COMP 546

Lecture 11

Illumination and Reflectance

Thurs. Feb. 14, 2019

Level of Analysis in Perception

high

- behavior: what is the task ? what problem is being solved?

- brain areas and pathways

- neural coding

- neural mechanisms

low

Level of Analysis in Perception

high

The next few lectures are more at this level.

- behavior: what is the task ? what problem is being solved?

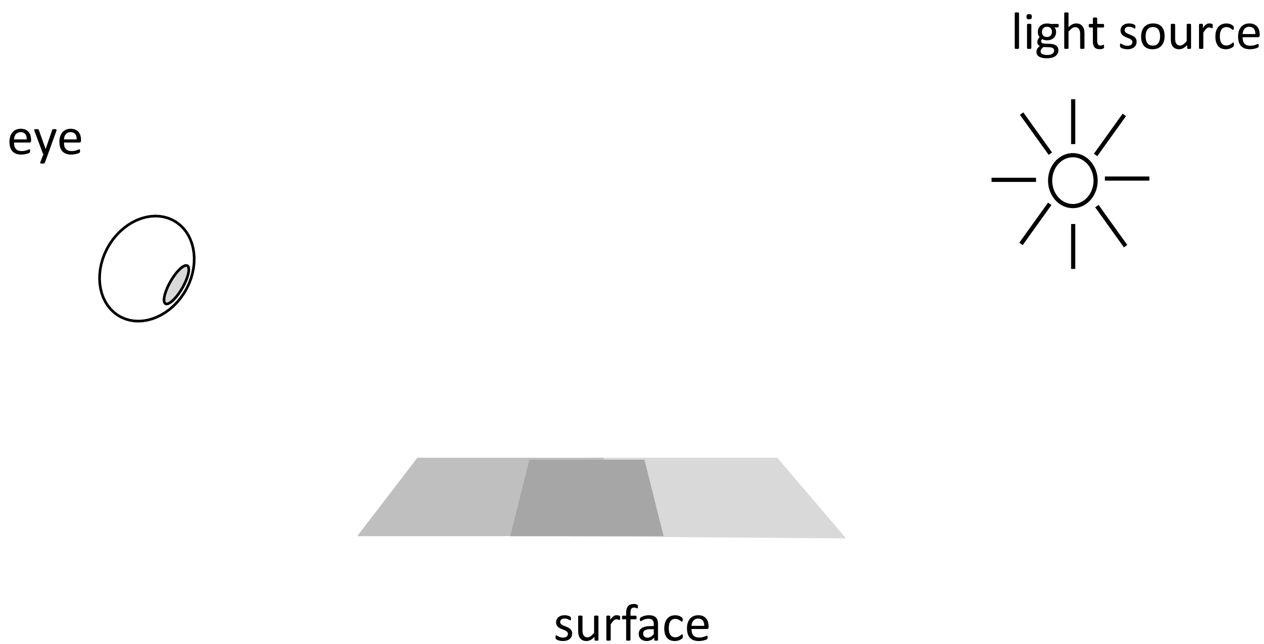
- brain areas and pathways

- neural coding

- neural mechanisms

low

$$I(x,y) = reflectance\,(x,y)\; * illumination(x,y)$$



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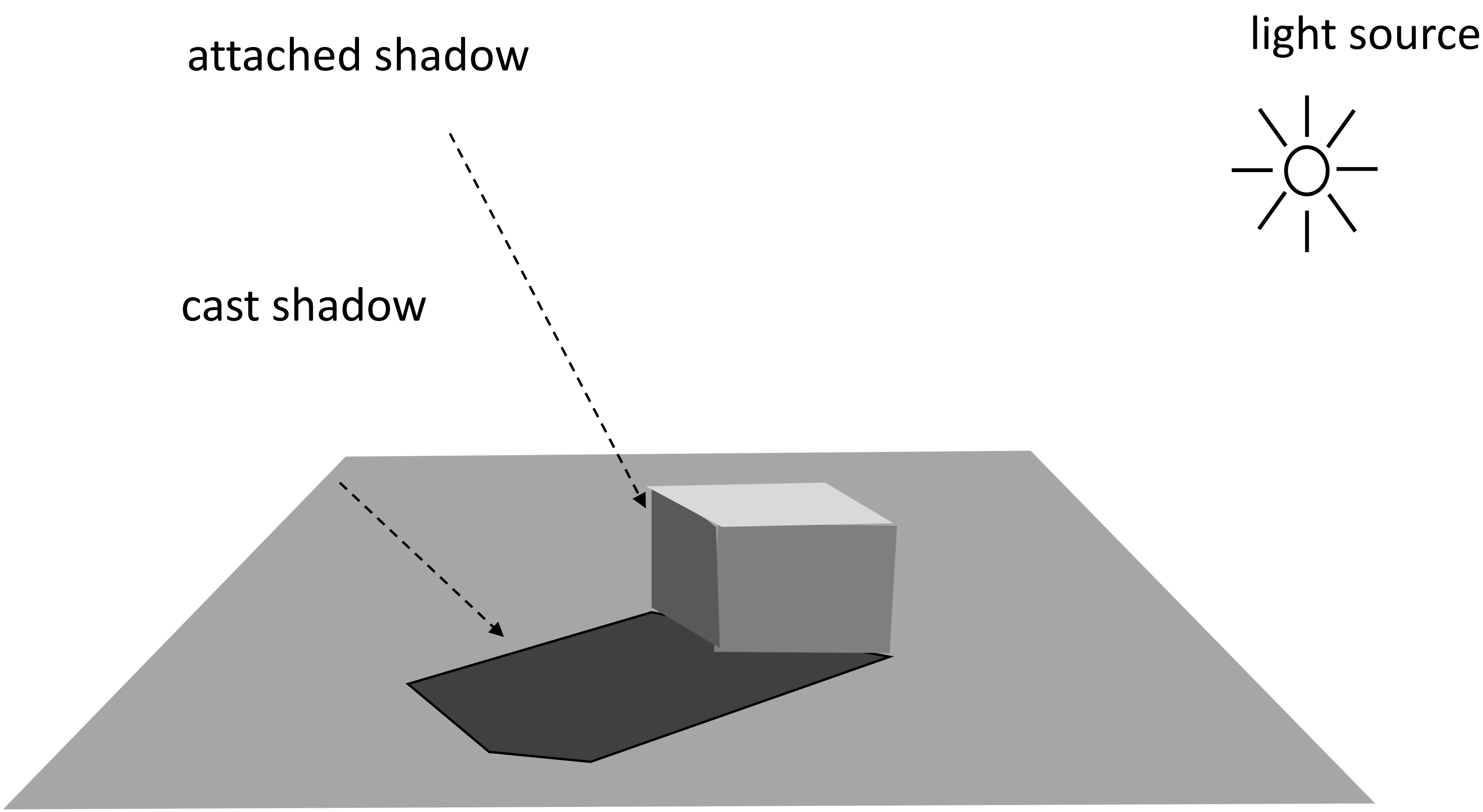
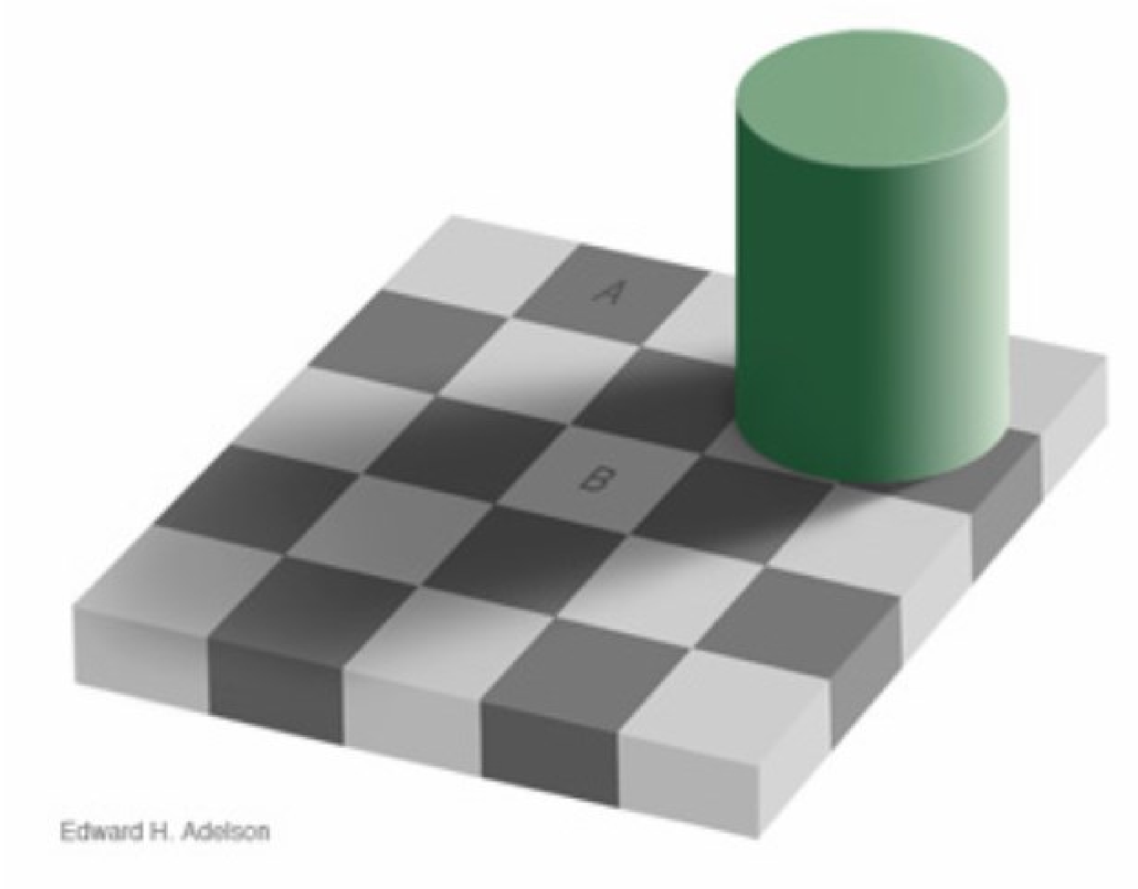


