The Slope of Self-luminous Neutral Scale: Independent Converging Evidence

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With acknowledgement of

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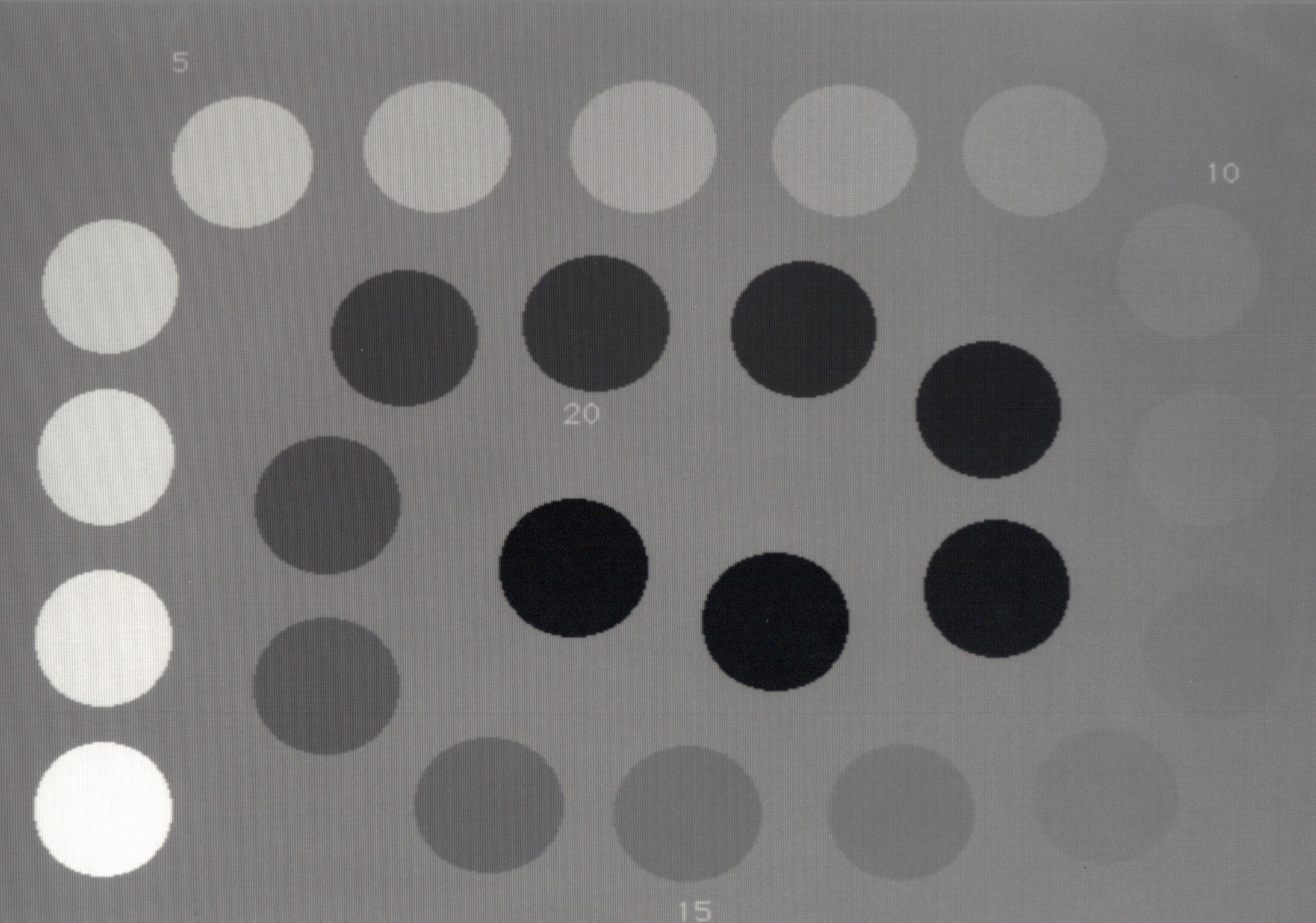
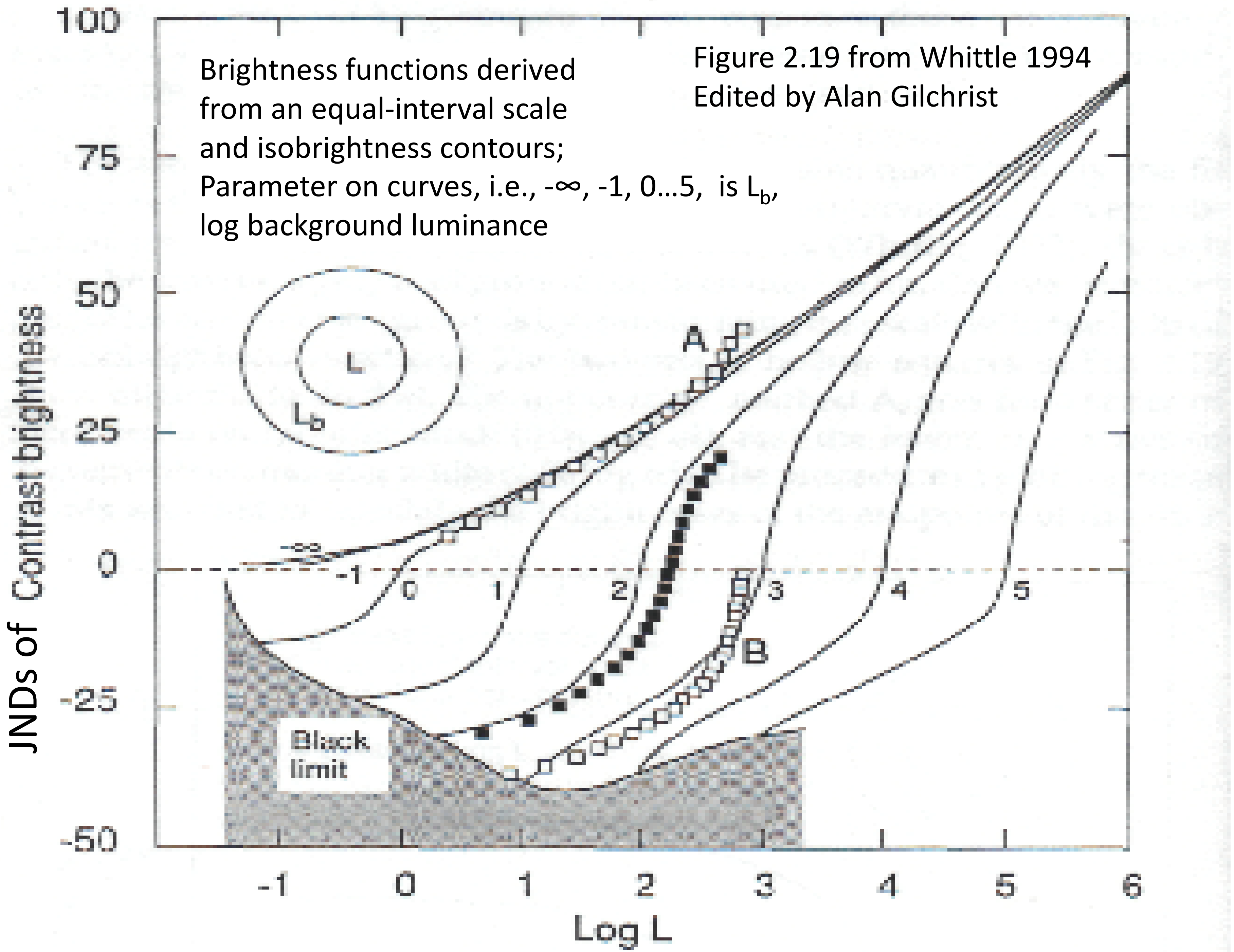
A Self-luminous Neutral Scale





