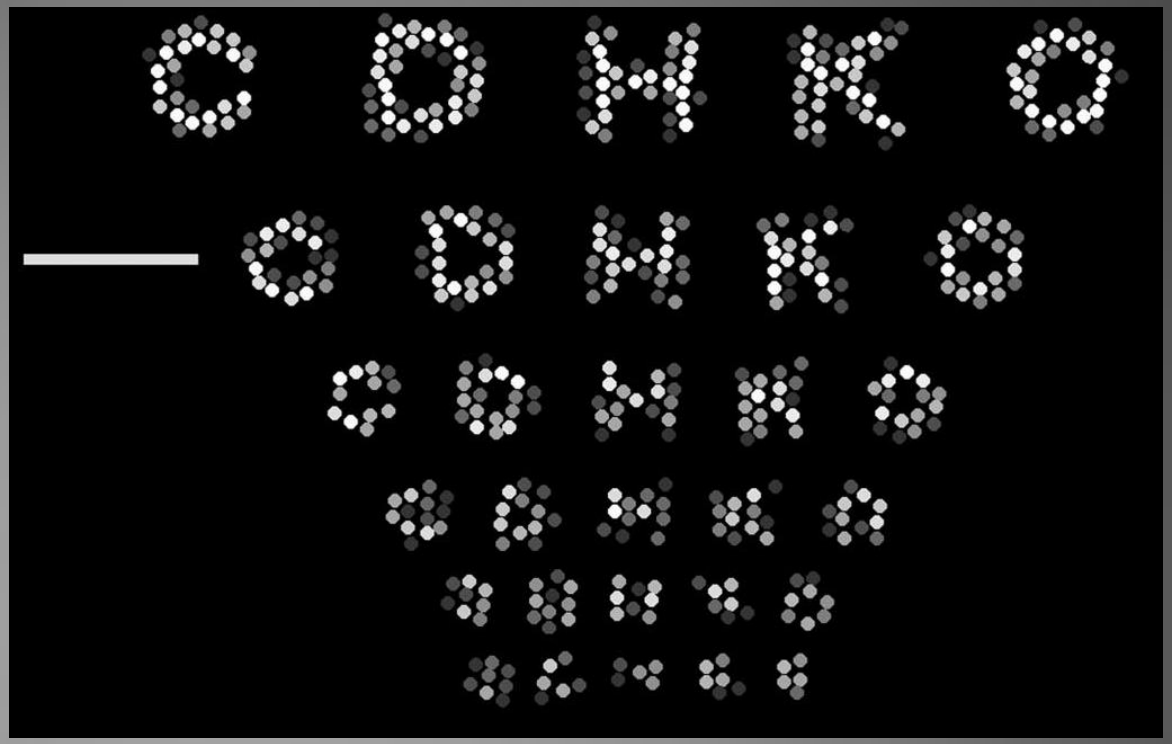
Carkeet et al 2008

Erdmann & Neale 1968.

Sampling densities of 3x3 to 5x5 samples per letter required to recognise letters at threshold

Carkeet et al OVS 2008

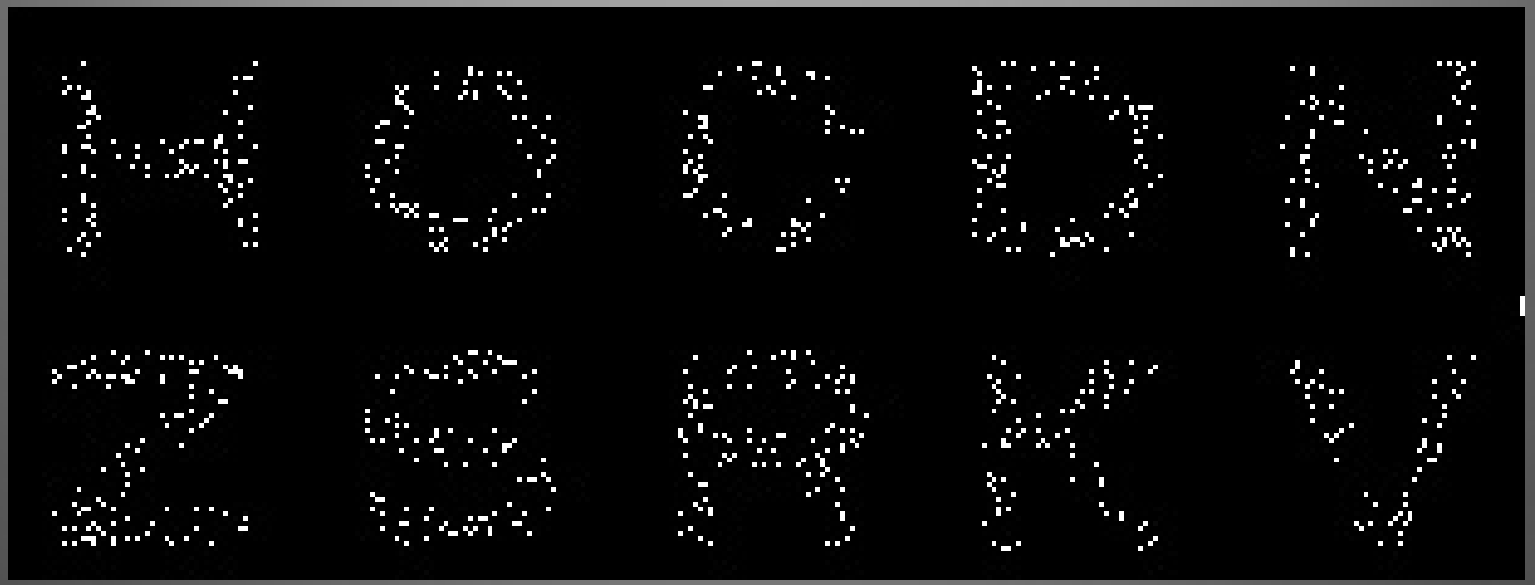
5x 5 samples per letter



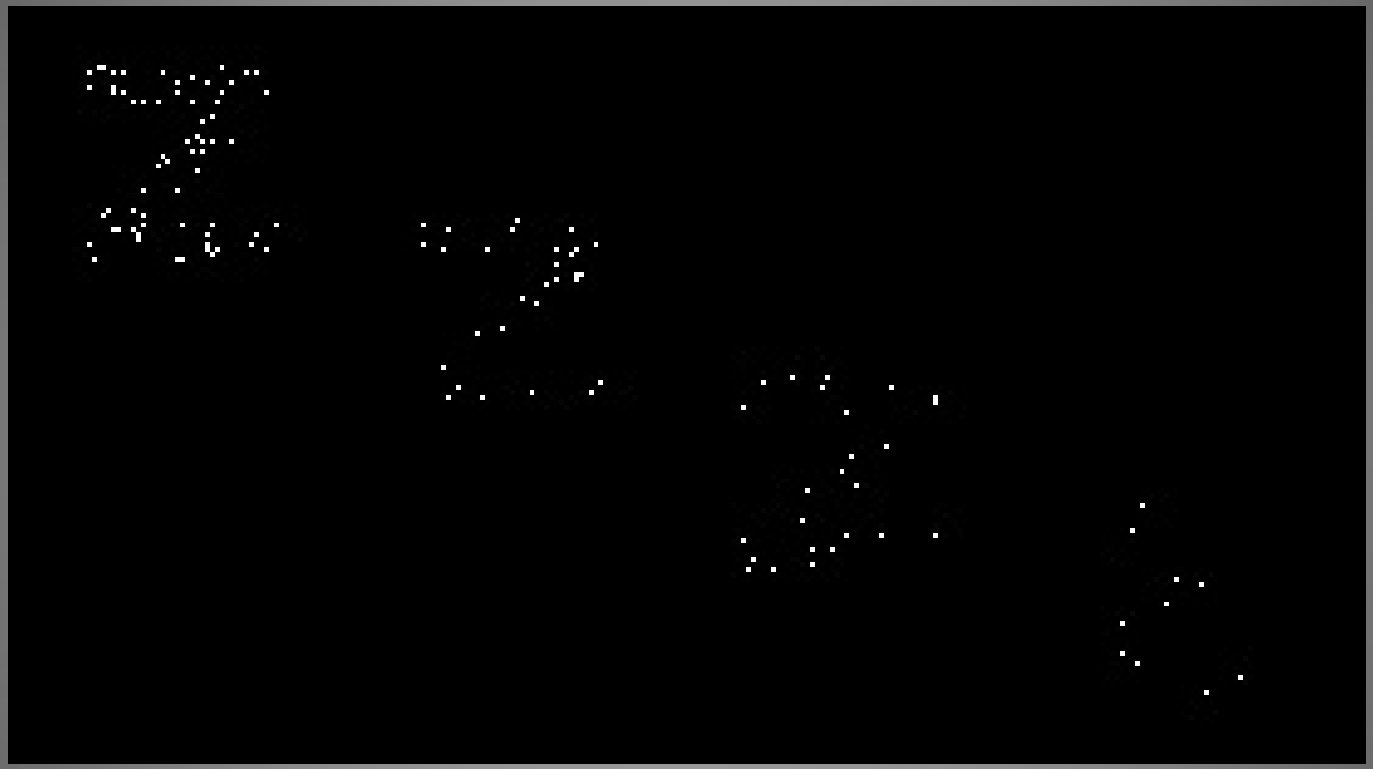
- Adding small amounts of sampling irregularity (e.g. cone like arrays) increases thresholds slightly.

