Prevalence induced Biases in Medical Image Decision-making

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The Prevalence Effect

- **Prevalence:** When targets are very rare or very common
- Extreme prevalence rates result in more errors as compared to more moderate prevalence rates (Wolfe & Van Wert, 2010; Horowitz, 2017)
  - Low prevalence → increase in misses
  - High prevalence → increase in false alarms

Why Does Prevalence Effect Occur?

- Signal Detection Theory shows the prevalence effect is due to changes in criterion and not discriminability (reviewed in Horowitz, 2017)
  - Conclusion: prevalence does not alter the perception of images
- But, an effect solely on criterion can arise from a perceptual effect (Witt et al., 2015)

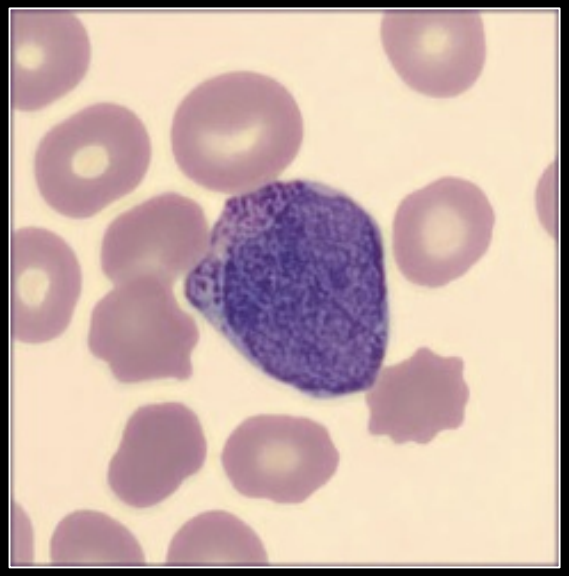
Goals for Today

1. Reevaluate the prevalence effect using the Diffusion Decision Model
   - Distinguish between two types of biases (White & Poldrack 2014)
     1. Response bias (preconceived, image independent bias)
     2. Perceptual bias (bias in how an image is processed)
2. Examine the similarity / difference in the prevalence effect for novices and experts

Blast Identification Task

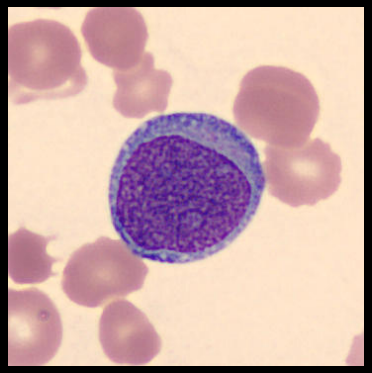
- **Distinguish between normal white blood cells and abnormal cancer cells ("blast" cells, associated with acute leukemia)**

"Is this a blast cell?"