$$I(x,y) = reflectance\,(x,y)\;*\,illumination(x,y)$$

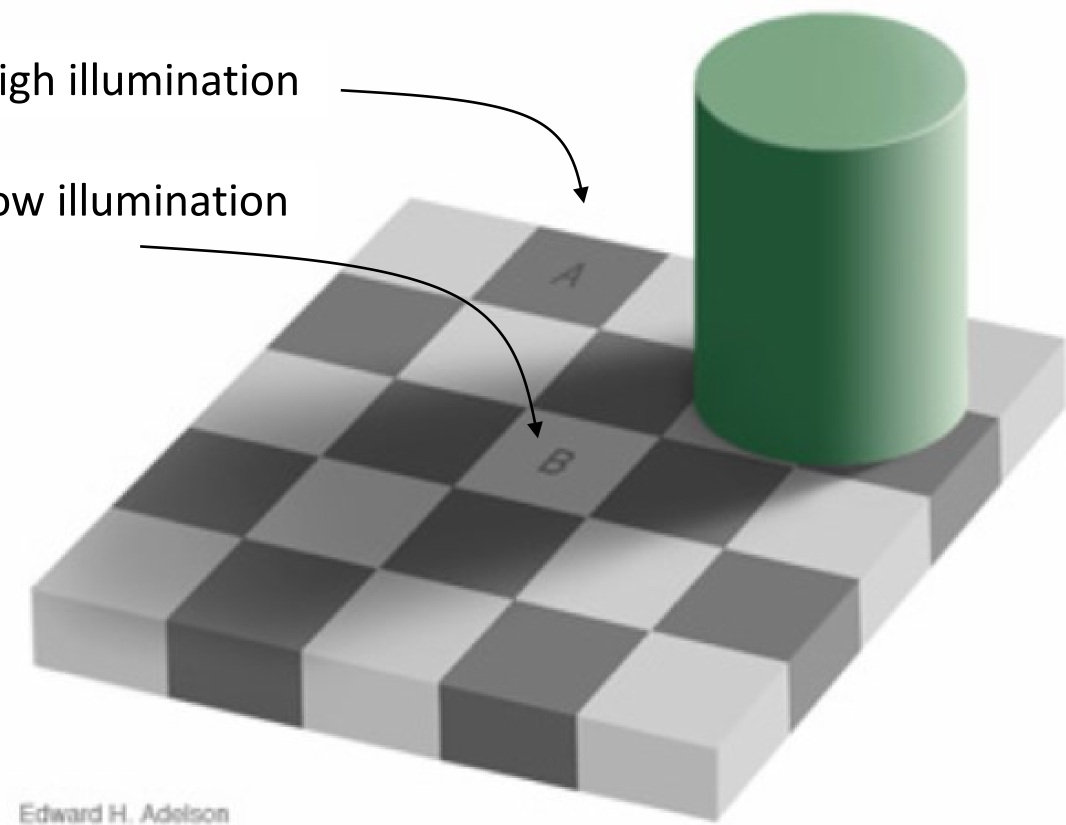


The squares A and B have the same image intensity $I(x,y)$ even though they appear to be grey and white.

$$I(x,y) = reflectance\,(x,y)\ * illumination(x,y)$$

low reflectance, high illumination

high reflectance, low illumination



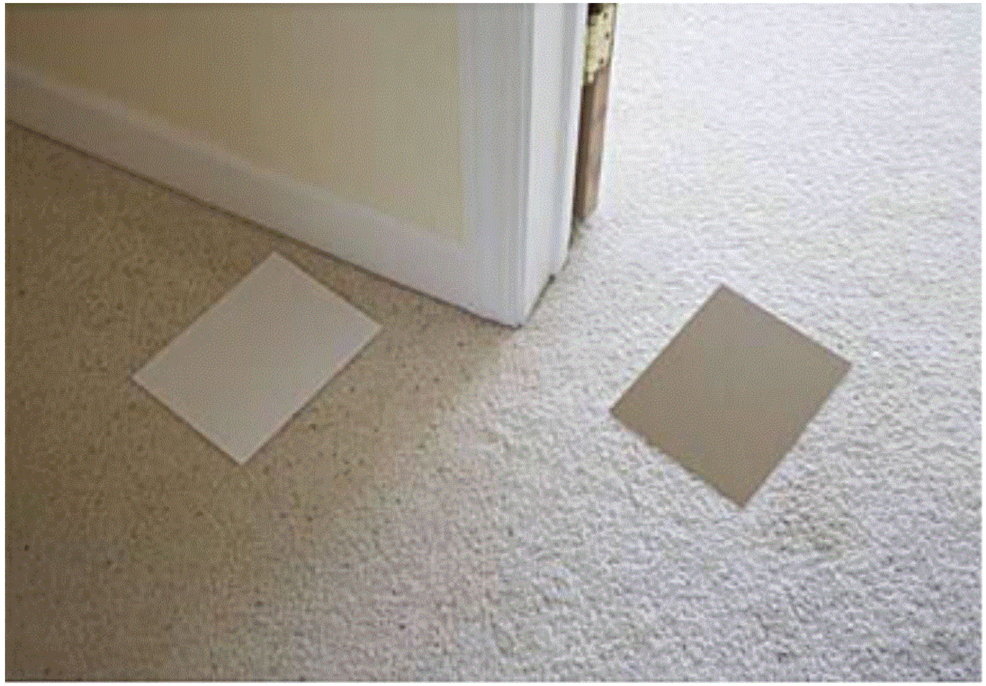
This “illusion” can be explained *to some extent* by interpreting $I(x,y)$ in terms of reflectance and illumination.

Which paper is *lighter* ?

Here we have two pieces of white paper. The paper on the left is in shadow. It has lower physical intensity.

$$I(x,y) = reflectance\,(x,y)\;*\,illumination(x,y)$$

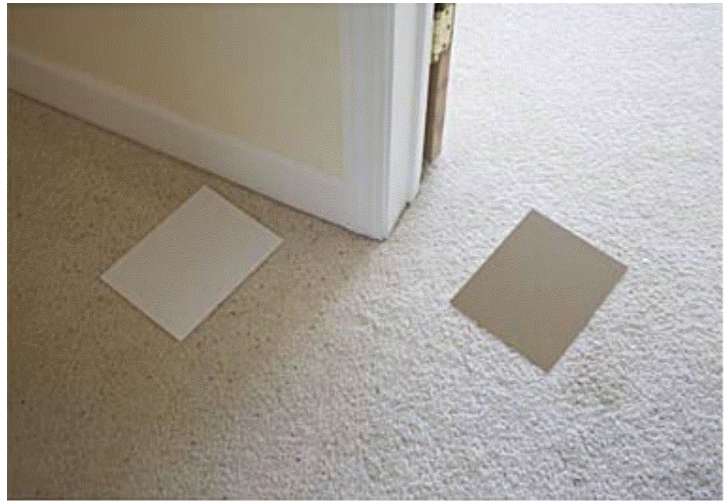
Which paper is *lighter* ?



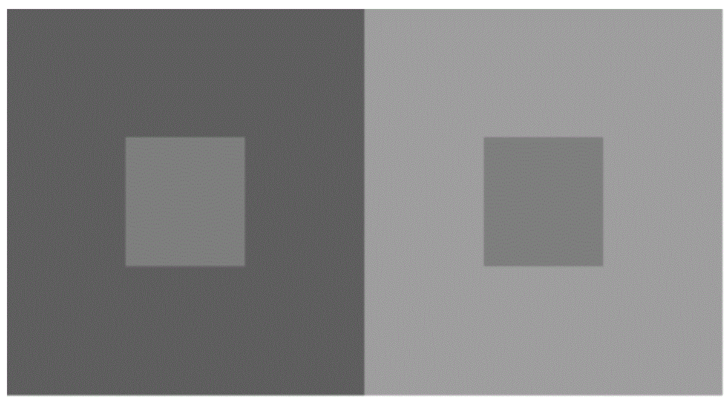
This image is processed so that the right paper is given same image intensities as left paper. Now, right paper appears to be made of different material. Why?

$$I(x,y) = reflectance\,(x,y)\ * illumination(x,y)$$

“Real” example



Abstract version
(“boiled down”)



$$I(x,y) = reflectance\ (x,y)\ * illumination(x,y)$$

Surface “lightness” perception

Q: What is the task ?

What problem is being solved?

A:

Surface “lightness” perception

Q: What is the task ?

What problem is being solved?

A: Estimate the surface reflectance*, by partially discounting the effects of illumination.*

$$I(x,y) = \cancel{illumination}(x,y) \ * \ reflectance\ (x,y)$$

?

Surface “lightness” perception:

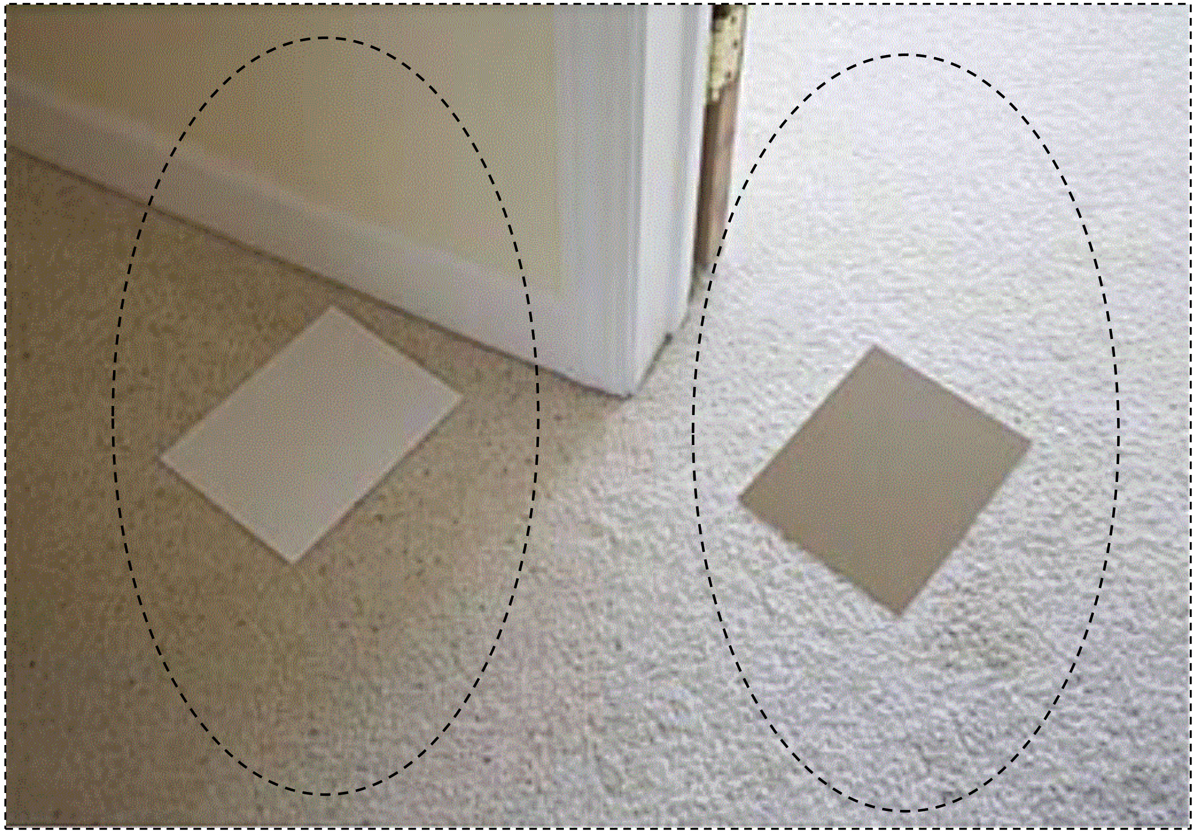
solution sketch

Idea: *Compare points that have same illumination.*

$$\frac{I(x_1, y_1)}{I(x_2, y_2)} = \frac{\cancel{illumination} * reflectance\,(x_1, y_1)}{\cancel{illumination} * reflectance\,(x_2, y_2)}$$

More generally, somehow parse the image into groups.

