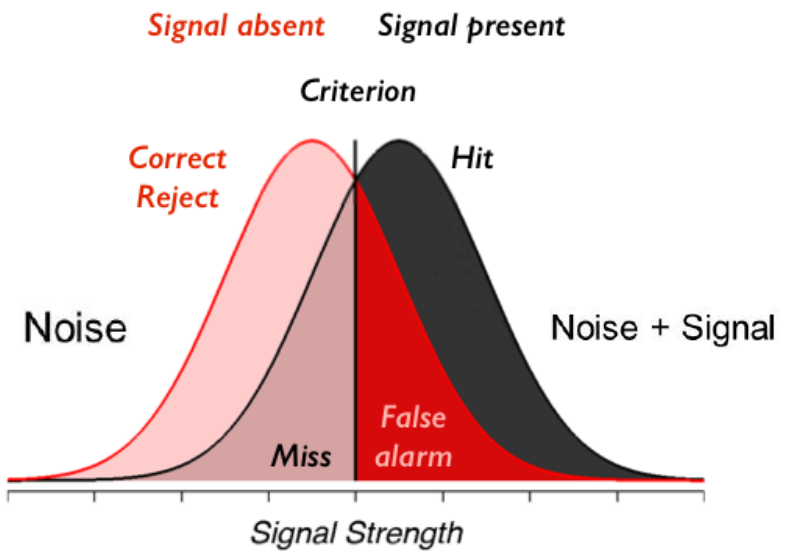
Signal Detection Theory in Radiology

By: Jenna Kleinow

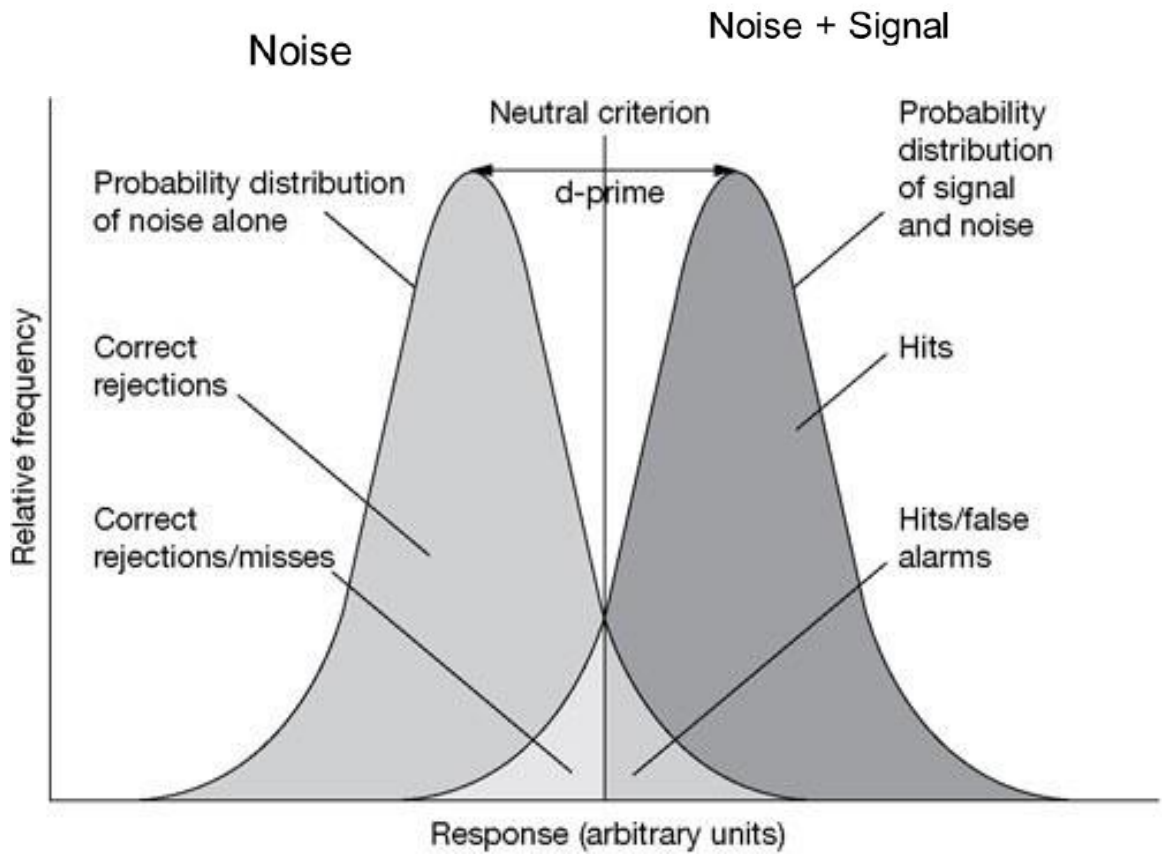
Decision Making

- Analyzing decision making in the presence of uncertainty

		State of the World	
		Signal Present	Signal Absent
Observer Response	"Present"	Hit	False Alarm
	"Absent"	Miss	Correct Rejection



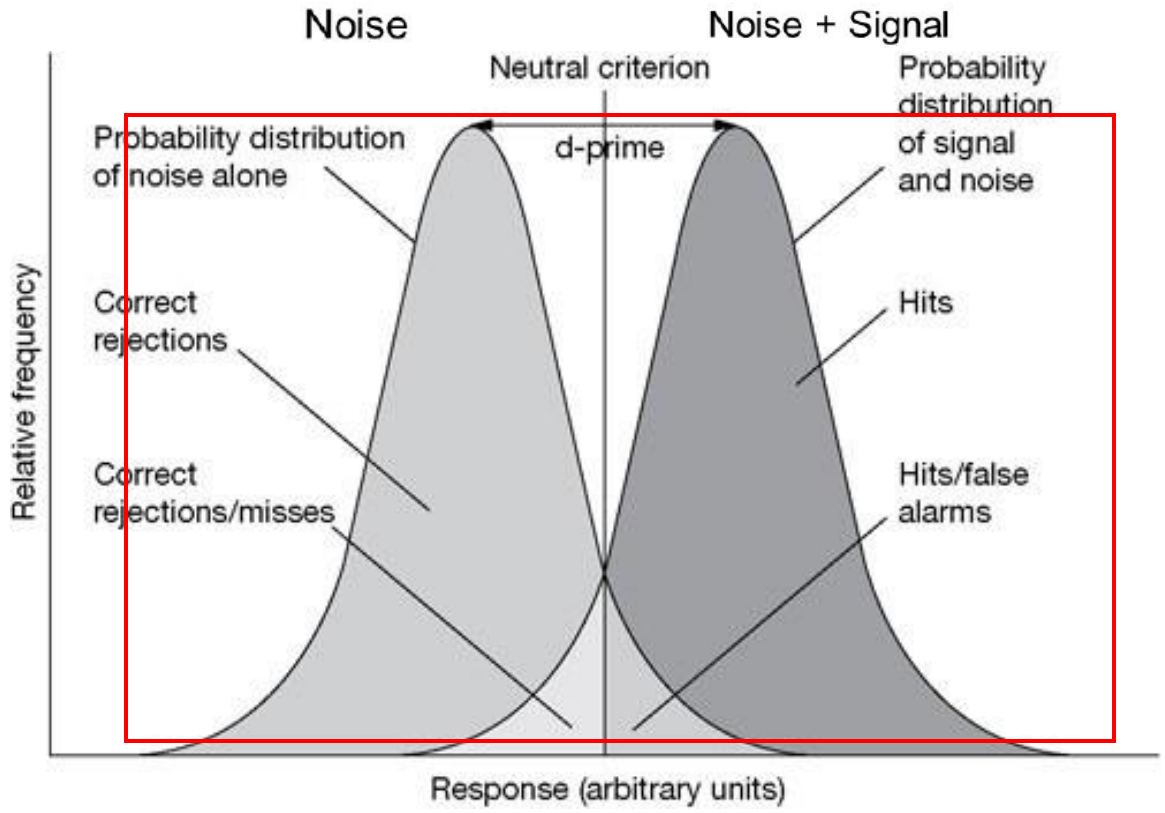
Components of the distributions



Bias (β)

