

# Visualisation and Perception

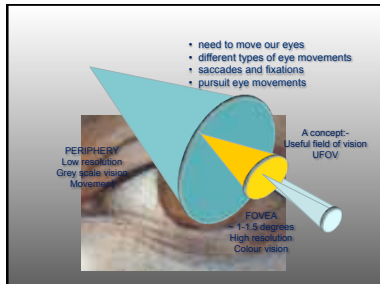
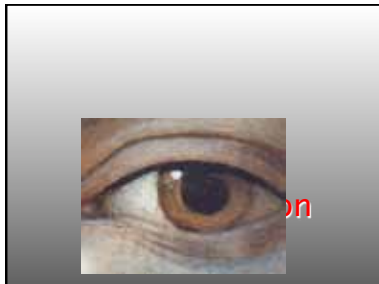
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## Overview

- Visual inspection in medical imaging
- Performance research and errors
- Importance of visual search
- Breast screening as an example
- Links to CAD and imaging

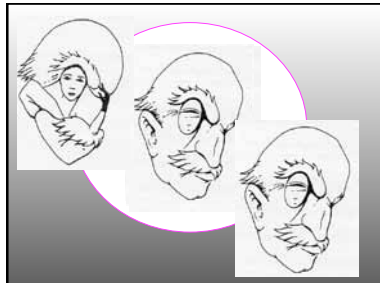
Visual search  
rare targets  
modeling performance  
Imaging interpretation  
**CAD aids vision**  
breast cancer



### Visual search

Visual attention  
- only attend to image areas that are directly examined by the fovea

What you see is not just determined by information in the image



Cognitive plans for looking

Look over there

Image demands - overt and covert cues

You can miss the most obvious



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### Visual Inspection

- Errors occur in every human visual inspection task
- Errorless performance – a myth?
- Rare targets (e.g. in medical screening) ..... make performance worse
- Factors: ...vigilance, time of day effects, time on task, experience, expertise, training, ...

Industrial inspection      Safety inspection (rivets)

### Visual inspection is just part of

**TIMES ONLINE**  
Blundering hospitals kill 40,000 a year

**MailOnline**  
NHS safety failings 'kill 40,000 a year' as patients pay price of target culture

### Medical Imaging

- Saturday, December 28, 1895 Roentgen submitted his first "provisoria" communication, *Ueber eine neue Art von Strahlen* (On a New Kind of Rays)
- One year later – 'roentgen picture' first used in a malpractice case
- Wisconsin appellate court decision 1996:
  - All radiologists were responsible for X-rays, but each was also not to end of themselves; immediate responsibility to treatment

at more breast test errors  
(on 05/11/2007 by Niall Harty, Editor)

Many patients have experienced the "scary" experience of being told that they have breast cancer, only to find out later that the diagnosis was incorrect. This is a common occurrence in the NHS, and it is often the result of human error.

Some errors will always occur

Need to reduce/eliminate preventable errors

after eight women given the wrong diagnosis

13th August 2007

period November 2003 to the hospital. All of the women were incorrectly told they had breast cancer. To date, seven of the group identified have been referred to the HSE, which says all of these women have been contacted and offered appropriate treatment and counselling.

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### Research in Imaging Interpretation

**Ergonomics / Human Factors**

- Patient centred
  - comfort / image quality
- Radiologist focussed
  - best image examination conditions

### Research in Imaging Interpretation

**Performance**

- 1940s / 1950s: Chest X-ray (film) – overlaying structures, single lesions
  - 10-30s interpretation
  - Continuing to the present day: main impact in 1970s-80s

**Main findings:**

- Experts look at high probability areas of abnormality
- Where radiologists look is affected by prior clinical information
- Experts make fewer saccadic eye movements with longer eye fixations
- Satisfaction of search
- What is expertise?