Compare intensities *within* groups.



More generally, somehow parse the image into groups.

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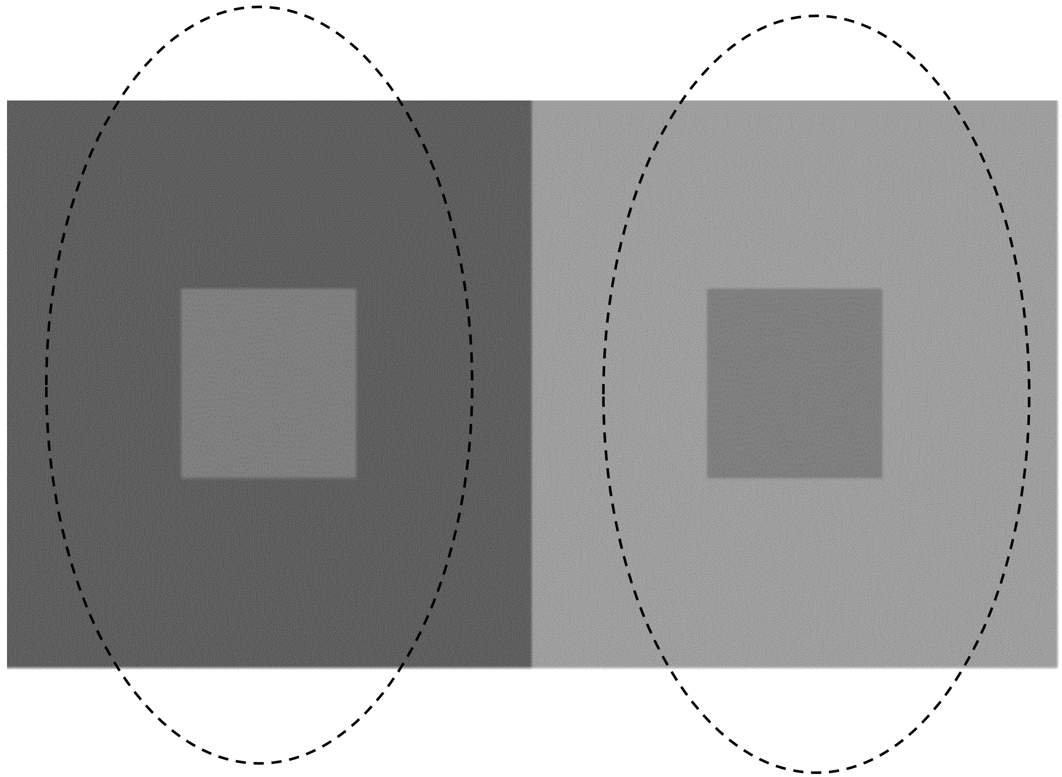
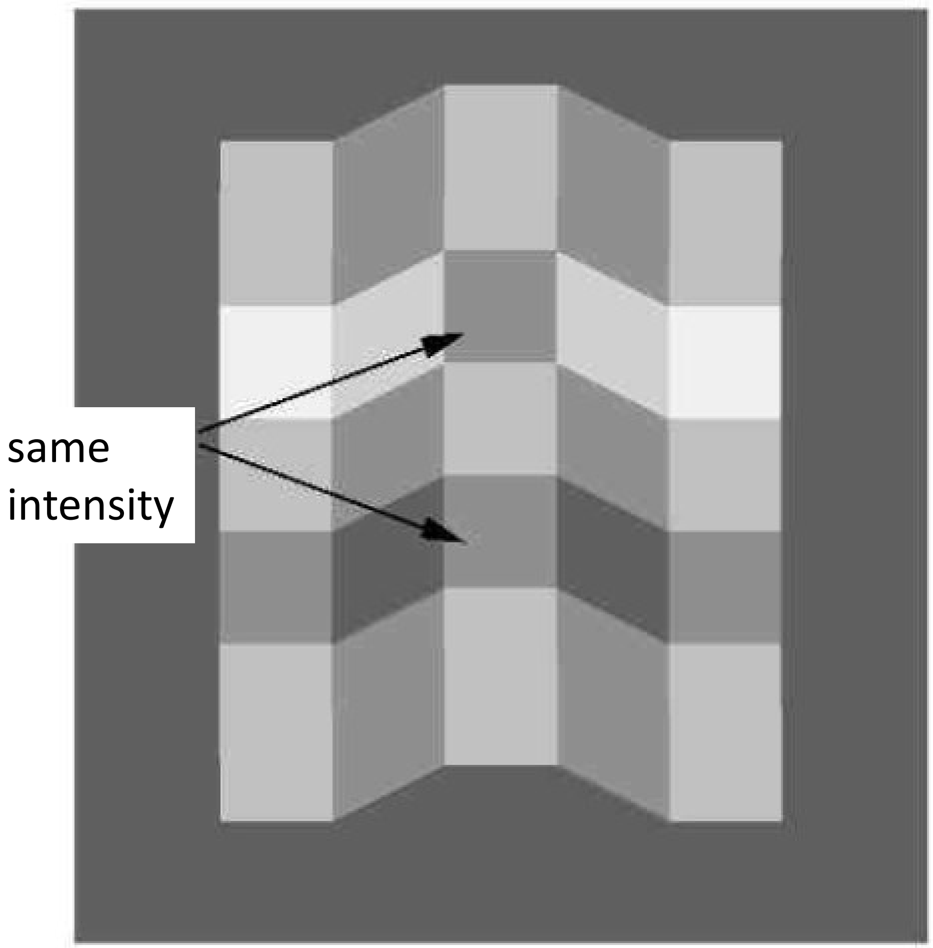
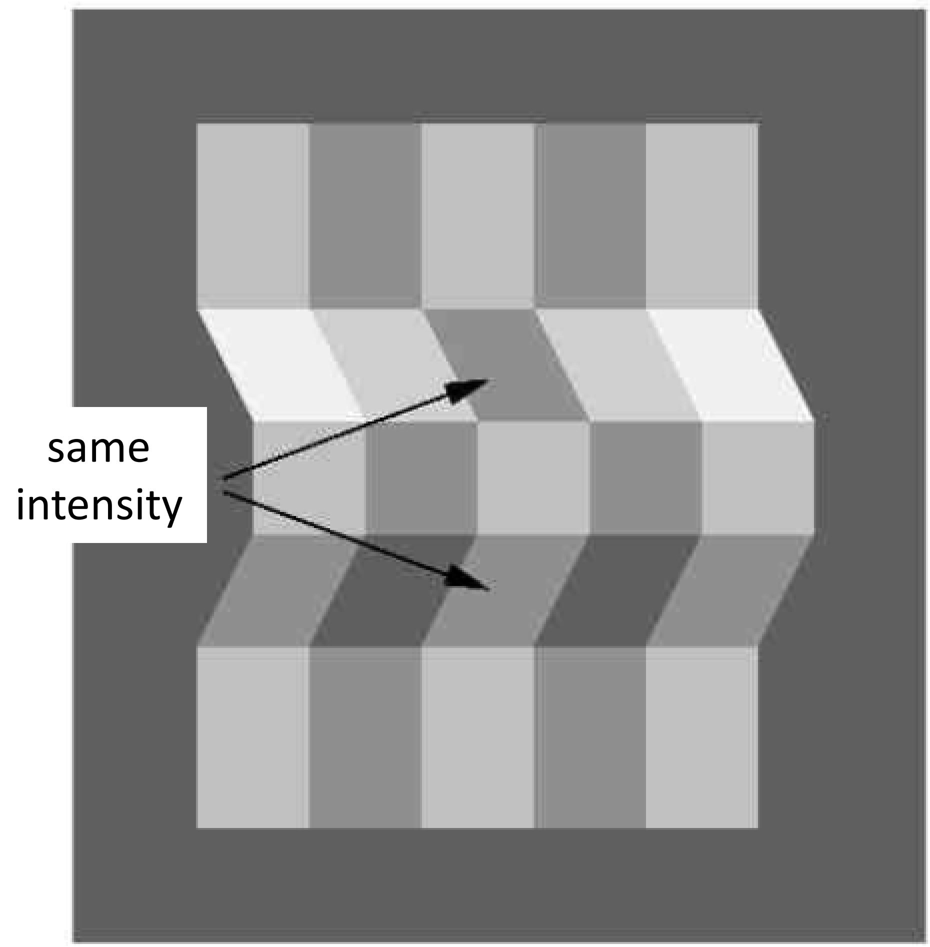


This is a different *level of explanation* than local contrast. (Recall Assignment 1).



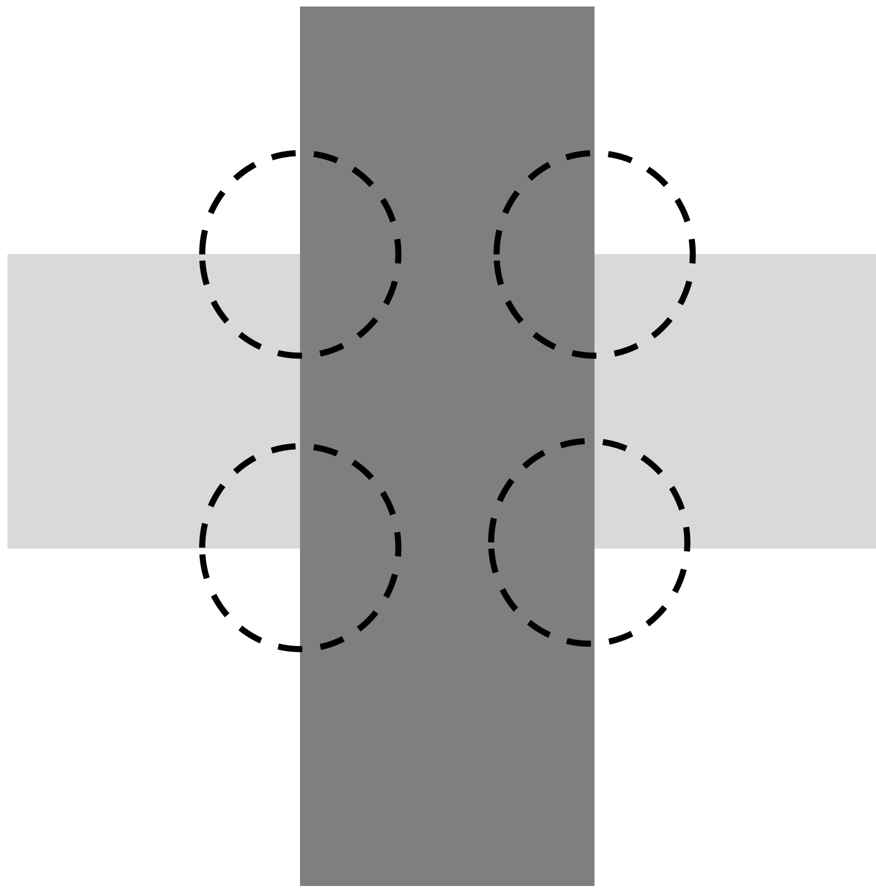


All four indicated "squares" have same intensity.

