Medical Imaging Displays: Psychophysics and Quality Assurance: Psychophysics and the Human Visual System

Rationale

- **Display options present significant challenge - which use, under what circumstances, how optimize given envt**
- **In addition calibration must understand basic display parameters for workstations (primary & secondary) & hand-held devices**

Objectives

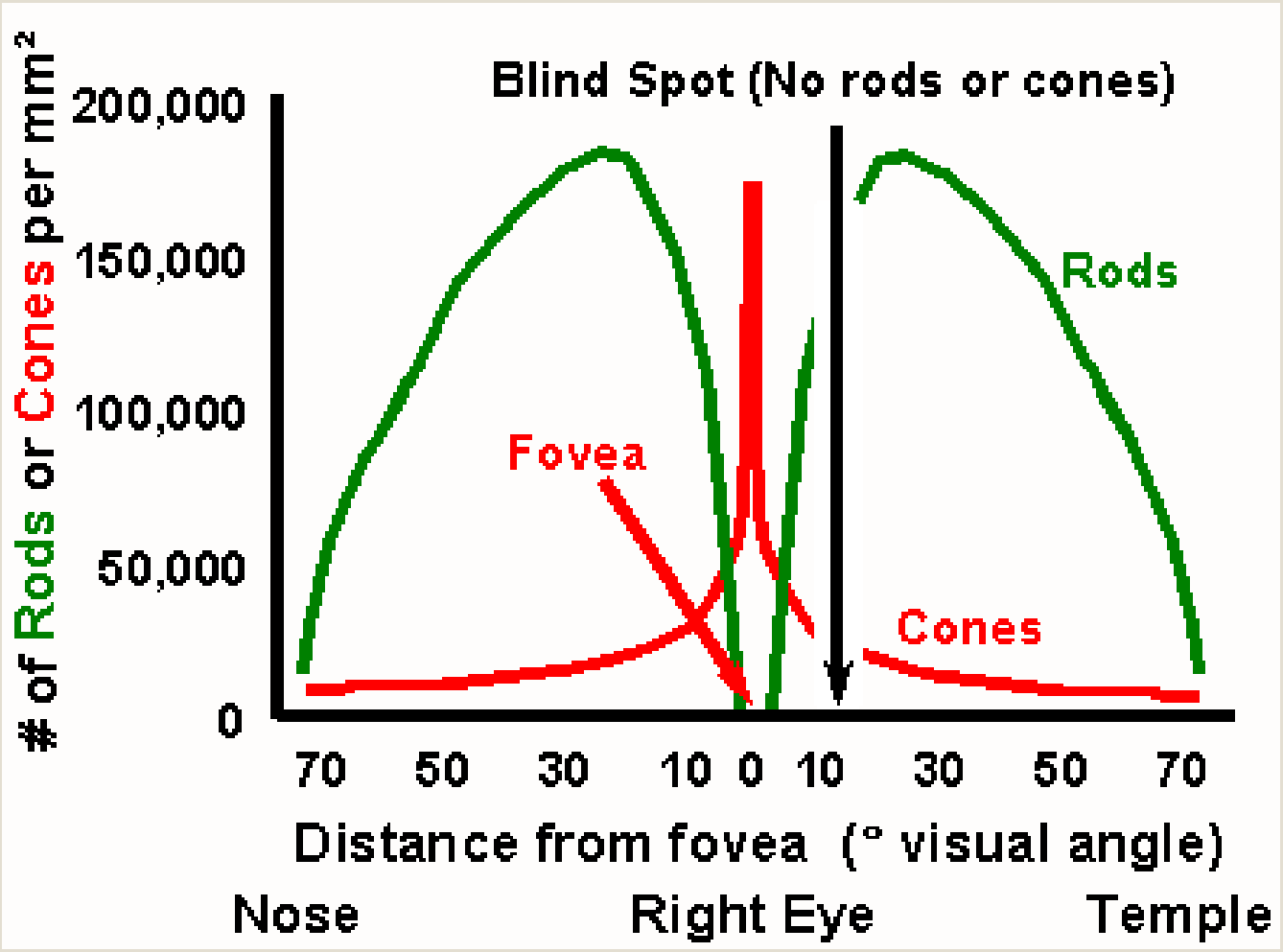
1) Review critical display properties pertain diagnostic interpretation

2) Describe methods calibration & consistent presentation primary/secondary displays & enterprise QA management

3) Understand capabilities & limitations secondary & hand-held devices

4) Appreciate role envt & ergonomics

No relevant financial interests to disclose


# of Rods or Cones per mm²
200,000
150,000
100,000
50,000
0
Blind Spot (No rods or cones)
Rods
Fovea
Cones
70 50 30 10 0 10 30 50 70
Distance from fovea (° visual angle)
Nose
Right Eye
Temple

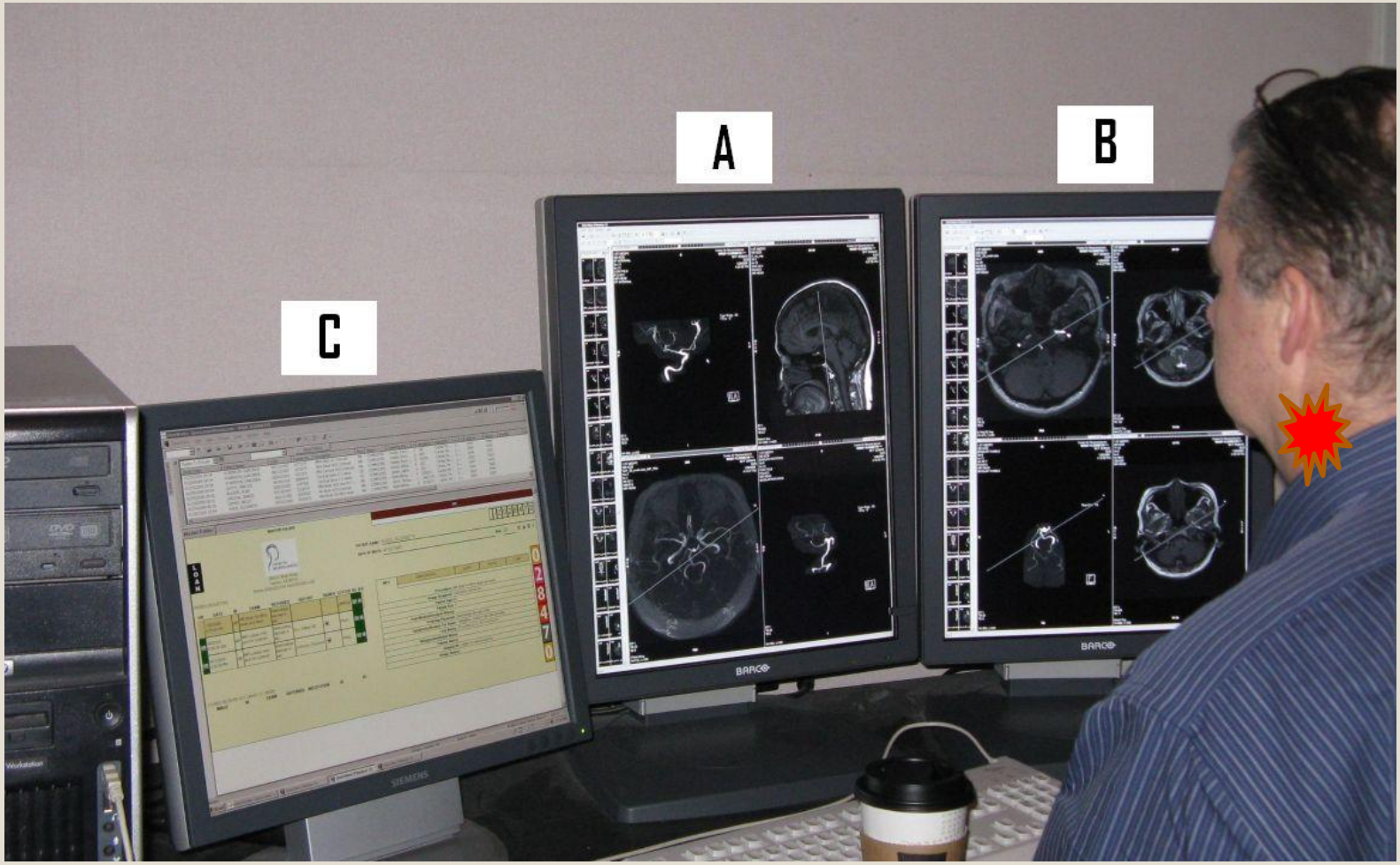
The peak receptor density of the cones in the retina is about how far from the fovea?

