Visual functional analysis in medical imaging

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There is no actual or potential conflict of interest in relation to this presentation.

Objectives

Describe the importance of human visual system on lesion detection in medical imaging perception research.

Discuss the relevance of research in medical imaging addressing visual function analysis.

Identify visual function tests which could be conducted on observers prior to participation in medical imaging perception research.

Introduction

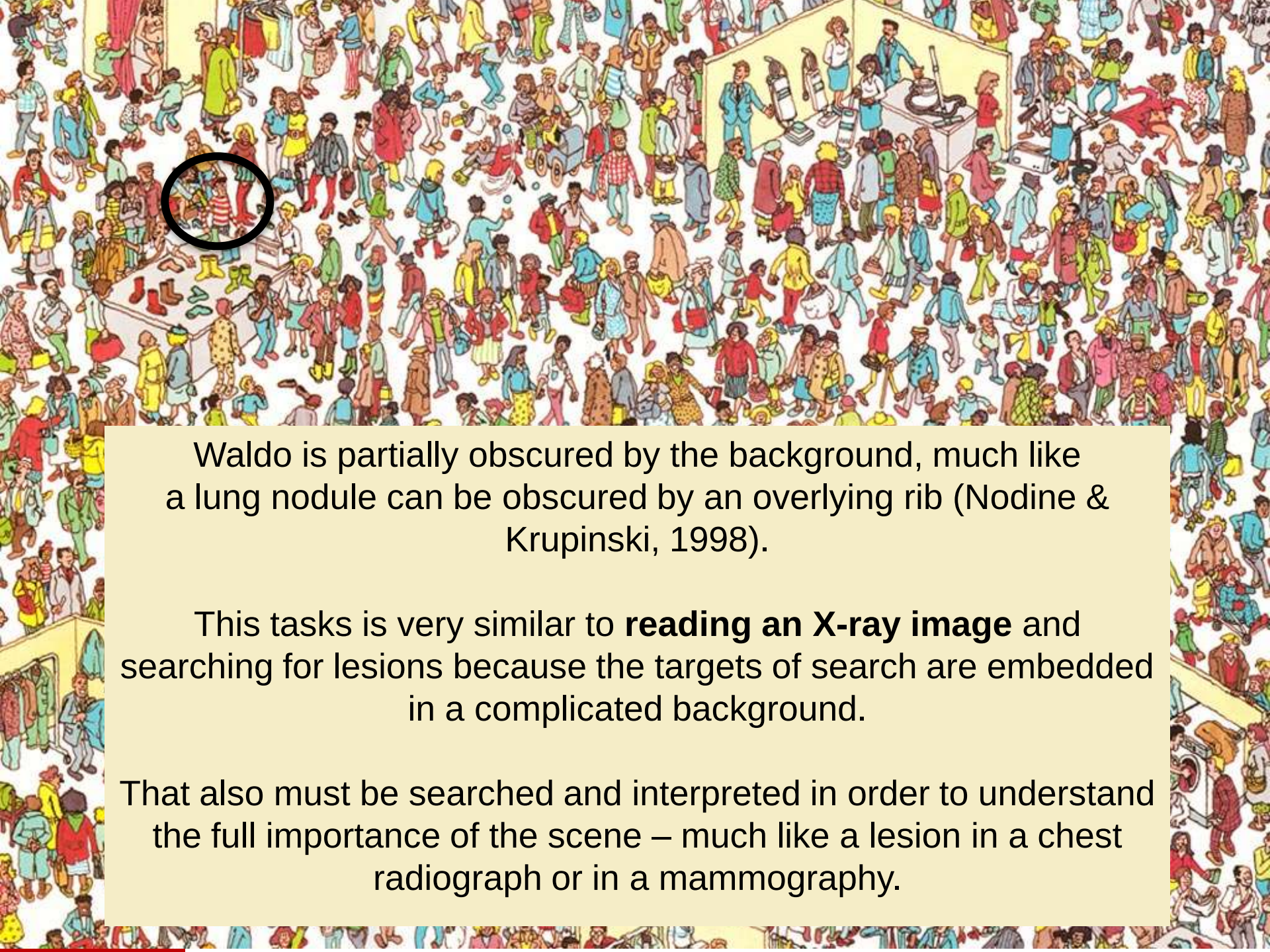
- **Diagnostic errors** in medical imaging have been reported since 1947 (Birkelo *et al.*, 1947).

http://www.wsumed.com/pathophysiology-of-medical-errors/

- The error rate among radiologic examinations is approximately 30% (Lee et al., 2013) .