### Research in Imaging Interpretation

**Performance**

- 1940s / 1950s: Chest X-ray (film) – overlaying structures, single lesions
  - 10-30s interpretation
- Late 1980s: Breast screening (film) – rare cancer appearance
  - Very fast interpretation 10s or more

**Main findings:**

- Relationship of key mammographic features to clinical outcome
- Experts look at high probability areas of abnormality
- Experts make fewer saccadic eye movements with longer eye fixations
- Expertise related to volume of cases read and years of experience

### Research in Imaging Interpretation

**Performance**

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**Main findings:**

- Use of 1 radiologist + CAD = performance of 2 radiologists
- CAD developments have led to fewer CAD FP decisions
- CAD is very usable and useful

### Research in Imaging Interpretation

**Performance**

- 1940s / 1950s: Chest X-ray (film) – overlaying structures, single lesions
  - 10-30s interpretation
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  - Very fast interpretation 10s or more

**Main findings:**

- Similar findings to chest and breast –
- Experts know where to look for primary lesions and then for potential related lesions
- Differences in visual search behaviour between naive, trainee and experienced radiologists

### Research in Imaging Interpretation

**Performance**


- 2008 – CT Colonography screening
  - Fly through examinations – possible 'its behind you' errors
  - Remember where you are and where you are going

**Main findings:**

- Ongoing research area
- More complex experimental situations

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### Find the abnormality



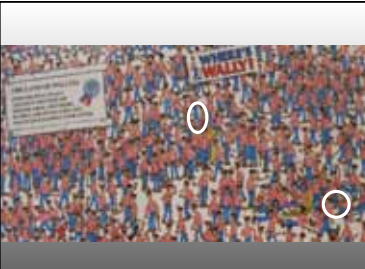
Where's Wally?

Very detailed abnormality description



Even with very detailed knowledge of the target it can still be hard to find

Overlaying structures  
Camouflage  
Other features competing for attention



### Recording visual search

Wide variety of methods to record visual search behaviour

### Visual Search

### Visual Search

### Search in Breast Screening

### Search in Breast Screening

Pattern of visual search by one expert radiologist

### Visual search in CT/MRI

	Naive	Experienced
Normal		
Chronic Stroke		

### Visual search behaviour

A. Circumferential pattern. B. Localized pattern. C. Complex pattern.

Examples of three kinds of visual scanning patterns

Similar to what is found in radiology

### The image affects how you look

Uncluttered image      Dense image

### Expertise affects how you look

experienced observer      inexperienced observer

High probability areas first  
long saccades

**The task affects how you look**

'look for abnormalities'      'assess image quality'

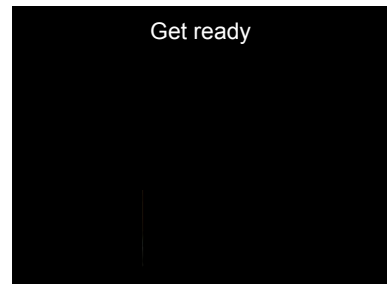
Foreknowledge directs search: the same observer but given different instructions



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**Detecting rare targets in images**

- who has a gun??



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**Measuring Performance in Radiology**

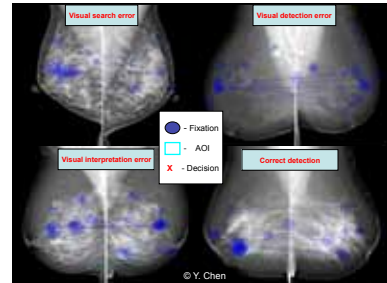
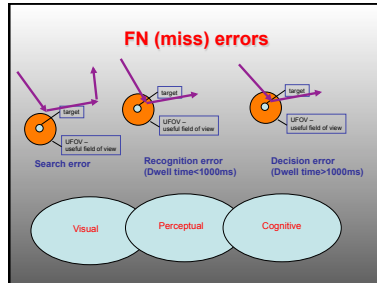
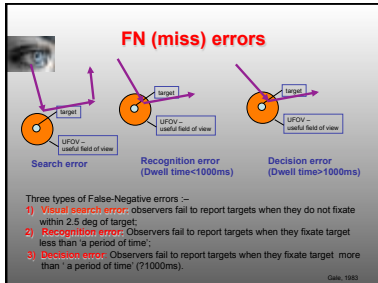
- Sensitivity and specificity
- Various ROC analysis techniques:-
  - Multiple readers
  - Multiple potential targets
  - Decision confidence
- ROC – typically single target present/absent
- LROC – both target and location have to be correct
- FROC – free response
- AFROC alternative free response
- MRMC – multiple reader and multiple conditions
- JAFROC analysis
- 'horses for courses' – technique used depends on the empirical investigation

