2018-01-22 Methods & Theories

PSY 525.001 • Vision Science • 2018 Spring

Rick Gilmore

2018-01-19 12:19:59

Today's topics

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Theoretical approaches to vision

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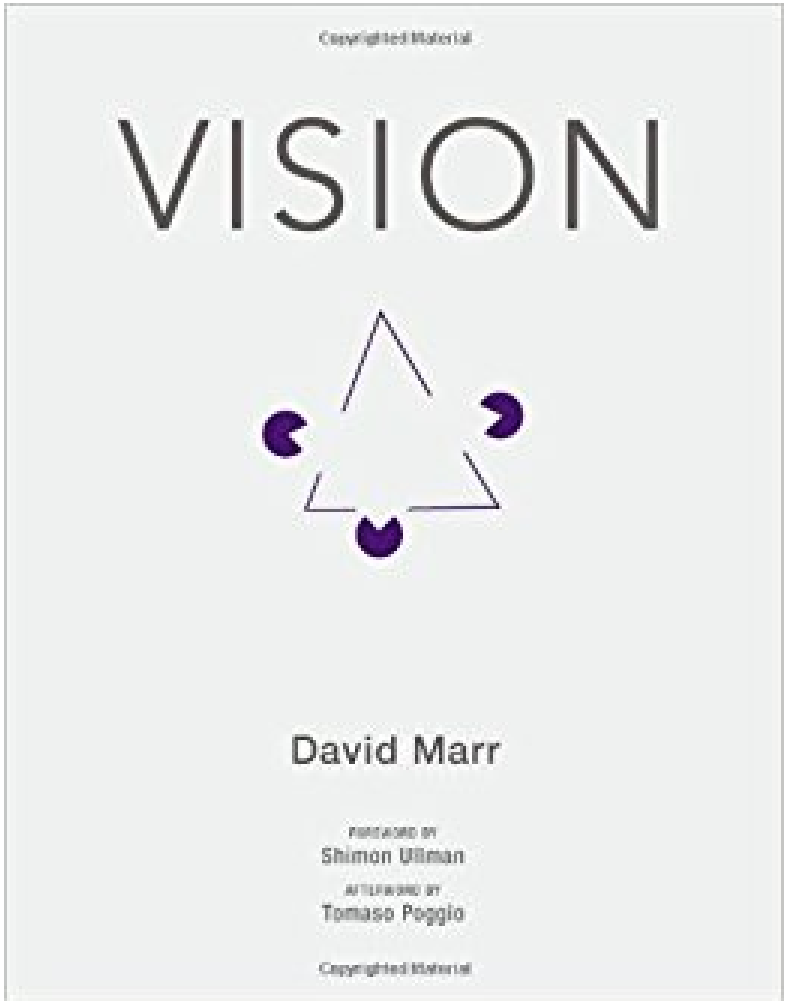
Methods in vision research

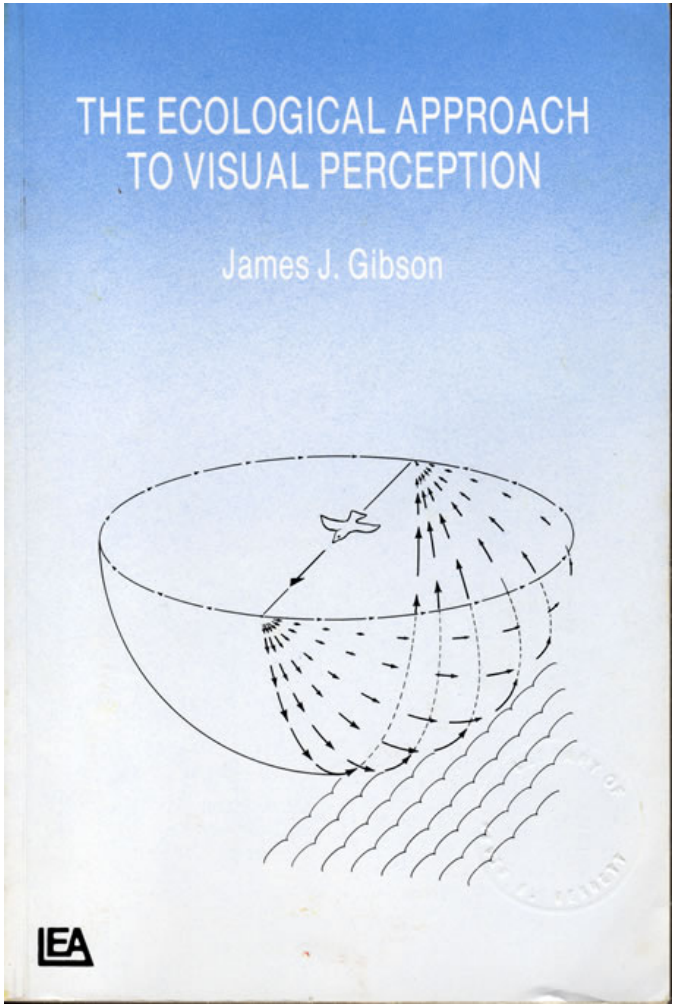
Goals

- Why vision science matters to other areas of cognition
- How vision (or perceptual methods) affect other areas of behavioral science

Seminal events



Seminal events



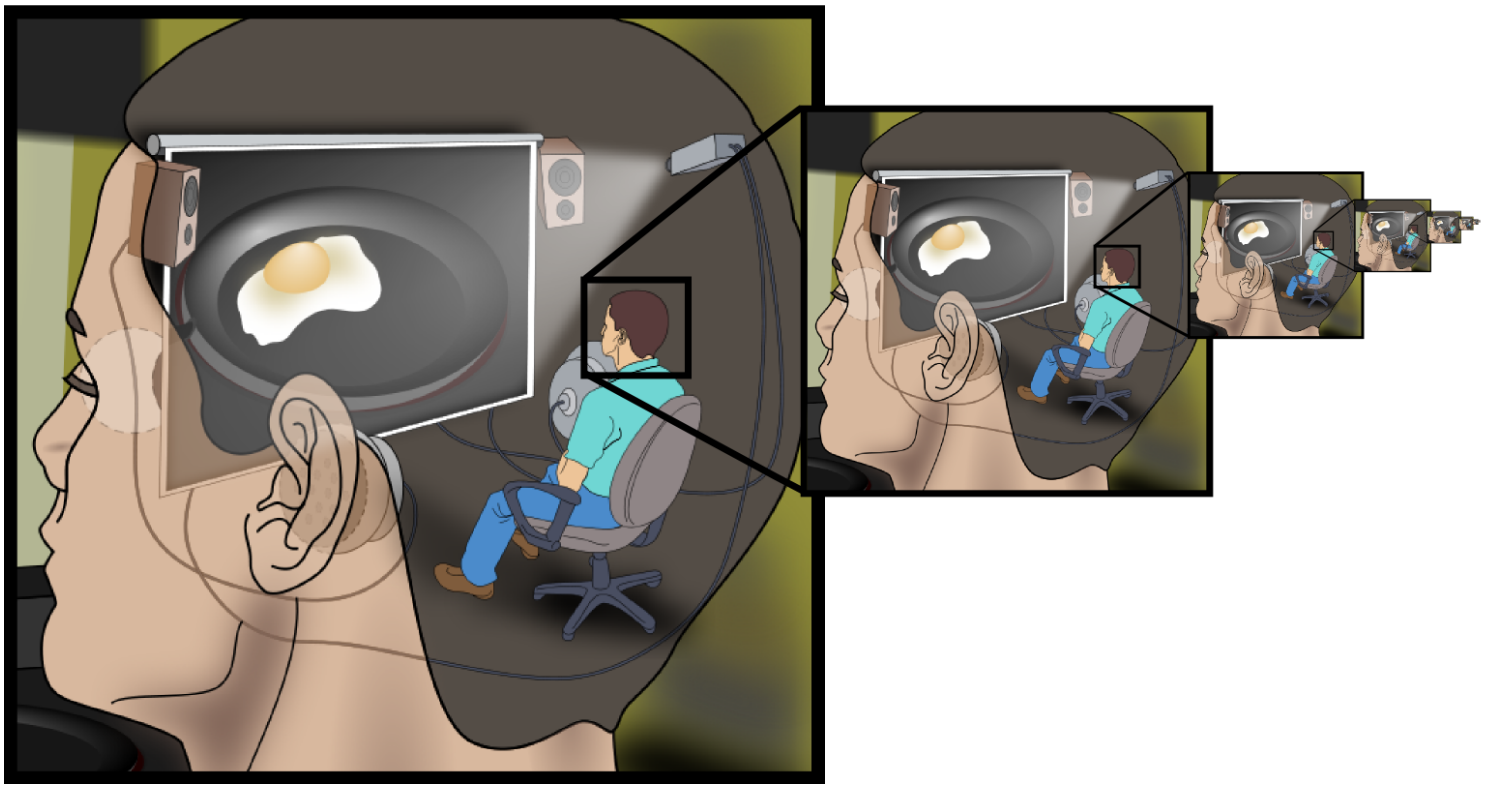
Palmer's claims

1. Perception is knowledge acquisition
2. Knowledge is about objects and events
3. Knowledge is extracted by information processing
4. Information comes from reflected, refracted, or emitted light.

Things to worry about

Or general problems that vision science keeps front and center

Homunculus problem

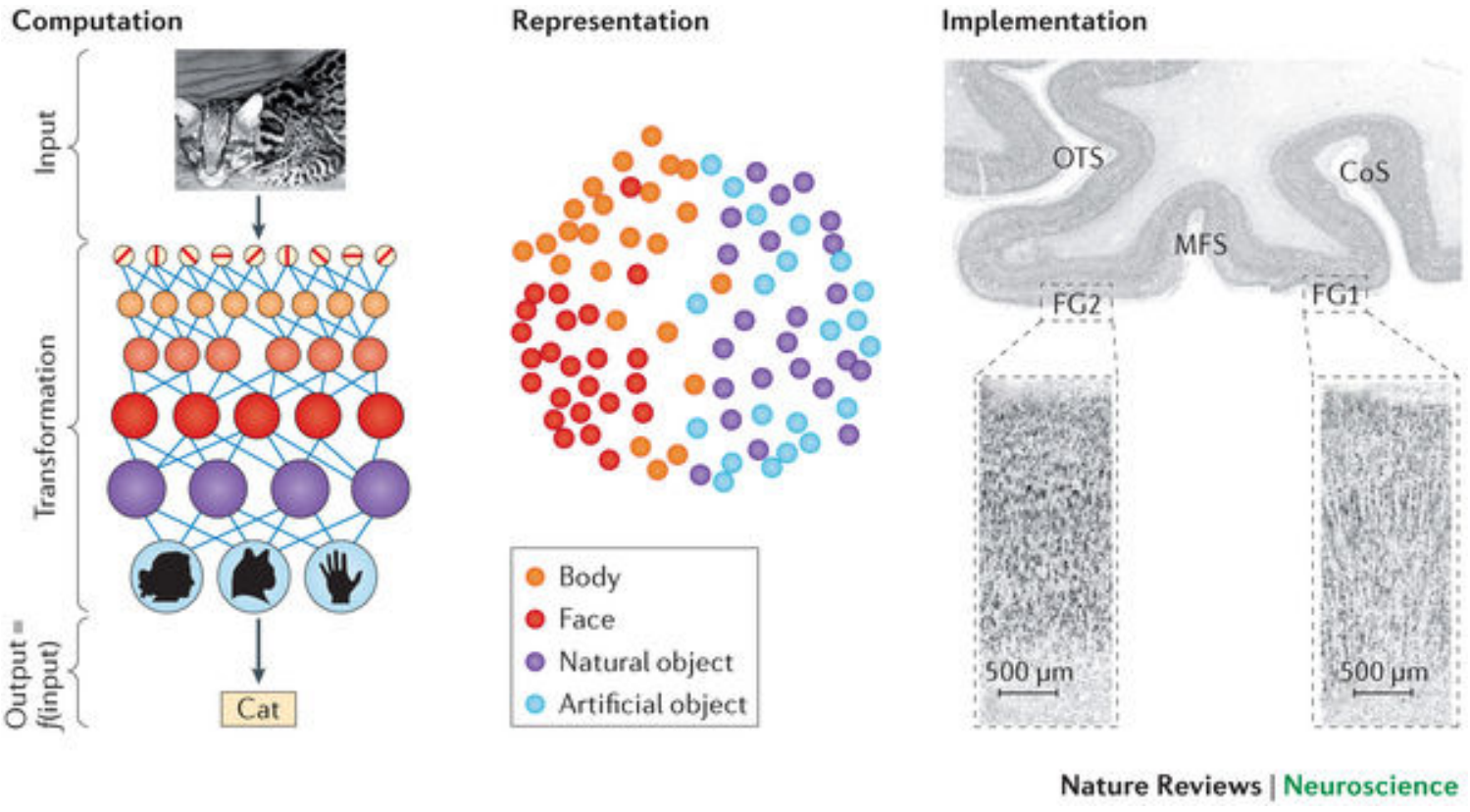


Marr's three levels

Computations

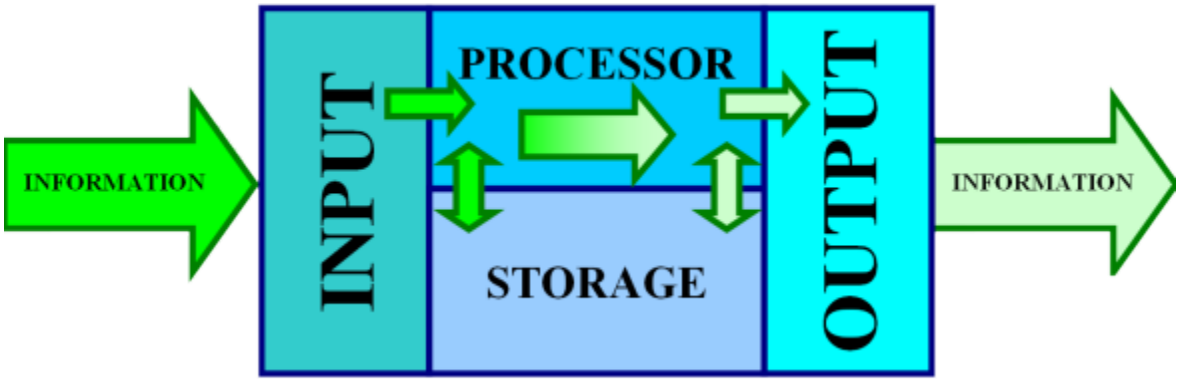
Algorithms

Implementations



(Grill-Spector et al., 2014)

What is information processing, anyway?



