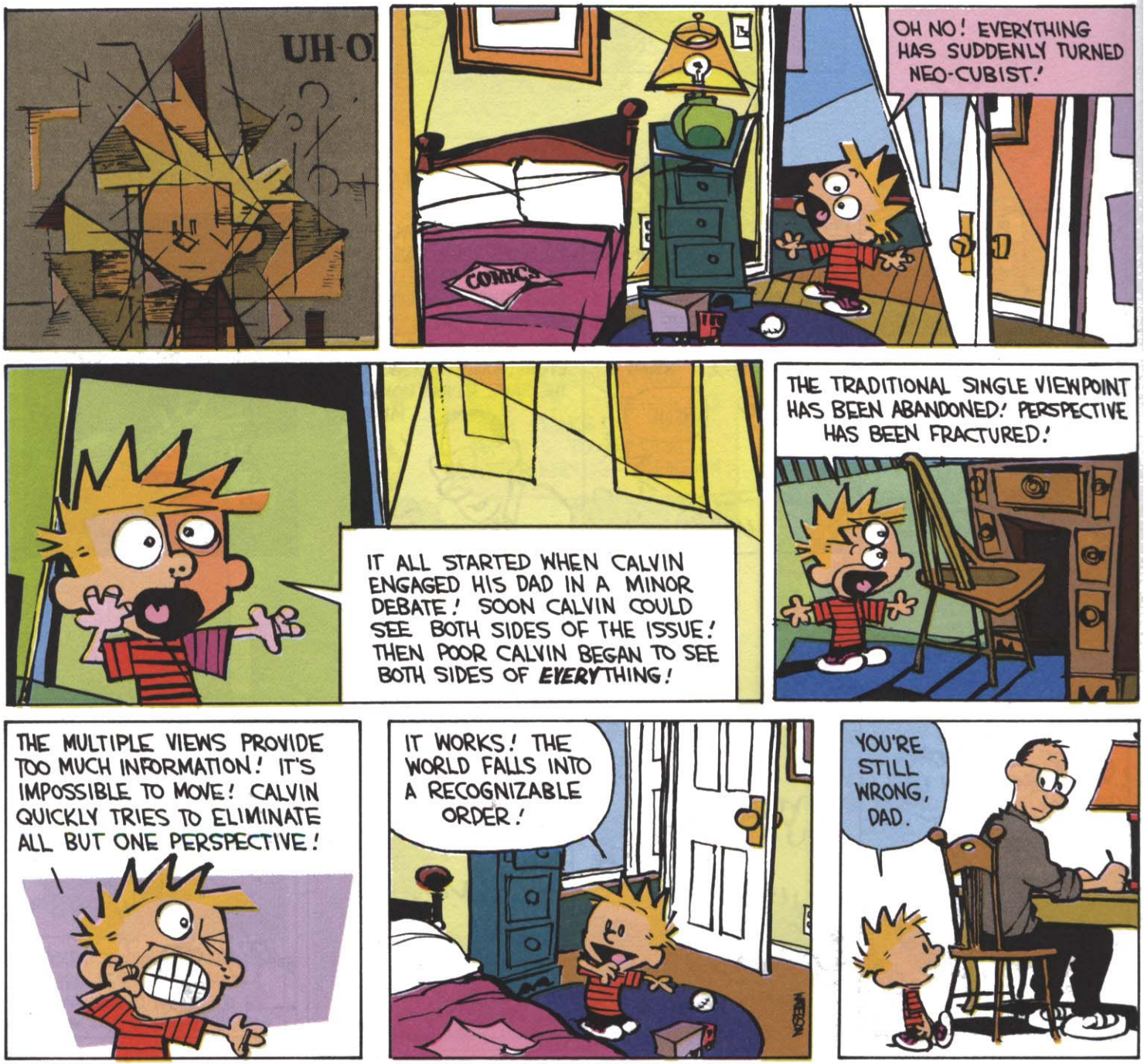
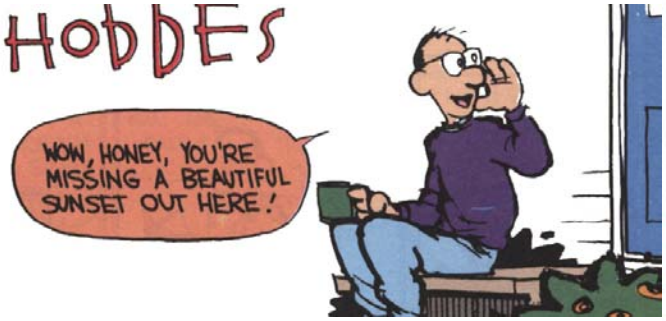
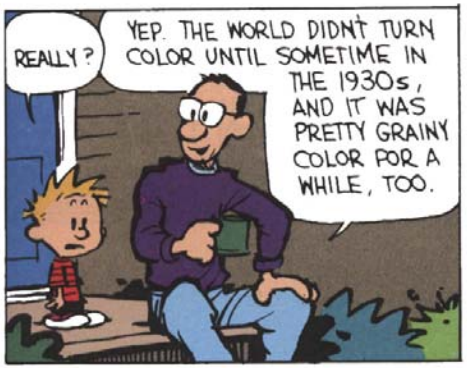

UH-O
OH NO! EVERYTHING HAS SUDDENLY TURNED NEO-CUBIST!
COMICS
IT ALL STARTED WHEN CALVIN ENGAGED HIS DAD IN A MINOR DEBATE! SOON CALVIN COULD SEE BOTH SIDES OF THE ISSUE! THEN POOR CALVIN BEGAN TO SEE BOTH SIDES OF EVERYTHING!
THE TRADITIONAL SINGLE VIEWPOINT HAS BEEN ABANDONED! PERSPECTIVE HAS BEEN FRACTURED!
THE MULTIPLE VIEWS PROVIDE TOO MUCH INFORMATION! IT'S IMPOSSIBLE TO MOVE! CALVIN QUICKLY TRIES TO ELIMINATE ALL BUT ONE PERSPECTIVE!
IT WORKS! THE WORLD FALLS INTO A RECOGNIZABLE ORDER!
WATTERSON
YOU'RE STILL WRONG, DAD.

Calvin and Hobbes





Perceptual and Artistic Principles for

Effective Computer Depiction

Computational Vision and Picture

Fredo Durand

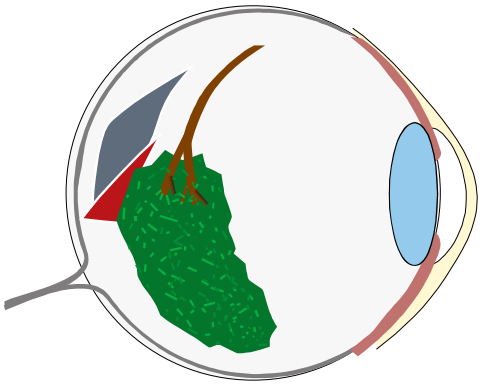
MIT- Lab for Computer Science

Plan

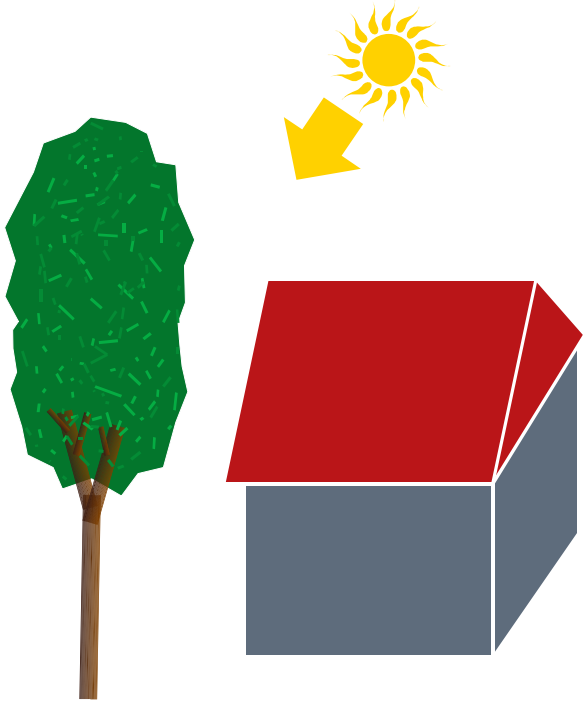
- Vision as an cognitive process
- Computational theory of vision
- Complex mapping

Distal vs. proximal stimulus

- Distal stimulus: reality
- Proximal stimulus: retinal image



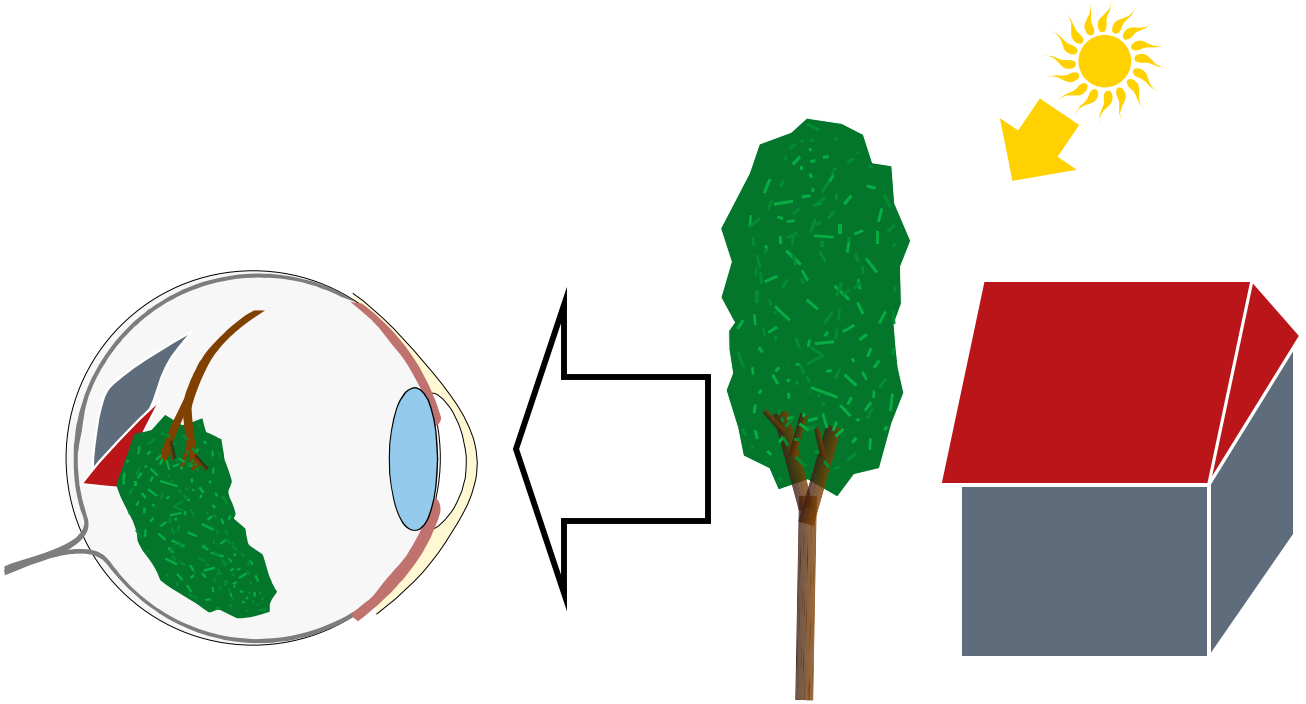
proximal stimulus (2D)



Distal stimulus (3D)

Vision as an inverse problem

- The distal stimulus is projected into a proximal stimulus

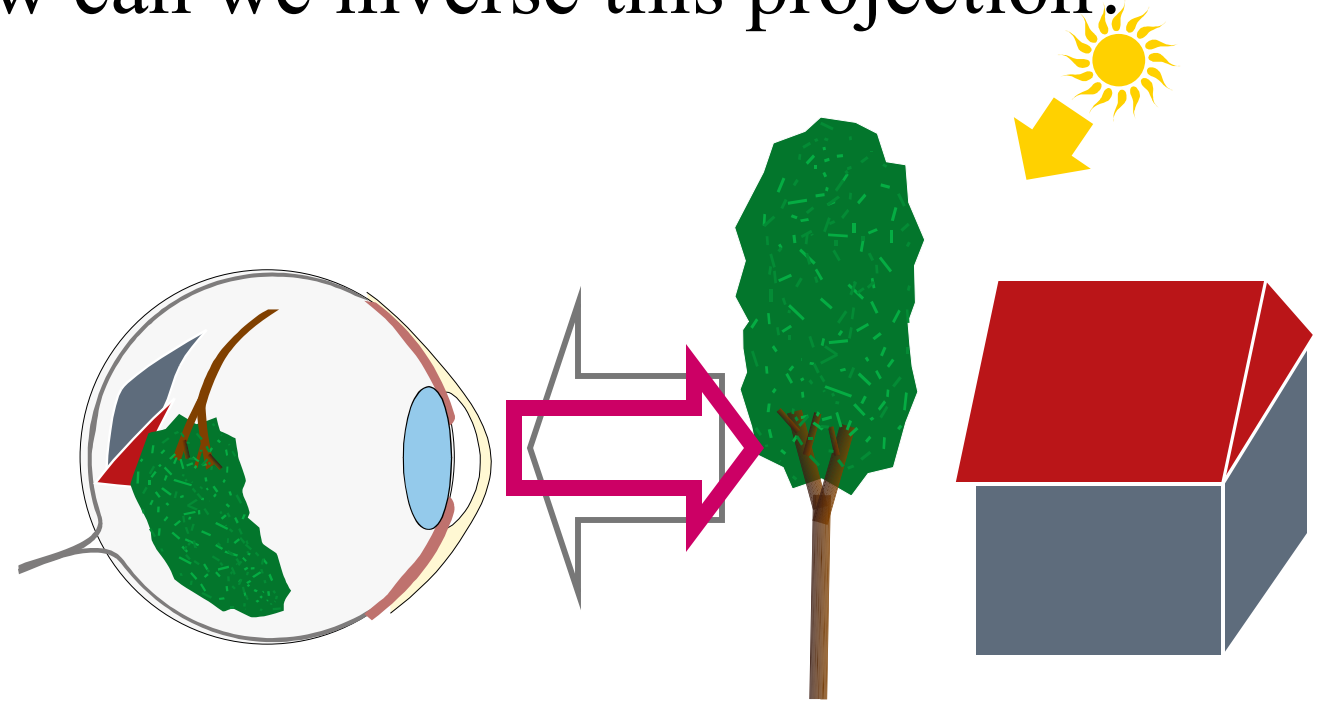


proximal stimulus (2D)

Distal stimulus (3D)

Vision as an inverse problem

- The distal stimulus is projected into a proximal stimulus
- How can we inverse this projection?

