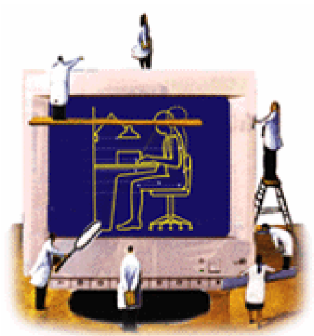
Displays



Computer Vision
Syndrome
Computer Vision Syndrome

NINTENDO 3DS

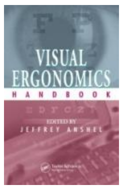



Outline

- **Introduction: display technologies and CVS**
  - **Image generation & encoding and other perceptual issues (HCI, scientific visualization, etc)**
- **Visual comfort**
  - **Visual functions involved using displays**
  - **Environmental issues**
  - **Ergonomic design recommendations & standards**
- **Computer vision syndrome and its prevention**
  - **2D vs. 3D displays**
- **Discussion**
  - **Supplementary reading and learning**
  - **Free activity no. 5**

Bibliography & Links

- **Basic:**



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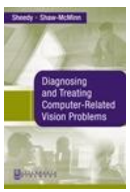

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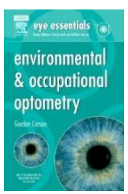

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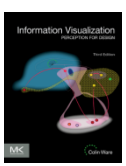

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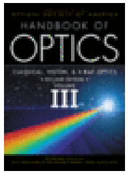

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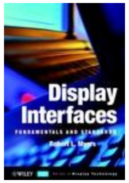

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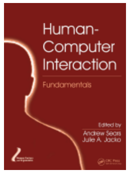

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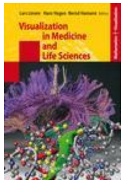

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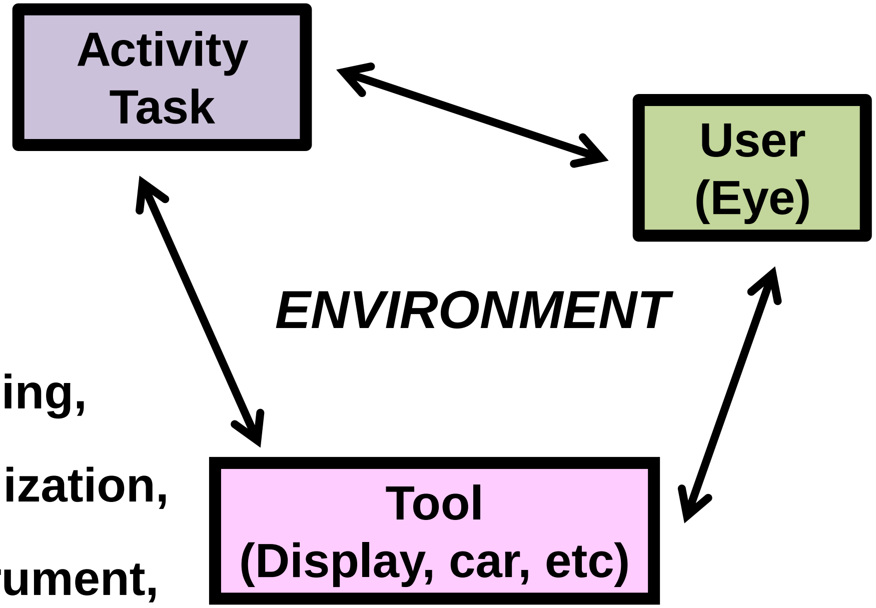
- **Complementary:**
  - **AOO website:** American Optometric Association
  - **INSHT website:** INSTITUTO NACIONAL DE SEGURIDAD E HIGIENE EN EL TRABAJO — Agencia Europea para la Seguridad y la Salud en el Trabajo
  - **AENOR website:** AENOR
  - **Journals in Optometry, Display Technology, Biomedical Optics, Computer Graphics, Visualization, etc.**

Introduction: display technologies

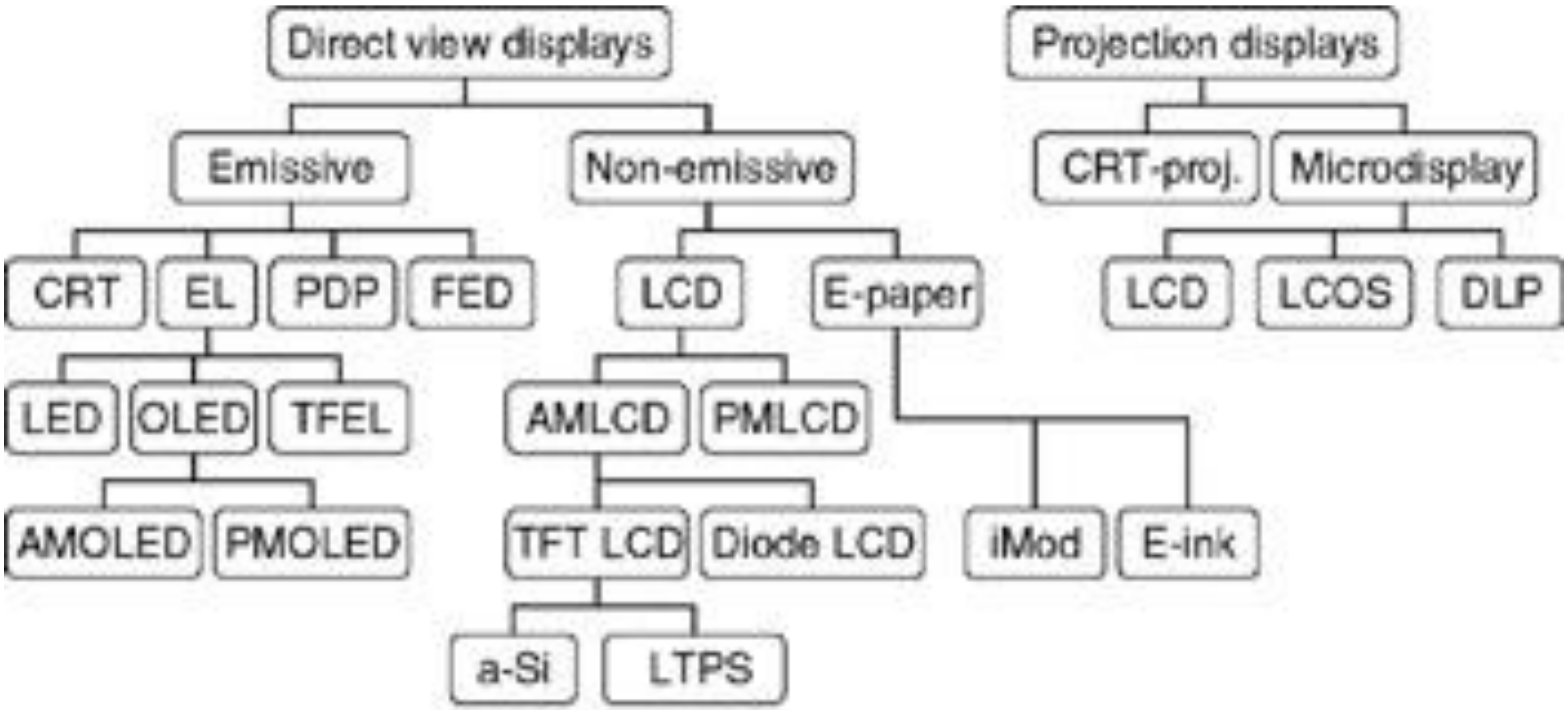
- **<u>Electro-optical</u> device used to display information to the human being, whether in text, figures, images, etc., so that it can manipulate it, change, transfer, etc.**

- **Examples:**
  - **Computer, TV, cinema,**
  - **Monitoring, tele-vendors, etc.,**
  - **Mobile, videogames, virtual learning,**
  - **Medical imaging, scientific visualization,**
  - **Sensor panel of a vehicle or instrument,**
  - **Future??**



Introduction: display technologies

- **History and types of display technologies**



CRT, cathode ray tube; EL, electroluminescent; PDP, plasma display panel; FED, field emission display; LED, light emitting diode; OLED, organic LED; LCOS, liquid crystal on silicon; DLP, digital light projection.

