Visual Object Recognition
Computational Models and Neurophysiological Mechanisms
Neuro 130/230. Harvard College/GSAS 78454

While we wait for others to join

What is this? Take a guess

Visual Object Recognition
Computational Models and Neurophysiological Mechanisms
Neurobiology 230. Harvard College/GSAS 78454

Note: no class on 09/04/2023 (Labor Day)
Class 1 [09/11/2023]. Introduction to Vision
Class 2 [09/18/2023]. The Phenomenology of Vision
Class 3 [09/25/2023]. Natural image statistics and the retina
Class 4 [10/02/2023]. Learning from Lesions
Note: no class on 10/09/2023 (Indigenous Day)
Class 5 [10/16/2023]. Primary Visual Cortex
Class 6 [10/23/2023]. Adventures into *terra incognita*
Class 7 [10/30/2023]. From the Highest Echelons of Visual Processing to Cognition
Class 8 [11/06/2023]. First Steps into in silico vision
Class 9 [11/13/2023]. Teaching Computers how to see
Class 10 [11/20/2023]. Computer Vision
Class 11 [11/27/2023]. Connecting Vision to the rest of Cognition [Dr. Will Xiao]
Class 12 [12/06/2023]. Visual Consciousness

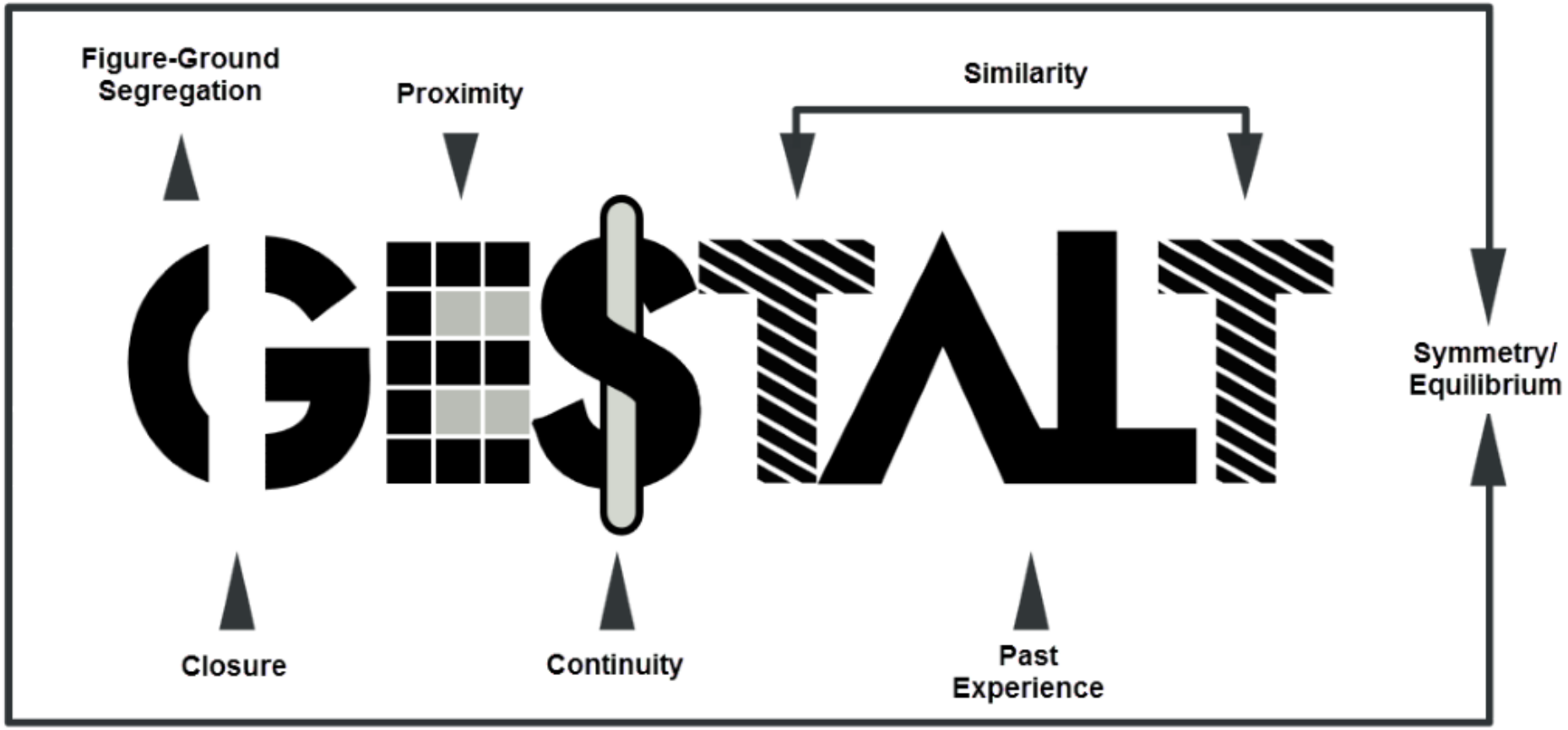
FINAL EXAM, PAPER DUE 12/11/2023. No extensions.

Psychophysics: Study of psychological experiences and the stimuli that generate them

- Reaction time — Indication (or upper bound) of how long the necessary psychological (and hence neural) processing takes
- Performance — Often inversely related to reaction time (speed-accuracy trade-off).
- Threshold — Boundaries for detection or discrimination
- Eye movements — Provide insights about tasks, goals, attention

