Designing the Optimal Reading Room: A Radiology Perspective

Elizabeth A. Krupinski, PhD
Department Radiology & Imaging Sciences
Emory University

No relevant financial interests to disclose

Some work was supported in part by a grant from NIH/NIBIB R01 EB004987

Clinical Relevance

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

- Accurate & efficient conveyance of information
- Diagnostic accuracy
  - Detection
  - Discrimination/classification
  - Measurement
  - Recommended action
  - Consistency
- Interpretation efficiency
  - Viewing time
  - Use of tools & decision aids
  - Reporting
It's All About Trade-offs

Ambient Lights

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

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
Eye-Tracking Study

- Total viewing time (F = 4.372, p = 0.0394)
  - 8MP = 54.65, sd = 24.09
  - 5 MP = 62.86, sd = 27.58
- Total # fixations (F = 4.073, p = 0.0466)
  - 8MP = 134.47, sd = 65.14
  - 5MP = 154.29, sd = 65.09
- # scans between images (F = 10.305, p = 0.0018)
  - 8MP = 6.83, sd = 2.58
  - 5MP = 8.22, sd = 2.99

Challenges?

- All-purpose workstation
  - Multi-modality
  - Multi-specialty
  - EHR
  - Integrated decision aids
  - Integrated user tools
  - Ergonomics & efficiency
  - New reading environments
- Reader fatigue
- Retrofitting old reading rooms
- Convincing planners build new ergonomically
Why Does it Matter?

“We could try a larger monitor with an ergonomic glare filter...but you’re still going to get headaches if you keep banging your head against the screen.”

Physical Complaints

• Tired & overworked
• Carpal tunnel syndrome
• Elbow & shoulder (cubital tunnel)
• Neck, back & shoulder strains
• Computer vision syndrome
  • Corneal erosion and abrasions
  • Eye strain
  • Dry eyes
  • Contact lens problems
  • Glaucoma
  • Headaches

No computer  Computer

Frequency of Major Discomforts

<table>
<thead>
<tr>
<th>Hours Elapsed from Start of Shift</th>
<th>Frequency of Major Discomforts</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>500</td>
</tr>
<tr>
<td>4</td>
<td>1000</td>
</tr>
<tr>
<td>6</td>
<td>1500</td>
</tr>
<tr>
<td>8</td>
<td>2000</td>
</tr>
<tr>
<td>10</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td></td>
</tr>
</tbody>
</table>
Cornell Musculoskeletal Discomfort Questionnaire

http://ergo.human.cornell.edu/ahmsquest.html

Seated worker (m/f)
Standing worker (m/f)
Hand (r/l)

“How often did you experience ache, pain or discomfort in..”
“If you experienced ache, pain, discomfort, how uncomfortable was this?”

<table>
<thead>
<tr>
<th>Area</th>
<th>Not at All</th>
<th>Slightly Uncomfortable</th>
<th>Very Uncomfortable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neck</td>
<td>67</td>
<td>73</td>
<td>61</td>
</tr>
<tr>
<td>RT Shoulder</td>
<td>60</td>
<td>40</td>
<td>33</td>
</tr>
<tr>
<td>LF Shoulder</td>
<td>60</td>
<td>40</td>
<td>33</td>
</tr>
<tr>
<td>Upper Back</td>
<td>67</td>
<td>33</td>
<td>33</td>
</tr>
<tr>
<td>Lower Back</td>
<td>67</td>
<td>33</td>
<td>33</td>
</tr>
<tr>
<td>RT Upper Arm</td>
<td>67</td>
<td>33</td>
<td>33</td>
</tr>
<tr>
<td>LF Upper Arm</td>
<td>67</td>
<td>33</td>
<td>33</td>
</tr>
<tr>
<td>RT Forearm</td>
<td>70</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>LF Forearm</td>
<td>70</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>RT Wrist</td>
<td>58</td>
<td>44</td>
<td>44</td>
</tr>
<tr>
<td>LF Wrist</td>
<td>58</td>
<td>44</td>
<td>44</td>
</tr>
<tr>
<td>Hip/Buttocks</td>
<td>60</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>RT Thigh</td>
<td>60</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>LF Thigh</td>
<td>60</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>RT Knee</td>
<td>60</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>LF Knee</td>
<td>60</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>RT Lower Leg</td>
<td>80</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>LF Lower Leg</td>
<td>80</td>
<td>20</td>
<td>20</td>
</tr>
</tbody>
</table>

“If you experienced ache, pain, discomfort, did this interfere with your ability to work?”

