CSC 589 Intro to computer vision
Lecture 13 The dress

American University
Bei Xiao

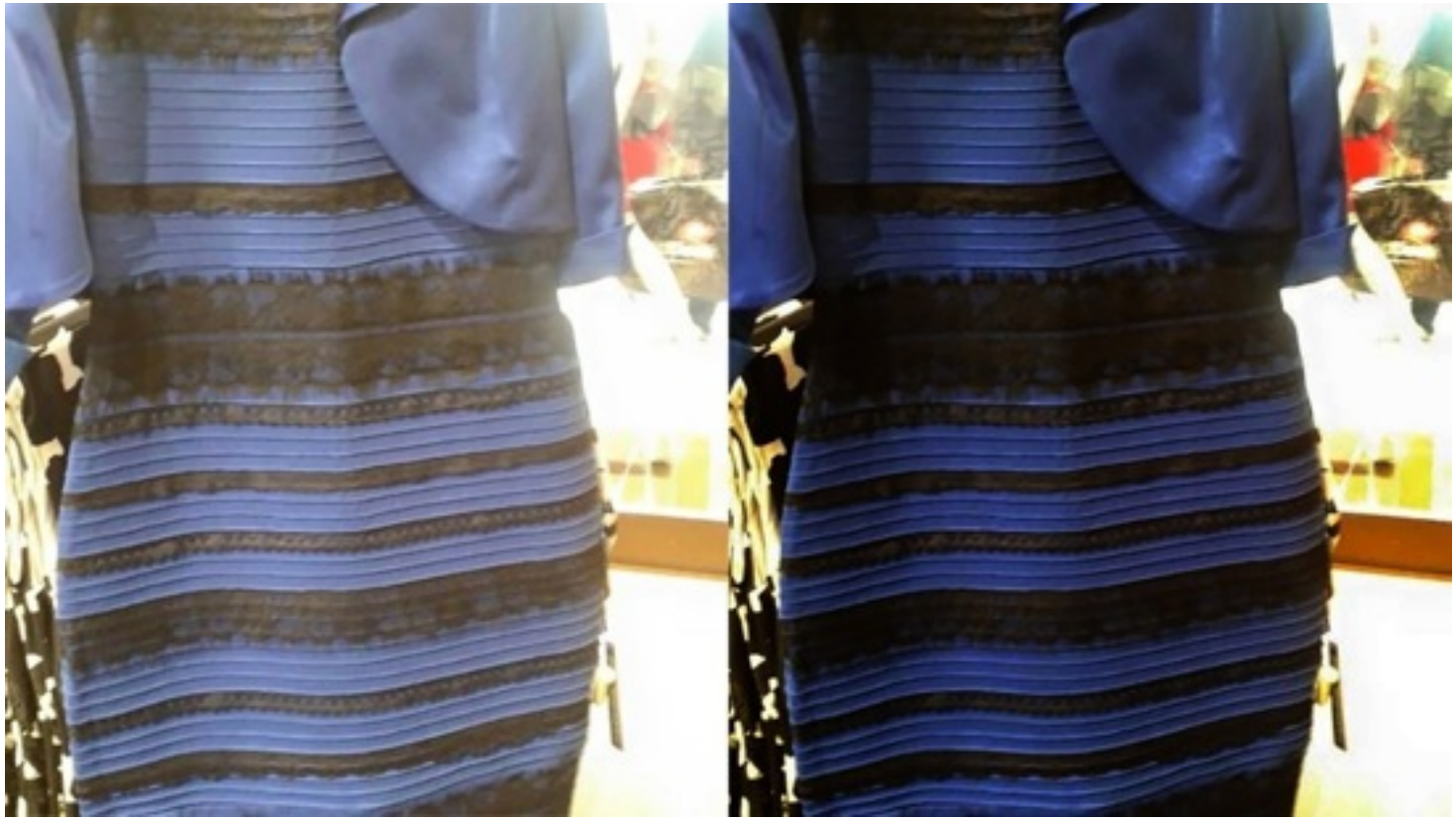
What color is this dress?

Let’s cast a vote? A. blue and black. B. gold and white.

What color is this dress?