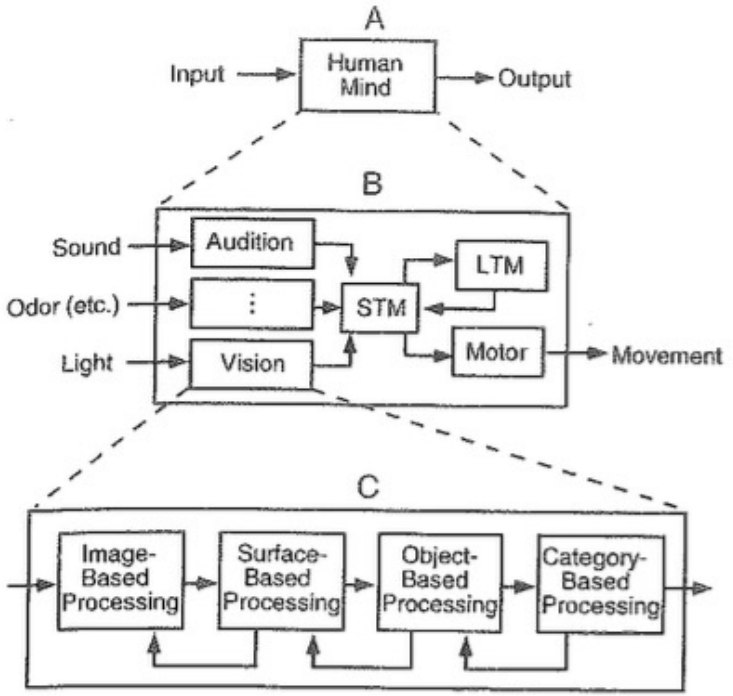


Figure 2.3.6 Recursive decomposition of human cognition. The mind can be described as an informational event at several levels of detail. Each flow diagram shows a functional decomposition of the black box above it (connected by dashed lines) into a set of simpler operations and the flow of information among them.

What is a representation of property X?

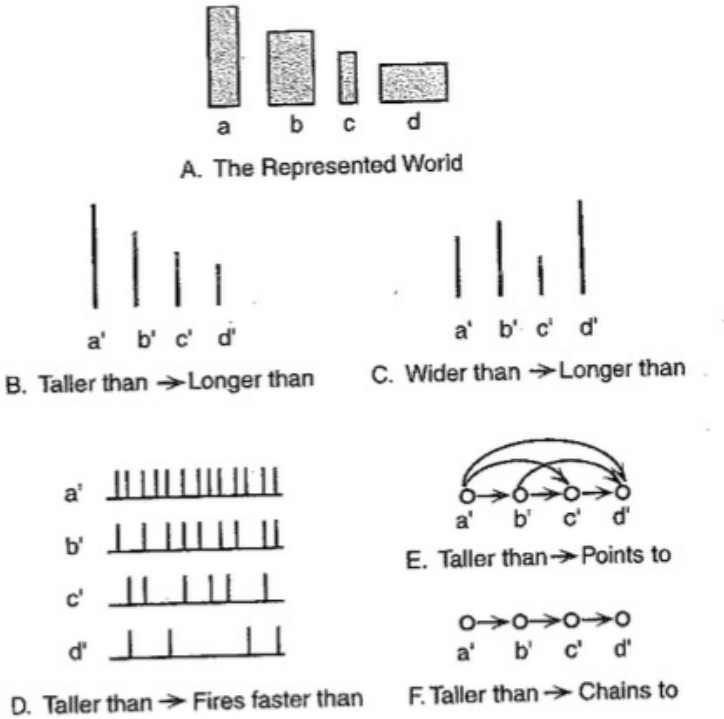
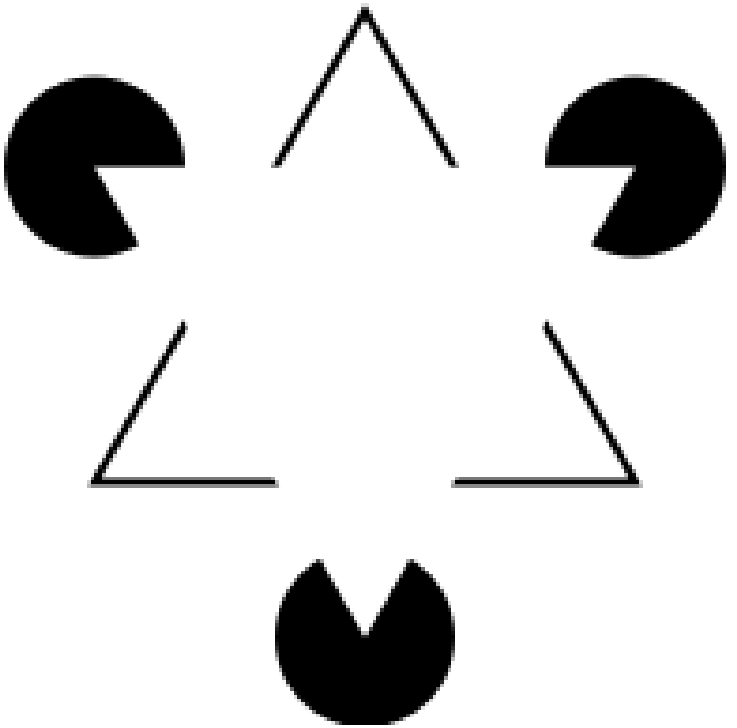


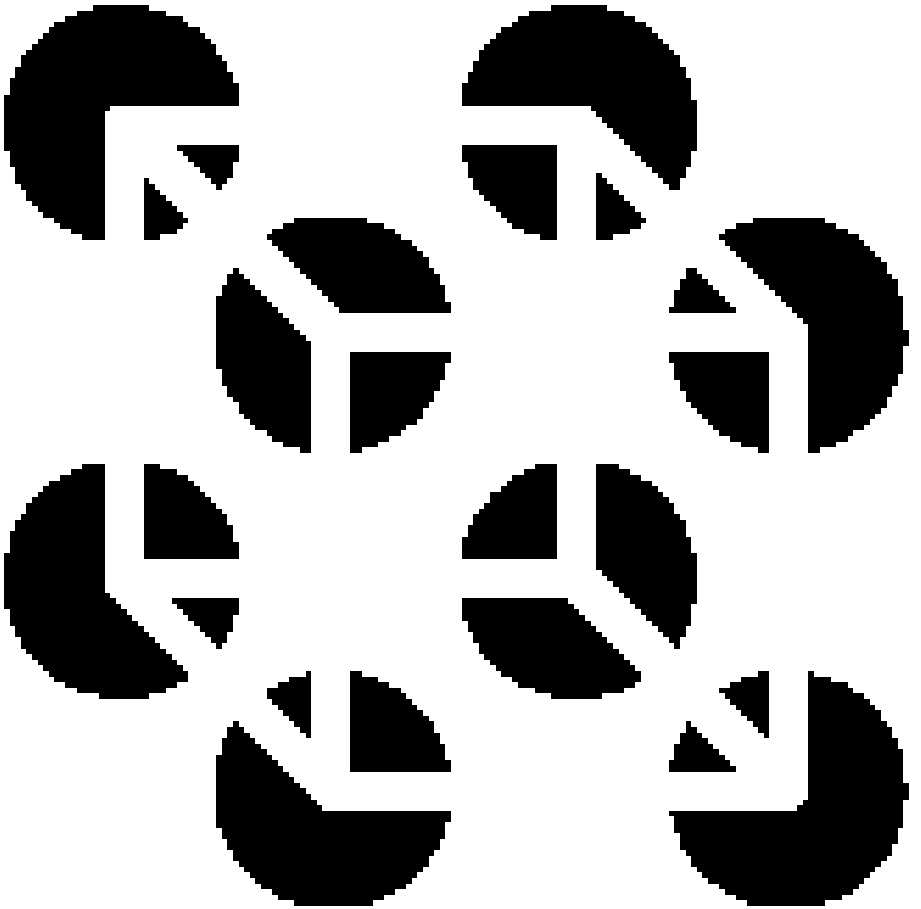
Figure 2.3.8 Examples of representational systems. Each representational system (parts B–F) represents the specified relations among properties of the rectangles in part A by different relations among the corresponding internal objects: line lengths in parts B and C, neural firing rates in part D, and network connections among nodes in parts E and F. (See text for details.)

Modeling the unseen environment

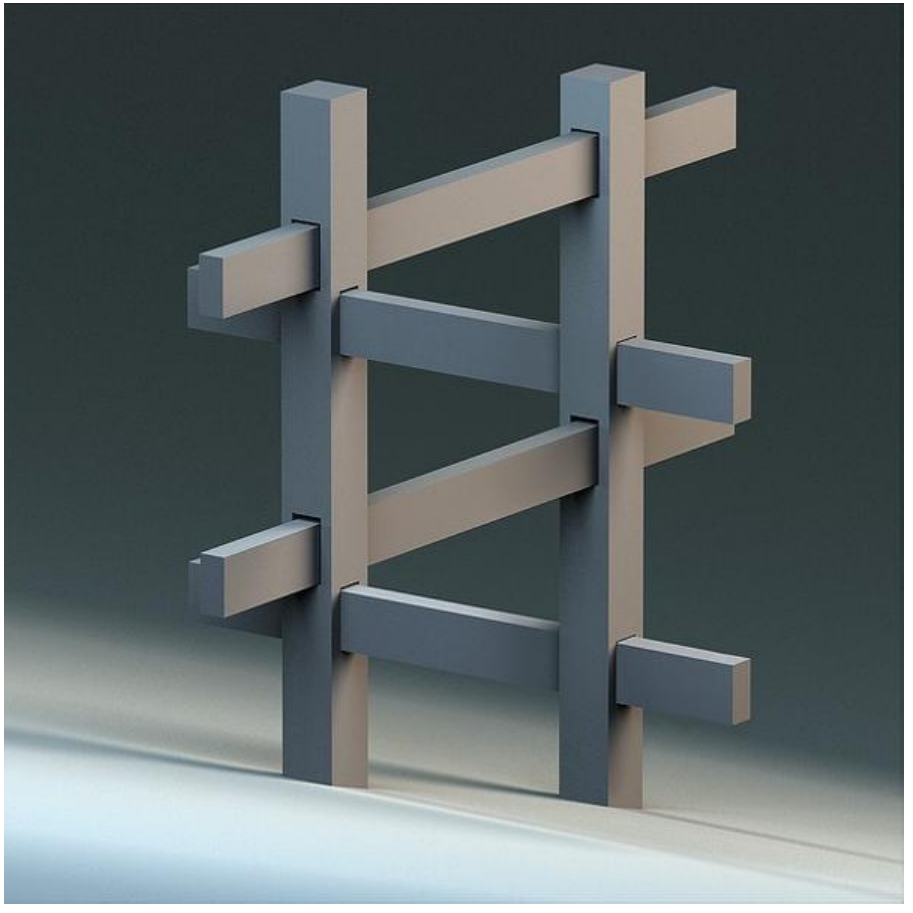


Kanisza triangle

Necker cube with illusory contours



Impossible figure



Inspired by M.C. Escher.

Bottom-up vs. top-down

What must (sighted) animals do?

What must (sighted) animals do?

Find food

What must (sighted) animals do?

Find food

Find mates

What must (sighted) animals do?

Find food

Find mates

Avoid predators

How does vision help them do these things?

How does vision help them do these things?

What is it?

How does vision help them do these things?

What is it?

Where is it located or moving?

How does vision help them do these things?

What is it?

Where is it located or moving?

How should I respond?

How does vision arise?