Introduction: display technologies

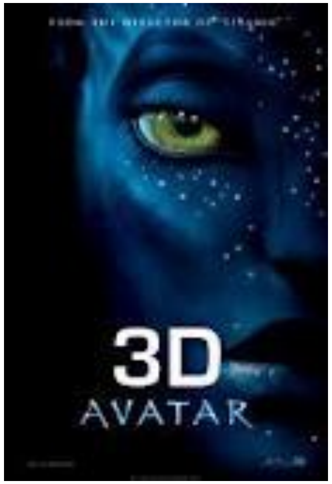
- Applications of display technologies

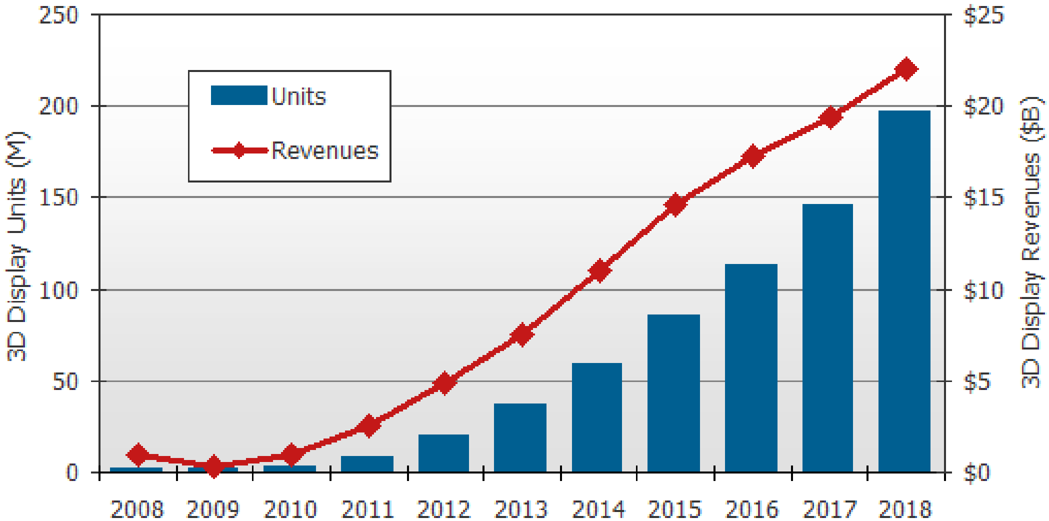
Applications of flat panel displays and their requirements towards the technologies and display properties

Applications/ Requirements	TV	PC	Auto-motive	Industrial	Handheld Devices	White Goods	Public Displays/ Digital Signage	Personal Smart Displays
Resolution	<100ppi	>100ppi	<100ppi	<100ppi	>150ppi	<100ppi	<100ppi	<100ppi
Size	10–100″	10–20″	<10″	10–20″	<10″	<10″	>20″	<10″
Color	Full color	Full color	Color	Color	Full color	Mono	Full color	Mono
Temperature	+5 – +50	+5 – +50	−40 – +90	−40 – +90	−20 – +70	0 – +50	−40 – +50	+5 – +50
Power Consumption	high	low/med.	low/med.	high	low	high	high	low
Sunlight Readability	no	no	yes	maybe	yes	no	yes	yes
Typical Volumes	large	large	small	small	large	small	small	large
Flexible	no	no	maybe	maybe	maybe	maybe	no	yes
Weight	heavy	light	medium	medium	light	medium	heavy	light
Thickness	mixed	thin	mixed	mixed	thin	mixed	thick	thin
Environmental	medium	medium	harsh	harsh	medium	harsh	harsh	harsh
Recyclability	green	green	medium	medium	green	medium	medium	medium
Video Capability	yes	yes	mixed	no	mixed	no	yes	no
Viewing Angle	critical	not	critical	not	not	not	critical	not
Lifetime	long	medium	long	medium	short	long	medium	long

Introduction: display technologies

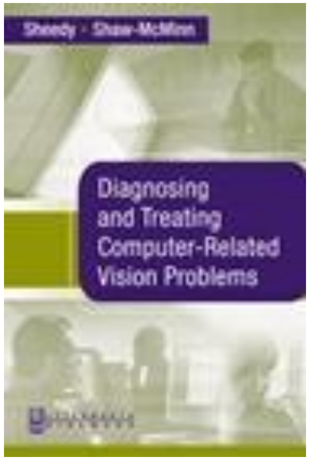
- **Prospects for optic-optometrist:**
  - **Incorporation in inter and multi-disciplinary teams related with multimedia technologies, occupational health, etc.**
  - **Can we be players in the future?**
    - **For flexible, immersive, 3D displays, etc?**
    - **Without visual asthenopia?**

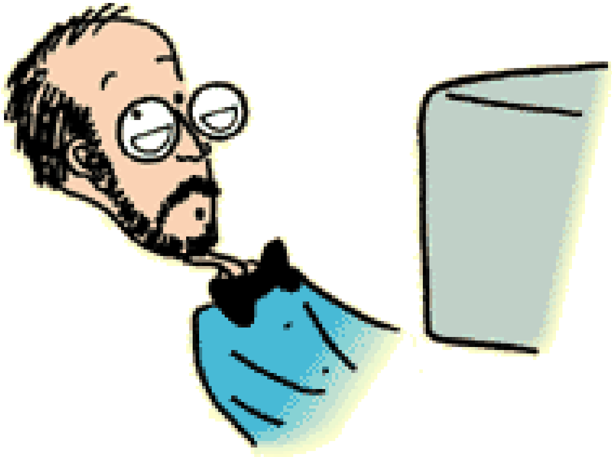




Introduction: CVS

- **Computer Vision Syndrome (CVS):**
  - **Describes a group of eye and vision-related problems that result from prolonged computer use. Many individuals experience eye discomfort and vision problems when viewing a computer screen for extended periods. The level of discomfort appears to increase with the amount of computer use.**





Introduction: CVS

- **The most common symptoms with CVS are:**
  - **eyestrain**
  - **headaches**
  - **blurred vision**
  - **dry eyes**
  - **neck and shoulder pain**

- **These symptoms may be caused by:**
  - **poor lighting**
  - **glare on the computer screen**
  - **improper viewing distances**
  - **poor seating posture**
  - **uncorrected vision problems**
  - **a combination of these factor**

Introduction: CVS

- **Why CVS arises after a long task with a PVD?**
- **What factors are involved in this visual syndrome?**
  - **Only optometric, i.e. attributable to the visual capabilities of the display' users?**
  - **Or there are also ergonomic and environmental factors?**
- **With all optometric and ergonomic data in hand, how can we provide visual comfort display' users?**
- **Which is the first priority for prevention, treatment or therapy?**
  - **Visual or ergonomic?**

Introduction: CVS

- **What kind of visual abnormalities (myopia, hyperopia, presbyopia, phorias, etc.) are more likely to suffer visual asthenopia in front a display?**
  - **http://onlinelibrary.wiley.com/doi/10.1111/j.1475-1313.2011.00834.x/full**

- **Would it apply the same kind of treatment / therapy to all visual abnormalities?**
  - **Refractive and accommodative disorders**
    - **Special lenses for display' users**
  - **Vergence anomalies**
    - **Visual Therapy**
  - **Dry eye**

Introduction: balance

- **Despite this variety of display technologies, is it possible that one of them is talking ergonomically superior than the rest?**

- **What kind of screen/display is better ergonomically speaking?**
  - **How do you quantify this?**

- **Or just the current market trend is due solely to economic factors and non-technical?**

- **What would the ideal or optimal display from the ergonomic point of view?**

Introduction: image generation

- **Visual factors for design of displays and their interfaces**

- **What are the limitations of the screen when displaying information?** → **physical parameters: image generation**

- **What are the interesting properties of the human eye as a receiver of visual information on the screen?** → **Visual perception**

