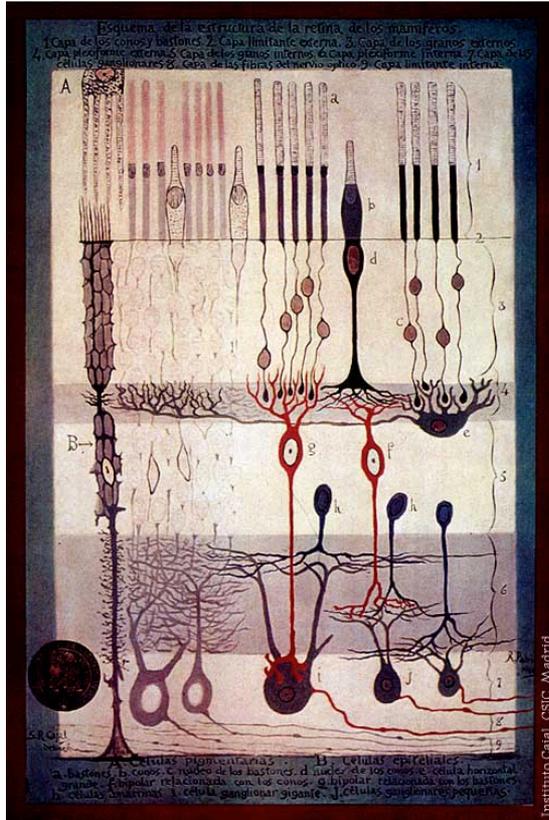
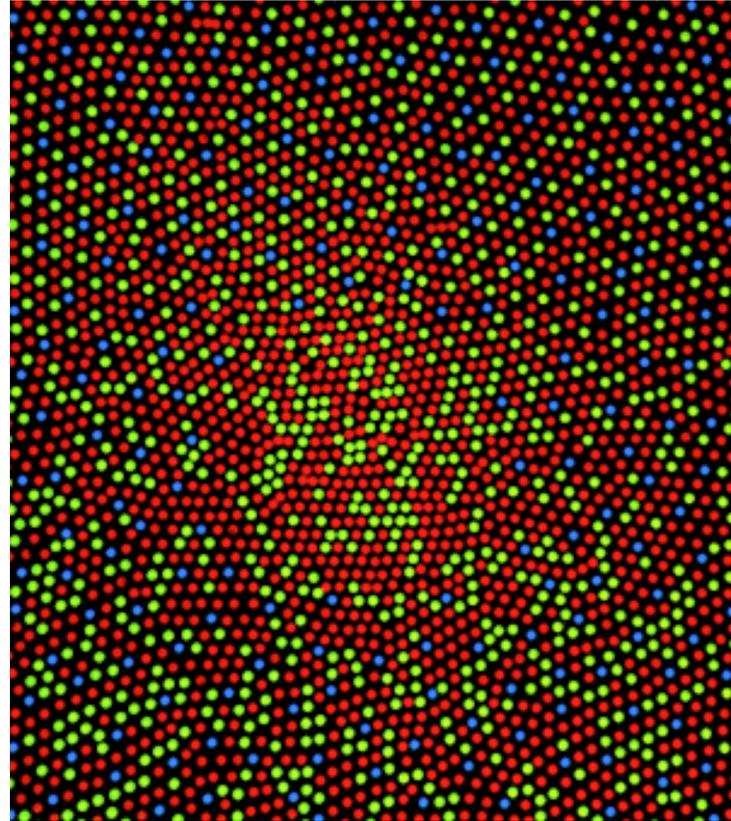
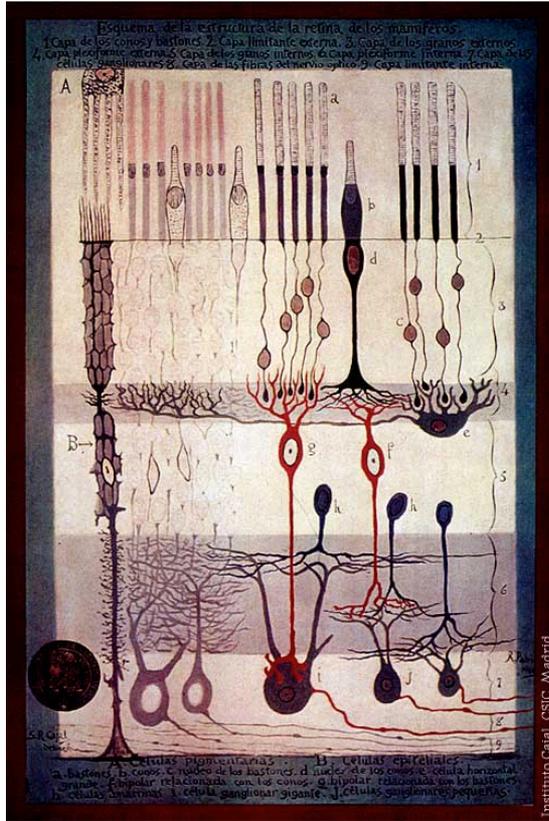


# Origins of structure in perception

Sarah Schwettmann  
Vision in Art and Neuroscience  
2020







# Perception as an inverse problem

Pizlo 2000

“perception is about inferring the properties of the distal stimulus  $X$  given the proximal stimulus  $Y$ ”

$$Y = AX$$



$$X = A^{-1}Y$$

where

$Y$  is the proximal stimulus (e.g. retinal image)

$X$  is the distal stimulus (e.g. 3D object)

$A$  is a perspective mapping (linear transformation)

ill-posed, determining a  
unique  $A^{-1}$  is difficult

many different things could have created the same retinal image (e.g. of a cube)

to solve:  $X = A^{-1}Y$

constraints!