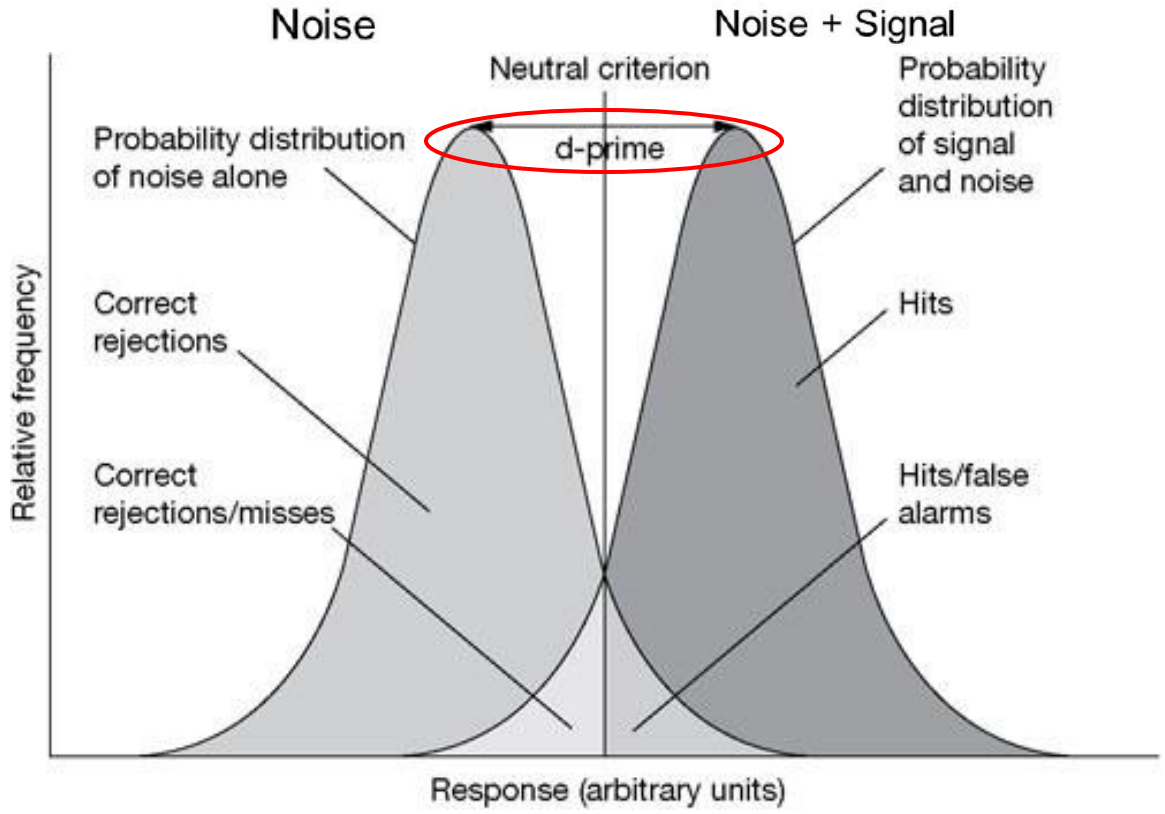
- Bias is calculated relative to the two distributions

Misses : False Alarms
Hits : Correct Rejections



Sensitivity (*d'*)

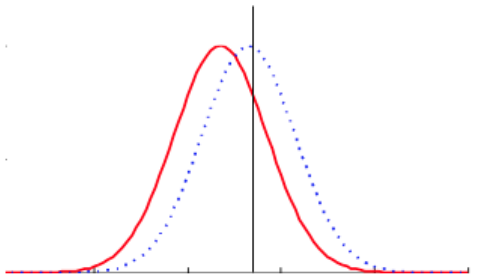
- The distance between the distributions

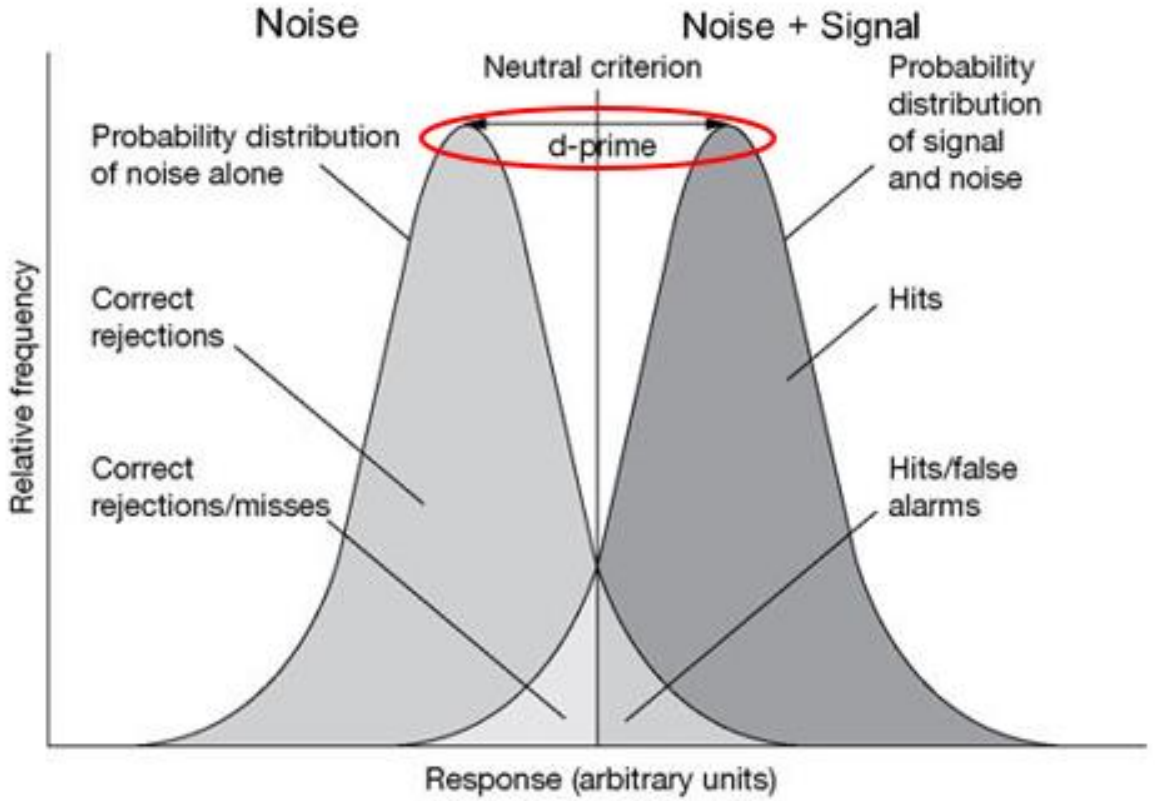


Sensitivity (*d'*)

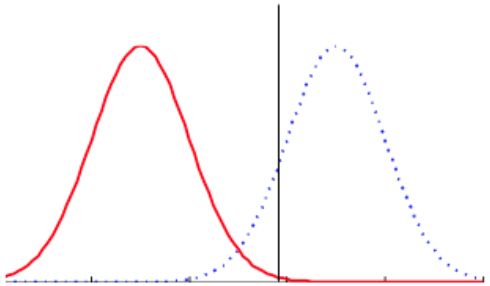
- The distance between the distributions