Introduction: image generation

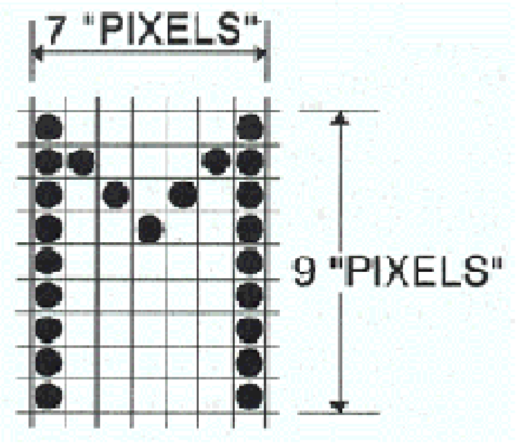
- **Temporal aspects:**
  - **Image sampling**
  - **Afterglow of pixels**
  - **Refresh rate**

- **Spatial aspects**
  - **Addressability**
  - **Resolution**

- **Encoding**
  - **Basic representation (digital, colorimetric, etc.)**
  - **Memory requirements**
  - **Palette and video formats (NTSC, PAL, VGA, XGA, etc)**

Introduction: image generation

- **Temporal aspects (I):**
  - **Main requirements:**
    - **The information must be static, as in a printed document**
    - **But, it must change quickly without realizing the human eye**
  - **Array or mosaic to represent an "continuous“ image**
    - **Pixel: matrix-element image (raster)**
    - **Line: row of pixels**
    - **Frame (frame) of an image / picture**
      - **Interlaced**
      - **Non-interlaced**

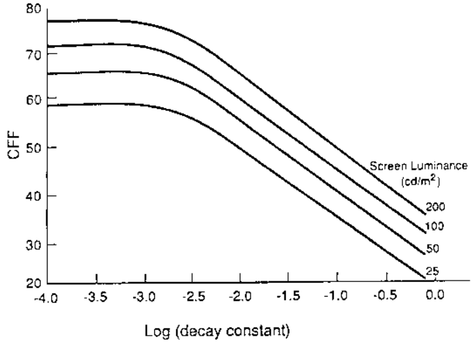


Introduction: image generation

- **Temporal aspects (II):**
  - **Afterglow of pixels:**
    - **The image elements should stop issuing in giving way to the next level of luminance data associated with the following information**

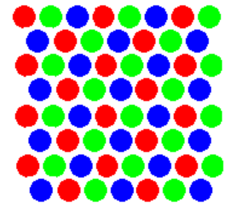
$$L = L_0 \exp\left(-\frac{t}{\tau}\right)$$

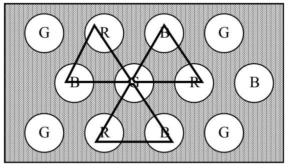
  - **Refresh rate: full sampling rate of a picture / image**
    - **If the refresh rate is low ⇒ flicker perception**
    - **Critical flicker frecuency (CFF):**
      - **If persistence t ↓ and L ↑ ⇒ CFF> 80 Hz**
      - **If persistence t ↑ and L ↑ ⇒ CFF> 50 Hz**
      - **If persistence cte ⇒ great CFF for bright screens**



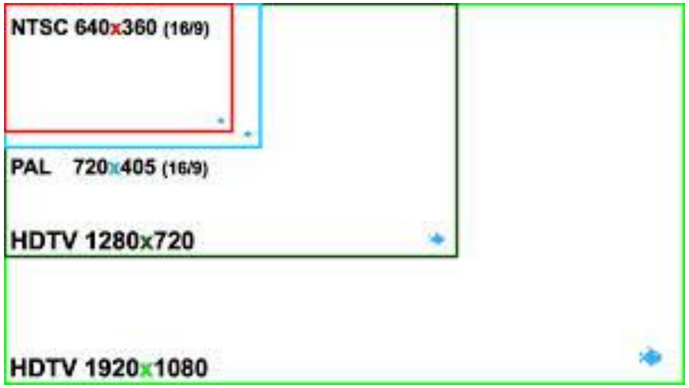
Introduction: image generation

- **Spatial aspects:**
  - **Pixel: RGB additive mixing**



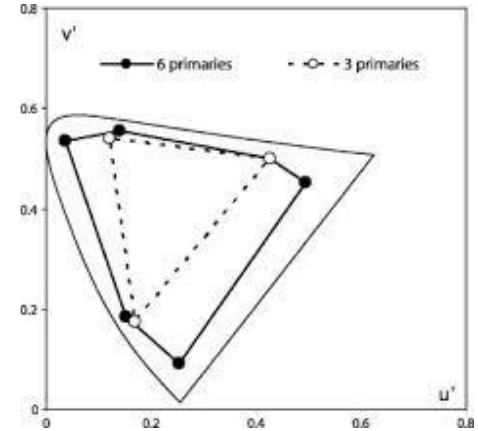


  - **Addressability: pixel separation (density)**
    - **Determines the spatial frequency that can be sampled an optotype**
    - **Horizontal spacing < 20 " arc to eliminate aliasing problems**
      - **For d = 45 cm is equivalent to 0.04 mm**
    - **Vertical spacing $\in$ [0.17, 0.90] mm**
  - **[Resolution]: [pixel size] (ppi, dpi)**
    - **Format types:**
      - **4:3 vs. 16:9, 4K vs. 2K, etc**
    - **[Diagonal screen](in inches)**

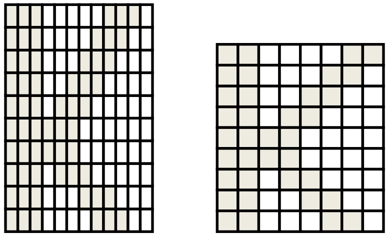


Introduction: image generation

- **Encoding:**
  - **digital, hexadecimal, binary (ASCII), analog, photometric**
    - **sRGB encoding: RGB2XYZ and L*a*b* in Excel**
    - **Multi-primary displays**



- **Basic representation: basic cell**
  - **Teletext (TV): 12x10 pixels**
  - **Computers: 7x9 pixels**



- **Memory requirements:**
  - **temporal + spatial + color balance for computational purposes**
  - **Palette and video formats (NTSC, PAL, VGA, XGA, etc)**

Visual comfort

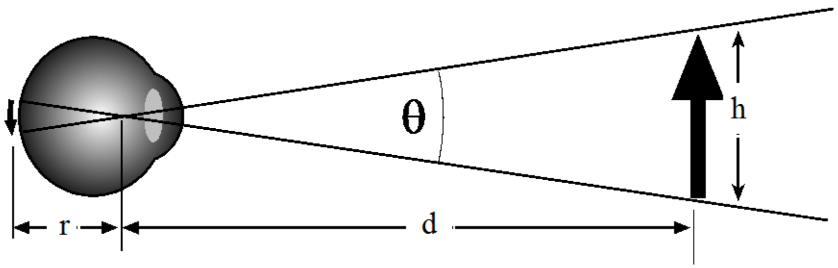
- **Visual capabilities involved (I):**
  - **Eye pursuit of mouse/pointer**
  - **Eye fixation for reading:**
    - **Saccades:**
      - **intervals between 250 ms and amplitudes 8 ± 4 characters**
    - **Processes in reading:**
      - **Text search interesting for us ⇒ text legibility**
      - **Reading or cognitive processing ⇒ text intelligibility**
  - **Accommodation: distant vision step closer, and vice versa**
  - **Peripheral vision work environment while you look at the screen (central visual task)**

Visual comfort

- **Visual capabilities involved (II):**
  - **Binocular coordination for not seeing double**
  - **Hand-eye coordination (keyboard, mouse, etc.)**
  - **Attention**
    - **Ability to maintain a particular activity easily without being interfered by other tasks (audio, visual, etc.)**
  - **Near visual acuity: $d_W \in [50, 75]$ cm**
  - **Visualization:**
    - **Ability to form "mental pictures" and retain them for later appropriate use**
  - **Relaxation $\Rightarrow$ vision therapy exercises**