(but even then, is the percept veridical?)

# The Beholder's Share<sup>1</sup>

Koenderink 2012:

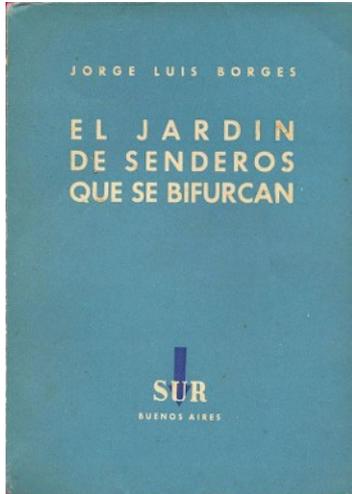
QUESTION: Is perception like a bundle of possible visual worlds (then the observer apparently abstains from a final – precognitive – decision) or is it like a single visual world (the observer really “sticks the neck out”) ?

← “many visual worlds” hypothesis

In other words, do observers resolve ambiguities when not required for an action or decision?

<sup>1</sup>Gombridge E H, 1959 Art and Illusion Part III The Beholder's Share (London: Phaidon Press)

QUESTION: Is perception like a bundle of possible visual worlds (then the observer apparently abstains from a final – precognitive – decision) or is it like a single visual world (the observer really “sticks the neck out”)?



I think that in a great many cases perceptions are more of the many visual worlds variety than like the single guess. You don't notice this in the laboratory because most psychophysical methods *force a unique response*. They simulate the decisions-in-action of daily life. That you don't notice the essential ambiguity of perception in real life is most likely due to the fact that you don't need to take decisions on issues on which no actions will be taken anyway. That the many visual worlds option is indeed likely is suggested by the fact that a change of psychophysical method or task often leads to distinctly different results. This is not to say that observers actually entertain many visual worlds interpretations explicitly, but merely that they don't necessarily resolve ambiguities when this is not specifically required for some action or decision.

*Multiple Worlds* (2012)

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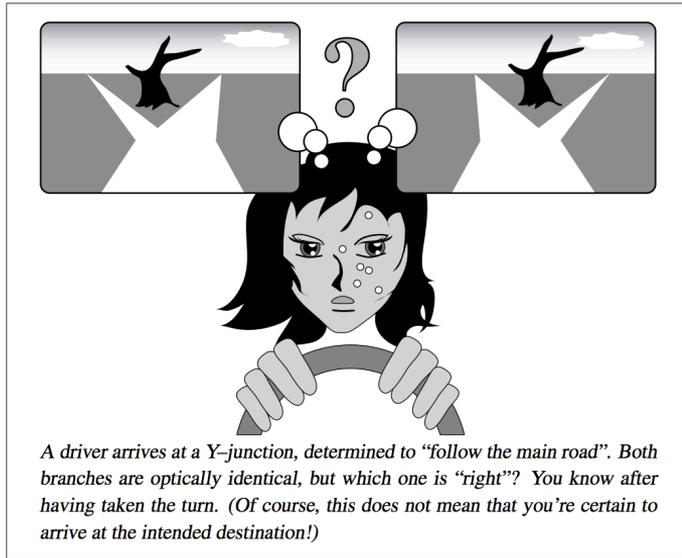
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**Consciousness: facing the consequences of decisions-in-action? (Schrodinger)**

Koenderink

QUESTION: Is perception like a bundle of possible visual worlds (then the observer apparently abstains from a final – precognitive – decision) or is it like a single visual world (the observer really “sticks the neck out”)?



Before I made the decision-in-action at the Y-junction my percept was undefined (multiple visual worlds), after my decision it became history, part of my mental make up. The multiple worlds collapsed into a single one at the moment of the decision-in-action. The percept became operationally defined. In real life the decisions-in-action occur at moments that are *forced upon me by the world*, there is typically no looking back. It is *the flow of time*. Quoth [Saint Augustine](#)<sup>16</sup>,

*All the while the man’s attentive mind, which is present, is relegating the future to the past . . .*

Decisions-in-action *happen* to you. The multiple visual worlds continually collapse. No doubt this is the reason why your percepts tend to be well defined most of the time.

*Multiple Worlds* (2012)

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*Multiple Worlds* (2012)



## Consciousness: facing the consequences of decisions-in-action? (Schrodinger)

Do decisions have consequences when looking at art?

Non-representational art?

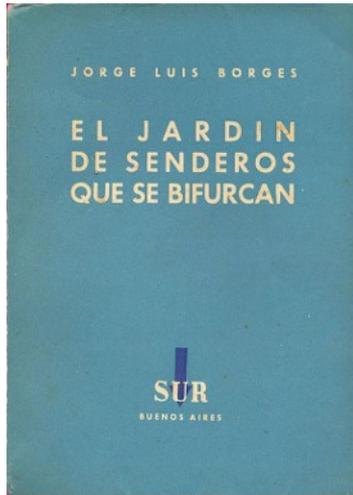


*Kandinsky* (1912)



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## Consciousness: facing the consequences of decisions-in-action? (Schrodinger)

What is the nature of your visual awareness? A single visual world?