- Some of the techniques are particularly prone to errors, for instance 20 to 50% of **Chest X-ray** (CXR) images are misdiagnosed (Forrest & Friedman, 1981).

- Difficulty in **separating** normal structures from early lung cancer was the apparent cause of these errors.



Waldo is partially obscured by the background, much like a lung nodule can be obscured by an overlying rib (Nodine & Krupinski, 1998).

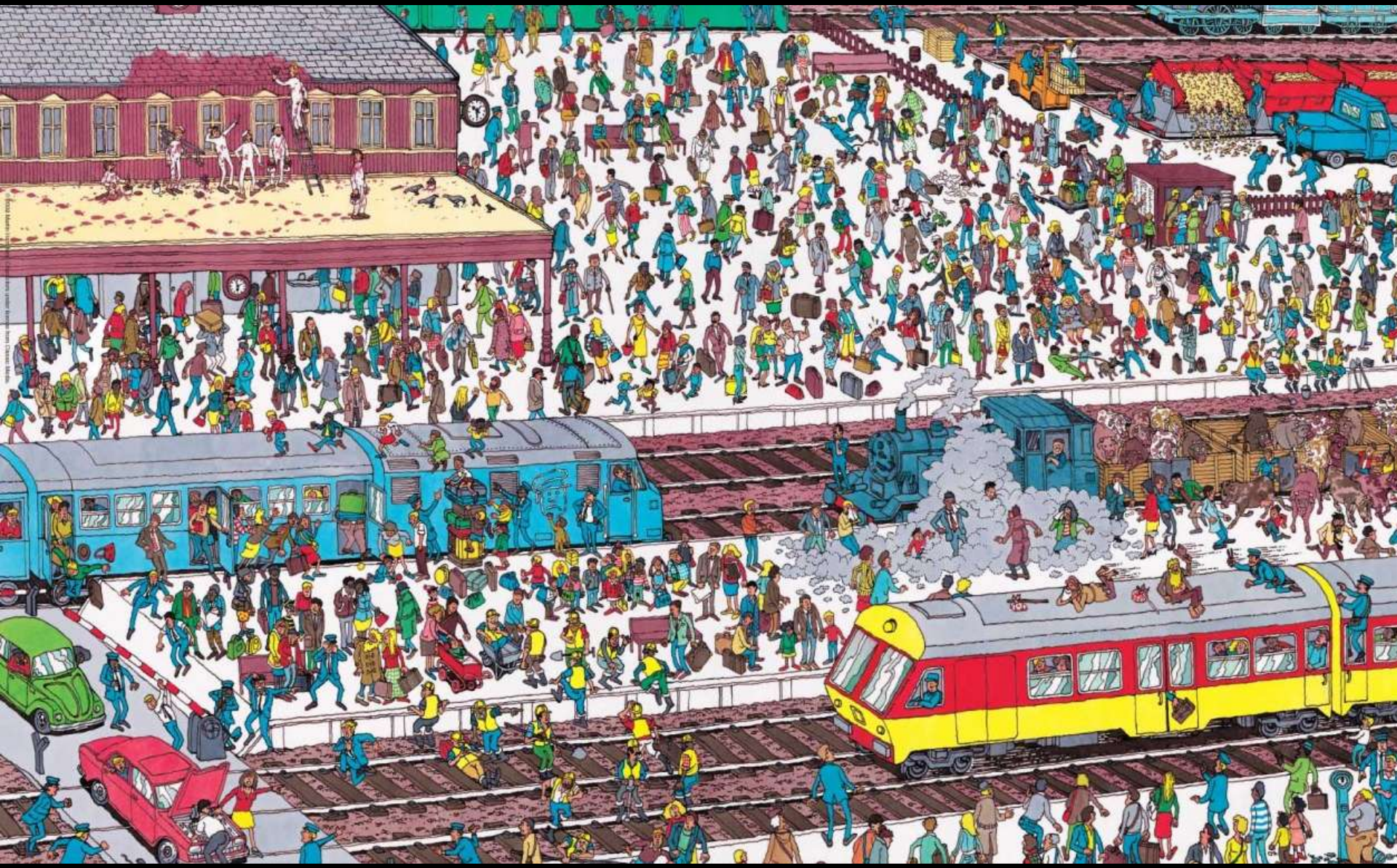
This tasks is very similar to **reading an X-ray image** and searching for lesions because the targets of search are embedded in a complicated background.