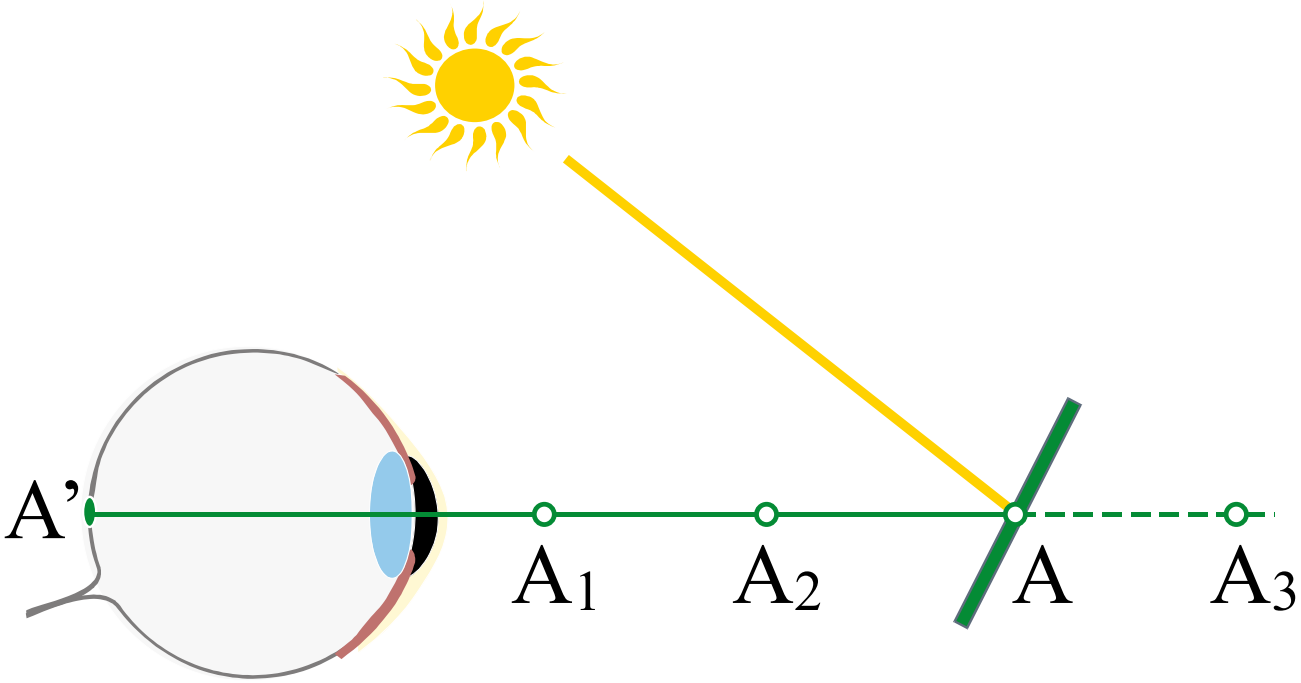


proximal stimulus (2D)

Distal stimulus (3D)

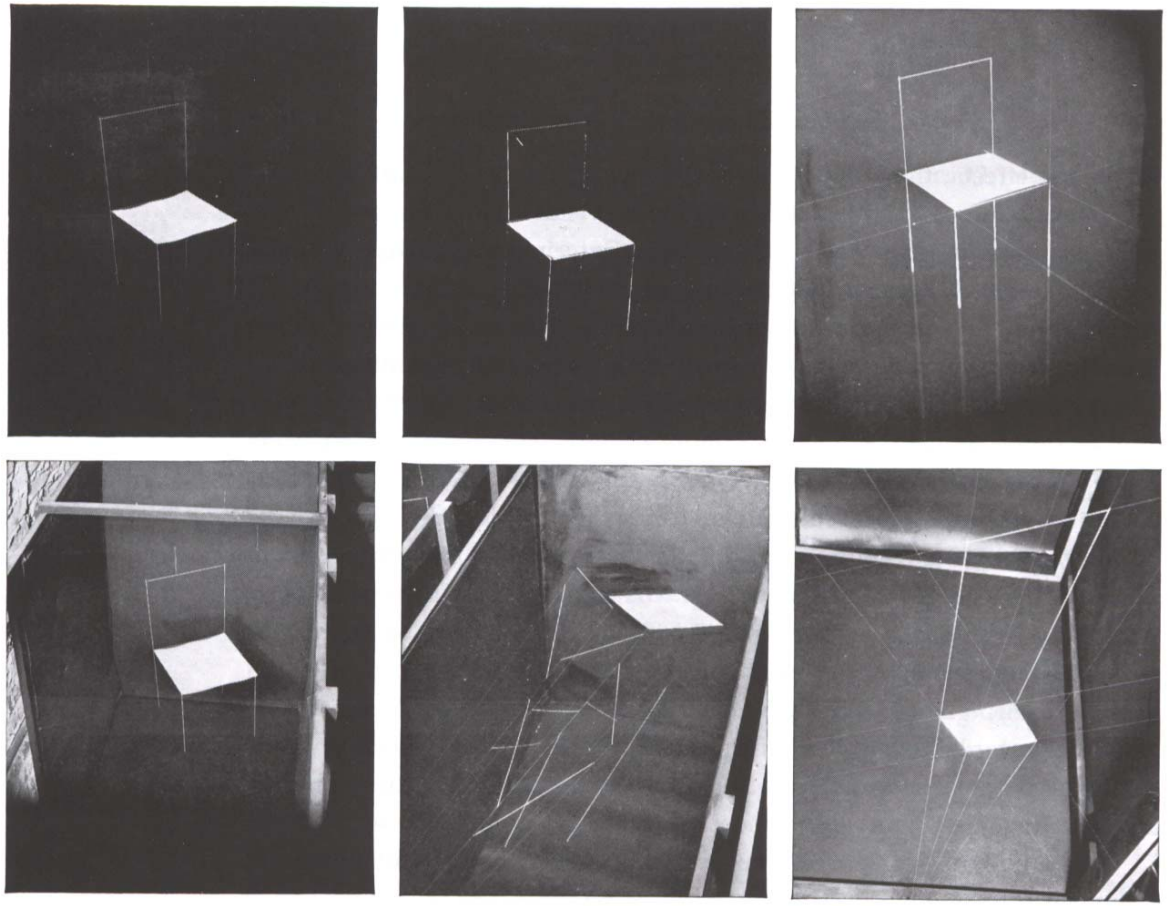
Unconscious inference (Helmholtz)

- Our vision system solves a problem
- Under-constrained problem
  - A visible point A' can correspond to an infinity of 3D points (A1, A2, A, A3…)



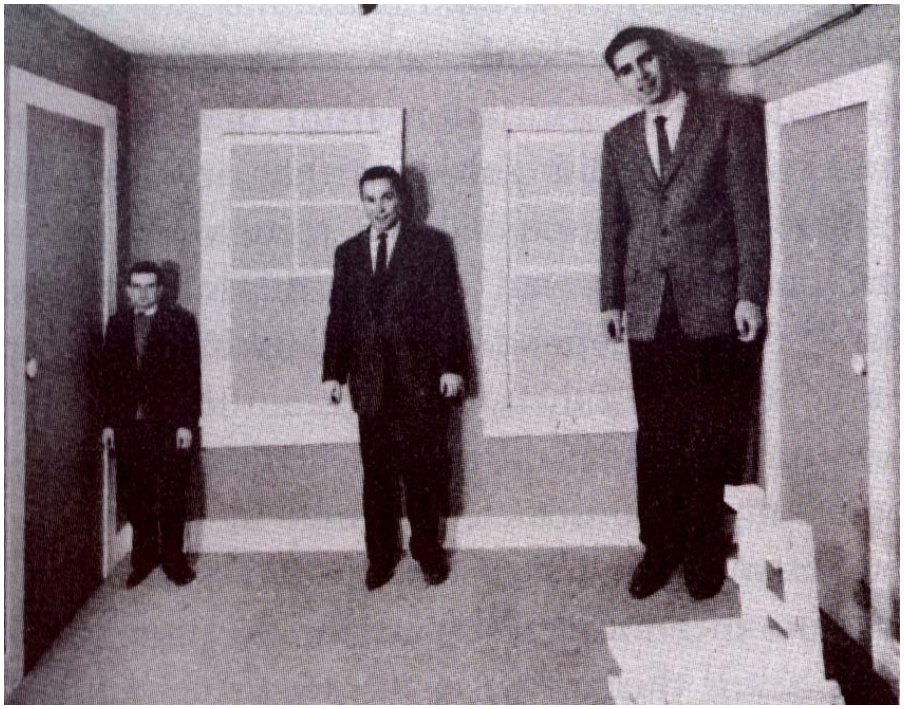
How assumptions help

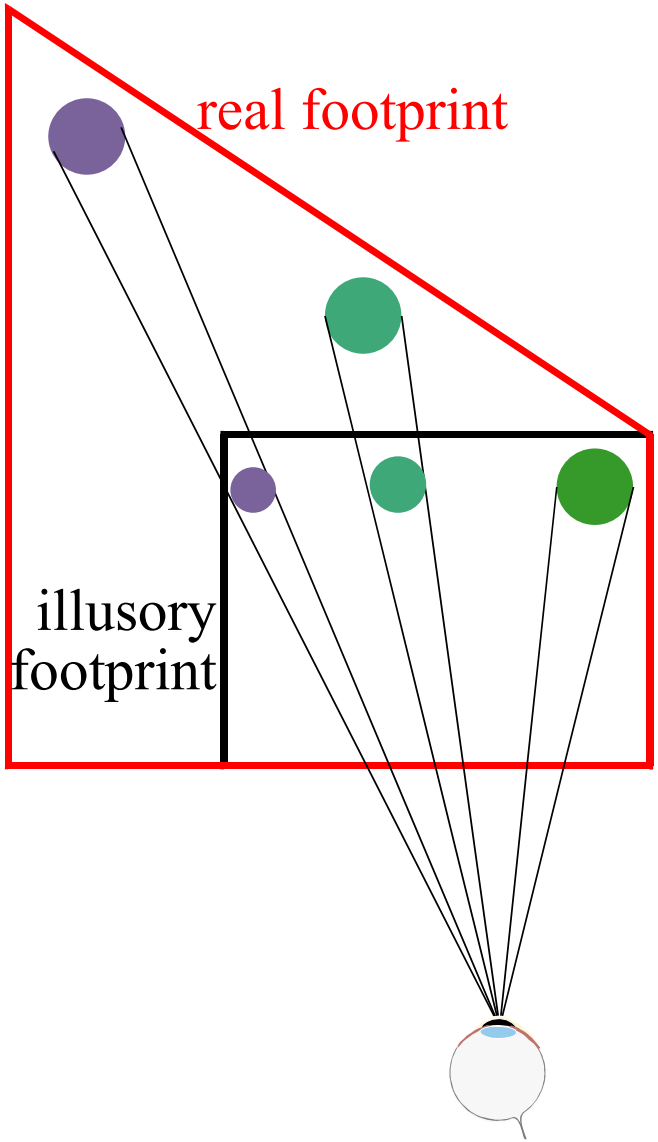
- Ames chair
  - 3 different scenes
  - Same projection
  - We assume it is a chair
  - Resolves ambiguity
  - Can be wrong



The Ames room

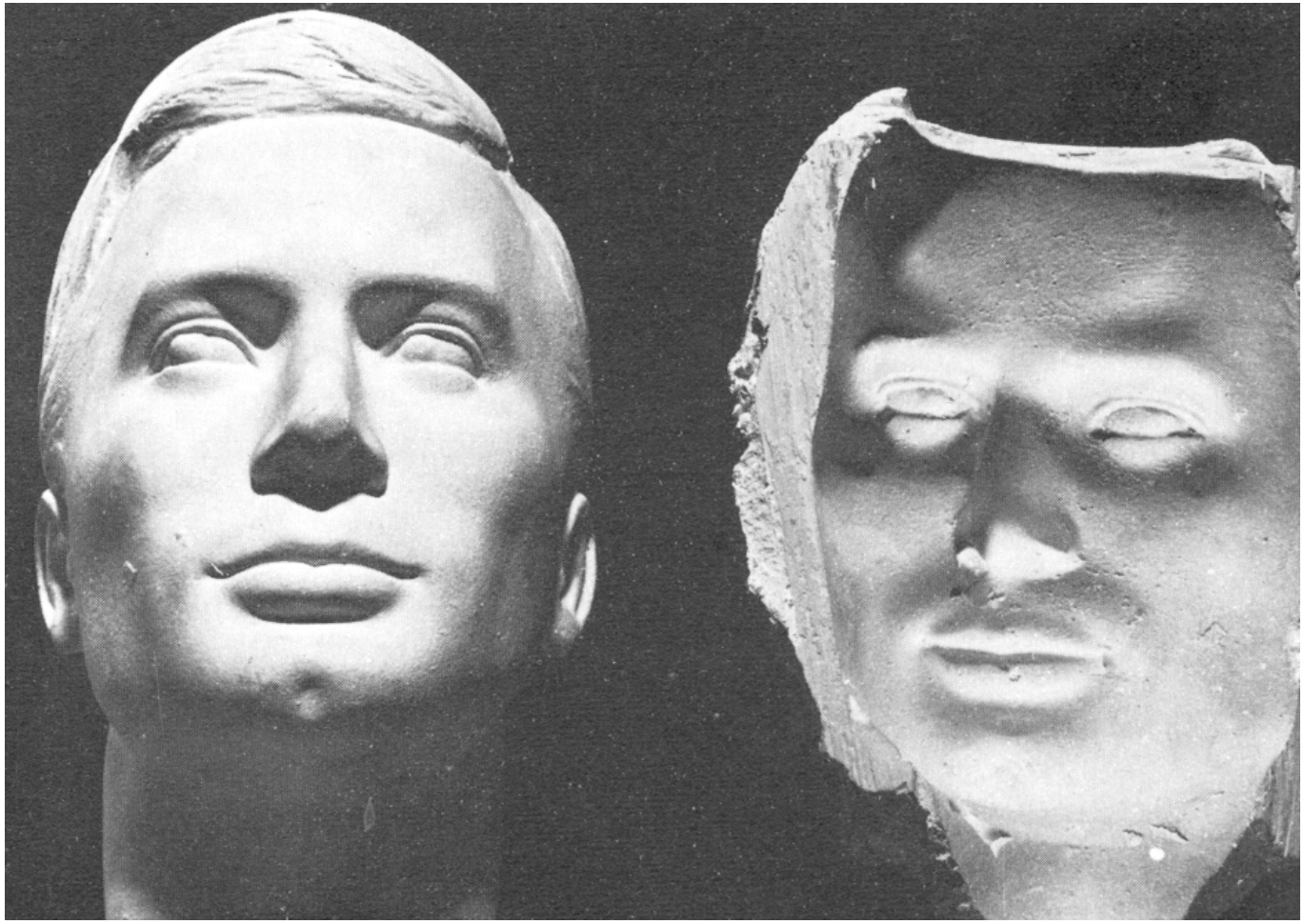
- Invalid assumption
  - Walls perpendicular
- Wrong conclusions
  - Men have different sizes