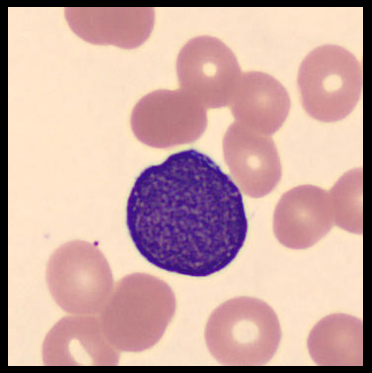


Trueblood et al. (2018) *CR:PI*

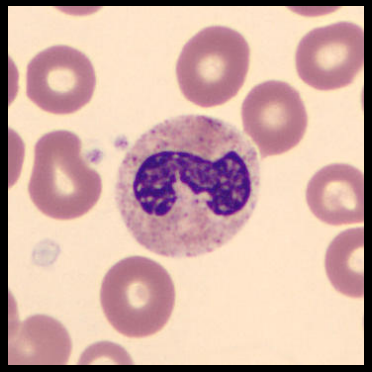
Image Categories



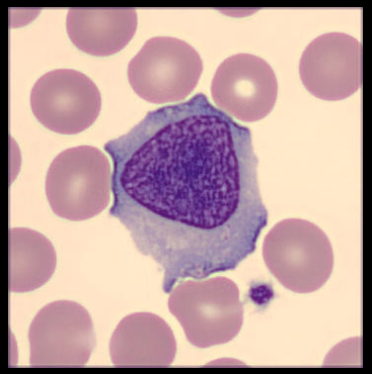
Blast Easy



Blast Hard



Non-blast Easy



Non-blast Hard

Two Prevalence Studies

1. Novice: 10/50/90% prevalence

2. Expert: 50/90% prevalence

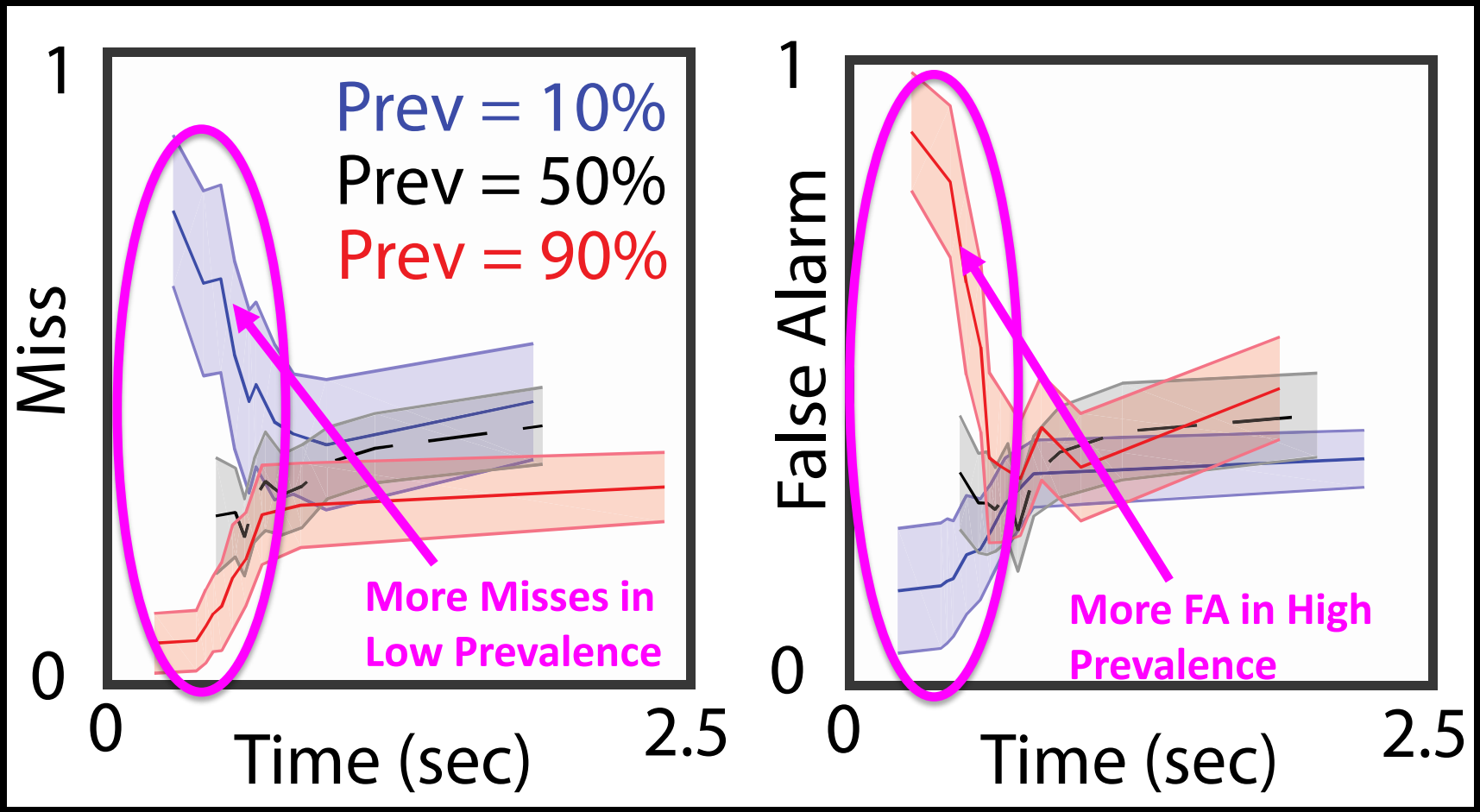
Prevalence: Experiment 1

Novice: 10/50/90% prevalence (between-subjects)