Low Sensitivity



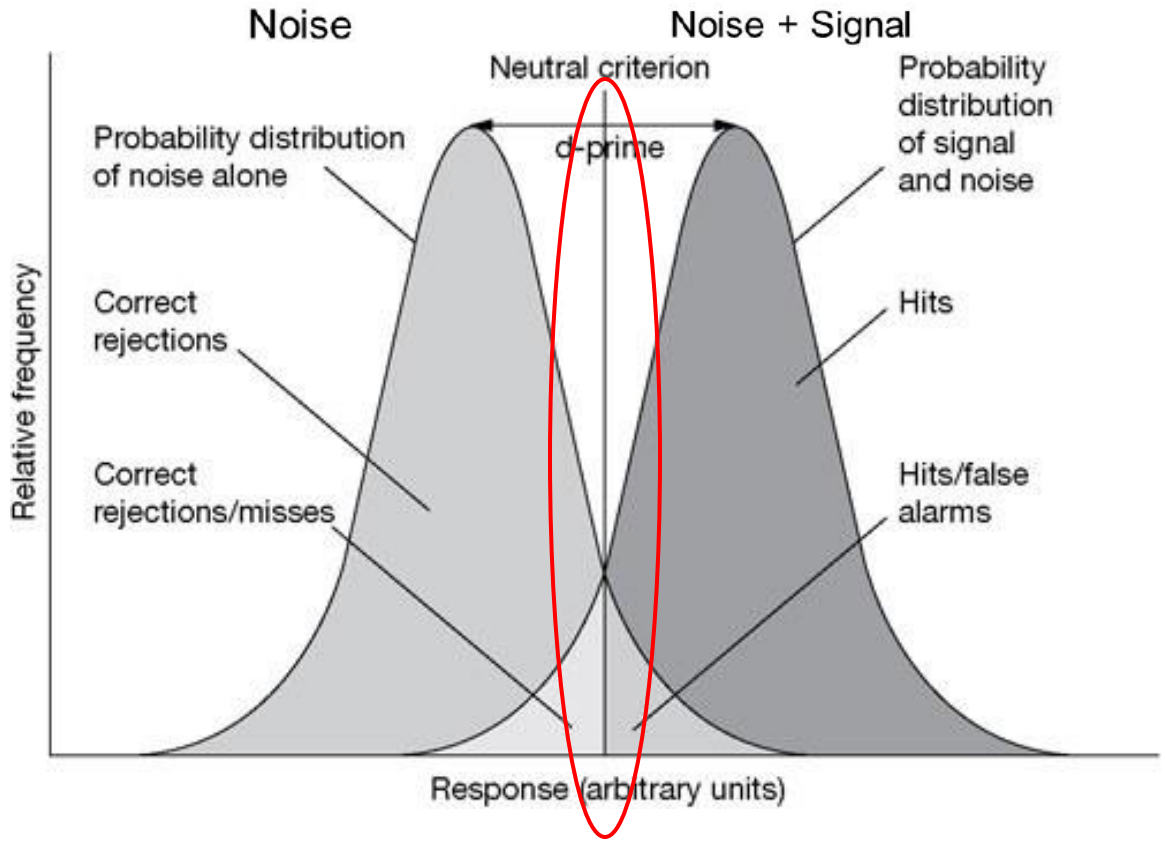


High Sensitivity



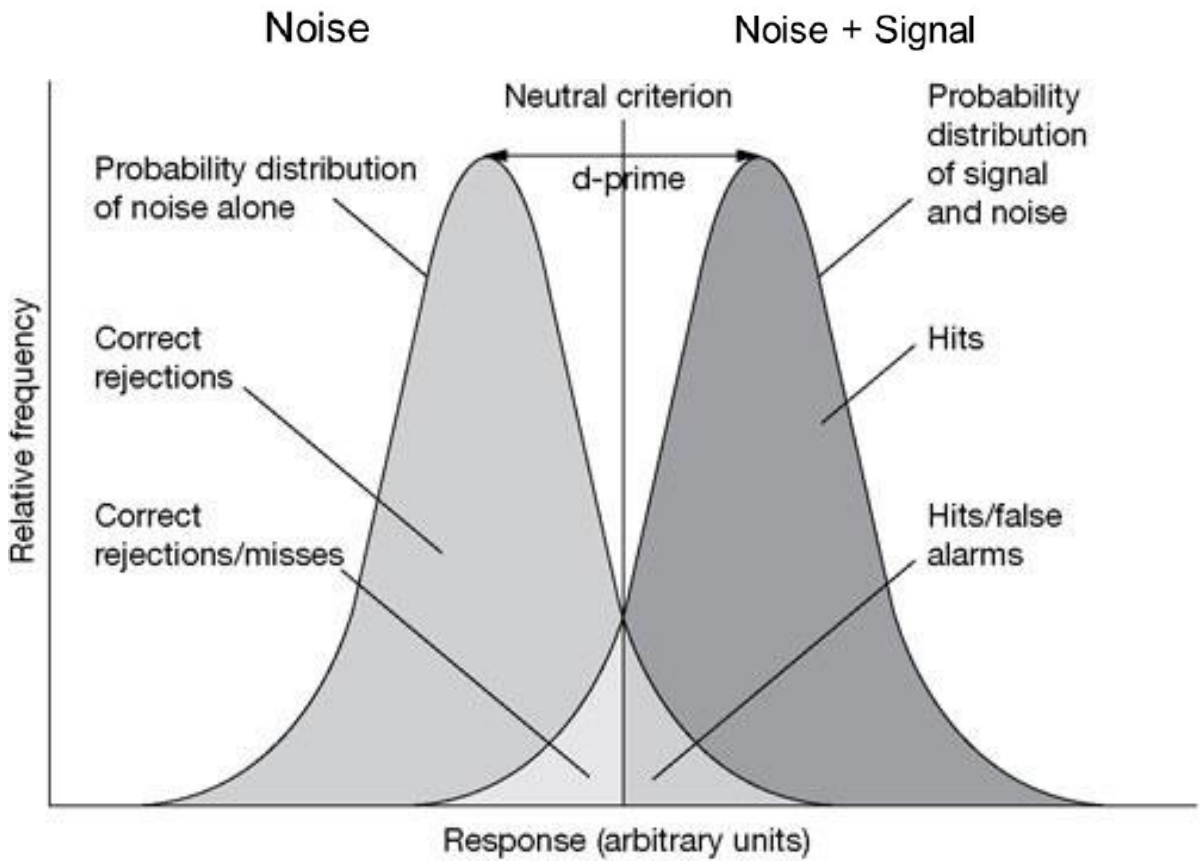
Criterion (X_c) λ

- Criterion is what separates bias from sensitivity



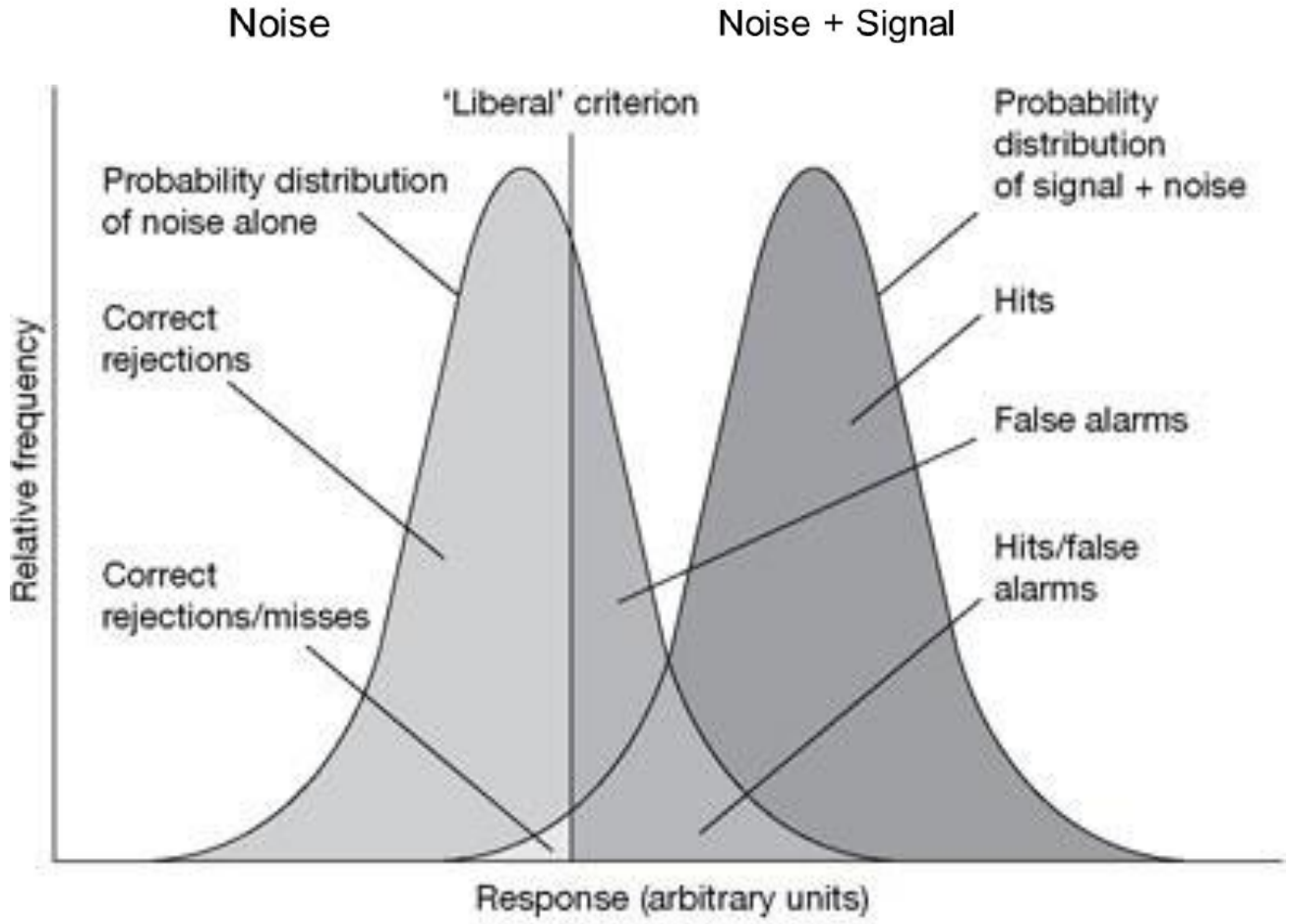
Neutral/no bias criterion

- Gains and costs are equal (β = 1)
  - Misses=False Alarms
  - Hits=Correct Rejections