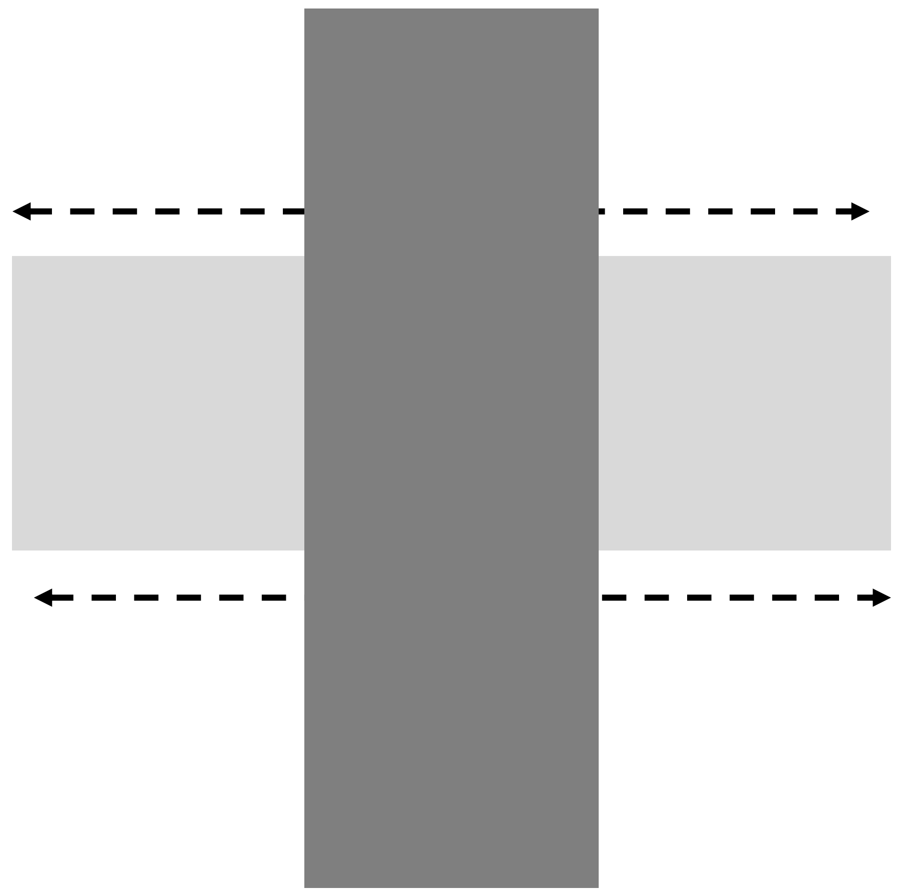
A key difference between the two configurations is how your visual system grouped squares together (based on perceived 3D configuration).

Some very basic ways of grouping: *based on layers*

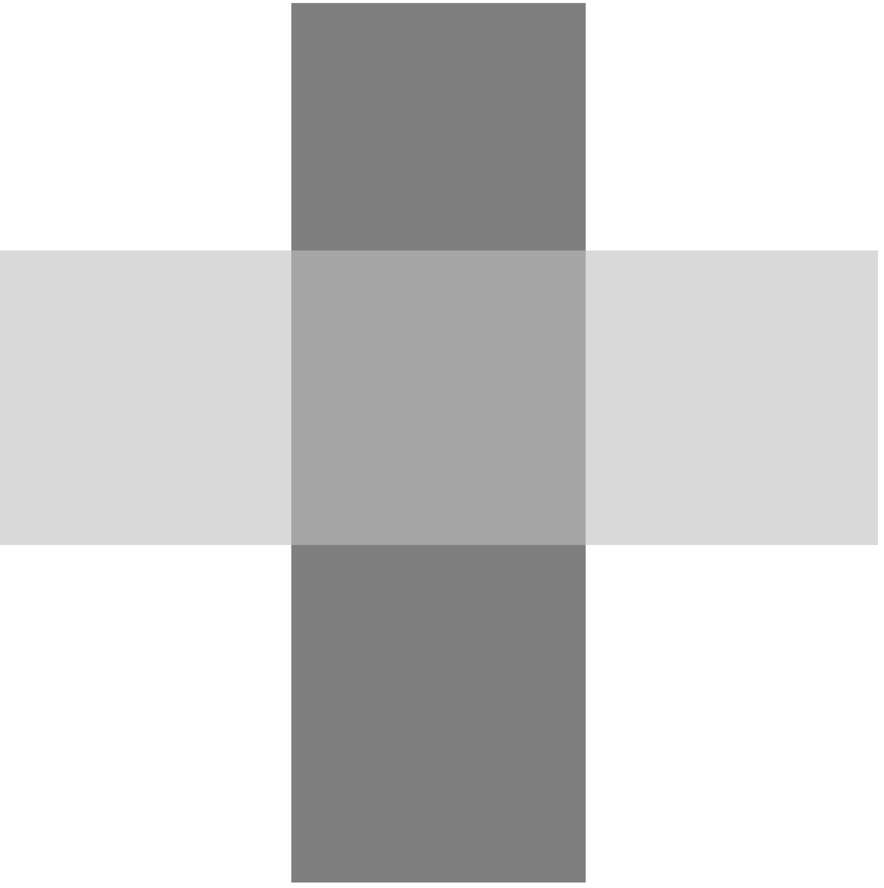
“T-junctions” can indicate a depth order relationship….



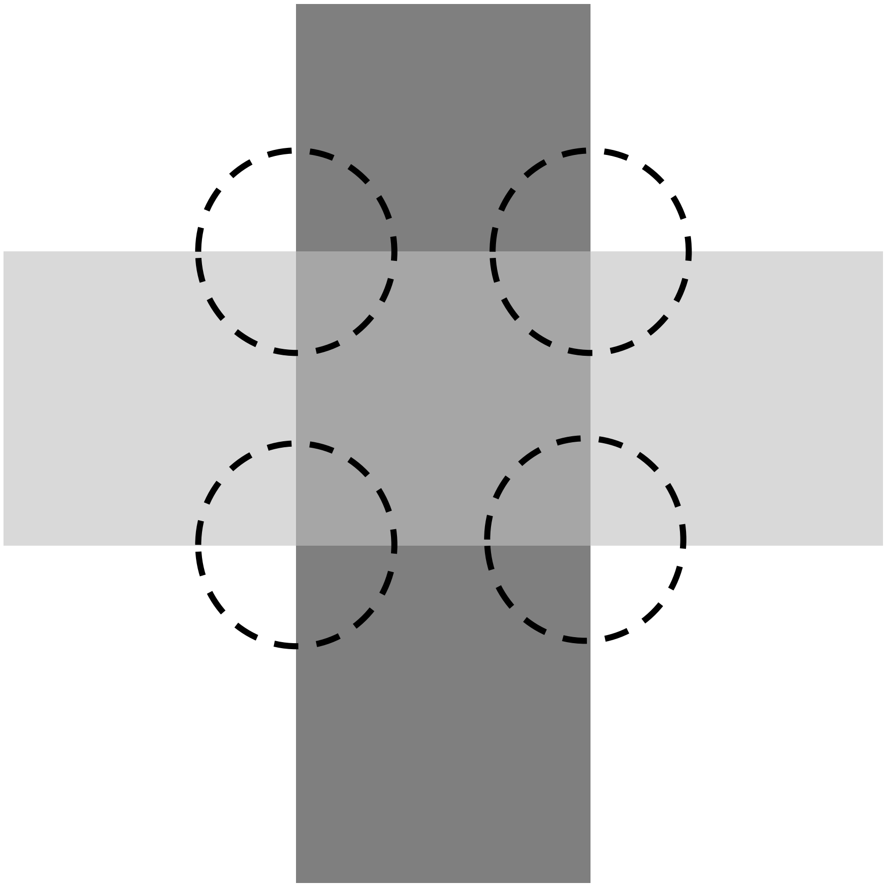
…. which can be enhanced by other cues such as collinearity of edges.



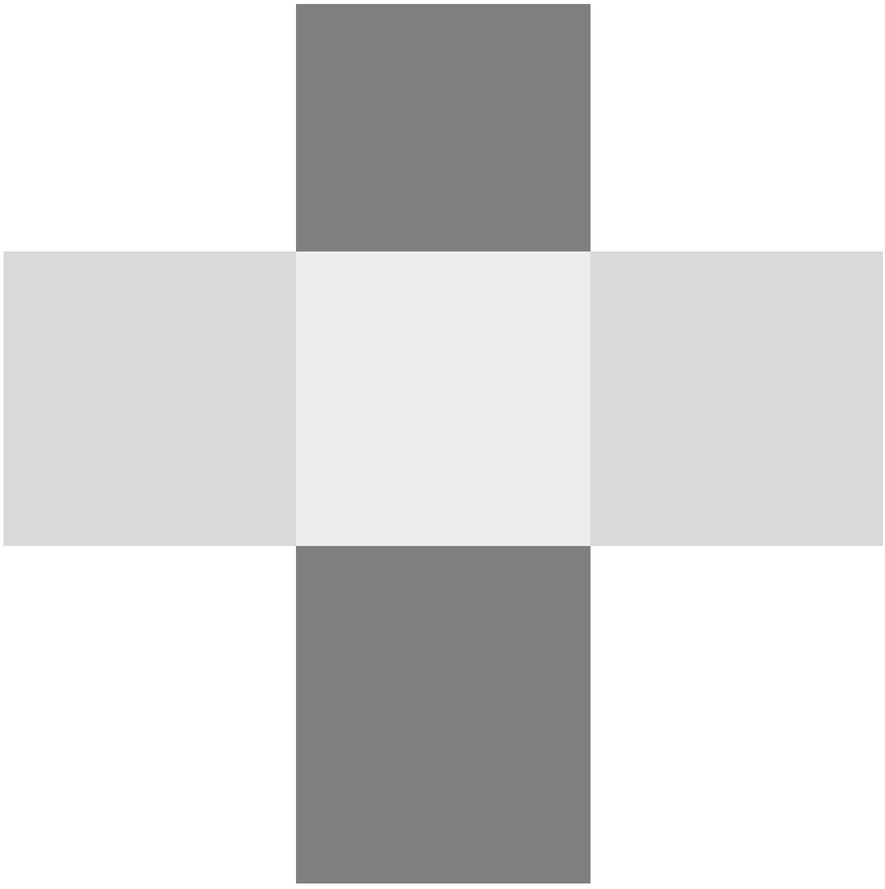
Which square appears to be in front?
What do you perceive here?