What happens for much more random sampling?

- In nature, such sampling occurs with the quanta reflected or emitted or absorbed at very low levels, and spatial information is lost from the letter, because it can only be detected in distinct randomly positioned chunks.



- At very low light levels, sufficiently few quanta will be collected for the letter not to be recognised.



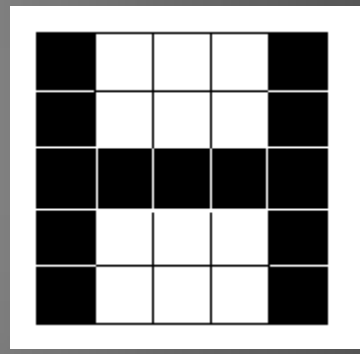
Purpose

- What is the smallest number of randomly distributed bits of information required to recognize a Sloan letter (Optotype used on EDTRS charts).

METHOD

- Subjects were the authors.
- Stimuli: Sloan Optotypes. Presented on a LCT monitor viewed at a distance of 1 m.
- Pixel brightness 6 x 10^{-6} cd/ pixel. Pixel size 0.61 mm. or 2.1 minutes of arc. All pixels well above threshold.
- Sloan letters are drawn 5 “strokes” wide and 5 “strokes” high.
- Stimuli were presented drawn with pixel densities of 1,2,4,8,16,32,64 pixels/stroke.

» 20/42 to 20/ 2684 size.



Psychophysics

Stimuli : random Sloan letters presented for 2 s.

Subject response: one of the 10 Sloan letters

Intial probability of an individual pixel being switched on approx 0.4 to 0.6 $\log_{10}$ units above threshold.

Blocks of 5 presented at same pixel prob

Successive blocks presented at 0.2 log units lower.

Until 3 mistakes in a block of 5.

(Used for letter counting thresholds).

Then 2 further smaller blocks included for use in Probit analysis.

Thresholds 2 ways

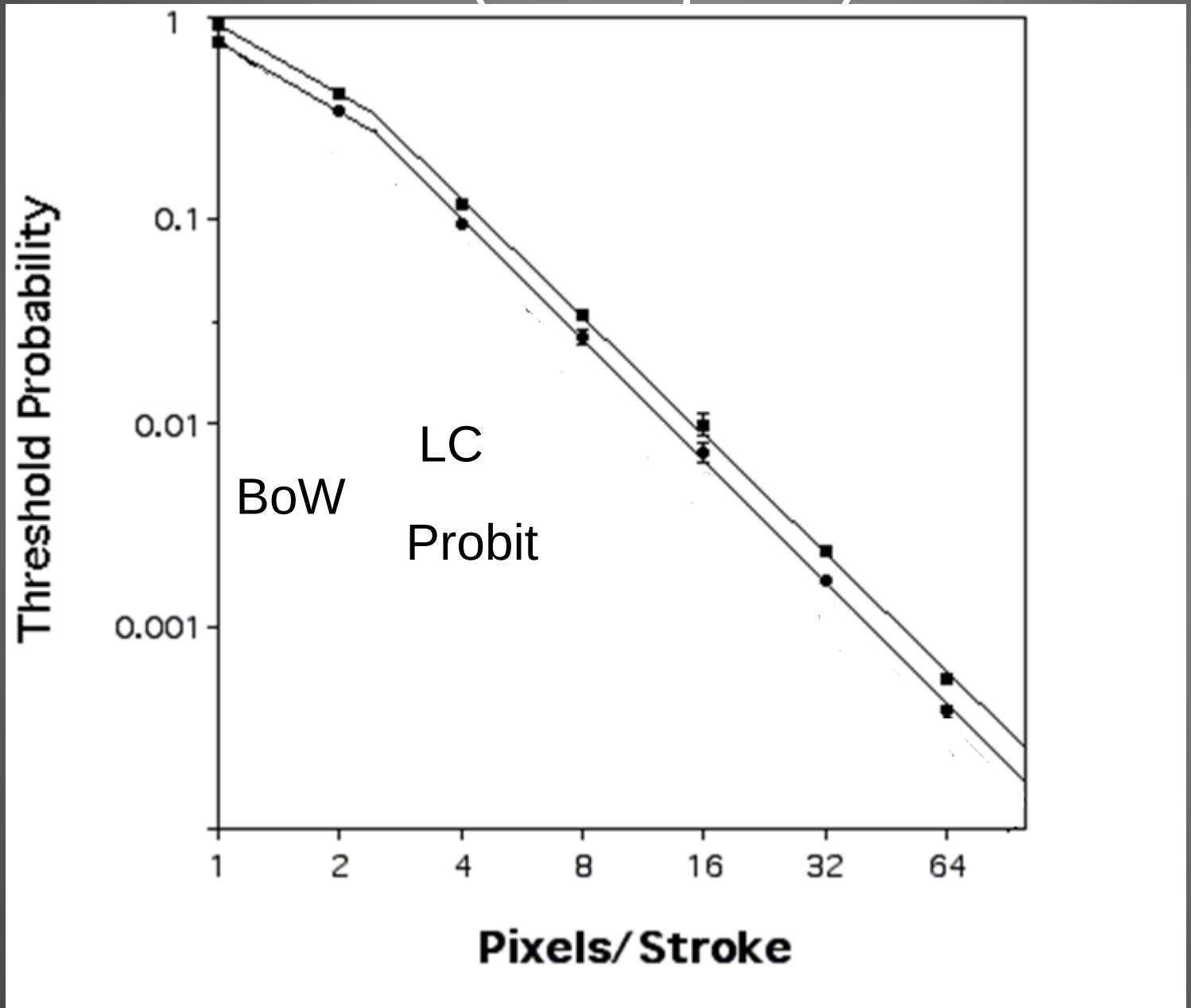
- Bailey's letter counting (modified)
- $\log_{10}$ threshold= $\log_{10}$ (Starting Prob) - (correct letters x0.04)+ 0.2.

- Probit analysis.