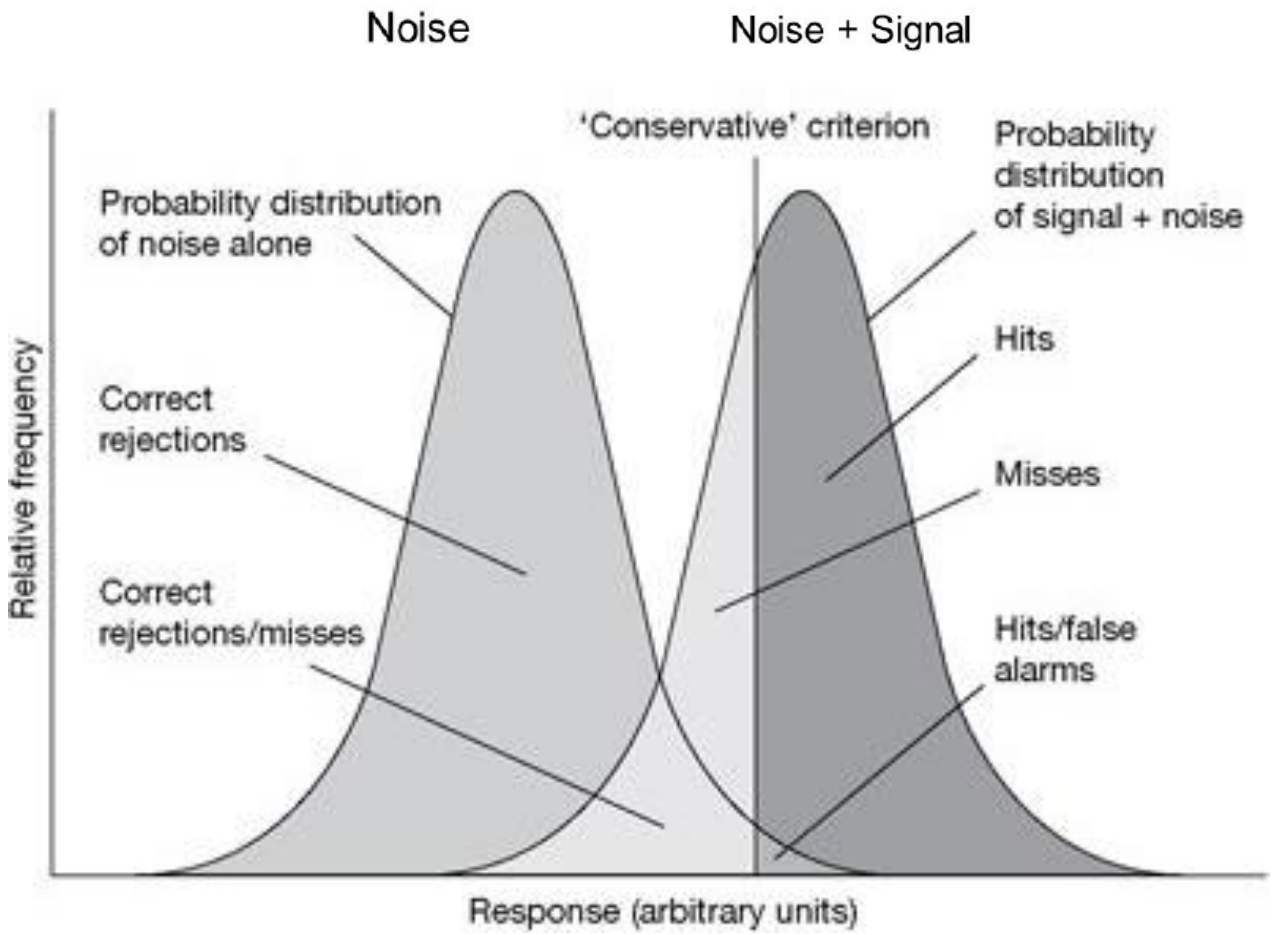
Risky/liberal bias

- Left shift
- Avoiding misses
- $\beta < 1$



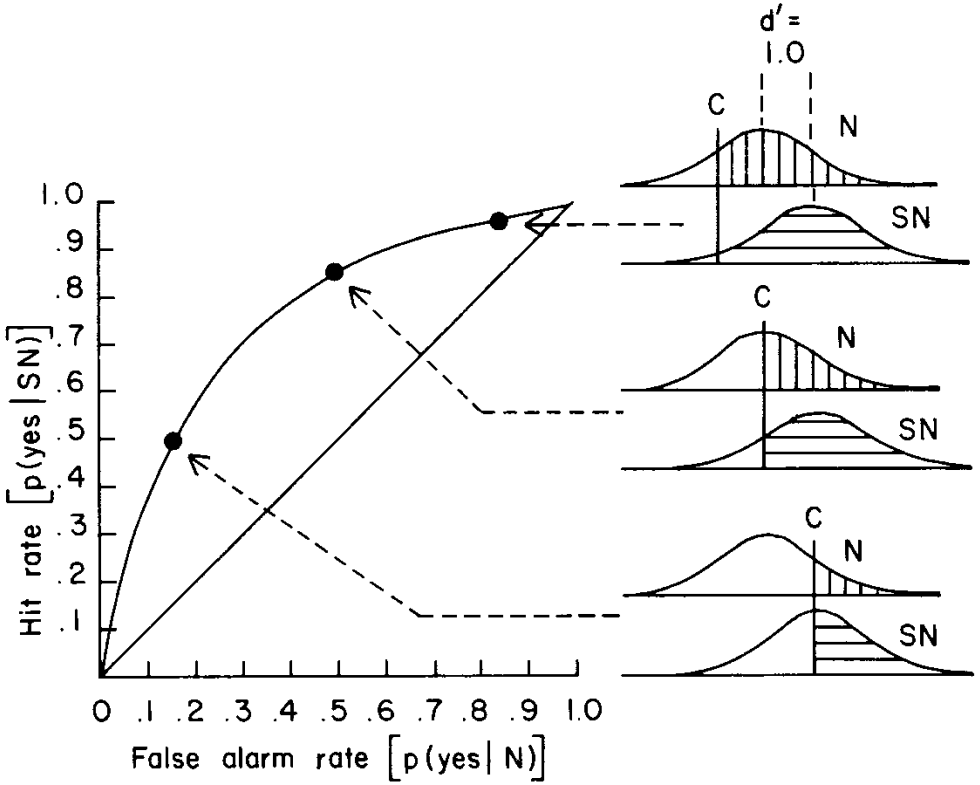
Conservative bias

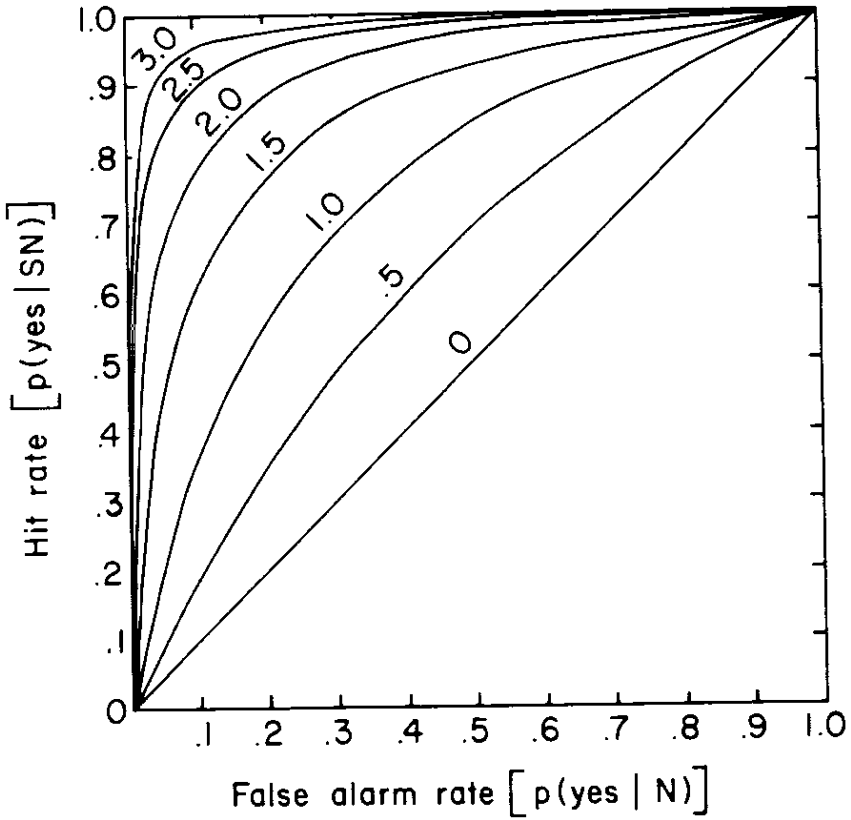
- Right shift
- Avoiding false alarms
- $\beta > 1$



Receiver Operating Characteristic (ROC) Curve

- Illustrating sensitivity and bias





Literature Review

Using signal detection theory to model changes in serial learning of radiological image interpretation

K. Boutis, M. Pecaric, B. Seeto, M. Pusic (2010)

Introduction

- Not just about pattern recognition….
  - Discern a signal amongst the noise
- Apply SDT to serial learning task of interpreting radiological images
- Development of expertise
  - Quantify signal detection over time
- Track sensitivity and bias as experience is gained