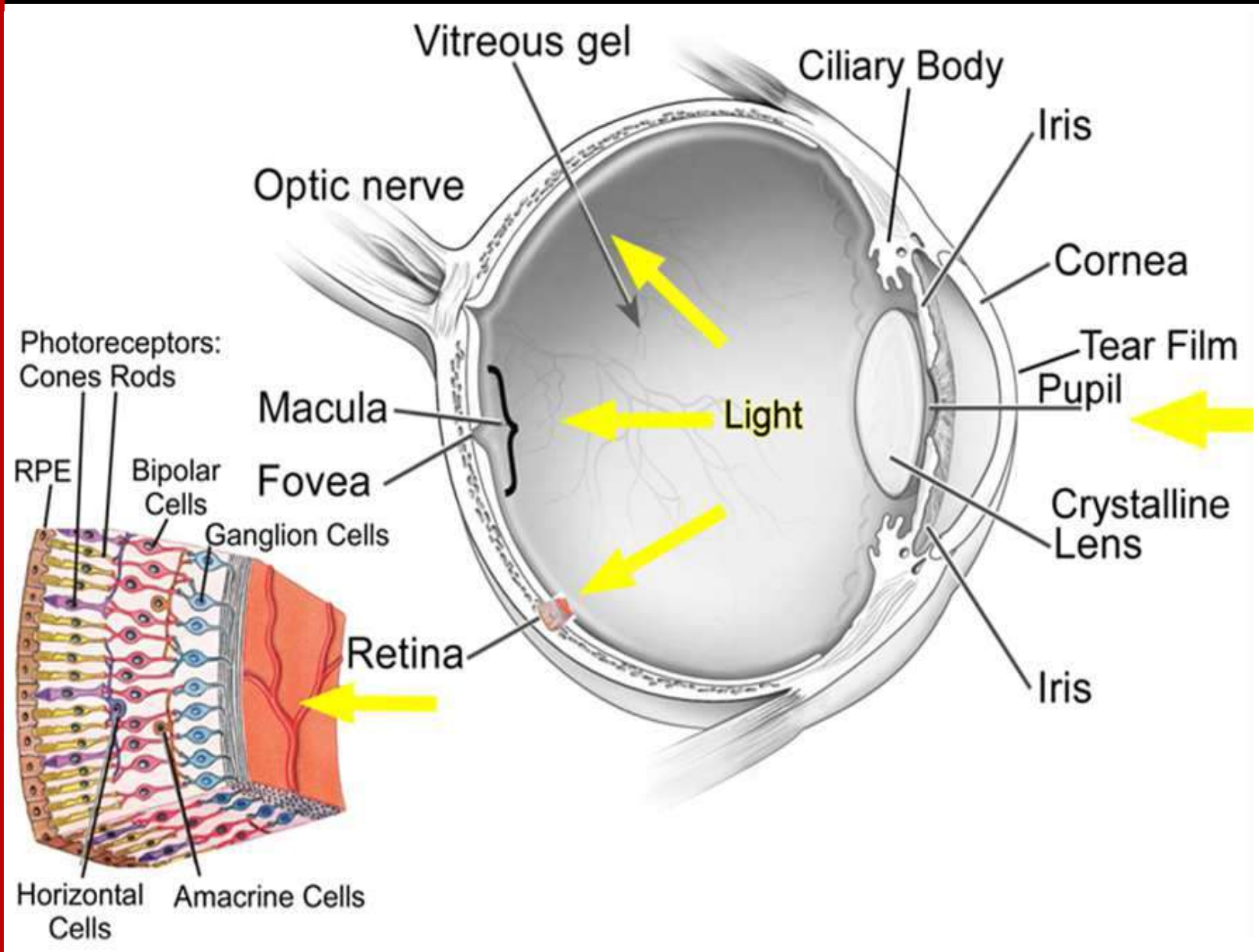
That also must be searched and interpreted in order to understand the full importance of the scene – much like a lesion in a chest radiograph or in a mammography.