*Joseph Mallord William Turner (Interior at Petworth c. 1837)*

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*Multiple Worlds* (2012)

“Suspended judgment” is quite typical of daily vision, although nobody seems to notice. This is from [John Ruskin](#):

*Go to the top of Highgate Hill on a clear summer morning at five o'clock, and look at Westminster Abbey. You will receive an impression of a building enriched with multitudinous vertical lines. Try to distinguish one of these lines all the way down from the next to it: You cannot. Try to count them: You cannot. Try to make out the beginning or end of any of them: You cannot. Look at it generally, and it is all symmetry and arrangement. Look at it in its parts, and it is all inextricable confusion.*

Compare this with [Friedrich Nietzsche](#), who wrote

*In the countryside I'm always amazed by the marvellous clarity of everything, the forest like this and the mountain like that, and that there is not a trace of unclarity or hesitation in these experiences.*

This Nietzschean euphoria is a common enough delusion.

## Consciousness: facing the consequences of decisions-in-action? (Schrodinger)

What is the nature of your visual awareness? A single visual world?



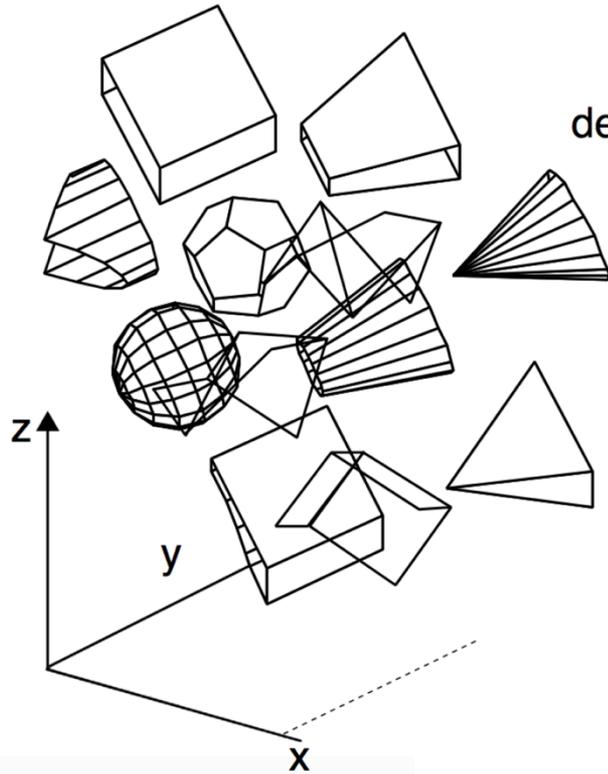
*Joseph Mallord William Turner (Interior at Petworth c. 1837)*

QUESTION: Is perception like a bundle of possible visual worlds (then the observer apparently abstains from a final – precognitive – decision) or is it like a single visual world (the observer really “sticks the neck out”) ?

What answers to this question do we find in visual awareness?

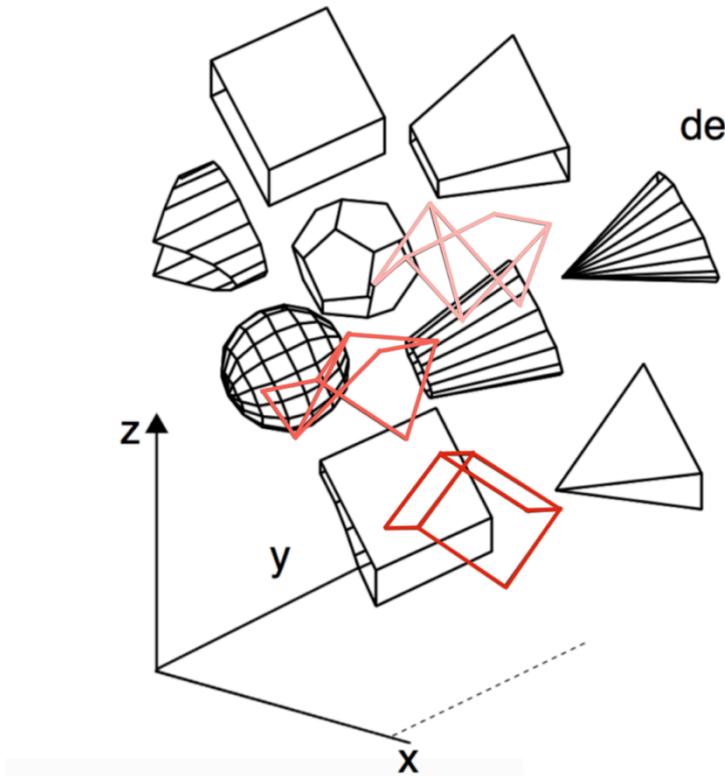
# Bayesian Models of Object Perception

object  
descriptions,  $S$

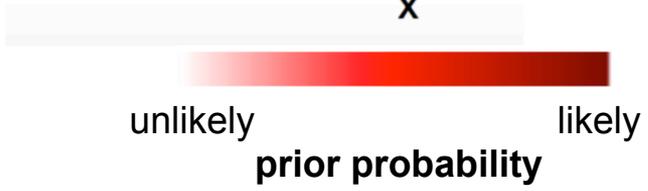


To delineate the ambiguity for given cues is an immense task for theoretical ecological optics. It is indeed very far from being completed. Solutions exist for many geometrical cues and some special cases of shading<sup>17</sup>, but for preciously little else. It is *a priori* to be expected that the ambiguities will turn out to be different for the different cues. The ambiguity in visual perception will then be the common core of ambiguities for all relevant cues.