Methods

- Participants: *46 total*
  - 20 medical students
  - 6 residents
  - 12 fellows
  - 5 staff pediatric emergency physicians
  - 3 staff radiologists

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Methods

- Participants: *46 total*
  - 20 medical students
  - 6 residents

  } Low experience group *n*=26

  - 12 fellows
  - 5 staff pediatric emergency physicians
  - 3 staff radiologists

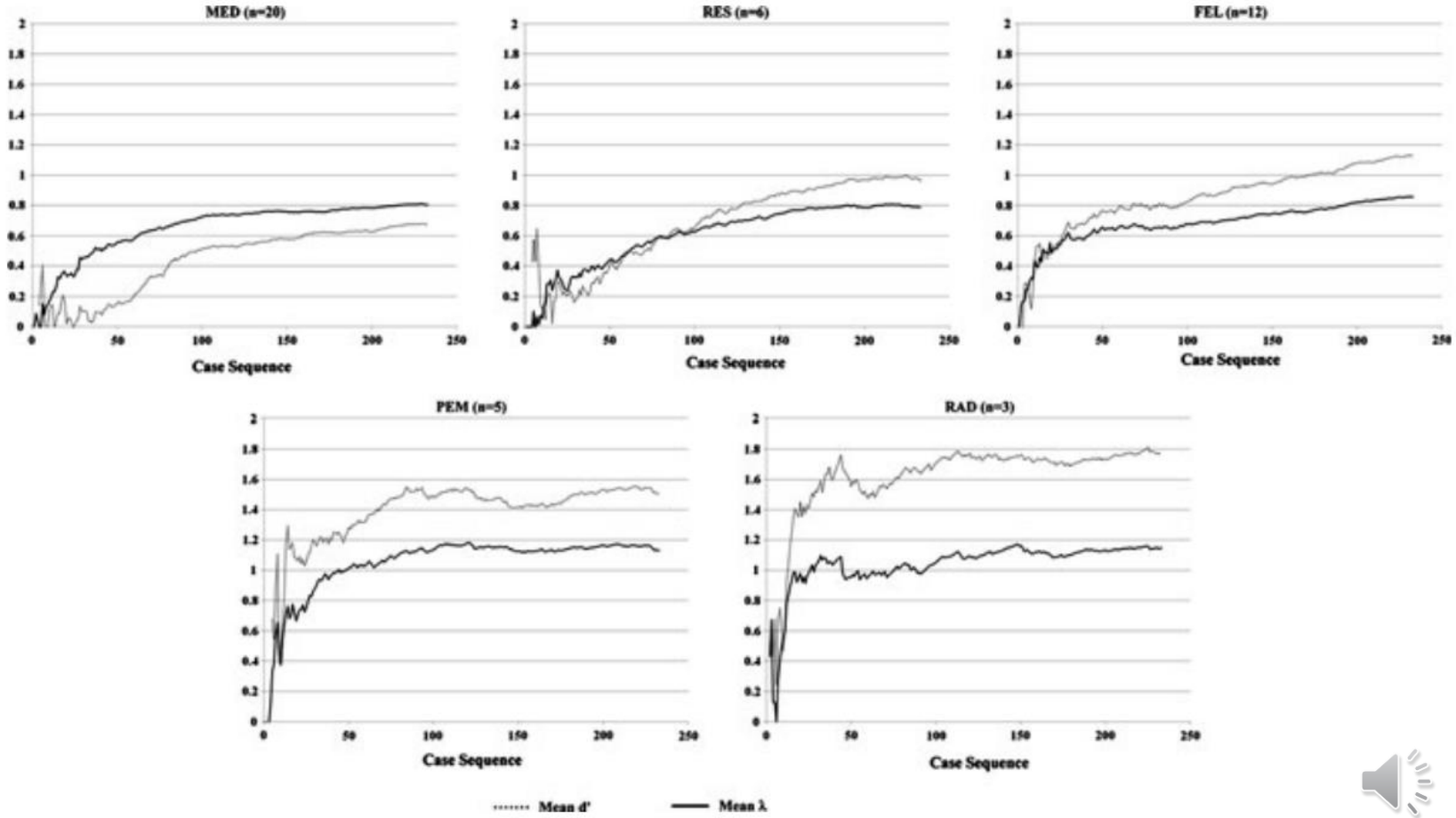
  } High experience group *n*=20

Methods

- Task
  - Interpret 234 pediatric ankle films as normal or abnormal. If abnormal, indicate where.
  - Given immediate feedback

Results: sensitivity

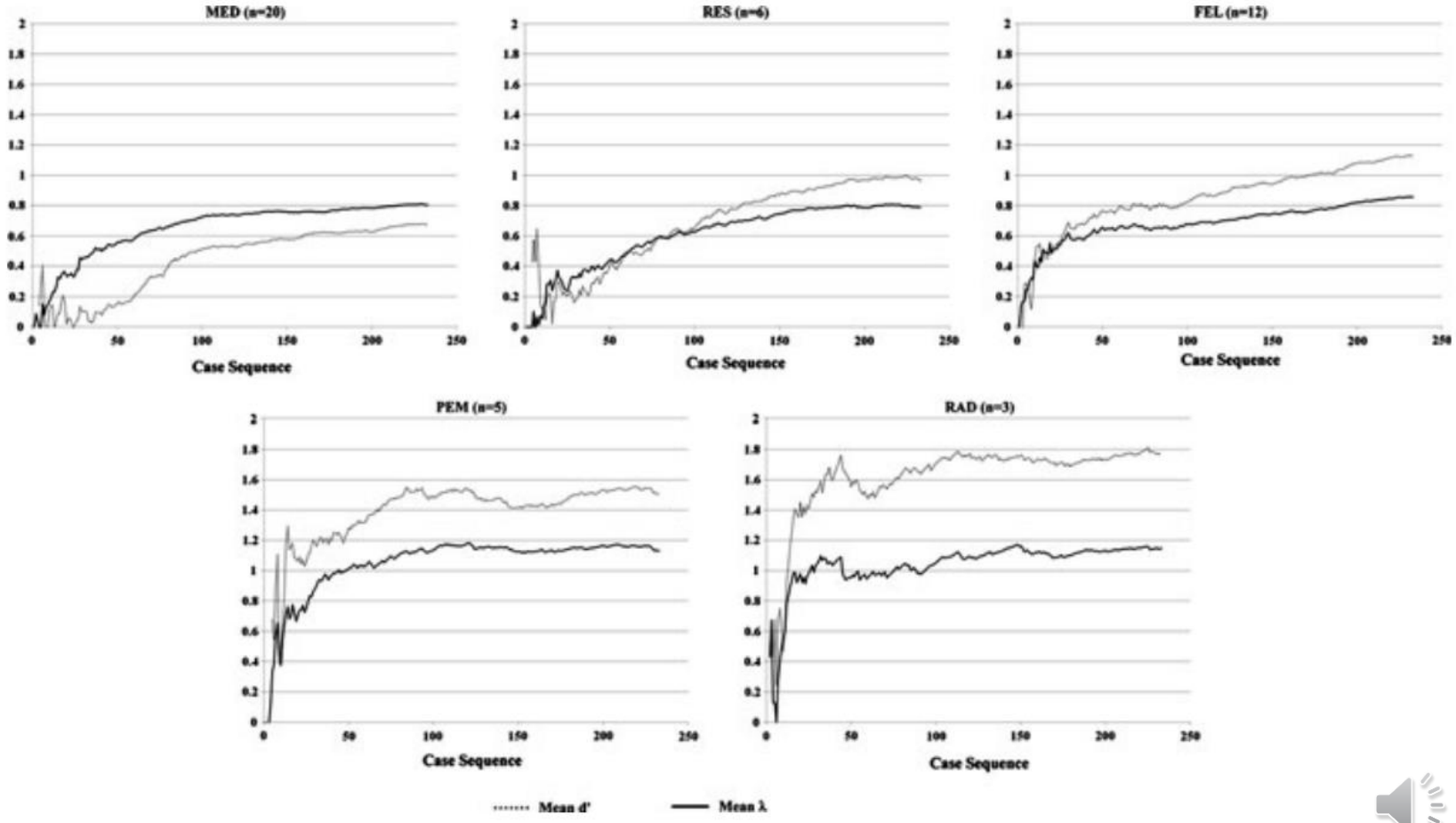
- *d'* was higher for high experience group
  - *d'* improved with each case for the low experience group
  - *d'* initially improved for the high experience group, then leveled off



Note: λ is denoted as the criterion

Results: criterion

- λ was stable after ~75-100 reviewed cases for high experience group
  - Maintained a balance between d' and λ
- λ was a developmental pattern for low experience group