Introduction

- Factors contributing to radiologic error are complex and hard to isolate.

- One potential source of error could be due to **reduced visual performance** that decrease observer's ability to correctly identify small solitary pulmonary nodules (Bass & Chiles, 1990).





Vera-díaz FA, Doble N. The Human Eye and Adaptive Optics. In: Tyson B, editor. Topics in Adaptive Optics [Internet]. InTech; 2012. p. 119–50. Available from: http://www.intechopen.com/books/topics-in-adaptive-optics/the-need-for-adaptive-optics-in-the-human-eye

Visual function

Visual acuity

- Makes possible the accurate detection of radiologic anatomic structures.

Contrast sensitivity

- Makes possible the discrimination of low and high contrast frequency information.

Stereopsis

- Reduces the amount of visual scanning necessary to extract spatial information, which sustains comprehension of complex visual experiences.

Visual acuity

- The most common measurement of visual function is **visual acuity** (Colenbrander, 2001; Kaiser, 2009).

- The term visual acuity is used to describe the capacity of the eye to resolve the **size of an object**.

- This function could determine an observer's ability to correctly identify small solitary pulmonary nodules (Bass & Chiles, 1990).

- A nodule may be missed because the capacity of the eye is not sufficient to **resolve the size of the nodule**.

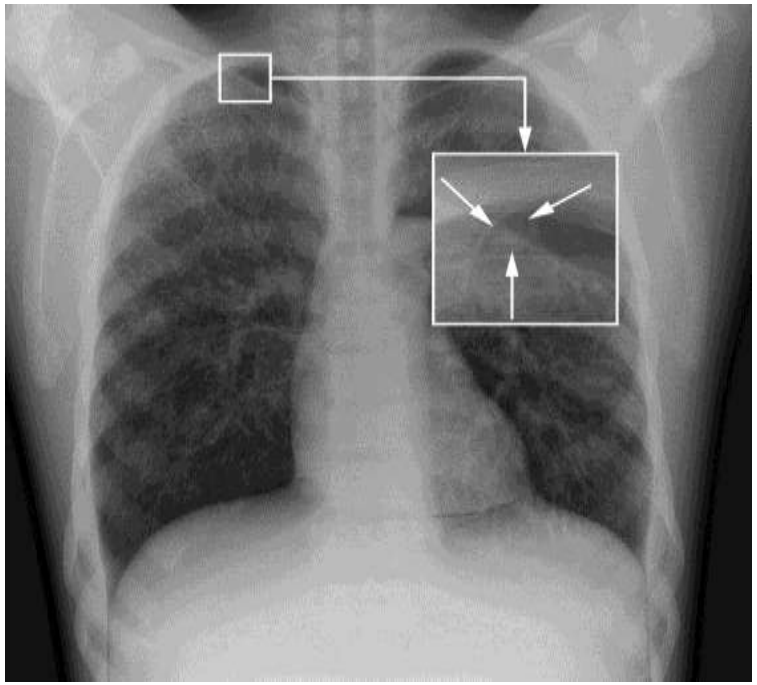
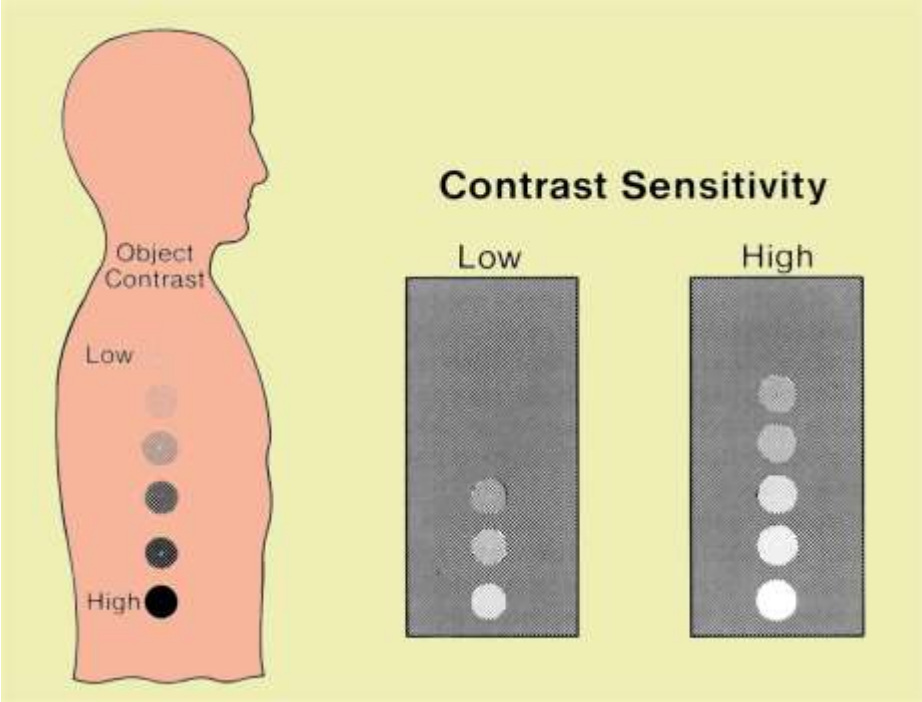