Let's cast a vote? A. blue and black. B. gold and white.

Corrected for overexposure



Mashable.com

Scene parsing

This image has almost no reference of white surface except the dress itself

Is this dress under shadow?

Is this the only light source?

Is the dress and the background being lit with the same source?

Why do we care about this?

1. This illusion shows that we have huge (non-agreeable) individual difference in color perception, which is very very little explored.
2. Unlike other bistable perception, it is impossible to see both views for the same viewer at the same time.

Summary of the thoughts

1. Color constancy! People interoperate the illumination differently. People have different priors of whether the dress is in the shade or not.
2. People have different material perception and material perception interacts with color vision. Some people see the dress as glossy. Some see them as matt.
3. Color naming might have an effect but small.
4. Effects of display systems can affect things, but this is less interesting because this effect is primarily cortical.

My cup of tea

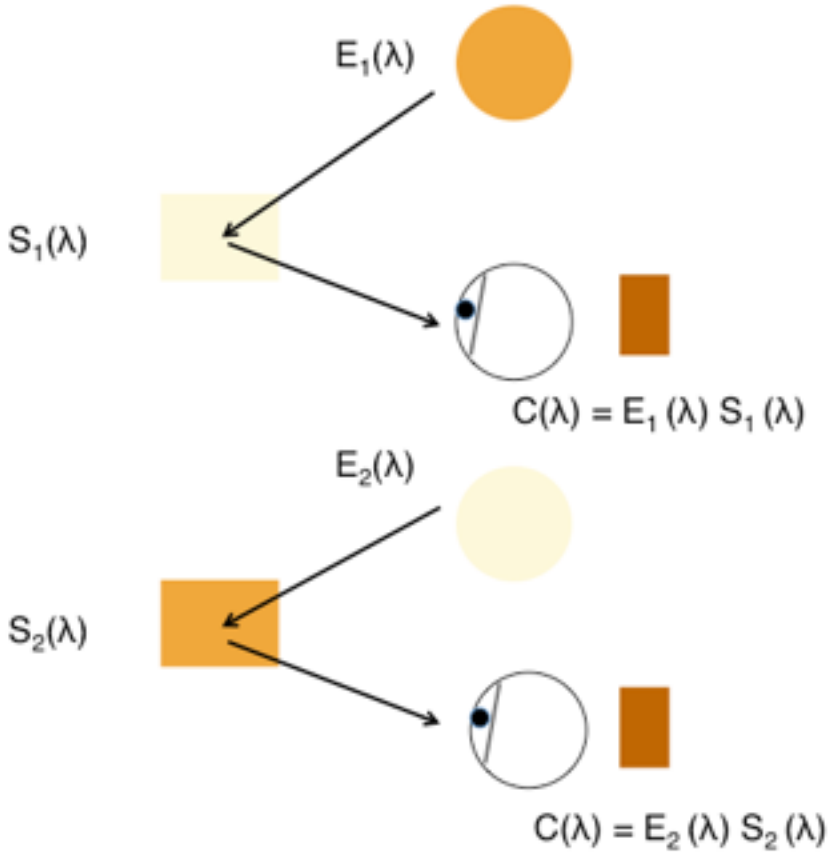
1. When the surface reflectance is complex (e.g. fabric materials and glossy surface), and the scene illumination is hidden and ambiguous. Color perception highly depends on scene interpretation.
2. There are strong individual differences in scene interpretation.
3. I suspect it is cortical (after the image reaching the retina), but the exact mechanisms is unknown.

Possible sources of difference

1. Different prior on how to group surfaces that are lighted under the same light source.
2. Different prior on illumination color.
3. Different prior on surface reflectance: whether the dress is glossy or not.