Brightness functions derived from an equal-interval scale and isobrightness contours;
Parameter on curves, i.e., -∞, -1, 0…5, is L_b, log background luminance
Figure 2.19 from Whittle 1994
Edited by Alan Gilchrist
JNDs of Contrast brightness
100
75
50
25
0
-25
-50
Log L
-1
0
1
2
3
4
5
6
L
L_b
A
B
Black limit

Noticeable Changes of Brightness in context

- Paul Whittle 1992: Settings of color-neutral differences “just noticeable at a glance” (JND)
- A critical context is minimum {background or negative contrast} luminance (L).

$$JND = F[W = \Delta L/(L\ \text{background})]\ \text{for + contrast}$$

$$JND = G[W = \Delta L/(L\ \text{target})]\ \text{for negative contrast}$$

$$W = \Delta L/L_{min}$$

"…the simplest and most precise mathematical description…"

L is target luminance, L_b is background luminance

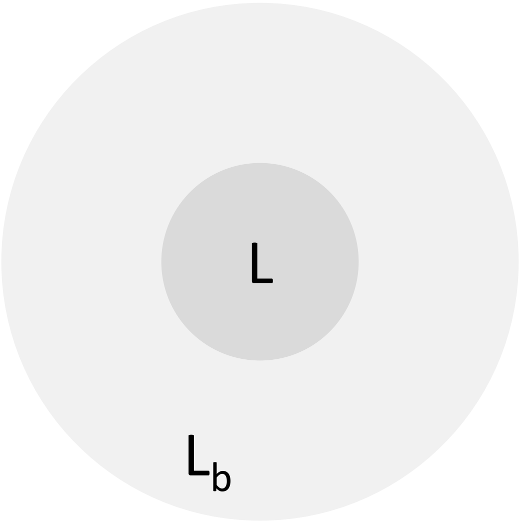
L_{min} = the minimum of L or L_b

$\Delta L = |L - L_b|$

The number of JNDs between L_b and L

= $a \log(1 + bW)$,

Two cases (e.g., negative contrast case is shown in figure):



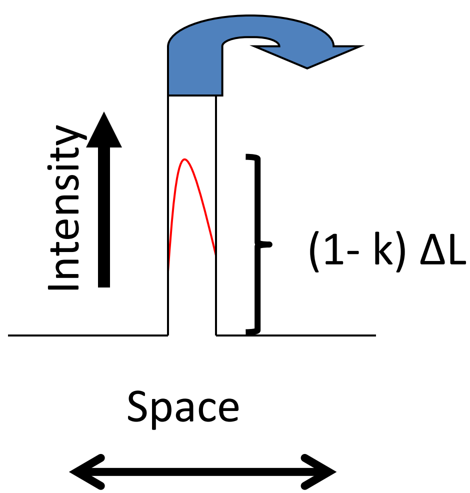
For negative contrast: $W = (1-k)\,\Delta L / (L_d + L_{min} + k\,\Delta L)$; a = -7.07

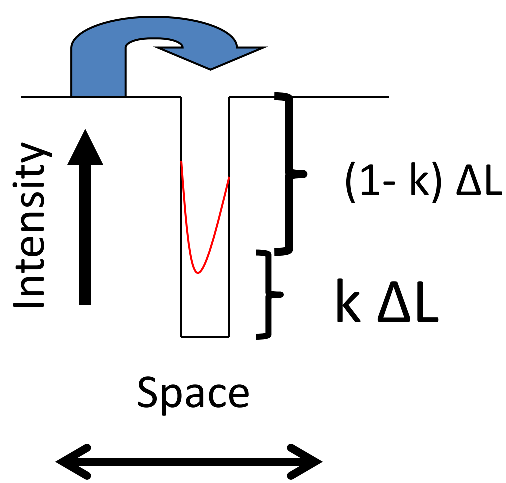
For positive contrast: $W = (1-k)\,\Delta L / (L_d + L_{min})$; a = 8.22

where $L_d = .39\ cd/m^2$ represents the black limit, b = 6.58, and k (0<k<1) represents intraocular light scattering and grows with decreasing subtense.

Explaining 0<k<1 in the Whittle formula:
Before the retina, **Intraocular Scattering** Reduces Contrast

- Light from a positive contrast (a target more-intense than its surround) is scattered out of the target by the intraocular media:
- Light from the surround of a negative contrast (a target less-intense than its surround) is scattered into the target by the intraocular media:





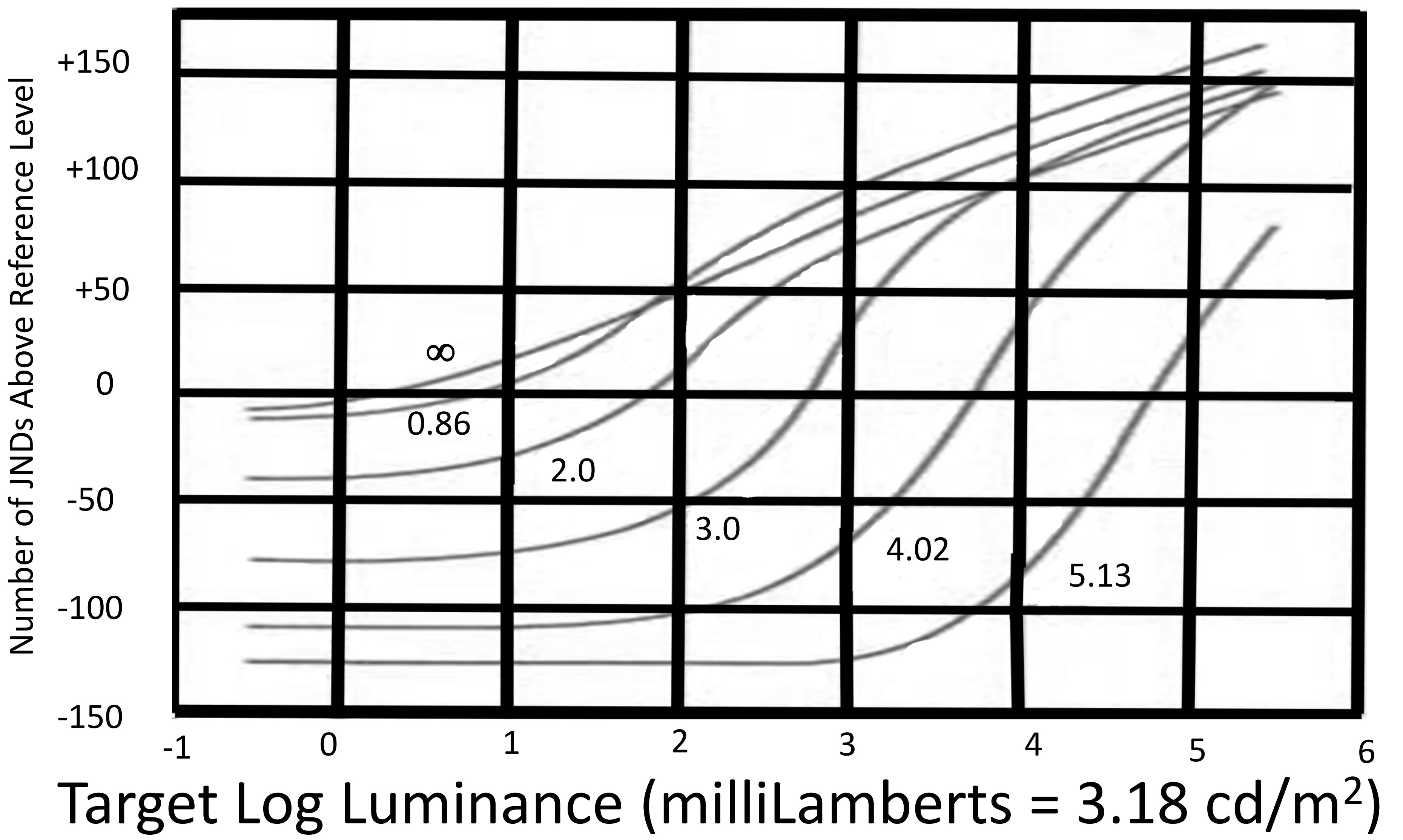
Slope of Whittle's Formula, JND

- JND = alog(1+bW)
- d(JND)/dL = JND' =

limit (as ΔL approaches 0) {JND(L+ ΔL) – JND(L)}/ ΔL

- Approximated with ΔL a constant on the order of threshold ΔL.
- We will plot these slopes against independently estimated slopes of the neutral scale…

Heinemann's (1972) cumulative gray-scale JND curves (Parameter on curves is log background luminance.)



Heinemann's Slope: $dJND/d(\log Y)$

Heinemann's 1972 Claim: $dJND/d(\log L) = L/\Delta L$, where ΔL is increment threshold.

Our Derivation: Start at left, apply chain rule & recall $d\log(L)/dL=1/L$.

$$dJND/d(\log L) = [dJND/dL][dL/d(\log(L))]$$
$$= [dJND/dL] / [d(\log(L))/dL]$$
$$= [dJND/dL]L$$

approximate dJND & dL by ΔJND & ΔL.

Set ΔJND as the unit of the gray scale...

$dJND/dL \sim \Delta JND/\Delta L = 1/\Delta L$.