Figure - The three arrows in the magnified box indicate a small (5mm) simulated solitary pulmonary nodule in a chest phantom model.

Contrast sensitivity

- The **contrast sensitivity** function has been recognized as an important fundamental measure of visual function.

- It measures the ability to **perceive slight changes in luminance** between regions which are not separated by definite borders (Arden, 1978; Apelt & Peitgen, 2008).



http://www.sprawls.org/ppmi2/IMGCHAR/

Contrast sensitivity

- Pattern-detection ability is provided by **eye contrast sensitivity** for stimuli of various sizes, and if abnormal contrast sensitivity is present low-contrast targets are difficult to appreciate and can be missed.

  - e.g. Isoechoic lesion on ultrasound or an isodense lesion on computed tomography that can be recognised only indirectly, through contour irregularities adjacent structures (Durr-e-Sabih *et al.*, 2011).

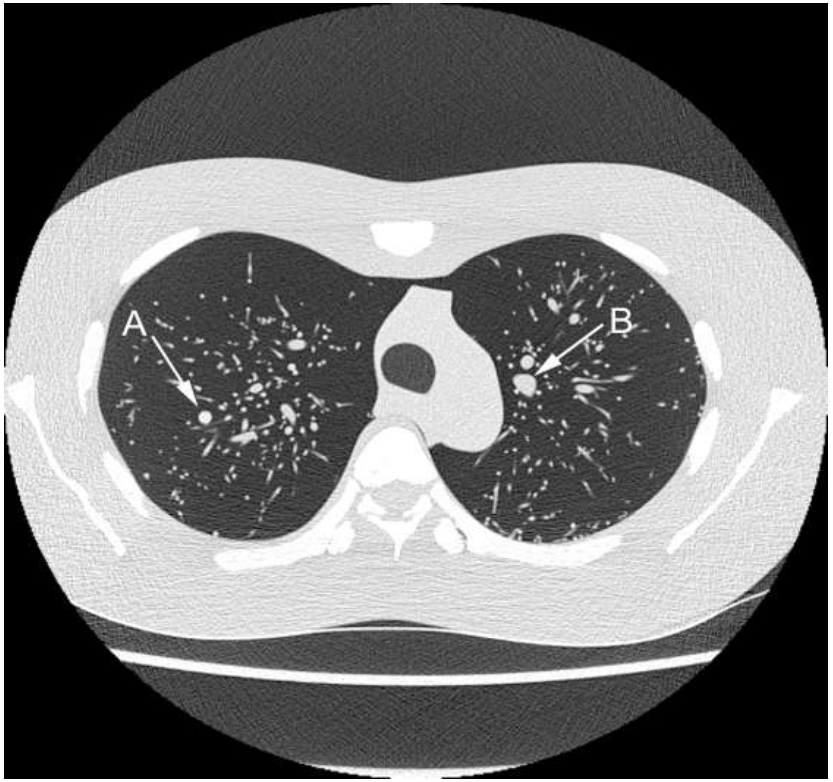


Figure - A simulated 5mm pulmonary nodule (A) that is only distinguishable from simulated pulmonary vessels (B) by the shape of the object.

Stereopsis

- Stereopsis (3-D perception) is a pattern of the highest level of binocular vision, which refers to the ability to **perceive the depth of an object**, and thus obtain binocular single vision (Lee & Koo, 2005).

- Although the radiographic image is a 2-D depiction it represents 3-D anatomy created from the shadows of the absorption pattern of X-rays passing through the body (Krupinski, 2010).

