Resolution and Contrast in Mobile Displays

Johan Bergquist
Multimedia Technologies Laboratory
Nokia Research Centre

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- Application, services, and pixel count
- User context and luminous environments
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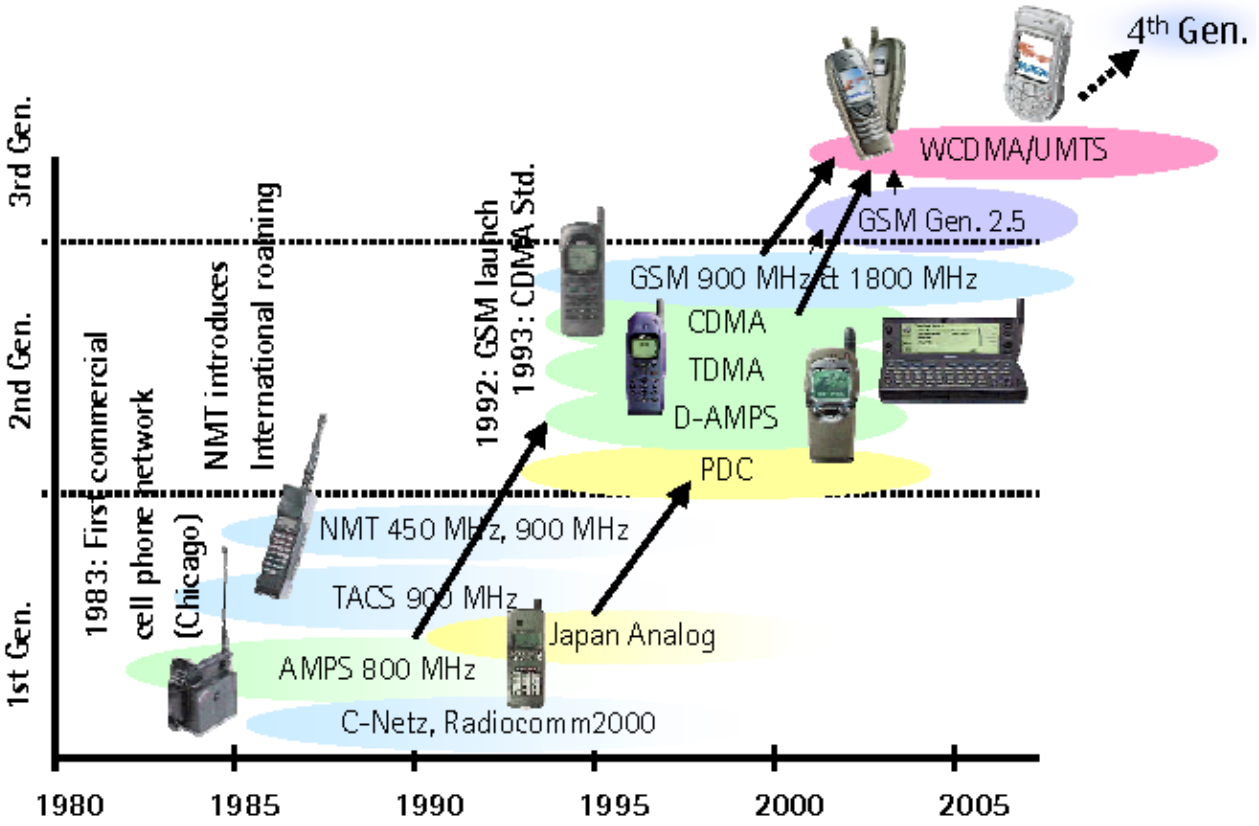
Infrastructures and Enabling Technologies



Infrastructure	Bitrate (Mbps)
Flash memory*	80
Hard disk*	320
1G	0.01
2G	0.028
2.5G	0.17
3G	2
Blue Tooth	0.7
WLAN (802.11a)	54
WLAN (802.11c)	11
DVB-T 13 segment	23
DVB-T 1 segment	1.8

*** 1 GB corresponds to > 2 hours of MPEG4 video @ 1 Mbps**

Slide courtesy of Jyrki Kimmel

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Applications, services, and pixel formats

- Web browsing: 800 pixels wide; 800x600, 800x480
- E-Mail, PIM: 240/480 pixels wide depending on language
- VOD, video conference: 320x240, 176x220 (QCIF)
- Terrestrial broadcasts: 320x240, 480x640, 576x768...
- Photo browsing, viewfinder: 240x320
- Archade games: 240x320
- Network games: 640x480 and up
- Navigation, map services: 640x480

Information density approaching that of a PC!