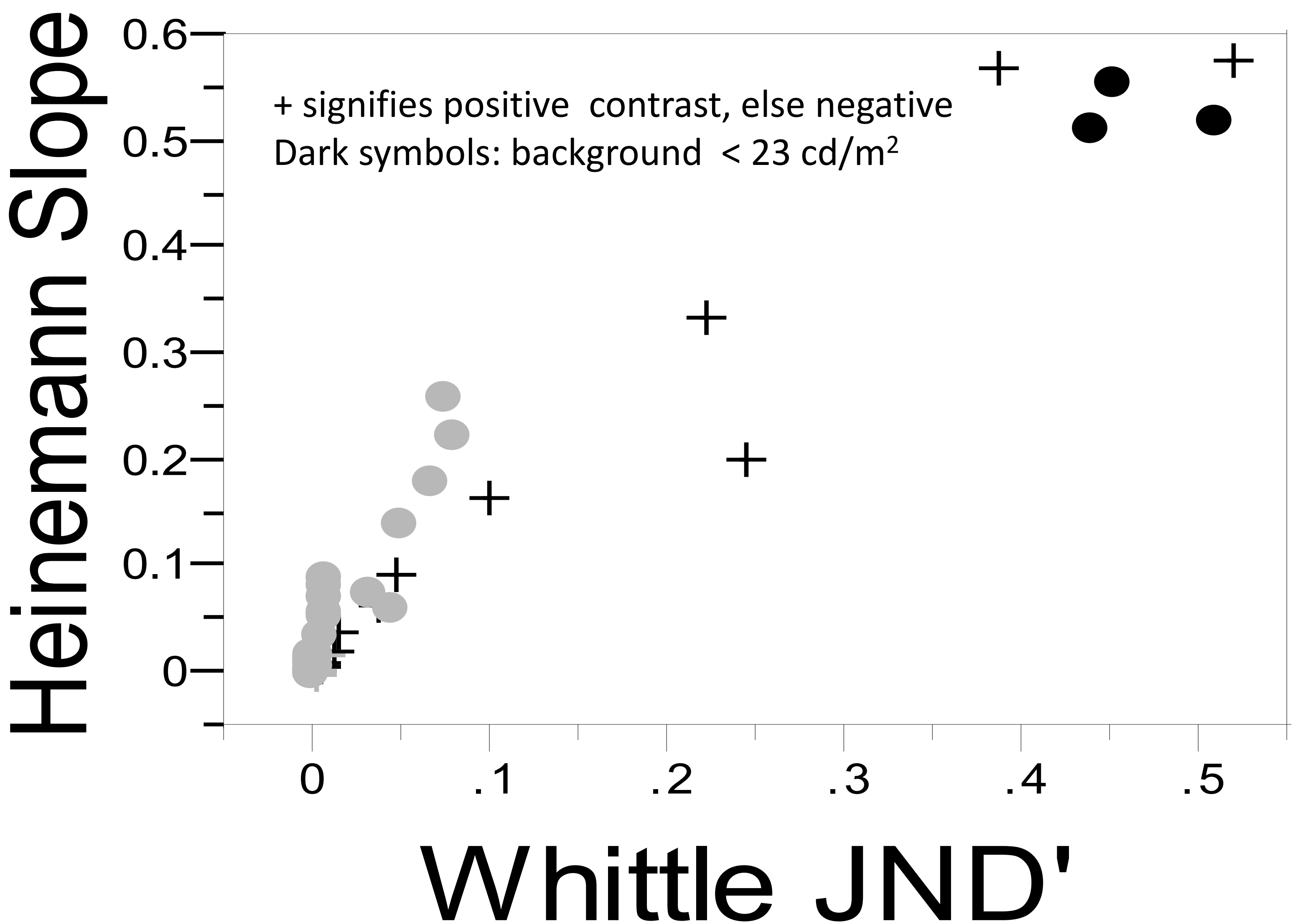
So, $dJND/d(\log L) = L/\Delta L$ = claimed slope of JND in line 1 , the slope of the gray scale.

But we really want $dJND/dL = dJND/d(\log L)\, d(\log L)/dL = dJND/d(\log L)/L = 1/\Delta L$

How do these slopes compare with Whittle's slopes, JND', at the same target and background luminances?...

Plot of independent slope estimates

78 combinations of target and background luminances (over 5 log units)



Conclusions

- ➢ Neutral (aka Gray, Brightness) scale is differentiable.
- ➢ *Slope of gray scale* is consistent, replicable, valid...
- Plotted "slopes" of gray scale correlate 0.966, N=78.
- The relationship has zero intercept and 45^o line, i.e., slopes measured differently are plausibly identical.
- Slopes are valid for positive **&** negative contrasts.
- All this despite: 1) our two "slopes" were generated by very different experimental paradigms, by different labs 30 years apart; 2) slopes, in general, are notoriously twitchy.