20%	1. < 10 deg
20%	2. > 10 deg
20%	3. > 20 deg
20%	4. > 30 deg
20%	5. Is no peak – it's uniform

Answer a.

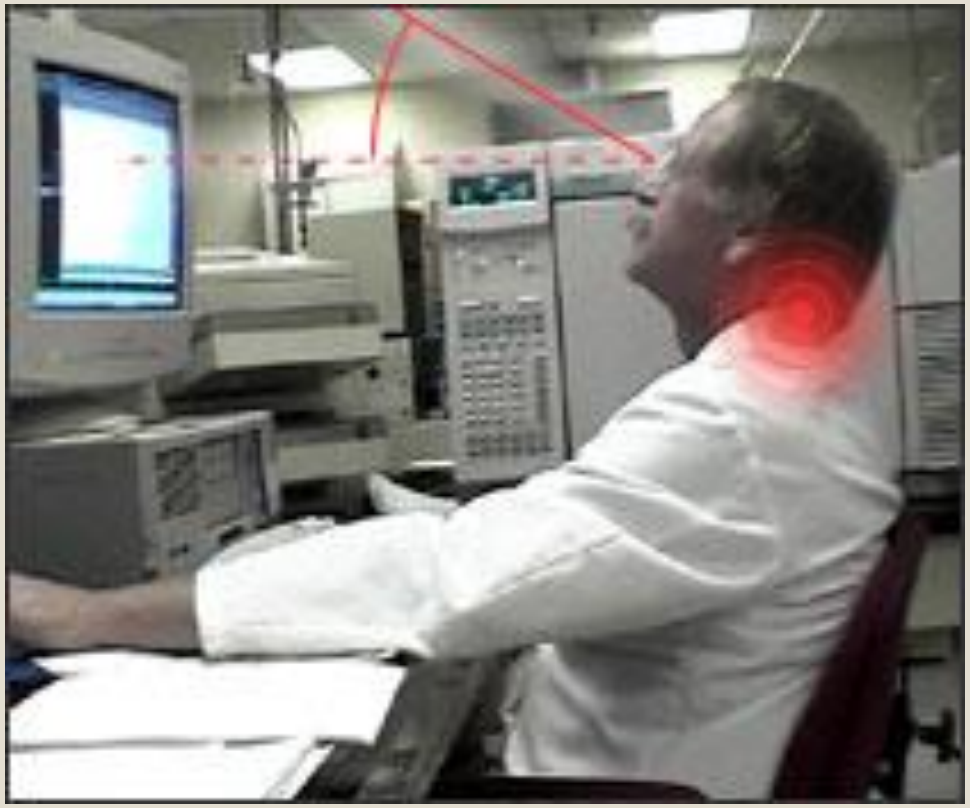
Reference: Purves D, Augustine GJ, Fitzpatrick D, et al., editors. Neuroscience. 2nd edition. Sunderland (MA): Sinauer Associates; 2001. Anatomical Distribution of Rods and Cones.