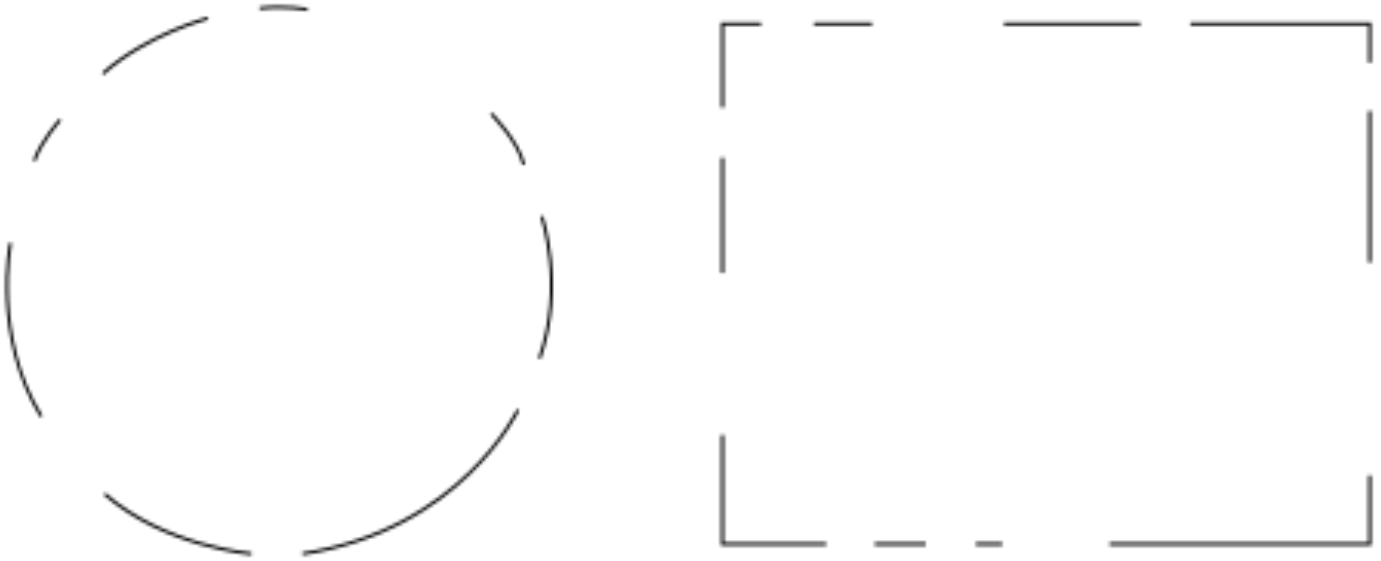
Gestalt laws of grouping

Basic phenomenological constraints



Law of closure

Perceiving objects as whole even if they are not complete



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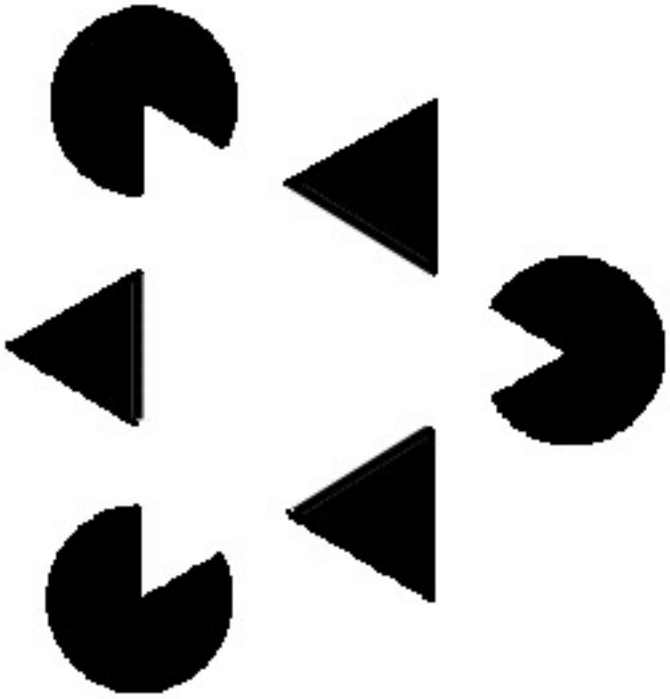
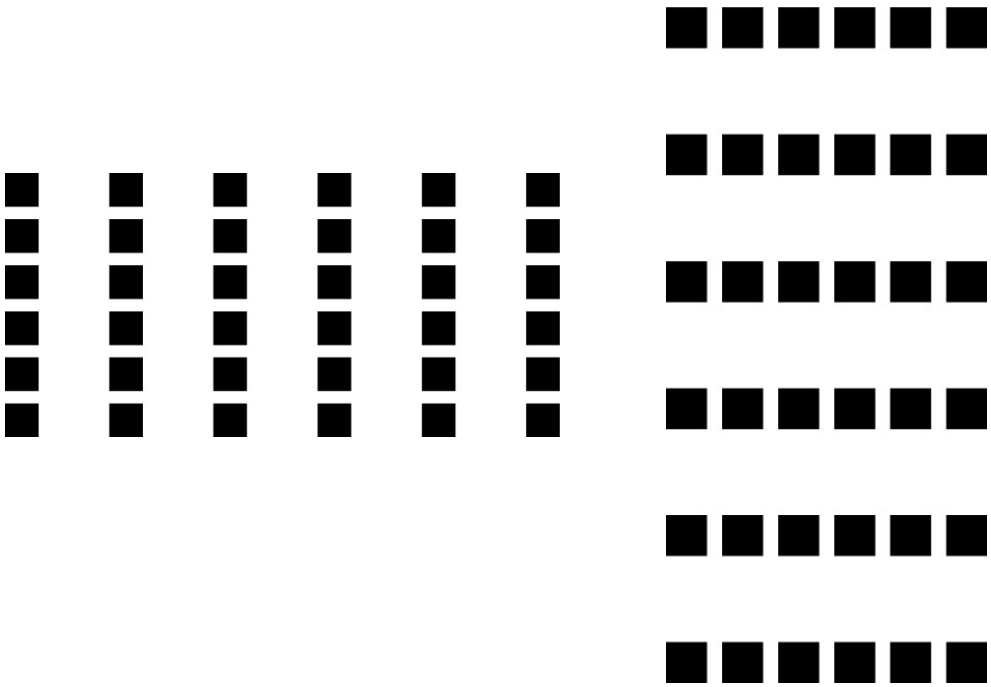


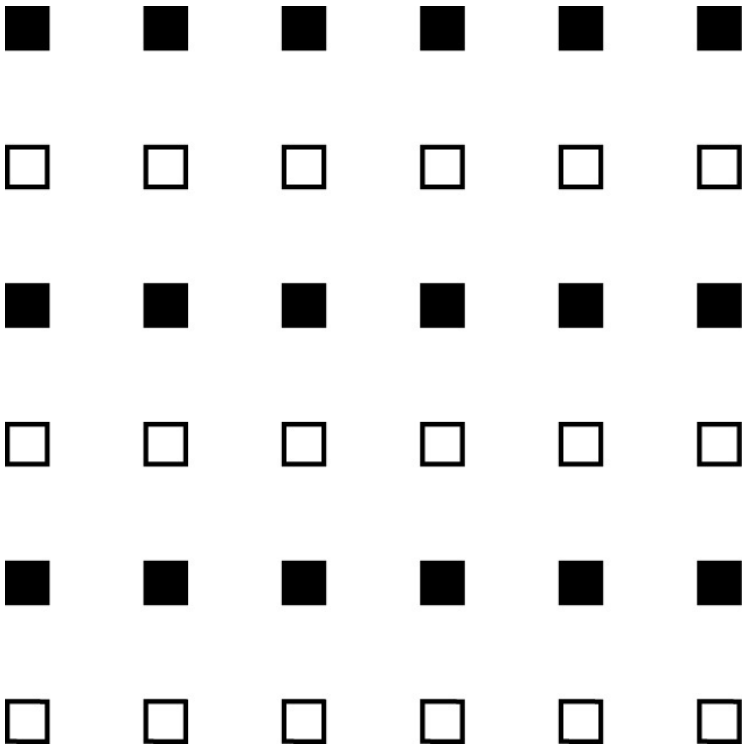
Law of proximity

Grouping nearby elements



Law of similarity

Grouping similar elements



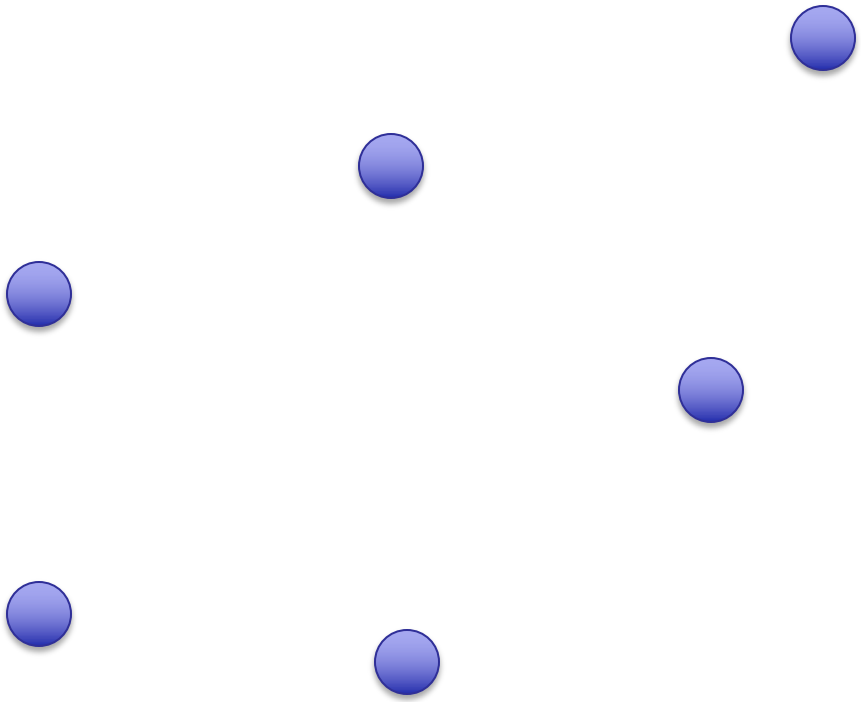
Similarity might depend on relationships of form, color, size, or brightness

Law of continuity

Continuing visual, auditory, and kinetic patterns

Law of common fate

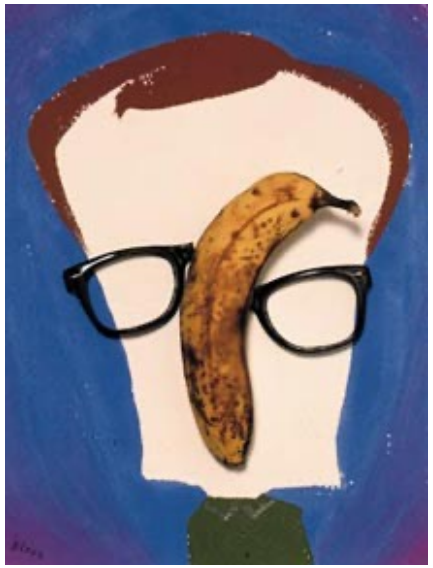
Grouping elements that move together

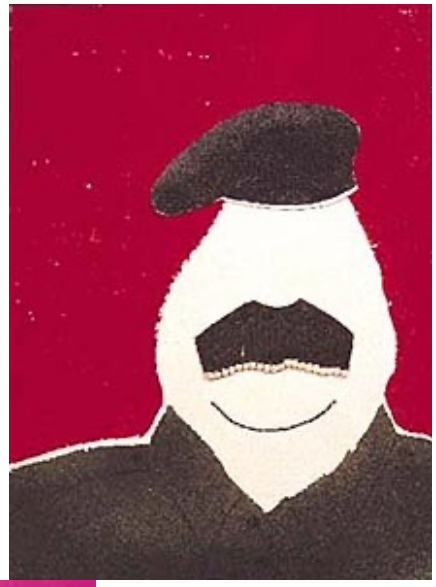


Object recognition

What features are important
to recognize an object?