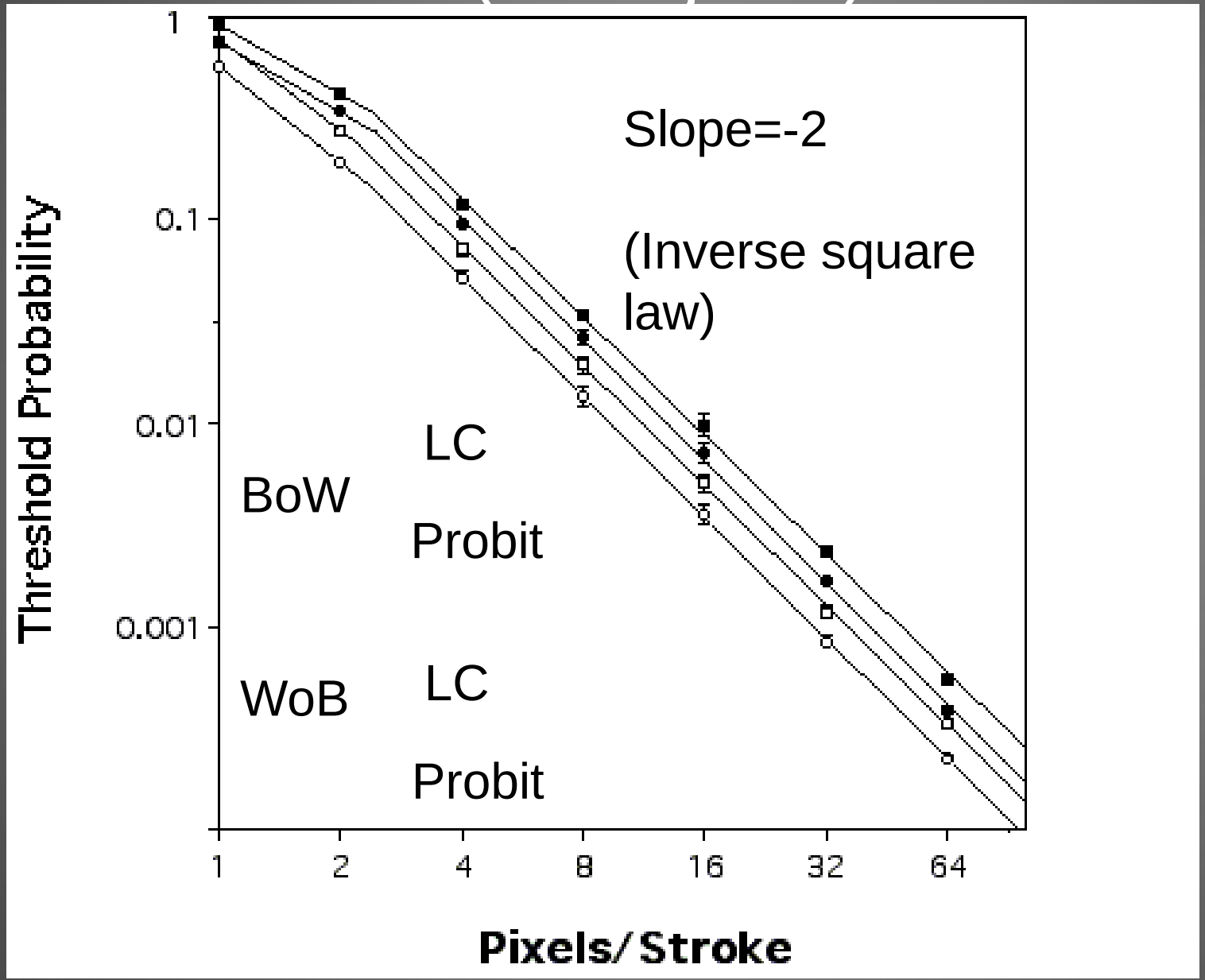
2 Polarities

- WoB
- BoW

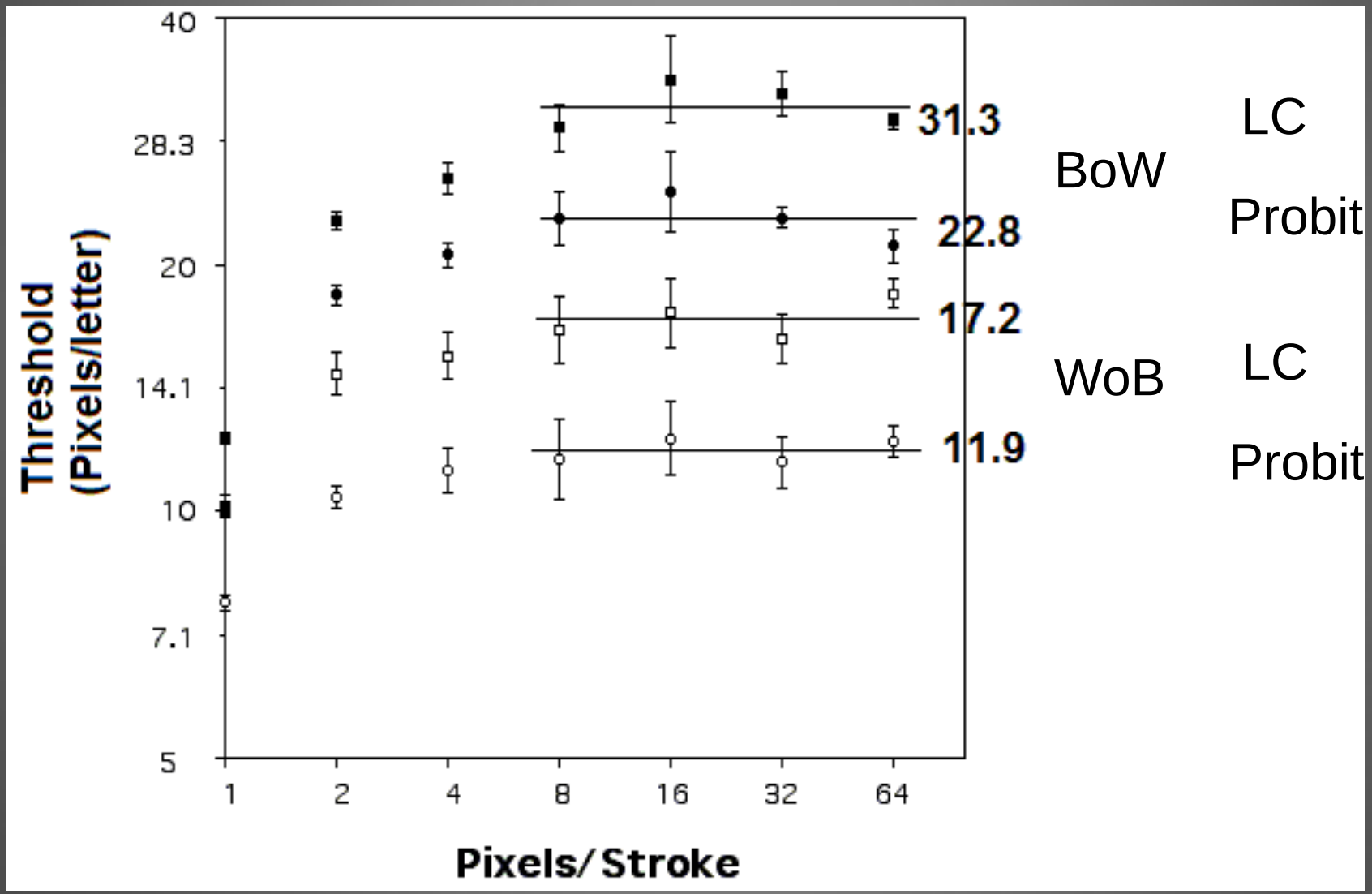
Results (4 subjects)

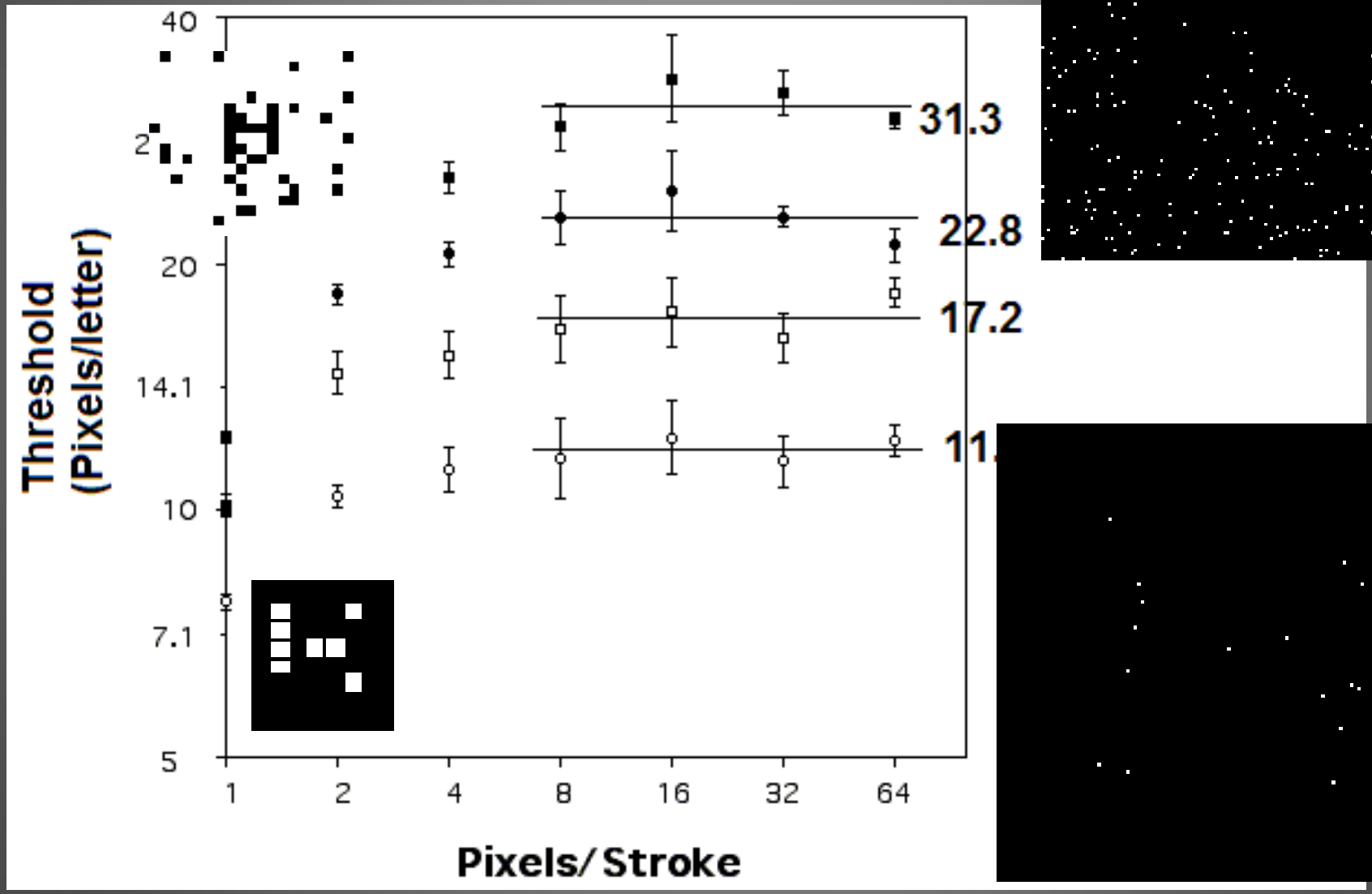


Results (4 subjects)