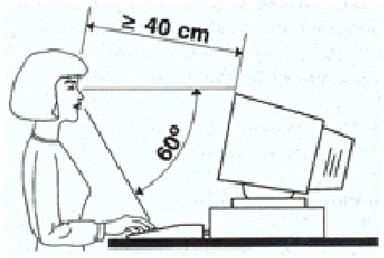
Visual comfort

- **Text legibility:**
  - **Typography (words): size, horizontal and vertical spacing**
  - **Character height: > 22 arc min**



$$\theta = \frac{h}{d} \quad [\mathrm{rad}]$$

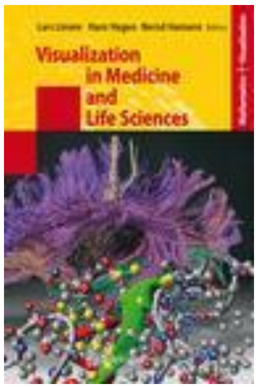
$$h_{\min} = 2.9e-4 \cdot 0.4 \cdot 22 = 2.5\ \mathrm{mm}$$

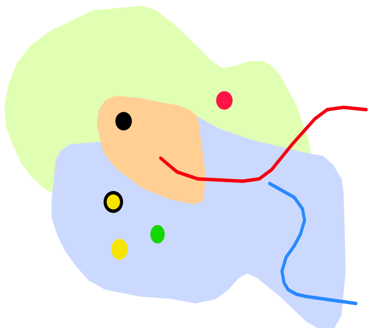


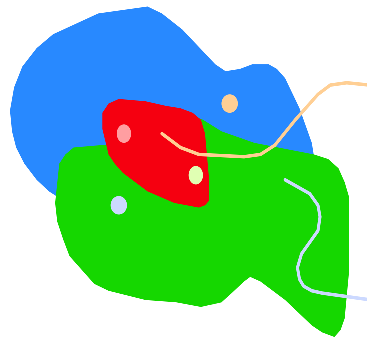
  - **Luminance contrast > 5:1 ⇒ $\Delta L^* > 18 \cdot [Y_{background}\ (\%)]^{1/3}$**
  - **Avoid colored background and text: ΔC_{ab}^* (> 20) before than ΔH_{ab}^***
  - **Design firstly in white and black**
  - **Locate carefully the strong colors because distracting**
  - **Small details saturated; large areas desaturated**

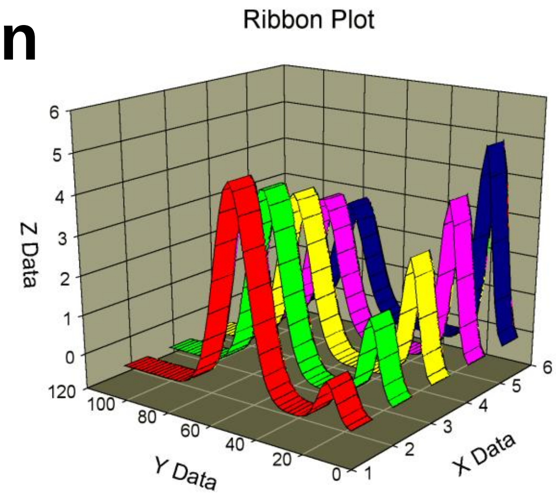
Visual comfort

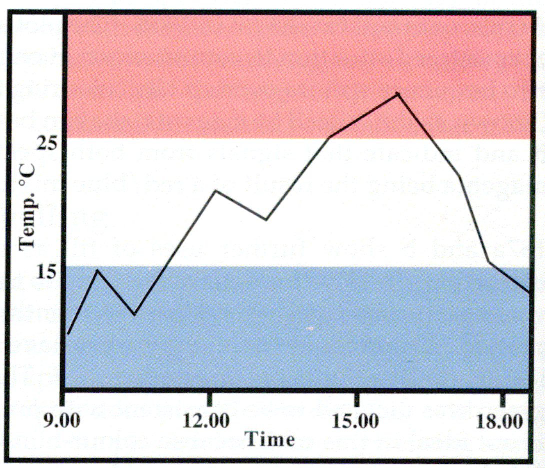
- **Text legibility: scientific visualization**

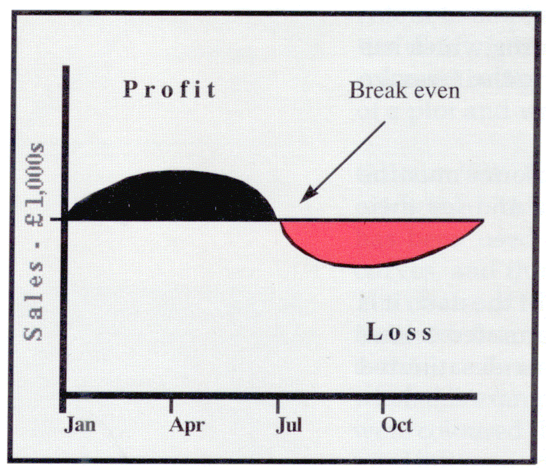


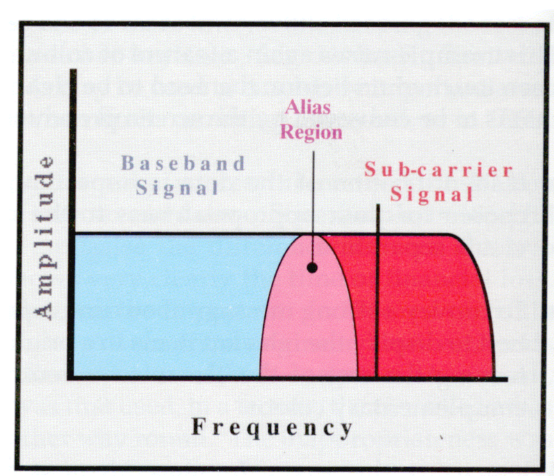








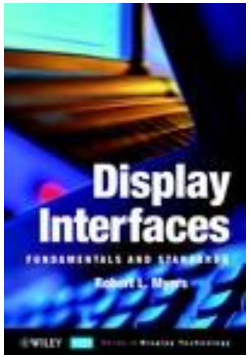


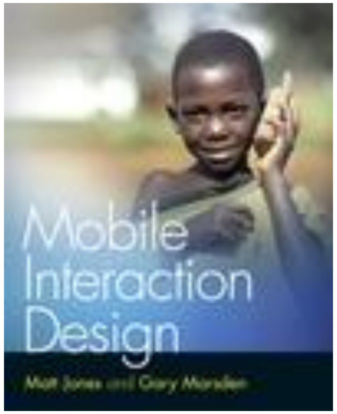


Visual comfort

- **Scientific visualization: information intelligibility**
  - **Printed vs. electronic**
    - **Sided printing for long texts**
      - **Exception: columns in newspapers and magazines: comfortable reading because the saccadic amplitudes for kicks are shorter**
      - **Scrolling vs. paged**

- **Scientific visualization: information usability**
  - **Software interfaces design (smartphones, etc.)**
    - **Windows**
    - **Icons**
    - **Charts**
    - **Tactile interaction**
    - **Etc.**





Visual comfort

- **Environmental issues: lighting conditions**
  - **What aspects of interior lighting design can interact with the characteristics of displays to improve visual comfort and performance of the tasks for users?**
  - **Poor lighting facilities**
    - **Static luminance imbalance**
    - **Dynamic luminance imbalance**
    - **Unwanted reflections on the screen**
    - **Effect of the polarity of the screen**
  - **Theoretical solutions**

Visual comfort

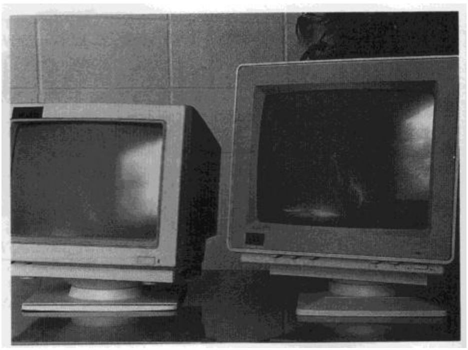
- **Lighting conditions: static luminance imbalance**
  - **ΔL ↑↑ among different sight lines**
  - **Example: near open windows in the field of view**
  - **Impact: contrast reduction, glare**