Koenderink *Multiple Worlds* (2012)



object descriptions, S



to solve:  $X = A^{-1}Y$

constraints!

object  
descriptions,  $S$

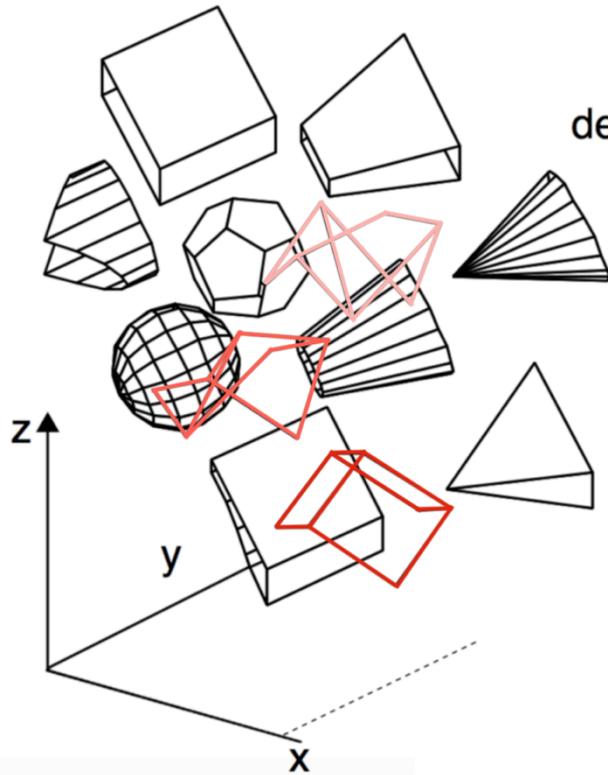


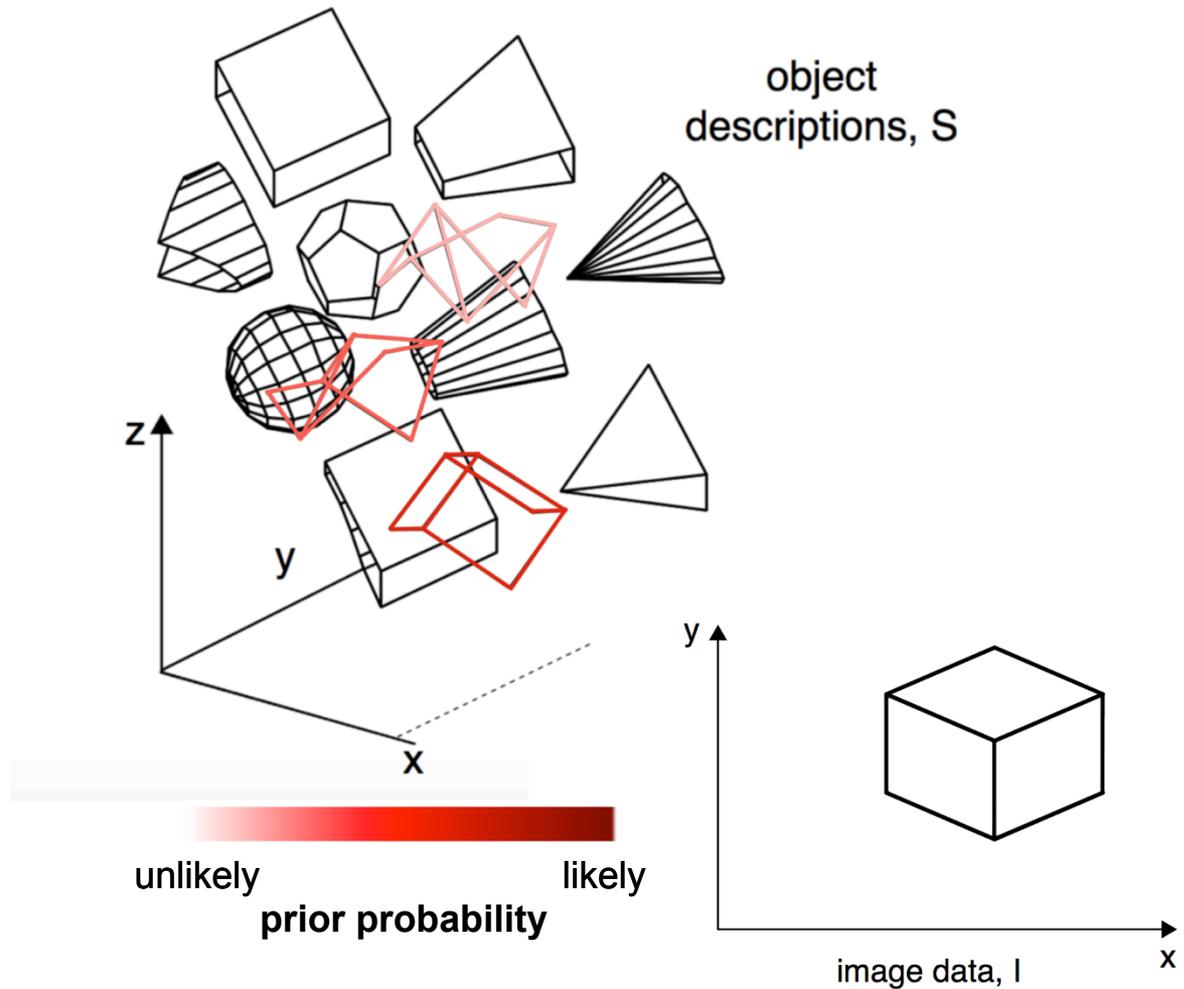
image data,  $I$

telling the robot what they are seeing. If you could see the world through a robot's eyes, it would look not like a movie picture decorated with crosshairs but something like this:

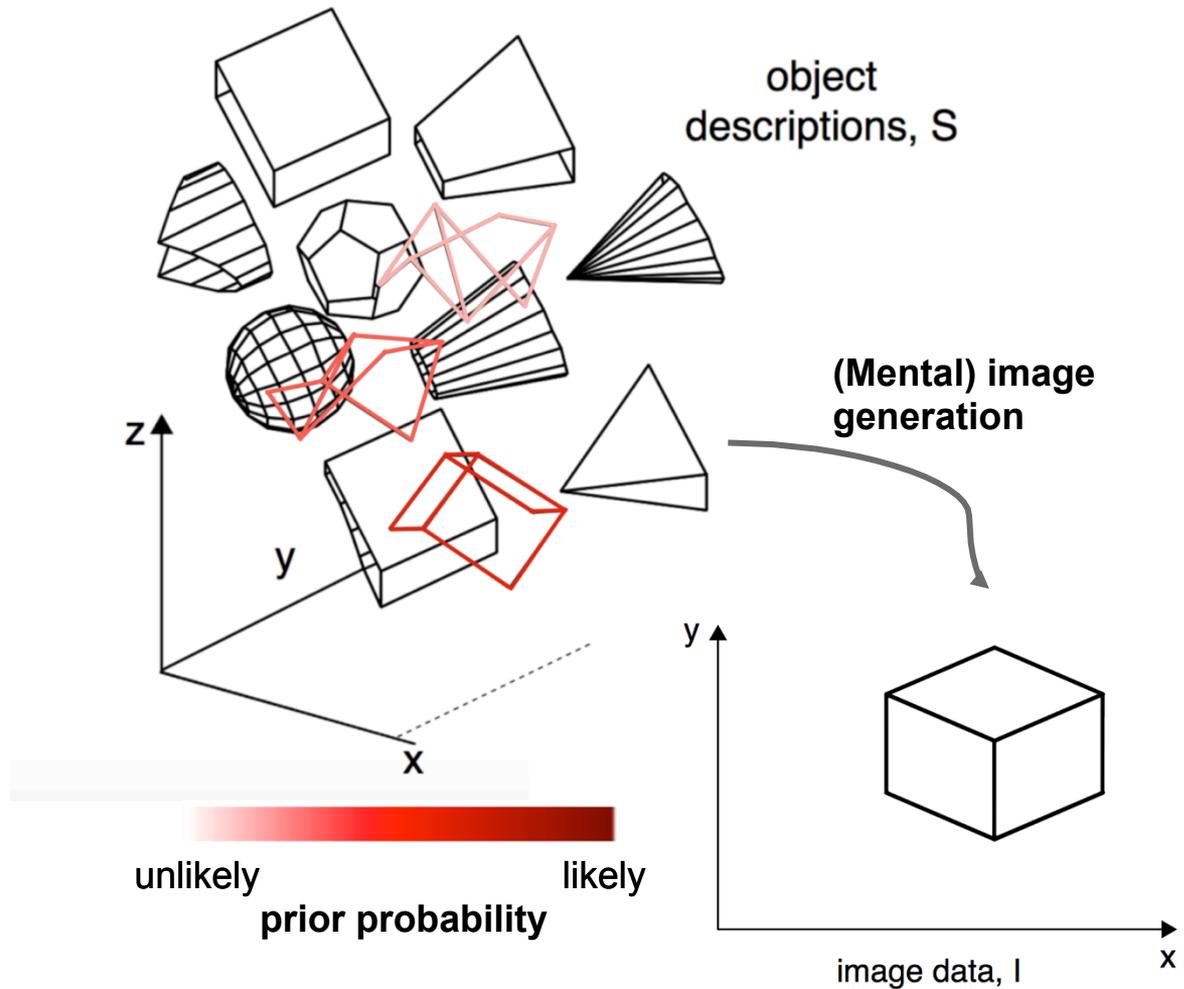
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225 221 216 219 219 214 207 218 219 220 207 155 136 135
213 206 213 223 208 217 223 221 223 216 195 156 141 130
206 217 210 216 224 223 228 230 234 216 207 157 136 132
211 213 221 223 220 222 237 216 219 220 176 149 137 132
221 229 218 230 228 214 213 209 198 224 161 140 133 127
220 219 224 220 219-215 215 206 206 221 159 143 133 131
221 215 211 214 220 218 221 212 218 204 148 141 131 130
214 211 211 218 214 220 226 216 223 209 143 141 141 124
211 208 223 213 216 226 231 230 241 199 153 141 136 125
200 224 219 215 217 224 232 241 240 211 150 139 128 132
204 206 208 205 233 241 241 252 242 192 151 141 133 130
200 205 201 216 232 248 255 246 231 210 149 141 132 126
191 194 209 238 245 255 249 235 238 197 146 139 130 132
189 199 200 227 239 237 235 236 247 192 145 142 124 133
198 196 209 211 210 215 236 240 232 177 142 137 135 124
198 203 205 208 211 224 226 240 210 160 139 132 129 130
216 209 214 220 210 231 245 219 169 143 148 129 128 136
211 210 217 218 214 227 244 221 162 140 139 129 133 131
215 210 216 216 209 220 248 200 156 139 131 129 139 128
219 220 211 208 205 209 240 217 154 141 127 130 124 142
229 224 212 214 220 229 234 208 151 145 128 128 142 122
252 224 222 224 233 244 228 213 143 141 135 128 131 129
255 235 230 249 253 240 228 193 147 139 132 128 136 125
250 245 238 245 246 235 235 190 139 136 134 135 126 130
240 238 233 232 235 255 246 168 156 144 129 127 136 134
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unlikely  likely  
prior probability