- The observer must translate the image into a 3-D mental representation in order to properly analyse and localize structures.

- This is an important function that helps the visual system in the **scanning of spatial information** from medical imaging, sustaining the visual analysis.

Stereopsis

- Stereopsis allows the observers to determine the depth of objects in the central visual area, enhancing vision quality through binocular summation.

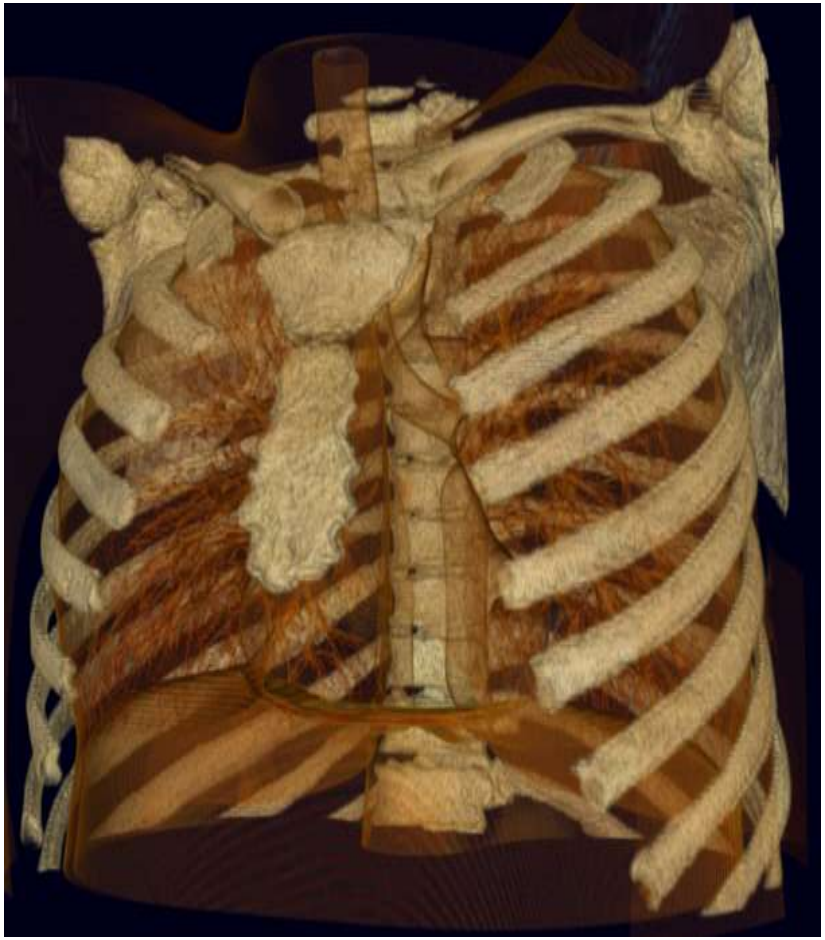
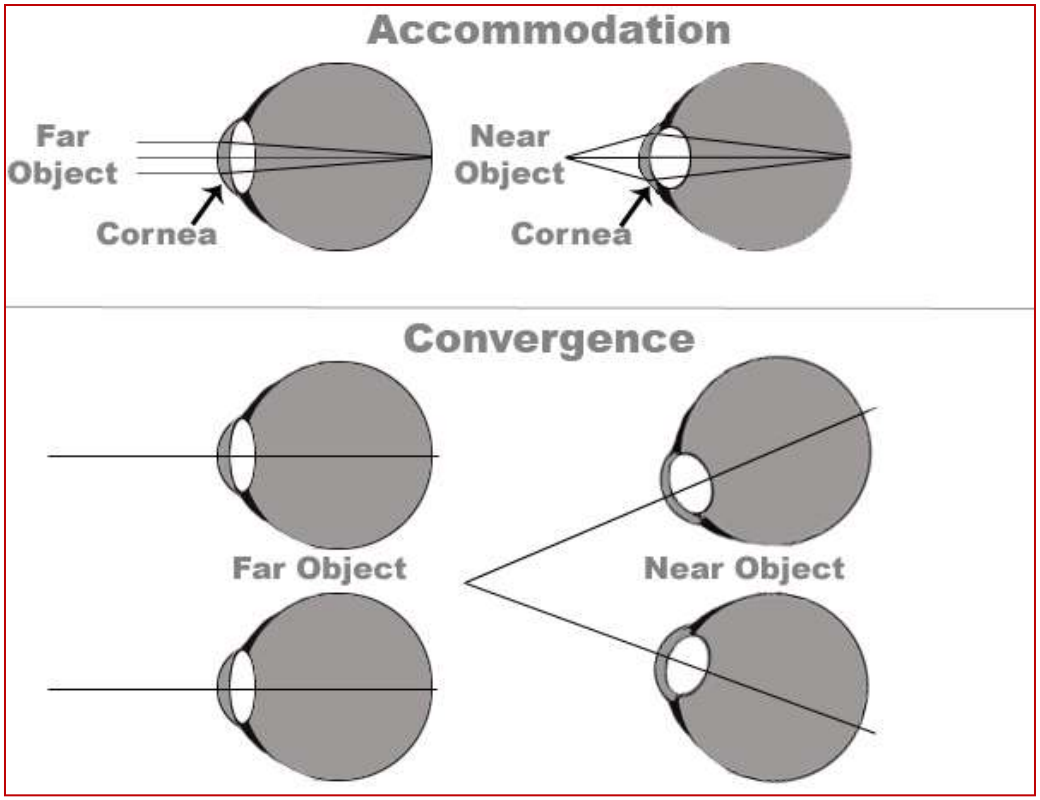