Visual comfort

- **Lighting conditions: dynamic luminance imbalance**
  - **ΔL ↑↑ between screen and desk, where reference document is**
  - **Impact: delay for accomplishing a comfortable luminous adaptation**

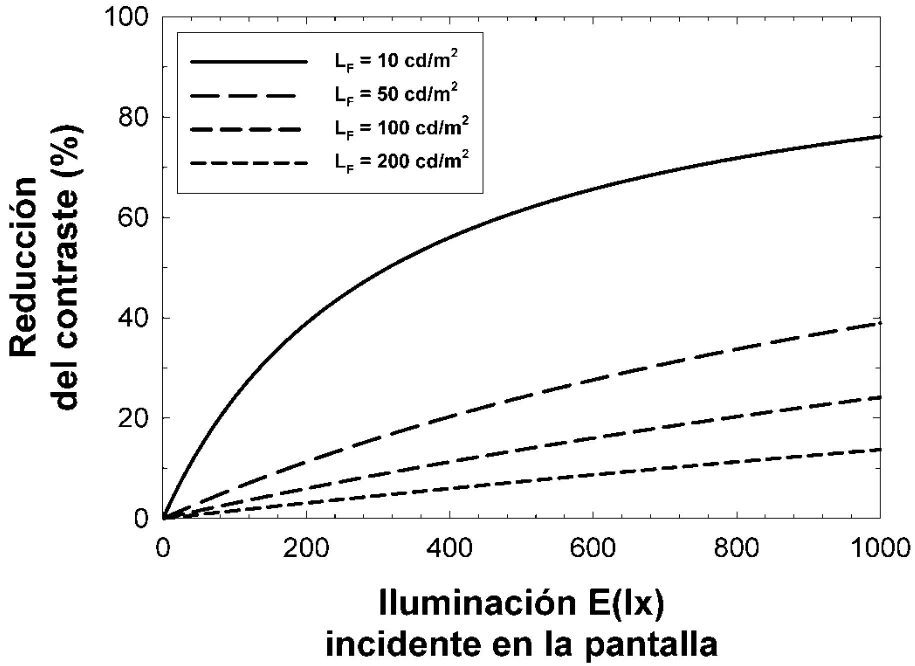
Visual comfort

- **Lighting conditions: unwanted reflections on screen**
  - **Screen coating is not an ideal black**
  - **Overlapped pictures over the important content on screen**
  - **Impact: contrast reduction, task distraction**



Visual comfort

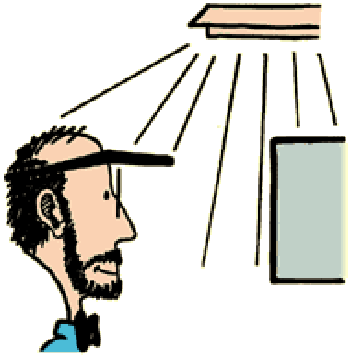
- **Polarity effects on screen:**
  - **Positive:**
    - **Lighter background + dark text**
  - **Negative:**
    - **Darker background + light text**
  - **When is it suitable a screen with negative polarity?**
    - **Flicker reduction**
    - **Low or impaired vision**



Visual comfort

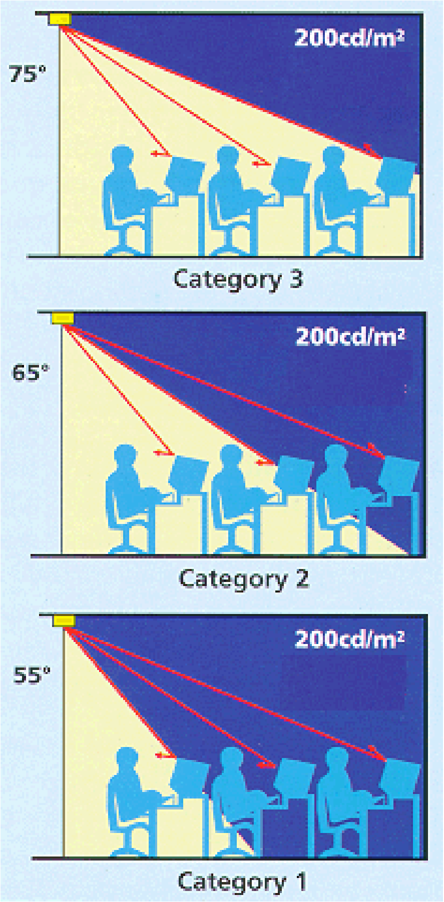
- **Practical and theoretical lighting solutions:**
  - **Objective: To <u>avoid</u> reflections on the screen and <u>control</u> the luminance imbalances**
  - **Solution 1: Using polarizing (antiglare) filters??**

  - **Solution 2: uniform lighting design**
    - **Blinds and curtains for the windows, even the screens**
    - **Reflection factors of the elements of the working environment:**
    - **ρ ~ 0.7 for roof**
    - **ρ ~ 0.3 for soil**
    - **ρ ~ 0.5 for wall**
    - **ρ ~ 0.5 for furniture**



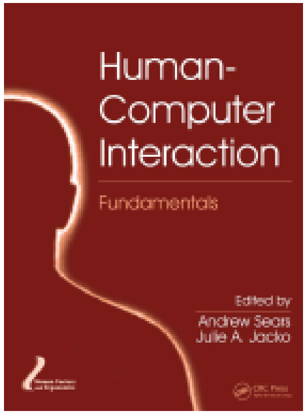
Visual comfort

- **Technical recommendations:**
  - **Direct lighting:**
    - **Category 1: areas where the displays use is sustained, intensive and critical errors are**
    - **Category 2: areas where the displays use is customary**
    - **Category 3: areas where displays use is casual or displays density is low**
  - **Indirect lighting:**
    - **Average luminance on ceiling < 500 cd/m^2**
    - **Maximum luminance on ceiling < 1500 cd/m^2**



Visual comfort

- **Ergonomic design recommendations & standards:**
  - **Ley 31/1995 (Prevención de Riesgos Laborales)**
  - **RD 488/1997 (Pantallas de Visualización de Datos)**
    - **INSHT website: technical guides**
    - **Spanish Ministry of Health: surveillance protocol**
  - **UNE-EN ISO – 9241**
    - **100 series: Software ergonomics**
    - **200 series: Human system interaction processes**
    - **300 series: Displays and display related hardware**
    - **400 series: Physical input devices - ergonomics principles**
    - **500 series: Workplace ergonomics**
    - **600 series: Environment ergonomics**
    - **700 series: Application domains - Control rooms**
    - **900 series: Tactile and haptic interactions**



CVS prevention for 2D displays (I)

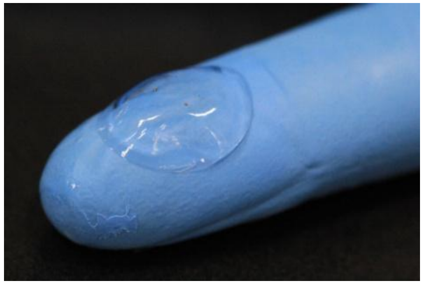
- **Optometric examinations needed**
  - **Refractive and accommodative dysfunctions:**
    - **Besg corrected VA, R and binocular balancing, accommodative lag to the working distance, mono and binocular Am, mono and binocular accommodative facility, and ARA- & ARA+**
  - **Vergence anomalies:**
    - **Near point of convergence, near heterophoria, (H/V) fixation disparity, vergence facility, and ARC- & ARC+, stereopsis, AC/A & CA/C ratios**
  - **Dry eye**
  - **Task visibility of the display:**
    - **lighting, color, contrast, comfortable size (5s) and distance, etc.**

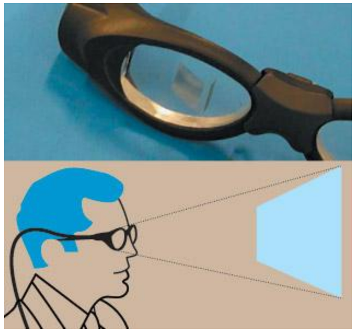
CVS prevention for 2D displays (II)