X-junctions can indicate transparency…



… but only under certain conditions.   Changing only the central square removes the effect of transparency here.



… and I could go on and on.

There are hundreds of these sorts of demos.

Most can be explained using combinations of a small number of grouping rules or simple image formation models (e.g. transparency, occlusion).

Level of Analysis in Perception

high

- behavior: what is the task ? what problem is being solved?
- brain areas and pathways
- neural coding
- neural mechanisms

low

These examples and theories are at a different *level* from what we have been discussing the past few weeks.

Illumination and Reflectance

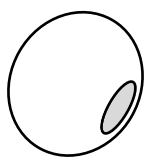
- Black and white

- Color

Recall lecture 3: three types of spectra

Emission spectrum

Absorption spectrum

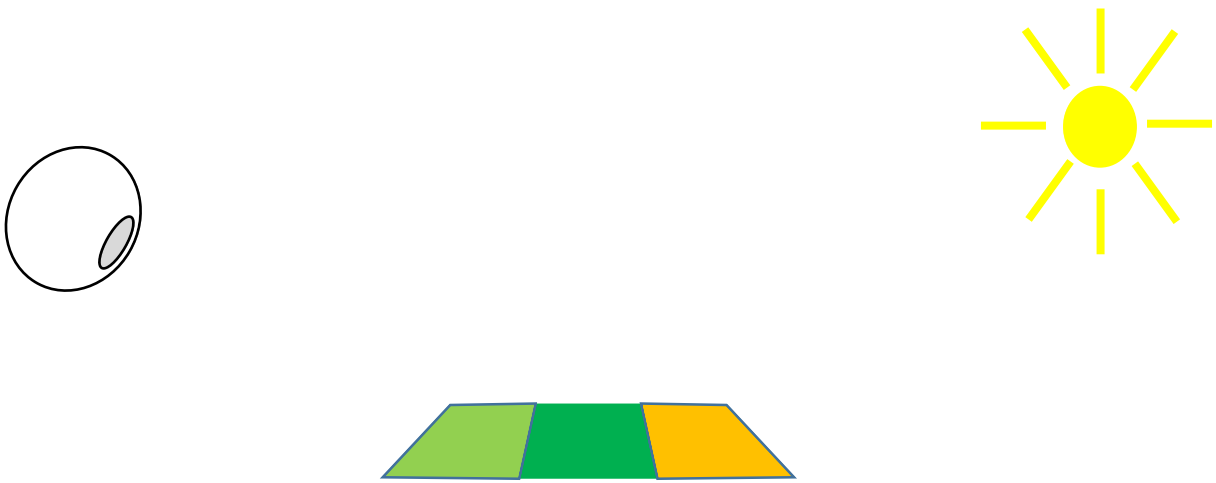


Surface Reflectance spectrum

$$I(x, y, \lambda) = illumination(x, y, \lambda) * reflectance(x, y, \lambda)$$

Surface Color Perception

Q: What is the task? What is the problem to be solved?



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Surface Color Perception

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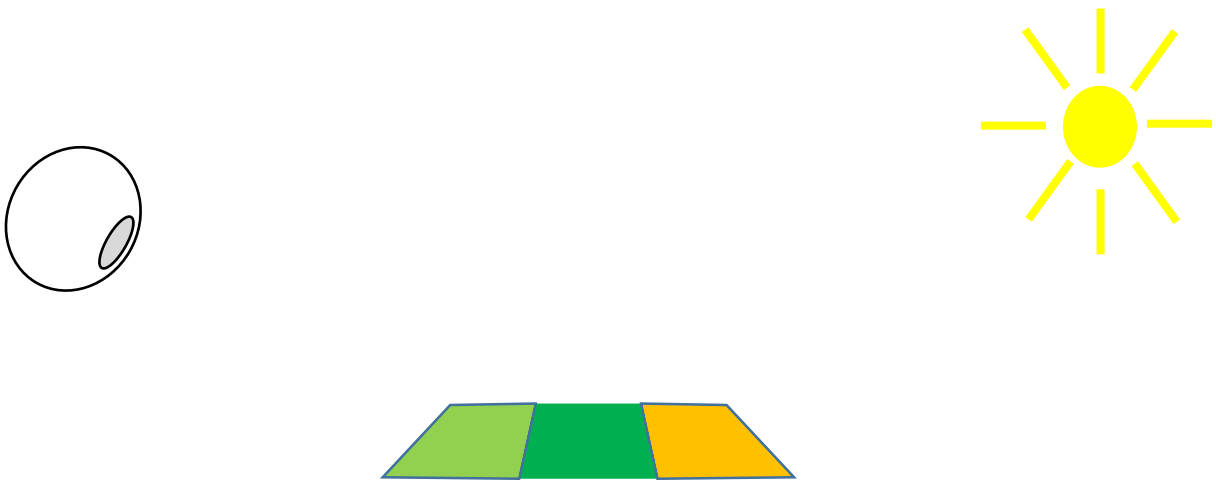


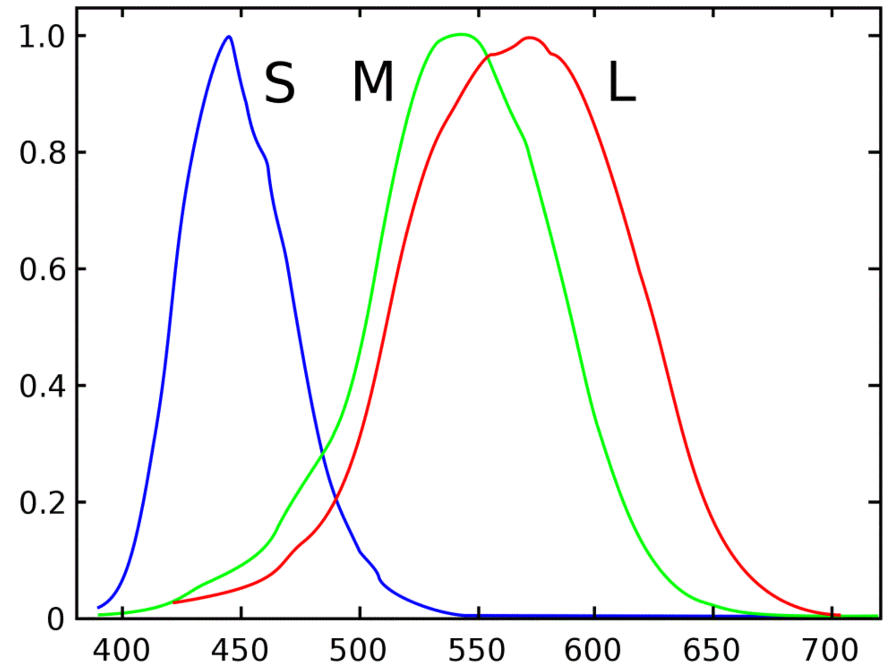
A: Estimate the surface reflectance, by *discounting the illumination*.

$$I(x,y,\lambda) = \cancel{illumination(x,y,\lambda)} * reflectance(x,y,\lambda)$$

LMS cone responses

Cone response

$$\int I(x, y, \lambda)\, C_{LMS}(\lambda)\, d\lambda$$



LMS cone responses

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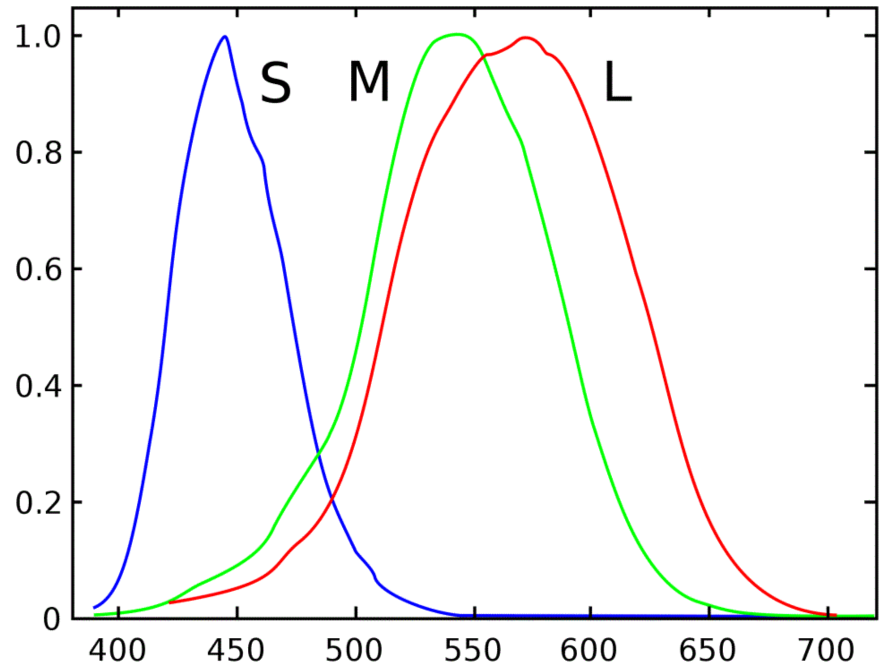
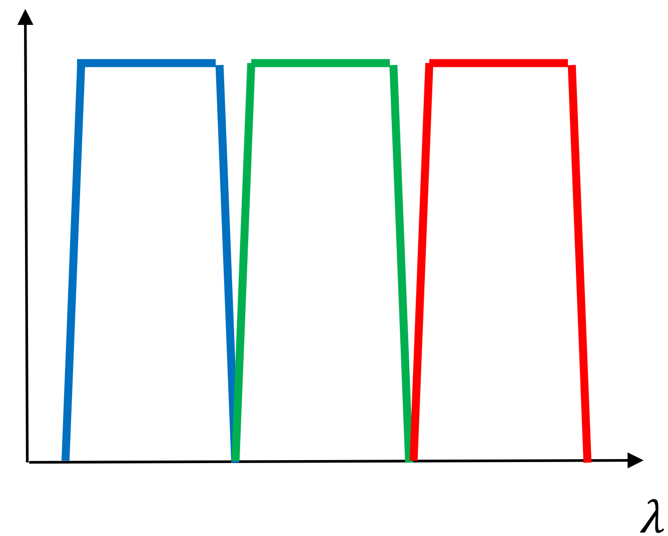


$$I(x, y, \lambda) = illumination(x, y, \lambda) * reflectance(x, y, \lambda)$$

For simplicity, let's ignore the cone spectrum overlap and just consider RGB (LMS).