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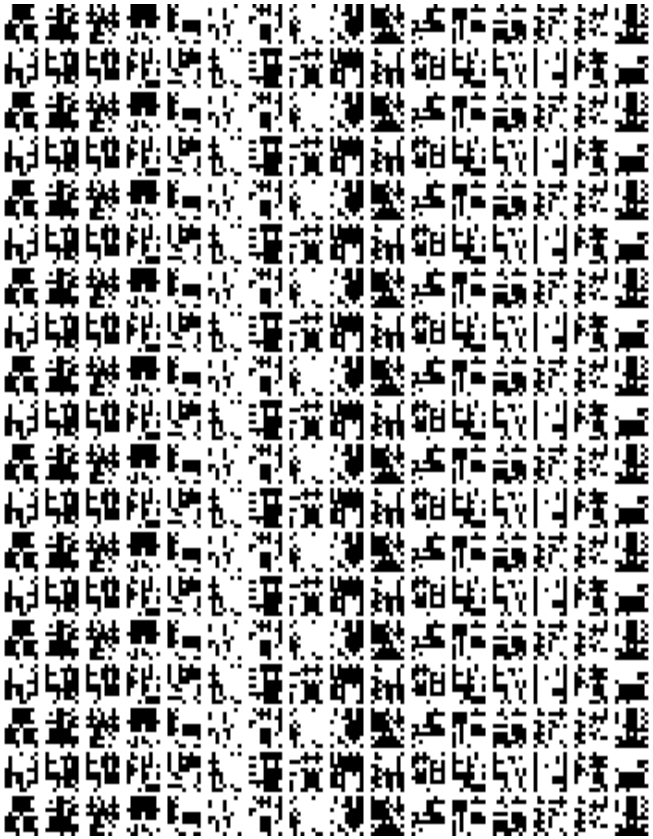
Text and resolution



12 pt fonts @ 2” 125 PPI

12 pt fonts @ 2” 250 PPI

Today's display resolution insufficient for Asian messaging !

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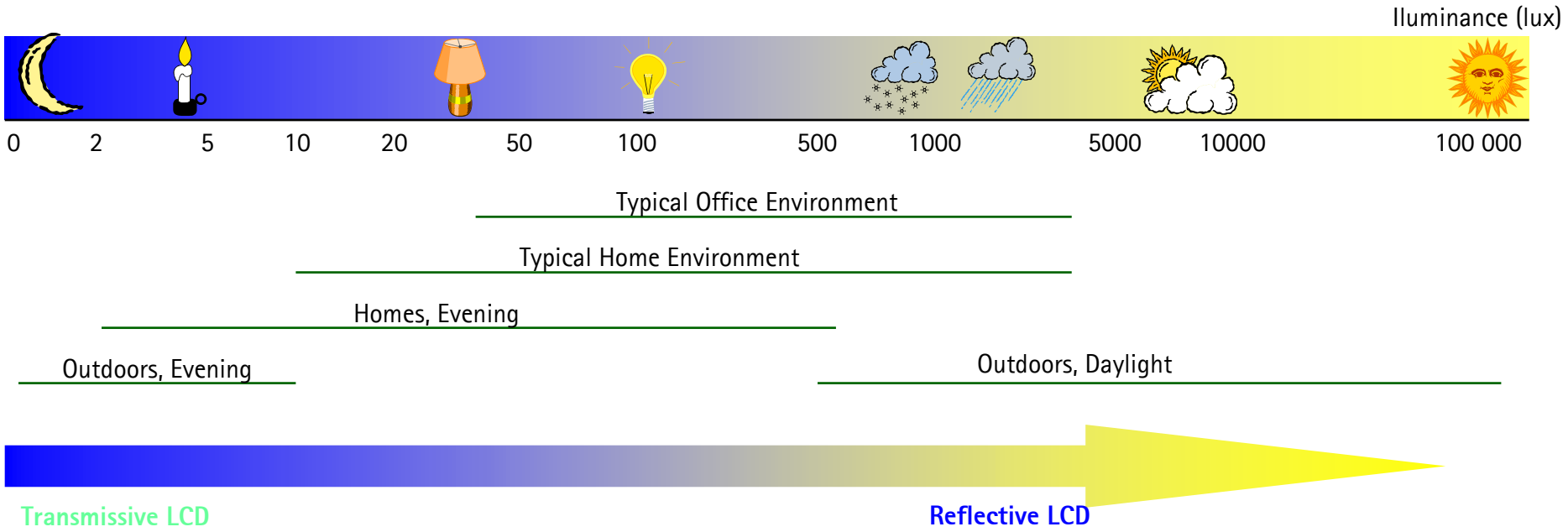
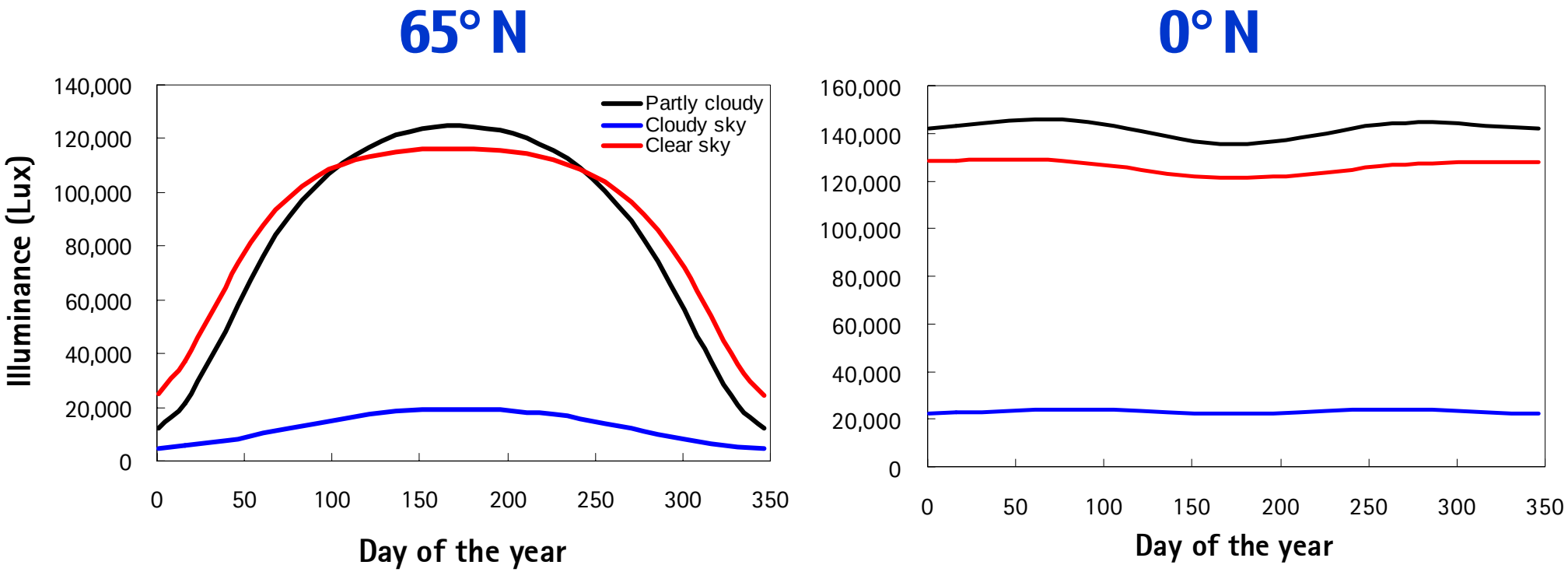
Illumination scenarios