- **Usual visual therapies: main objectives**
  - **Ranking of prevalence:**
    - **presbyopia, hyperopia, esophorias, ocular and systemic diseases contributing to dry eye, etc.**
  - **Refractive and accommodative dysfunctions**
    - **R compensation firstly, ARA+ & ARA- > 1.5 D**
  - **Vergence abnormalities:**
    - **Dark vergence > 4 am**
  - **Dry eye:**
  - **Task visibility of the display: 3x rule for size and/or distance**
    - $(5s)_{comfort} = 3 \cdot (5s)_{min}$ $\quad$ $d_{comfort} = 1/3 \cdot d_{max}$

CVS prevention for 2D displays (III)

- **Using “special” lenses for display’ users:**
  - **Conventional or progressive spectacles are questionable**
    - **Adjust rightly the field of view to the screen size**
    - **Measure eye-screen distance**
    - **Measure the screen height and reference documents regarding the primary gaze**
    - **Check with the patient clear and blurred vision ranges with "special“ spectacles**





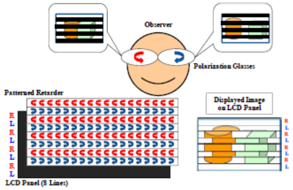
CVS prevention for 2D displays (IV)

- **Typical visual therapies: strengthening of**
  - **1- accommodation**
    2 - pursuit eye movements
    3 - saccadic eye movements
    4 - hand-eye (monocular) coordination
    5 - central and peripheral fixation
    6 - Marsden ball
    7 - Brock cordon
    8 - viewing stereograms in parallel mode
    9 - accommodation in the dark

- **Postural exercises proposed occupational health services**
  - **UA prevention service (Spanish RD 488/1997)**

CVS prevention for 3D displays (I)

- **3D display technologies: past, present and future**
  - **Direct or indirect viewing: binocular disparity**
  - **With optical aid**
    - **1 image: colored anaglyphs, polarizing filters, shutter glasses**
    - **2 images: effective binocular object,**
  - **Without optical aid: auto-stereoscopy**
    - **Volumetric, integral imaging, holography, multi-view, etc.**



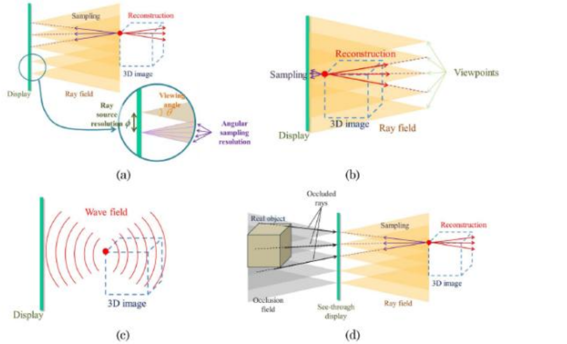
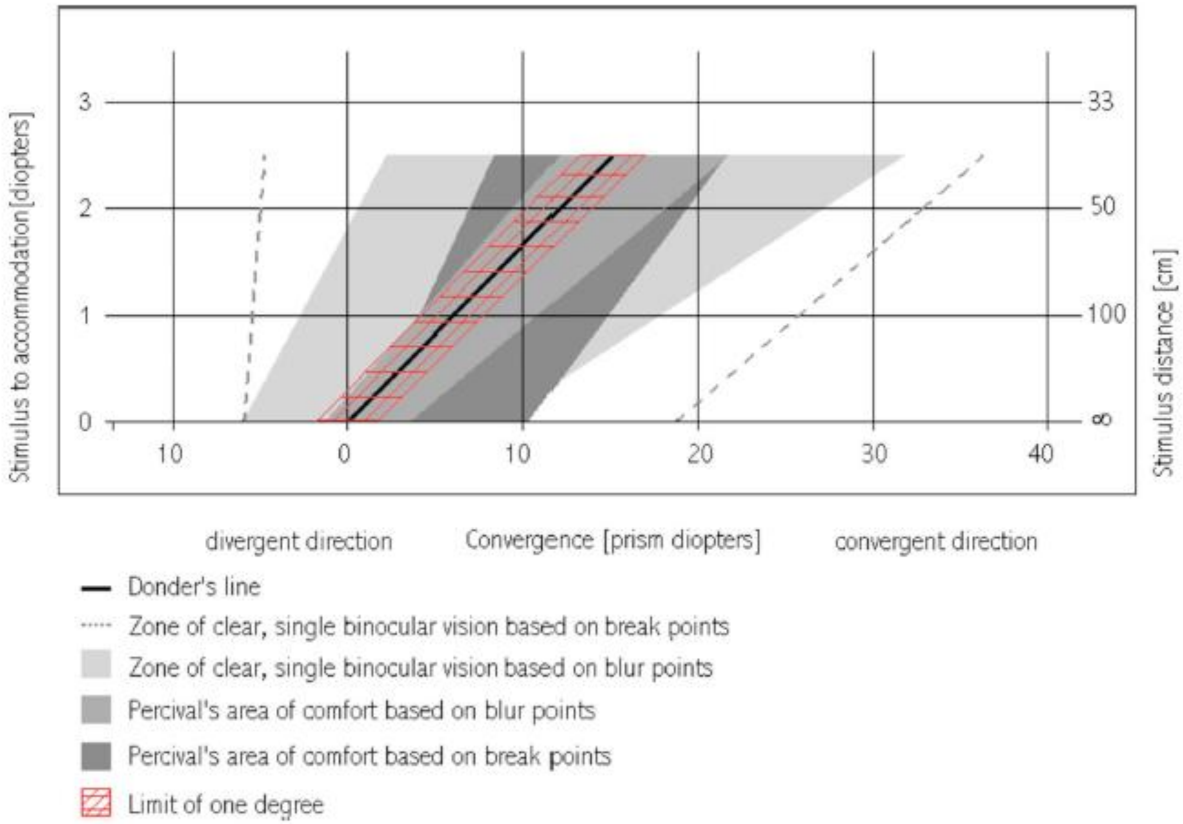


Fig. 35. (Color online) Sampling and reconstruction processes of outlined technologies: (a) integral imaging, (b) multiview display, (c) holography, and (d) see-through 3D display.

CVS prevention for 3D displays (I)

- Comfortable vision using 3D display technologies

Lambooij et al.: Visual discomfort and visual fatigue of stereoscopic displays: A review



Within the comfort zone (η <1 deg) can also be visual asthenopia due to:

- **Fast and abrupt depth changes**
- **3D artifacts**
- **Unnatural blur**

Table I. Limits of comfortable viewing at different viewing distances corresponding to one degree of screen disparity for both crossed and uncrossed disparity. The limits set the area around the display measured from the viewer.

	Limits for comfortable viewing	
View distance (mm)	Near (mm)	Far (mm)
500	440	580
1000	780	1400
2000	1300	4800
3000	1600	23000

CVS prevention for 3D displays (II)

- **Clear and single binocular vision zone (CSBVZ):**
  - **Clinical study by Shibata et al. (2011):**
    - **doi: 10.1167/11.8.11**
    - **Risley prisms with 20 observers**
  - **C / A conflicts generating asthenopia:**
    - **Are less comfortable in parallel view, i.e., near to far distances**
    - **Stereo content behind the screen in parallel vision are less comfortable**
    - **However, stereo content ahead of the viewing screen in cross viewing are also discomfort**
    - **Measuring CSBVZ and predicting visual discomfort depending on 3D screen (cinema, TV, mobile, etc)**

CVS prevention for 3D displays (III)

- **Clear and single binocular vision zone (CSBVZ):**
  - **Clinical study by Shibata et al. (2011)**
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CVS prevention for 3D displays (IV)