Note: λ is denoted as the criterion

Discussion

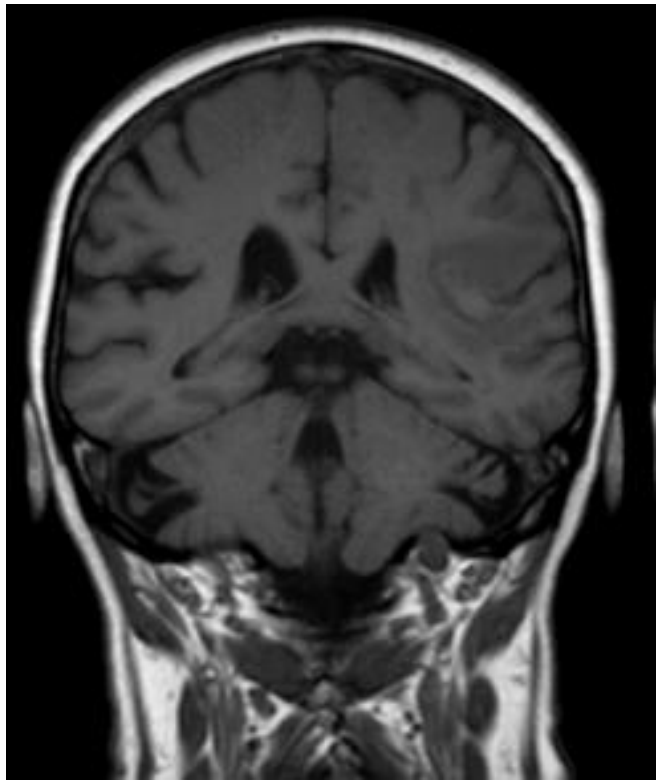
- With serial exposure to many cases, *d'* improved for all groups
  - As expertise level increased, *d'* increased
- Low experience groups set a high criterion relative to their discrimination ability
- High experience groups set a low criterion
- Different perceptions of the cost of false positives vs the cost of false negatives

Limitations

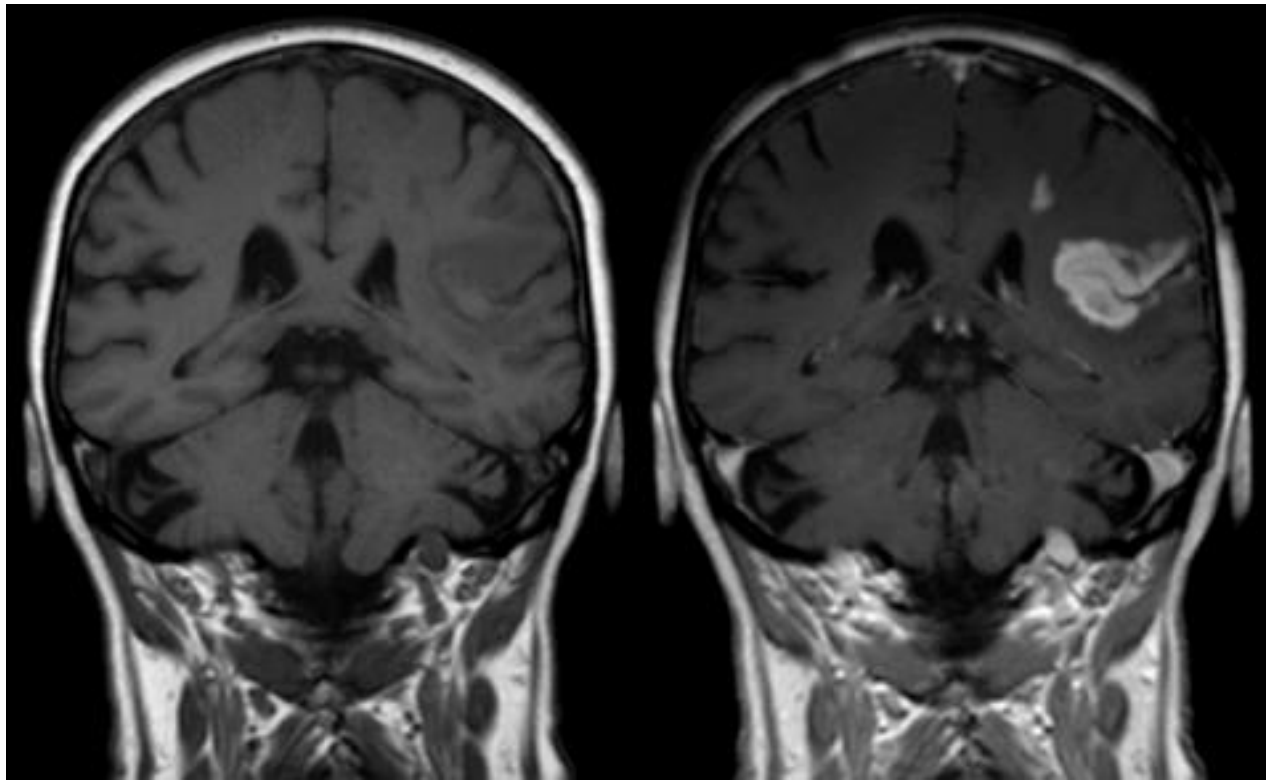
- Knowledge gained from assessing one case is immediately applicable to the next one
- Dichotomous nature: either a fracture is or is not present
- Responder bias
- Small sample sizes in each group

Examples

Can you spot the low contrast lesion?

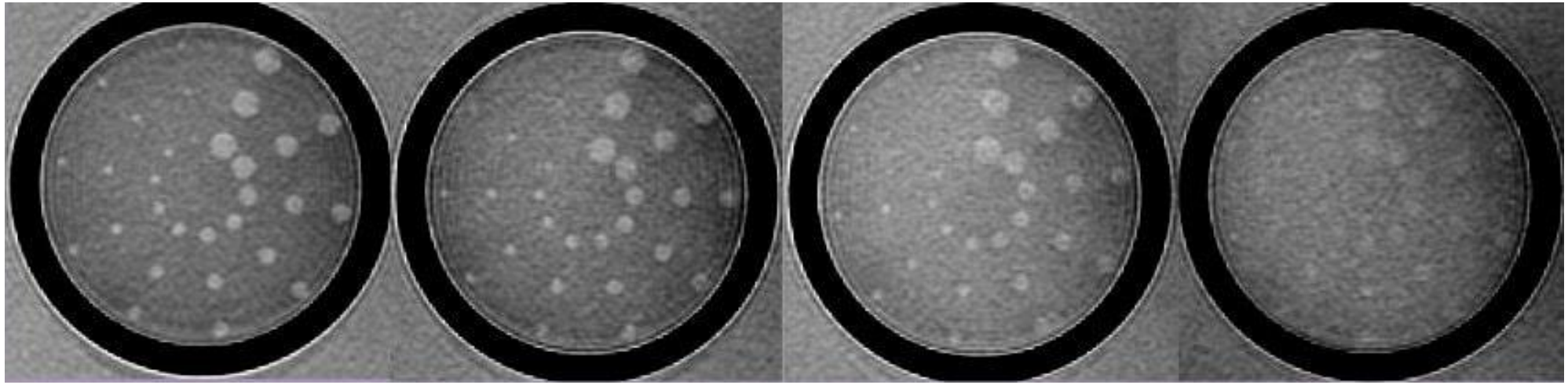


Add IV contrast to increase visibility and differentiate pathology



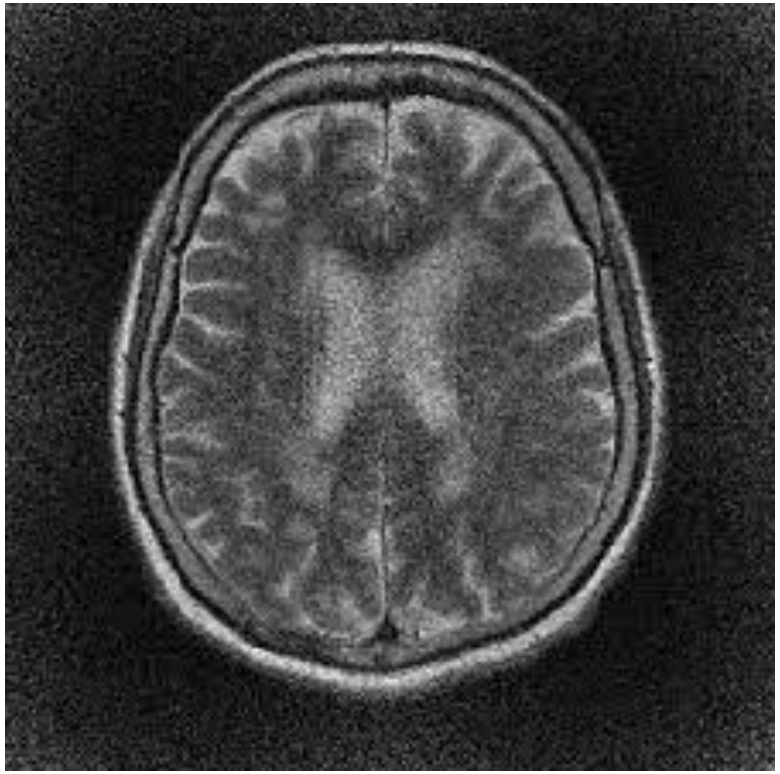
MRI Quality Assurance: Low contrast detectability