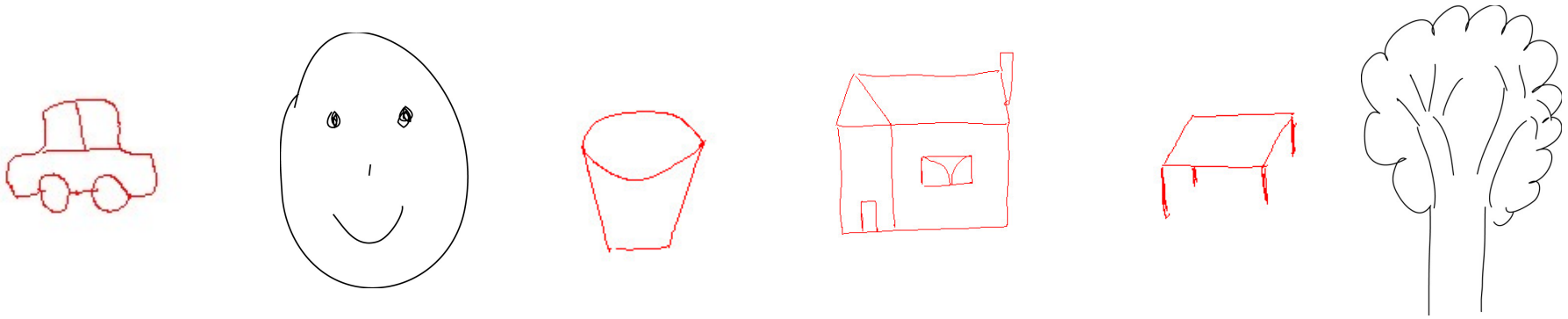
Recognition of caricatures





Images:
Hanoch Piven

Recognition of hand drawings



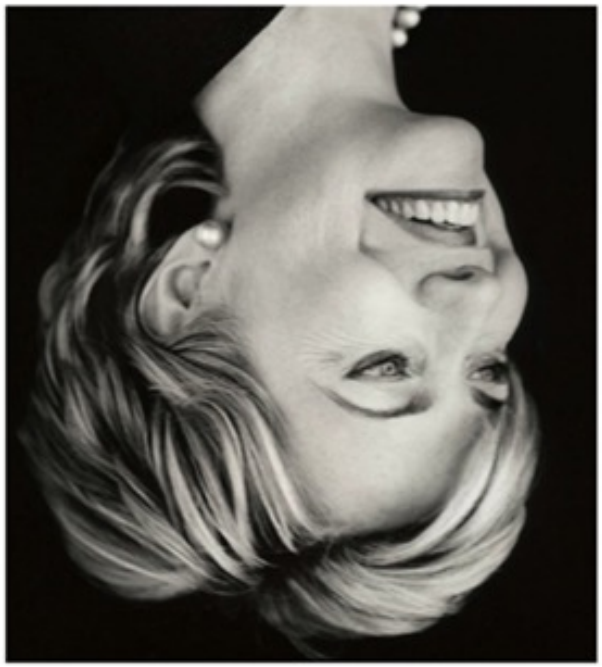
MIRCs
Minimal Recognizable Configurations

Ullman, PNAS 2016

Canonical views help recognition

A **Thatcher illusion**

Inverted

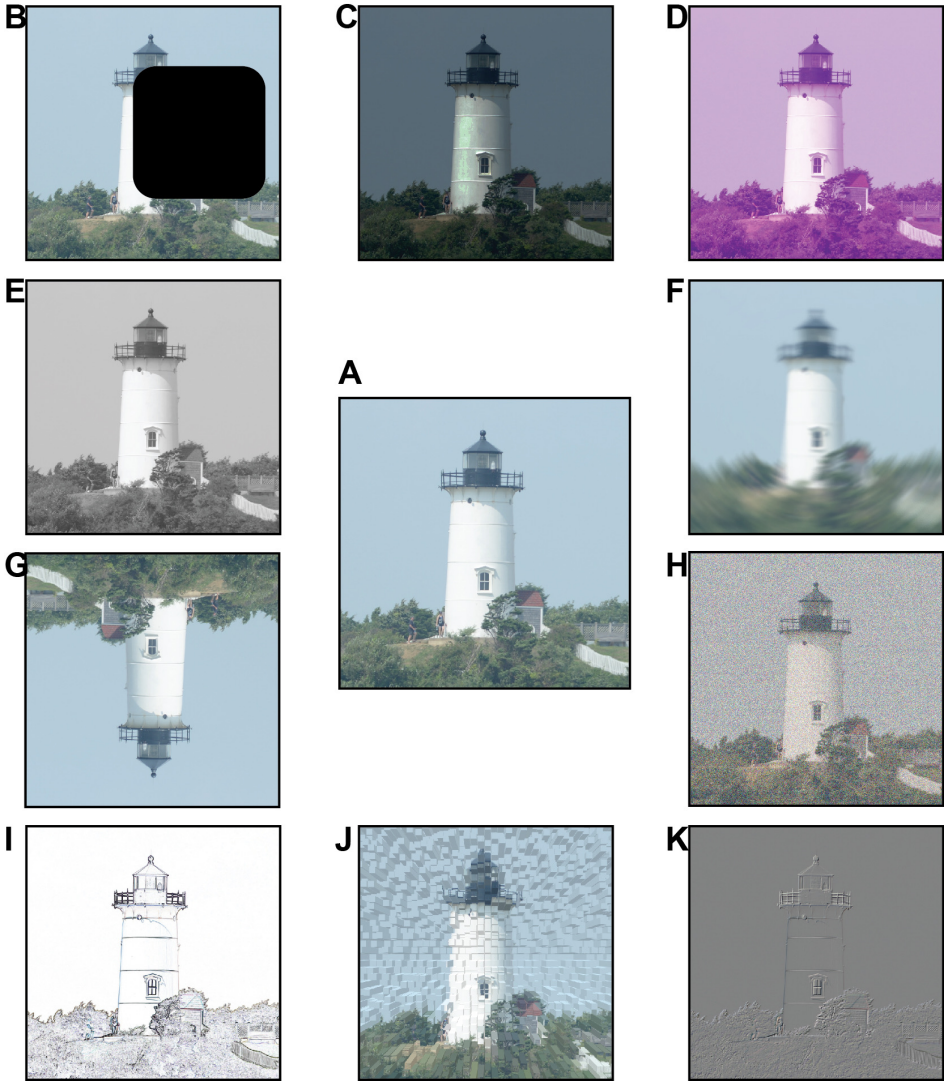


McKone et al, Frontiers in Psychology, 2013

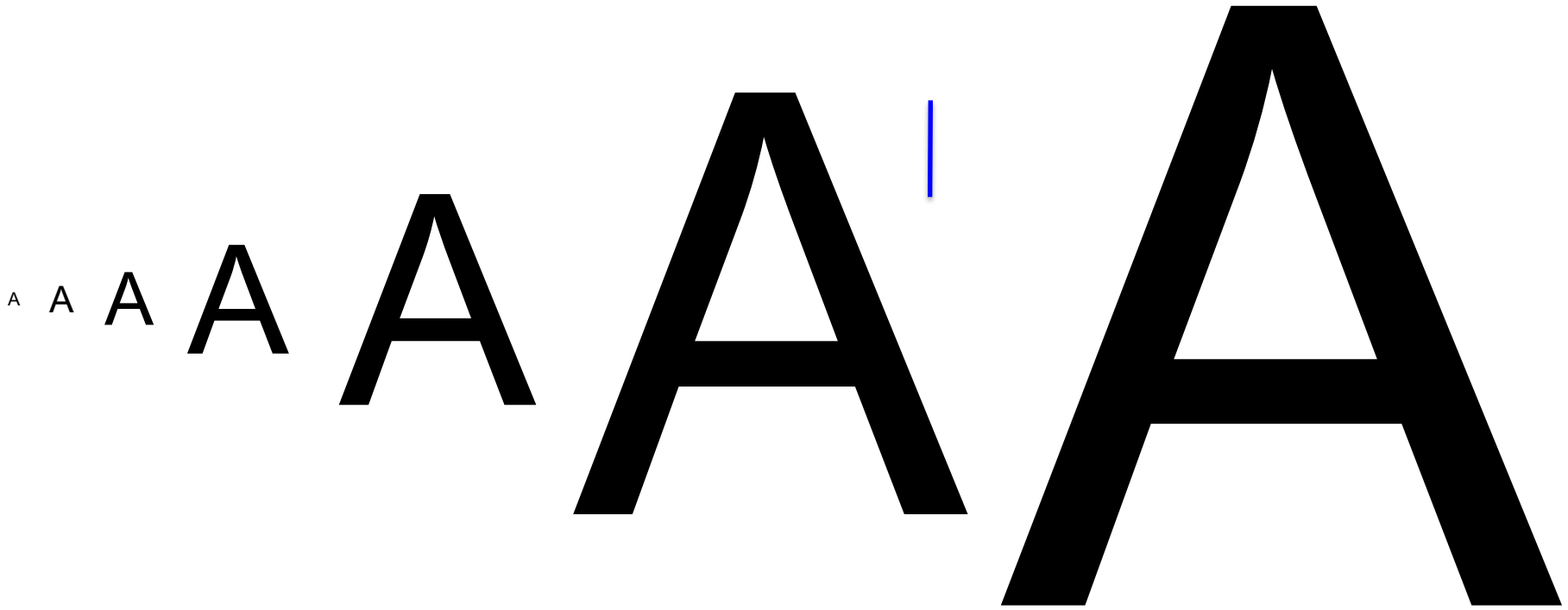
Four key properties of visual recognition