- 57 VU undergrads
- Procedure
  1. Learning and Training phases
  2. Main task:
     - 2 blocks of 80 trials at 50%
     - High prevalence group: 12 blocks of 80 trials at 90% prevalence
     - Low prevalence group: 12 blocks of 80 trials at 10% prevalence

Results Exp 1: Error Rates

Novice: 10/50/90% prevalence



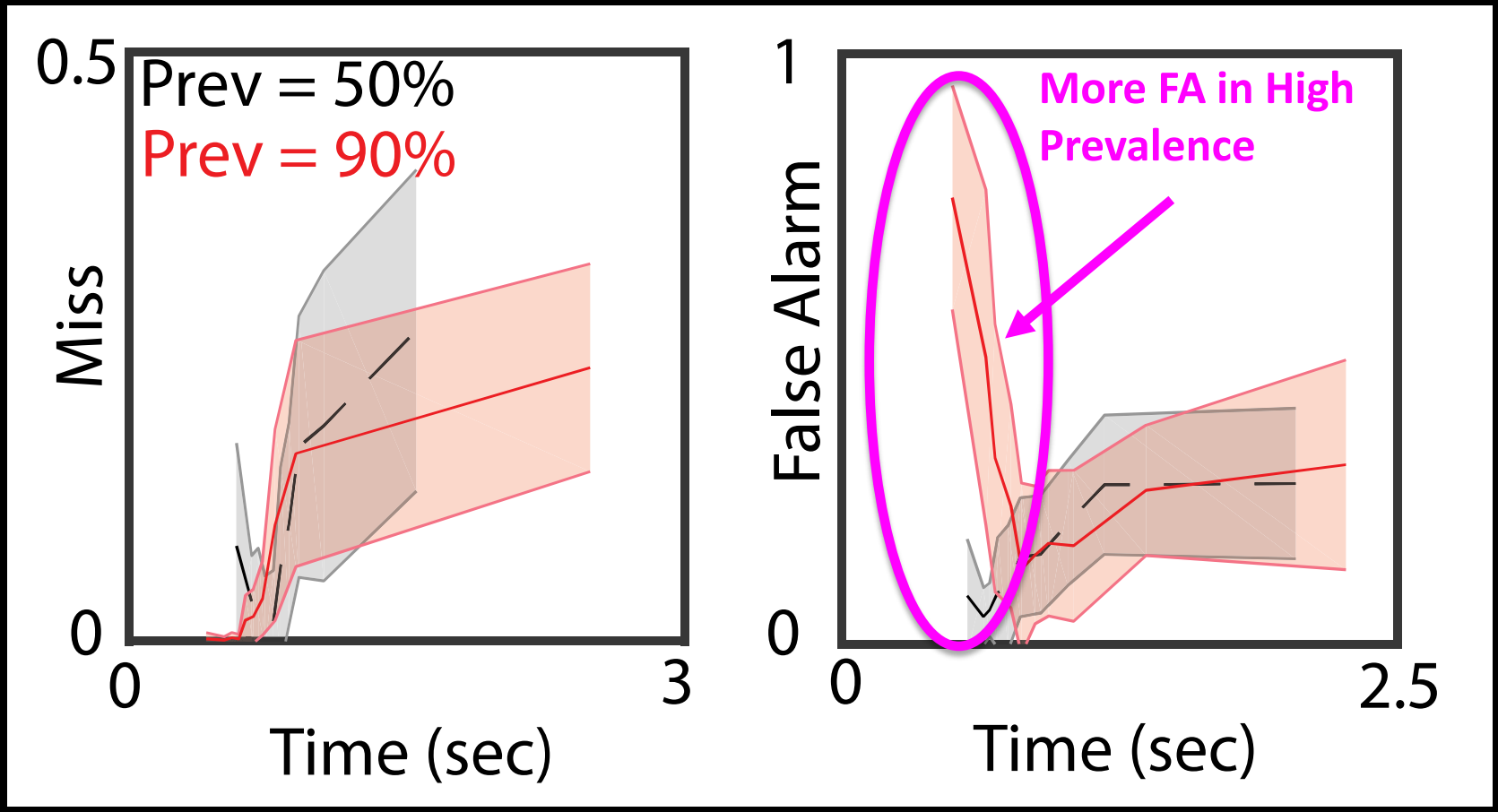