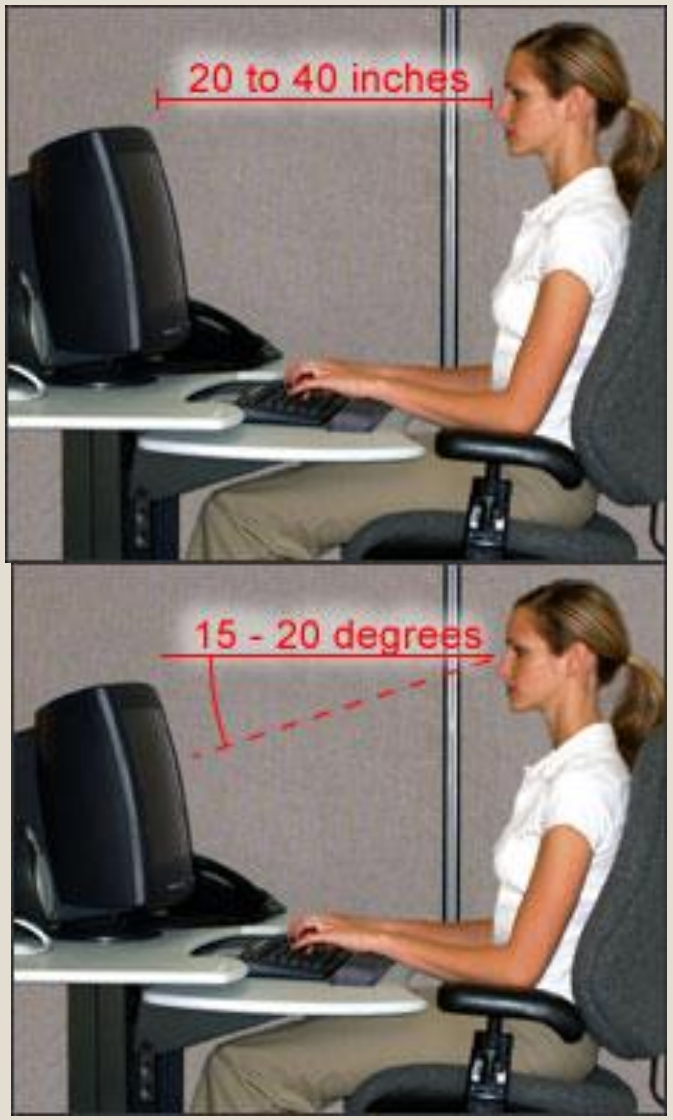
Display Arrangements



Monitors should not be farther than 35 degrees to the left or right

Height & Distance



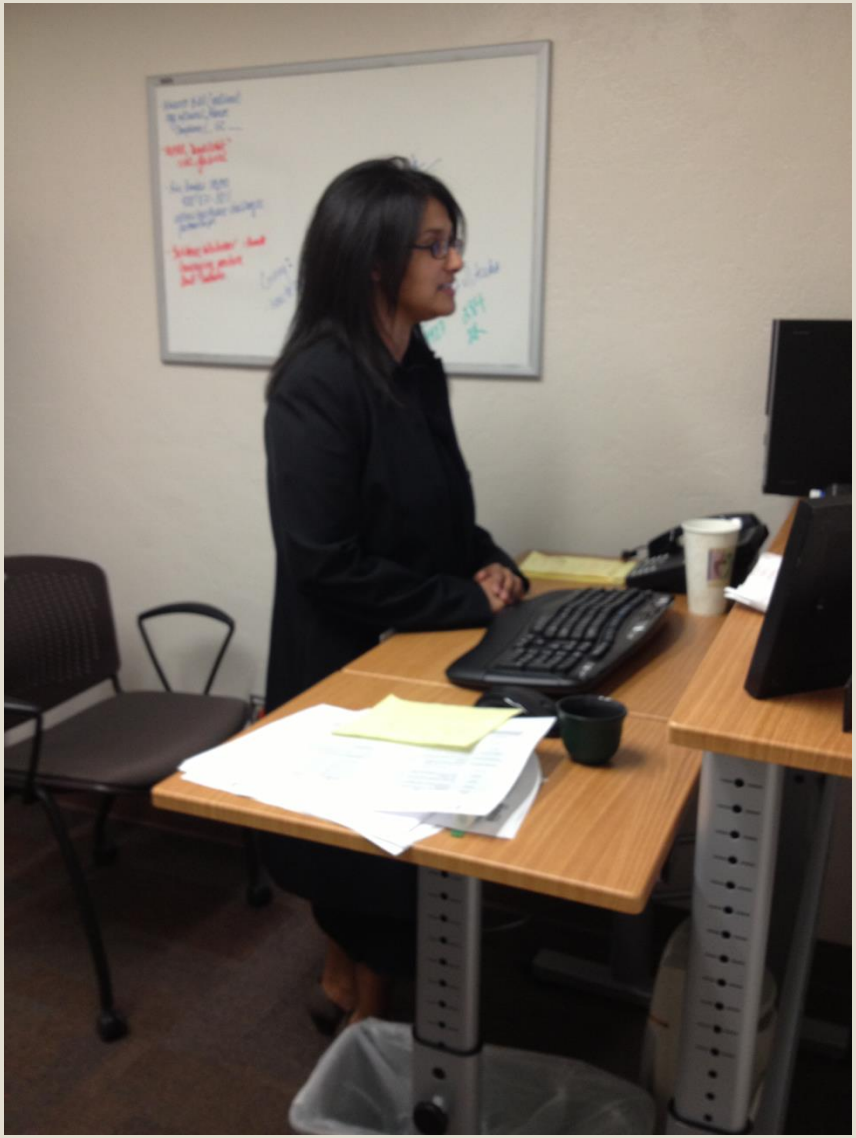


For a specific viewing distance the diagonal dimension of a display should be about:

20%	1. ¼ the viewing distance
20%	2. ½ the viewing distance
20%	3. ¾ the viewing distance
20%	4. No relation viewing distance
20%	5. Same as viewing distance

Answer c.
Reference:
http://www.thx.com/consumer/home-entertainment/home-theater/hdtv-set-up/

Viewing Options



Neutral Body Positions



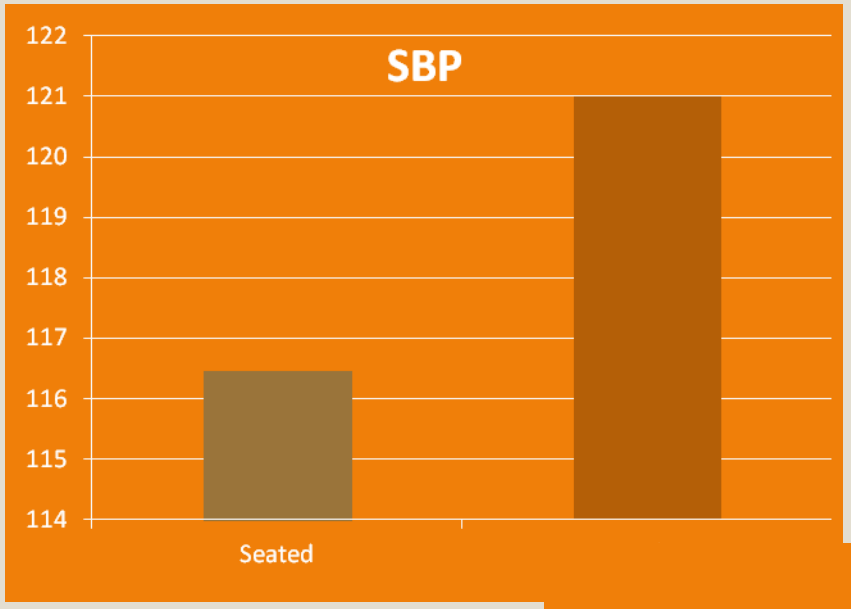

Neutral position reduces stress & strain on muscles, tendons, skeletal system & reduces risk developing musculoskeletal disorder

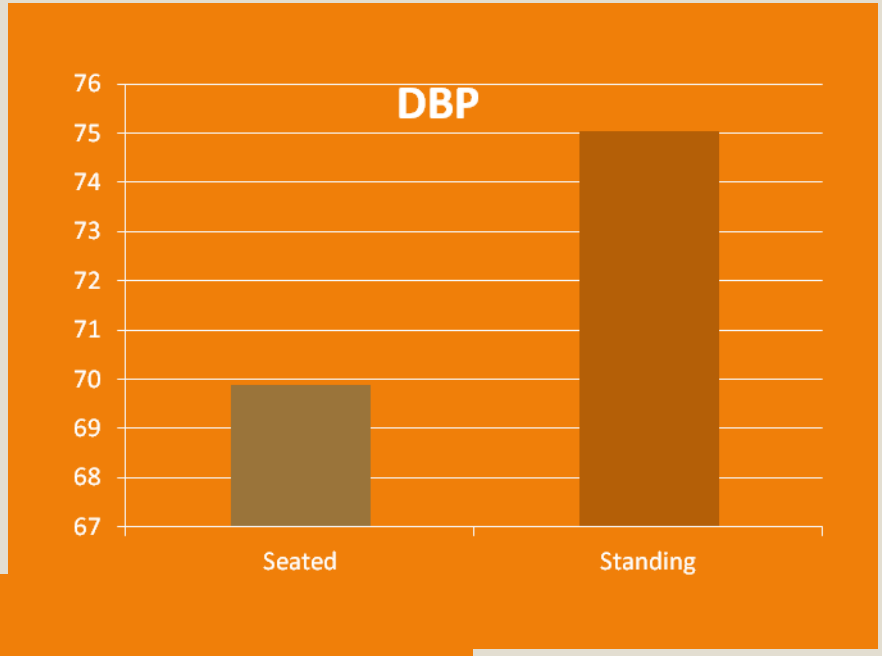
What is the typical viewing distance for a radiologist with multiple workstations?