- Selectivity
- Invariance
- Speed
- Large capacity

Tolerance to image transformations

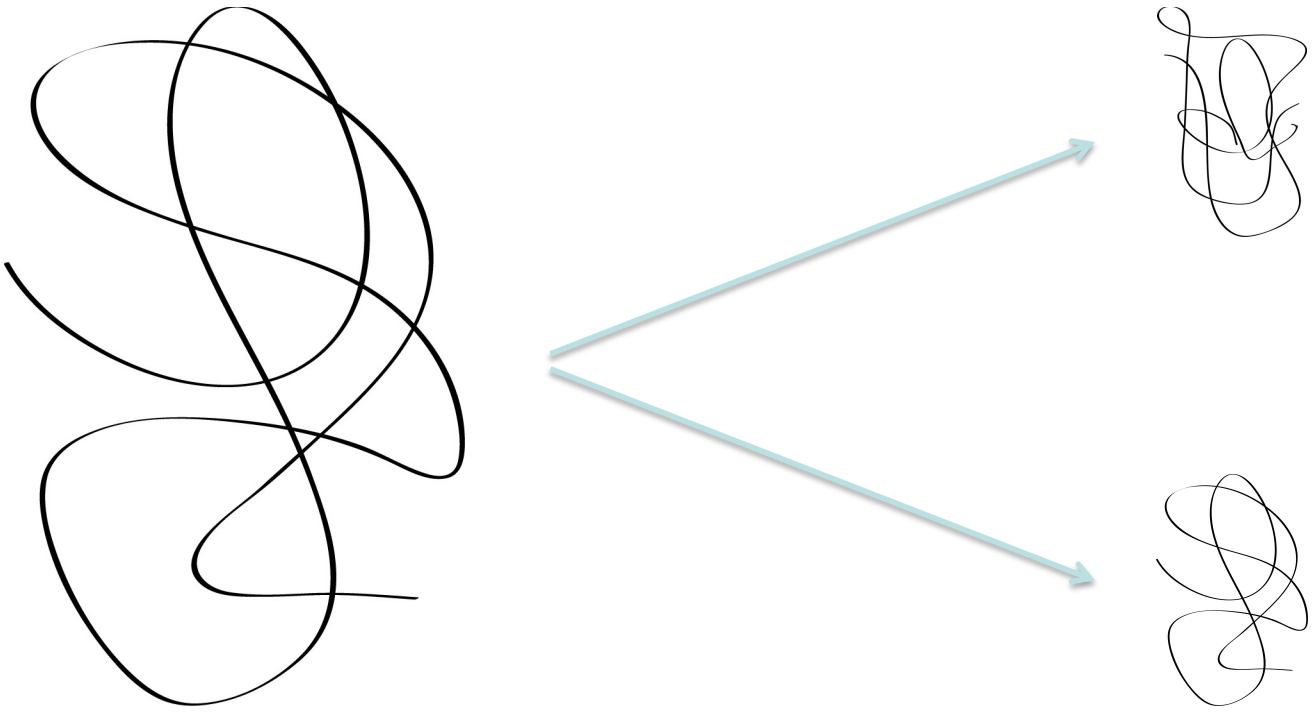


Scale tolerance

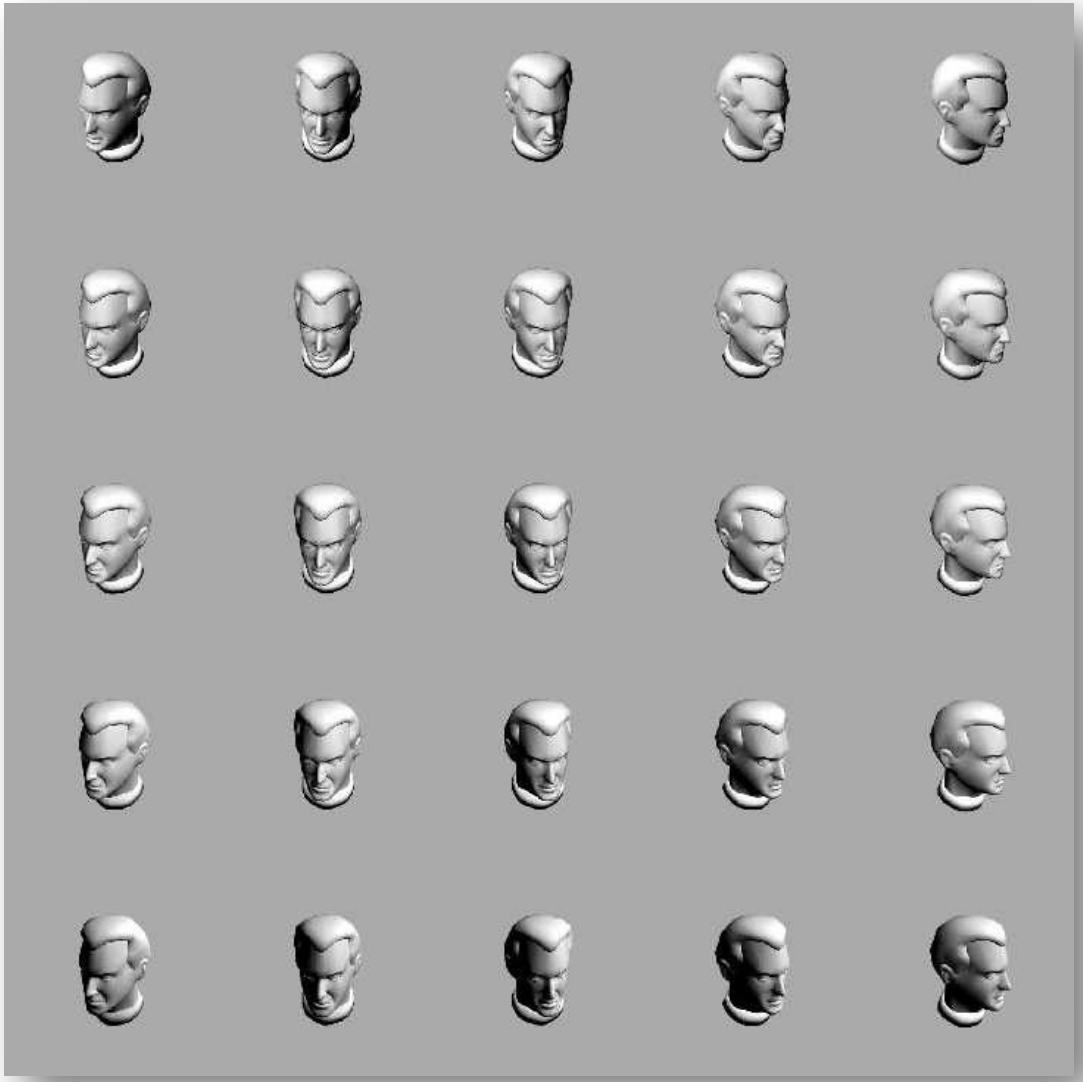


One-shot learning for scale tolerance

Which one is it?



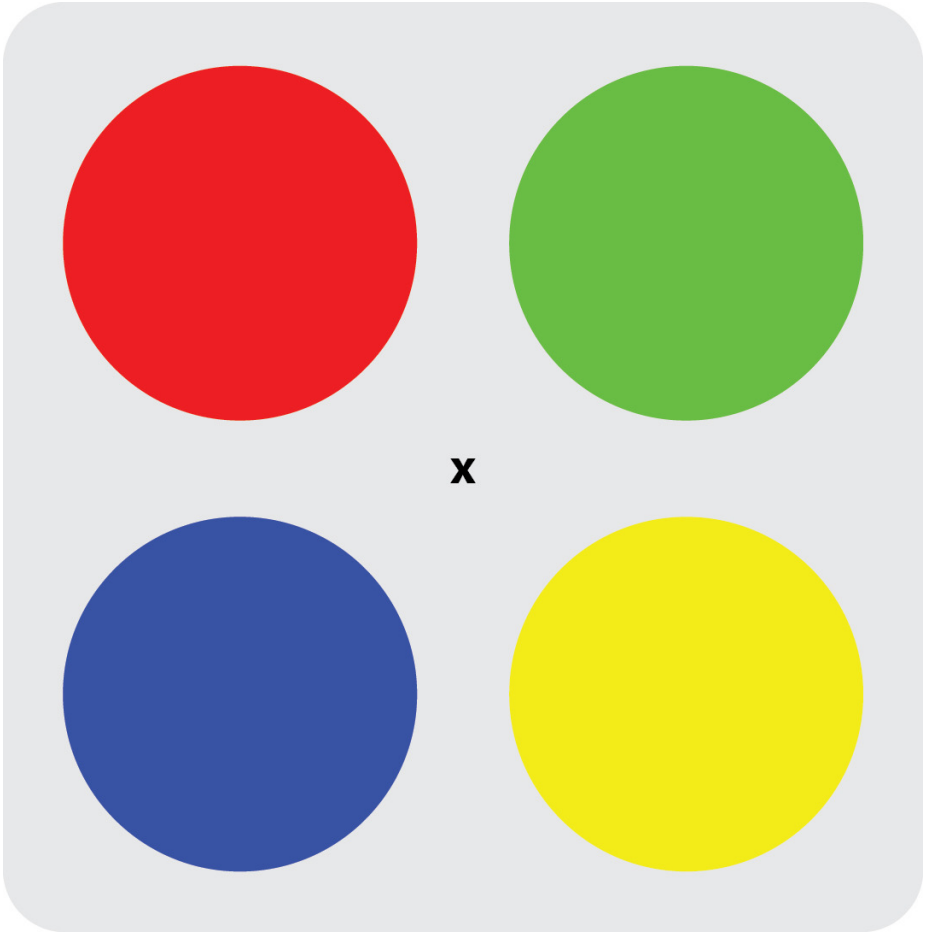
Tolerance to viewpoint and illumination changes