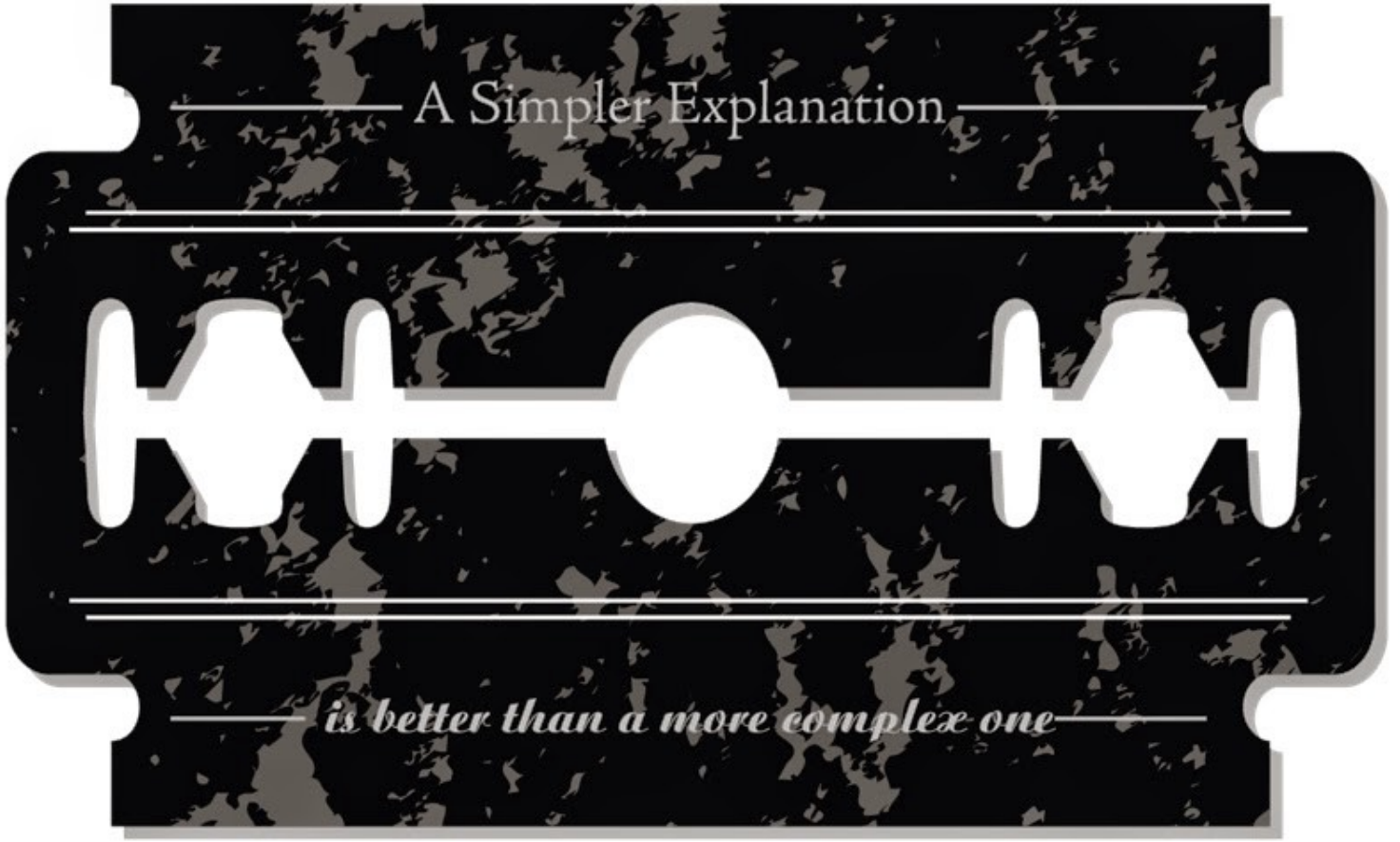
How does vision arise?

Empiricism vs. nativism

How does vision arise?

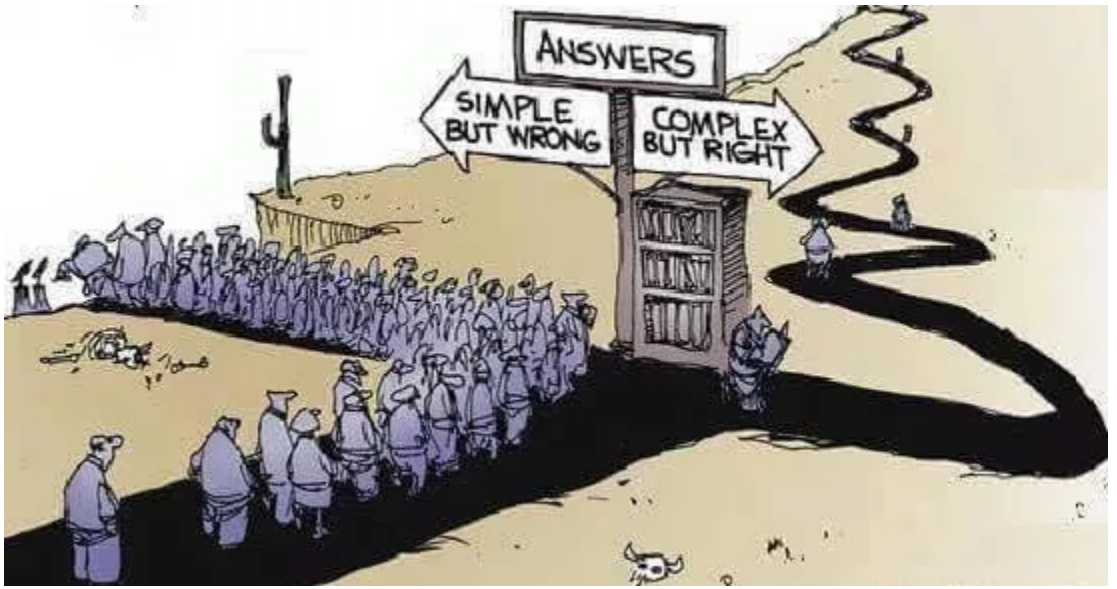
Empiricism vs. nativism

Are 'maturational' accounts nativist?



OCKHAM'S RAZOR

Are parsimonious accounts necessarily better?



Classical theories of vision

"Why do things look as they do?" (Koffka, 1935)

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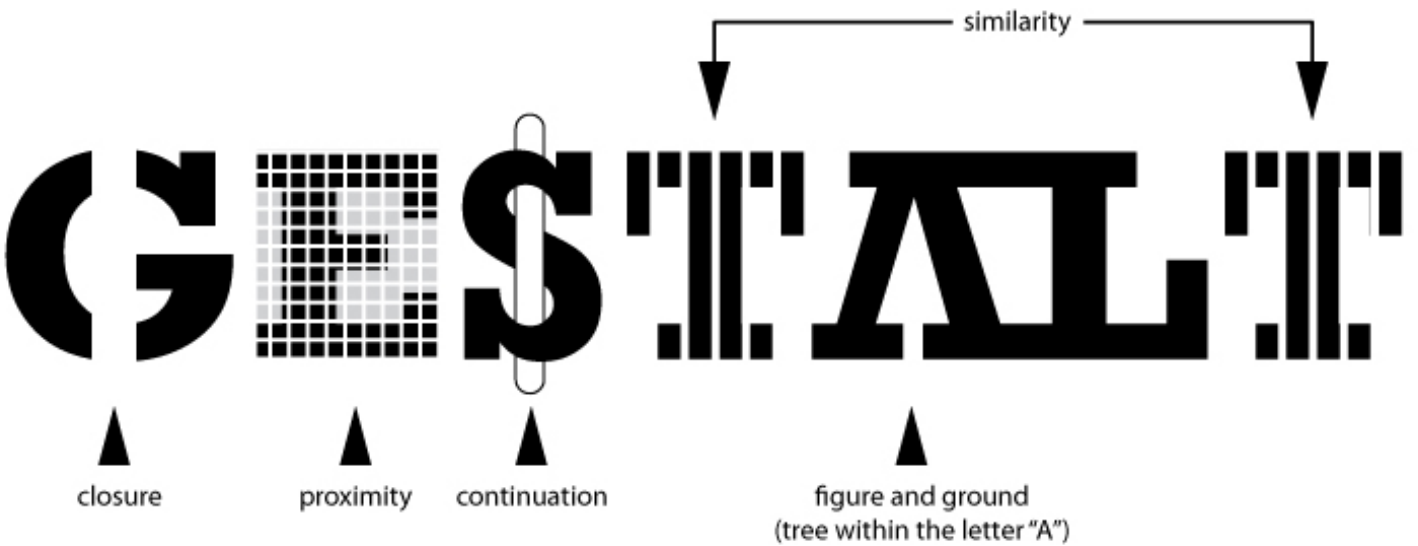
A: *Atomism vs. holism*: "Because of the way (each small piece/the whole visual field) appears."

A: *Introspection vs. behavior*: "How things *look* matters (more/less) than what we *do* with the information."

Theoretical approaches and their champions

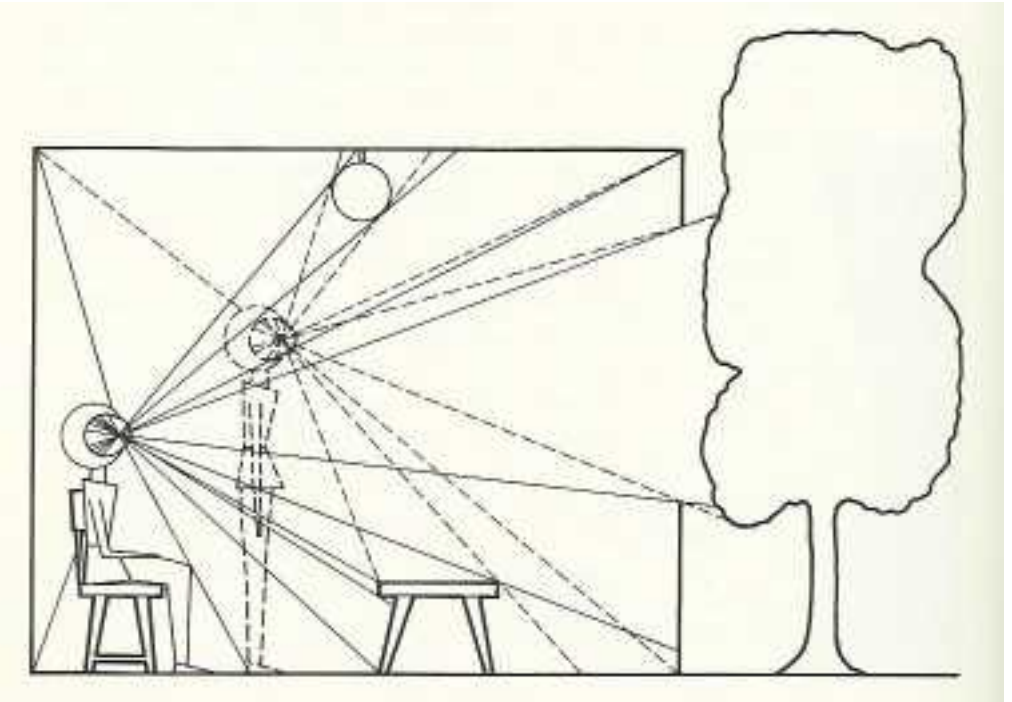
Gestaltism, Max Wertheimer



Holism, emergent properties, psychophysiological isomorphism, physical Gestalt

Theoretical approaches and their champions

Ecological optics, James J. Gibson



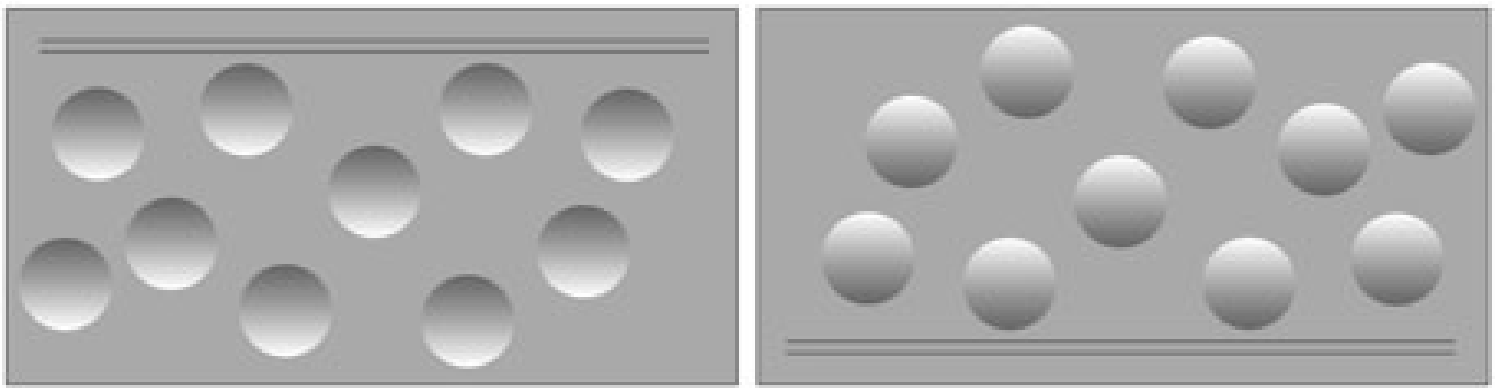
Ambient optic array, information pickup, direct perception

What is first-person visual experience actually like?

Gilmore, R.O., Raudies, F., Franchak, J. & Adolph, K. (2015). Understanding the development of motion processing by characterizing optic flow experienced by infants and their mothers. Databrary. Retrieved January 19, 2018 from http://doi.org/10.17910/B7.116

Theoretical approaches and their champions

Constructivism, Herman von Helmholtz



Unconscious inference, likelihood principle (~ Gestalt Pragnanz), heuristics

e.g., concavity vs. convexity a function of luminance + direction of illumination

A 'Helmholtzian' demonstration of 'unconscious inference'

Saccade

Move eye with finger

Why 'visual stability' in one case, not the other?

Four stages of visual perception

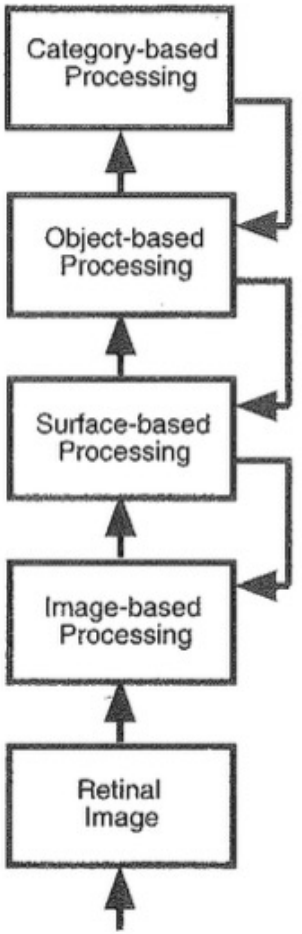
(Spatio-temporal structure of events, objects, entities in the world...)