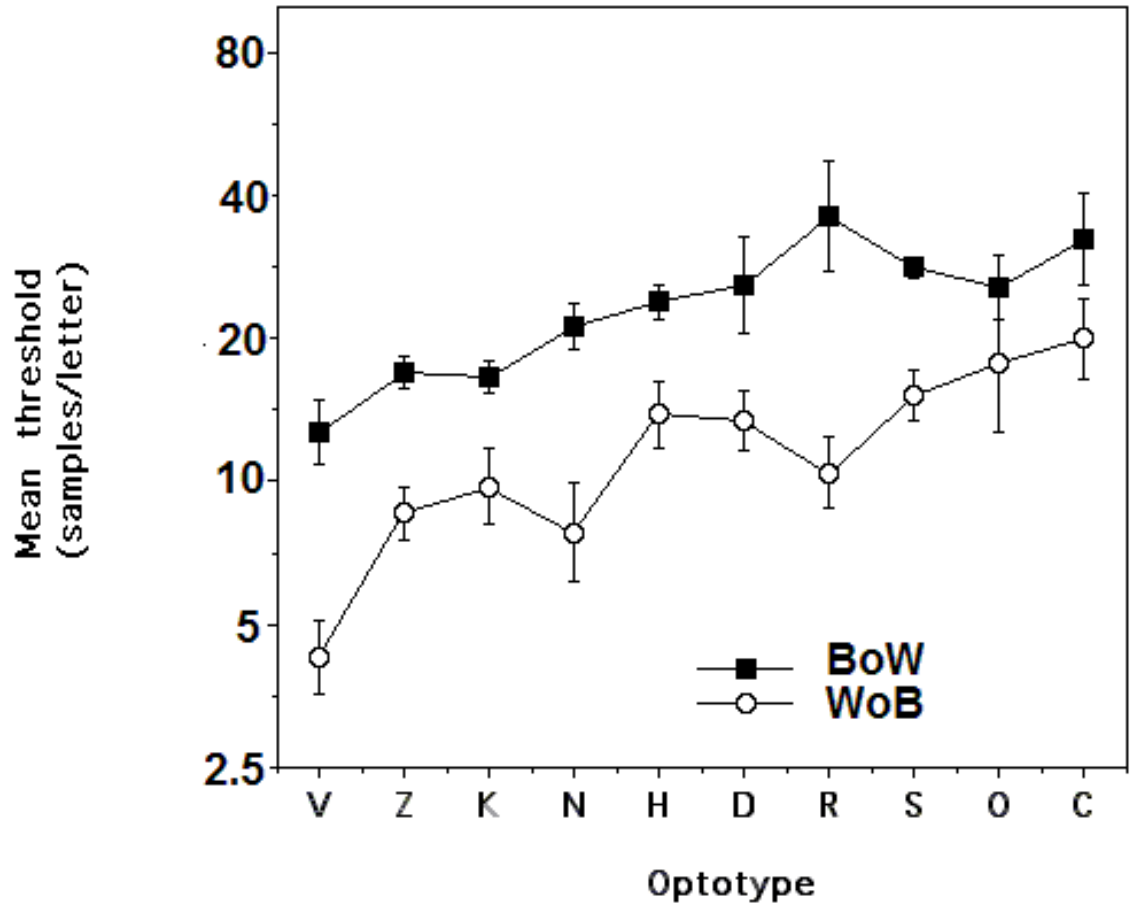


Expressed in terms of average pixels switched on (WoB) or blocked (BoW)



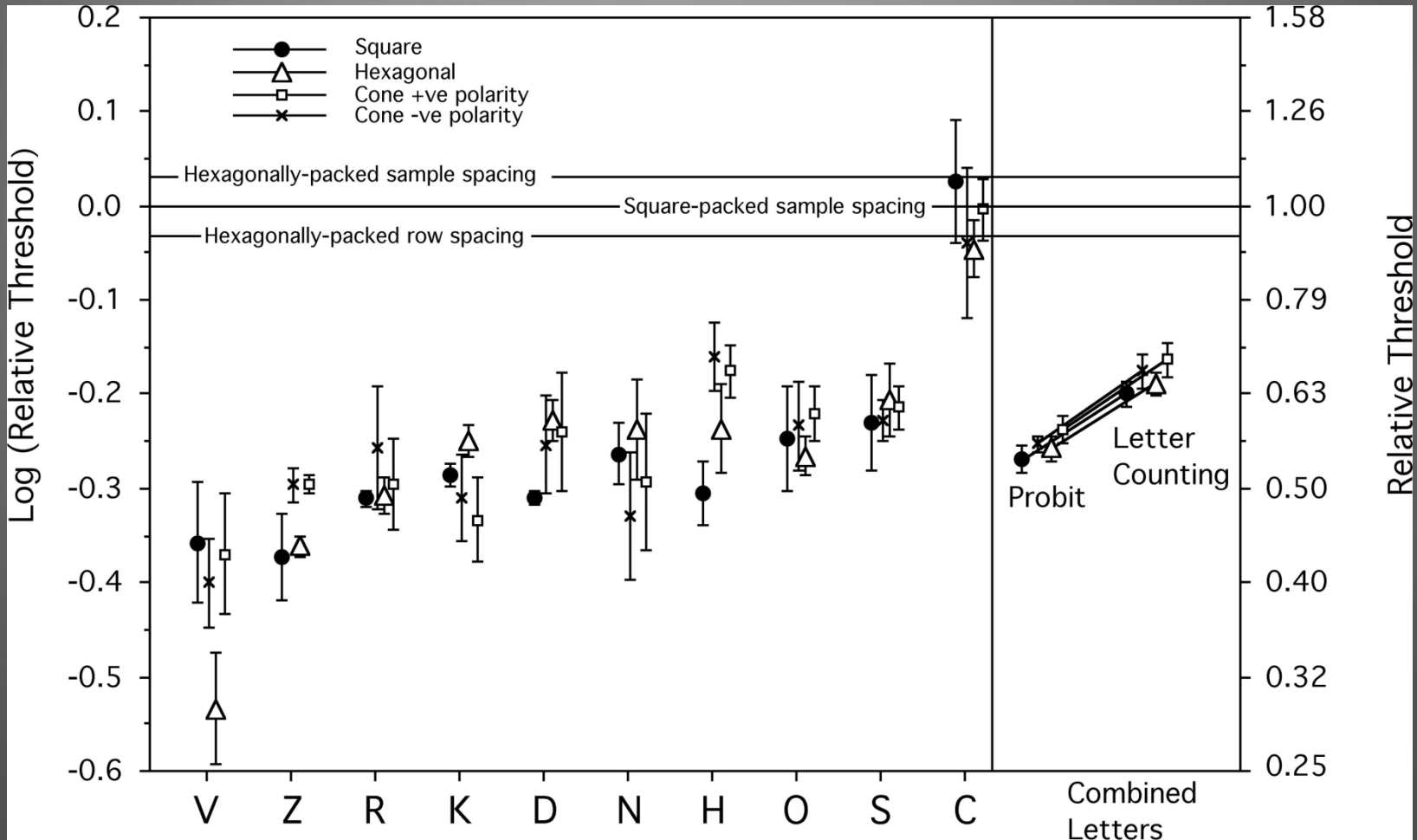

40
20
14.1
10
7.1
5
1
2
4
8
16
32
64
Threshold
(Pixels/letter)
Pixels/Stroke
31.3
22.8
17.2

Significant difference between Optoypes in terms of thresholds



Similar to previous work on more regular sampling (rho=0.83)

(Carkeet et al,2008)

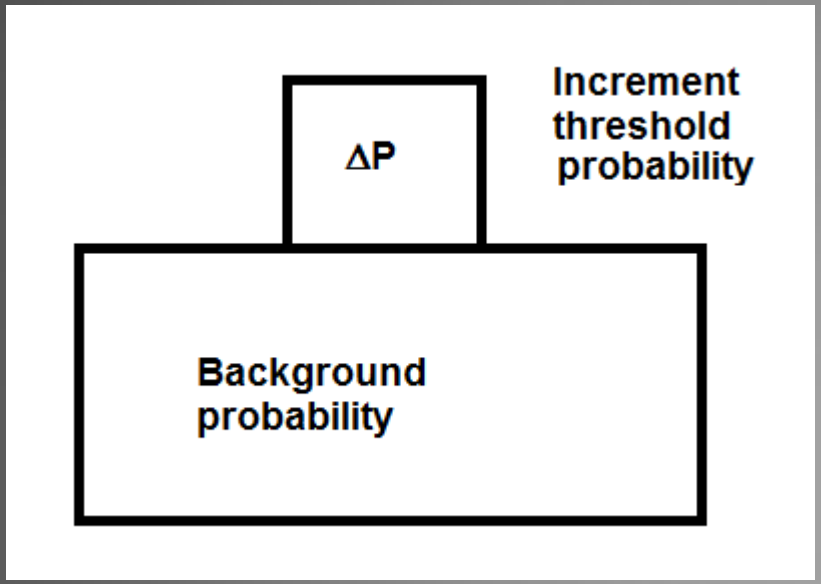


Simulating “Contrast”

- Why ?