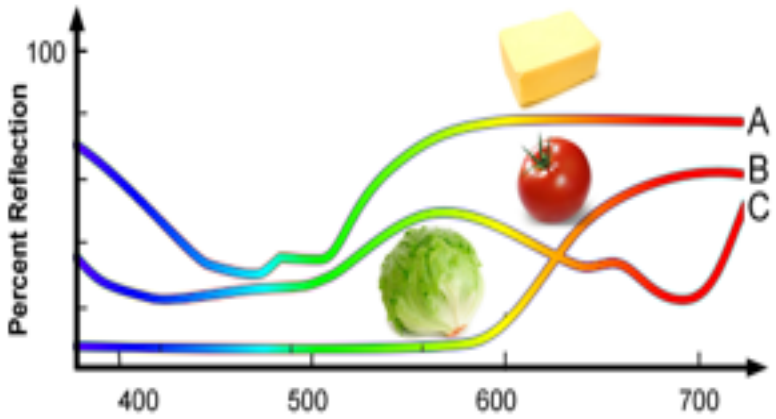
A mini tour of color constancy

Color perception is a result of illumination and surface



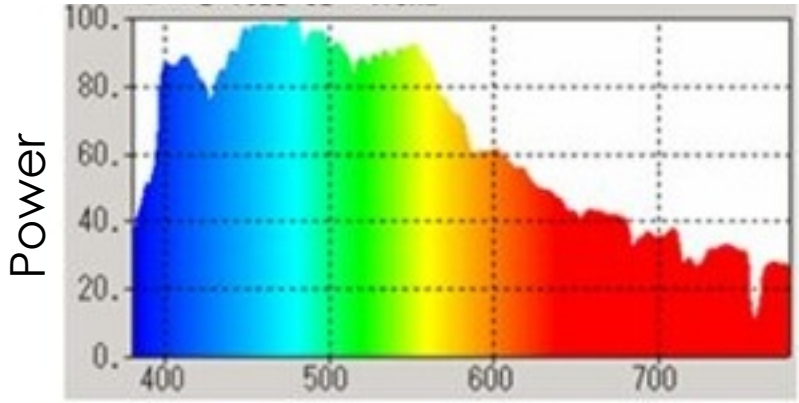
In reality, we care about object/surface color. Therefore, we must discount the color of the illumination!

Spectral reflectance curves of butter, tomato, lettuce



Wavelength (nm)

Spectral density curve of daylight



Wavelength (nm)