Image-based

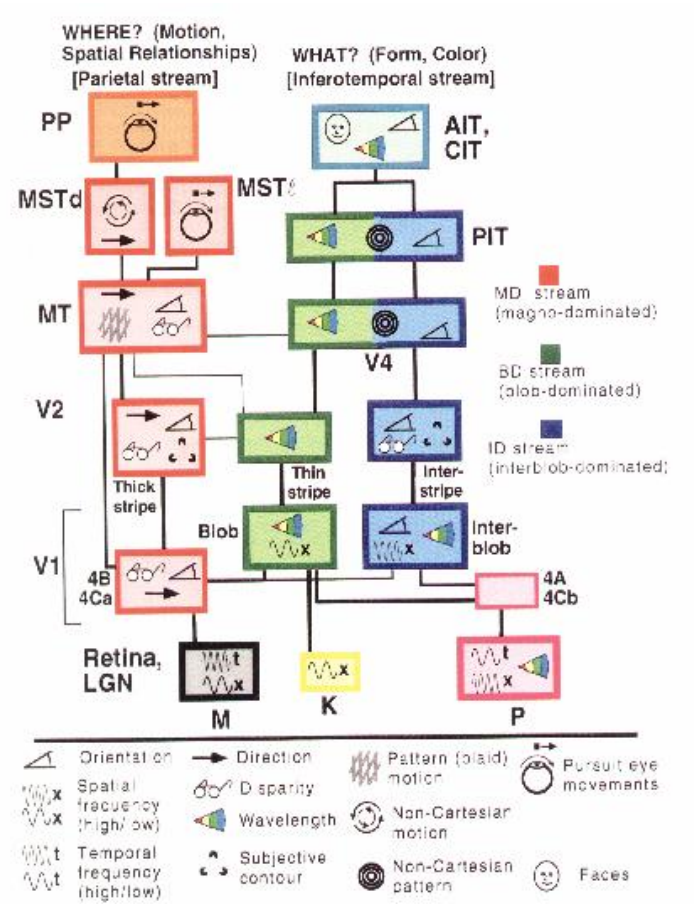
Surface-based

Object-based

Category-based


Category-based Processing
Object-based Processing
Surface-based Processing
Image-based Processing
Retinal Image

Hierarchical + parallel processing



Break time

Methods in vision research

Psychophysical methods

Measuring thresholds

Signal detection theory

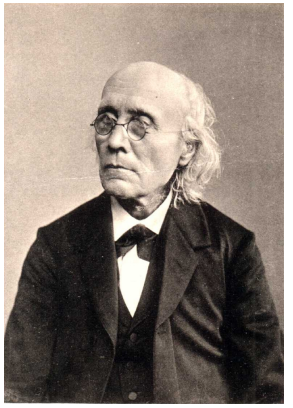
Difference thresholds

Psychophysical scaling


“Can you hear me now?”
verizon

Measuring (absolute/detection) thresholds

Gustav Fechner's (1860) methods



Method of adjustment

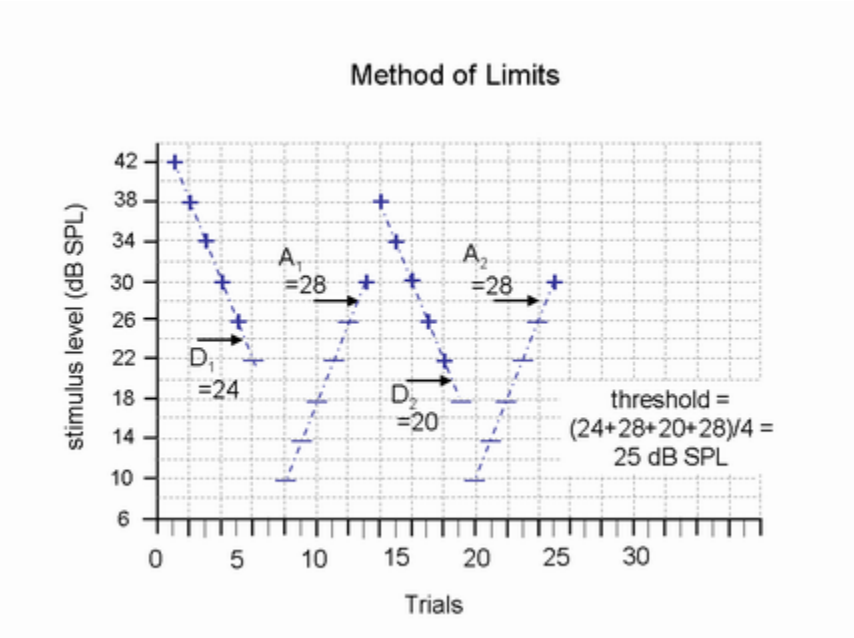
Method of limits

Method of constant stimuli (constants)

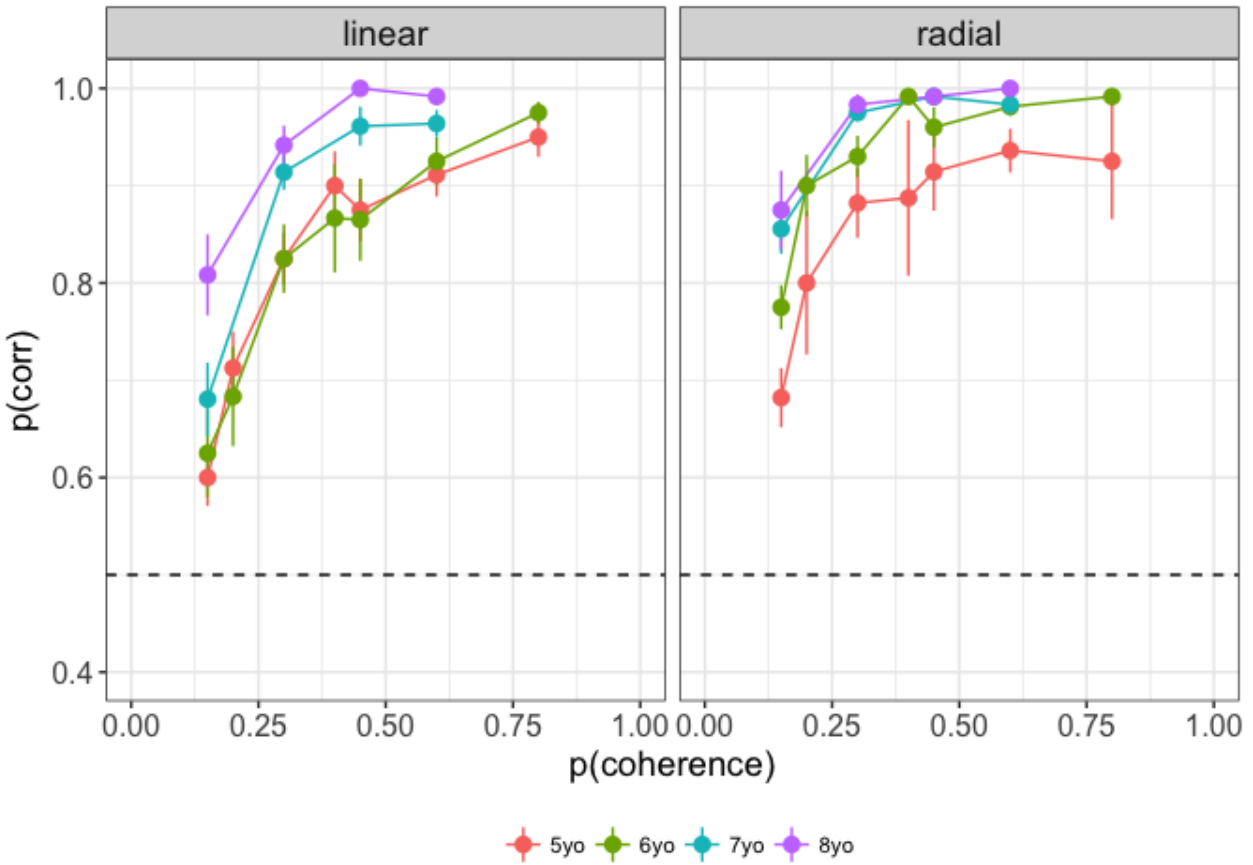
Method of adjustment

Method of limits

Psychophysical staircases a kind of method of limits



Method of constants



Your turn

Pros and cons of method of adjustment?

Pros and cons of method of limits?

Pros and cons of method of constants?

Psychometric functions

Fitting psychometric functions is goal of psychophysical methods.

Relates percent (proportion) detections vs. magnitude of some perceptual variable (brightness, contrast, motion speed, direction, etc...)

Psychometric functions

Usually on $[0, 100]$ or $[0, 1]$ scale.

Often curvlinear, monotonic (increasing) functions of stimulus intensity

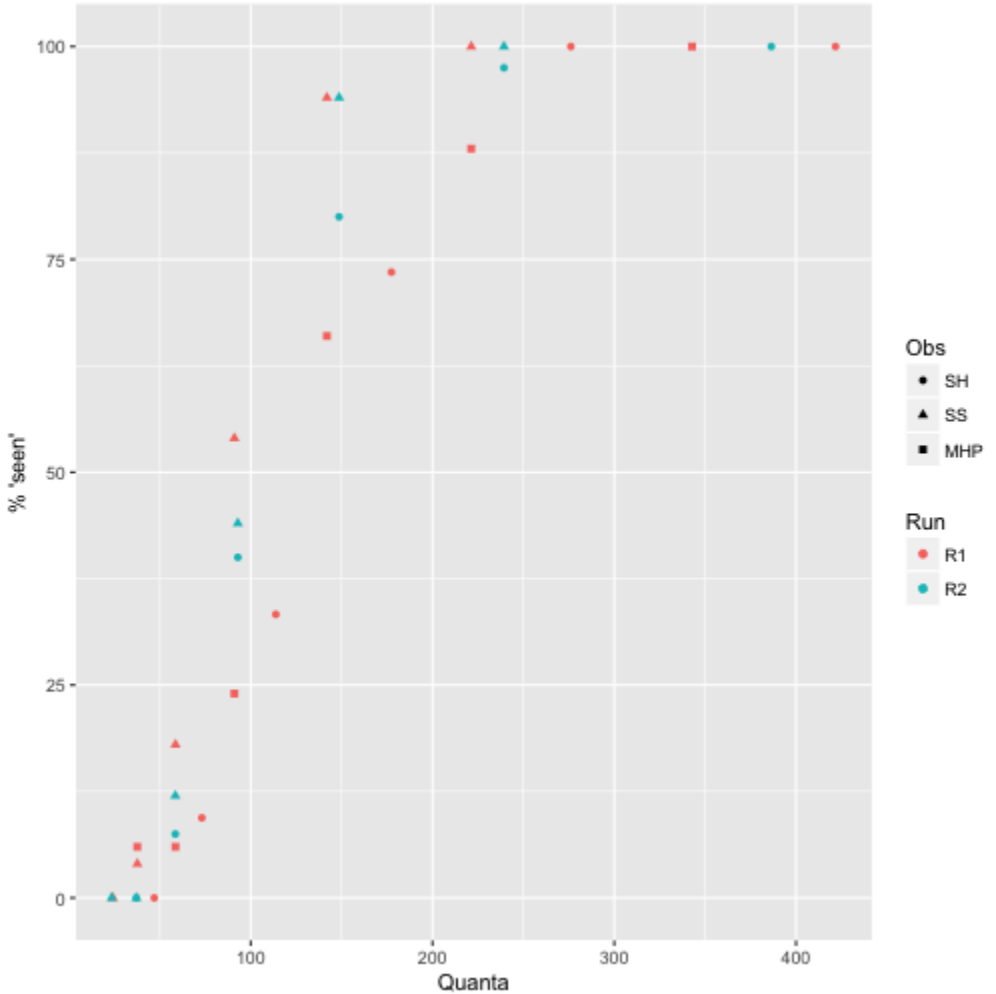
$$P(respond) = f(stimulus, observer, situation, \dots)$$

Analysis often focuses on *threshold* responses: detect (yes/no) or discriminate (same/different)