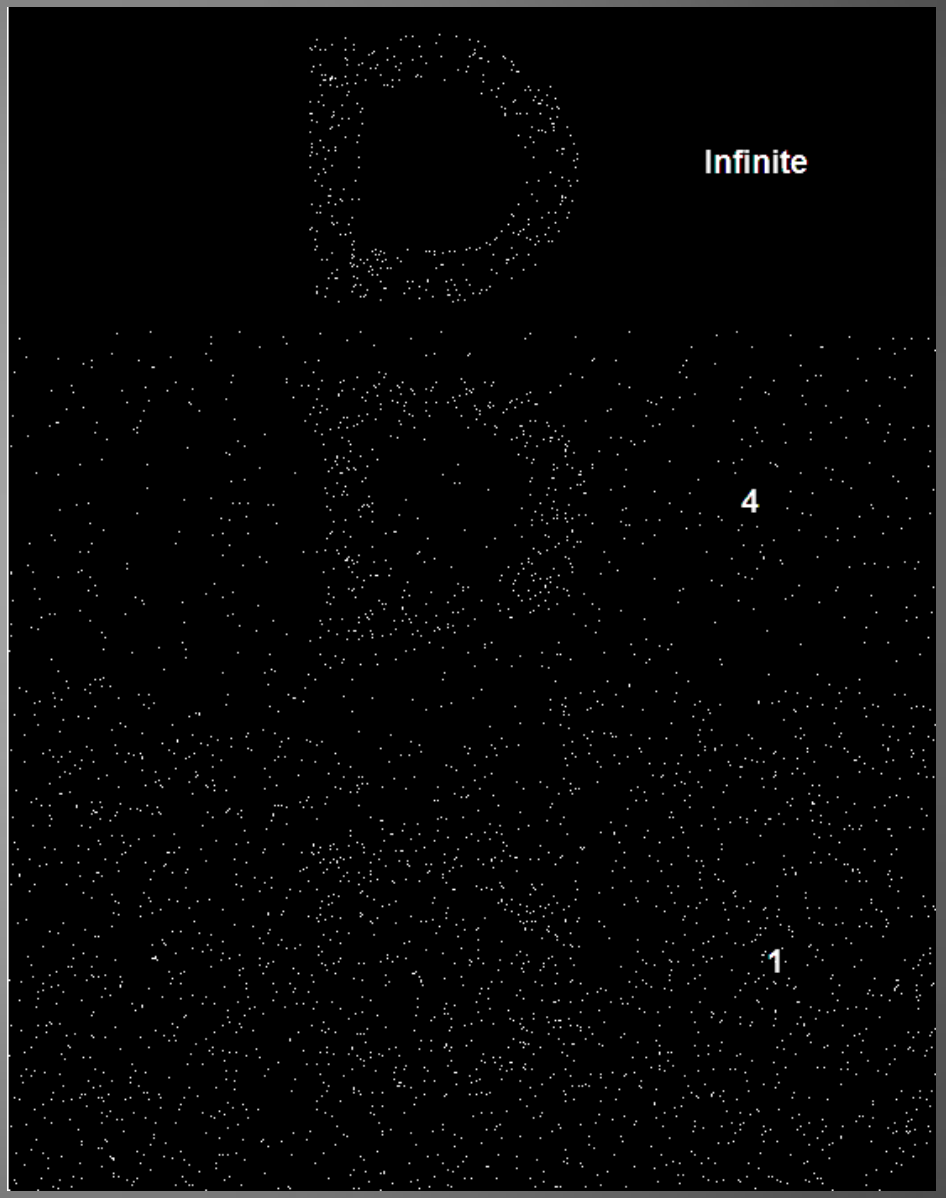
Difficult to generate real world stimuli that have maximum contrast.

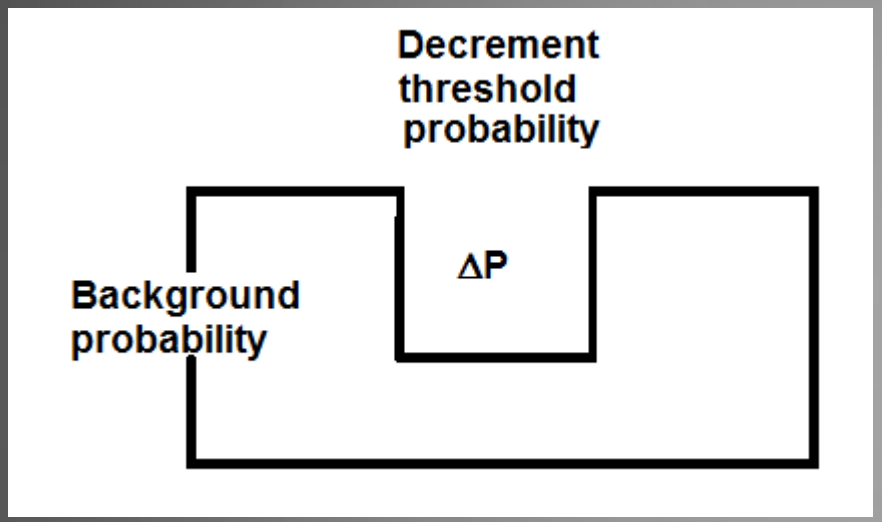
Even with high contrast stimuli, may have to pick out stimuli against a background of intrinsic noise. e.g. random firing of neurones, or in a night vision goggle system, electronic noise.



Weber Contrast

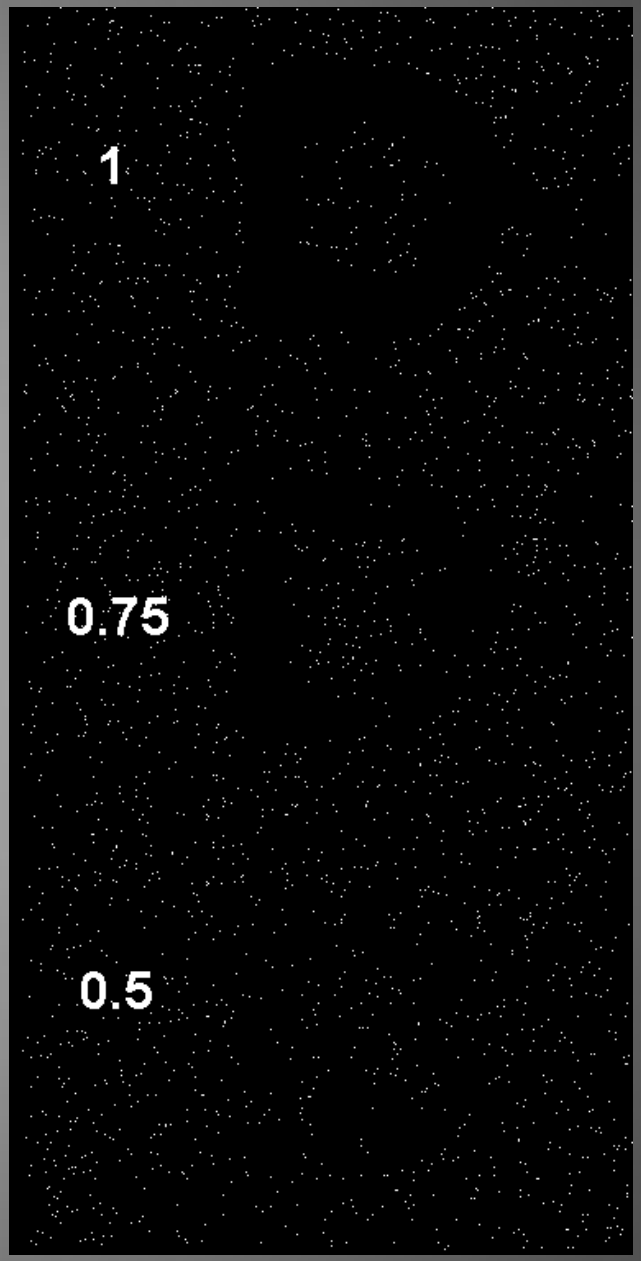
= ΔP/ background P



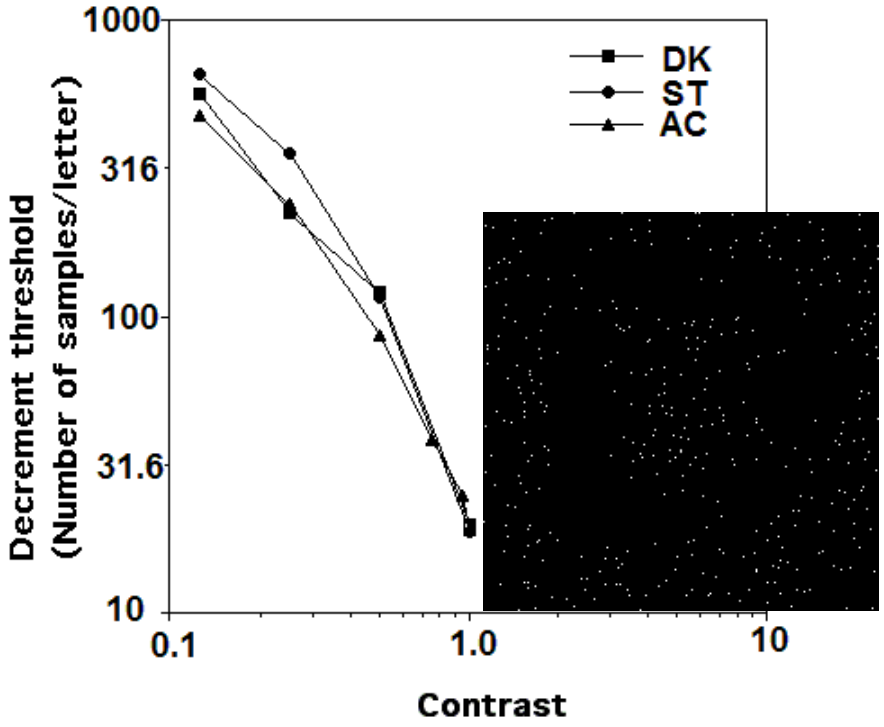


Weber Contrast

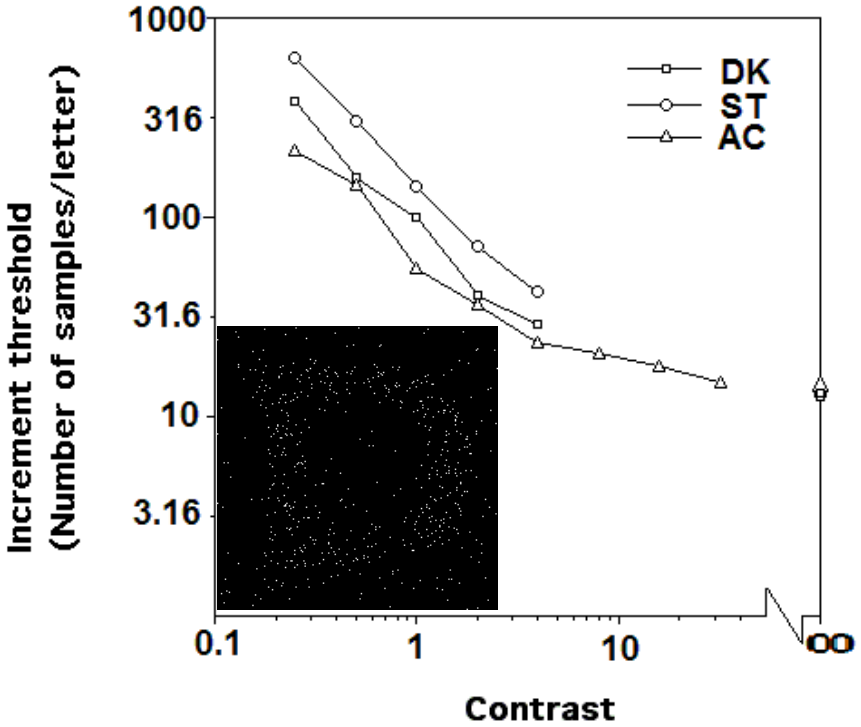
= ΔP/ background P



BoW


1000
316
100
31.6
10
0.1
1.0
10
Contrast
Decrement threshold
(Number of samples/letter)
DK
ST
AC