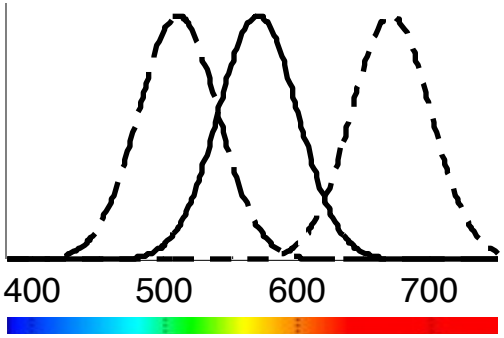
Reflectance of surface

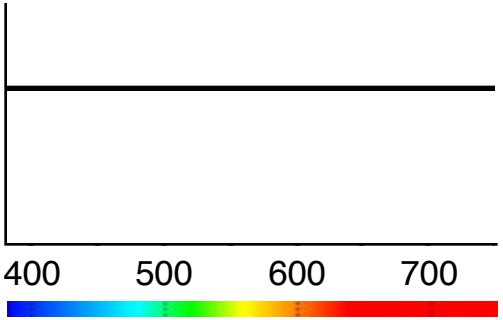
Spectral density of illuminant

Spectral density measured by retina

Slide Courtesy
Weiji Ma

White illuminant



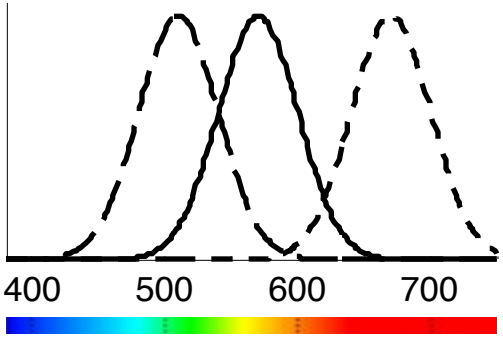


Reflectance of surface

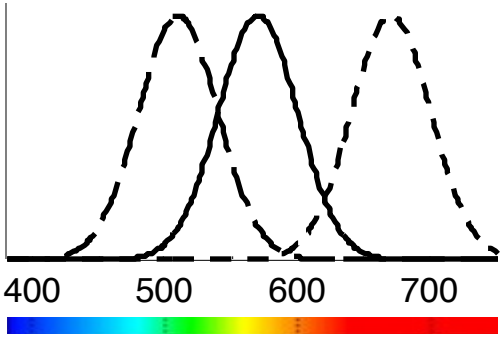
Spectral density of illuminant

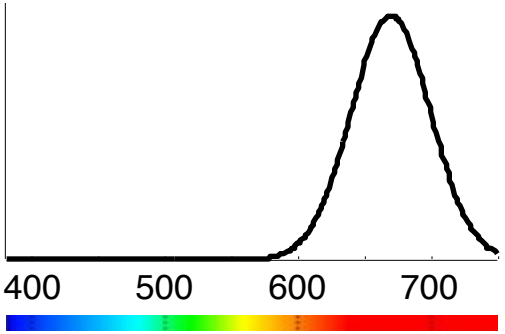
X

Spectral density measured by retina