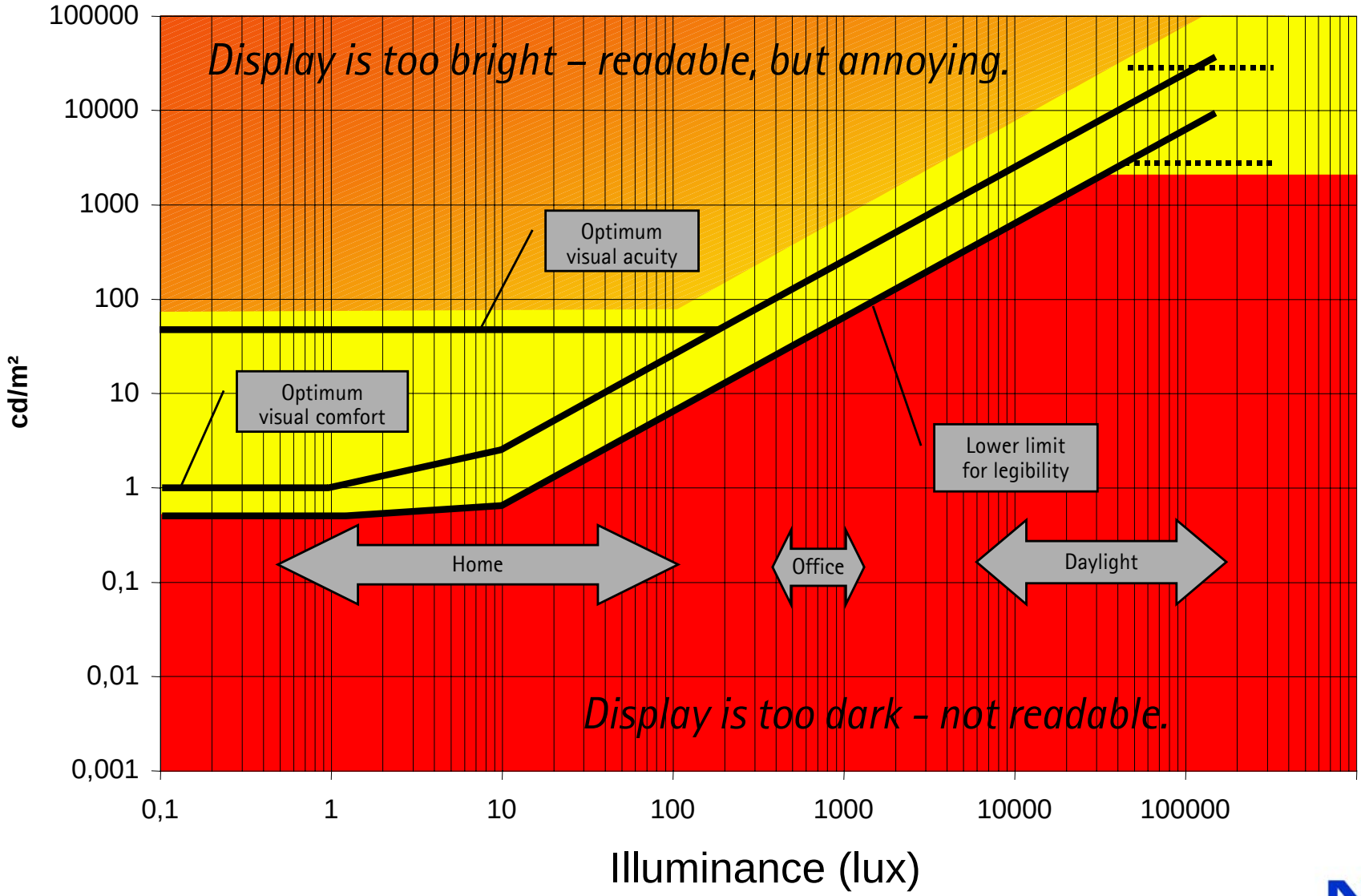


Geo-location and illuminance

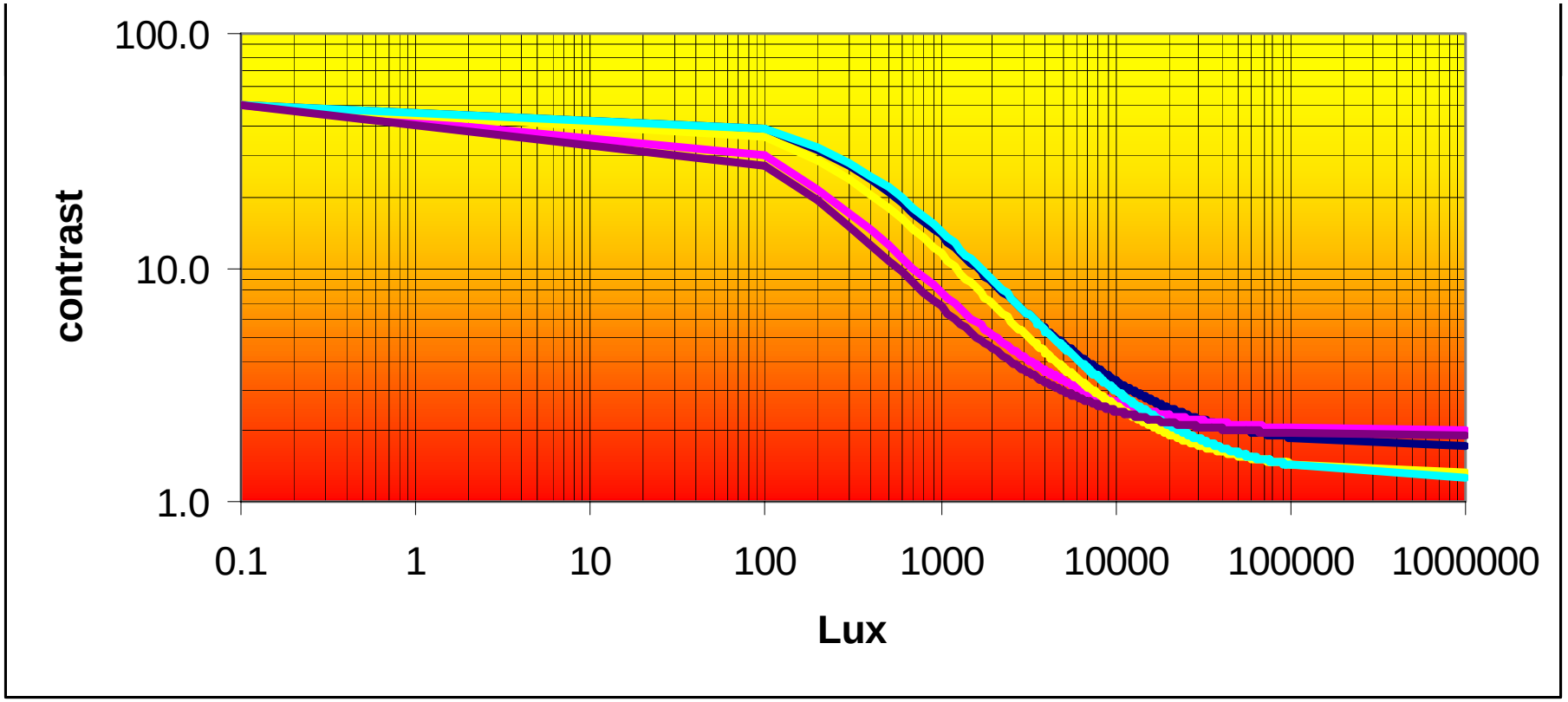