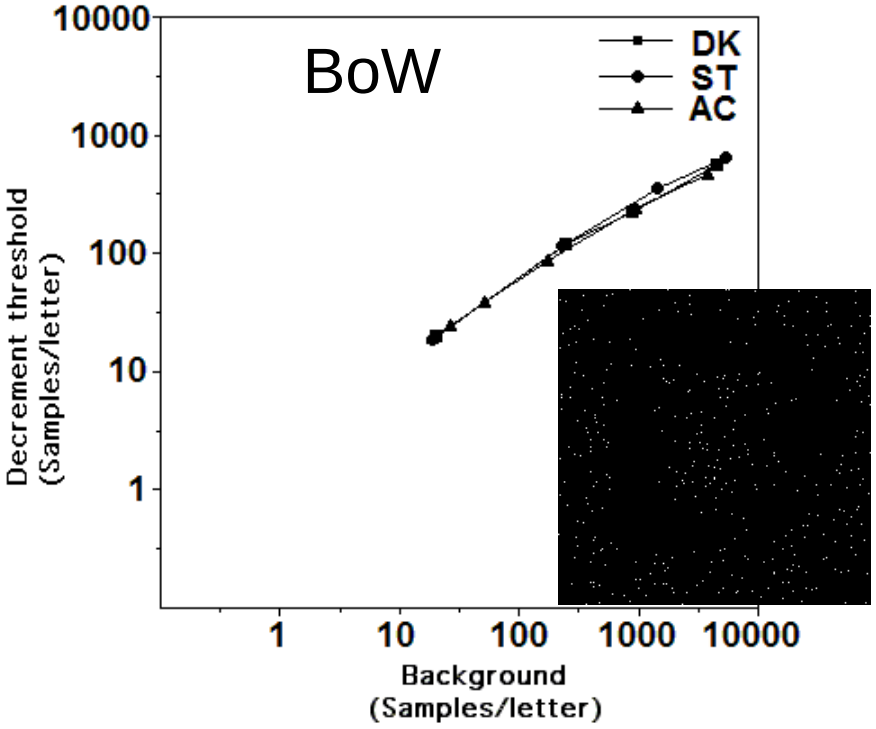
WoB

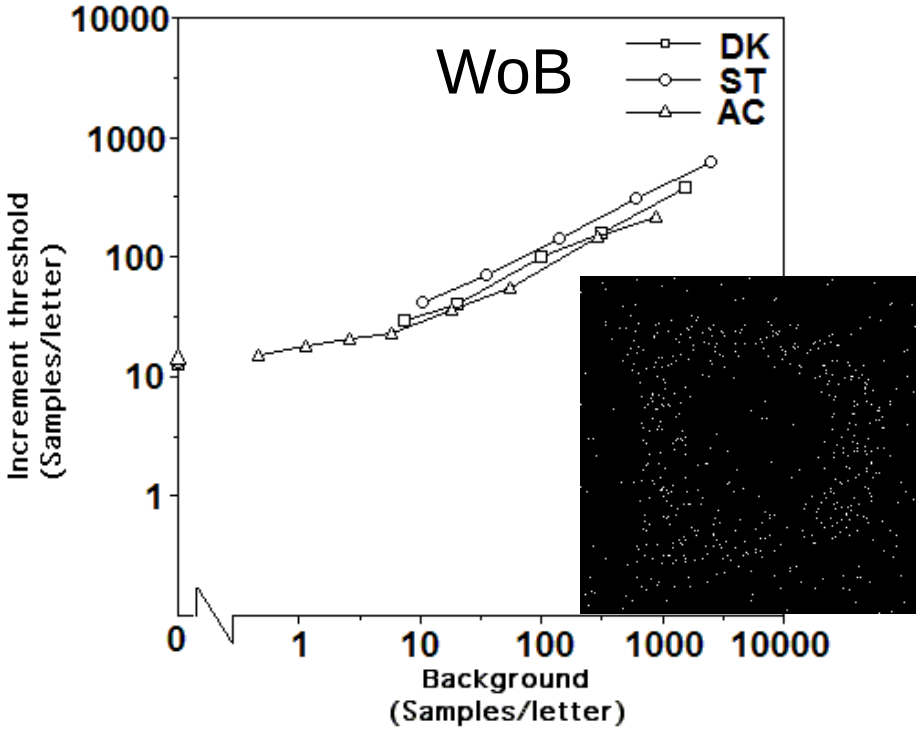

1000
316
100
31.6
10
3.16
0.1
1
10
∞
Contrast
Increment threshold
(Number of samples/letter)
DK
ST
AC

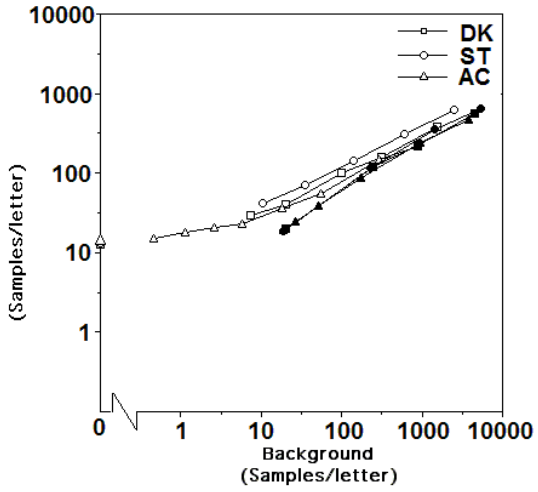
- Increment and decrement thresholds elevated for reduced contrast.