Prevalence: Experiment 2

Expert: 50/90% prevalence

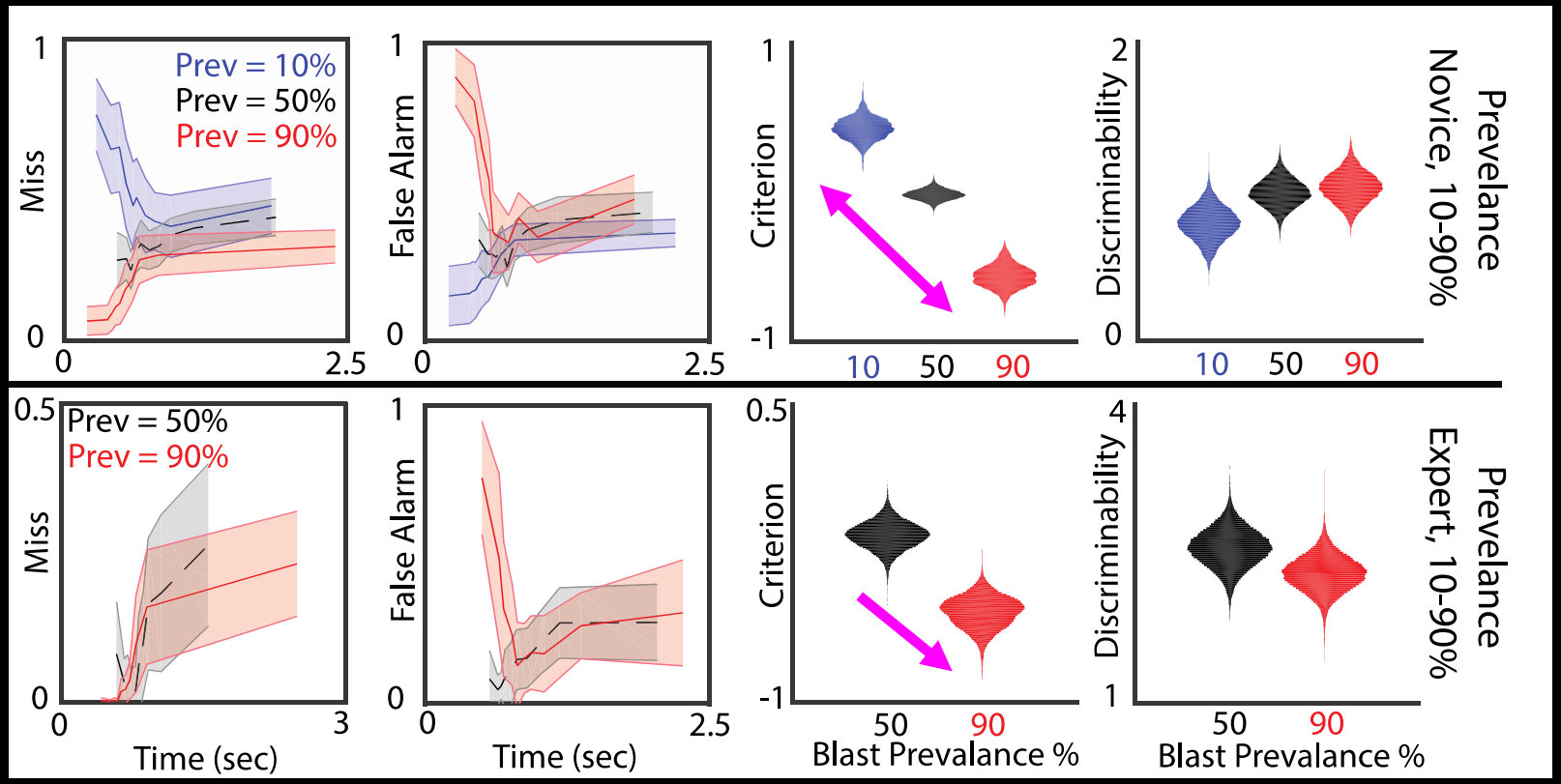
- 19 medical laboratory professional from VUMC
- Procedure
  1. **Same training** as Experiment 1 (no learning)
  2. **Main task**:
     - 2 blocks of 80 trials at 50%
     - 8 blocks of 80 trials at 90% prevalence
       - Excluded easy, non-blast images