Source: The IESNA Lighting handbook, 9th edition, chapter 8

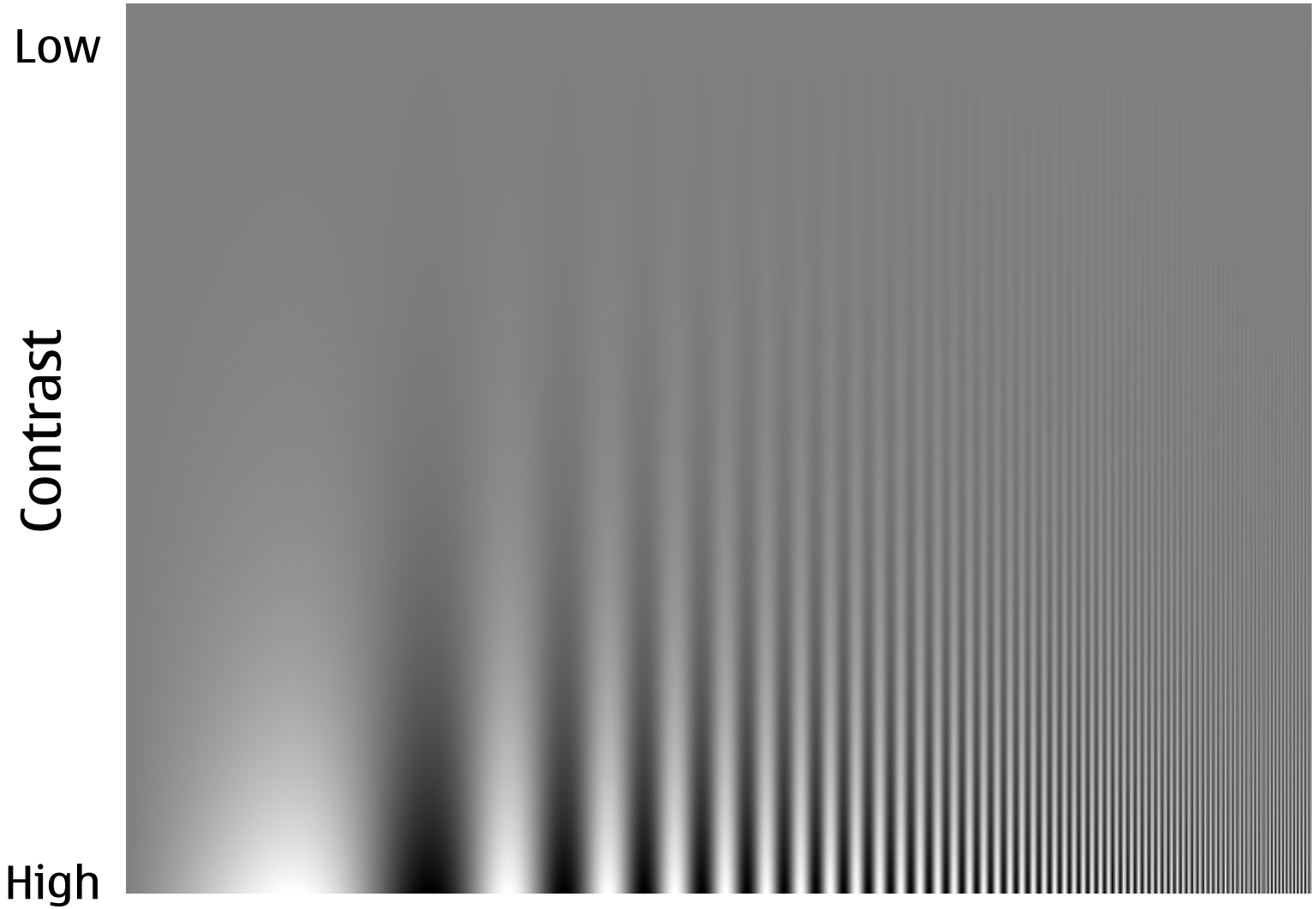