Red illuminant



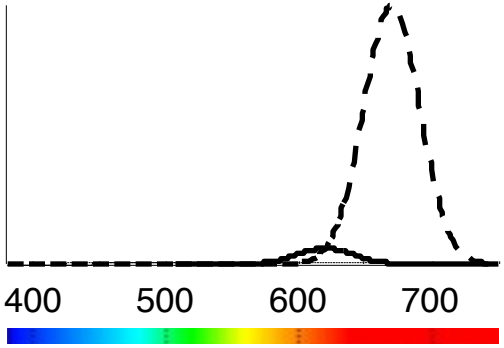


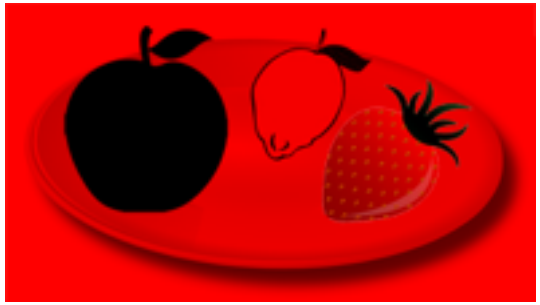
Reflectance of surface

X

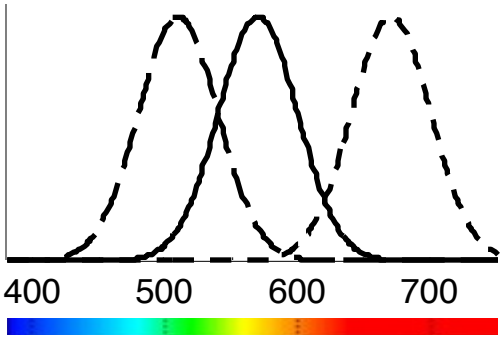
Spectral density of illuminant

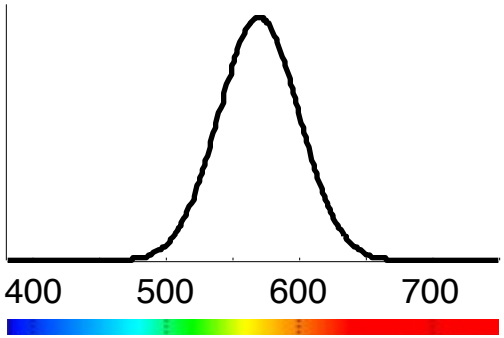
Spectral density measured by retina





Green illuminant



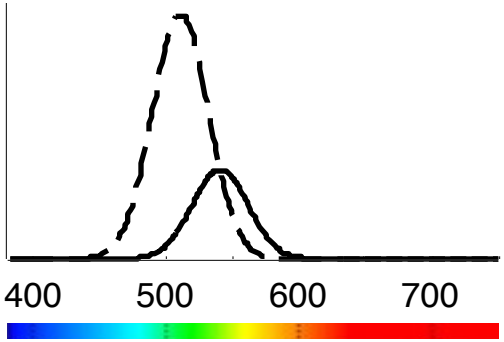


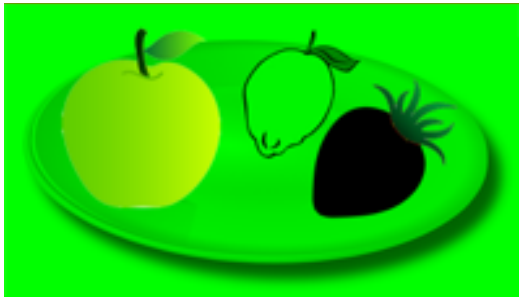
Reflectance of surface

Spectral density of illuminant