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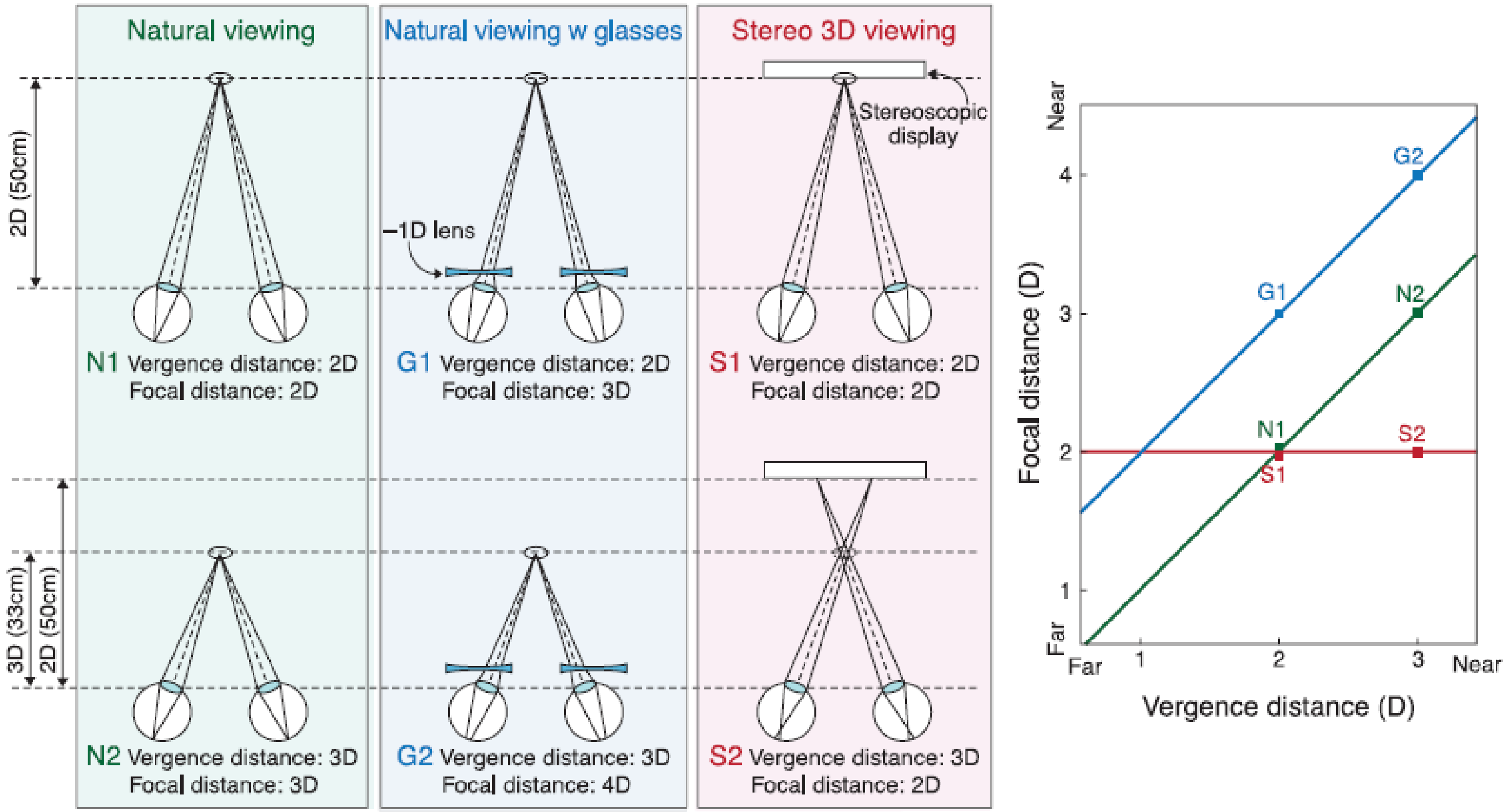
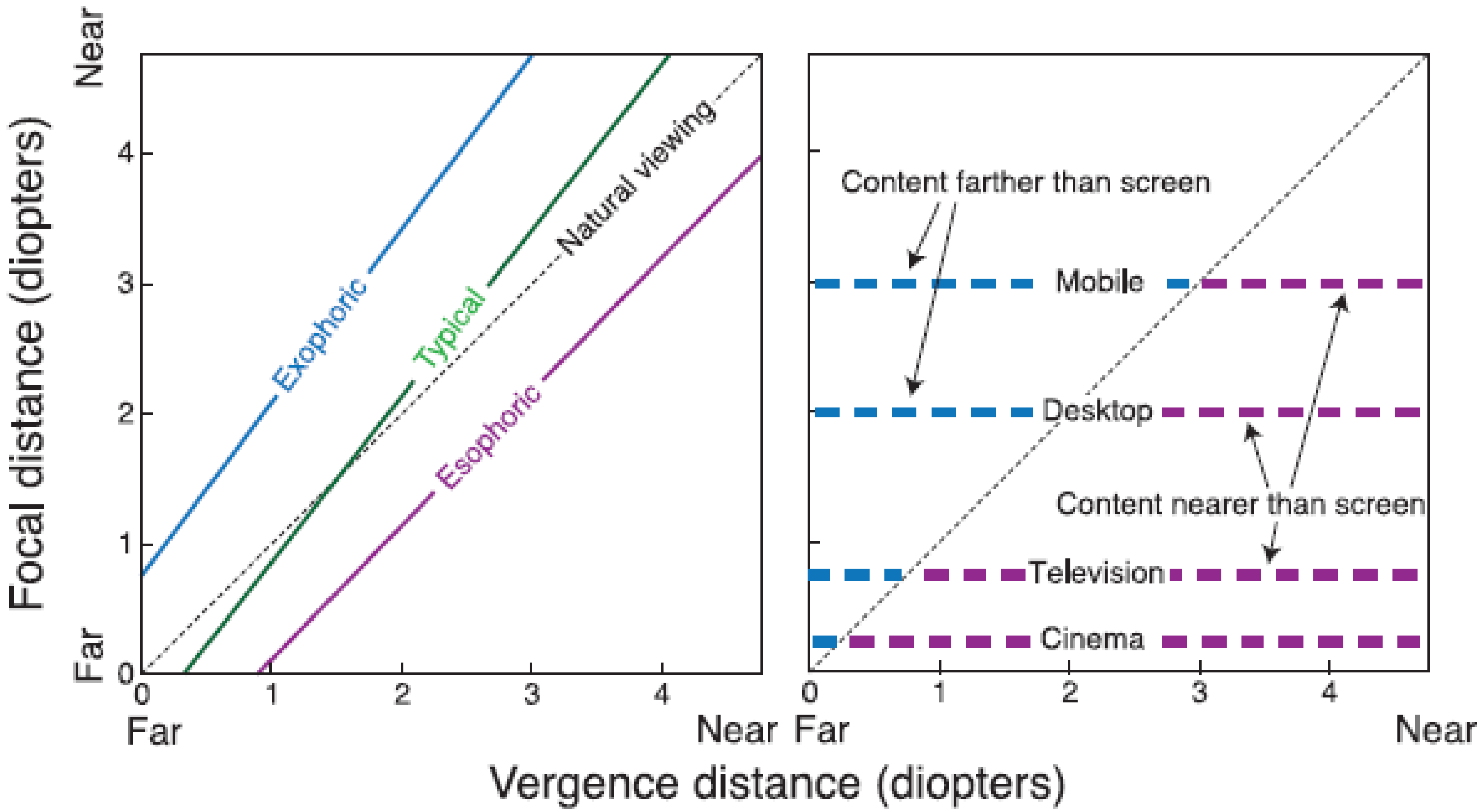
  - **Clinical study by Shibata et al. (2011)**



CVS prevention for 3D displays (V)

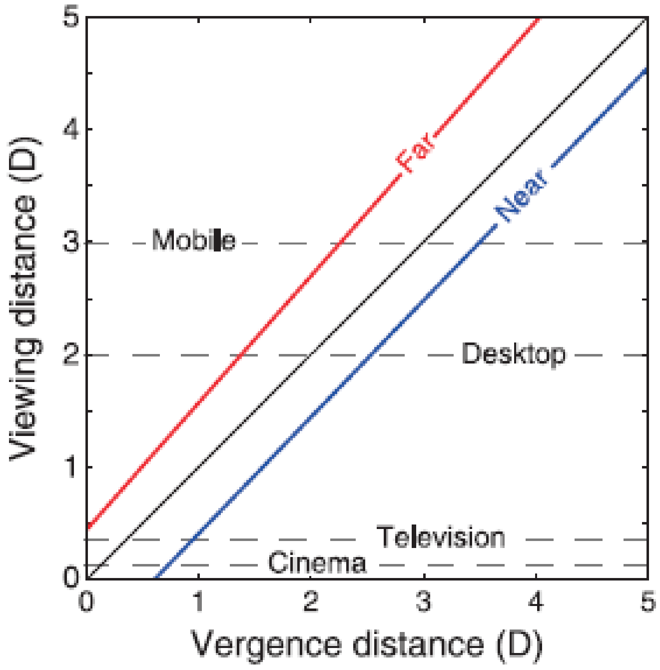
- **Clear and single binocular vision zone (CSBVZ):**
  - **Clinical study by Shibata et al. (2011)**