Illuminance and visual ergonomics



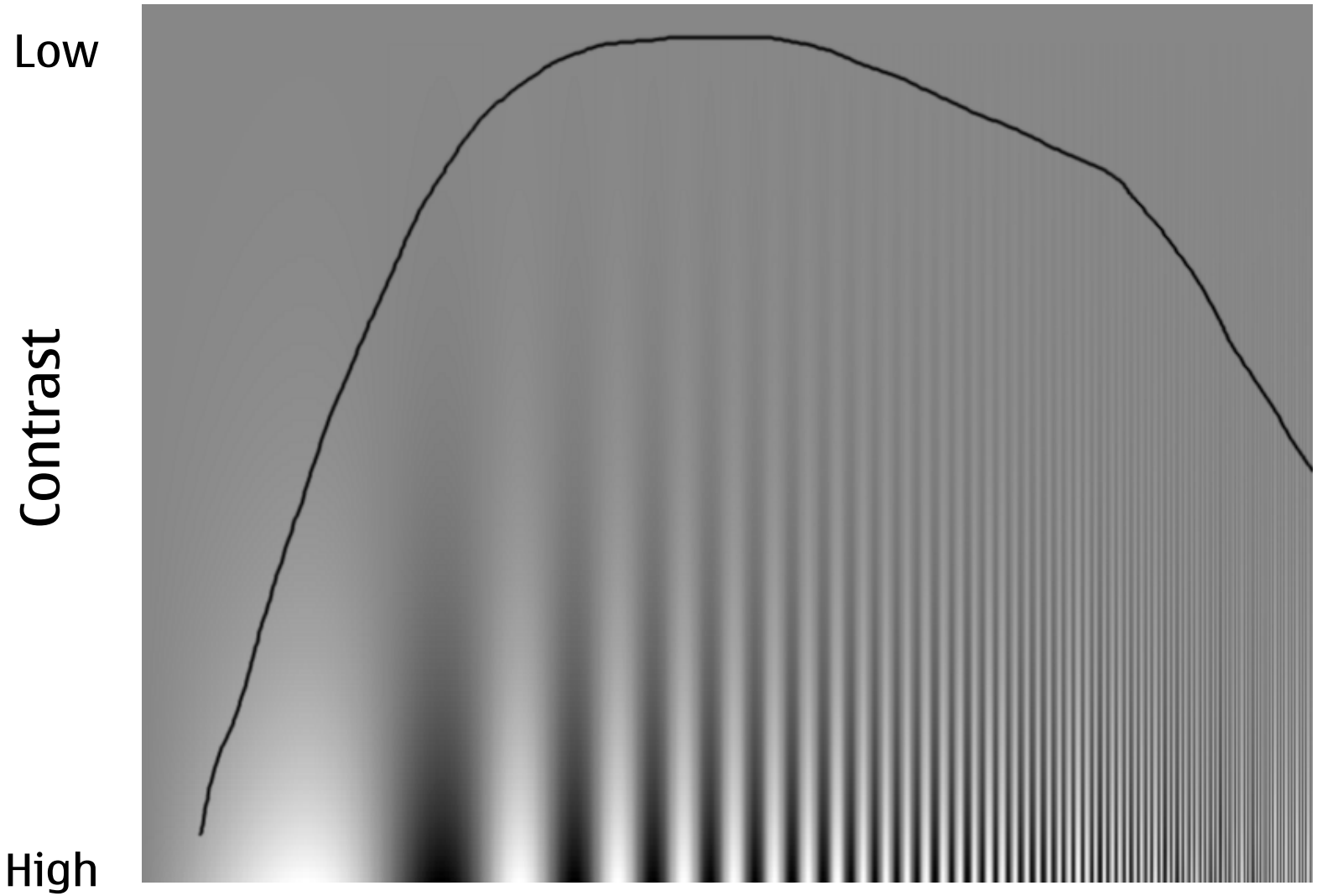
Illuminance and display contrast