~~Cone response~~

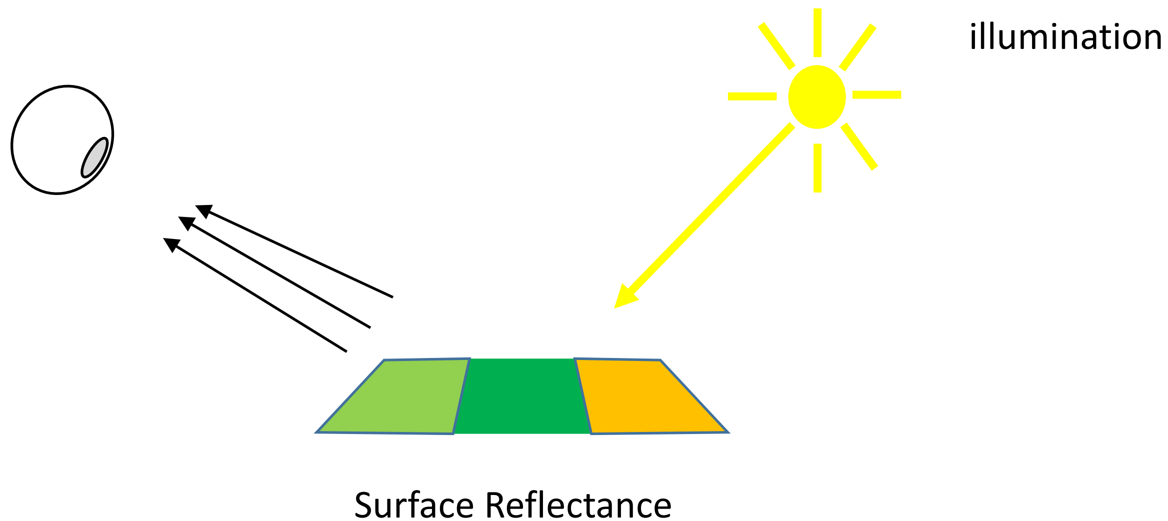
$$\cancel{\int I(x,y,\lambda)\, C_{LMS}(\lambda)\, d\lambda}$$



$$I_{RGB}(x,y) = \; illumination_{RGB}(x,y) \, * \, reflectance_{RGB}\,(x,y)$$

"Color Constancy" problem

Task: estimate the surface material color, by *discounting the color of the illumination.*

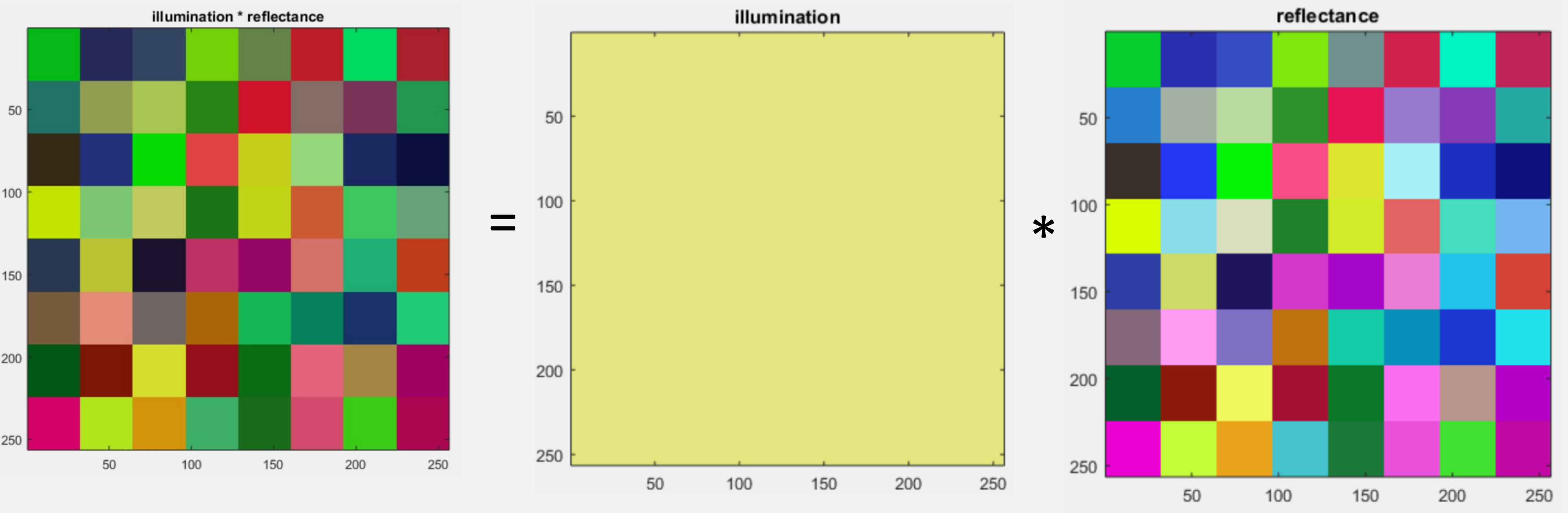


$$I_{RGB}(x,y) = illumination_{RGB}(x,y) \; * \; reflectance_{RGB}\,(x,y)$$

Why humans need "color constancy"

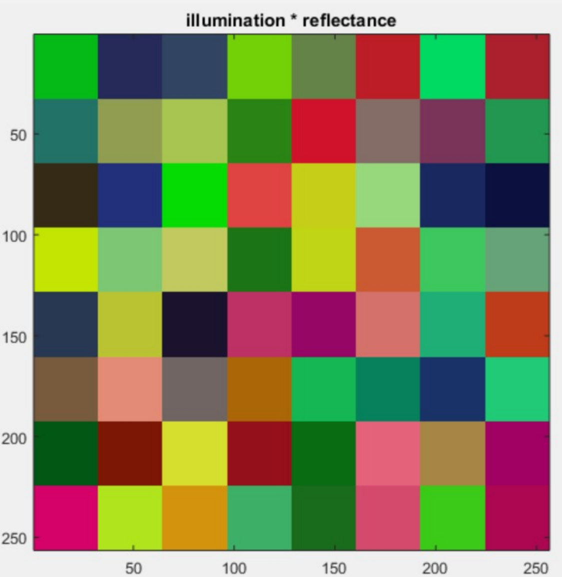
- object recognition
- skin evaluation (health, emotion, …)
- food quality
- …

Example 1: spatially uniform illumination



$$I_{RGB}(x,y) = illumination_{RGB}(x,y) \ * \ reflectance_{RGB}\,(x,y)$$

Example 1: spatially uniform illumination



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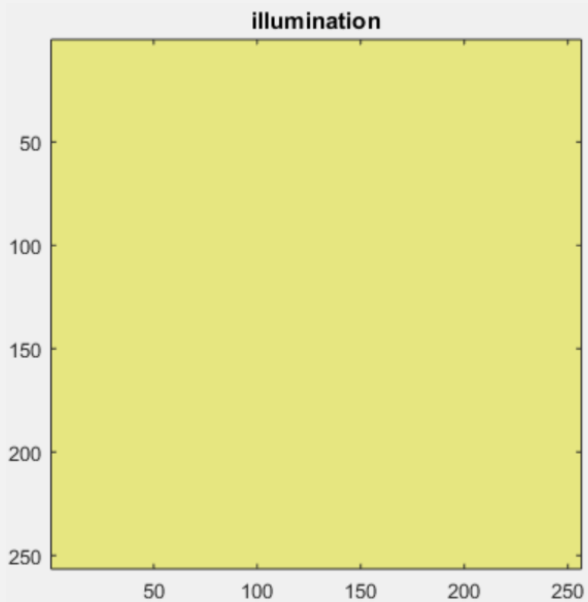

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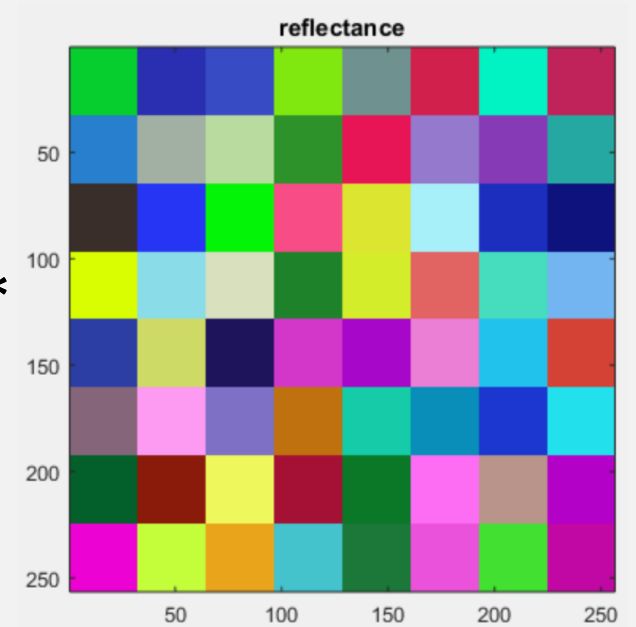
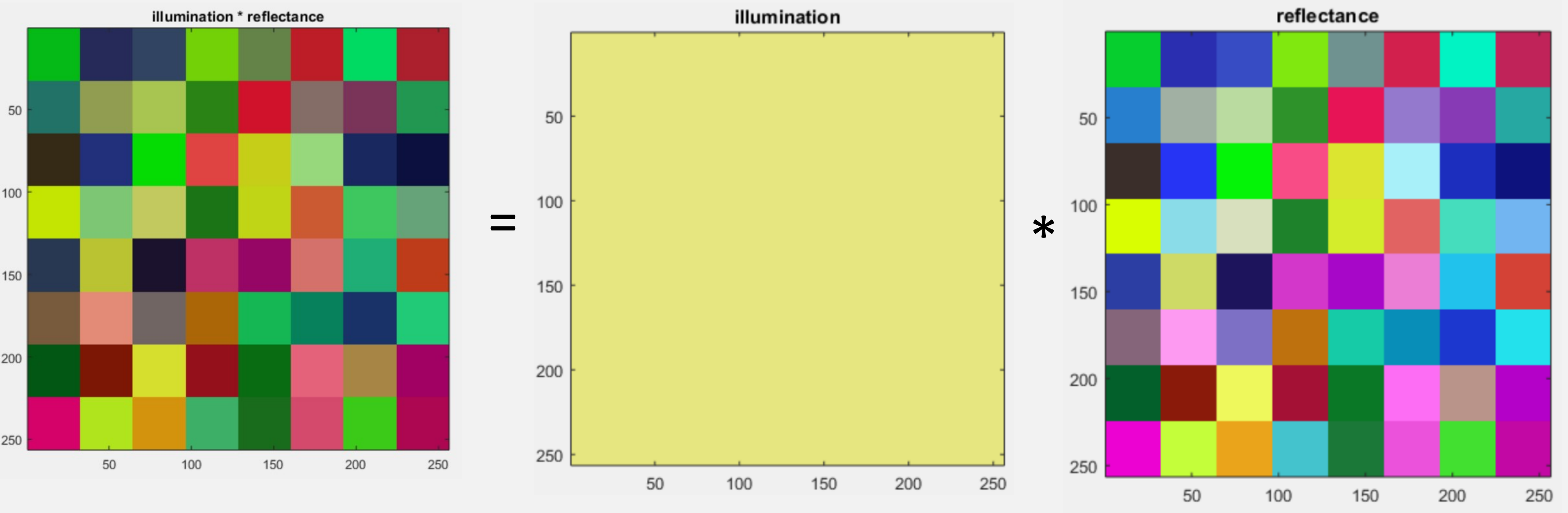


$$I_{RGB}(x,y) = illumination_{RGB}(x,y) \; * \; reflectance_{RGB}\,(x,y)$$

Given this, how to estimate this?