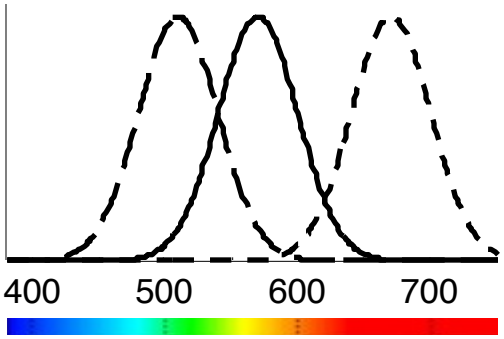
X

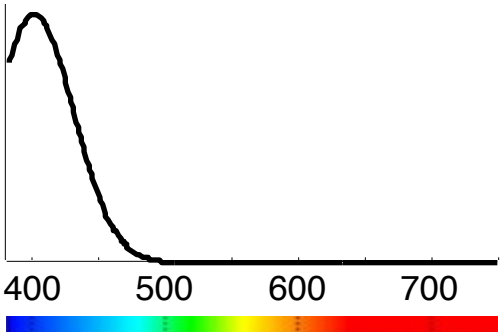
Spectral density measured by retina





Blue illuminant



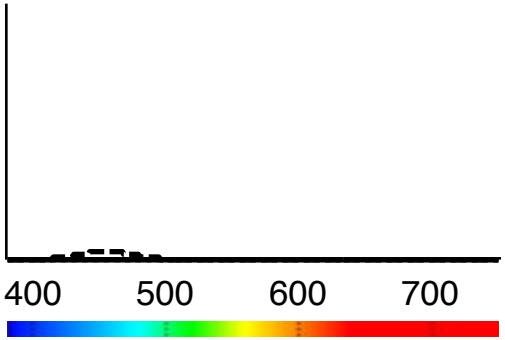


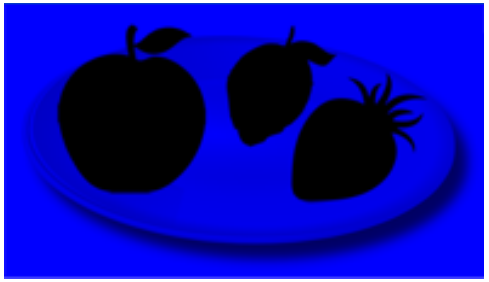
Reflectance of surface

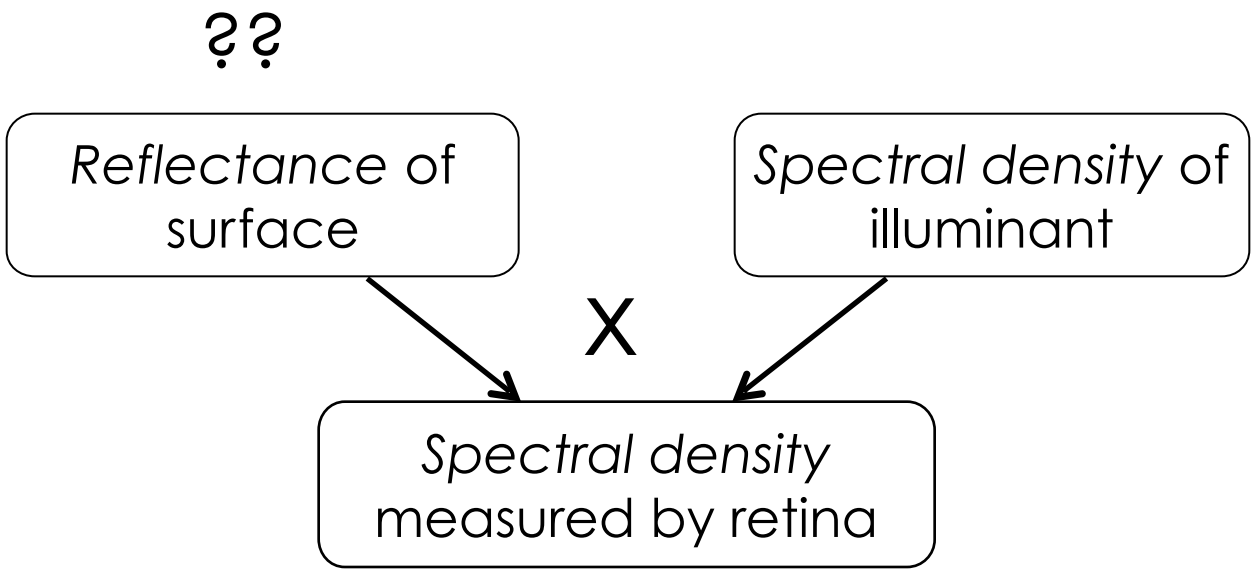
Spectral density of illuminant

X

Spectral density measured by retina





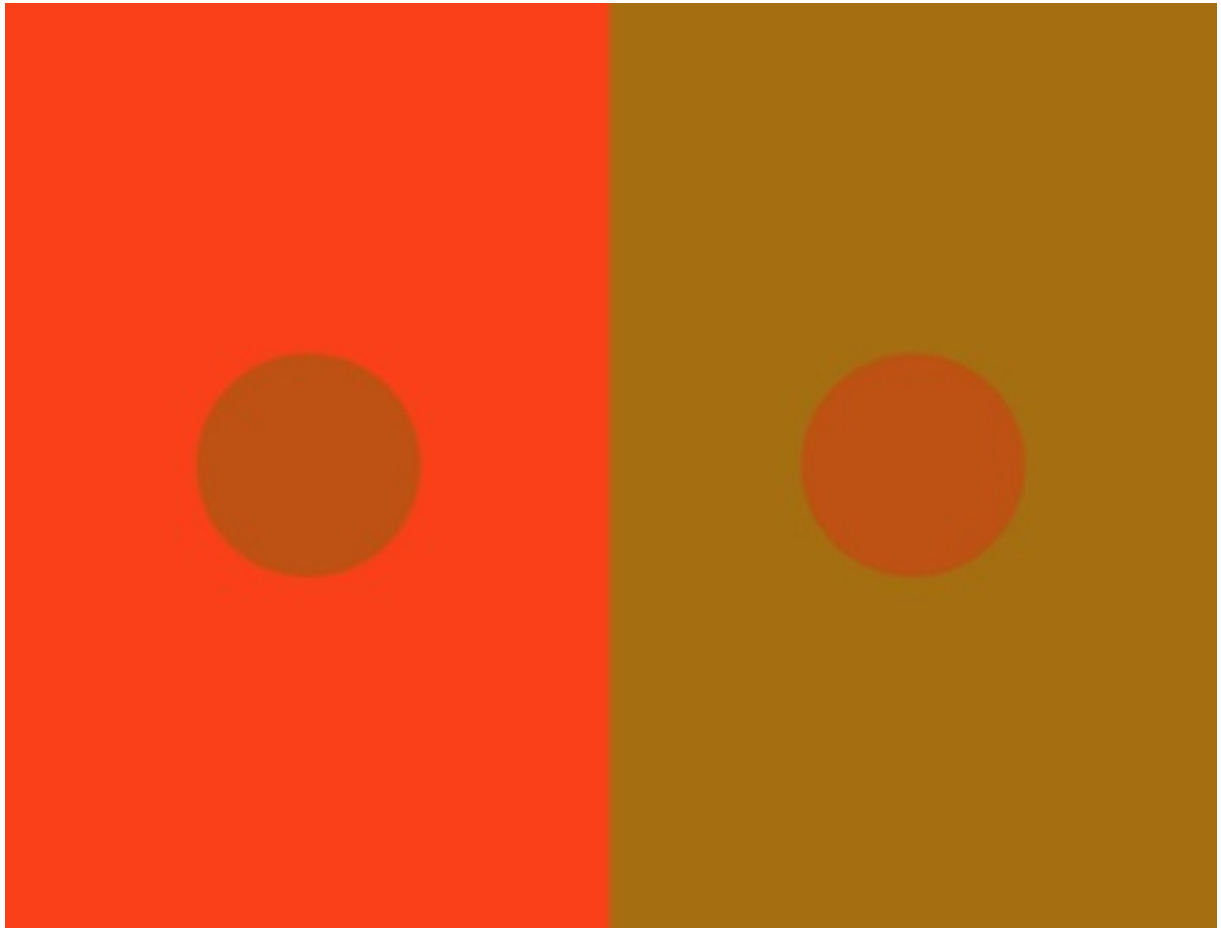