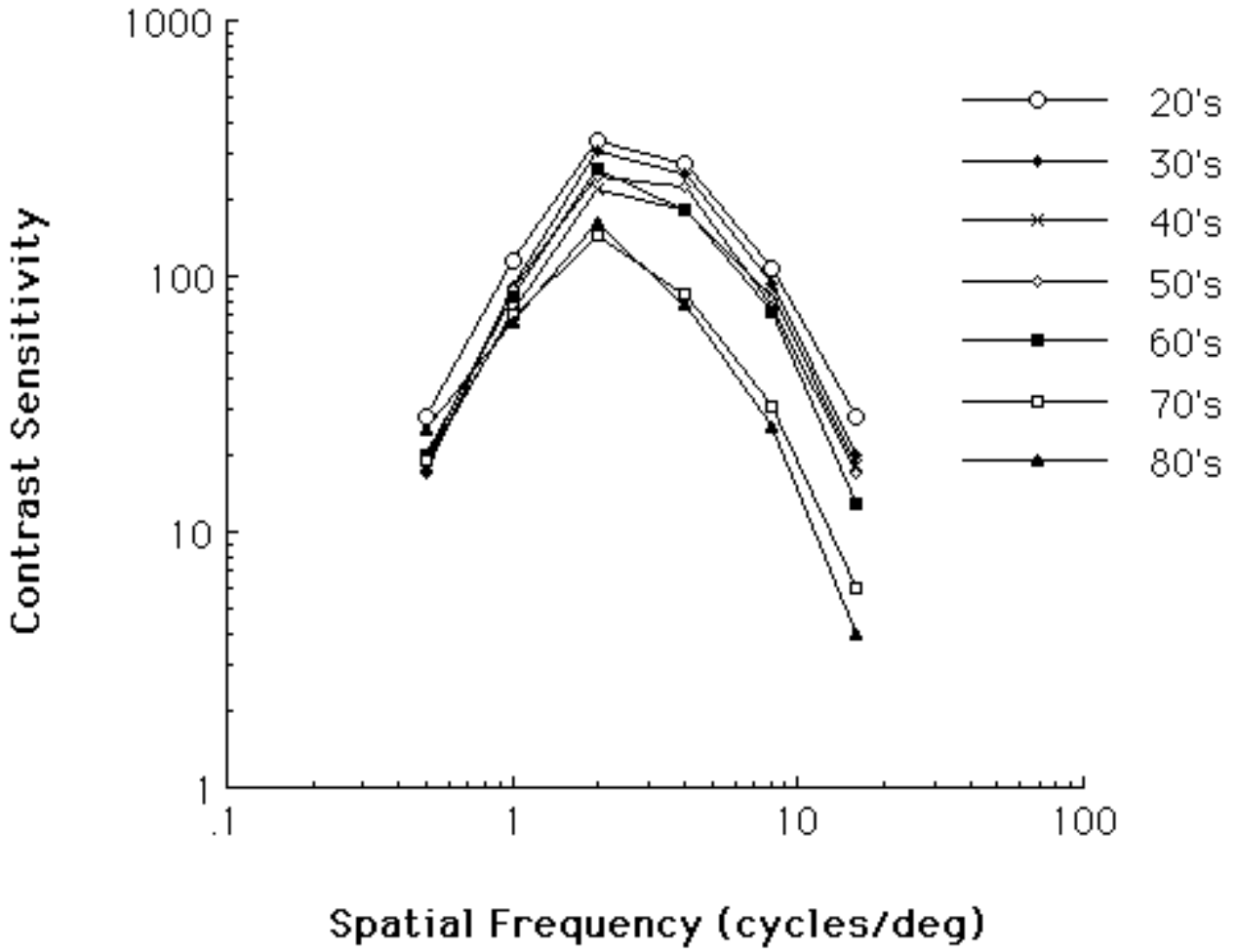
Campbell-Robson Contrast Sensitivity Chart



Contrast Sensitivity Function (CSF)