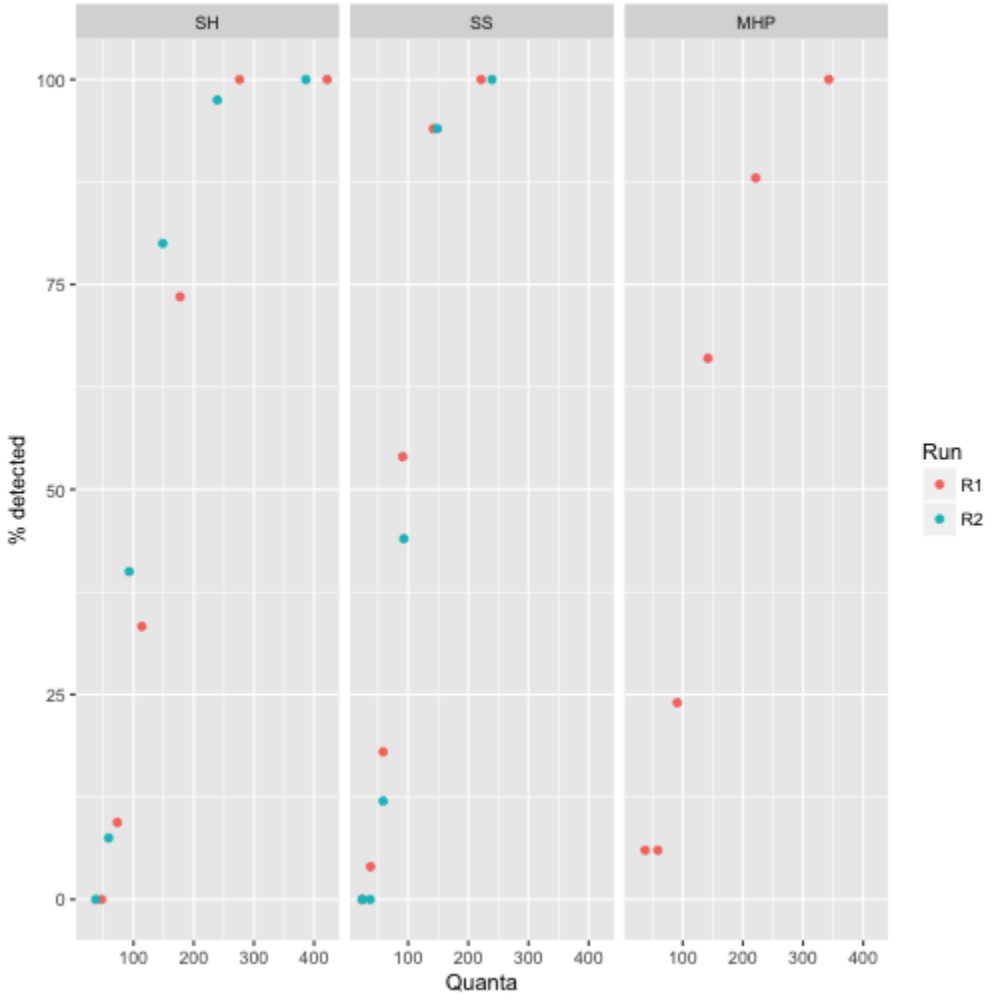
Hecht et al. experiment

Hecht, S., Shlaer, S., & Pirenne, M. H. (1942). Energy, Quanta, and vision. *The Journal of General Physiology*, *25*(6), 819–840. jgp.rupress.org. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/19873316

What is the minimum quantity of light that can be reliably detected by human observers?



Knoblauch, K., & Maloney, L. T. (2012). *Modeling Psychophysical Data in R*. Springer Science & Business Media. Chapter 1.



Knoblauch, K., & Maloney, L. T. (2012). *Modeling Psychophysical Data in R*. Springer Science & Business Media. Chapter 1.

How to model these data?

```
str(HSP)
```

```
## 'data.frame':    30 obs. of  5 variables:
##  $ Q  : num  46.9 73.1 113.8 177.4 276.1 ...
##  $ p  : num  0 9.4 33.3 73.5 100 100 0 7.5 40 80 ...
##  $ N  : int  35 35 35 35 35 35 40 40 40 40 ...
##  $ Obs: Factor w/ 3 levels "SH","SS","MHP": 1 1 1 1 1 1 1 1 1 1 ...
##  $ Run: Factor w/ 2 levels "R1","R2": 1 1 1 1 1 1 2 2 2 2 ...
```

- Predictors (independent variables, IVs)
  - Quanta (Q), Number replications (N), Run, Observer (Obs)
- Responses (dependent variables, DVs)
  - % seen (p)
- *Notice*: Quanta are log-distributed

One approach

$$P[yes] = \Phi(\frac{Q - Q_{0.5}}{\sigma})$$

where $Q_{0.5}$ is the # of quanta that yields 50% responding, and σ determines the 'slope' of the function.

The cumulative normal (Gaussian) distribution is one type of function Φ that has the 'S' shape we want. There are others.

With a bit of algebra, we can "linearize" this into a familiar form

$$\Phi^{-1}(E[R]) = \frac{Q - Q_{0.5}}{\sigma} = \beta_0 + \beta_1 Q$$

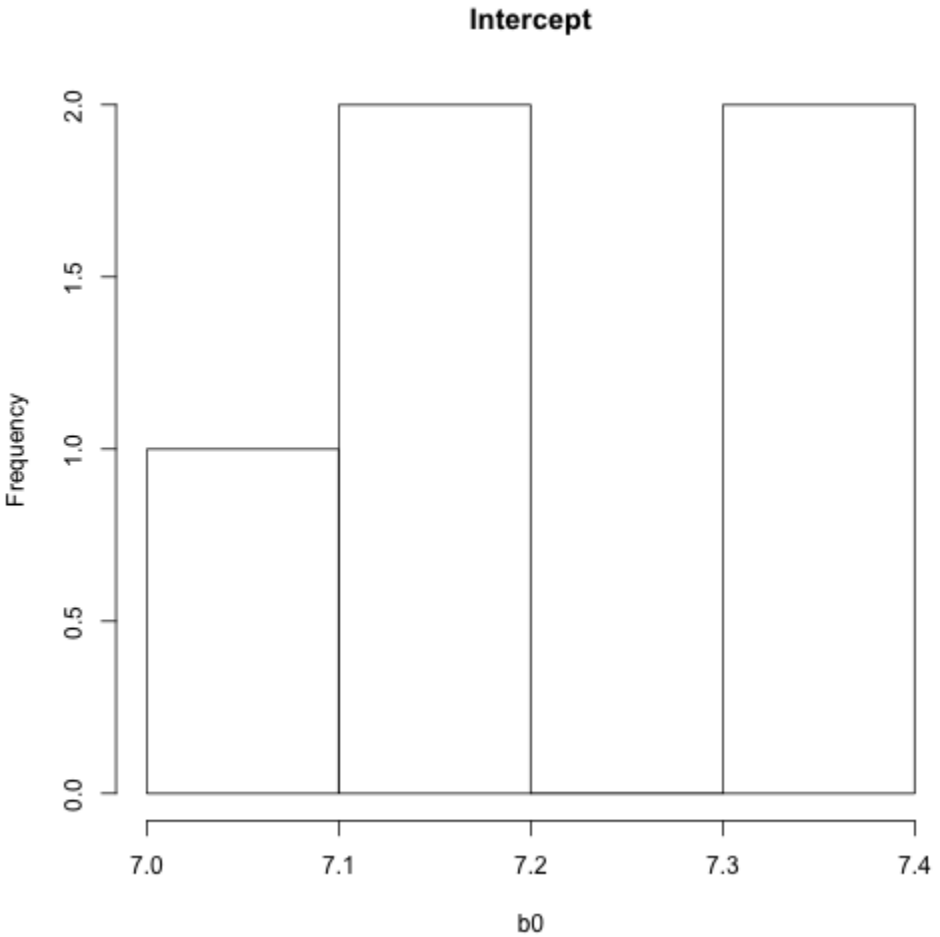
where the $E[R]$ are (0,1) responses, $B_0 = -Q_{0.5}/\sigma$ and $B_1 = \sigma^{-1}$.

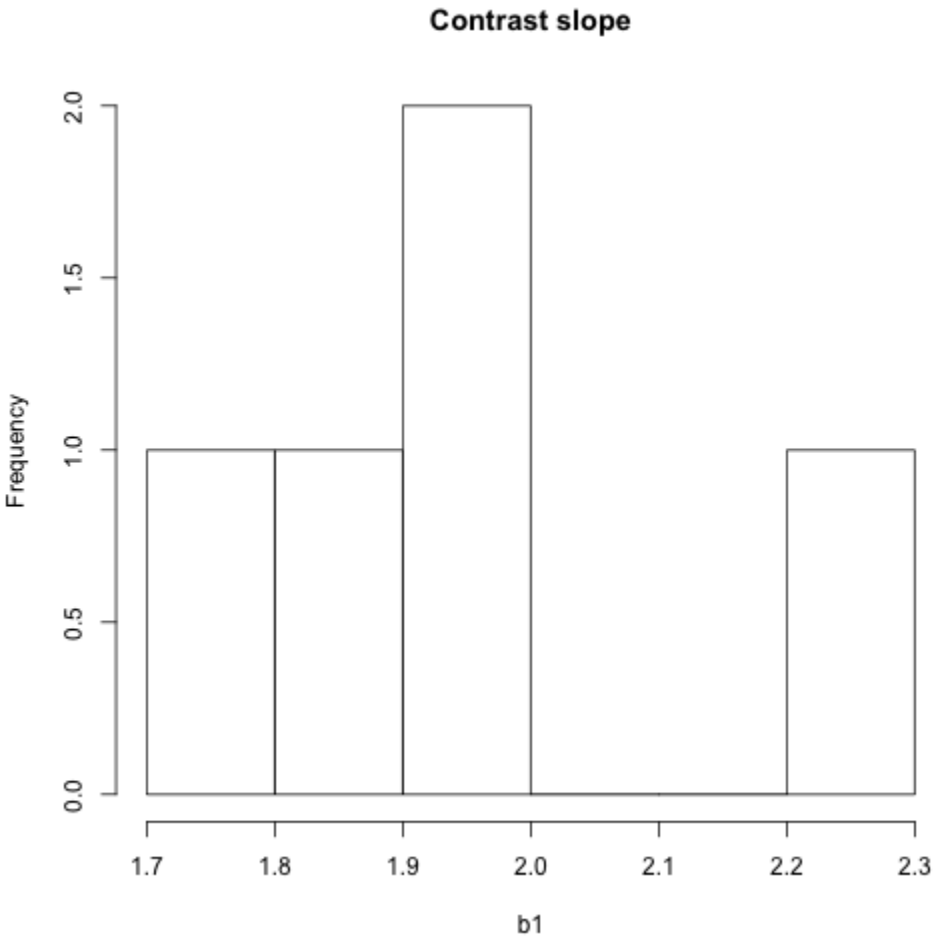
Knoblauch, K., & Maloney, L. T. (2012). *Modeling Psychophysical Data in R*. Springer Science & Business Media. Chapter 1.

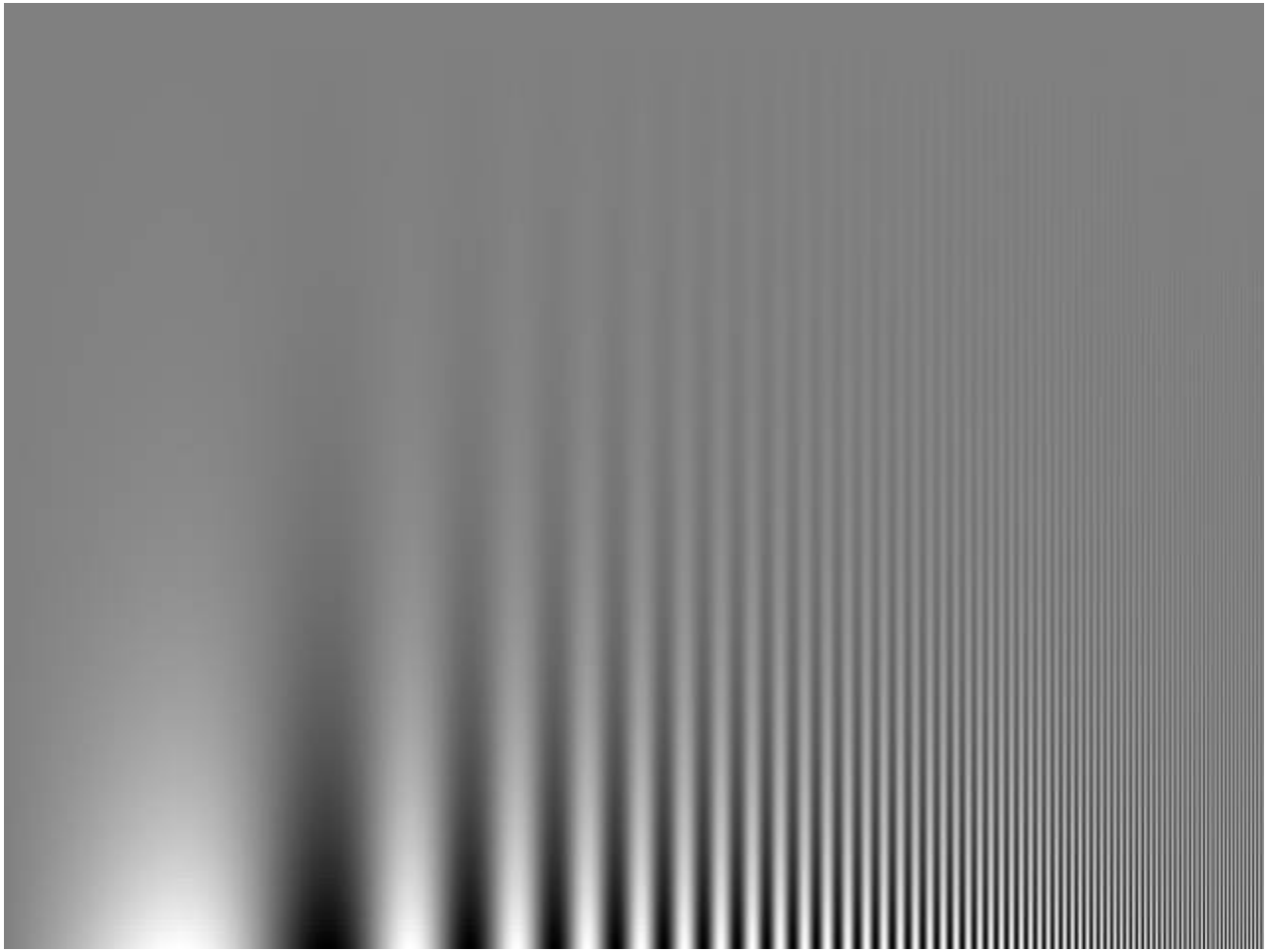
Another approach

Example adapted from https://tomwallis.info/2014/05/06/simulating-data/

$$p(respond) = \beta_0 + \beta_1 log(contrast) + spatialfreq$$


Intercept
Frequency
0.0
0.5
1.0
1.5
2.0
7.0
7.1
7.2
7.3
7.4
b0


Contrast slope
Frequency
0.0
0.5
1.0
1.5
2.0
1.7
1.8
1.9
2.0
2.1
2.2
2.3
b1



Sensitivity increases with increasing contrast, and there are different "baseline" levels that vary by spatial frequency (peak in middle).