[www.mps.uw.edu](http://www.mps.uw.edu)

**Measuring Performance in Radiology**

Kundel & Nodine (1970s)

- Built on psychological models
- Emphasised visual inspection
- Importance of eye tracking research
- Recently revisited and extended (Mello Thoms, 2009)
- Of practical utility
- Separation of errors into those due to search, detection and interpretation
- Mathematical approach - Ideal observer
- Health informatics - ontological descriptions.
- Image analysis techniques – potential non-verbalisable feature approaches
  - e.g. SIFT (Scale Invariant Feature Transform) algorithm



### FN (Miss) errors

Can tease out whether someone:-

- has not looked at key features – search training
- Has not recognised features – need training focussed on features
- Recognise features ok - but then not utilised that information to make a decision of abnormality – need different type of training

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### PERFORMS

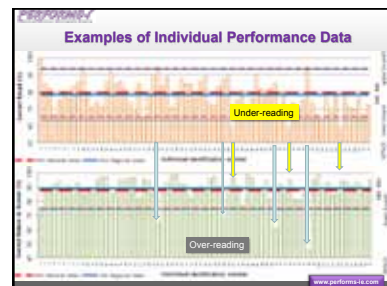
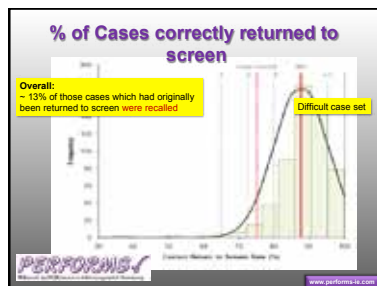
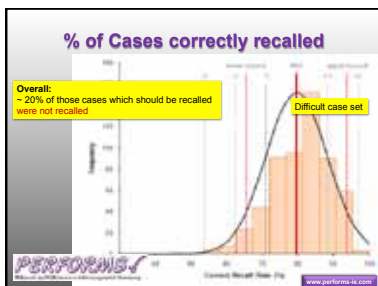
PERsonal PERFORMANCE in Mammographic Screening

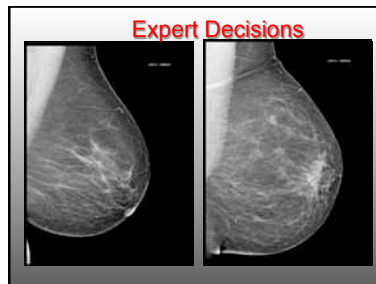
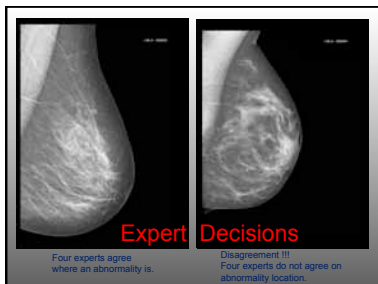
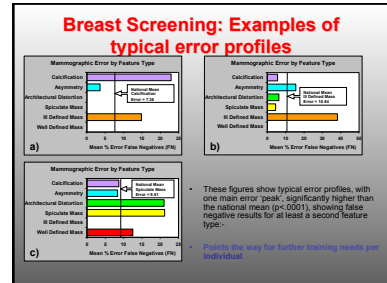
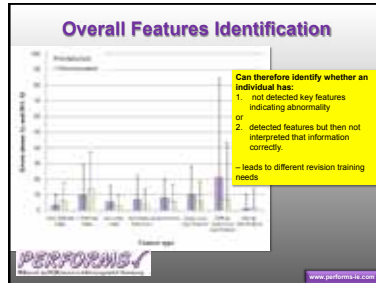
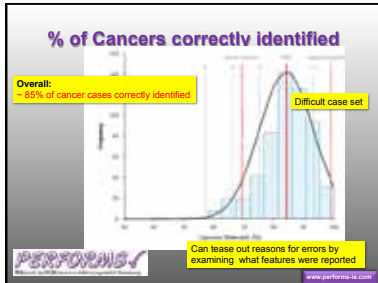
- Every year a difficult case set is circulated around the UK
- In 2009/2010 almost 600 screeners read the same set of challenging recent screening cases

Data analysed in terms of:

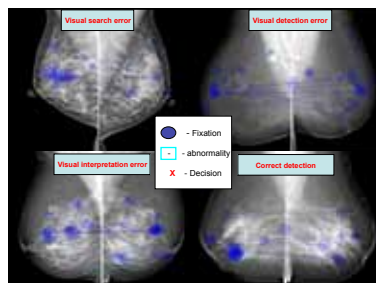
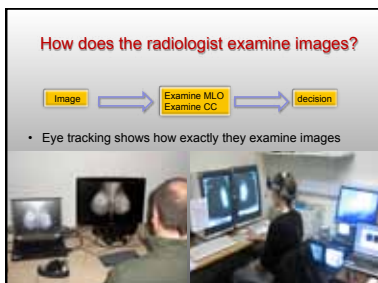
1. An individual's decision to recall/refer recall a case compared to all their peers (i.e. if this woman presented anywhere in the UK would she be treated in the same way)
2. An individual's agreement with known case pathology (i.e. did they detect cancer)

www.performsi4.com

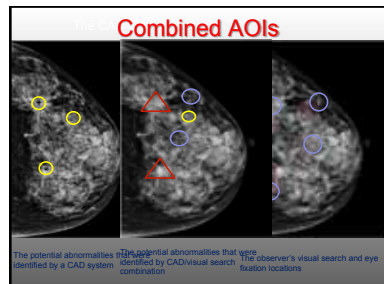
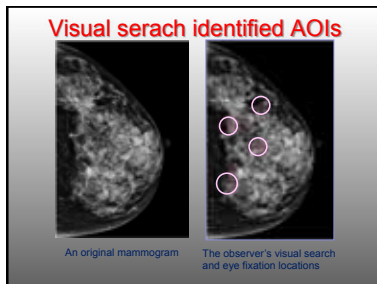
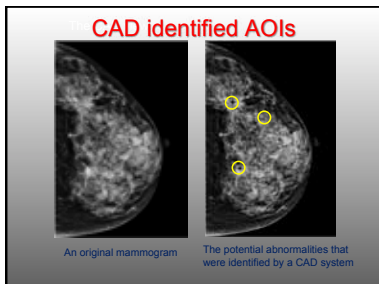
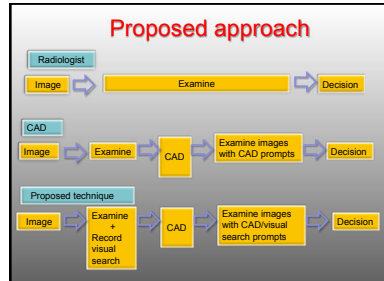
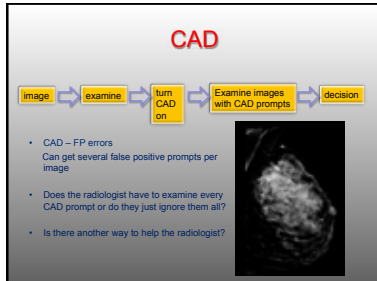
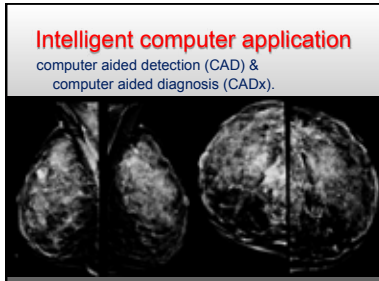




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- ### CAD
- How best can image processing help the radiologist?
  - CAD algorithms – minimal false positive detections
  - Mammography CAD systems a few years ago – many FPs; now few FPs, much improved
  - With today's mass of data streams and complex image visualisations we become more reliant on accurate image processing and CAD technologies
  - Can (or should) CAD be tailored to the individual?



- ### Conclusions
- Visualisation and perception vitally important in interpreting medical imagery
  - Errors will always occur in radiological interpretation
  - Need to minimise these
  - Appreciating what causes errors gives us ways to overcome them
    - can provide individualised targeted training which will improve performance
    - can provide CAD approaches tailored to the individual
  - The PERFORMS scheme is now internationally available
- [www.performs-uk.com](http://www.performs-uk.com)

**Thank you**

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[www.performs-uk.com](http://www.performs-uk.com)