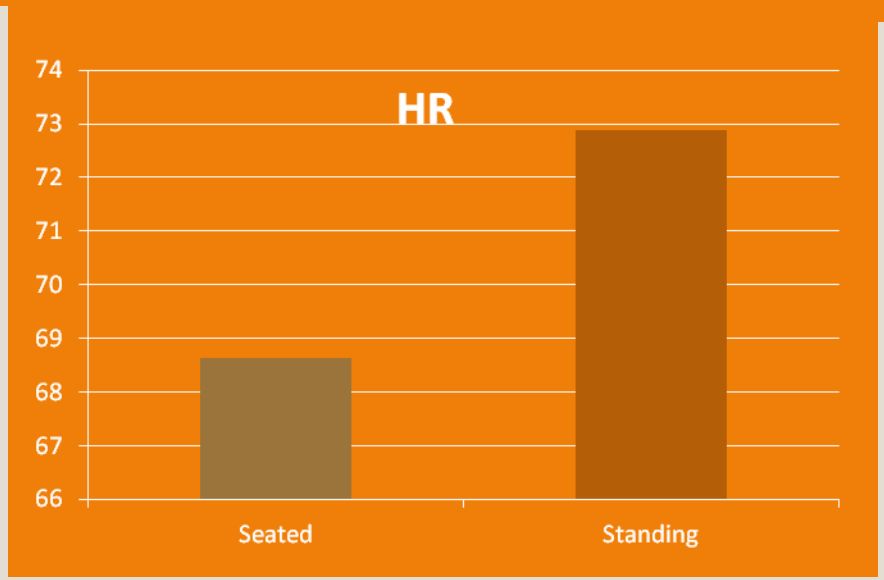
20%	1. 10 inches
20%	2. 20 inches
20%	3. 30 inches
20%	4. 40 inches
20%	5. 50 inches

- Answer c.
- Reference: http://www.thx.com/consumer/home-entertainment/home-theater/hdtv-set-up/

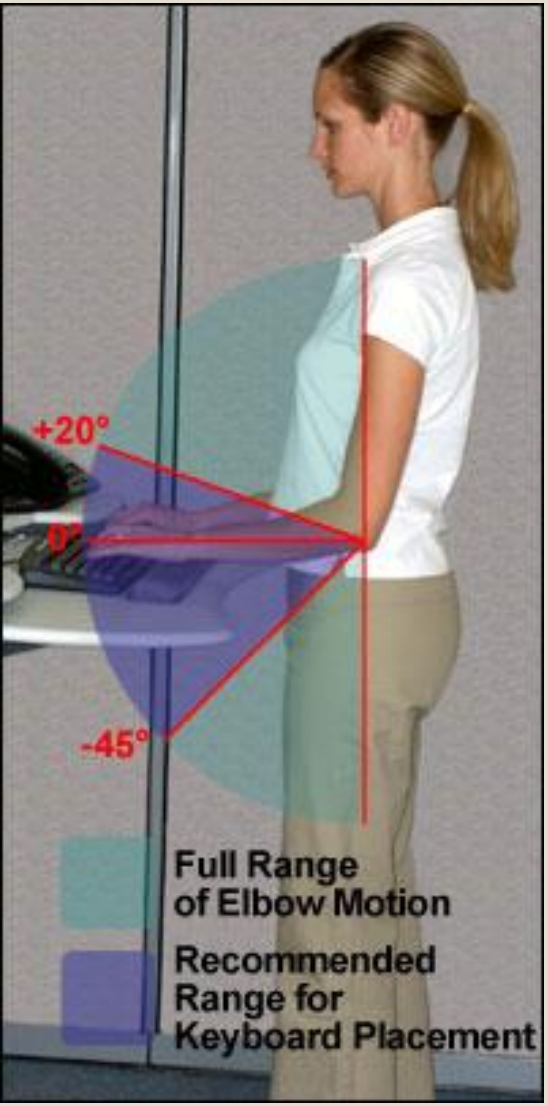
Physiological Activity







Keyboards & Mice



Hands, wrists, forearms straight, in-line, parallel to floor

Head level, or bent slightly forward, forward facing, balanced - in-line with torso

Shoulders relaxed & upper arms hang normally at side

Elbows close body & bent 90 - 120 deg

Feet fully supported by floor/footrest

Back fully supported appropriate lumbar support

Thighs & hips supported well-padded seat

Knees about same height hips feet slightly forward


SONY
SELECT
START

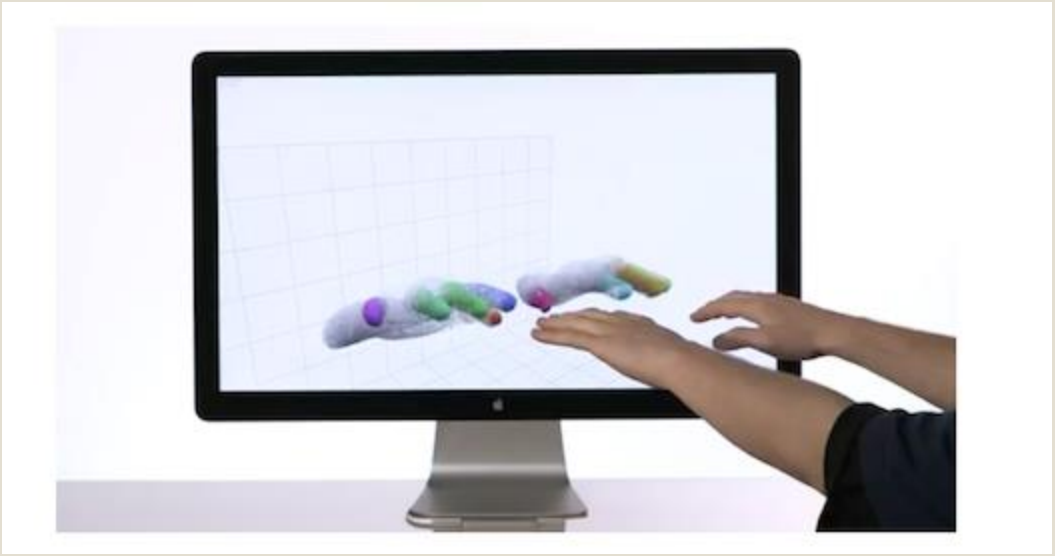


Table 2 Prevalence of occupational injury symptoms ($n = 123$)

Symptom(s) induced by working as a radiologist	%
Eye sensitivity to glare	14
Eye discomfort	17
Neck discomfort	25
Lower back discomfort	41
Shoulder discomfort	27
Elbow discomfort	7
Wrist discomfort	20
Hand discomfort	12

Rodrigues et al. Musculoskeletal symptoms amongst clinical radiologists and the implications of reporting environment ergonomics – a multicentre questionnaire study. JDI 2014;27:255-261

Table 5 Average and maximum uninterrupted reporting time at a PACS workstation

Time spent reporting at PACS station without a break (hours)	%
Average time ($n=123$)	
<0.5 h	3
0.5–1 h	16
1–2 h	46
2–3 h	25
>3 h	10
Maximum time within last month ($n=122$)	
1–2 h	21
2–3 h	26
>3 h	53

Table 4 The prevalence of musculoskeletal symptoms in respondents with good ergonomic knowledge ($n=7$) compared with those with poor ergonomic knowledge ($n=7$)

Musculoskeletal symptom	Ergonomic knowledge % Good	% Poor	*P* value
Neck discomfort	14	14	=1.0
Back discomfort	0	71	<0.005
Shoulder discomfort	0	14	=0.3370
Elbow discomfort	0	14	=0.3370
Wrist discomfort	0	14	=0.3370

Table 6 Compliance with best ergonomic practice

Best ergonomic practice	% Yes
At my workstation, there is the option to alter:	
Computer monitor height ($n=121$)	55
Desk height ($n=121$)	2
Chair height ($n=121$)	98
Chair back support ($n=121$)	61
Chair armrest height ($n=121$)	25
Ambient light ($n=121$)	83
Ambient temperature ($n=121$)	60
When available, I routinely alter:	
Computer monitor height ($n=67$)	19
Desk height ($n=3$)	67
Chair height ($n=118$)	58
Chair back support ($n=74$)	28
Chair armrest height ($n=30$)	13
Ambient light ($n=101$)	73
Ambient temperature ($n=72$)	79
The following are at my disposal:	
Computer screen shield ($n=122$)	4
Foot rest ($n=122$)	3
Wrist support mouse mat ($n=122$)	23
Hands-free dictation ($n=122$)	32