Psychophysical functions

What is the best *statistical* model of the decision process?

Logit, probit, Weibull distributions commonly used

Same issues apply here as with GLMs in other contexts (fixed vs. random effects; variables nominal/ordinal/interval/continuous; goodness-of-fit; etc.)

Your turn

Pros and cons of estimating psychophysical functions?

Prerequisites for estimating psychophysical functions?

Utility of fitting behavioral functions?

Signal detection theory

	Signal present	**Signal absent**
Respond Yes	Hit	False Alarm
Respond No	Miss	Correct rejection

$$p(Hit) + p(Miss) = 1, p(FalseAlarm) + p(CorrectRejection) = 1$$

Type I Error

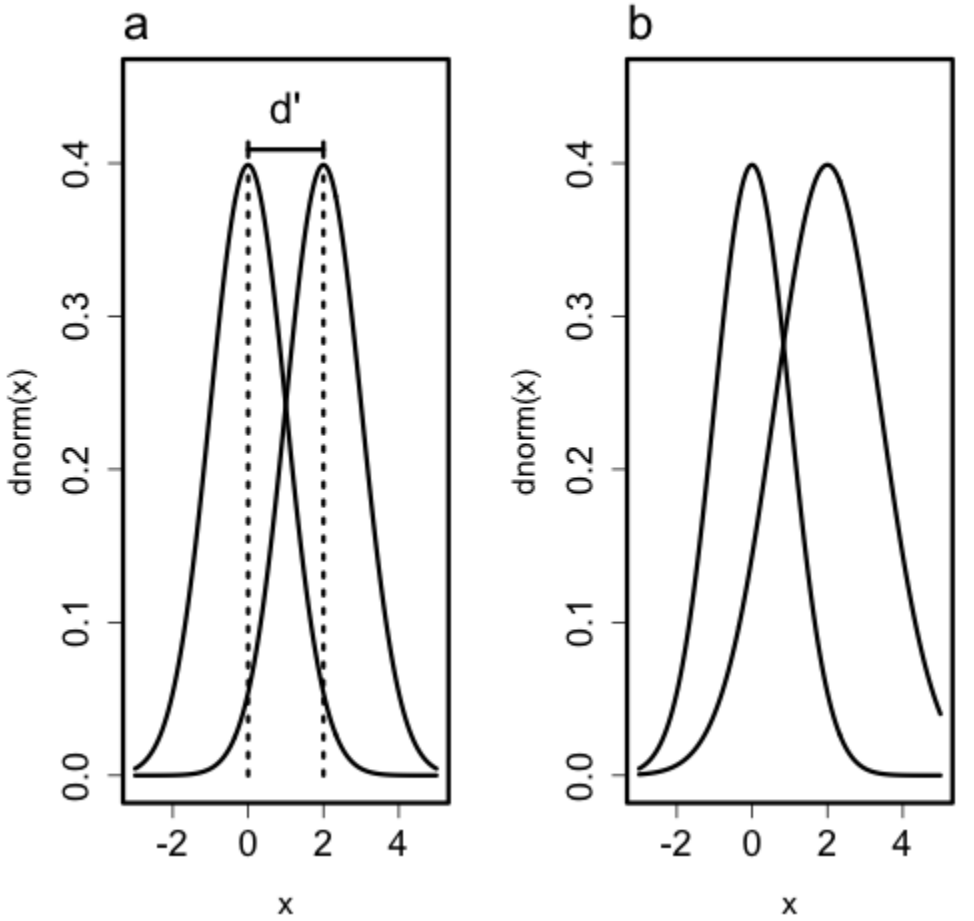
Type II Error

Goal: Minimize both (== maximize Hits & Correct Rejections)!

Similar logic applies in medicine

		Patients with bowel cancer (as confirmed on endoscopy)		
		Condition Positive	Condition Negative	
Fecal Occult Blood Screen Test Outcome	Test Outcome Positive	**True Positive** (TP) = 20	**False Positive** (FP) = 180	**Positive predictive value** = TP / (TP + FP) = 20 / (20 + 180) = **10%**
	Test Outcome Negative	**False Negative** (FN) = 10	**True Negative** (TN) = 1820	Negative predictive value = TN / (FN + TN) = 1820 / (10 + 1820) ≈ **99.5%**
		Sensitivity = TP / (TP + FN) = 20 / (20 + 10) ≈ **67%**	Specificity = TN / (FP + TN) = 1820 / (180 + 1820) = **91%**	

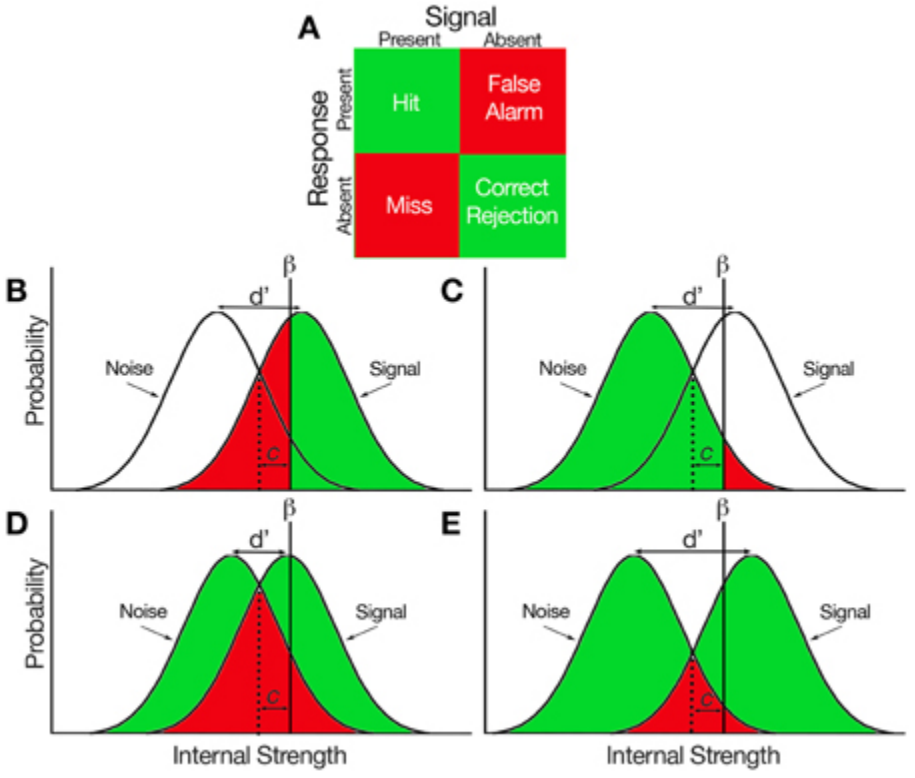
High *sensitivity* and *specificity* desired.



Knoblauch, K., & Maloney, L. T. (2012). *Modeling Psychophysical Data in R*. Springer Science & Business Media. Chapter 3, p. 65.

Gaussian SDT

- "Noise" distribution, "Signal" distribution offset by d'; variances of signal and noise distribution equal (or not)
- Q: Given internal signal strength d' and signal X_i, what decision rule maximizes $p(corr)$?
    - A: Observer sets a criterion ($/beta$) & responds "yes" when $X_i>= \beta$ it
    - A: Observer may have a 'bias' that shifts the criterion



Anderson, N. D. (2015). Teaching signal detection theory with pseudoscience. *Frontiers in Psychology*, *6*, 762. Retrieved from http://dx.doi.org/10.3389/fpsyg.2015.00762

(A) Response matrix of all signal-response combinations that can be made in a binary decision task. Green indicates correct decision, red indicates incorrect decision. (B) Proportions of hits and misses represented under the signal distribution. β reflects the subject criterion, c reflects bias, and d' reflects sensitivity which represents the difference in position between the two distributions. (C) Proportions of false alarms and correct rejections represented under the noise distributions. (D) A condition which hypothetically reflects low subject sensitivity. When the distributions are closer together (i.e., d' is smaller), the difference between the proportion of hits and false alarms is lower. (E) A condition which reflects high subject sensitivity. When the distributions are farther apart (i.e., d' is larger), the difference between the proportion of hits and false alarms is higher.

Anderson, N. D. (2015). Teaching signal detection theory with pseudoscience. *Frontiers in Psychology*, *6*, 762. Retrieved from http://dx.doi.org/10.3389/fpsyg.2015.00762

SDT in your (frequentist, traditional, null hypothesis significance testing) psychological life

	Effect ≠ 0	**Effect ~= 0**
Reject H_0	Hit	False Alarm
Don't reject H_0	Miss	Correct rejection

Maximizing correct decisions means minimizing *False Alarms* (small α; aka Type I errors)

AND

minimizing *Misses* (small β, aka Type II errors) or maximizing 'power' (1- β) or *Hits*.

Mentioning in passing...

Receiver Operating Characteristic (ROC) curves

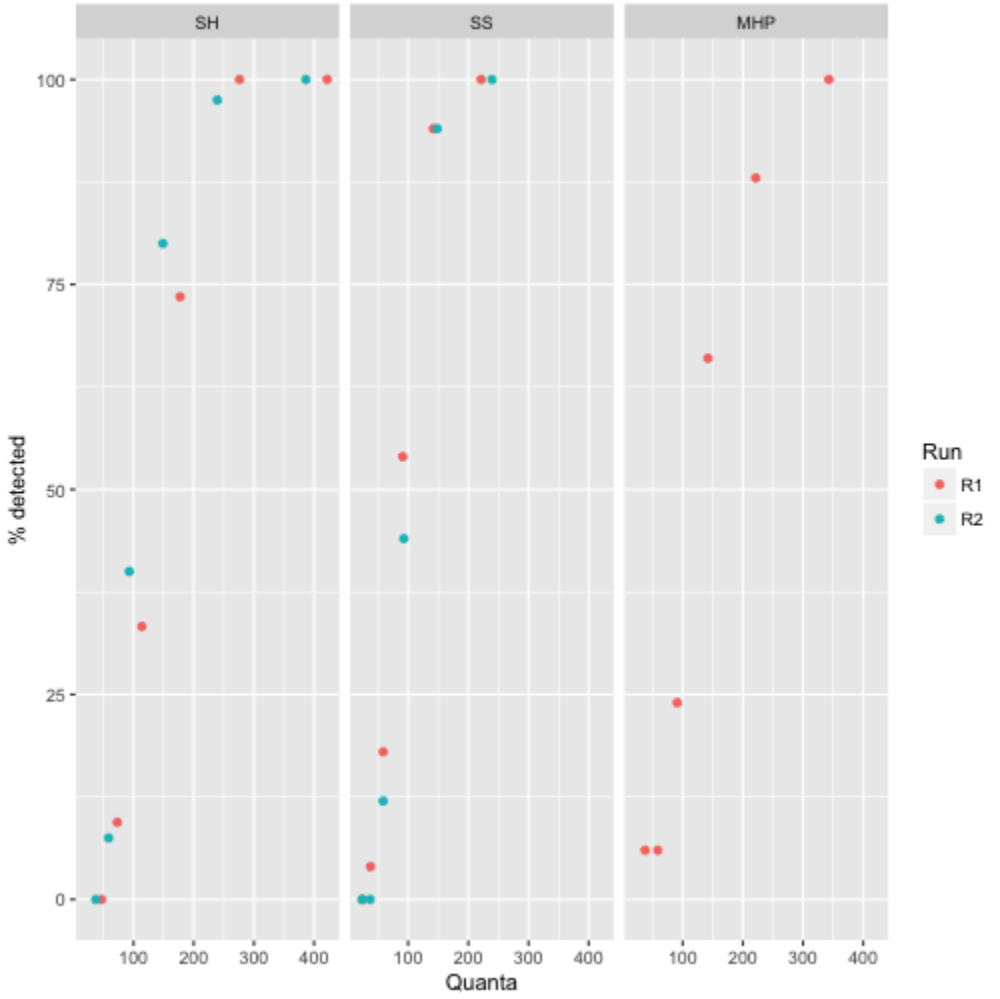
Your turn

Why might an observer choose a liberal decision criterion? A conservative one?

How realistic is the assumption that the 'noise' and 'signal' distributions have the same σ? What can experimenters realistically manipulate or measure?

Does the link between SDT, perceptual research, medical diagnosis, and NHST reasoning make sense?