Results Exp 2: Error Rates

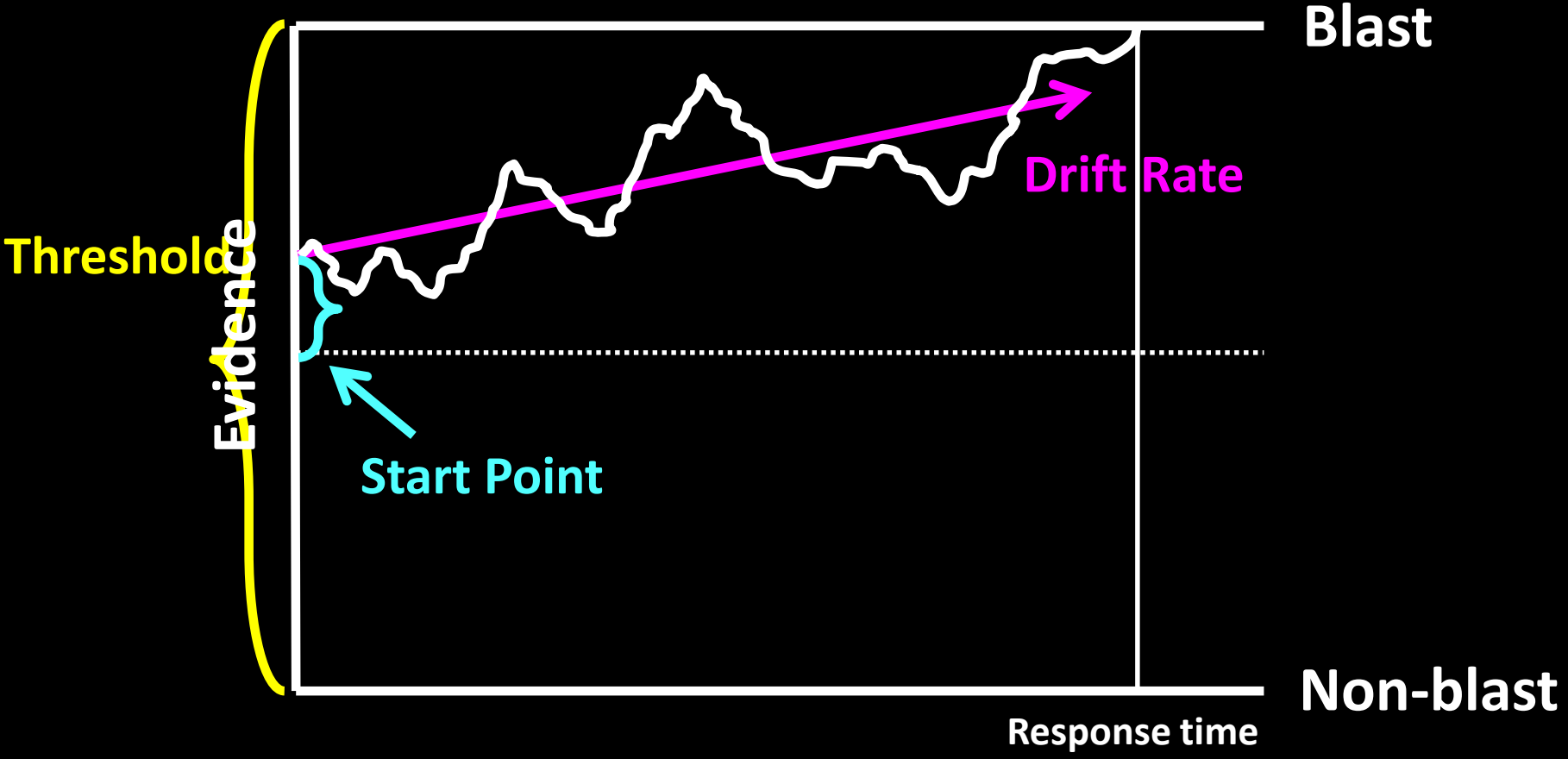
Expert: 50/90% prevalence



Signal Detection Results



Diffusion Decision Model (DDM)