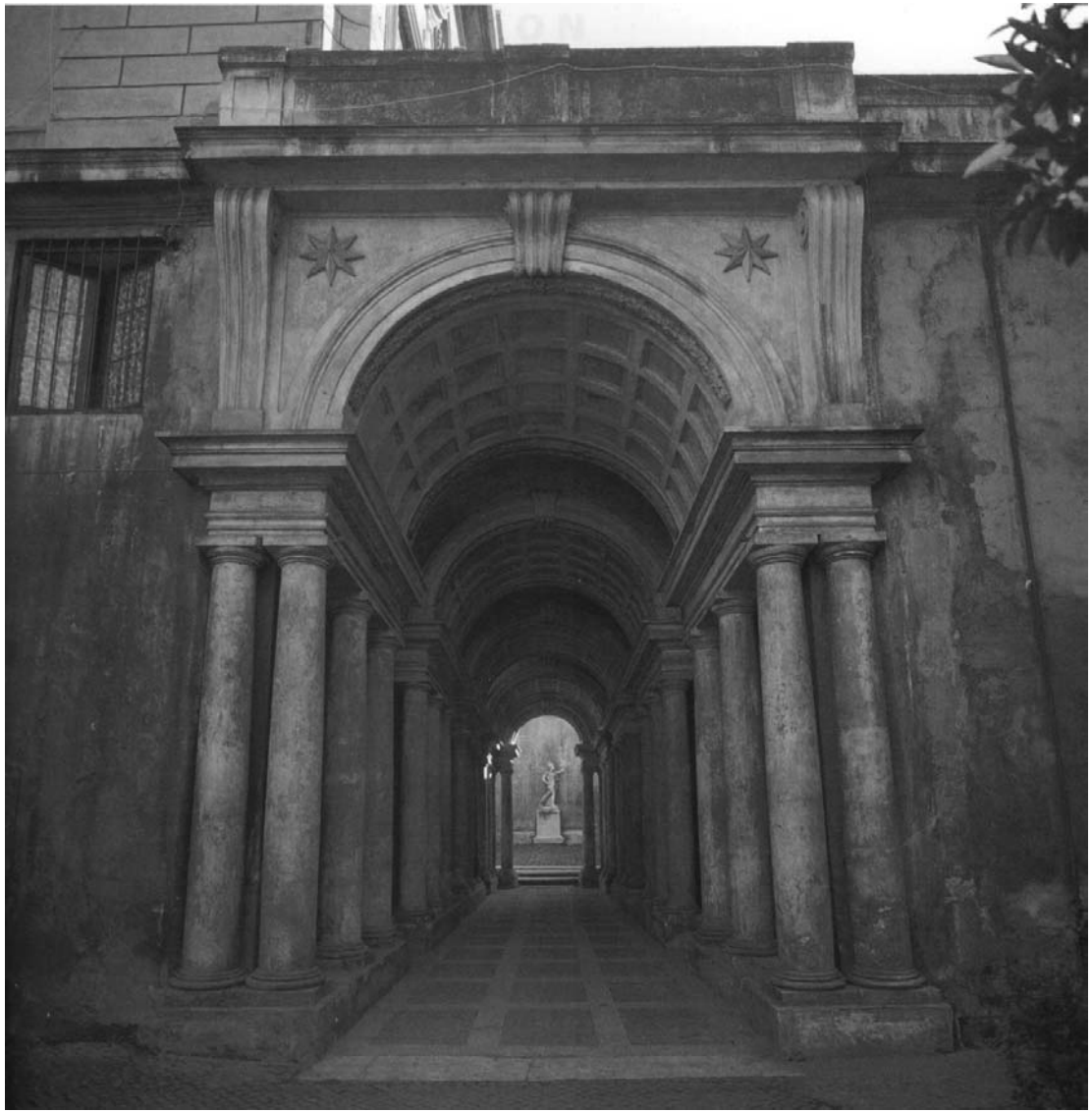
Positive and hollow face

- Both seen convex because hollow faces are rare!



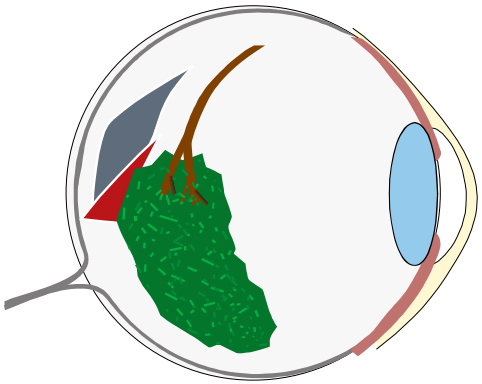
Constancy & architecture

- Palazzo Spada in Rome (by Boromini)
- Short corridor
- Column size decreases
- Appears longer

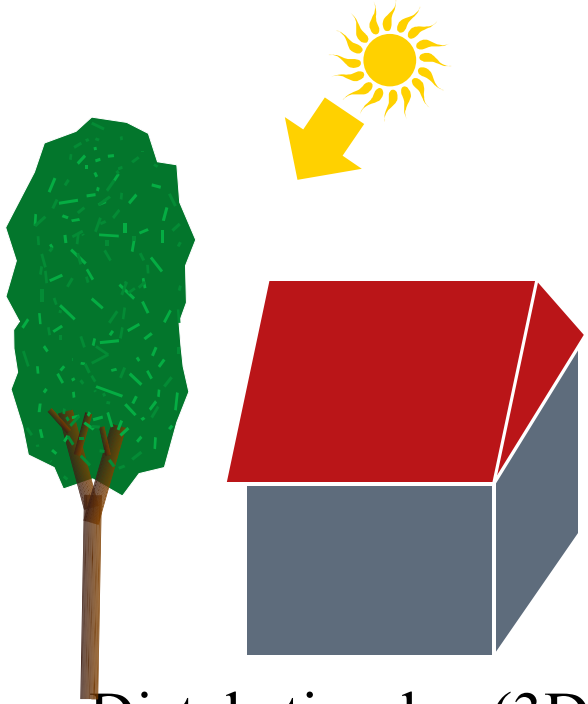


The paradox of vision

- Available information: proximal stimulus
- Conscious information: distal stimulus



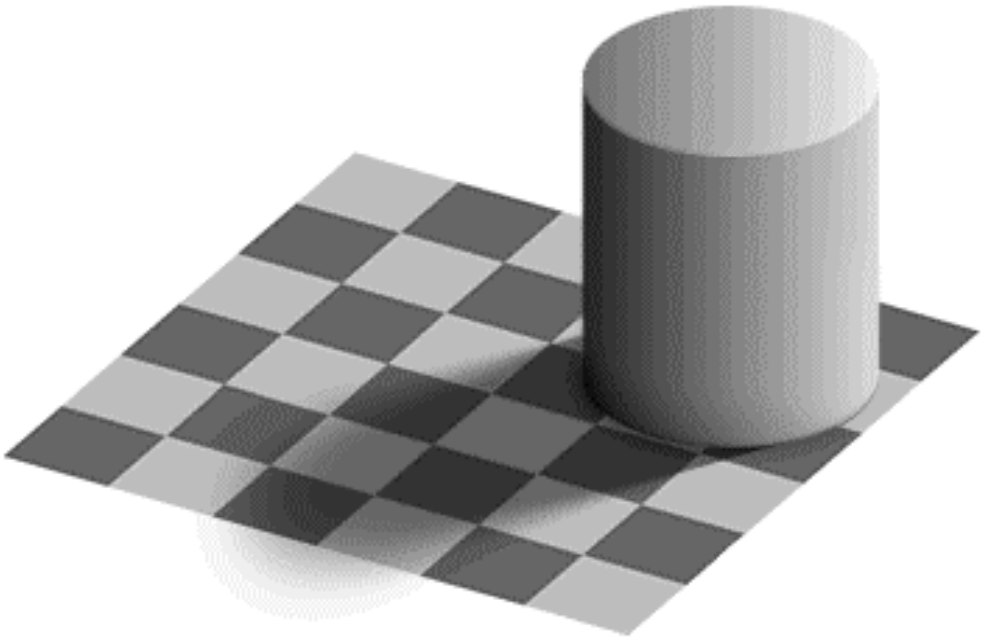
proximal stimulus (2D)



Distal stimulus (3D)

Brightness vs. lightness

- Brightness: subjective amount of light
- Lightness: how “white”

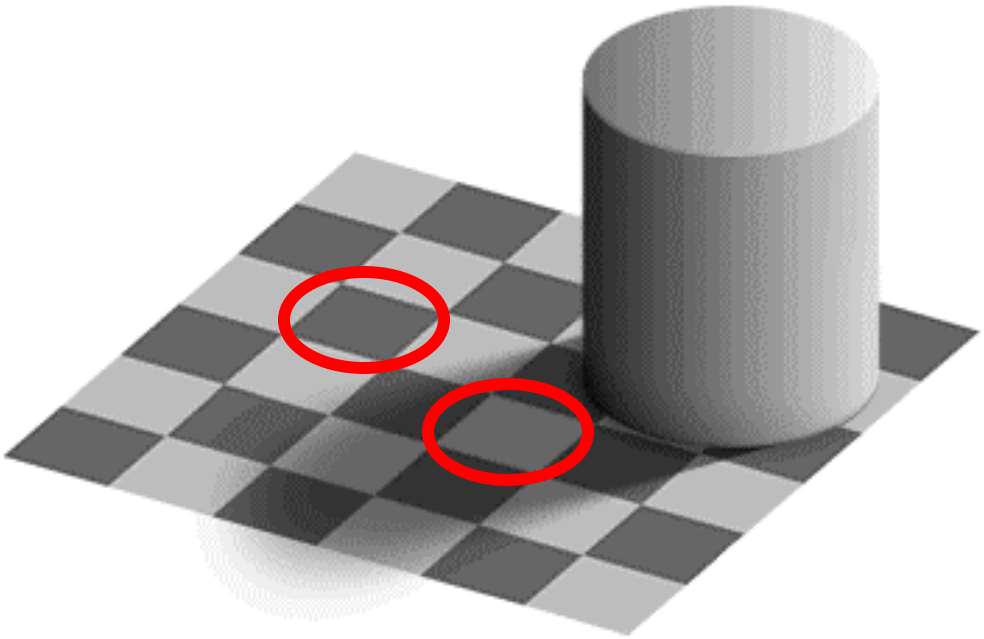


Illusion by
Ted Adelson

The white cells in shadow are as dark
as the black illuminated cells

Brightness vs. lightness

- Brightness: subjective amount of light
- Lightness: how “white”



The white cells in shadow are as dark as the black illuminated cells

Brightness vs. lightness

- Brightness: subjective amount of light
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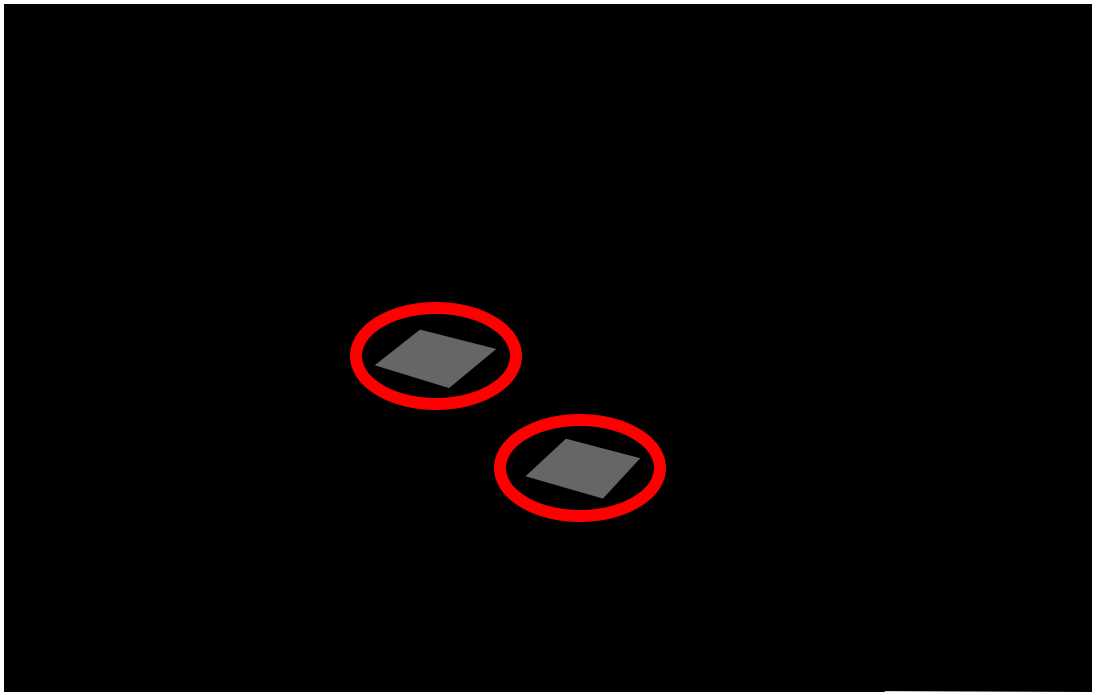