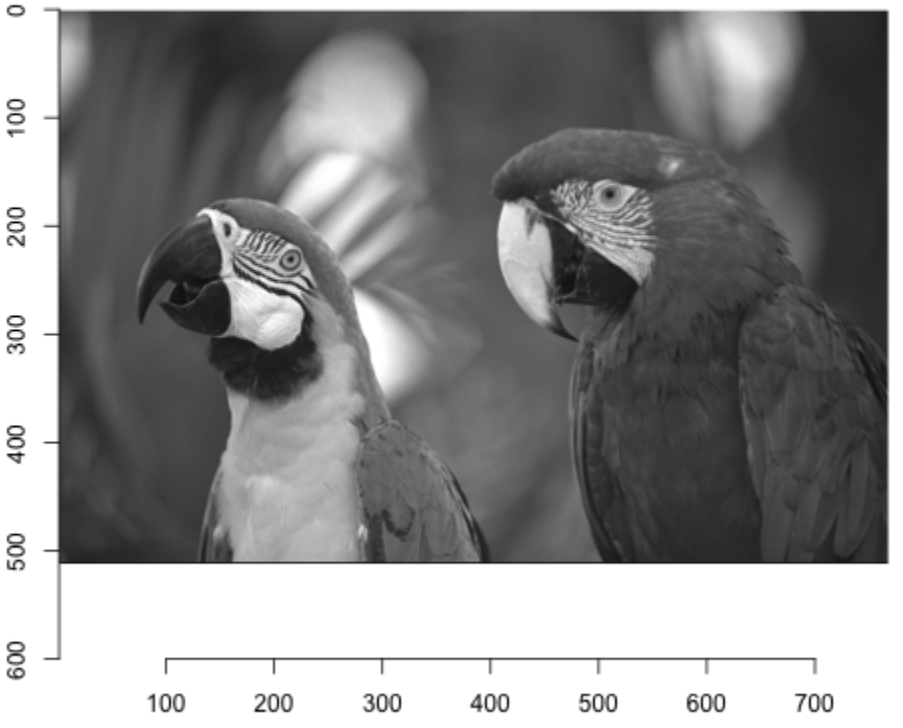
Absolute thresholds



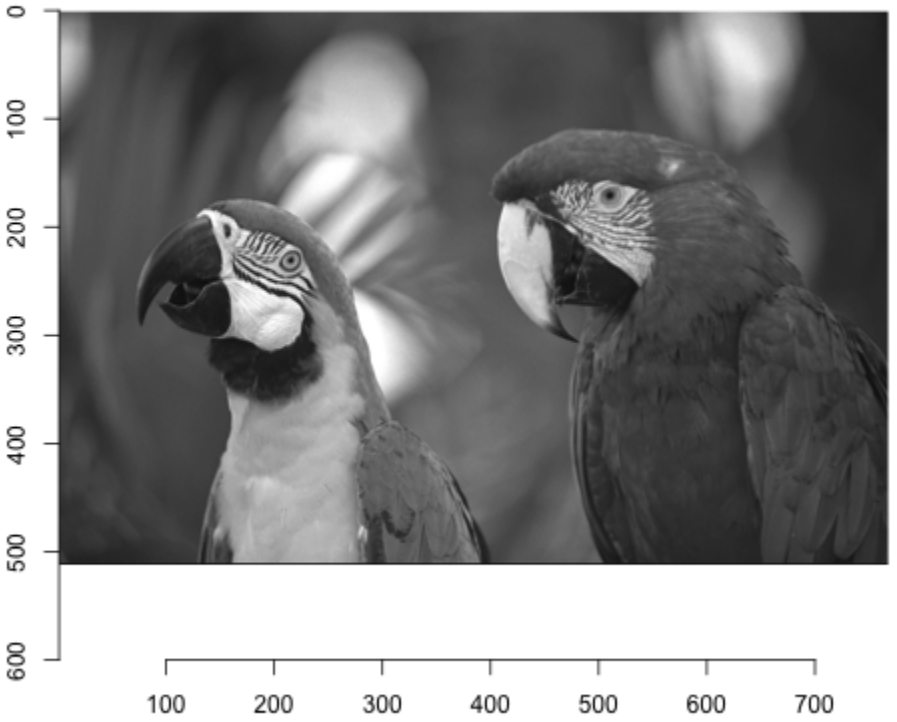
vs. Difference thresholds

```
parrots <- load.image(system.file('extdata/parrots.png',package='imag
                              plot(parrots)
```

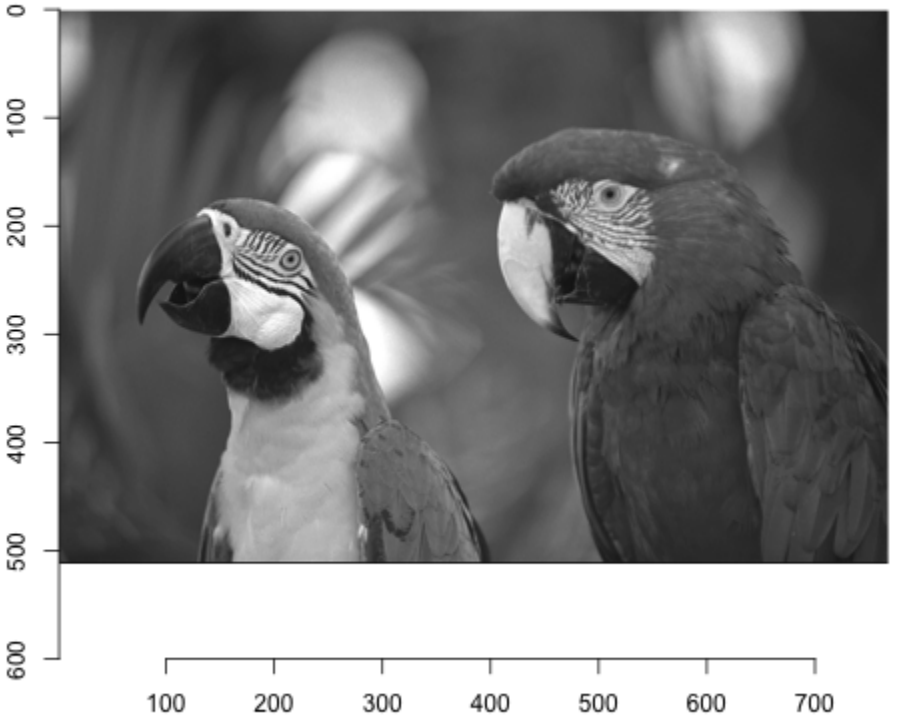
Standard



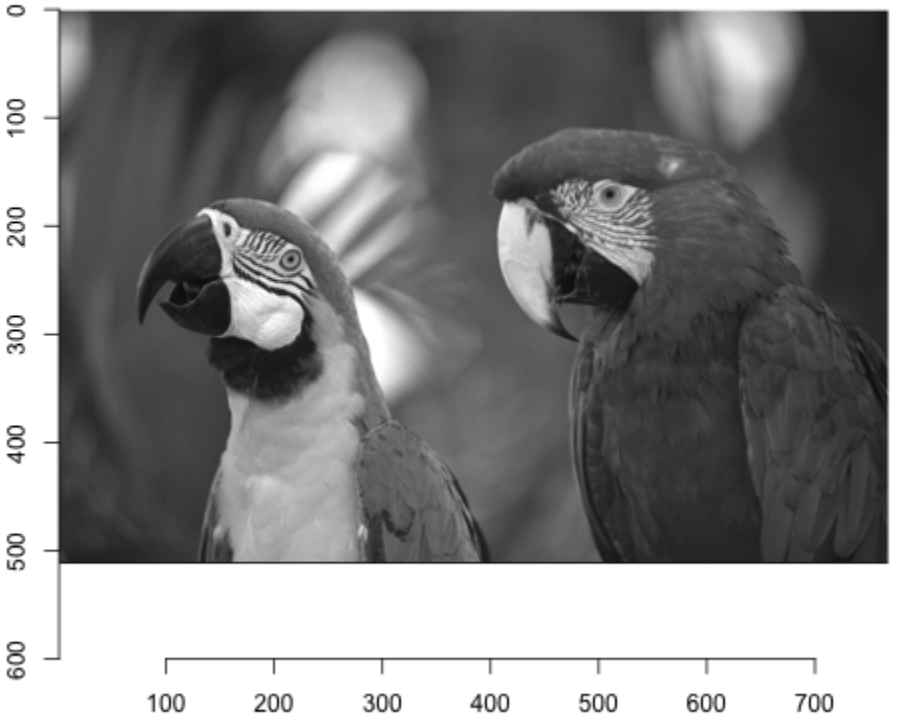
Test



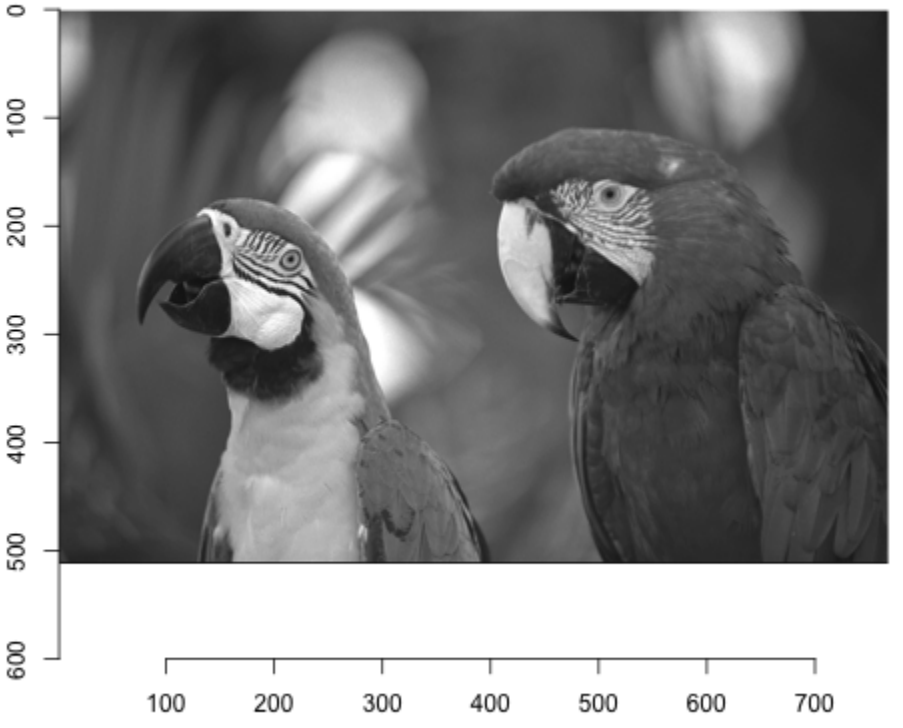
Standard



Test



Standard



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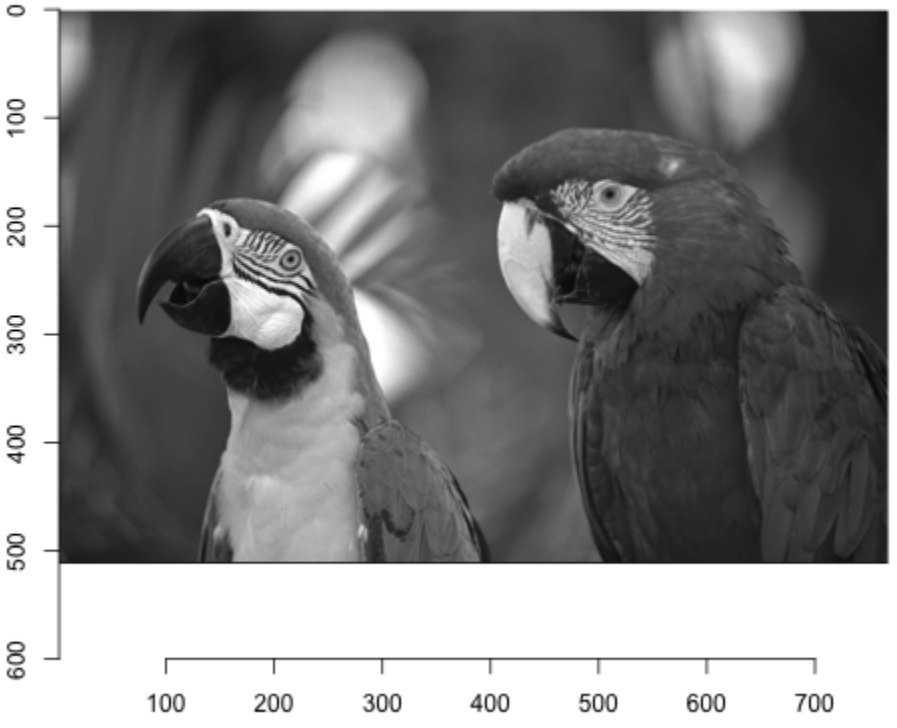
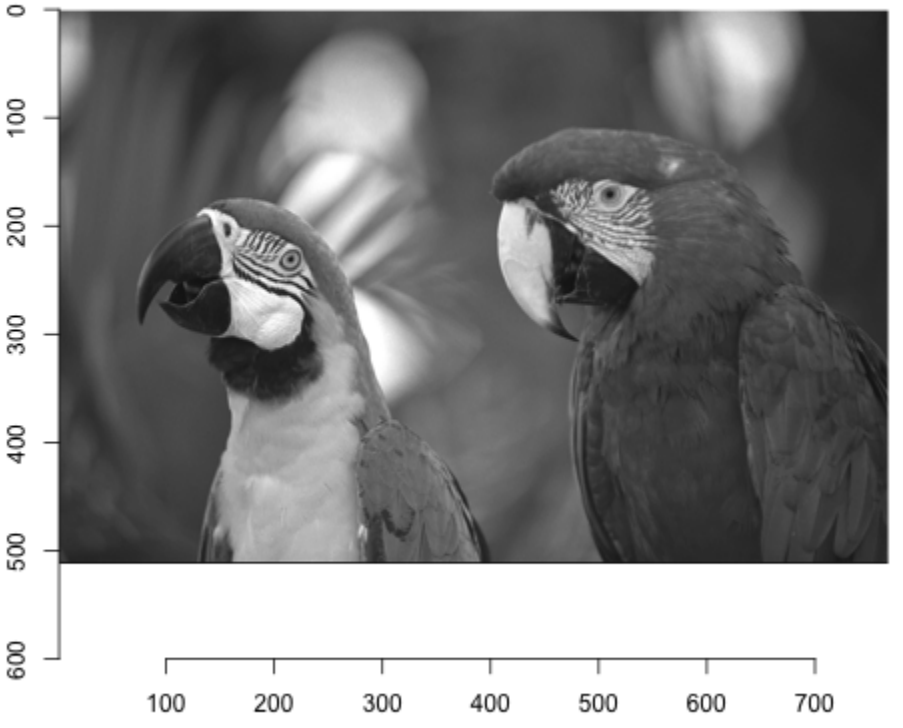
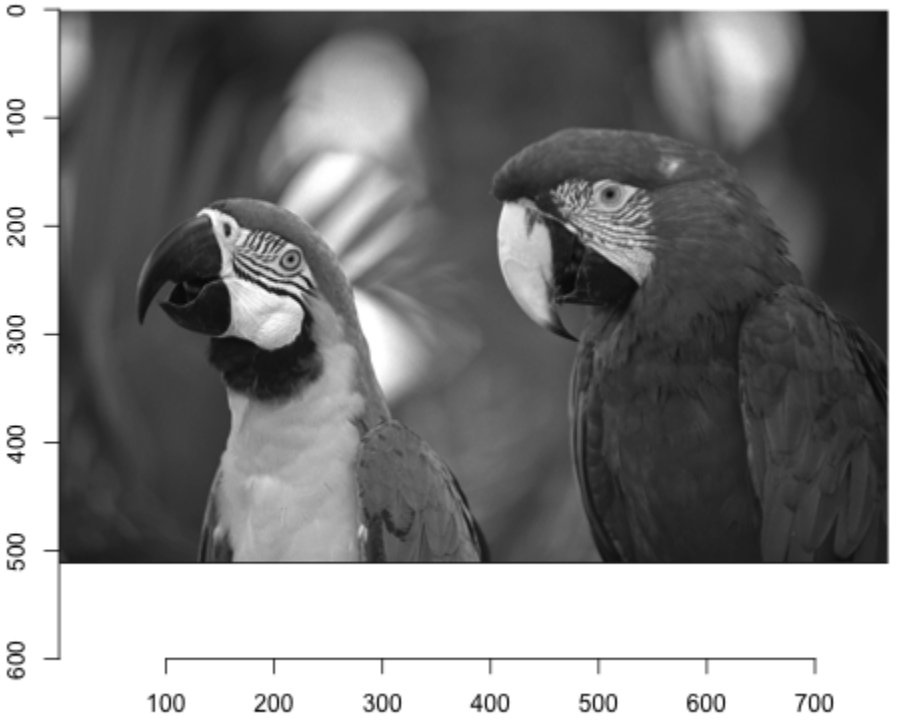