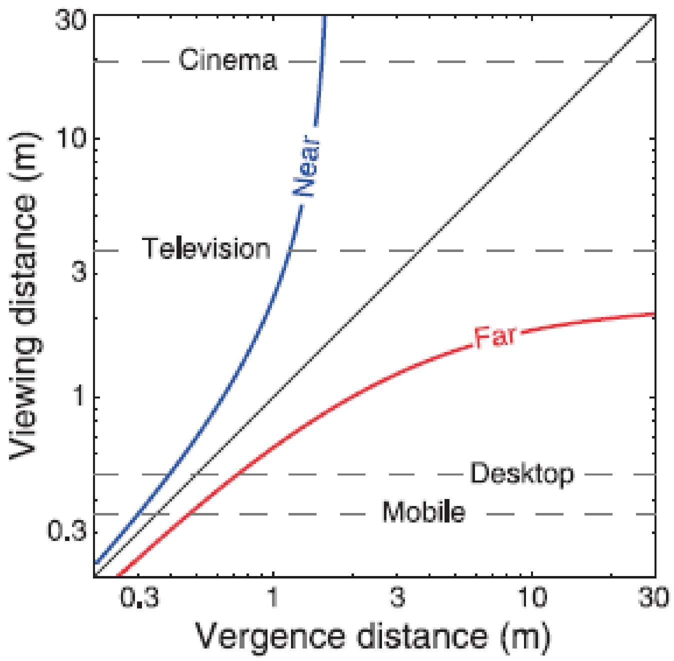


CVS prevention for 3D displays (VI)

- **Clear and single binocular vision zone (CSBVZ):**
  - **Clinical study by Shibata et al. (2011)**
    - **Limit straight lines:**

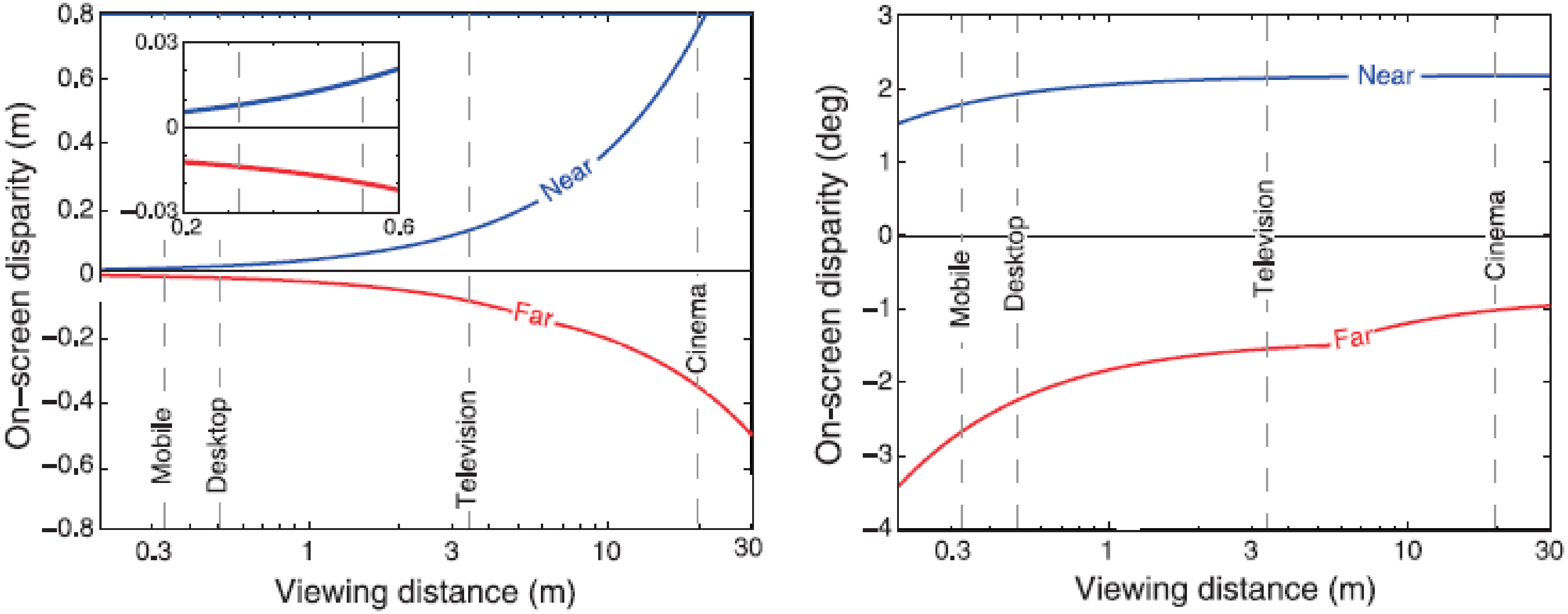
A = 1.129*C + 0.442 (far) ; A = 1.035*C - 0.626 (near)





CVS prevention for 3D displays (VII)

- **Clear and single binocular vision zone (CSBVZ):**
  - **Clinical study by Shibata et al. (2011)**
  - **Disparities in m, o in deg**
    - **Positive: cross viewing; Negative: parallel viewing**



CVS prevention for 3D displays (VIII)

- **Typical cases for controlling comfortable vision**
  - **Case 1: fixed contents and 3D display**
  - **Variable distance viewing ⇒ get away from the 3D display and using cross-view (with contents in front of the screen) is more comfortable**
  - **Examples: 3D video games, 3D movies / TV**

  - **In case of necessity to approach to the 3D screen (stereograms books), using 3D content behind the (paper) screen to view in parallel view**

CVS prevention for 3D displays (IX)

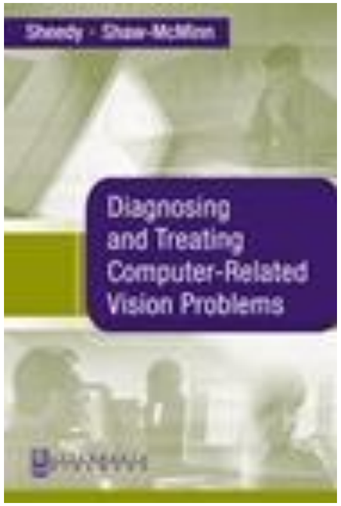
- **Typical cases for controlling comfortable vision**
  - **Case 2: scalable contents in small displays**
    - **Examples: from 3D cinema to 3D mobile, laptop or tablet**

  - **With fixed distance ⇒ better decrease 3D image**
  - **<u>But</u>, with variable distance:**
  - **Better minimize 3D image and approach**
  - **Worse increase 3D image and get away**

Supplementary reading and learning

- **Download the next review paper about CVS syndrome published in 2011:**
- **doi: 10.1111/j.1475-1313.2011.00834.x**

  - **Why it is interesting? Who people are more prone to this syndrome?**
  - **Are there updated studies of visual prevalence in Spain?**
  - **What potential treatments are more interesting for you?**
  - **Why?**



Free activity nº 5

- **Relative Weight: 0 %**
- **Delivery process by Virtual Campus, section forum**
- **Individual Task:**
  - **Check and compare normative documents on displays from the Spanish Ministry of Employment and Social Security (INSHT) and the Spanish Ministry of Health, Social Services and Equality.**
  - **Which of them do you consider that the participation of an optometrist can capital to be good preventive action in ocular and / or visual risks?**
  - **Are all done or is there much to be done? Justify.**