The white cells in shadow are as dark as the black illuminated cells

Pictures and the inverse problem

- Pictures can
  - Simplify the analysis
  - Be a puzzle, a riddle

Plan

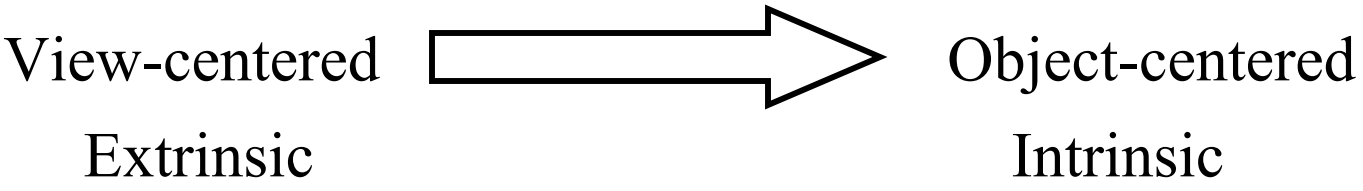
- Vision as an cognitive process
- Computational theory of vision
- Complex mapping

Vision as information processing

- Input: retinal image
- Output: 3D layout, object recognition, etc.

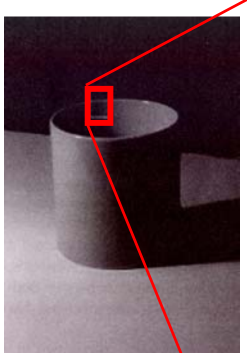
Computational theory of vision

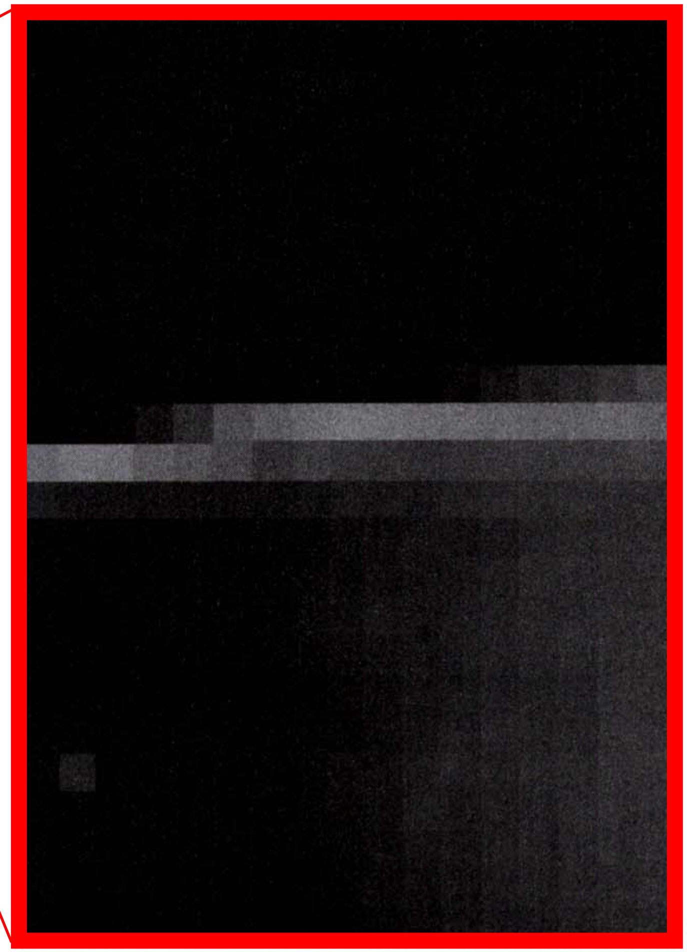
- Marr's stages (extended by Palmer et al.)
- Human and Computer Vision
- Classification of different kinds of processes
- Has proved fruitful in art studies



Retinal image

- Intensity: hard to comprehend





Retinal Image

B

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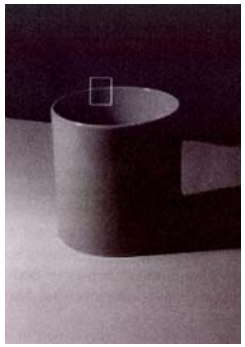
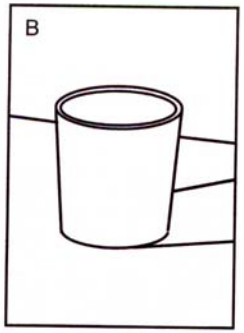
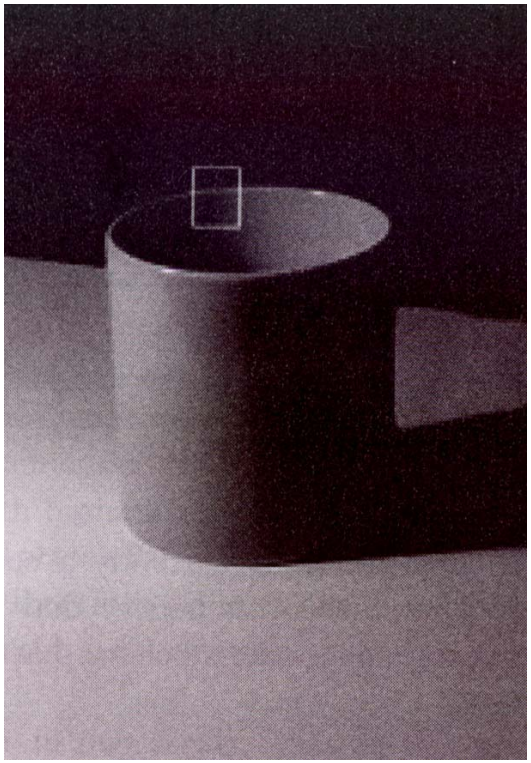
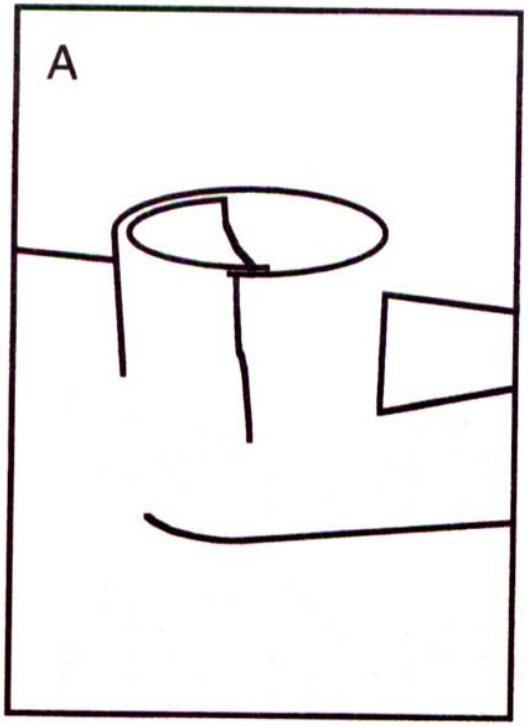
Image-based (primary sketch)

- Contrast, edge detection
- Not so easy







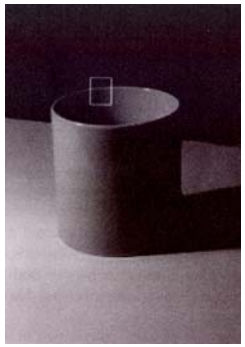


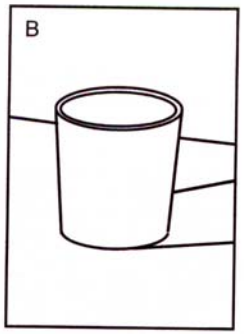
Raw edge detection

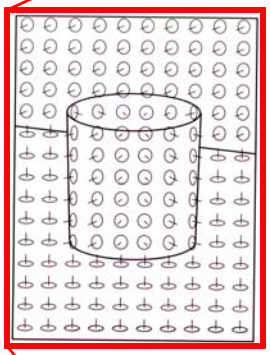
Retinal Image → Image-based processing

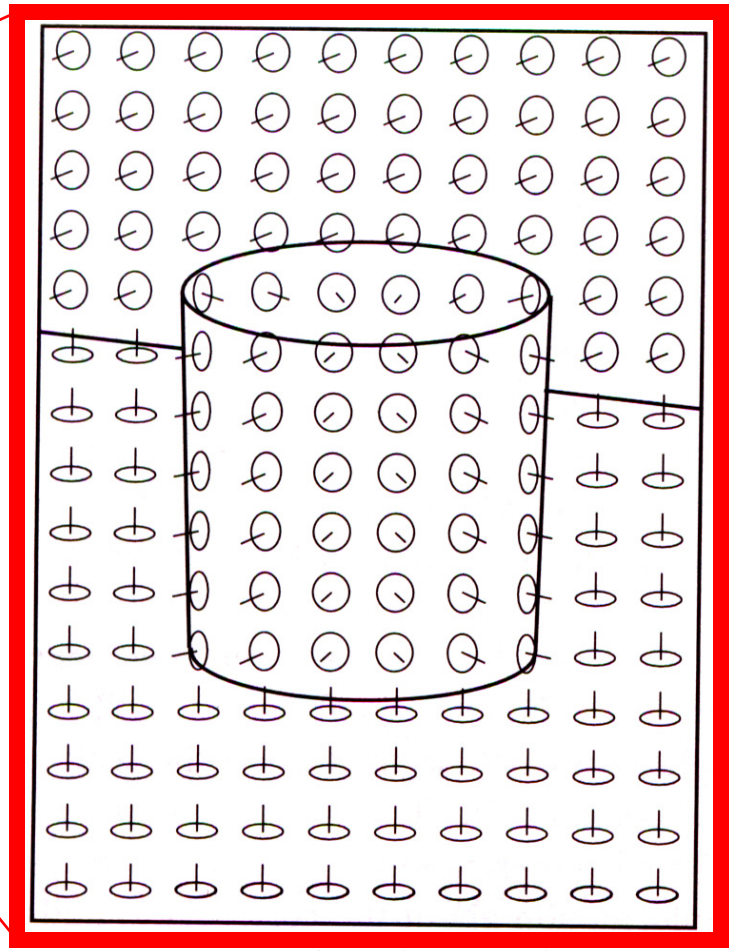
Surface-based

- Visible surfaces, organization
- Distance, orientation







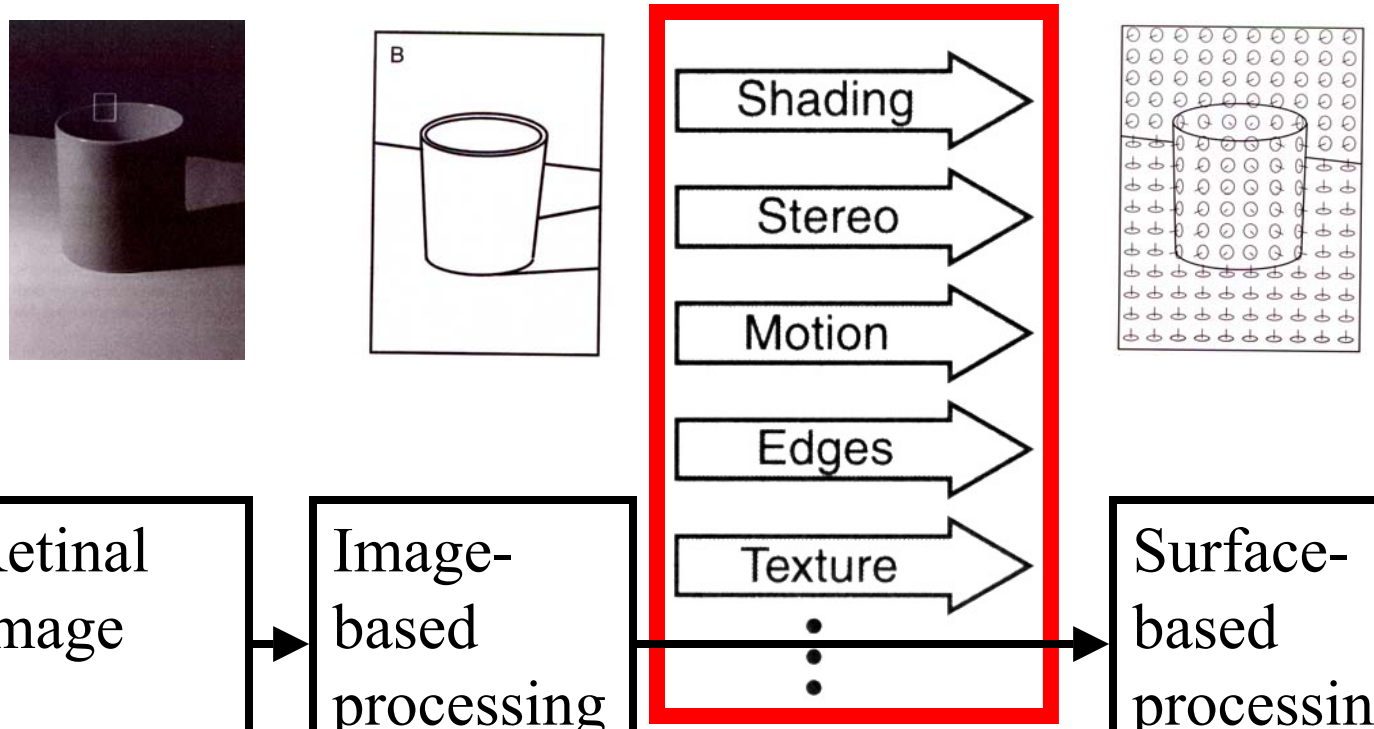


Retinal Image → Image-based processing → Surface-based processing

Local orientation

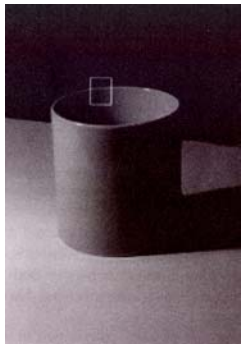
Surface-based

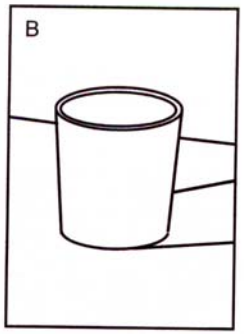
- Visible surfaces, organization
- Distance, orientation