Tolerance to illumination changes: color constancy

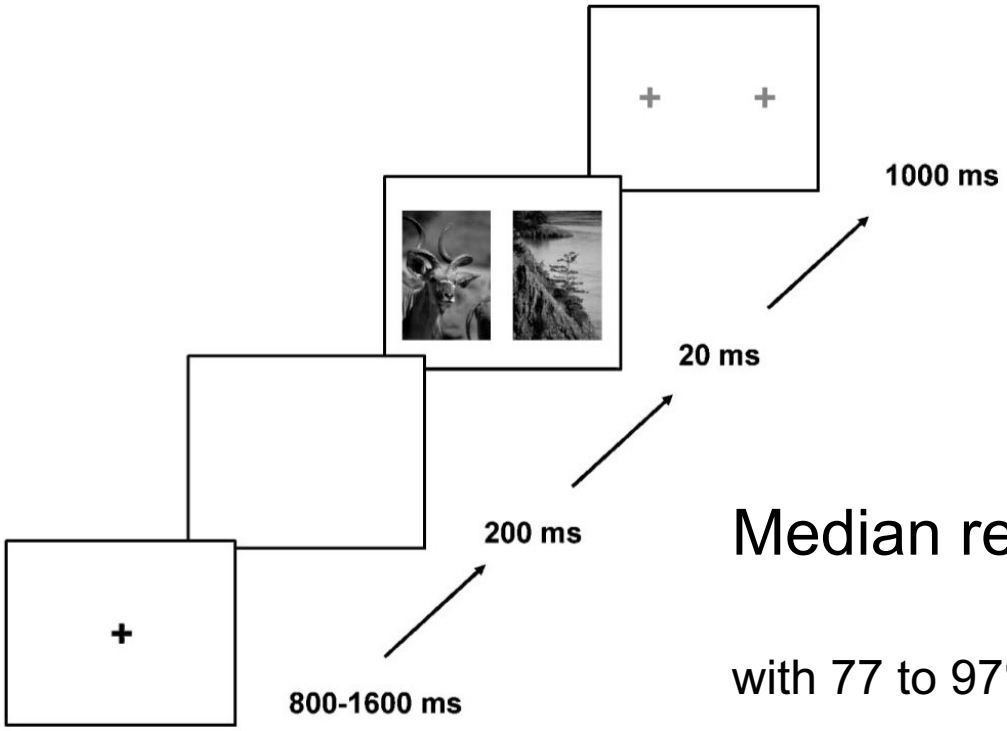
Visual recognition depends on experience

Visual adaptation



Recognition of images flashed for ~100 ms (demo)

Visual recognition can be extremely fast

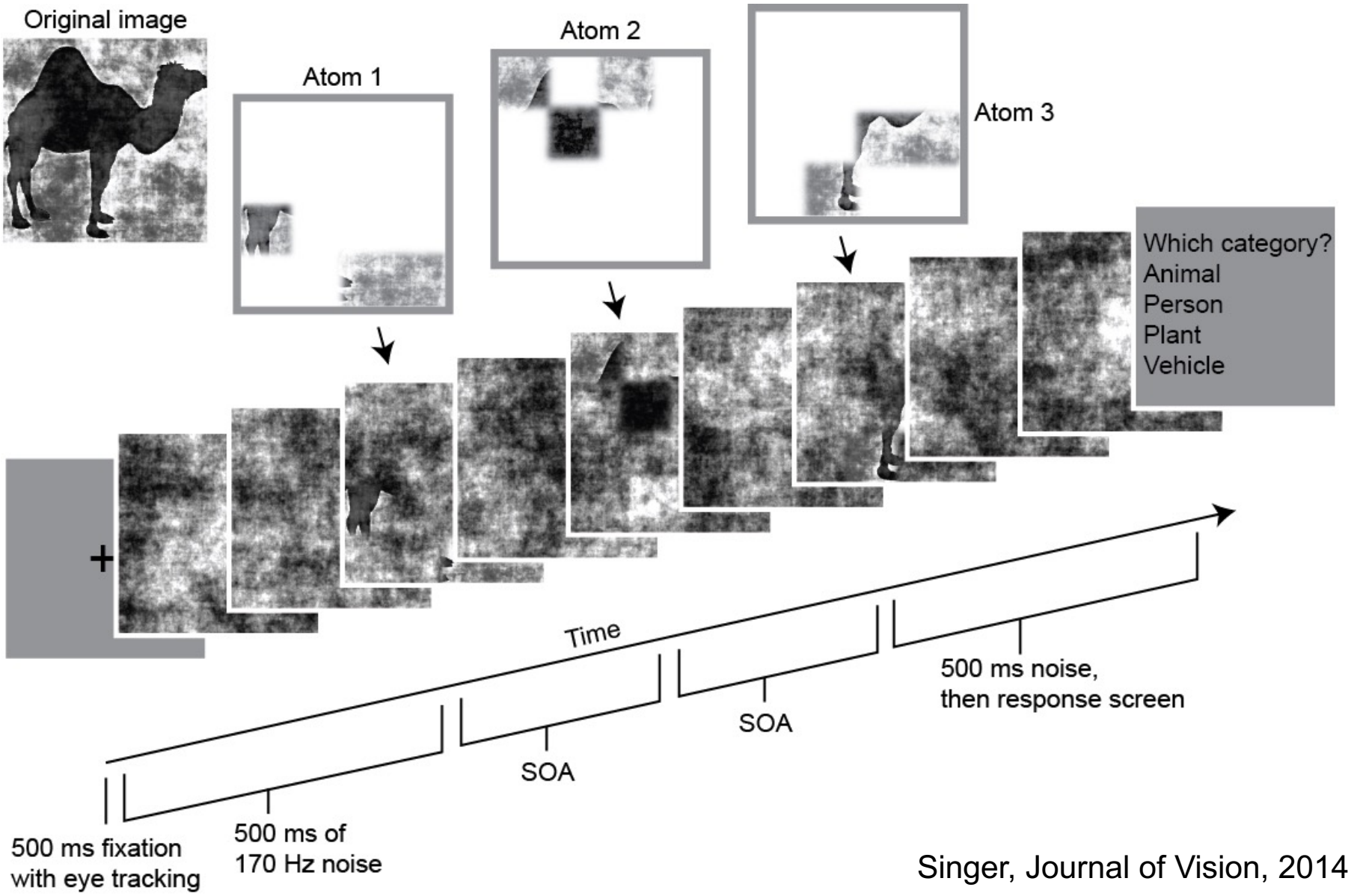


Median reaction times: 159 -- 301 ms

with 77 to 97% correct

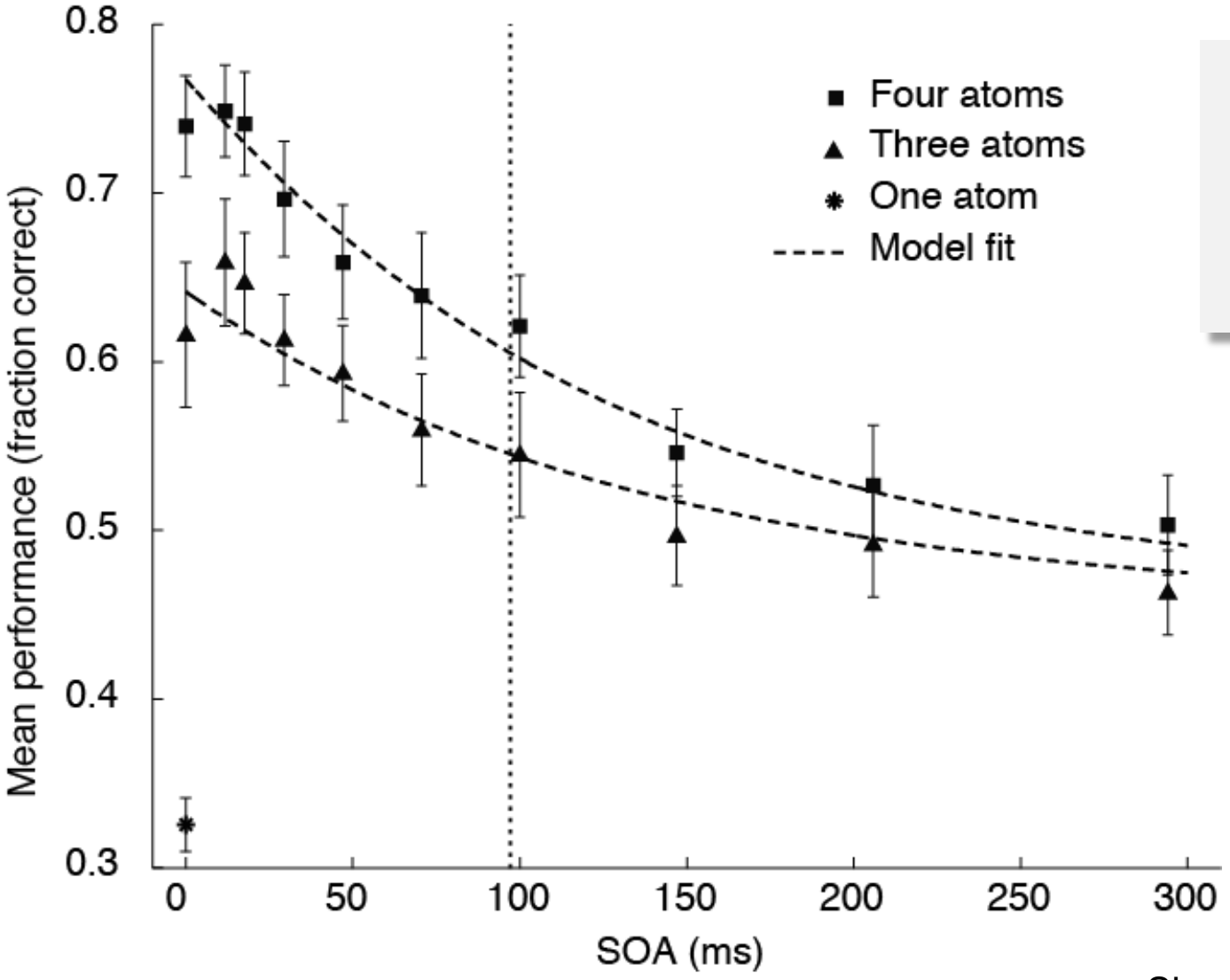
Kirchner, H., & Thorpe, S. J. (2006). Ultra-rapid object detection with saccadic eye movements

Is information integrated over time?