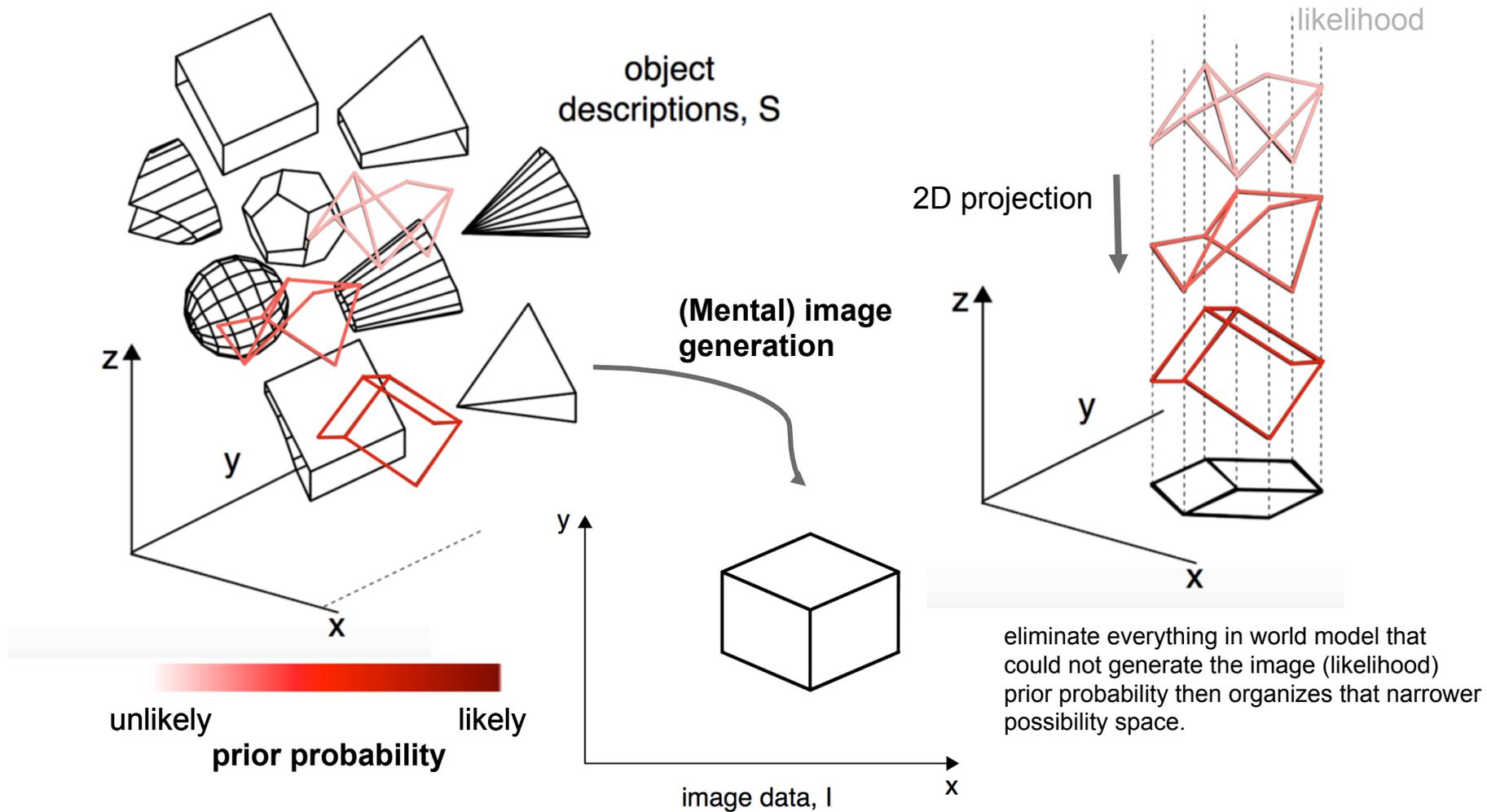
adapted from Kersten & Yuille (2003)