Ratcliff, 1978

Key Components of the Theory

- Three core cognitive components:

1. **Drift Rate**
   - Information Processing
   - Perceptual bias

2. **Threshold**
   - Response caution

3. **Start point**
   - Initial response bias

Modeling Perceptual Bias

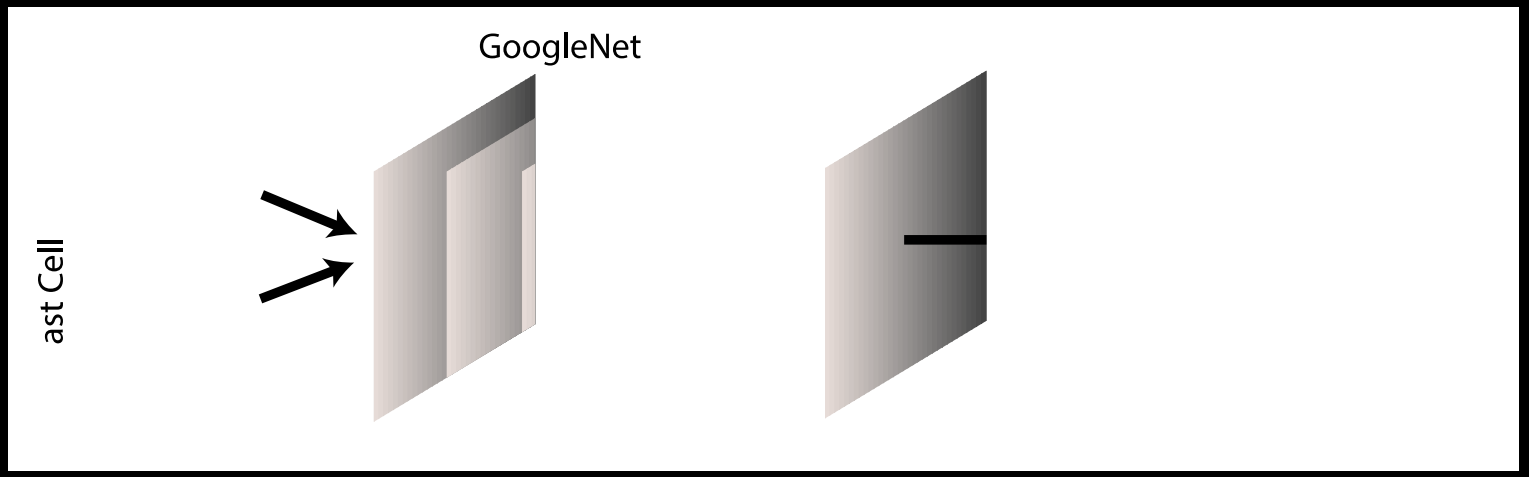
Fit DDM with a different drift rate for each image determined from a Convolutional Neural Net