Singer, Journal of Vision, 2014

Rapid decay in recognition of asynchronously presented object parts



Brief asynchrony disrupts object recognition

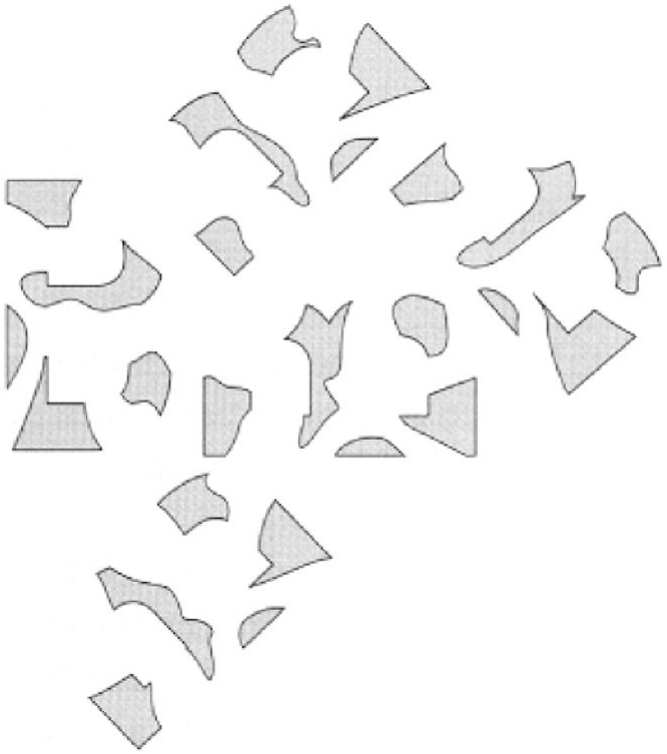
Singer, Journal of Vision, 2014

The visual system has a very large capacity

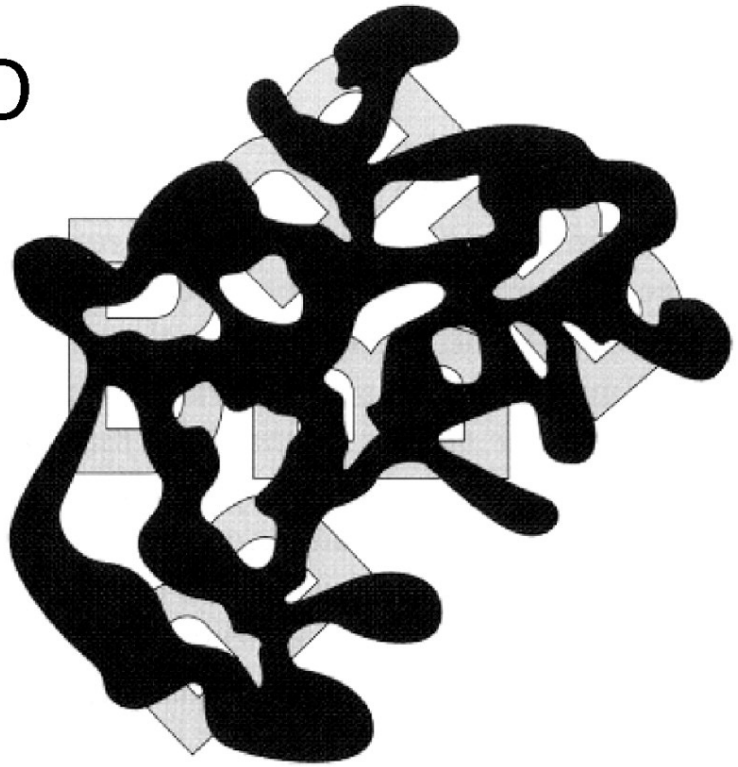
Object recognition from partial information