Solution: max normalization



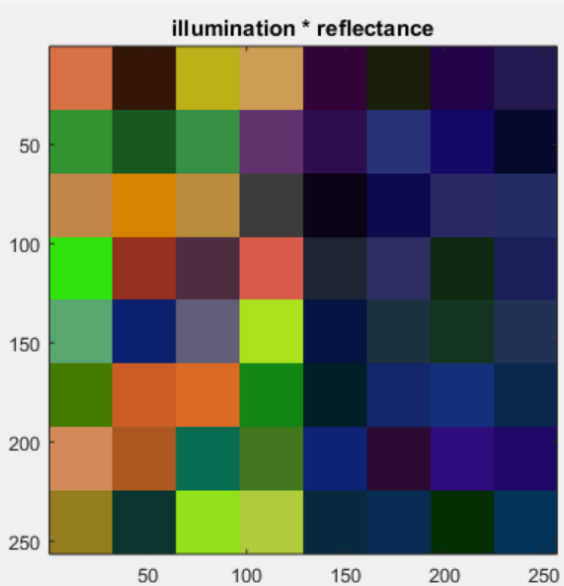
$$I_{RGB}(x,y) = illumination_{RGB}(x,y) \, * \, reflectance_{RGB}\,(x,y)$$

Divide each I_{RGB} channel by the max value of I_{RGB} in each channel.

When does this give the correct answer?

Example 2:   non-uniform illumination

sun + blue sky   only blue sky



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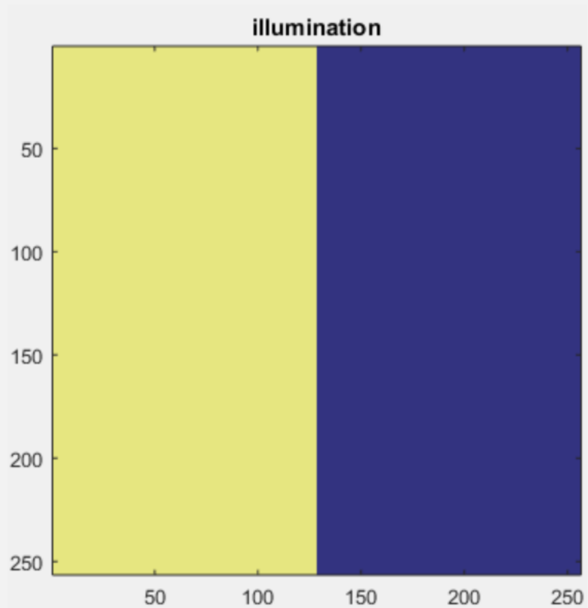

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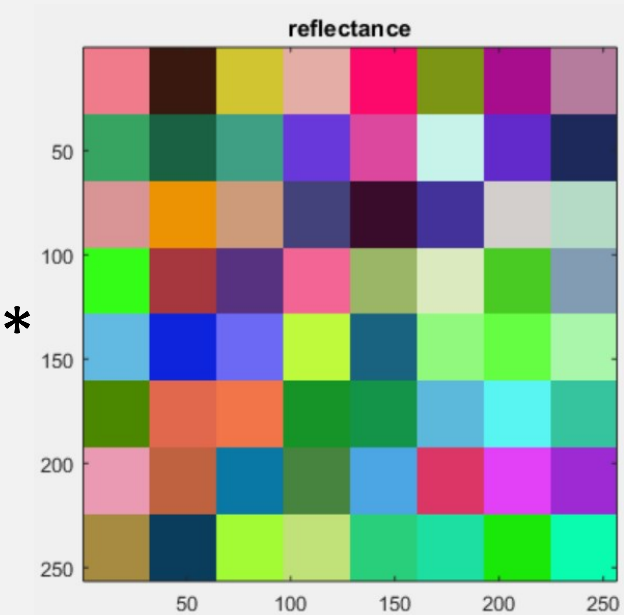
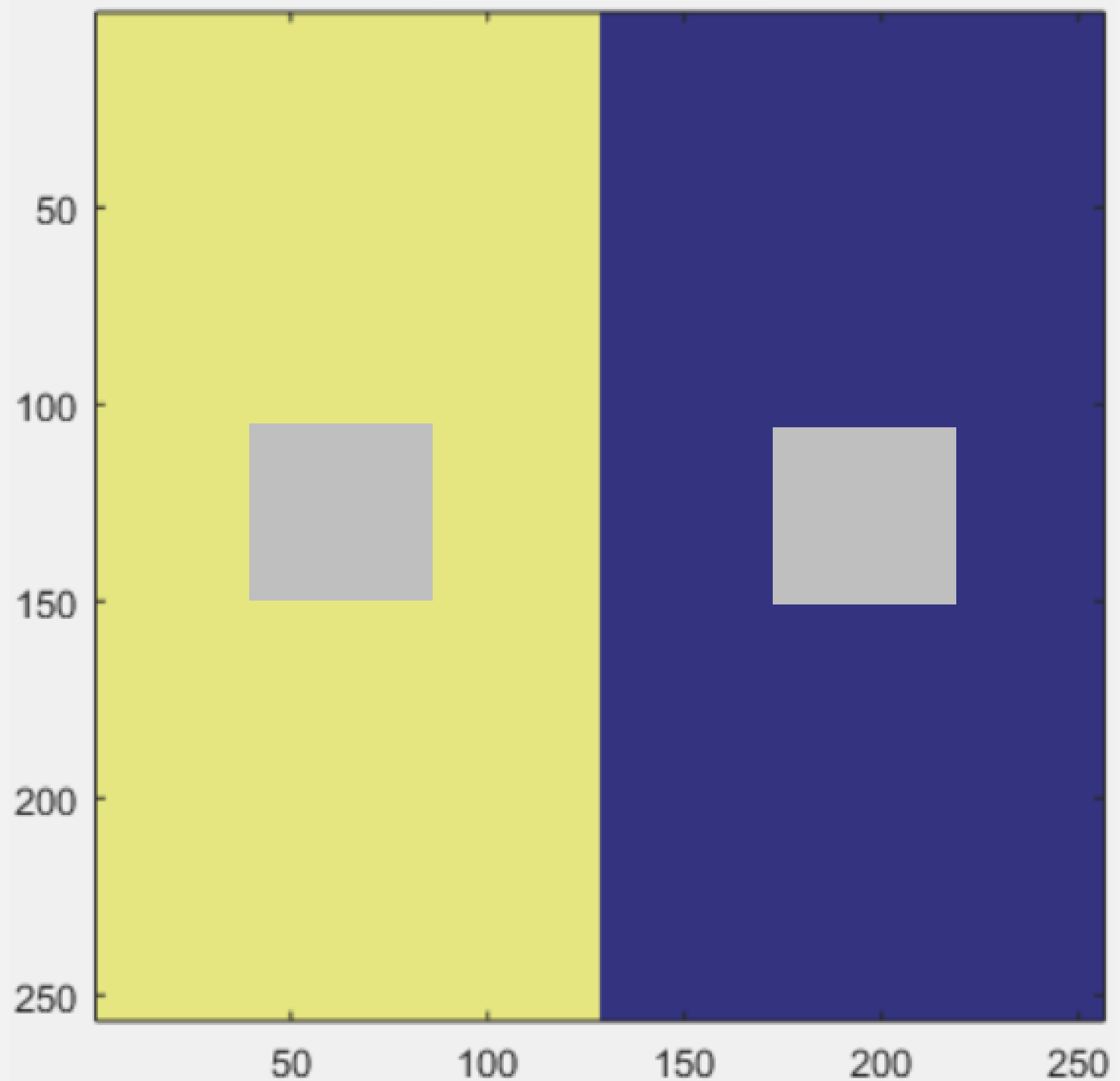


$$I_{RGB}(x,y) = illumination_{RGB}(x,y) \ * \ reflectance_{RGB}\,(x,y)$$

Solution: See Exercises.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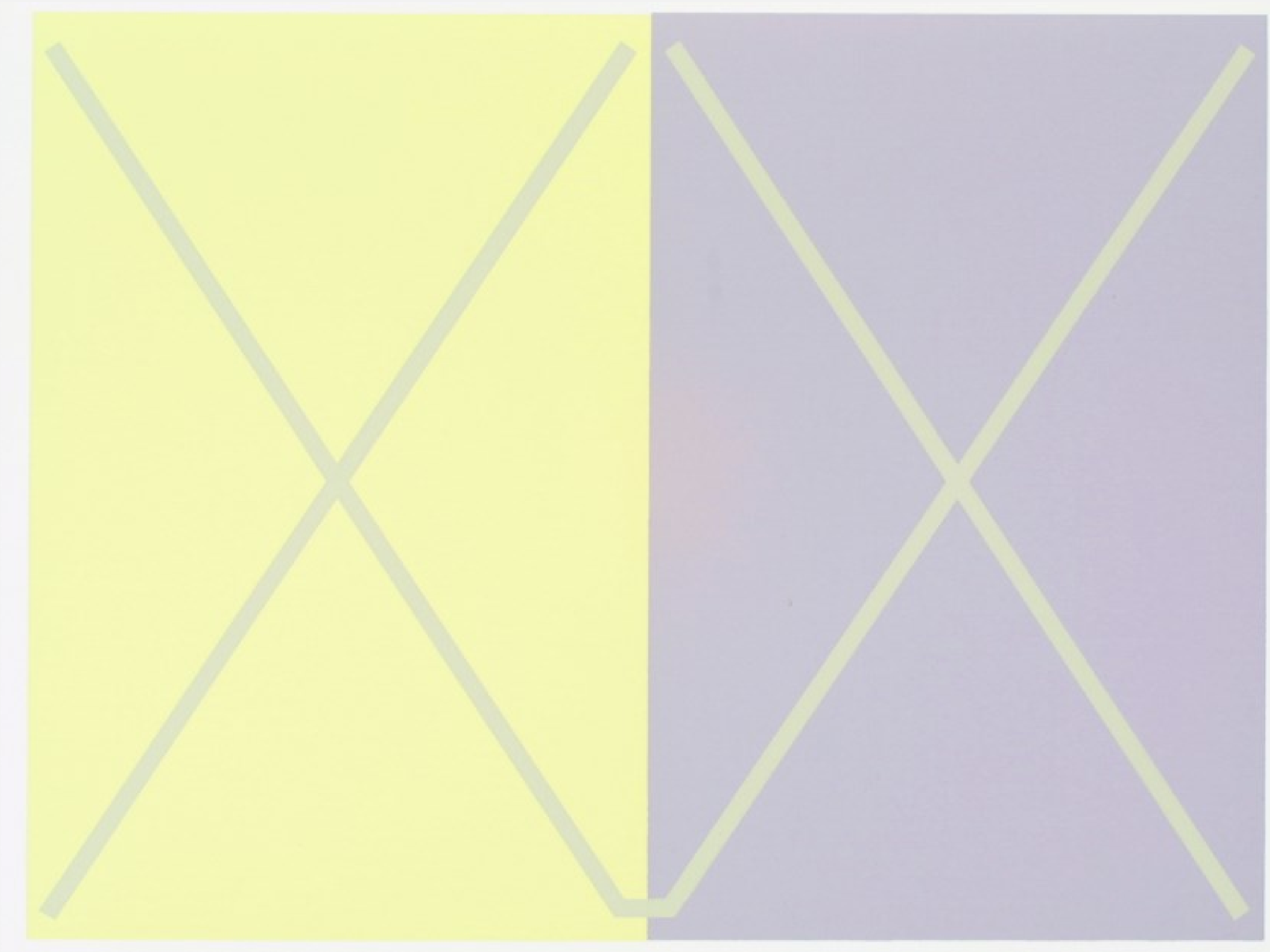

