Object recognition 2

"The uncrowded window for object identification" Submitted to *Science*.

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## Conclusions.

Vision is usually limited not by object size, but by spacing.
Bouma law: Critical spacing is proportional to distance from fixation, depending only on where (not what) the object is.
The critical spacing corresponds to 6 mm at the primary visual

cortex.

4. Observers can identify objects only in the uncrowded window within which object spacing exceeds critical spacing.

5. Rates for reading (at all ages) and searching are proportional to the size of this window.

6. The rest of our visual field is crowded, does not recognize or name things, and is hardly ever mentioned, but it does allow us to see unnamed stuff and space.

#### An A in chaff.

# 

Effects of crowding on letter identity, number, and position.

ABABA B<sub>B</sub>BA



Freeman & Pelli 2007 Journal of Vision

#### Crowding in a word.

r -



# Faces are like words. The governor and the King.







Critical spacing is independent of object and size.



Critical spacing is independent of object and size.

## "Lacking keen eyesight, we were told to read small letters from a distance" (Plato).

Plato. Republic, 2, line 368d

"The fairly rapid decline in reading rate for characters smaller than 0.3° is undoubtedly associated with acuity limitations" (Legge et al. 1985).



# Reading rate depends on spacing, not size.

Levi, Song, & Pelli 2007 Journal of Vision

Critical spacing is proportional to eccentricity



Adapted from Toet & Levi 1992. Pelli & Tillman 2007 submitted to Science

... and independent of size.



Pelli, Tillman, Freeman, Su, Berger, & Majaj 2007 Journal of Vision

# Bouma law implies a fixed critical spacing in the brain.

 $\Delta \varphi = b\varphi$ 

 $\Delta \varphi$  is critical spacing at the visual field. b is Bouma's proportionality constant between critical spacing and eccentricity.  $\varphi$  is eccentricity in the visual field.

 $\varphi = \exp(\alpha + \beta d)$ d is position (in mm) on the cortex.  $\alpha$  and  $\beta$  are empirical constants, unique to each cortical area (Larsson & Heeger 2006).  $d = (\log(\varphi) - \alpha)/\beta$ 

 $\Delta d = d_{\varphi + \Delta \varphi} - d_{\varphi}$ = log(1+b)/ $\beta$  $\Delta d$  is the cortical spacing.

b = 0.4in psychophysics $\beta = 0.0577/\text{mm}$ in V1 $\Delta d = 6 \text{ mm}$ in V1

#### What is your uncrowded span?

# xuncrowdedx

ine ehcsa tbe seocrd cpficr. "I beh rc s qenscrel-ebs husircss miqbf ba." Sbc bar hcsk tcr tbe letter from Xiroarf D'Am if fc Hemilton. His eyebrows warf uq es h Ha's eomirq bcne at three c'olcok." Ncne cen sac, ba qcints out tbet fhana's a de cd tnicrb cf mirc, Frir Kcllay, arswcre

Crowded Uncrowded Crowded periphery center periphery



10

.03

.1

.3

30

stationary silent

10

►MK

CHARACTER WIDTH (degrees)

3



Pelli, Tillman, Freeman, Su, Berger, & Majaj (2007) Journal of Vision

#### Reading rate vs. span.



The Rey figure copying test.



Courtesy Marialuisa Martelli, in Pelli & Tillman 2007 submitted to Science

## Uncrowded neighborhoods of bottle and magazine.



# Experience the vagueness of feature position predicted by maximum pooling.

Κ

"A jumble of lines or an unorganized heap of marks" (Zigler et al. 1930).

"I see something that appears to be composed of straight lines about half an inch high. Could be a drawing. Could be a letter or letters. I cannot see clearly what it is. At the moment it looks like a capital Y, but it's undefinable. The lines are not precise. They appear to be shimmering, fading in and out. Very unstable figure."

## Peripheral viewing.

indistinct, blurry, vague, fuzzy, uncertain, confused, jumbled

"Farther out [in the periphery], the structure becomes ever weaker and cruder ... The unifying effect of proximity becomes overwhelming. ... [D]ifferences ... cause an imbalance and restlessness in each intrafigural organization that is difficult to describe and can best be compared with what, in clearly seen objects, is called their grain, or texture, the material nature of their perceived structure. You see in that region ... no clearly segregated, countable, or, above all, individually identifiable component parts, such as actual stripes, spikes, knots, holes, and the like" — Wolfgang Metzger (1936)

"Things are less distinct as they lie farther from my gaze. It is not as if things there go out of focus ... it's as if somehow they lost the quality of 'form'" — Jerry Lettvin (1976)



## A forest. Mostly texture.

Ray K. Metzker Landscapes



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