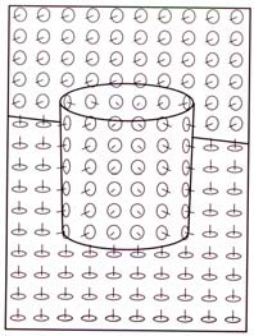


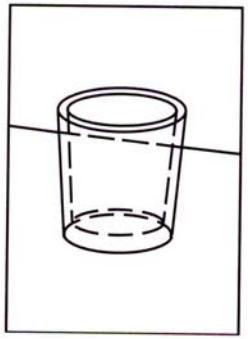
Object-based

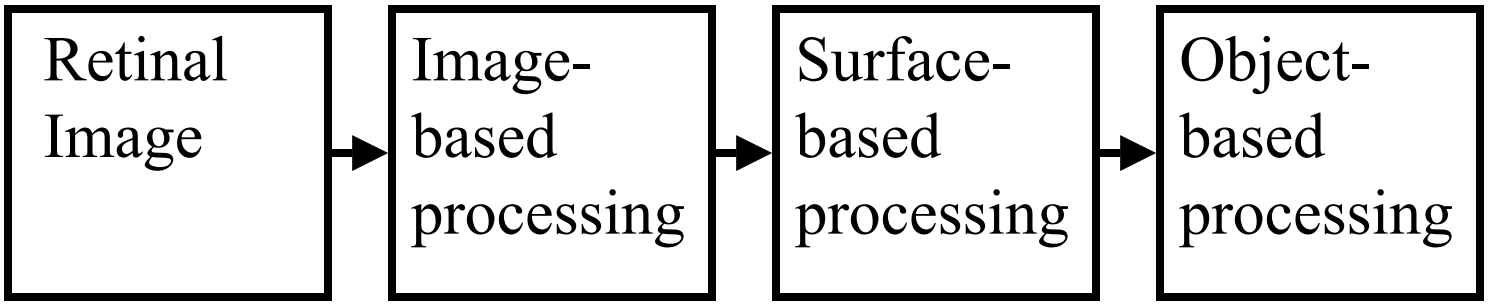
- 3D properties, structure
- Nature of the description highly discussed





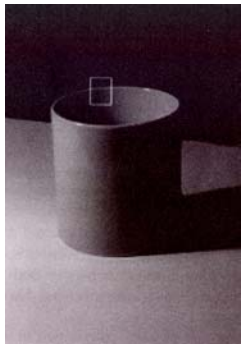


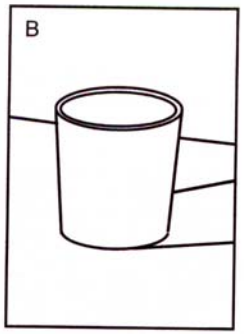


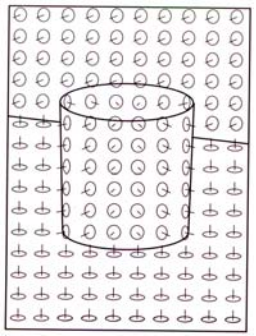


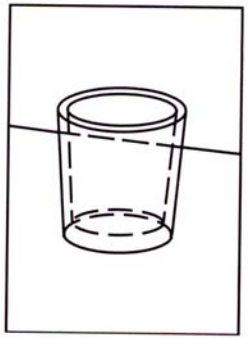
Category-based

- Recognition, category, function

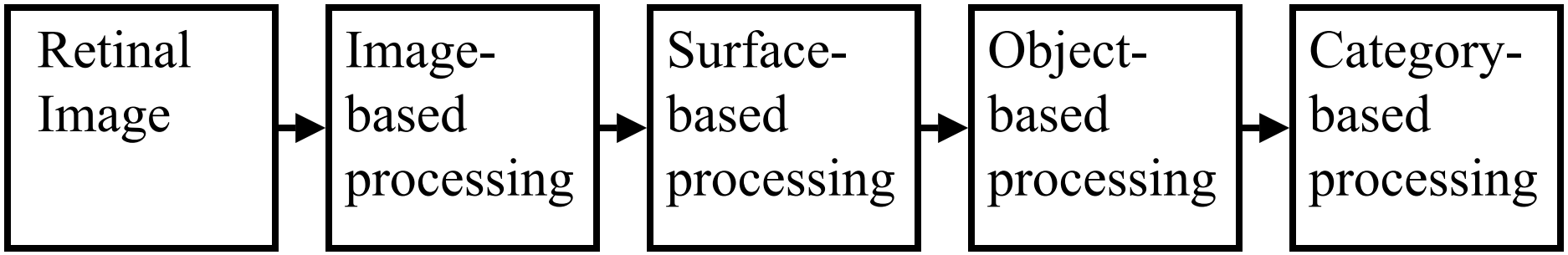






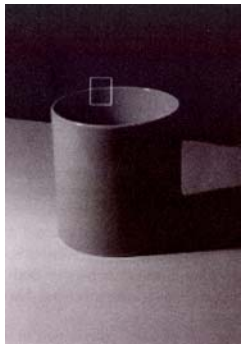


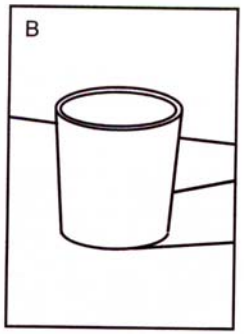
Cup

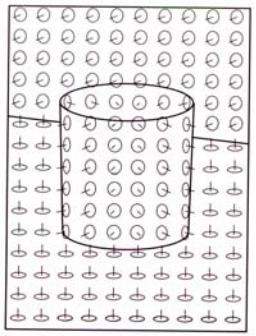


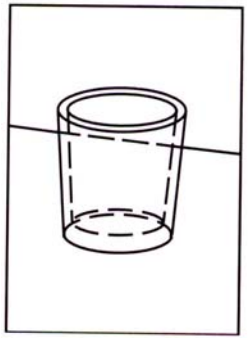
Feedback

- Bottom-up and top-bottom

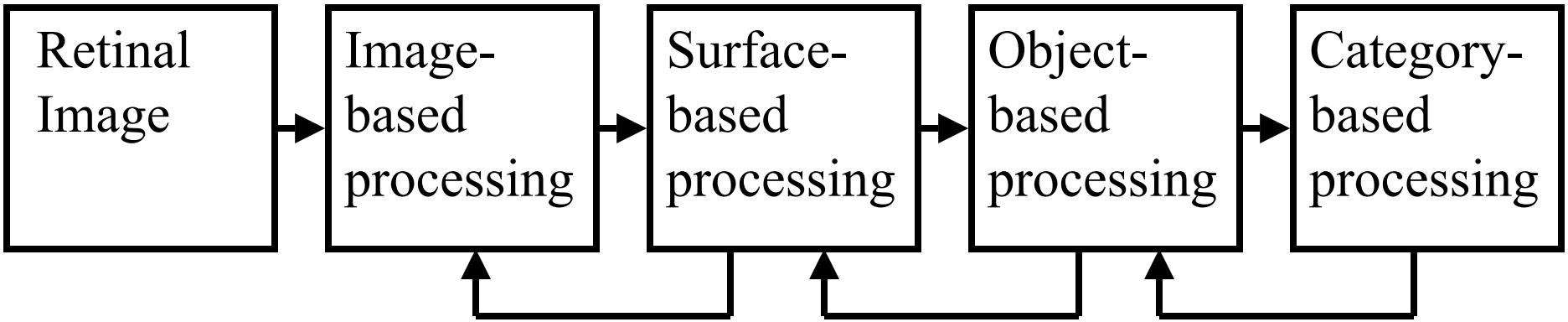






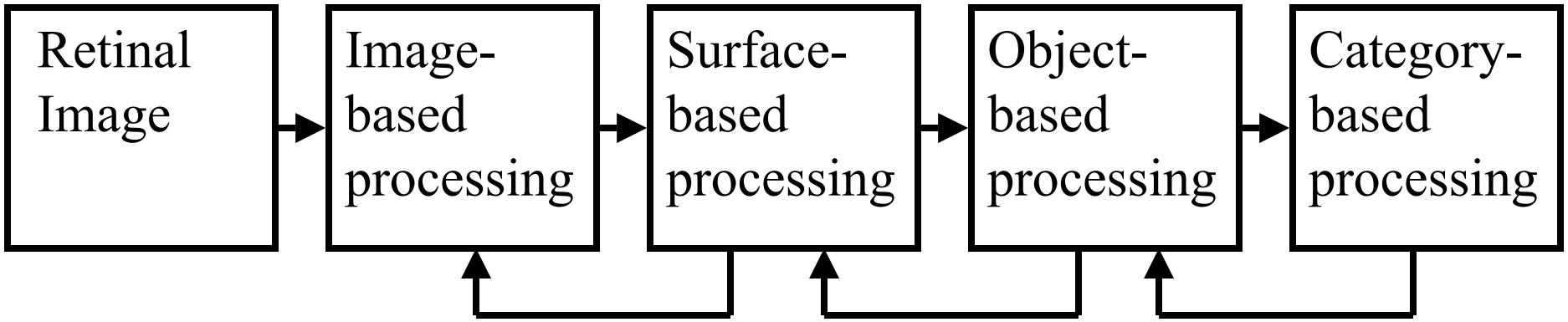


Cup



Scope of the theory

- Computer Vision
- Human Vision
- No direct correspondence in the brain
- Has proved fruitful conceptual tool



Relation to children drawing

- First children draw what they know
  - Object-centered
- Then, what they see
  - View-centered

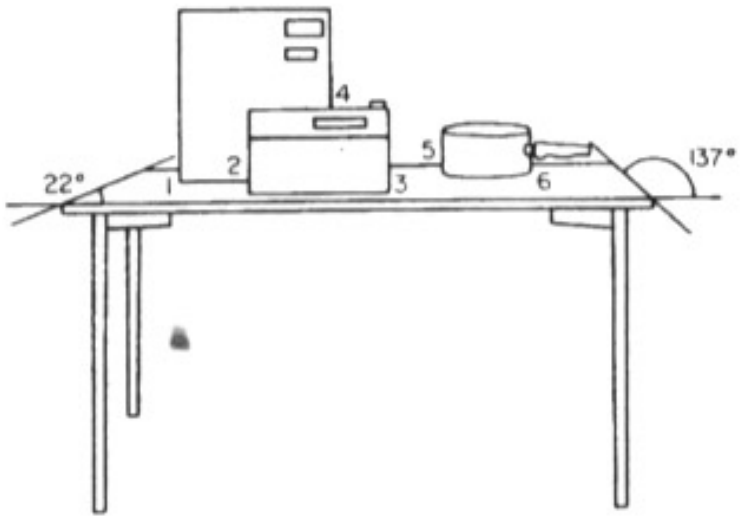
Age 5

Age 9 (gifted!)