Table 1. Satisfaction Levels with Digital Reading Room Components [18] *(1 - very dissatisfied; 2 - dissatisfied; 3 - neutral; 4 - satisfied; 5 - very satisfied)

Furniture and Workspace Questions	Average Satisfaction Rating*
Adequacy of Desk space	3.73
LCD Monitor Placement	3.89
Keyboard & Mouse Placement	3.45
Dictation Microphone Placement	3.55
Adjustability of Desk	3.7
Chair Comfort	4.1
Sufficient space for personal belongings	2.93
Fabric portable dividers between workstations	3.6
Open floor layout of reading room	3.66
Layout encourages collaboration between radiologist	3.57
Amount of space in reading room	3.93
Ease of access to reading room coordinators spaces	4
Reading room testbed enhances radiology workflow	3.64
Overall comfort of workspace	3.8

Hedge, Evaluating ergonomics risks for digital radiologists. Human Body Model Ergon Lect Notes Comp Sci 2013,;8026:50-58

Checklist

Cornell Digital Reading Room Ergonomics Checklist (Hedge)

1) Display Screens

2) Input Devices

3) Workstation & Accessories

4) Chair

5) Ambient Environment

DISPLAY SCREENS

	Arm/Wall mounted			Freestanding		
1. The display screens are:	Left (**L**)	Middle (**M**)	Right (**R**)	Left (**L**)	Middle (**M**)	Right (**R**)
	O	O	O	O	O	O

	Monochrome			Color		
2. The display screens are:	Left (**L**)	Middle (**M**)	Right (**R**)	Left (**L**)	Middle (**M**)	Right (**R**)
	O	O	O	O	O	O

3. What is the display screen size? **LEFT**: _____ inches/cm **MIDDLE**: _____ inches/cm **RIGHT**: _____ inches/cm

4. The display screens are easily adjustable in:	Height	O Left (**L**)	O Middle (**M**)	O Right (**R**)
	Distance from person	O Left (**L**)	O Middle (**M**)	O Right (**R**)
	Angle/Tilt	O Left (**L**)	O Middle (**M**)	O Right (**R**)
	Twist/Rotation	O Left (**L**)	O Middle (**M**)	O Right (**R**)

5. Is there glare on the display screens that affects image reading? _____

NO O
Continue to item 6

YES O What are the sources of the glare?

O	Overhead lighting	O	Paper	O	Task lights
O	Windows	O	Clothing	O	Other, please specify:

Please mark or fill in the screen areas affected by glare:

INPUT DEVICES

9. What is the wrist angle? Please check the image that fits the posture:

If the workstation has a keyboard tray:

O

Neutral wrist angle

O

Wrist Flexion

O

Wrist Extension

If the workstation keyboard is placed on the desk:

O

Neutral wrist angle

O

Wrist Flexion

O

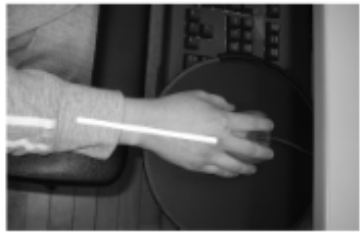
Wrist Extension

10. Check the circle if the mouse designed for: O Right handed use only O Left handed use only O Use with either hand

11. Where is the mouse used? O On platform over keyboard O Platform adjacent to keyboard O On desk

12. What is the wrist position? Please check the image that fits the posture:

O



Neutral wrist

O

Radial Deviation

O

Ulnar deviation

13. Please check any other hand operated input devices used at the workstation that put the hand or arm in an awkward posture:

O Trackball O Touchpad O Touchpoint O Joystick O Lightpen O Other: _____

14. Is voice recognition used?

O NO O A hands-free headset O A free standing microphone O A hand-held microphone

Ambient Lights

- Patrick Brennan, PhD
- Mark Mc Entee, PhD
- Michael Evanoff, PhD
- Peter Phillips, MSc
- David Manning, PhD

ST MARTIN'S COLLEGE
LANCASTER

American Board of Radiology

Ambient Conditions

- 19 Radiologists at 480 lux
  - Simulates office lighting
- 15 under each of the following
  - 100 lux current recommendations
  - 40 and 25 lux dim lighting
  - 7 lux the absence of all light
- 30 bone images with & without subtle fractures

Results

Table 3: **Mean number of false positives at each of the ambient light levels for both groups of Radiologists. Standard deviations (SD) are shown in parentheses.**

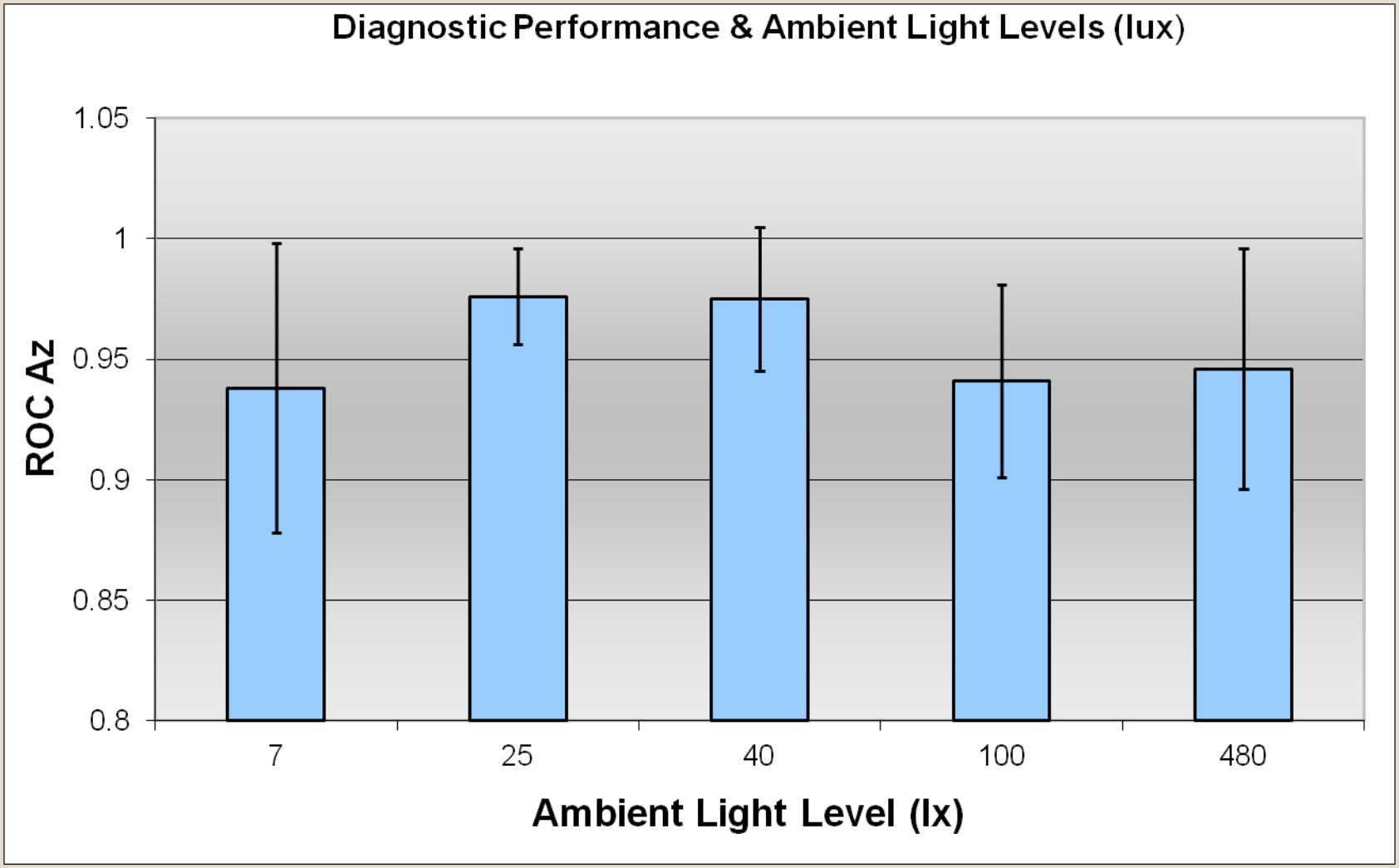
Radiologist type	Illuminance levels (lux)				
	480	100	40	25	7
All Radiologists	4.8 (0.5)	5.1 (0.5)	2.2 (0.4)	2.3 (0.4)	4.6 (0.7)
MSK Radiologists	5.0 (0.8)	5.5 (0.5)	3.3 (0.6)	3.4 (0.7)	3.6 (0.8)