Contrast sensitivity by age

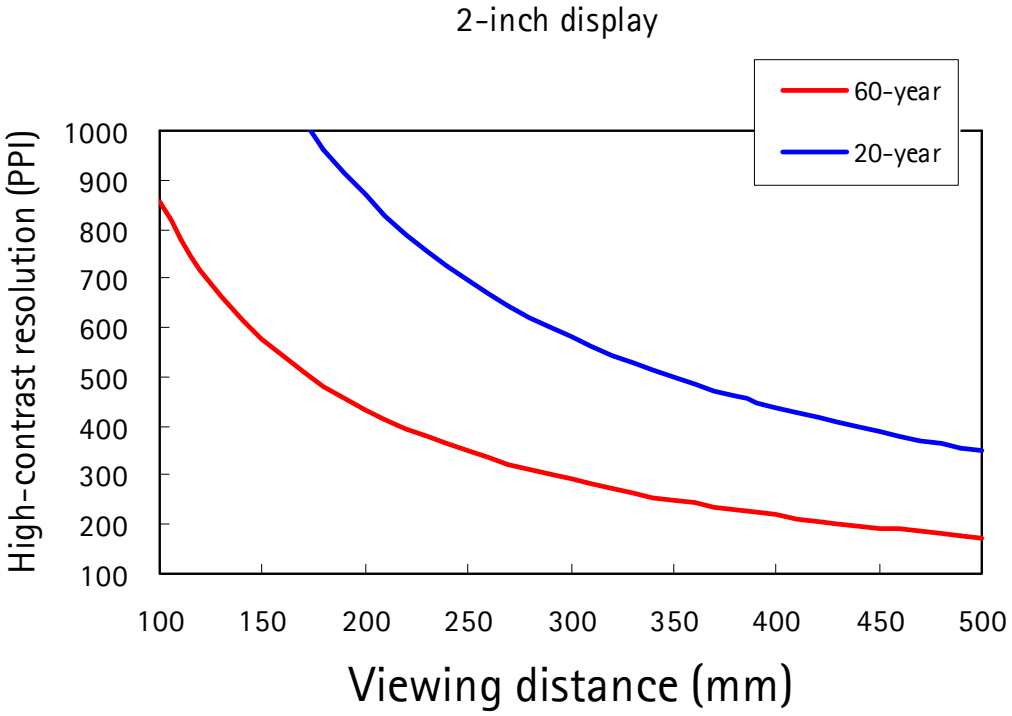


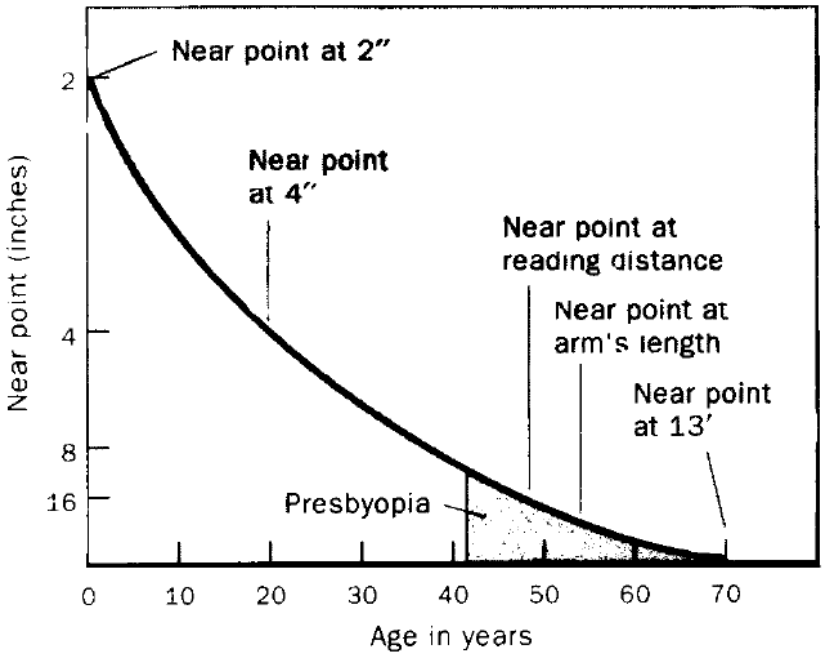
Source: USD Internet Sensation & Perception Laboratory, http://www.usd.edu/psyc301/CSFIntro.htm

Reading tasks and resolution in high-contrast regime

Viewing distance (mm):	400		Font matrix/resolution (PPI)					
Reading task	Font size (')	Phone example	24	22	20	18	16	14
			Asian fonts			Western fonts		
User with reduced vision	22	All info on UI	238	218	198	179	159	139
Long complex reading	20	E-book	262	240	218	196	175	153
Short complex reading	16	Web page	327	300	273	246	218	191
Simple/familiar content	13	SMS/Email	403	369	336	302	269	235
Iconic reading/labels	10	Menu icons	524	480	437	393	349	306
Small details	10		524	480	437	393	349	306

Viewing distance and resolution





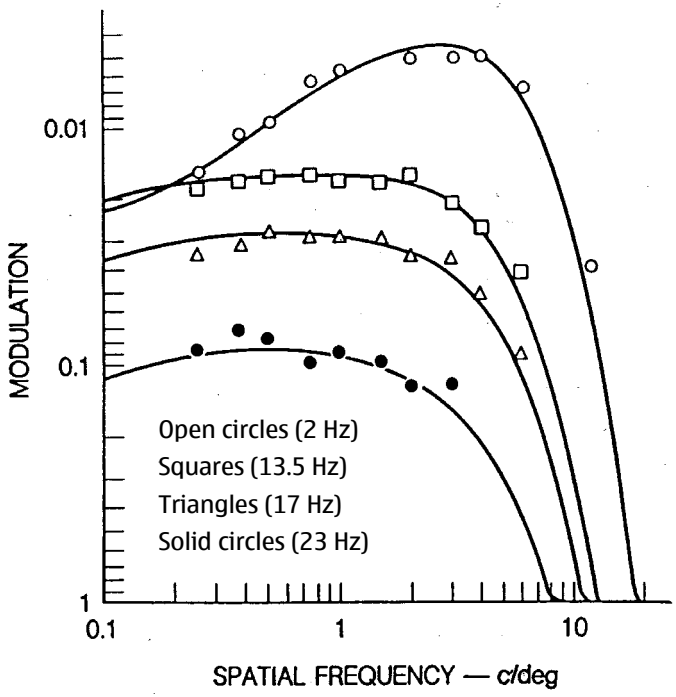
Source: University of Abertay Dundee

- Young people benefit from > 500 PPI in high-contrast regime
- Viewing distance and contrast sensitivity varies hugely by age
- Character height and content must be adjusted accordingly