Presence of the occluder can help

C

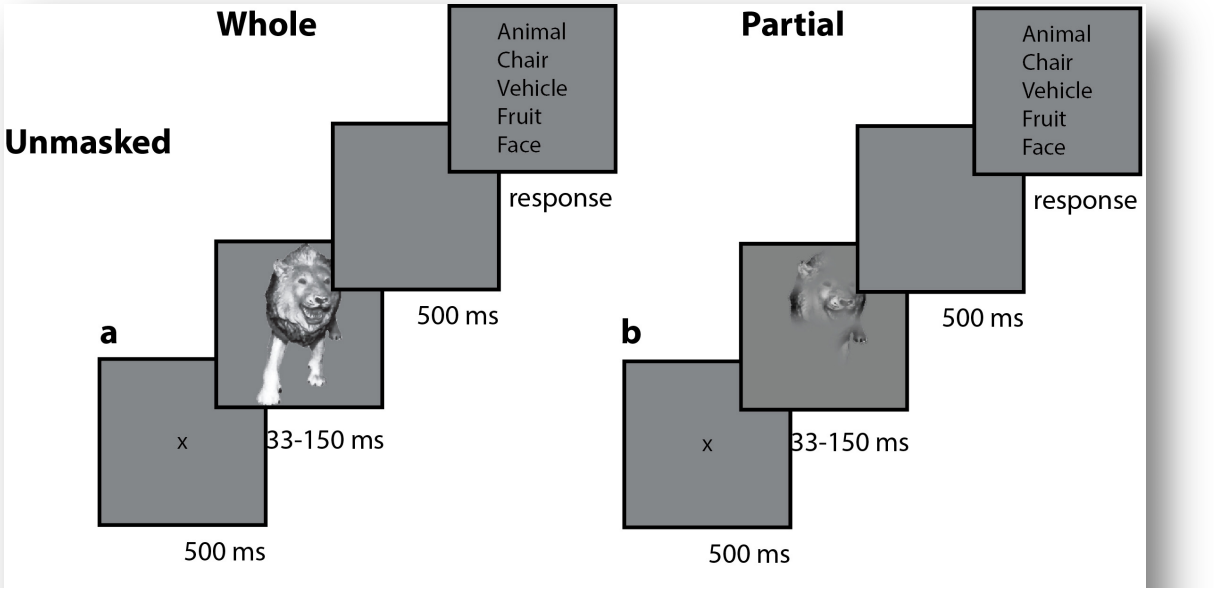


D

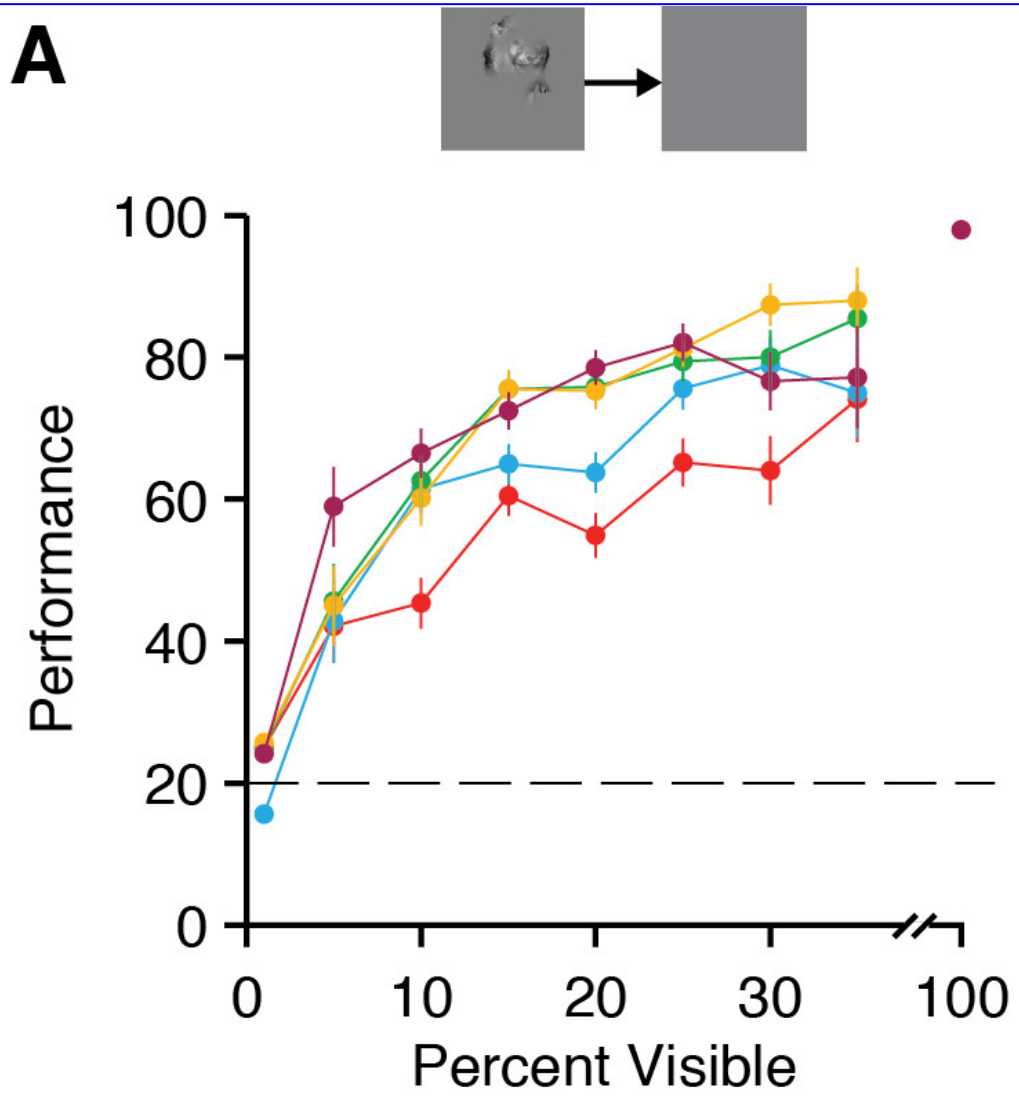


Bregman 1981

Object completion task

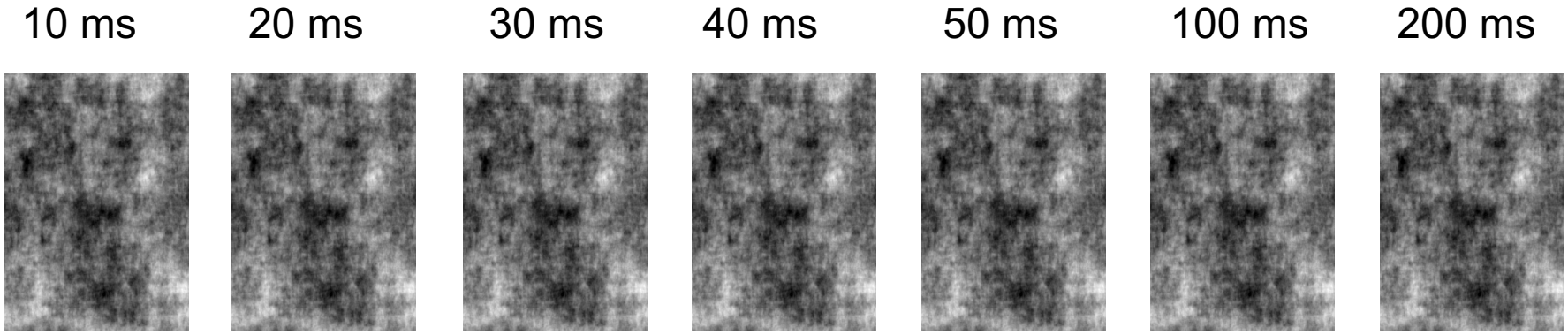


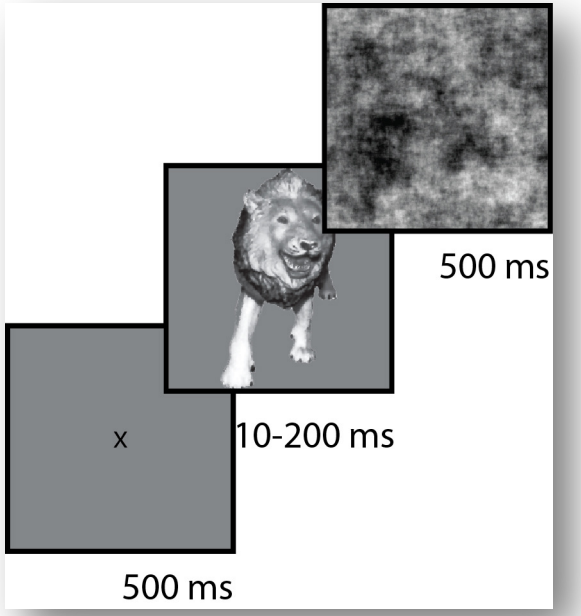
Strong robustness to limited visibility



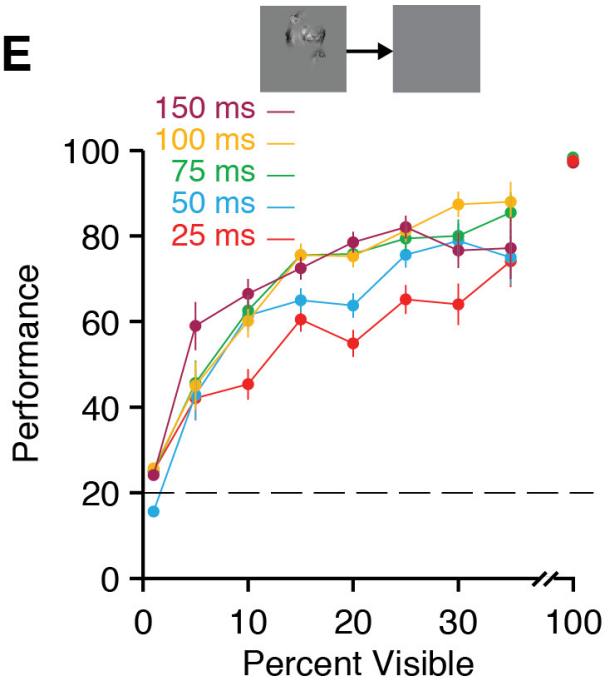
Tang et al, PNAS 2018

Backward masking allows investigation of computational processing times

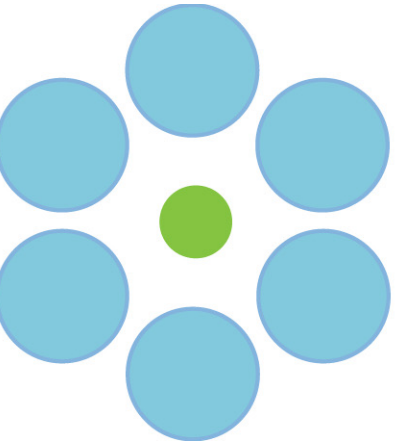




Backward masking disrupts pattern completion

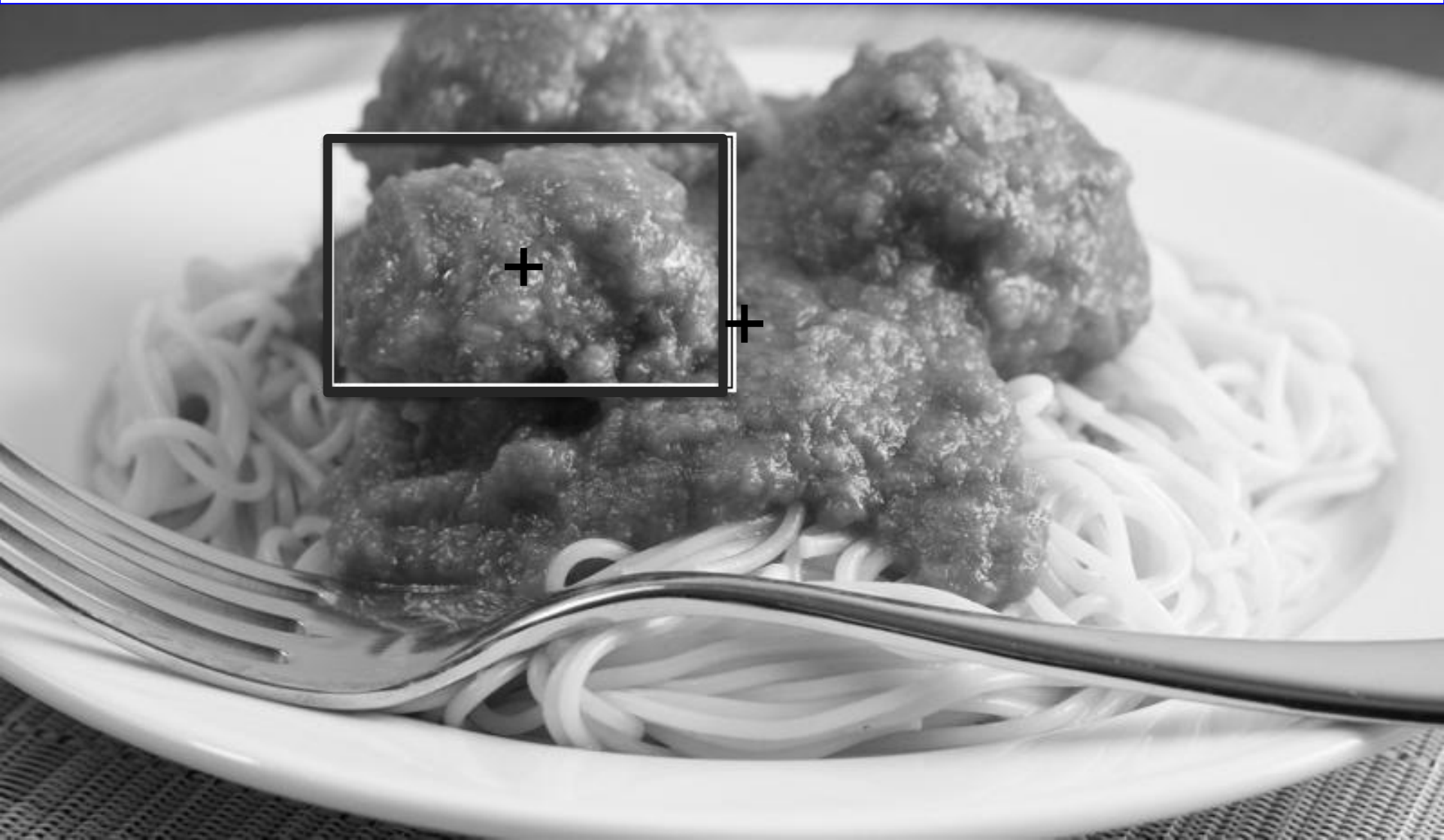


Beyond pixels – Context matters

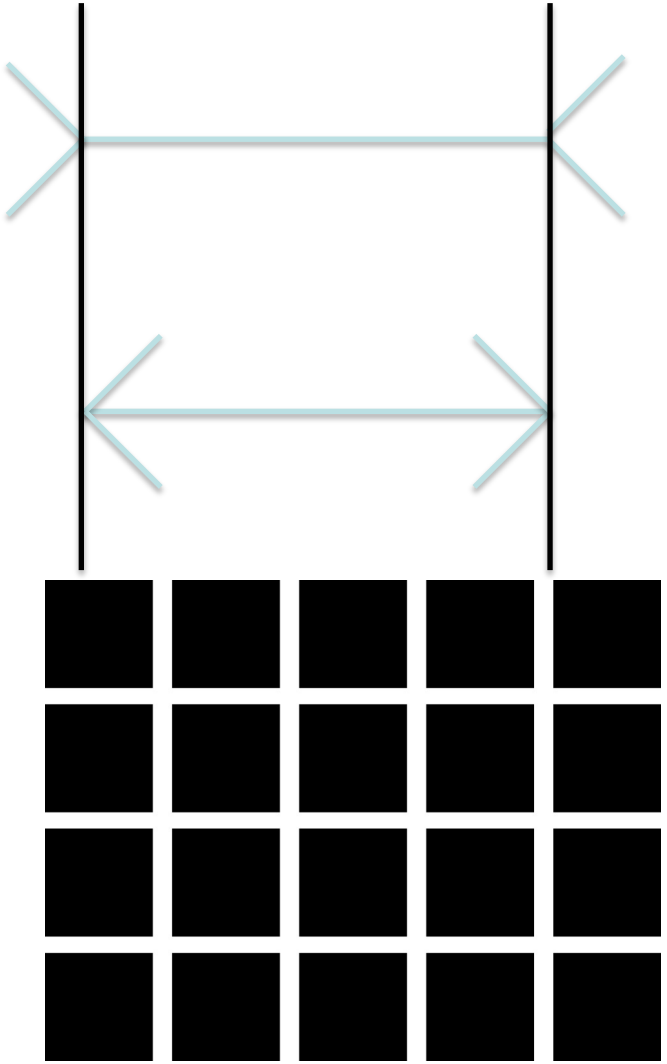


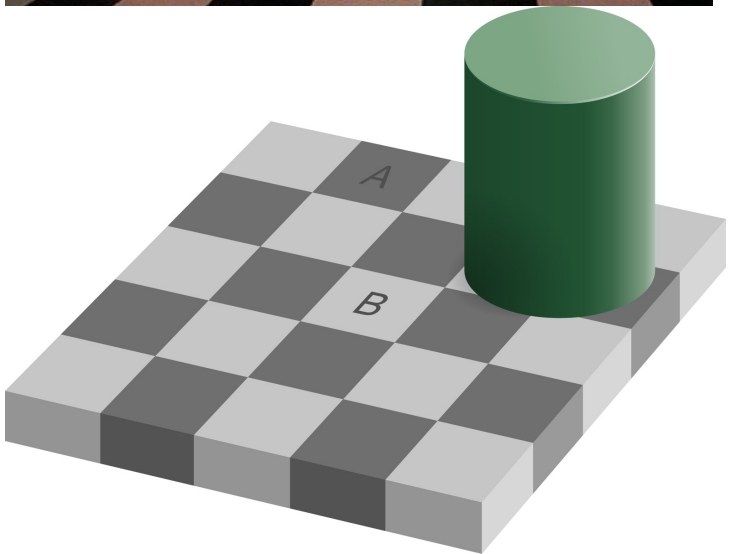
Context example

Context example

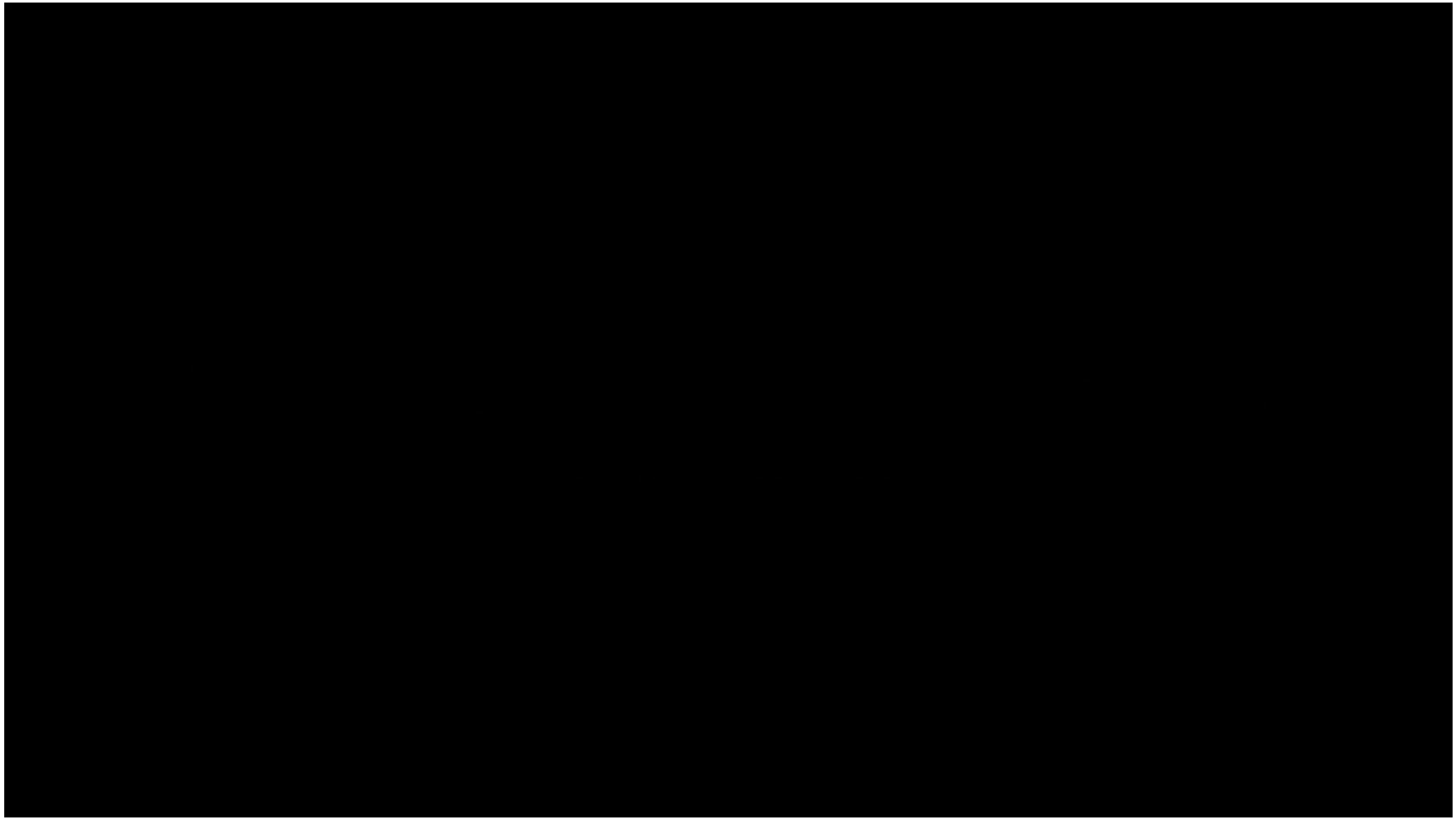


Visual illusions: The visual system does not always get it right





The critical role of attention



Quick comment: people are approximately the same wherever you go

Quick comment: animals show fascinating visual behavior too

Summary

- Visual behavior constrains computation: reaction time, performance, and eye movements
- Brains make up stuff
- Gestalt rules: grouping image parts --> objects
- Recognition is tolerant to large transformations
- Brains make inferences from partial information
- Visual recognition is fast
- Contextual information can help recognize objects