Results

Table 4: **Mean number of false negatives at each of the ambient light levels for both groups of Radiologists. Standard deviations (SD) are shown in parentheses.**

Radiologist type	Illuminance levels (lux)				
	480	100	40	25	7
All Radiologists	0.9 (0.3)	0.9 (0.4)	0.6 (0.2)	0.5 (0.2)	1 (0.3)
MSK Radiologists	0.8 (0.6)	1.0 (1.0)	0.5 (0.5)	0.4 (0.2)	1 (0.5)

Results


Diagnostic Performance & Ambient Light Levels (lux)
ROC Az
1.05
1
0.95
0.9
0.85
0.8
7
25
40
100
480
Ambient Light Level (lx)

Optimal ambient light for viewing radiographic images is:

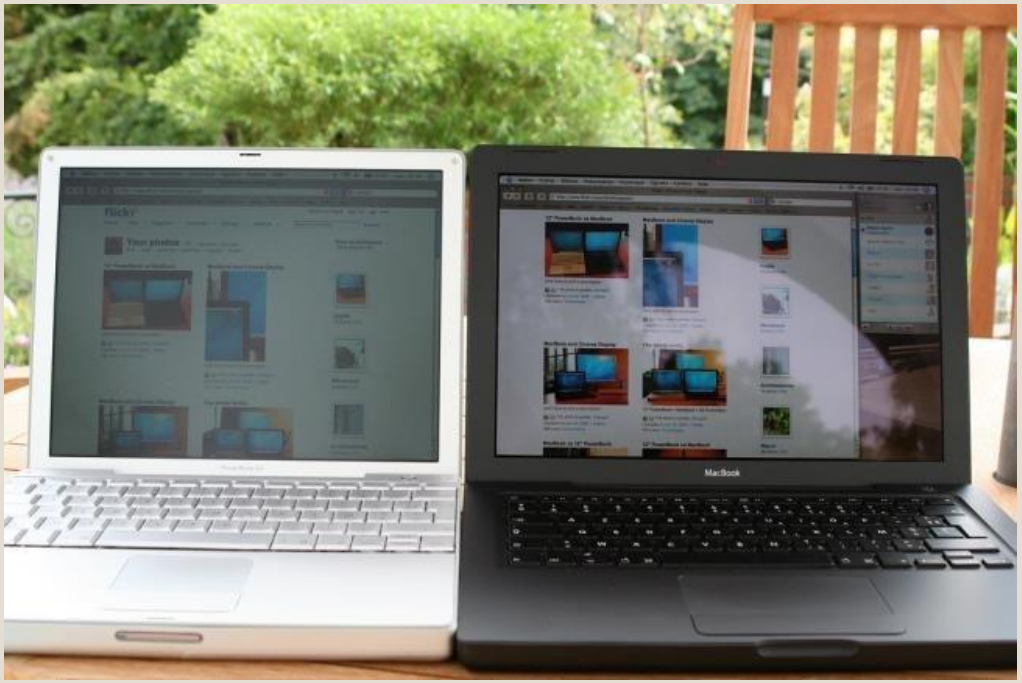
20%	1. 0 Lux
20%	2. 7 – 15 lux
20%	3. 15 – 20 lux
20%	4. 25 - 40 lux
20%	5. > 100 lux

Answer d.

Reference: Brennan PC, McEntee M, Evanoff M, Phillips P, O'Connor WT, Manning DJ. Ambient lighting: effect of illumination on soft-copy viewing of radiographs of the wrist. AJR 2007;188:177-180.

Mobile Displays

- **Mobile MIM app includes labeling & safety features mitigate risk poor image display due to improper luminance or lighting conditions**
- **Includes interactive contrast test - small part screen slightly different shade**
- **If user can ID & tap this portion lighting conditions not interfering ability discern subtle differences contrast**


flickr
MacBook

What Does It Matter?

Clinical Relevance

- High-tech modalities increasing
- More studies & more images being read
- Radiologist shortages
- Increased workloads
- Reading increased volume takes time
- More studies read after hours or by on-call radiologists, especially CT & MRI

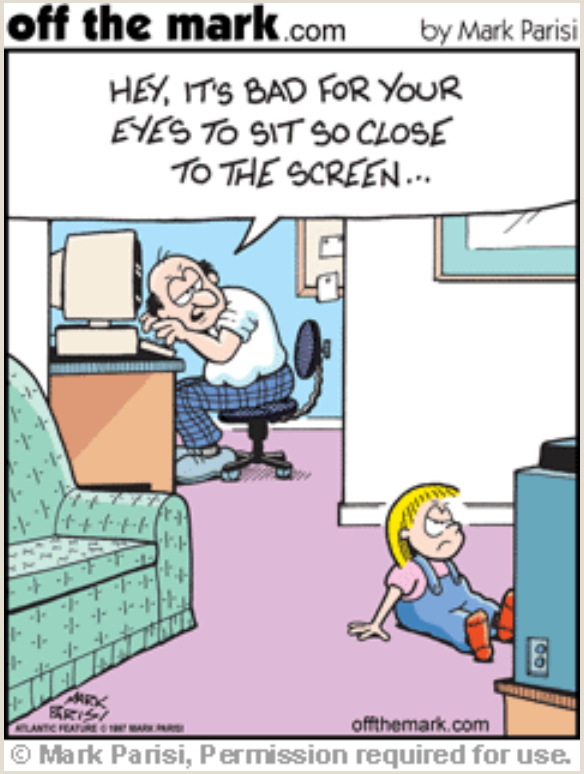
Which of the following is not generally impacted by not having optimal viewing conditions?