- Discern spokes within noise
- Tests the capability of the MRI system



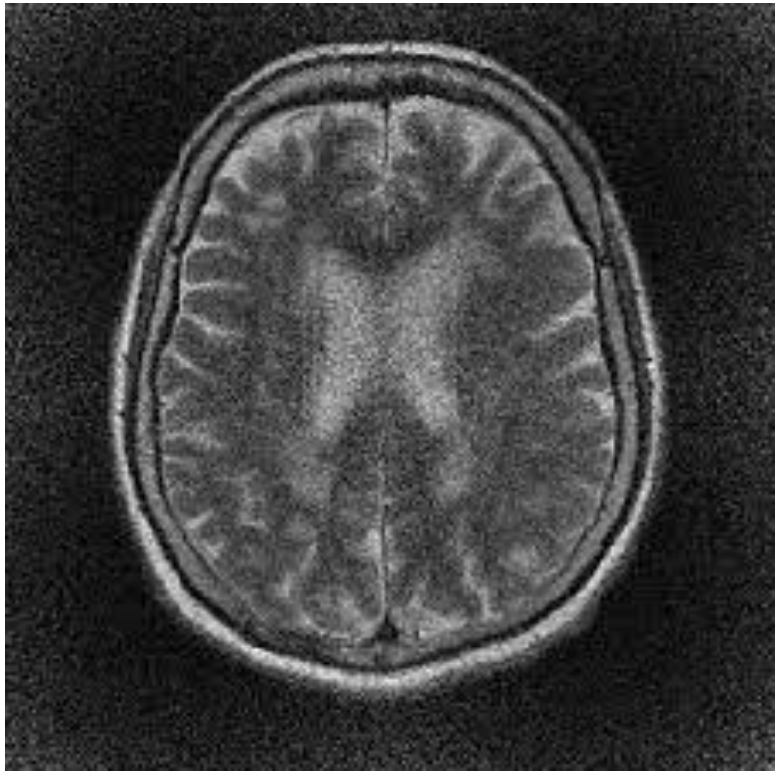
Signal to Noise Ratio (SNR)

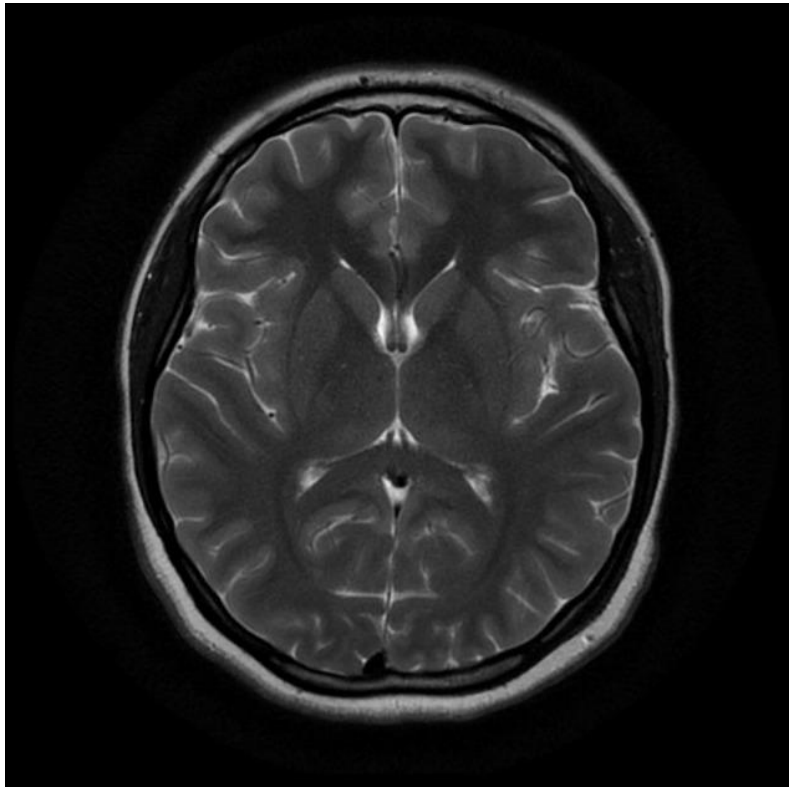
- Poor SNR
  - Noise too high
  - Signal too low



Signal to Noise Ratio (SNR)

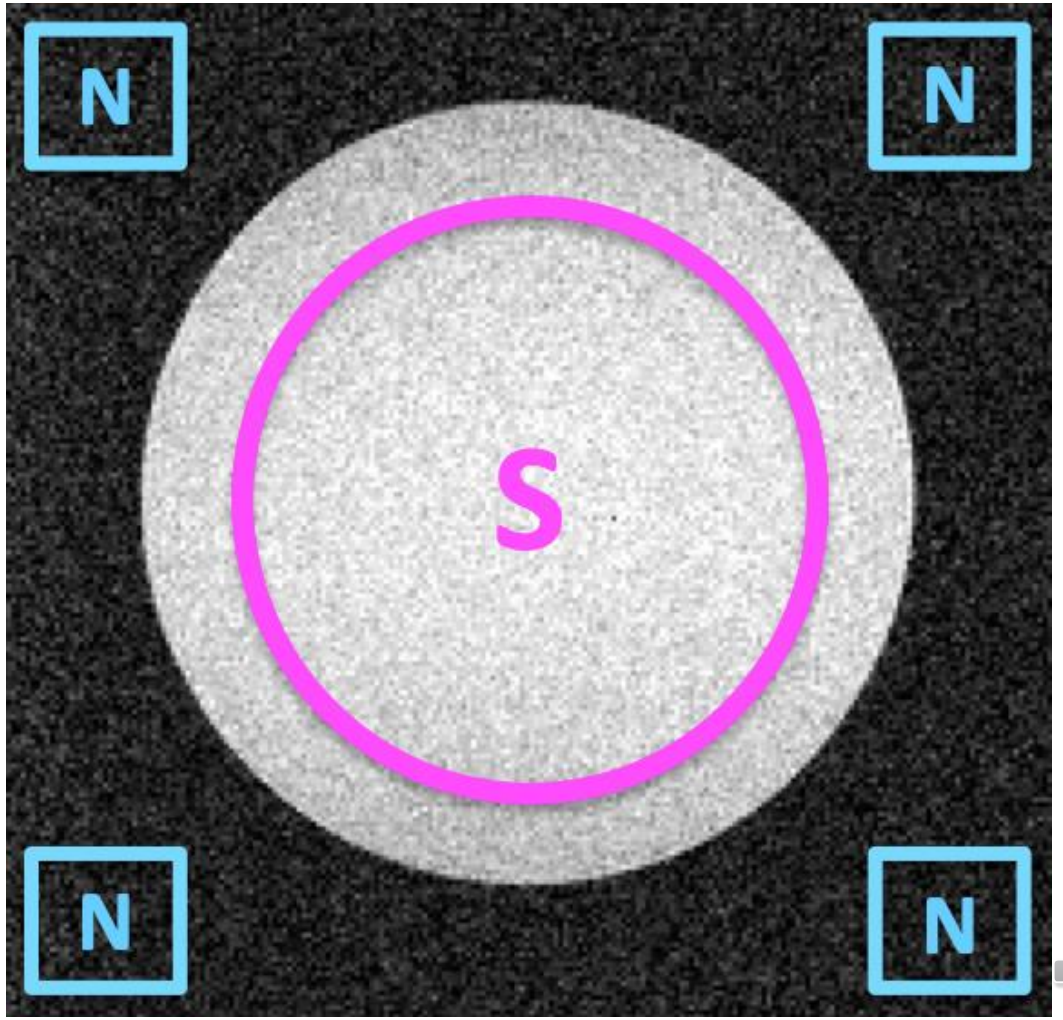
- Optimal SNR
  - Noise decreased
  - Signal increased
- There is still some noise!