Figure - A 3-D reconstruction of a chest computed tomography acquisition.

Other visual functions

- Interpretation of diagnostic images involves sustained daily focus at near and intermediate distances, which requires both ocular **accommodation and convergence**.



http://ucalgary.ca/pip369/mod4/depthperception/oculomotor

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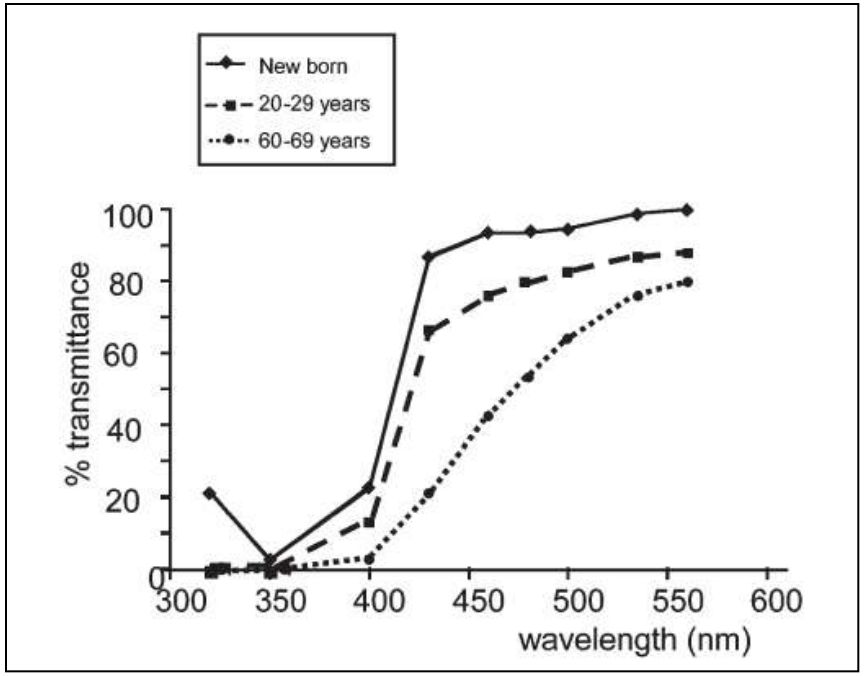
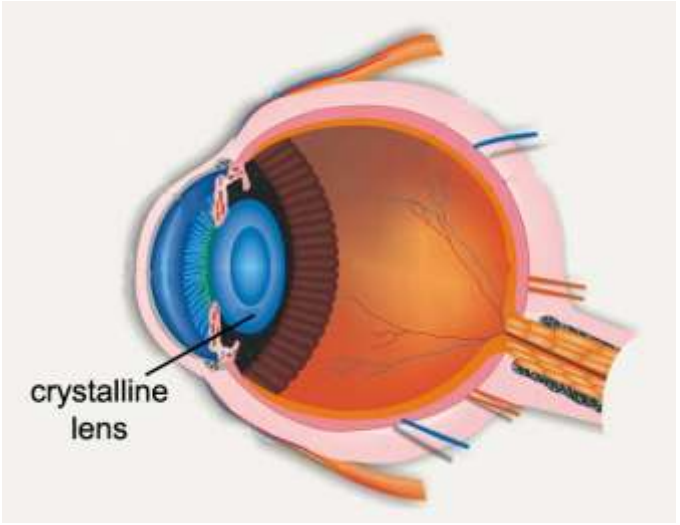
Safdar NM, Siddiqui KM, Qureshi F, Mirza MK, Knight N, Nagy P, et al. Vision and quality in the digital imaging environment: how much does the visual acuity of radiologists vary at an intermediate distance? Am J Roentgenol [Internet]. 2009 Jul [cited 2014 Jul 31];192:W335–40.