20%	1. Display brightness
20%	2. Diagnostic accuracy
20%	3. Reader fatigue
20%	4. Diagnostic efficiency
20%	5. Reader comfort

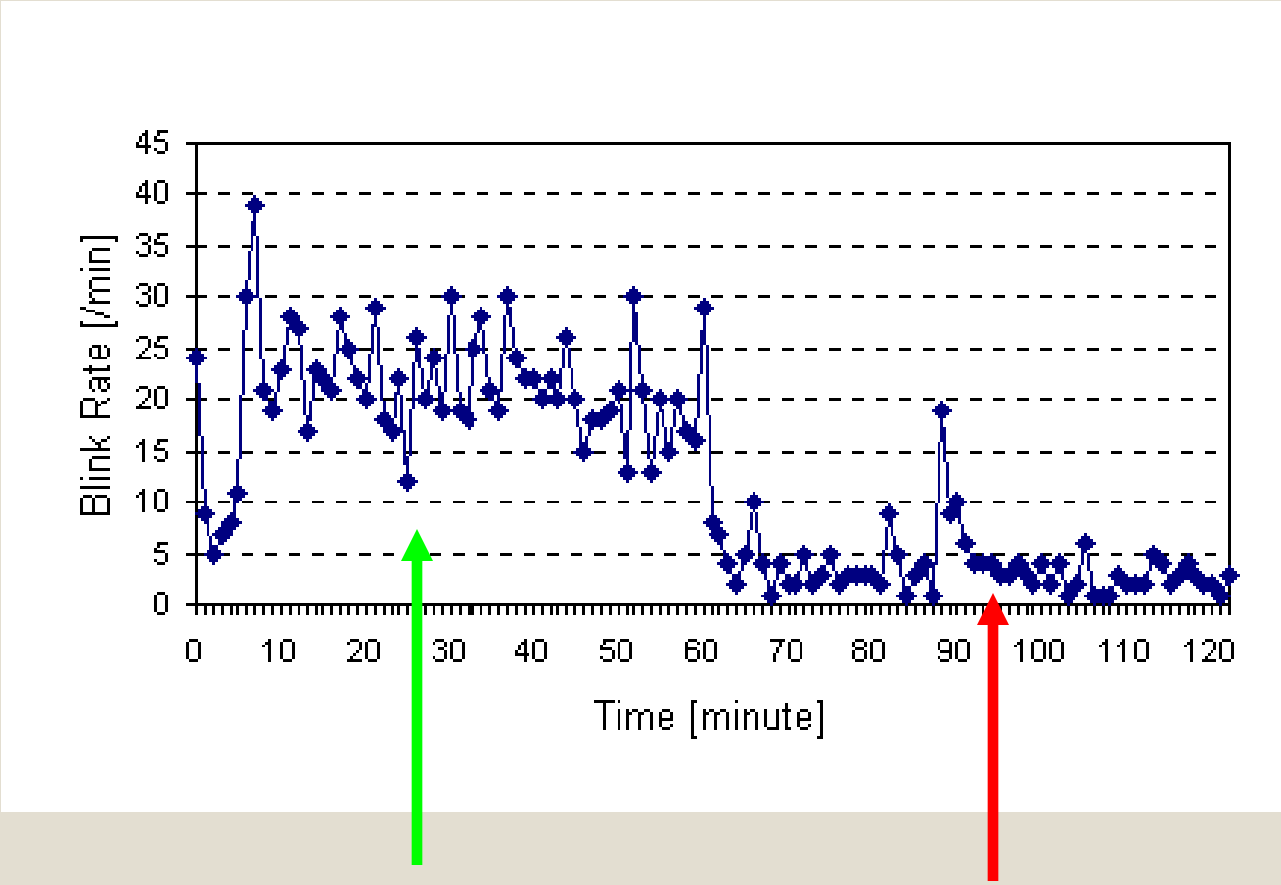
- Answer: a
- Reference: Krupinski EA. Human factors and human-computer considerations in teleradiology and telepathology. Healthcare 2014; 2:94-114.

Asthenopia

- Viewing distance
- Ambient lighting
- Resolution
- Glare
- Viewing angle
- Length viewing
- Mental workload
- Just 4 hours produces fatigue
- May *induce* myopia