Signal to Noise Ratio (SNR)

- Maintaining a certain amount of signal to the noise
- Monitor trends of SNR to ensure discernability between the two

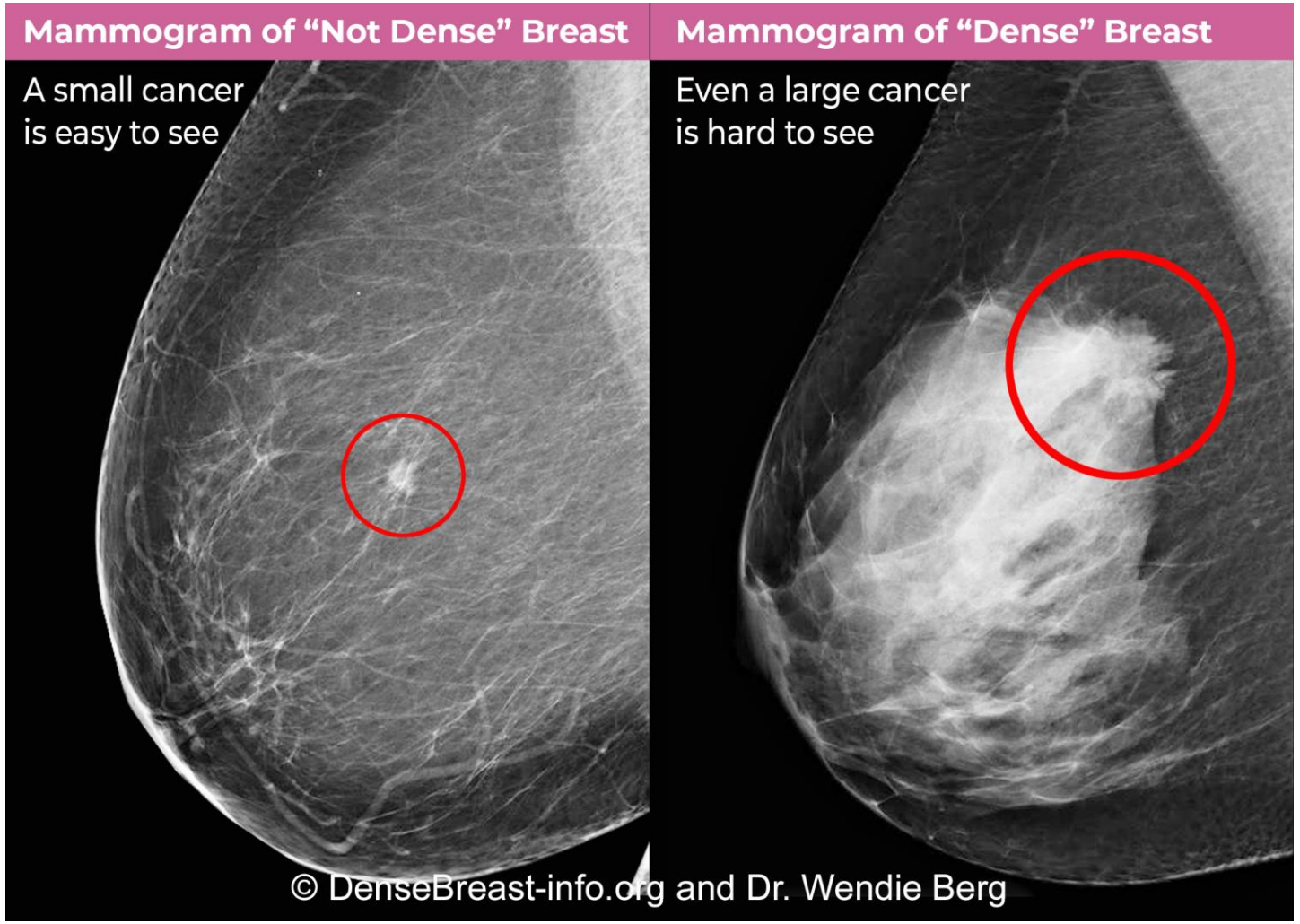


Artifact or Pathology?

- Artifact : Noise
- Pathology : Signal

Breast cancer detection

- Breast cancer is harder to detect in dense breast tissue vs not dense tissue
- Patients with dense breast tissue may require a test with a higher sensitivity, such as an ultrasound or MRI



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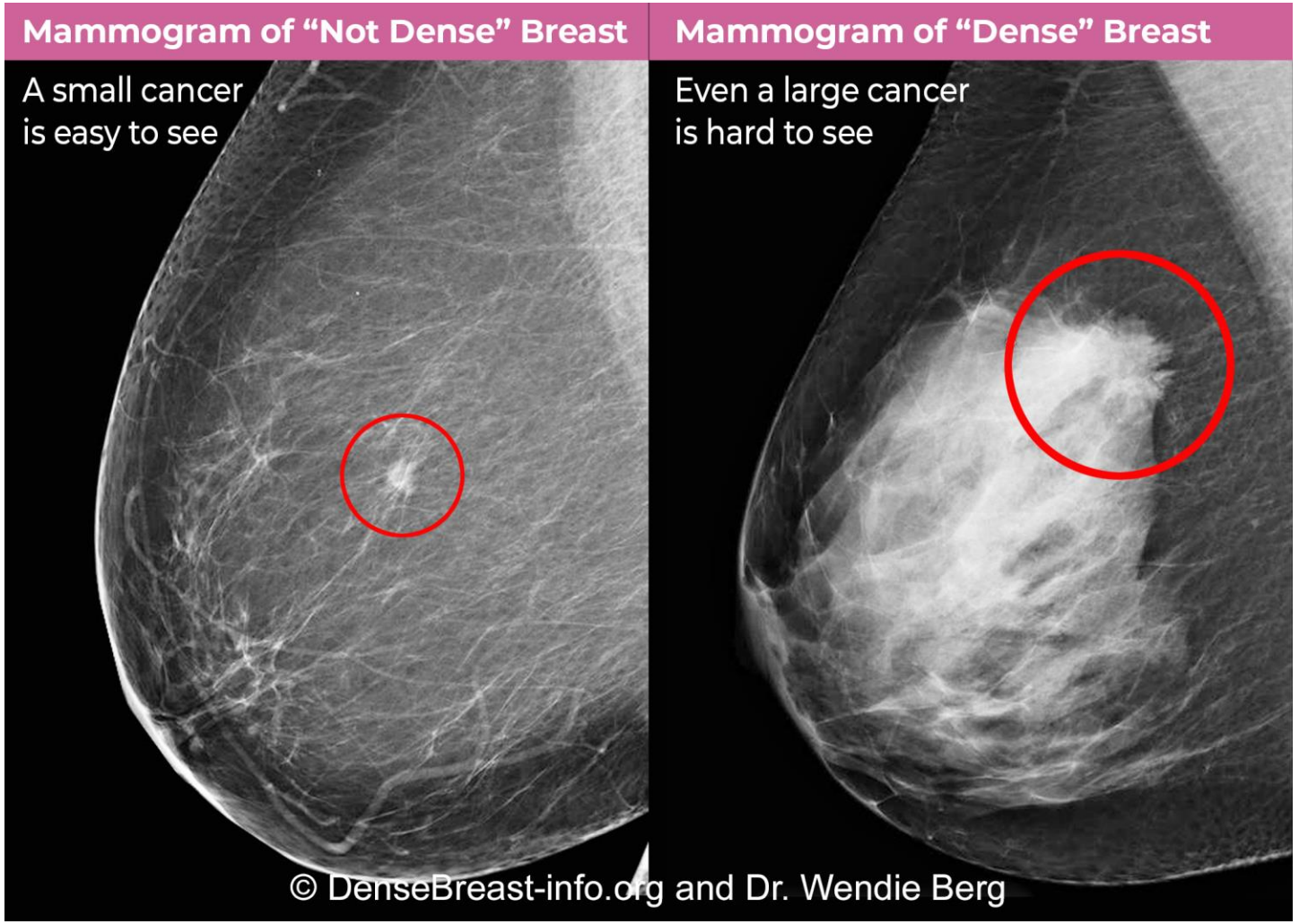
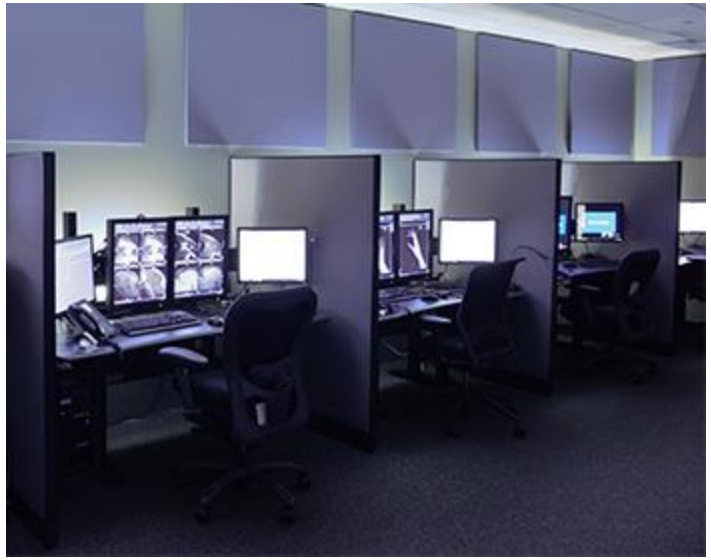


Environmental Noise

- Acoustics
- Lighting
- Interruptions



Thank you!