- 50% contrast thresholds are
- 106 samples/letter BoW
- 192 samples/letter WoB

The thresholds can be replotted against background

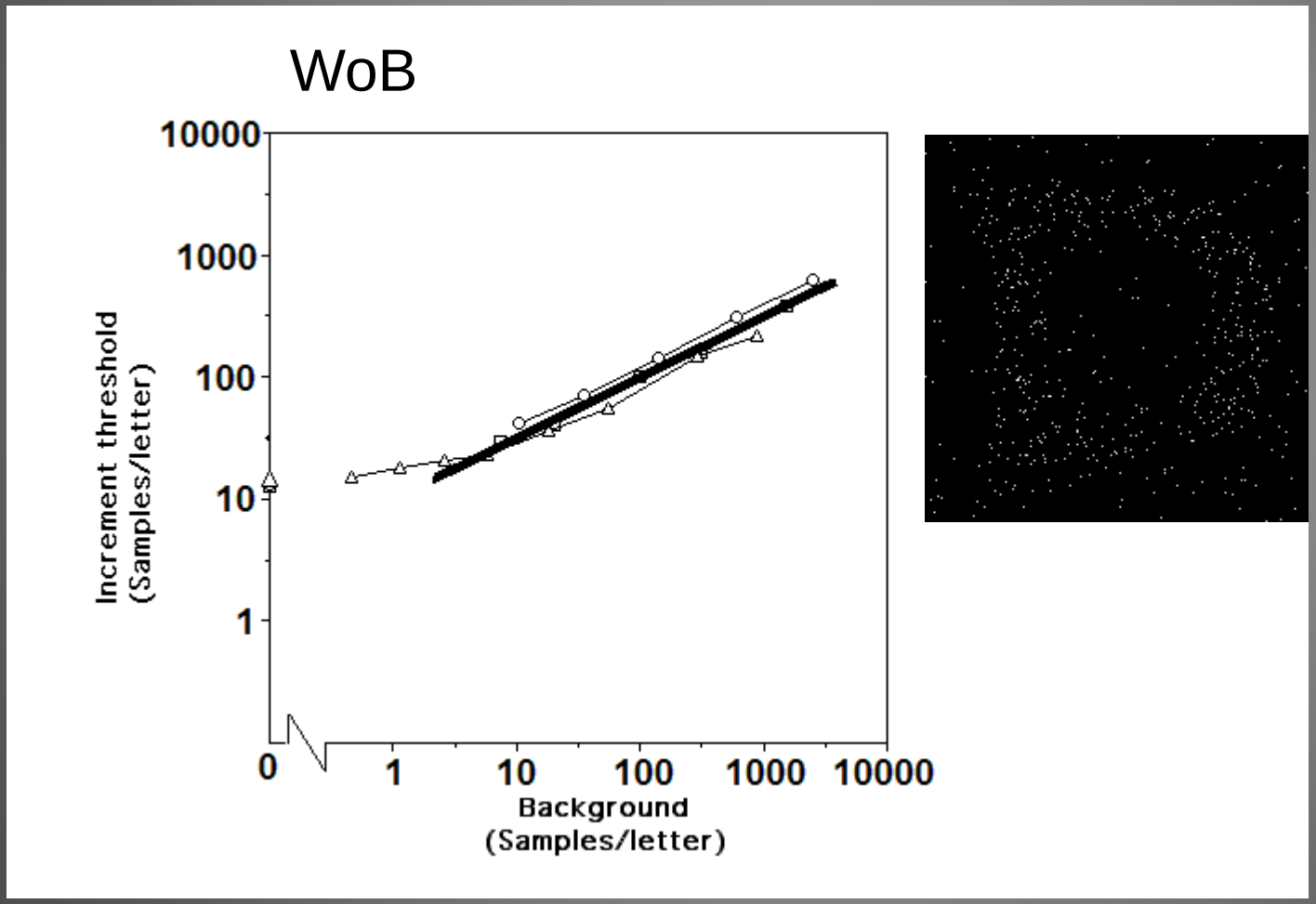

BoW
DK
ST
AC
Decrement threshold
(Samples/letter)
10000
1000
100
10
1
1
10
100
1000
10000
Background
(Samples/letter)


WoB
DK
ST
AC
Increment threshold
(Samples/letter)
10000
1000
100
10
1
0
1
10
100
1000
10000
Background
(Samples/letter)

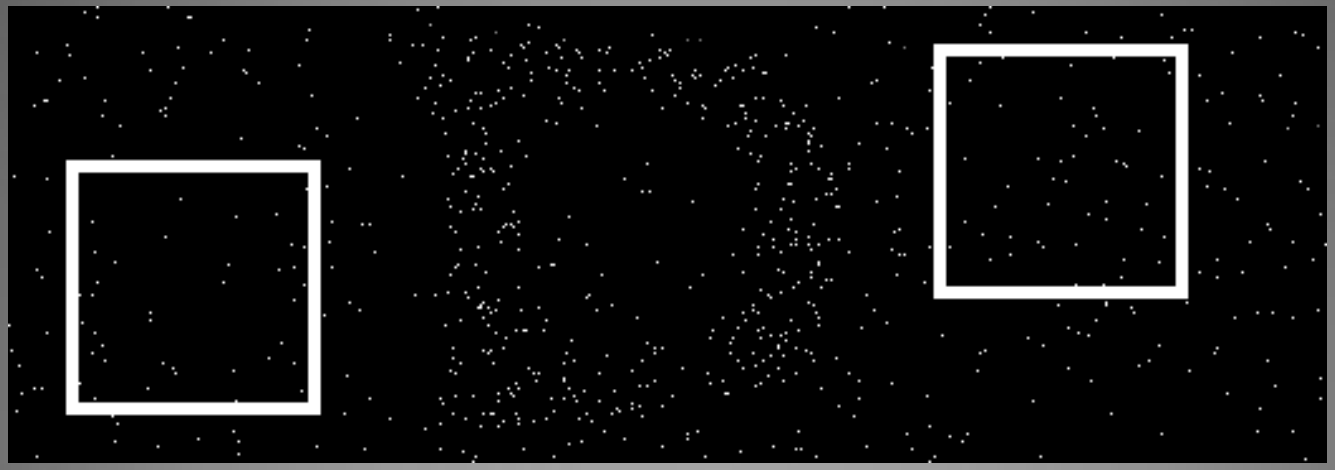

DK
ST
AC
(Samples/letter)
10000
1000
100
10
1
0
1
10
100
1000
10000
Background
(Samples/letter)

For much of the curve

$$\text{Threshold} \propto \sqrt{background}$$



Background is intrinsically variable

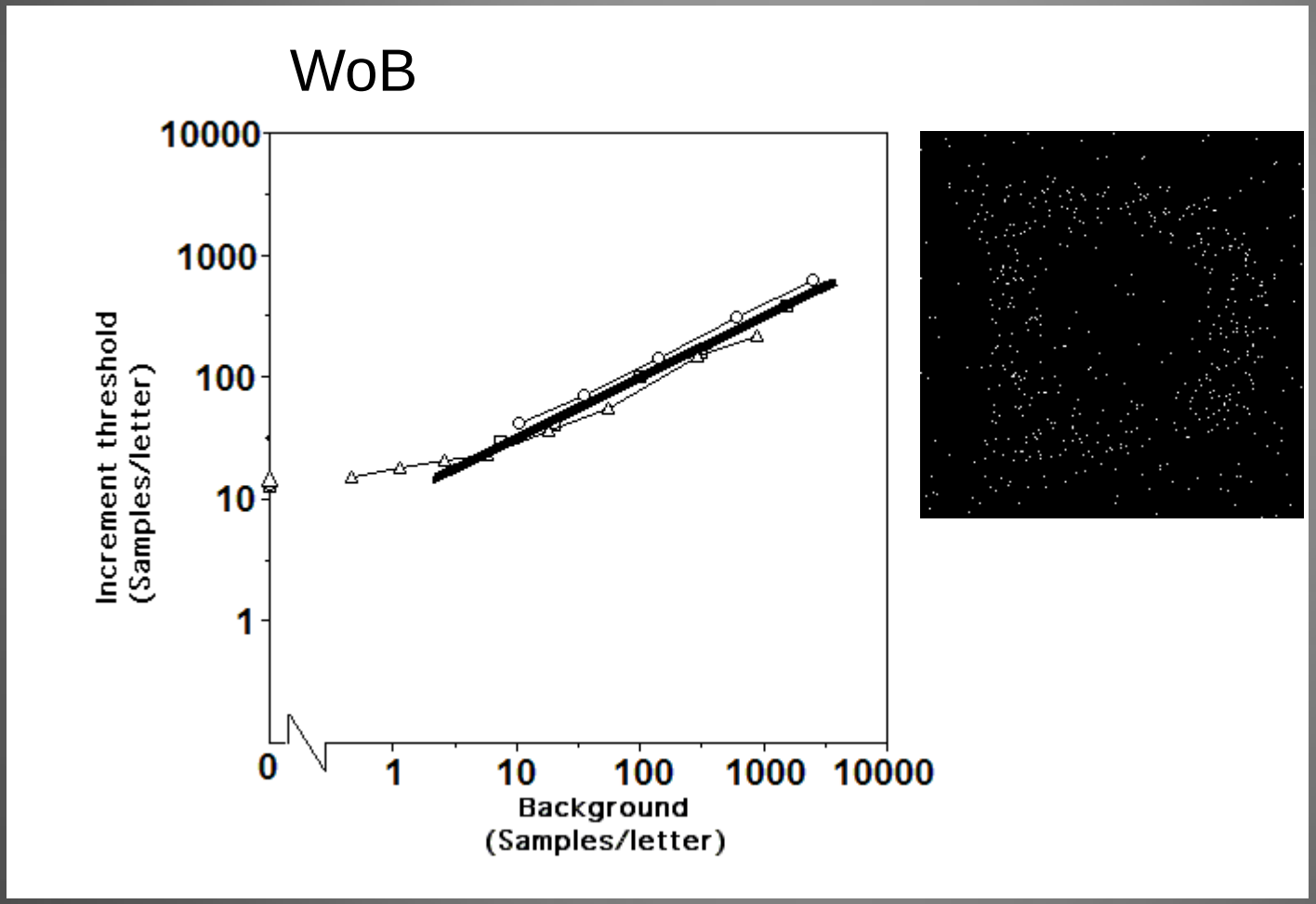


If there are an average of *n* pixels switched on in a given area.