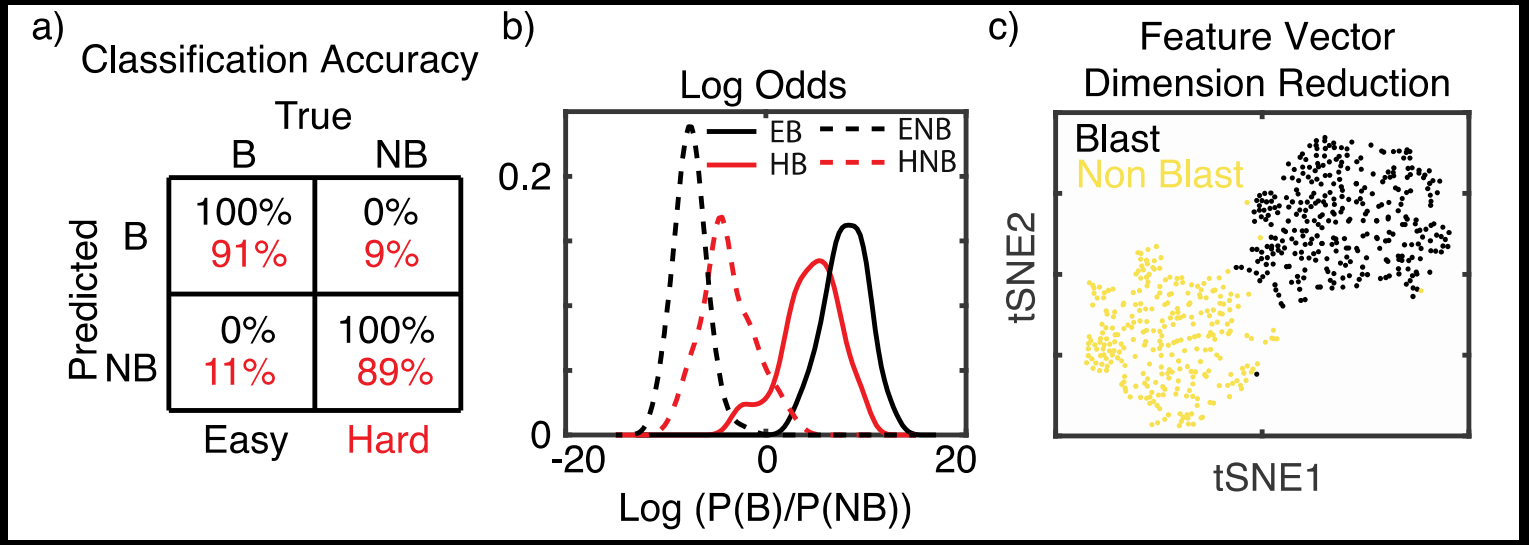
$$d_i = u + v * o_i$$

- d_i: **Drift rate for image i** — Varies with prevalence rate
- u: **Global stimulus bias (White & Poldrack, 2014)**
- v: **Weight on log odds**
- o_i: **Log odds from convolutional neural net for image i**