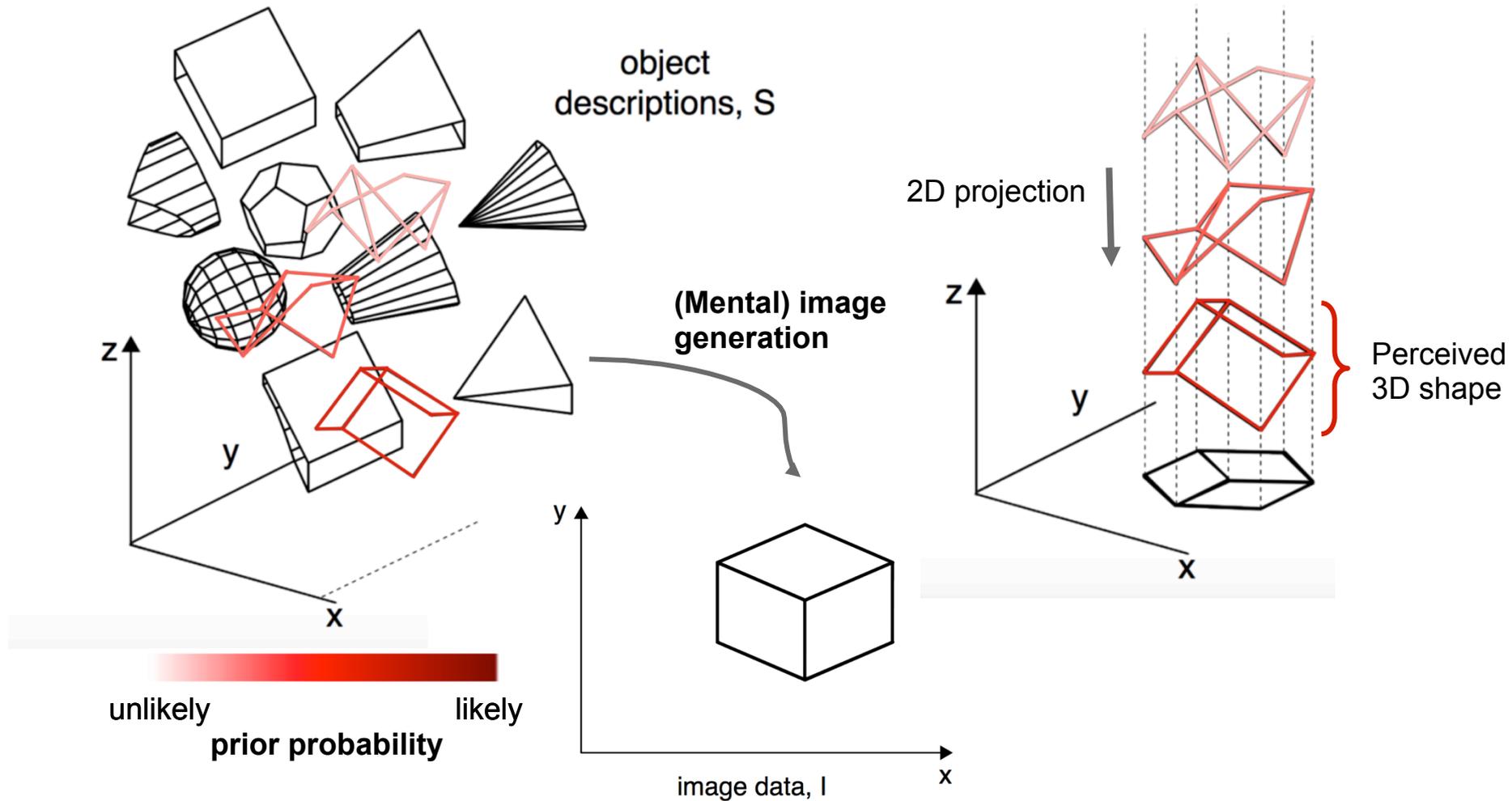
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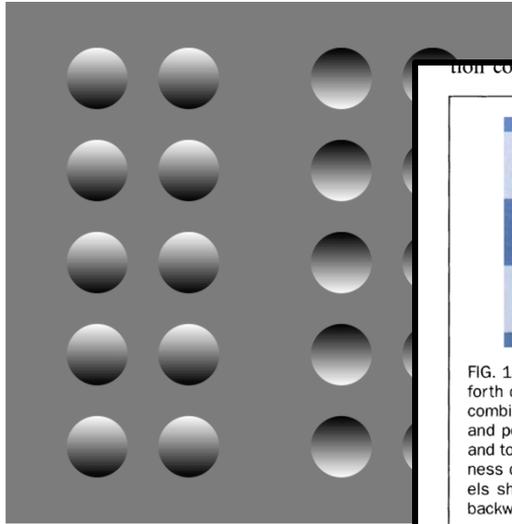


adapted from Kersten & Yuille (2003)

# Visual system embodies principles of ecological optics

- Lighting from above, shadows, reflection, ...