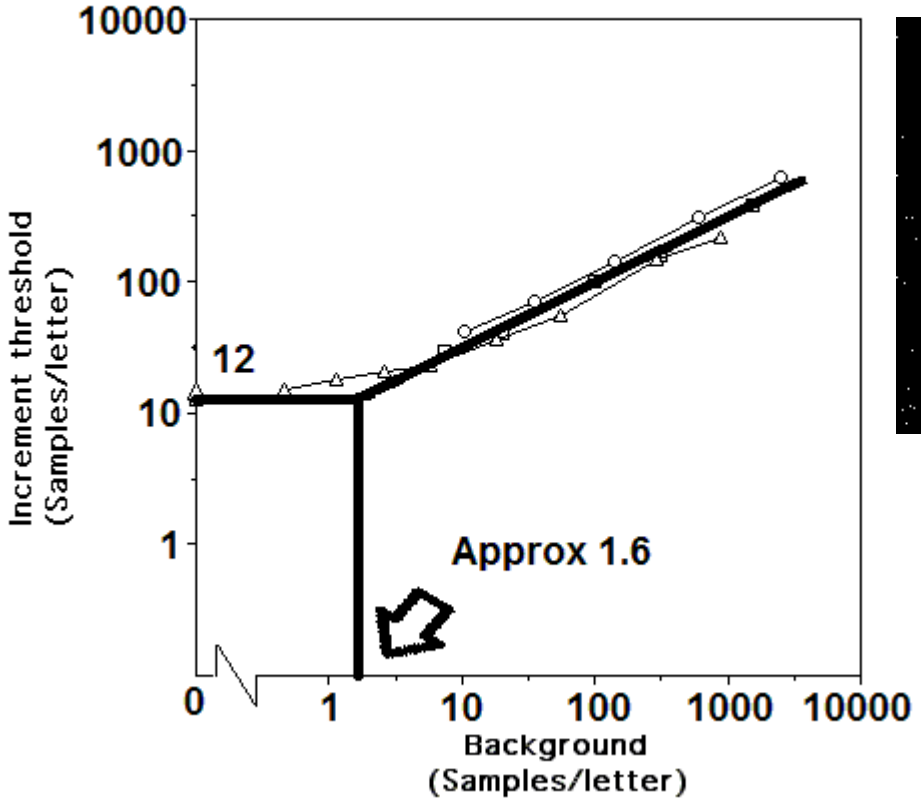
$$SD \cong \sqrt{n}$$

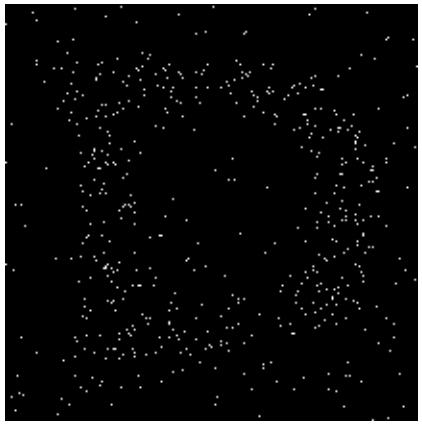
The subject has to distinguish the increment threshold from this background variability

So for this section of the curve Increment thresholds are proportional to the variability in the curve

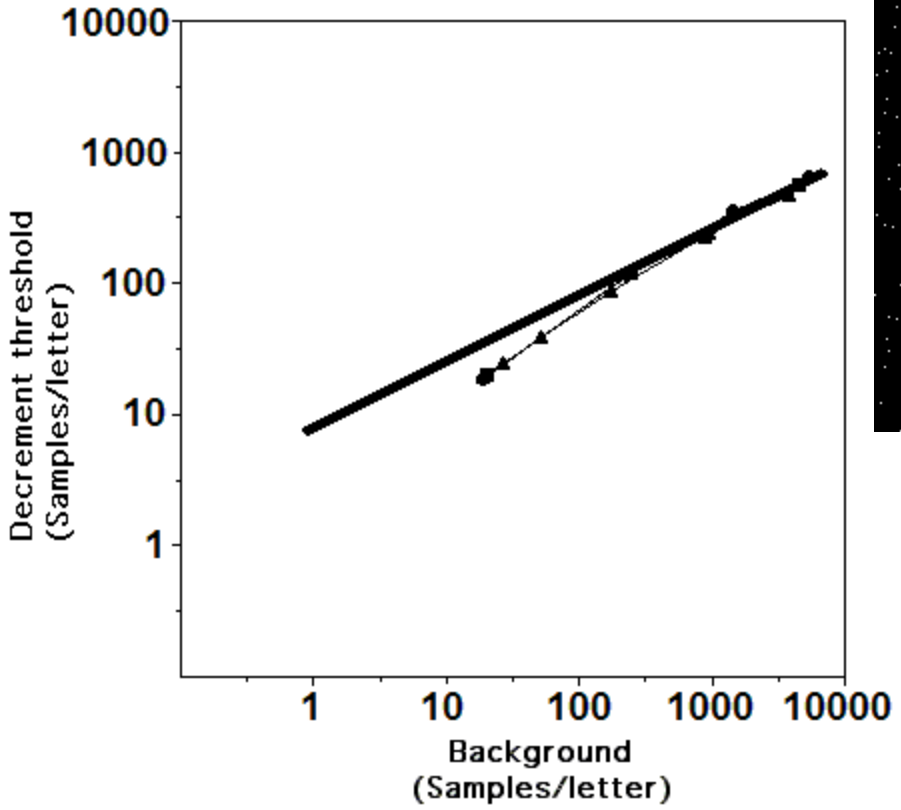


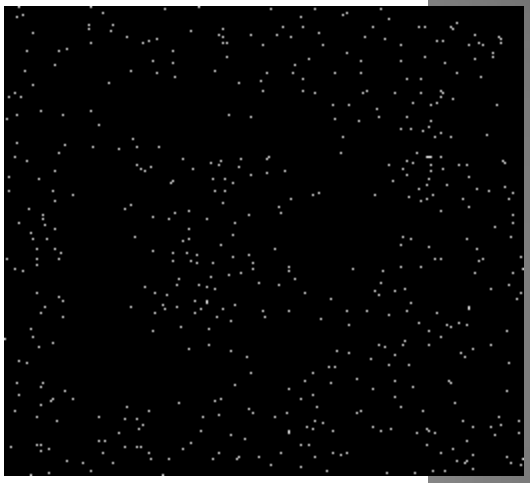
If the background drops below approx 1.6 samples/letter thresholds level out at 12 samples/letter



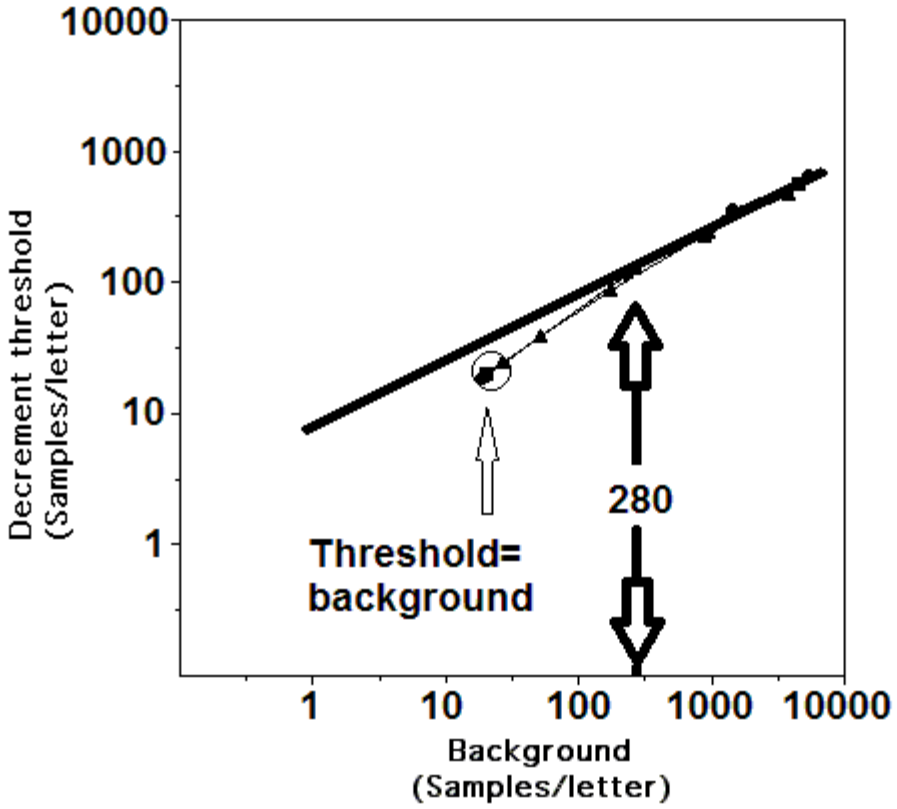


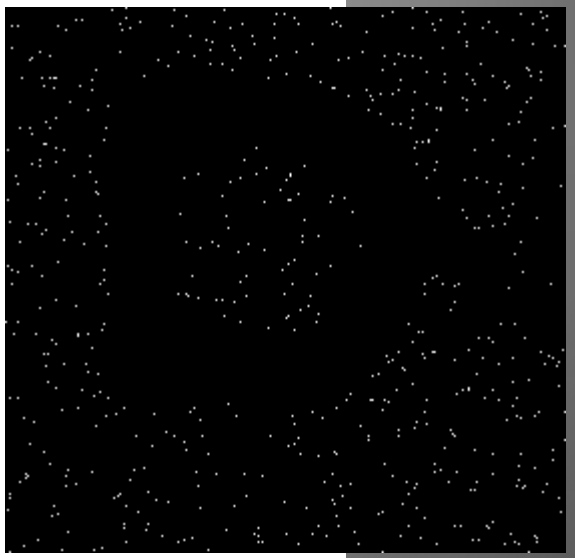
For decrement thresholds, a similar square root relationship occurs for high backgrounds.





But the curve is steeper for backgrounds less than approx 280 samples/letter





Summary

- Recognising Sloan letters requires an average threshold of 11.8 randomly distributed pixels for WoB letters or 22.8 randomly distributed pixels dropped out for BoW.
- There is a considerable diversity of letter visibility under these conditions.
- These thresholds can be markedly elevated by adding random background elements.

On a positive note

On a positive note

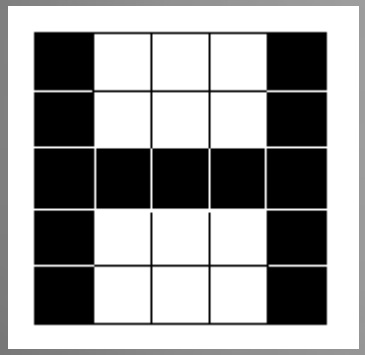
- Have a nice day!

On a negative note

On a negative note

- Also have a nice day!

If that light levels become too low, then



0.52	H
0.503	O
0.462	C
0.571	D
0.583	N
0.584	Z
0.617	S
0.615	R
0.503	K
0.398	V