Holmes et al. (in press) *Computational Brain & Behavior*

Convolutional Neural Net + DDM

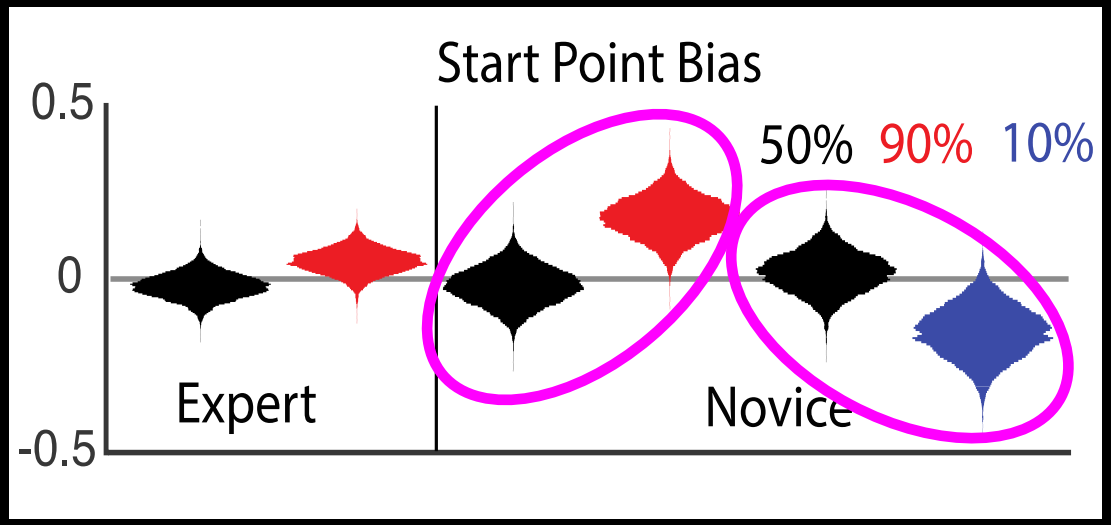




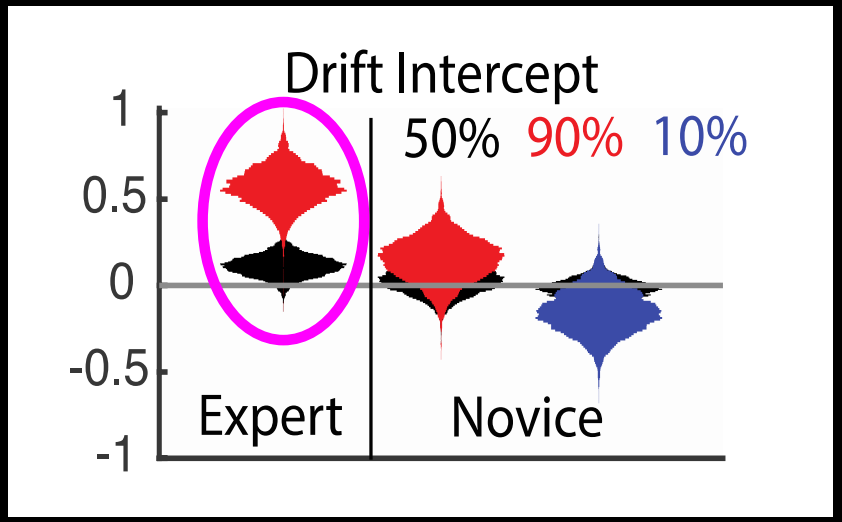
Holmes et al. (in press) *Computational Brain & Behavior*

Modeling Results

Response bias



Global stimulus (perceptual) bias



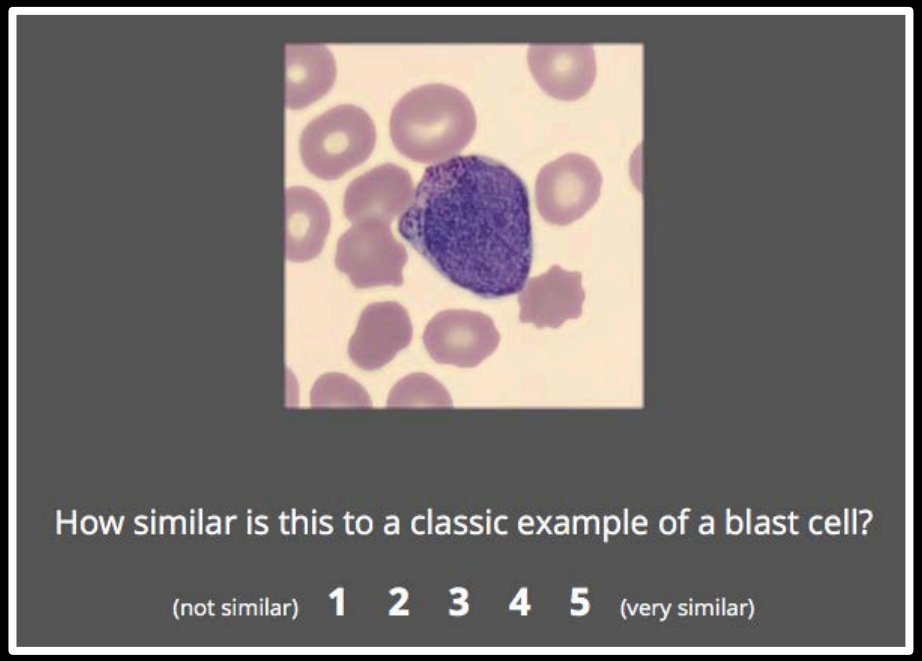
Take Home Message

- SDT results show standard prevalence effect: change in criterion and not discriminability
- CNN + DDM model distinguishes between two types of biases
  - Response bias in novices
  - Global stimulus (perceptual) bias in experts
- Prevalence can influence the perception of medical images

Thank you

Image Curation

- Ratings Panel of three hematopathology faculty from VUMC
  - Identified each image as a blast or non-blast
  - Provided a rating of difficulty



Prevalence: Experiment 1

Novice: 25/50/75% prevalence (within-subjects)

- 39 VU undergrads
- Procedure
  1. **Learning phase**: single image + label
  2. **Training phase**: select the image that matches the label
  3. **Practice phase**: 3 blocks of 48 trials at each prevalence rate (25% blast, 50% blast, 75% blast)
     - Proportion of blast / non-blast cells provided at the start of block
     - Trial-by-trial feedback
  4. **Main task:** 21 blocks of 48 trials (7 blocks at each prevalence level)
     - Proportion of blast / non-blast cells provided at the start of block
     - No feedback

Results Exp 1: Error Rates

Novice: 25/50/75% prevalence