Joseph Albers 1963

Level of Analysis in Perception

high

- behavior: what is the task ? what problem is being solved?
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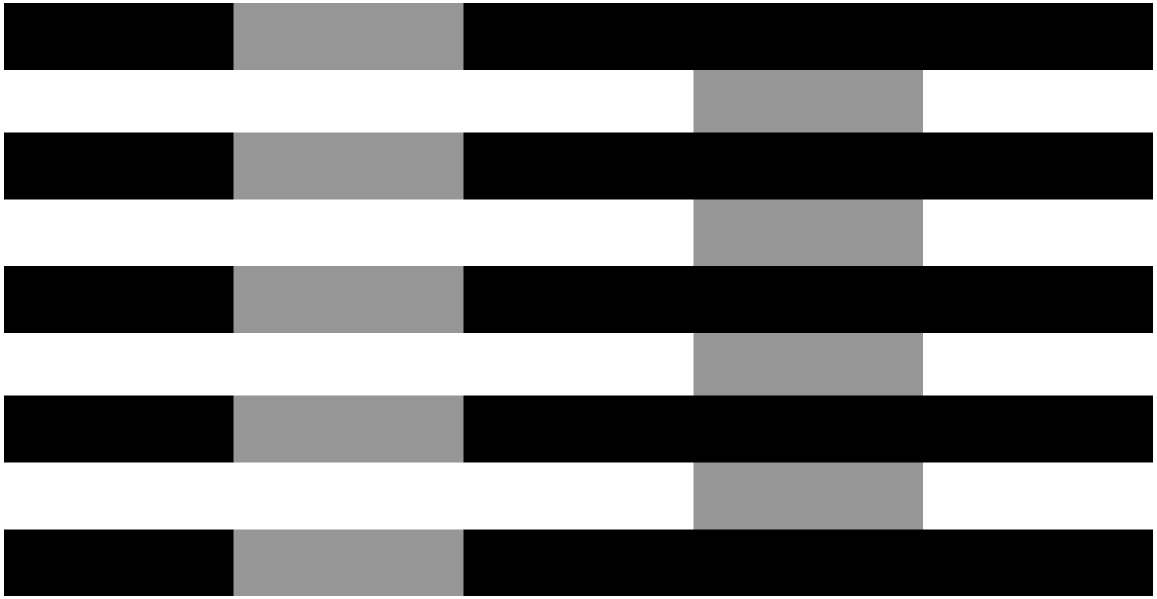
low

Our visual systems have evolved to solve certain problems.   We use lots of tricks, rules, and sophisticated computations. This leads to artifacts, such as examples shown.

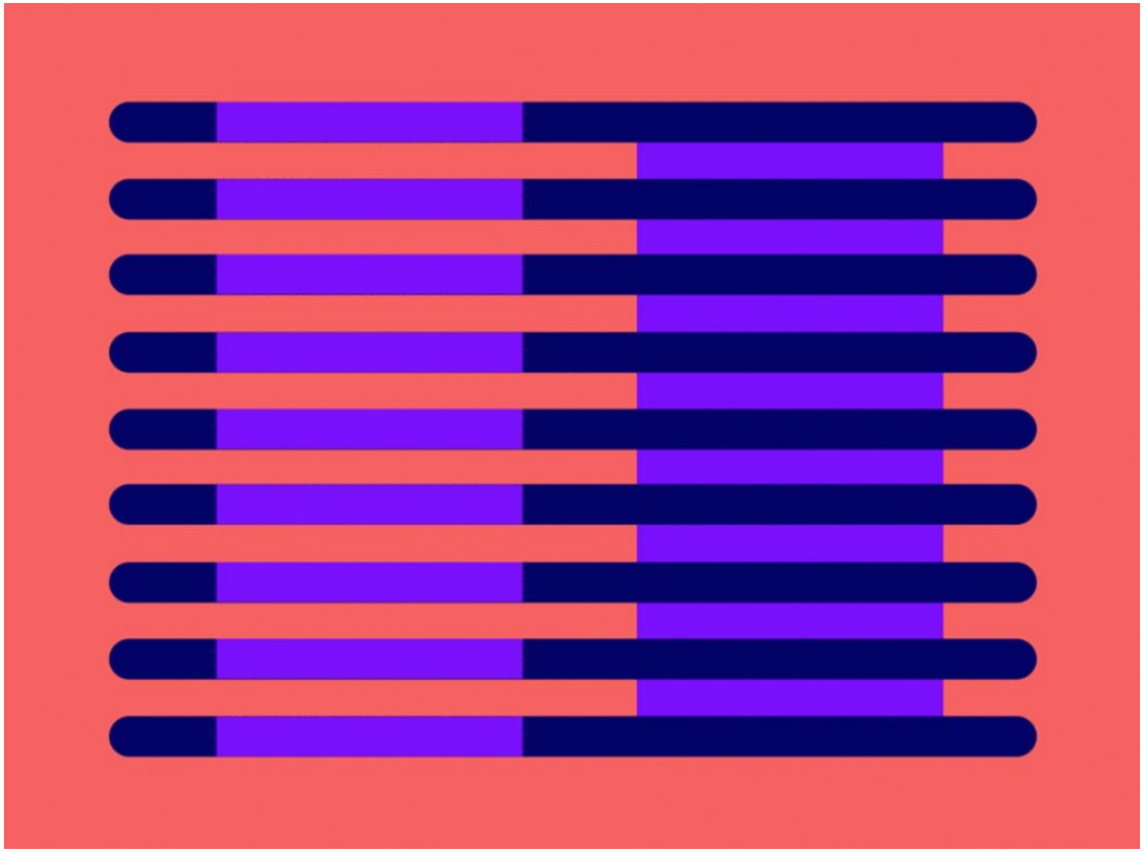
Time permitting… a few of my favorites

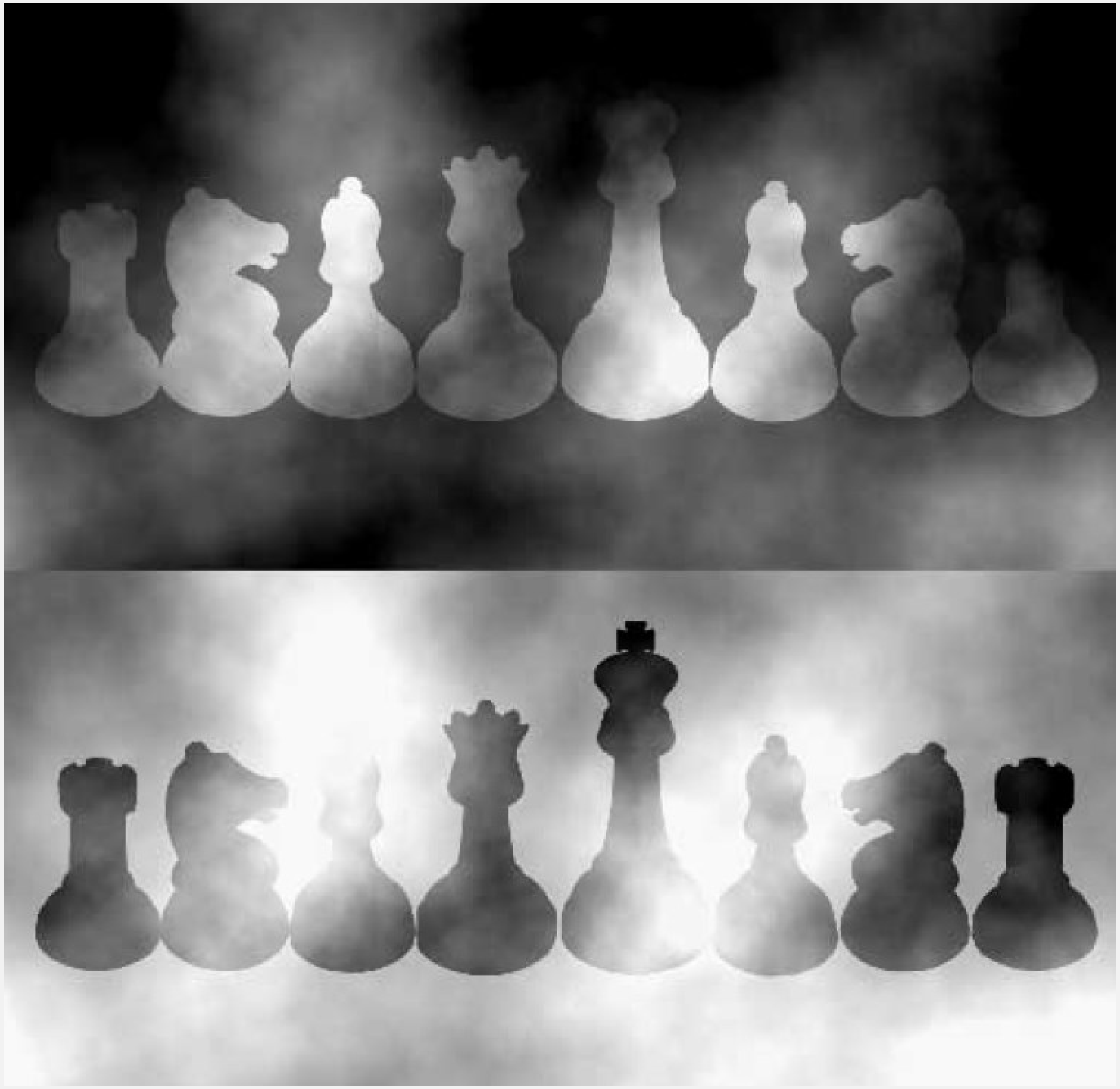
White’s illusion



The grey squares on the left & right are the same intensity (grey level).

(aka) Munker-White illusion





Anderson & Winawer 2005