<table>
<thead>
<tr>
<th>Area</th>
<th>Not at All</th>
<th>Slightly Uncomfortable</th>
<th>Very Uncomfortable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neck</td>
<td>67</td>
<td>33</td>
<td>33</td>
</tr>
<tr>
<td>RT Shoulder</td>
<td>60</td>
<td>40</td>
<td>33</td>
</tr>
<tr>
<td>LF Shoulder</td>
<td>60</td>
<td>40</td>
<td>33</td>
</tr>
<tr>
<td>Upper Back</td>
<td>67</td>
<td>33</td>
<td>33</td>
</tr>
<tr>
<td>Lower Back</td>
<td>67</td>
<td>33</td>
<td>33</td>
</tr>
<tr>
<td>RT Upper Arm</td>
<td>67</td>
<td>33</td>
<td>33</td>
</tr>
<tr>
<td>LF Upper Arm</td>
<td>67</td>
<td>33</td>
<td>33</td>
</tr>
<tr>
<td>RT Forearm</td>
<td>70</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>LF Forearm</td>
<td>70</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>RT Wrist</td>
<td>58</td>
<td>44</td>
<td>44</td>
</tr>
<tr>
<td>LF Wrist</td>
<td>58</td>
<td>44</td>
<td>44</td>
</tr>
<tr>
<td>Hip/Buttocks</td>
<td>60</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>RT Thigh</td>
<td>60</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>LF Thigh</td>
<td>60</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>RT Knee</td>
<td>60</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>LF Knee</td>
<td>60</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>RT Lower Leg</td>
<td>80</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>LF Lower Leg</td>
<td>80</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>LF Lower Leg</td>
<td>80</td>
<td>20</td>
<td>20</td>
</tr>
</tbody>
</table>

Results

- 87% of radiologists reported ache, pain or discomfort in at least one body area at least 1-2 times in the week prior to the survey
- Respondents reported discomfort 1-2 times per week or more most frequently in the
  - Neck (66%)
  - Lower back (61%)
  - Upper back (43%)
  - Right shoulder (36%)
  - Right wrist (33%)
- Radiologists who spent greater than 90% of their day seated were more likely to report discomfort in their left shoulder ($P = 0.01$) and upper back ($P = 0.0007$)
• Females > males report right shoulder, left shoulder & left forearm symptoms
• Females > males report moderately or very uncomfortable neck, low back & hip/buttock pain
• Females > males right thigh pain slightly or substantially interfered with ability work
• Radiologists older & board certified > 10 years more likely report neck pain interfered with work

• Comfortable chairs with good lumbar support & easy height adjustment
• Place keyboards & mice properly avoid stress injuries
• Place displays proper heights avoid neck & shoulder stress injuries
• Height-adjustable workstations

https://www.osha.gov/SLTC/etools/computerworkstations/positions.html
Visual Strain

• Occurs when oculomotor system works to maintain convergence, accommodation & direction of gaze
• Accommodative asthenopia caused by strain of ciliary muscles leads to blurred vision, headaches & pain in/around eyes
• Breakdown in physiological mechanism could underlie symptoms radiologists experience & lead to diagnostic performance changes

WAM-5500
Auto-Refkeratometer

Error in Accommodation

Distance from eye (cm)
SOFI & SSQ

Physical Exertion
F = 1.042, p = 0.3135

Sleepiness
F = 3.688, p = 0.0616

Lack of Energy
F = 9.134, p = 0.0044

Lack of Motivation
F = 8.226, p = 0.0066

Visual Strain
F = 10.818, p = 0.0001
Impact Performance?

- Bone fx
- Chest nodules
- CT chest nodules
- Satisfaction of search

Diagnostic Performance

- Fitted proper binormal model to rating data
- Analyzed Az with ANOVA with independent variables institution, training & time-of-day

**Significant drop in detection accuracy:**
*Early vs Late ~ 5%*

Zenker’s diverticulum with residual barium + nodule
CR images instead of film 25 years after 1st study
What To Do?

- Take advantage technological solutions
  - CAD & image-analysis tools designed to assist radiologists should be used – as long as properly integrated into clinical reading workflow & not impediment
- Properly optimizing (e.g., calibration, luminance, contrast, viewing angles, ambient light levels) display & viewing environment
Standing on periodic basis
Take periodic breaks - simply stand up & walk around for 5 minutes
  • Gives chance to unwind & use muscles not used when simply sitting all day
Yoga, light aerobics
Power naps
  • 15-20 min = boosts alertness & motor skills
  • 30-60 min = boosts memory, creativity, decision-making skills
  • Cannot “buy back” lost sleep – need to make up

Conclusions
• Good reading room design in critical
• Fatigue & stress common problems
• Particularly important for residents
• Guidelines available
  – ACR-AAPM-SIIM Electronic Practice
  – ACR-AAPM-SIIM Digital Radiography
• Much of what can do is common sense
• JUST DO IT!
Questions?

ekrupin@emory.edu