Deterioration with age

- There is a progressive normal deterioration in visual acuity with age which will affect image readers, and in addition, there is also a deterioration of the transmittance of the eye crystalline lens (gradually turn yellowish).





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Deterioration with age

- Contrast sensitivity and ocular accommodation also decrease with age.
- Contrast sensitivity declines with age across all spatial frequencies.
- This decline normally starts at 45 years of age and higher spatial frequencies are more affected than lower frequencies (Sia *et al.*, 2013).
- However, this topic has been subject to very little scrutiny in medical imaging.

Does this decline influences

lesion detection performance?

Deterioration with age

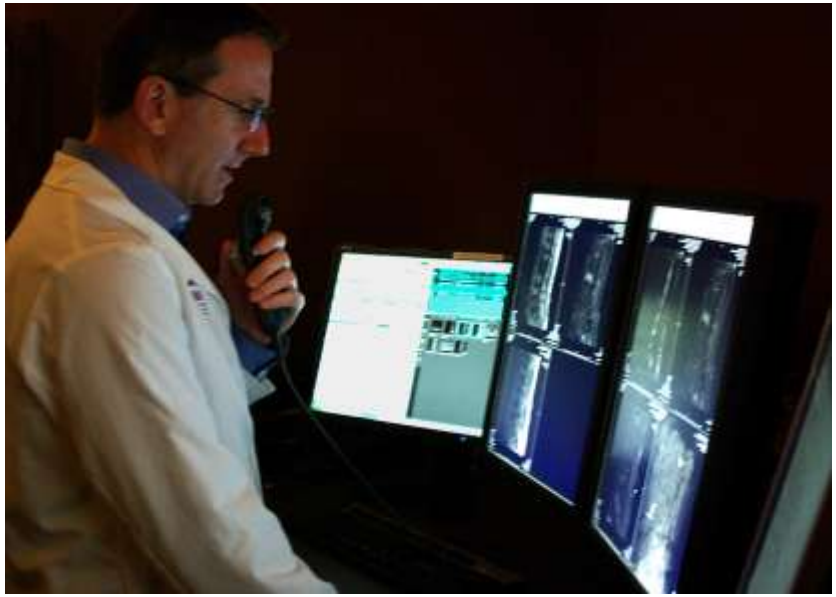
Does this decline influences lesion detection performance?

- Some have argued that **experience** brings an economy of effort and greater efficiency which can improve visual performance, mainly visual search (Krupinski, 1996; Nodine et al., 2002; Manning et al, 2006).
- The expert radiologist has been exposed to more images and has had much more practice searching these images than the novice (Krupinski, 2000).
- One would expect their search to be more efficient and accurate.

Prescribed Glasses

- We propose that observers without prescribed glasses should be tested and when visual anomalies are detected they must be excluded from studies that involve image interpretation unless corrective lenses are used.

- Observers with corrective lenses should have **routine eye examinations**, and if necessary an updated prescription, to ensure they maintain the maximal visual performance.



http://en.wikipedia.org/wiki/Radiology#mediaviewer/File:Radiologist_in_San_Diego_CA_2010.jpg

Conclusions

- Perception in medical imaging relies on visual data to study the quantitative relationship between a visual stimulus and an observer's response.

- Research on quality characteristics of the visual function of people who use digital imaging has been absent within the literature.

- Although quality control programs have been implemented for the performance of digital displays, similar attention has not been devoted to adequate quality control of image reader's visual function.

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Thank you for your attention!

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