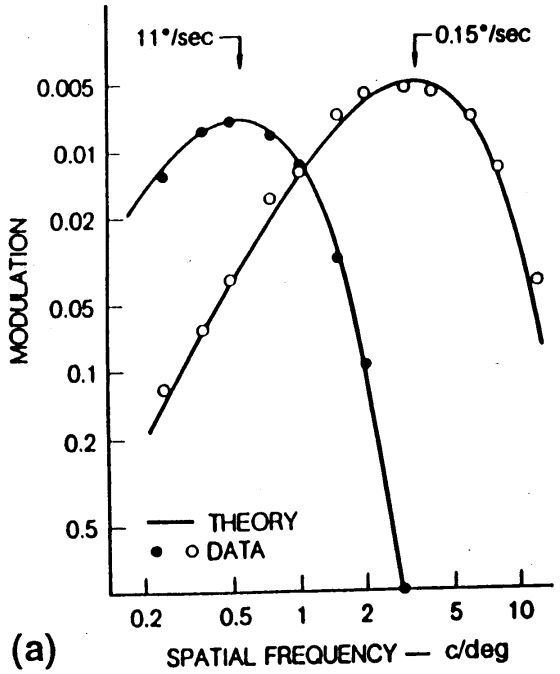
Motion and resolution

- Images have lower contrast and spatial frequency content compared to text
- Motion-dependence of contrast sensitivity function (CSF)

Contrast sensitivity for different flashing frequencies



Contrast sensitivity for different object speeds (experiment)



D.H. Kelly (ed), "Visual Science and Engineering", Marcel Dekker Inc., New York 1994

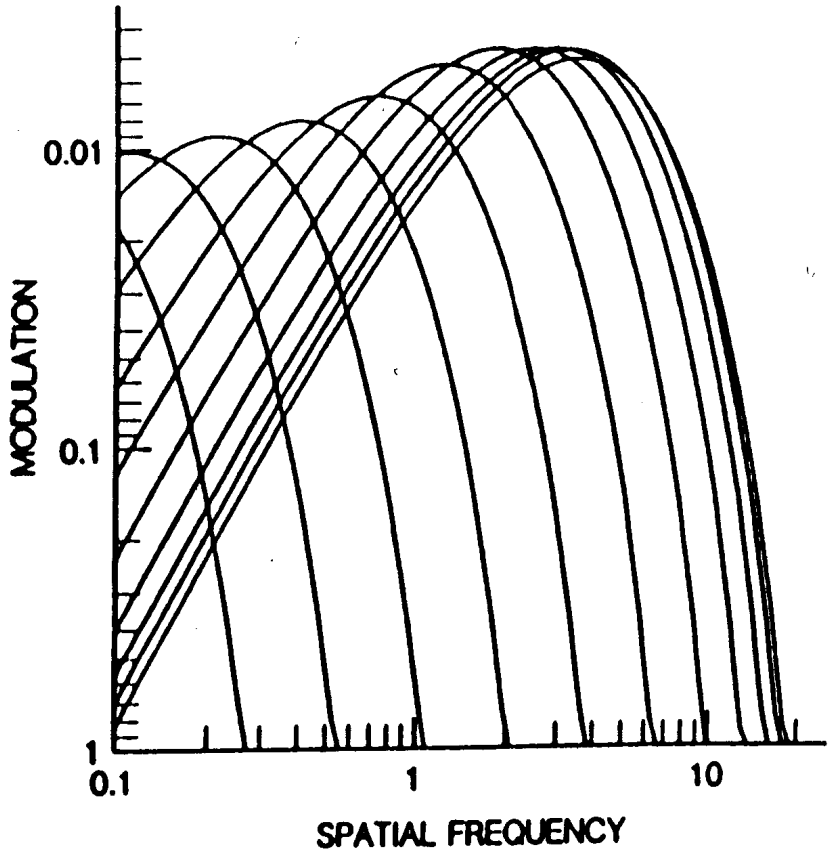
Example: Mobile Display

- Assumptions:
  - Viewing distance: 400 mm
    3” display: FOV=9.5°
  - Object motion speed: 2° s^{-1}
  - Maximum contrast limit of CSF

- Static CSF: 30 cycles/degree (437 PPI @ 400 mm)
- For motion at 2 deg/s, the max resolution becomes 10 cycles/degree (146 PPI @ 400 mm)
- Conclusion: >150 PPI is not necessary for video

Motion-dependent CSF model

0.125, 0.25, 0.5, 1, 2, 4, 8, 16, 32, 64, 128 ° s^{-1}



Page 101-2, D.H. Kelly (ed), “Visual Science and Engineering”, Marcel Dekker Inc., New York 1994

Conclusions

- Variety of users and contexts require high resolution displays for text
- Today's display resolution insufficient for some reading tasks and markets
  - >400 PPI necessary for young Asian text readers
  - Colour depth can be relaxed
- Multimedia displays relax resolution requirements but wide gamut needed
- ~150 PPI sufficient for video services
- Pixel- and colour marketing parameter race continues, though