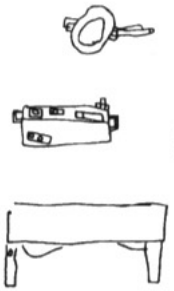
Evolution of children's drawings

- Asked to draw a table
- First, draw what they know
- Later, what they see

Child's view



Class of drawing & average age



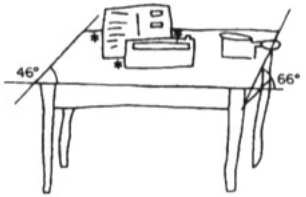
b

7.4

9.7

d

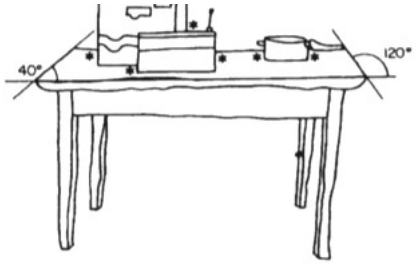
11.9



13.6

f

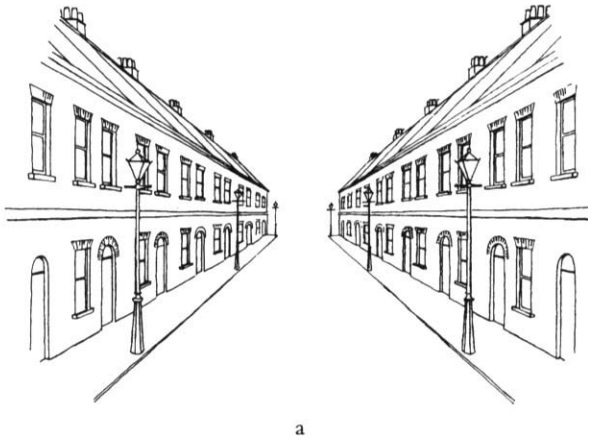
14.3

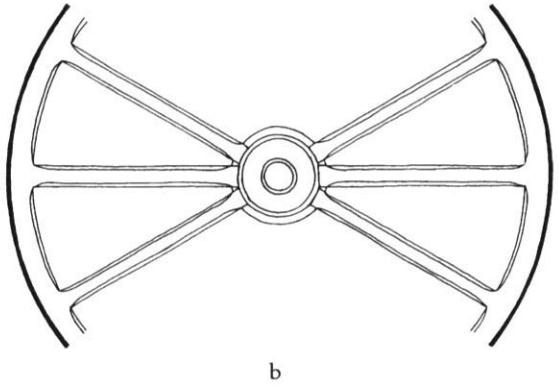


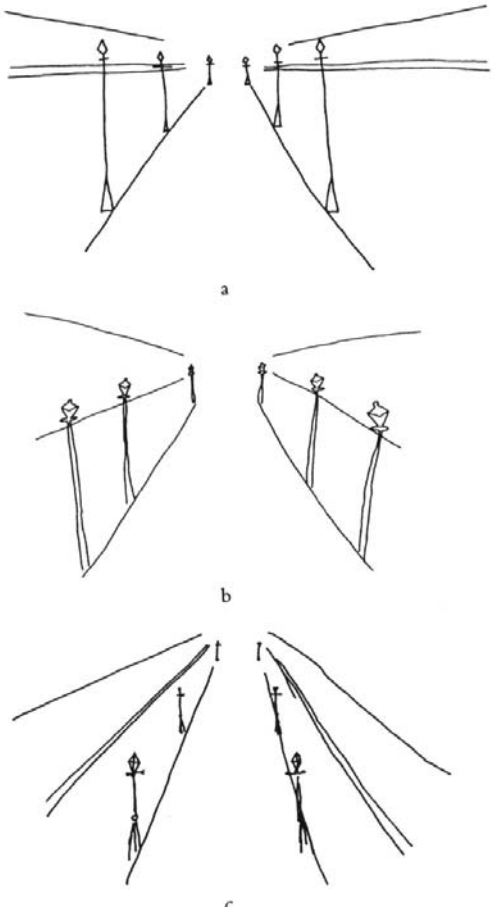
13.7

What about adults?

- Reproduce two drawing with similar angles
- Wheel:
  - Accuracy ~5°
- Street:
  - Error: 32 °







- Because in the first case, they focus on the 3D (distal) interpretation

Drawing reproduction

- *Drawing on the right side of the brain,* Edwards
- Advises to reproduce drawings upside down
- Distal interpretation does not impede
- Forgers often reproduce paintings upside-down

Original Picasso drawing

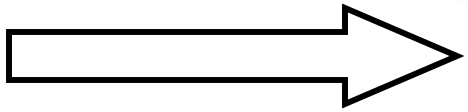
Reproduction

Reproduction upside-down

Relation to pictures

- Different classes of pictures for different stages
- Not a strict classification

View-centered
Extrinsic

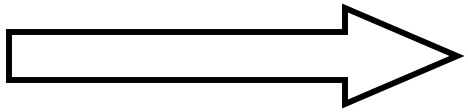


Object-centered
Intrinsic

Relation to pictures

- Chinese painting refuse extrinsic, only essential
- No shadow

View-centered
Extrinsic



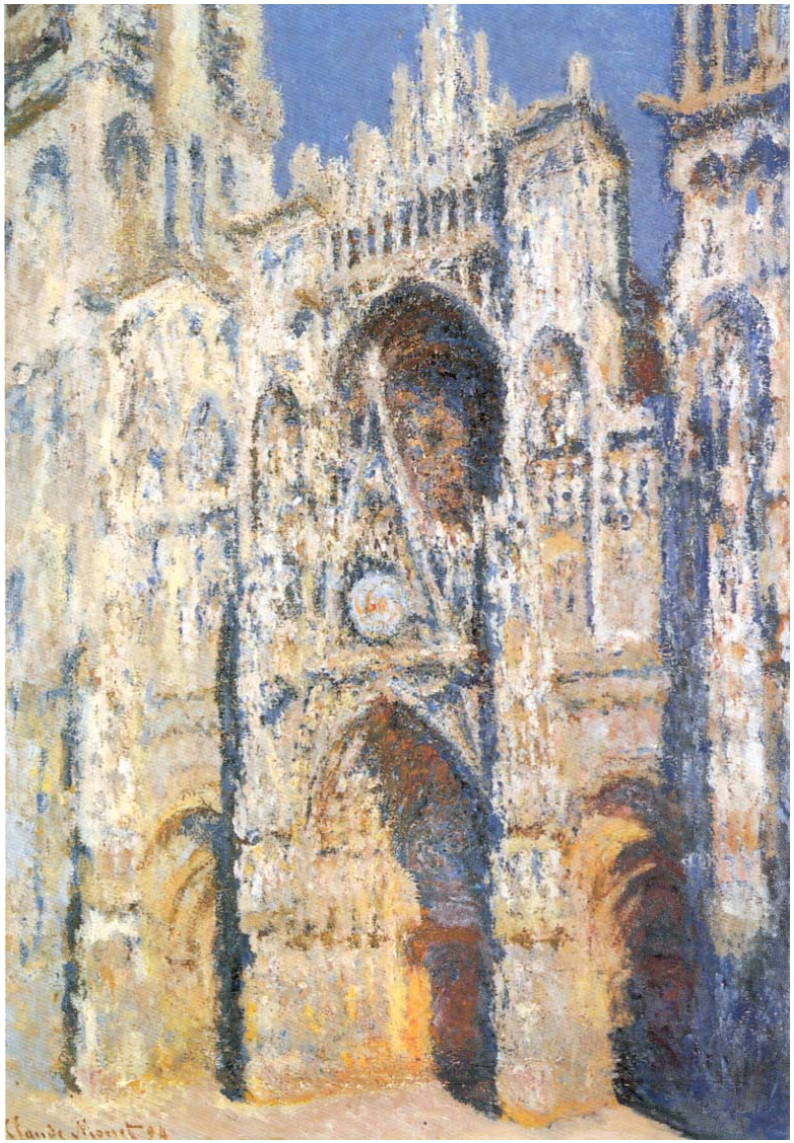
Object-centered
Intrinsic

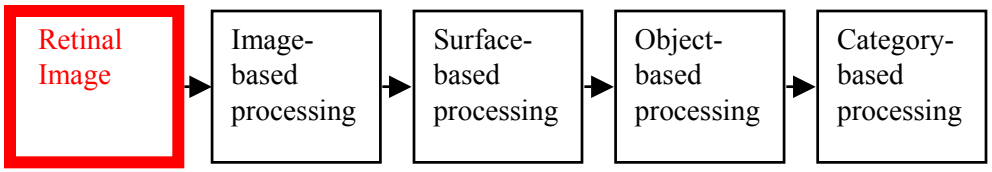
Retinal image

- Turner
- “My business is to paint not what I know, but what I see”

Retinal image

- Impressionism





Retinal image

- Impressionism
- Photography

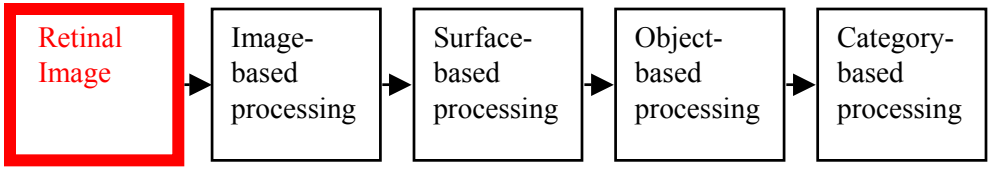
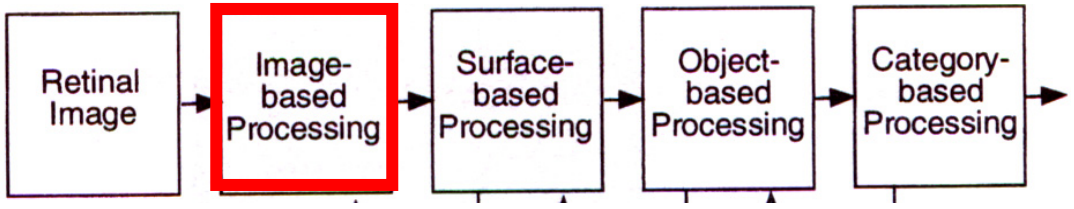


Image-based

- Line Drawing
- Rivera



Intrinsic vs. Extrinsic

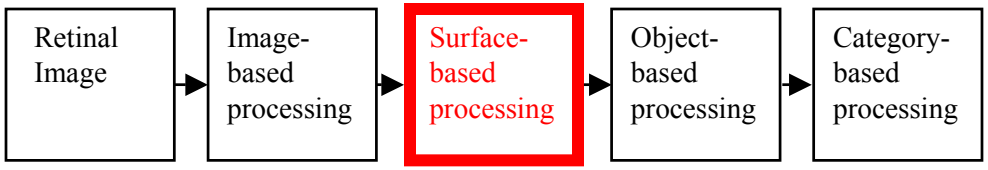
- Visual angle vs. true size
- Caravaggio:
  Wrong geometrically
  but looks good

Intrinsic vs. Extrinsic

- Visual angle vs. true size
- Vermeer:
  too accurate to be true!

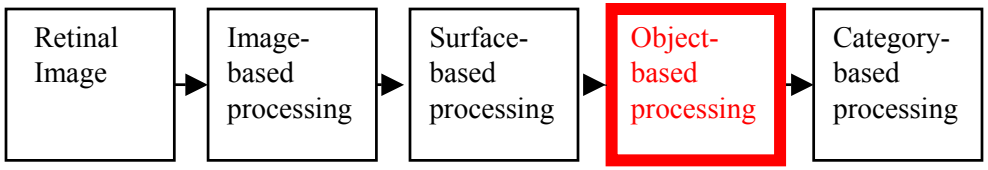
Intermediate

- View-based
- Cues for surface-based feature extraction are enhanced
  - Depth cues
  - Orientation cues
- No subjective feature (e.g. lighting)



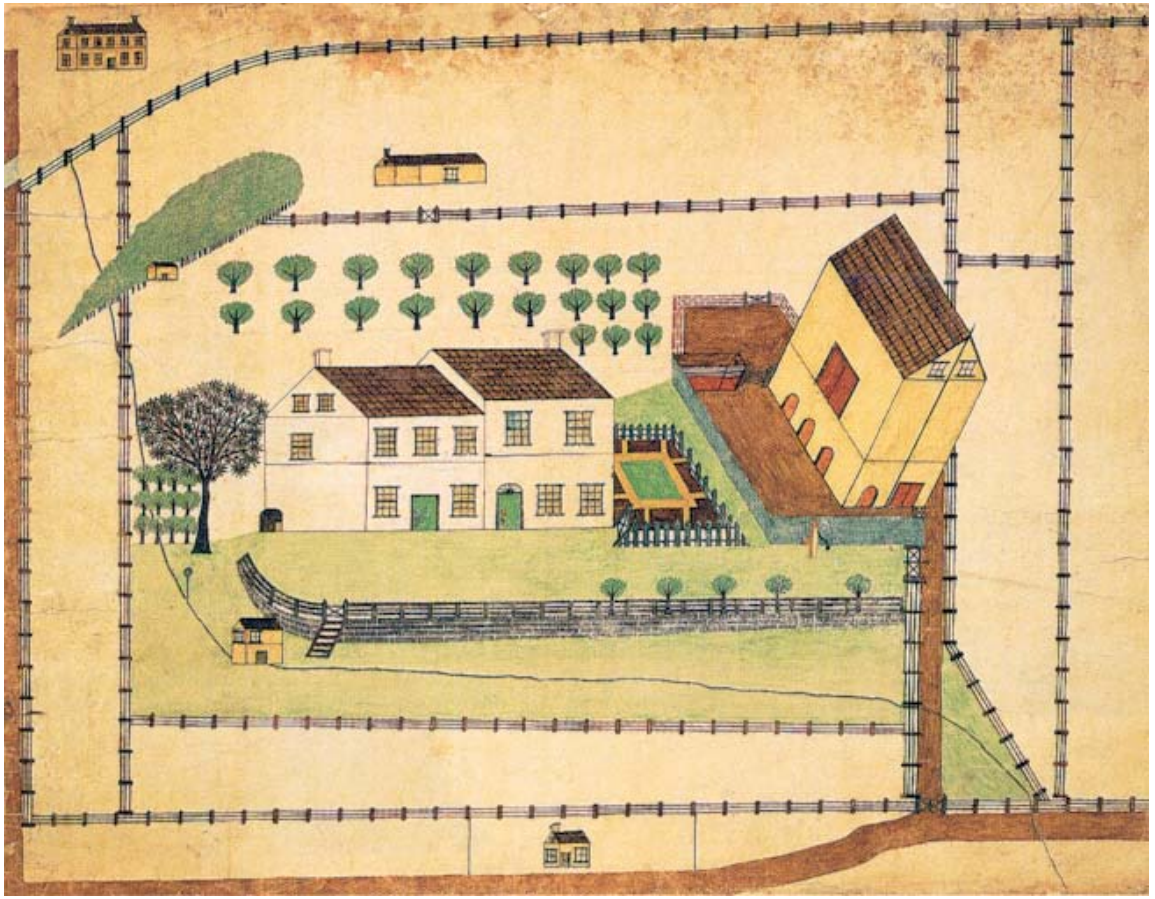
Higher level

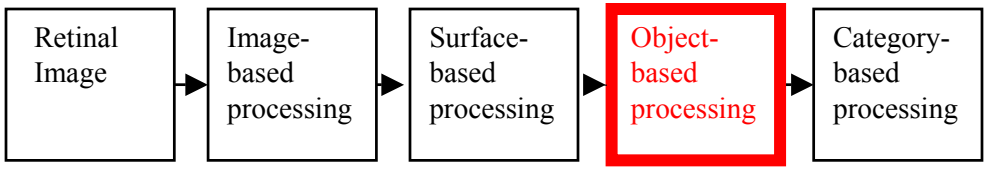
- Primitive art
- Cubism
- Schema
- “What I know”