Blinking Rates



Not at computer

Using Computer

Dry Eyes

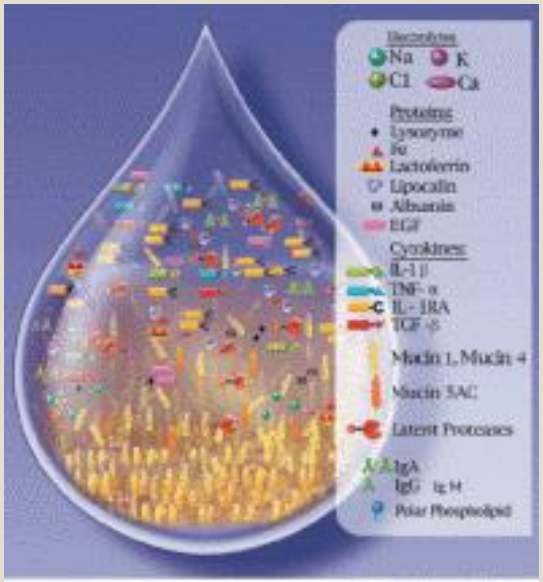


Figure 1: Normal healthy tears

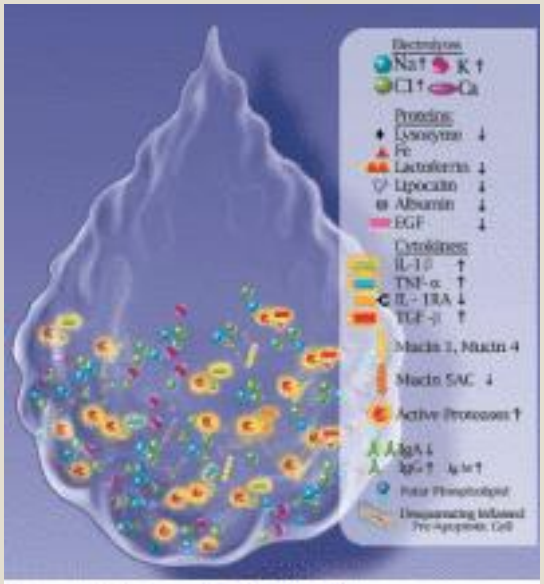
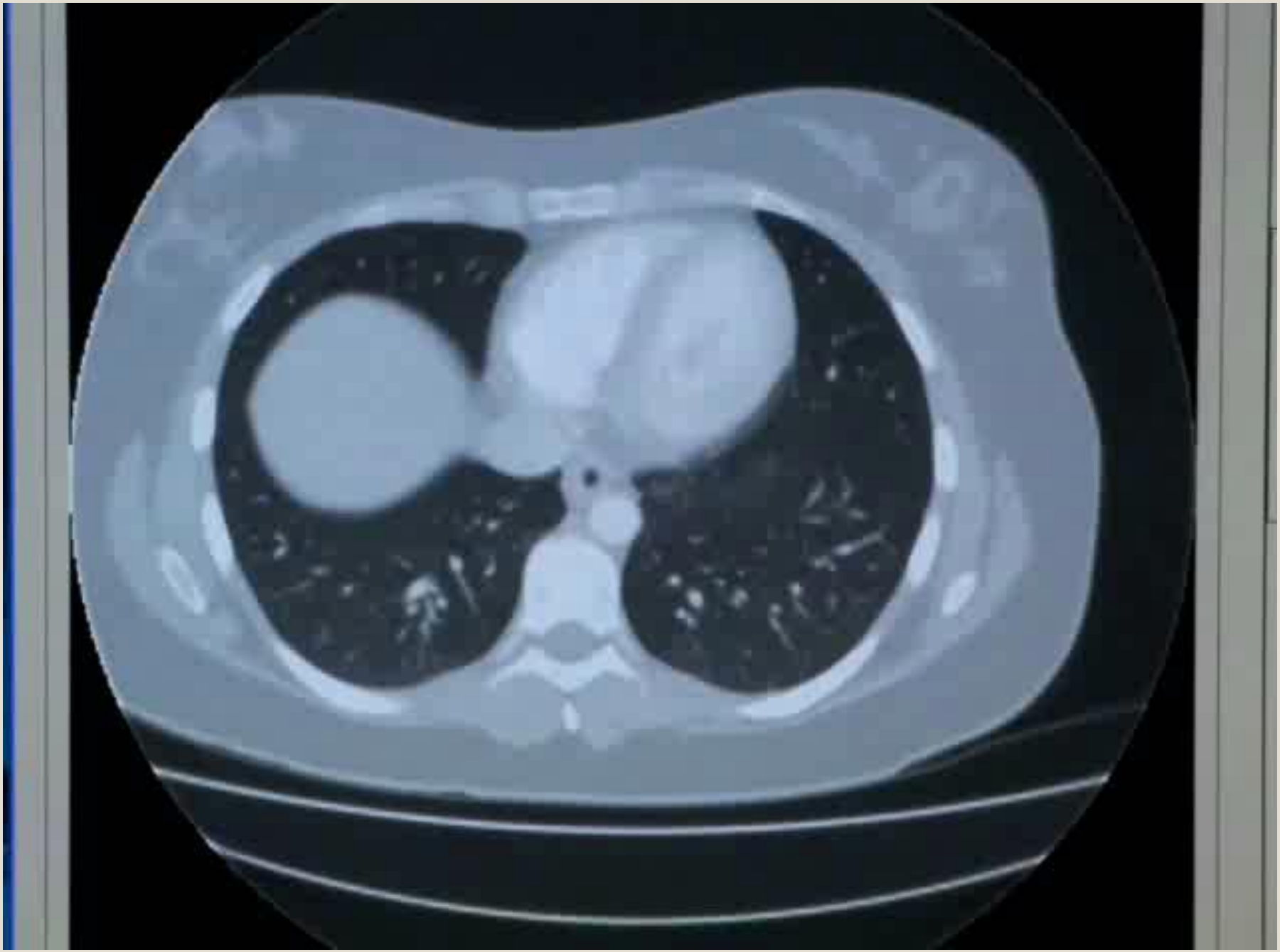


Figure 2: Tears in chronic dry eye

Exacerbated by age, contacts, AC/heating, Geographic location, dust, allergies etc.

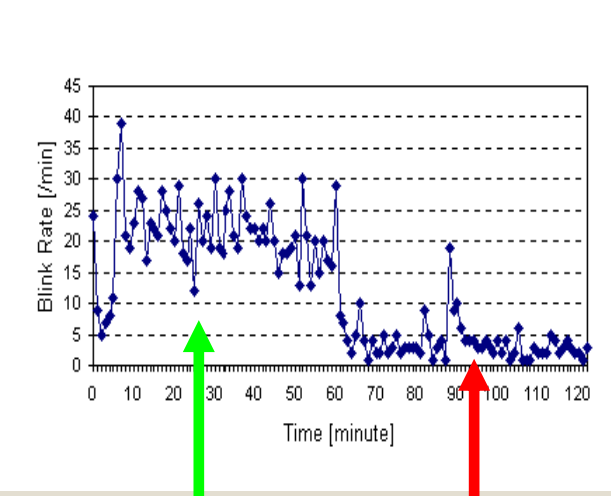
Impact Performance?

- 3 studies impact fatigue
- Bone & CT diagnostic performance
- Bone search performance
- Visual accommodation & dark vergence
- SOFI & SSQ
  - Phys Exert, Phys Discomfort, Sleepiness, Lack E, Lack Motivation, Vis Strain
- Detection accuracy (ROC)
- Search parameters



Take Care of Your Eyes!

- Annual eye exam & proper corrections
- Blink & use eye drops (esp. with contacts)
- Reduce direct exposure AC, dust etc.
- 20-20-20 rule



No computer Computer

A good rule to avoid visual fatigue is the 20-20-20 rule which has all but which component?

20%	1. Every 20 minutes
20%	2. Take 20 sec break
20%	3. Look 20 feet away
20%	4. Turn your head 20 deg
20%	5. None of the above

- Answer: d
- Reference: http://visianinfo.com/the-20-20-20-rule-preventing-digital-eye-strain/

Summary

- ***Significant drop accuracy*** **reading cases after long day reading bone & CT**
  - **Residents > faculty**
- **No sig differences reading time**
- **Sig drop accommodation & vergence**
- **SOFI & SSQ =** ***increased fatigue*** **all parameters**
  - **Residents > faculty**
- **Longer detect, longer discriminate**

Solutions

- Ergonomics checklist
- Optimize reading environment
- Promote awareness warning signs
- 20-20-20 rule & micro-breaks
- Regularly adjust position
- Alternate tasks
- Keystrokes instead of mouse clicks
- Creative alternatives!!


Thank you!
krupinski@radiology.arizona.edu

1. What is the typical viewing distance for a radiologist with multiple workstations?
    a. 10 inches
    b. 20 inches
    c. 30 inches
    d. 40 inches
    e. 50 inches

    Answer c.
    Reference: http://www.thx.com/consumer/home-entertainment/home-theater/hdtv-set-up/

2. For a specific viewing distance the diagonal dimension of a display should be about:
    a. ¼ the viewing distance
    b. ½ the viewing distance
    c. ¾ the viewing distance
    d. No relation to viewing distance
    e. Equal to the viewing distance
    Answer c.
    Reference: http://www.thx.com/consumer/home-entertainment/home-theater/hdtv-set-up/

3. The peak receptor density of the cones in the retina is about how far from the fovea?
    a. < 10 deg
    b. > 10 deg
    c. > 20 deg
    d. > 30 deg
    e. There is no peak it is uniform across the retina

    Answer a.
    Reference: Purves D, Augustine GJ, Fitzpatrick D, et al., editors. Neuroscience. 2nd edition. Sunderland (MA): Sinauer Associates; 2001. Anatomical Distribution of Rods and Cones.

4. Optimal ambient light for viewing radiographic images is:
    a. 0 lux
    b. 7 - 15 lux
    c. 15 – 20 lux
    d. 25 - 40 lux
    e. > 100 lux

    Answer: d

    Reference: Brennan PC, McEntee M, Evanoff M, Phillips P, O'Connor WT, Manning DJ. Ambient lighting: effect of illumination on soft-copy viewing of radiographs of the wrist. AJR 2007;188:177-180.

5. A good rule to avoid visual fatigue is the 20-20-20 rule which has all but which component?
    a. Every 20 minutes
    b. Take a 20 second break
    c. Look 20 feet away
    d. Turn your head 20 deg
    e. None of the above

Answer: d

Reference: http://visianinfo.com/the-20-20-20-rule-preventing-digital-eye-strain/

6. Which of the following is not generally impacted by not having optimal viewing conditions?
    a. Display brightness
    b. Diagnostic accuracy
    c. Reader fatigue
    d. Diagnostic efficiency
    e. Reader comfort

Answer: a

Reference: Krupinski EA. Human factors and human-computer considerations in teleradiology and telepathology. Healthcare 2014; 2:94-114.