Standard



Test



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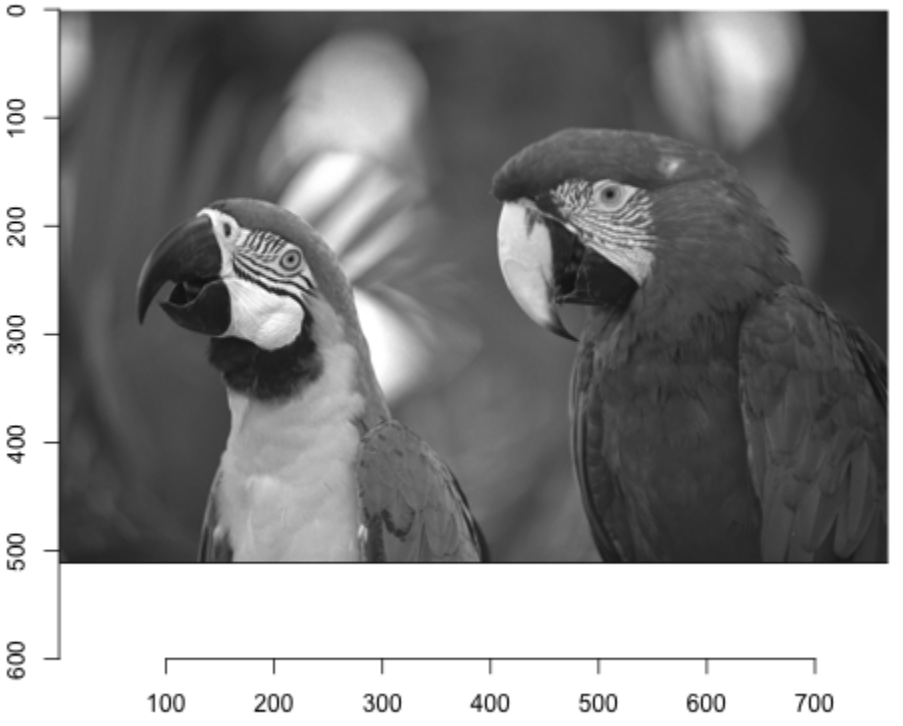

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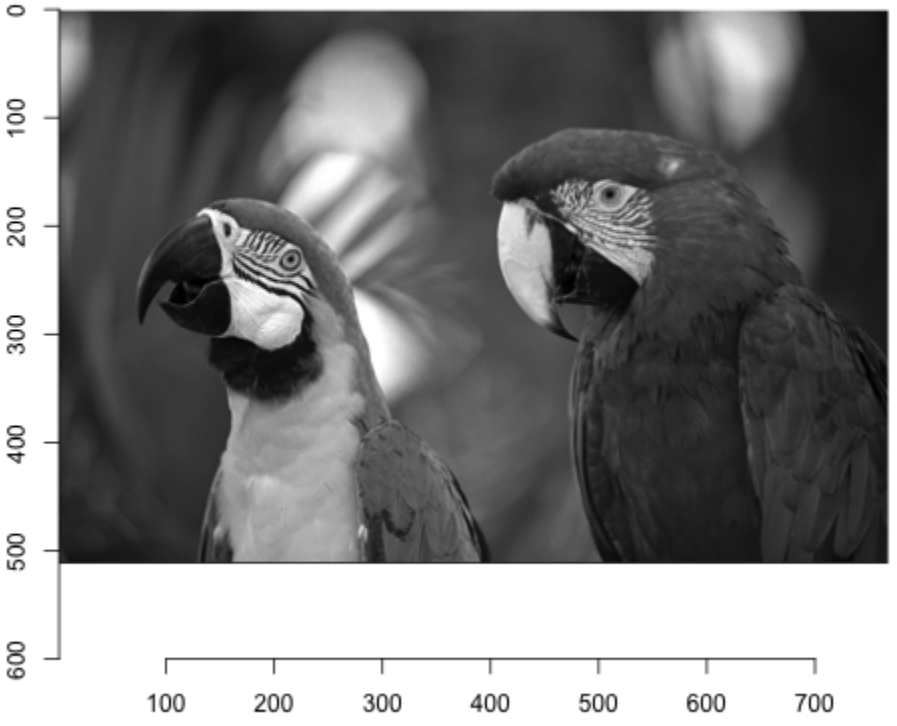

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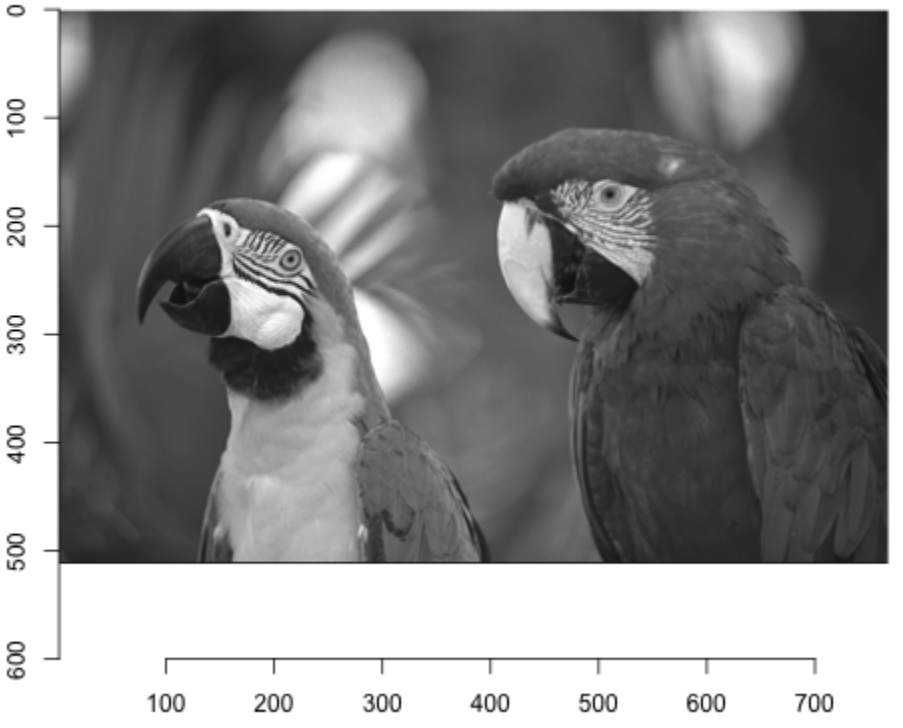

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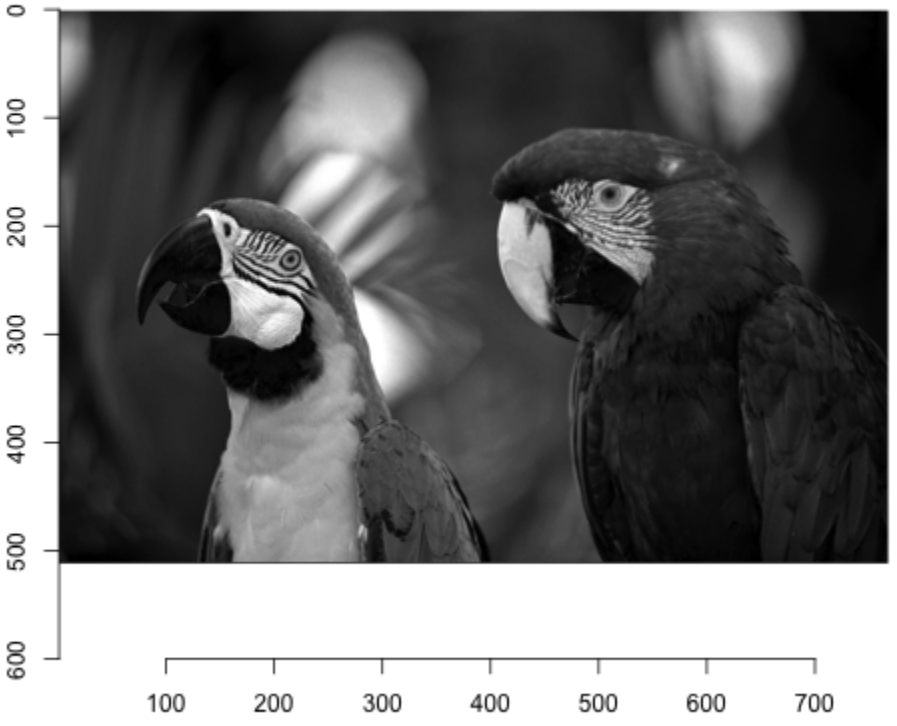


Just-noticeable Difference (JND)

Smallest reliably detected change in stimulus property

(Max) Weber's Fraction k -> (Gustav) Fechner's Law

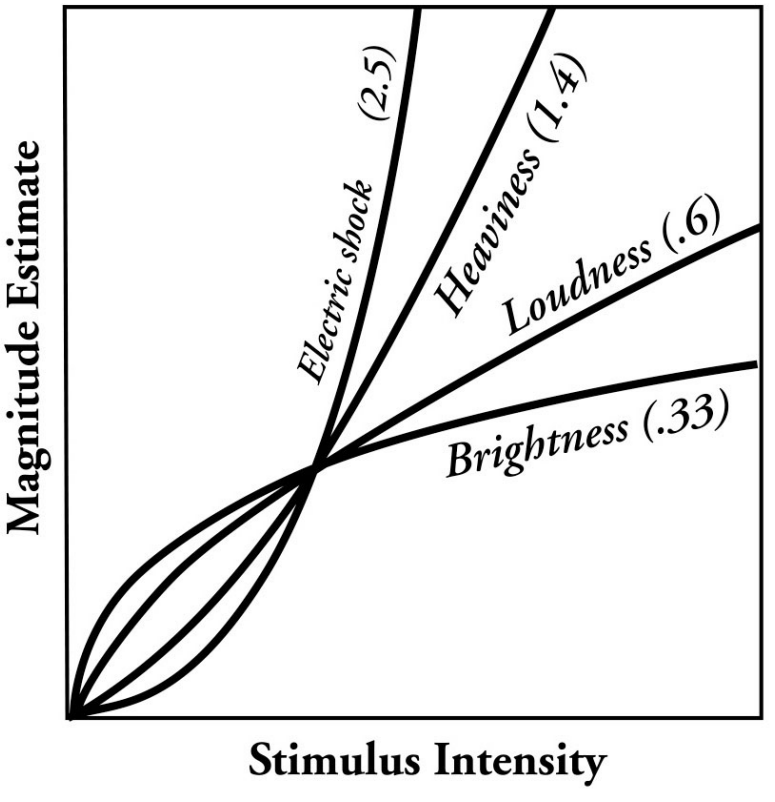
$$\frac{\Delta I}{I} = k$$

or

$$log(\Delta I) - log(I) = log(k)$$

Psychophysical scaling

Assign numeric ratings to perceived qualities (Stevens)



$$\Psi(I) = kI^{\alpha}$$

Not all scaling relations are logrhythmic, but most are curvlinear!

Summing up

Perceptual theories at the core of psychology

Perceptual methods at the core of psychology

Next time...

The retinal image

Slides created via the R package **xaringan**. Rendered HTML and supporting files are pushed to GitHub where GitHub's 'pages' feature is used to host and serve the course website.