“evolutionary internalized regularities”  
(Koenderink)



tion consisting of a checkerboard with a visual interpretation is ambiguous. The

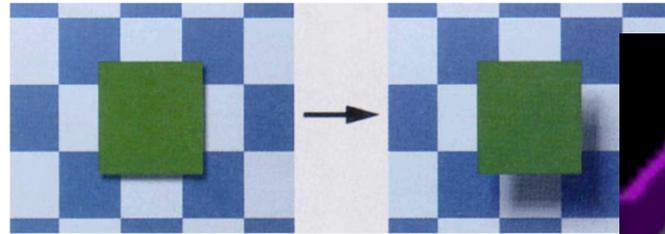


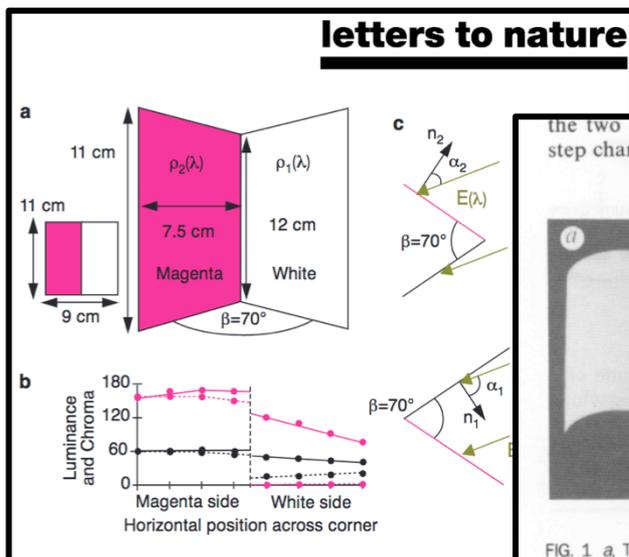
FIG. 1 A central square superimposed over a checkerboard pattern was made to move forth directly along the line of sight. The coincidental alignment of motion and viewing combined with the use of orthographic projection, resulted in an image of the square and position did not vary over time. A rectangular light panel illuminated the scene from above and to the left of the square, generating a cast shadow which moved diagonally and whose length decreased as the central patch moved away from the checkerboard. The left and right panels show the first and last frames from a 24-frame sequence which was played forward in a 48-frame loop at 15 frames  $s^{-1}$ .

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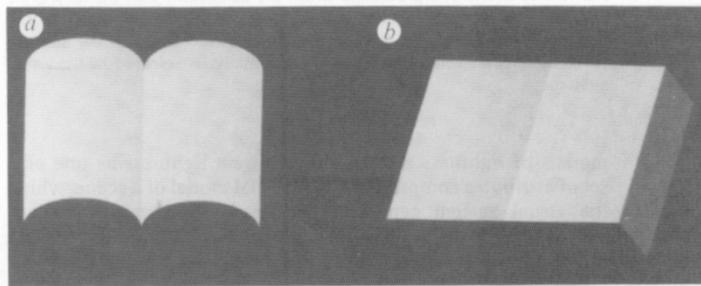
# Visual system embodies principles of ecological optics

- Interactions of shape and illumination



**Figure 1** The experimental stimulus. **a**, The chromatic Mach card. The

the two halves, based on the luminance difference across the step change. For more general scenes, the filtering stage factors



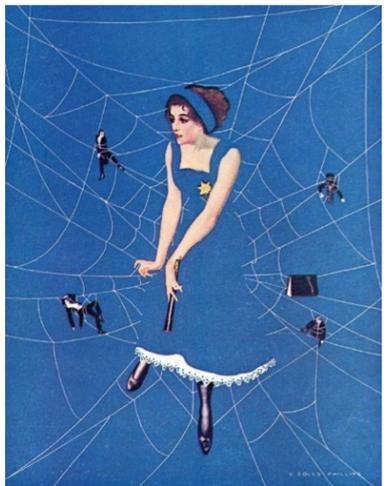
**FIG. 1** **a**, Two abutting cylinders rendered to have a horizontal luminance profile consisting of two linear luminance ramps, shown in **c**. **b**, A rectangular polyhedron, the top face of which also has the horizontal luminance profile shown in **c**. The only difference between the two images is in the shape of

Figure 3 shows the results from the experiment. The 5.8% average increase in luminance needed to make the target patch

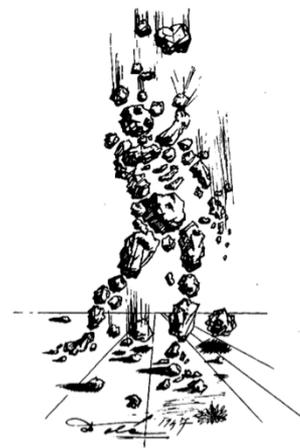
equal in luminance to the patch in the permanently light half (Fig. 1a, no significant increase in  $E(\lambda)$ ) was found for the two patches. As predicted by the demonstration in the previous section, the two patches were perceived as having different colors. As the two patches were perceived as having different colors, the two patches were perceived as having different colors. The results show that the visual system is not simply in the apparent cause but of error and that the visual system is an image to determine luminance properties of the bounding contours of the surfaces, leading to the different shape percepts, which in turn determine one's percept of the reflectance patterns on the front faces of the two surfaces.

the bounding contours of the surfaces, leading to the different shape percepts, which in turn determine one's percept of the reflectance patterns on the front faces of the two surfaces.

# Models in Art



clarence coles phillips (1880-1927)



possible renderings of a common shape are infinite but no problem!



Koenderink (2014)