Further reading

- Regan, D. Human Perception of Objects (2000). Sinauer Associates. Sunderland, Massachusets.
- Frisby, JP and Stone JV. Seeing (2010). MIT Press. Cambridge, Massachusetts.

Supplementary contents at http://bit.ly/38buAhB

Original articles cited in class (see lecture notes for complete list)

- Potter, MC (1969) Recognition memory for a rapid sequence of pictures. Journal of Experimental Psychology 81:10-15.
- Kirchner, H., & Thorpe, S. J. (2006). Ultra-rapid object detection with saccadic eye movements: visual processing speed revisited. Vision Res, 46(11), 1762-1776.
- Brady, T. F., Konkle, T., Alvarez, G. A., & Oliva, A. (2008). Visual long-term memory has a massive storage capacity for object details. Proc Natl Acad Sci U S A, 105(38), 14325-14329
- Mooney CM. (1957). Age in the development of closure ability in children. Canadian Journal of Psychology 11: 219-226
- McKone et al, Frontiers in Psychology, 2013
- Singer and Kreiman (2014). Short temporal asynchrony disrupts visual object recognition. Journal of Vision 12:14.
- Tang, H., et al. (2014). "Spatiotemporal dynamics underlying object completion in human ventral visual cortex." Neuron **83**: 736-748.
- Tang, H., et al. (2014). "A role for recurrent processing in object completion: neurophysiological, psychophysical and computational evidence." CBMM Memo(9).