Higher level

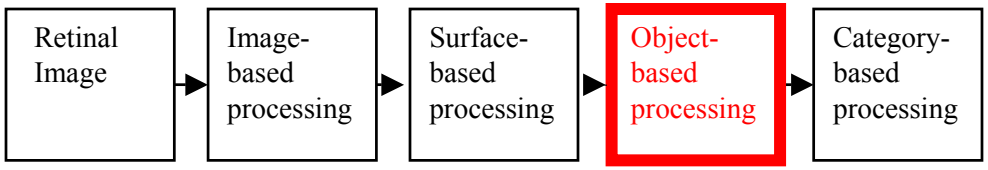
- Primitive art
- Cubism
- Schema
- "What I know"





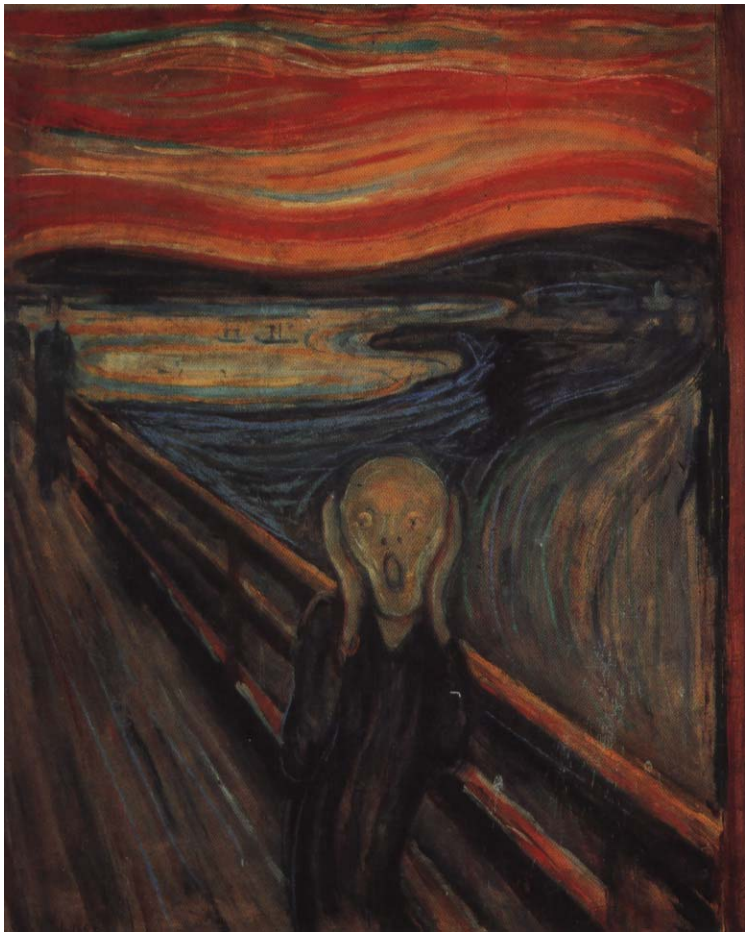
Higher level

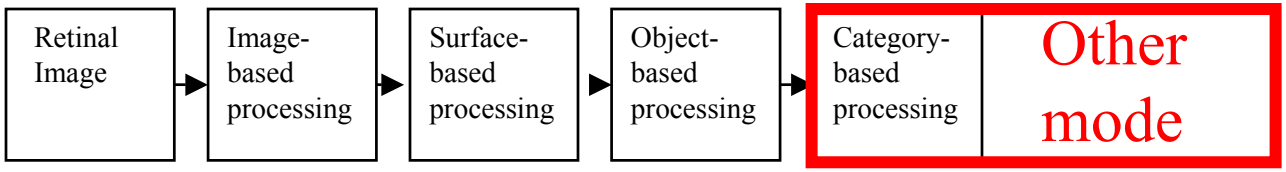
- Primitive art
- Cubism
- Schema
- "What I know"



Expressionism

- "What I feel"





Relation with 2D/3D emphasis

- Almost the opposite!
- 3D impression corresponds to retinal image
- 2D quality arises from higher-level pictures
- Because of vision paradox
  - Distal is seen when proximal is shown

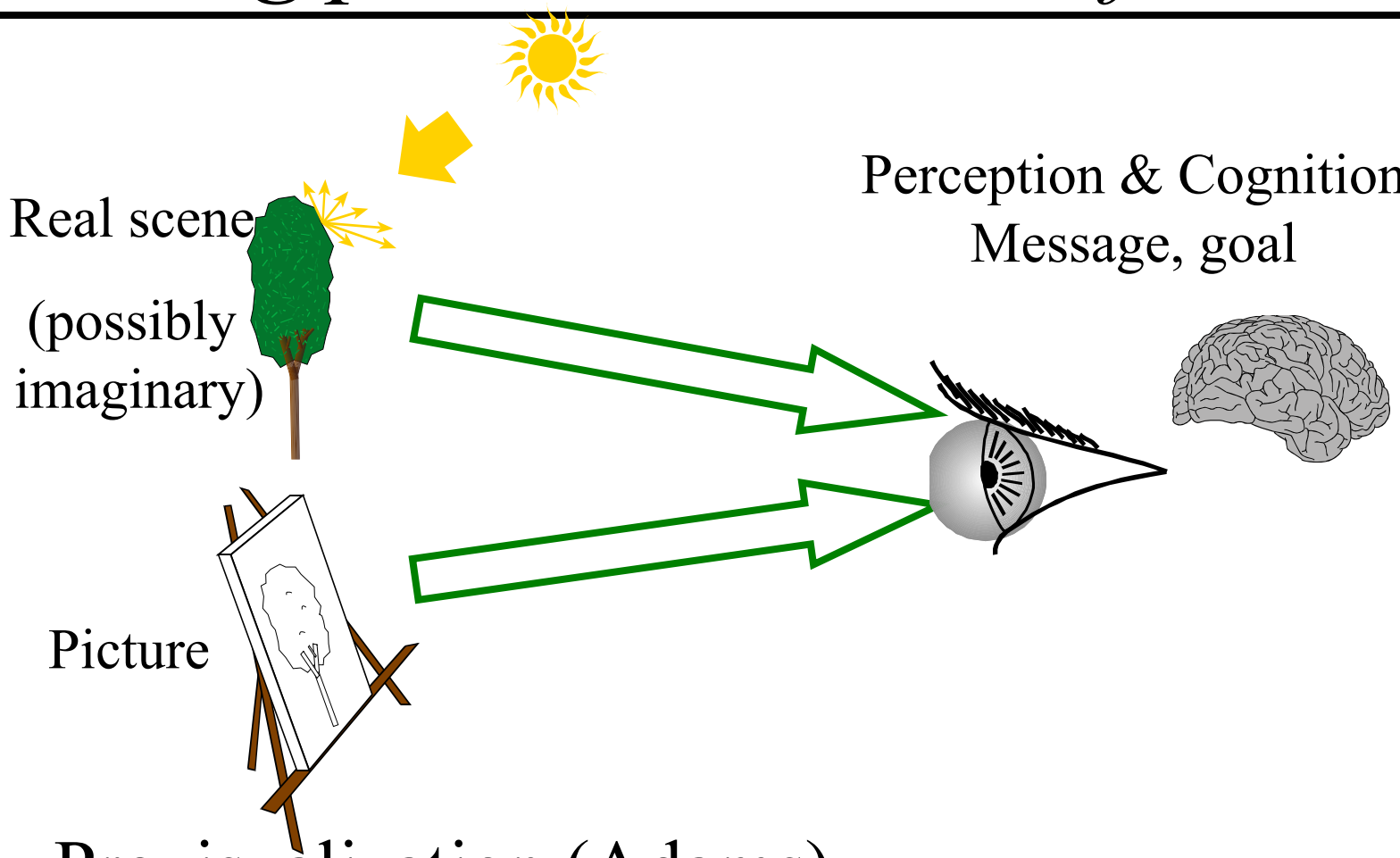
Relation with 2D/3D qualities

- 3D impression but Retinal image

Relation with 2D/3D qualities

- 2D emphasis but Higher level

Making pictures: inverse of inverse



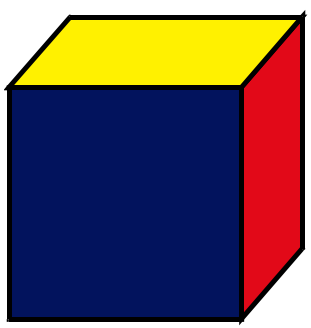
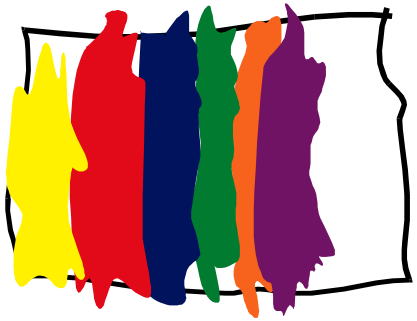
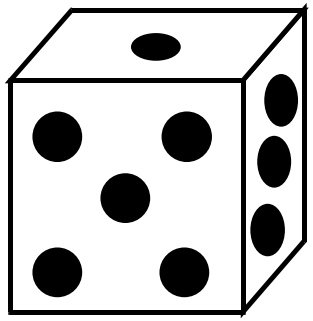
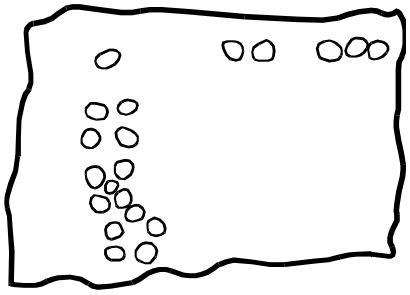
- Previsualization (Adams)
- Solving the direct problem is a good start, but…

Plan

- Vision as an cognitive process
- Computational theory of vision
- Complex mapping

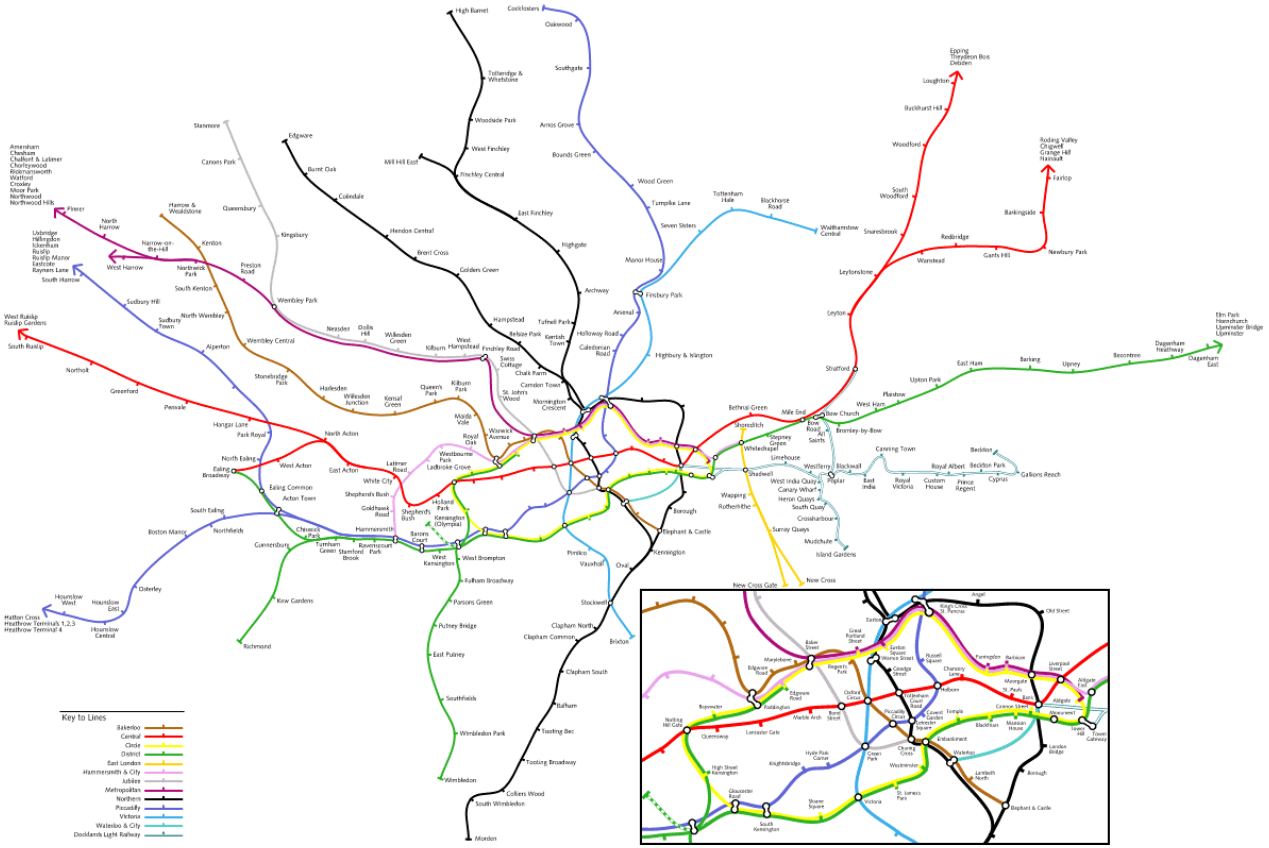
3D and 2D attributes

- [Willats 97]
- Show coloured or numbered die to children (6-7)
- The still draw a rectangle
- But different colours or many points
- The rectangle stands for the whole dice
- The notion of 3D object with corners is translated as a 2D object with corners

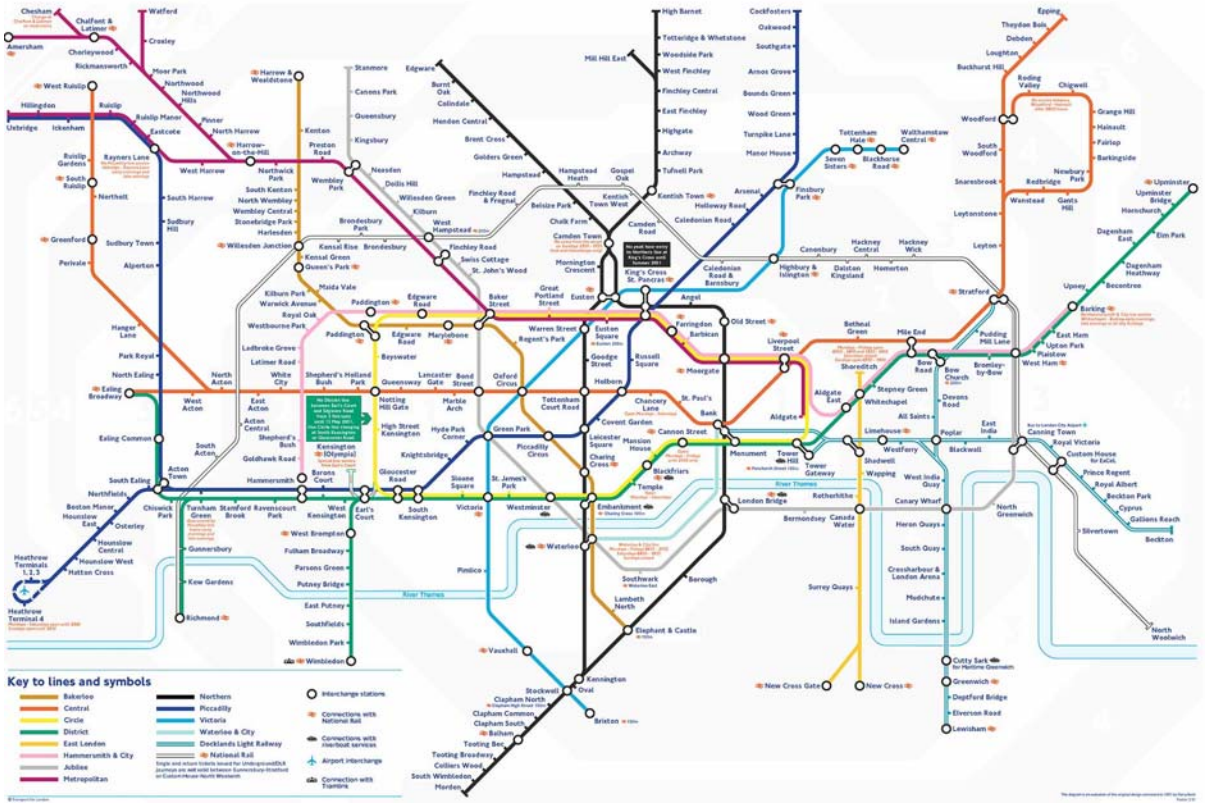
Projection: Topographical

- London underground
- Metric properties are used



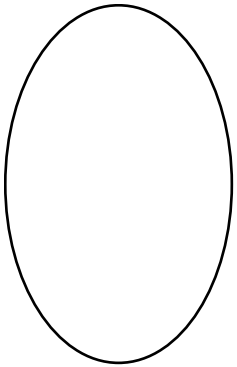
Projection: Topological

- Beck's map of London underground, 1931
- Only the connectedness and organization are preserved
- [Agrawala, in this volume]

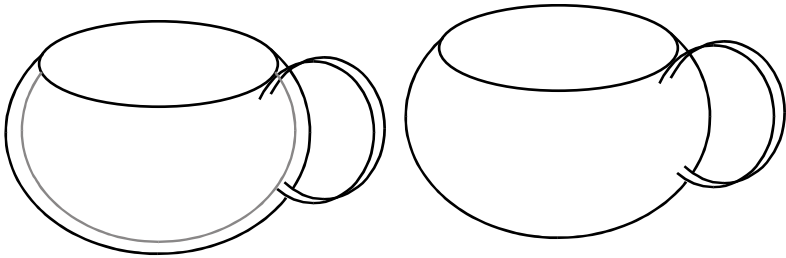


Mapping of curvature

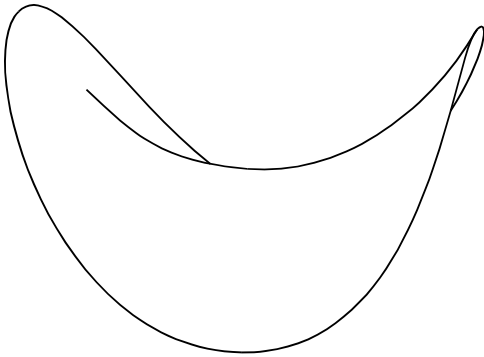
- Convex: positive curvature
  - 3D example: Egg
  - 2D: Convex contour



- Concave: negative curvature
  - 3D example: Interior of cup
  - 2D: Nothing, hidden contour

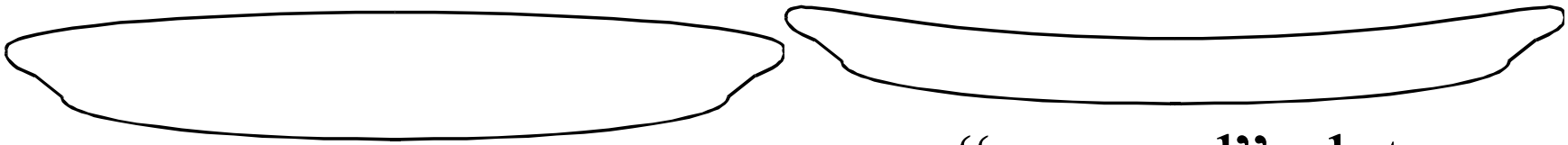


- Saddle: mix of positive and negative curvature
  - 3D example:Saddle (surprising!)
  - 2D: Concave contour



Mapping of curvature

- But some artists map 3D concave objects to 2D concave outlines
- This maps the property of concavity
- The left view of the plate is more “correct” but does not convey the notion of concavity

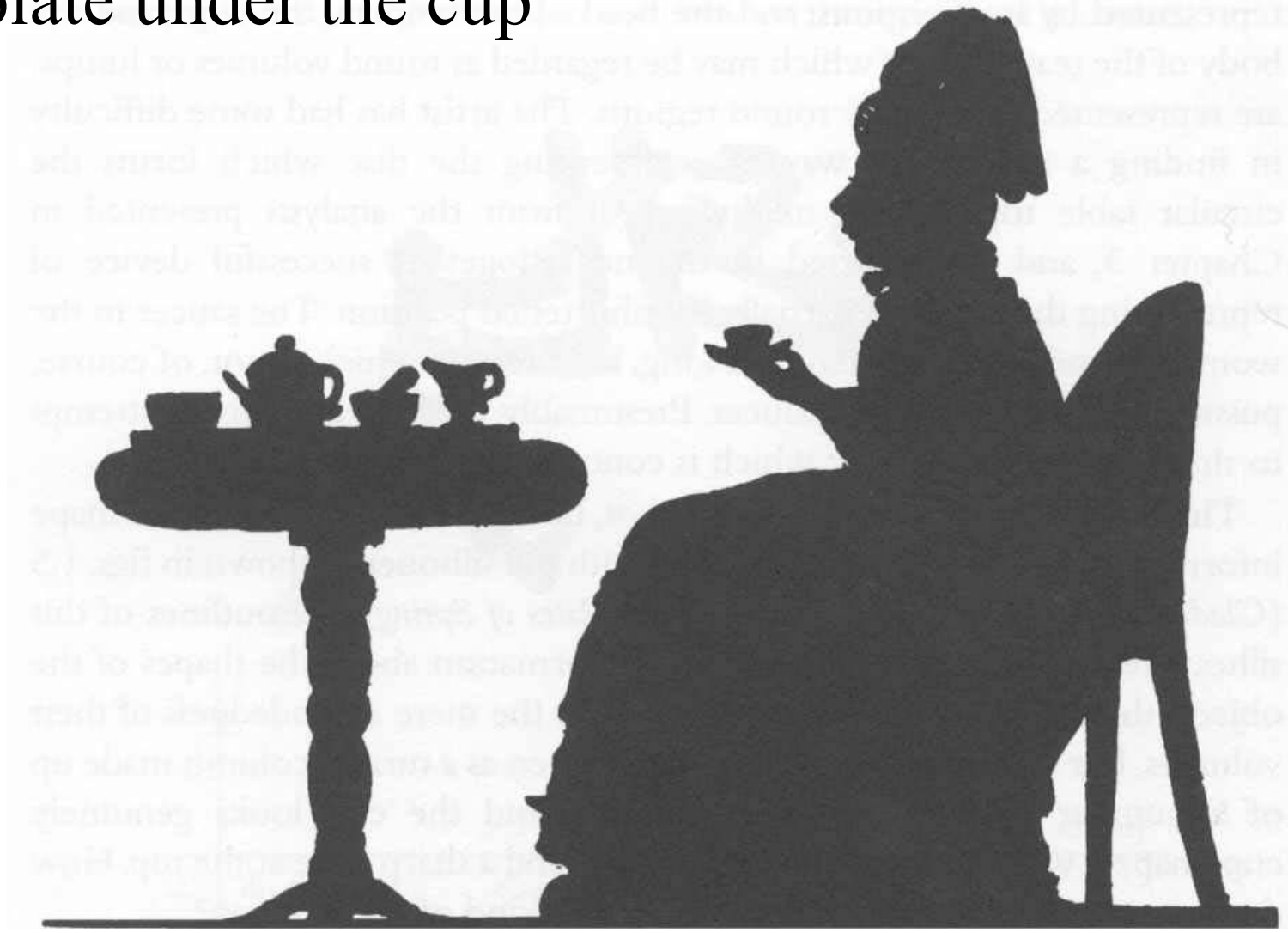


“projective” plate

“mapped” plate

Mapping of curvature

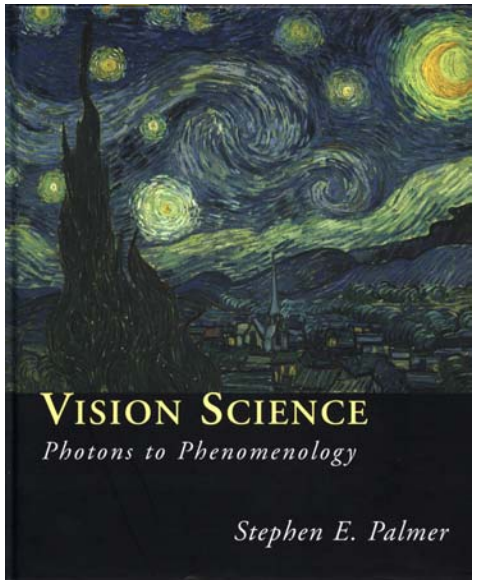
- Small plate under the cup

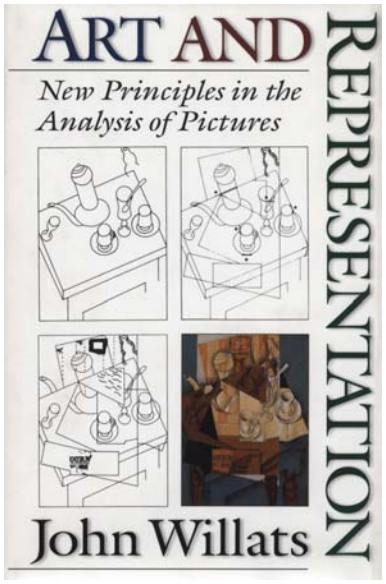


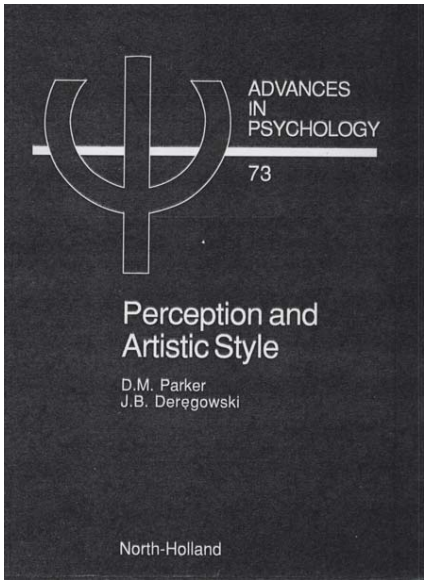
Mapping of curvature

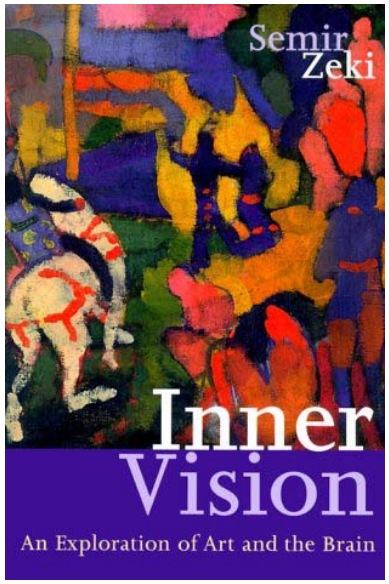
- Complex denotation
- See [Durand, page 15]

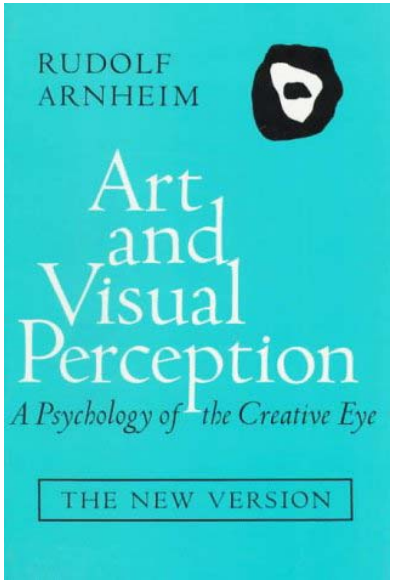
Further reading











Further reading

- Calvin & Hobbes by Watterson !