Inference: what is the posterior over reflectance given the spectral density measured by the retina?

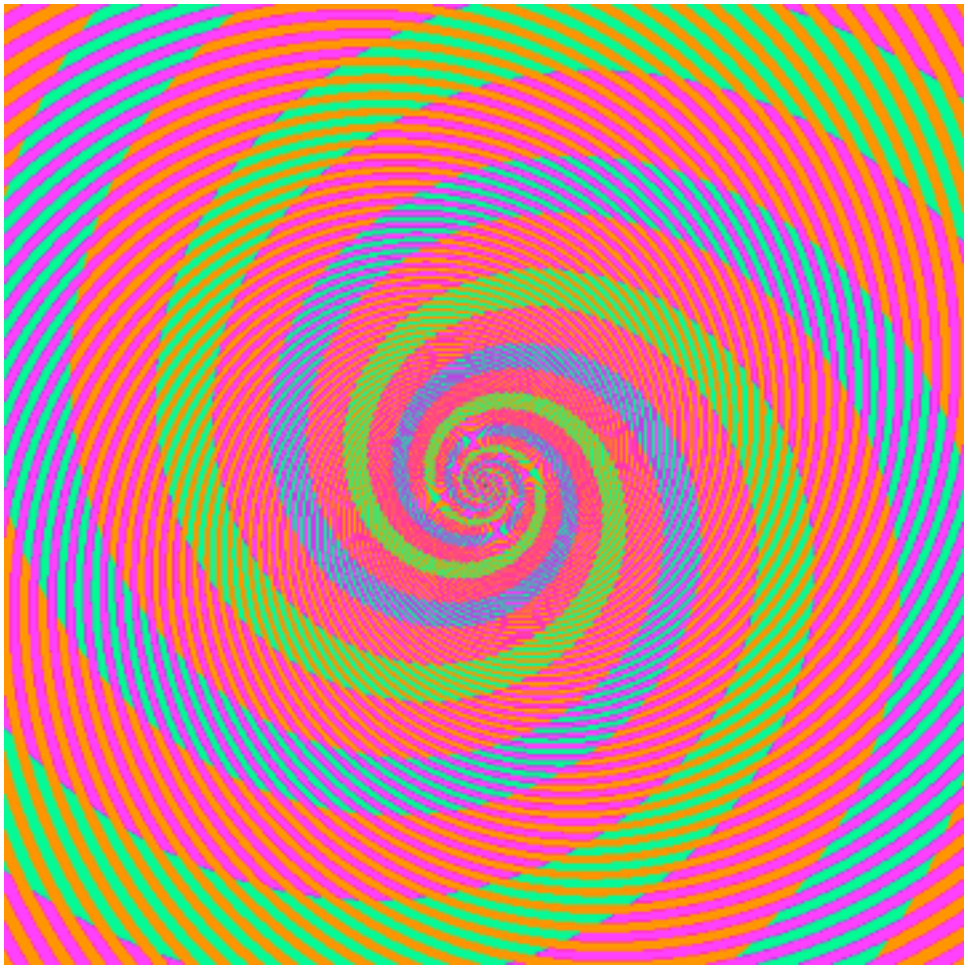
Inference over color requires some belief about illumination!

If you believe the illumination differs, then you might infer the same colors from *different* retinal colors!

Color constancy: the ability to perceive stable object colors, despite variation of illumination and scene context.



Simultaneous contrast

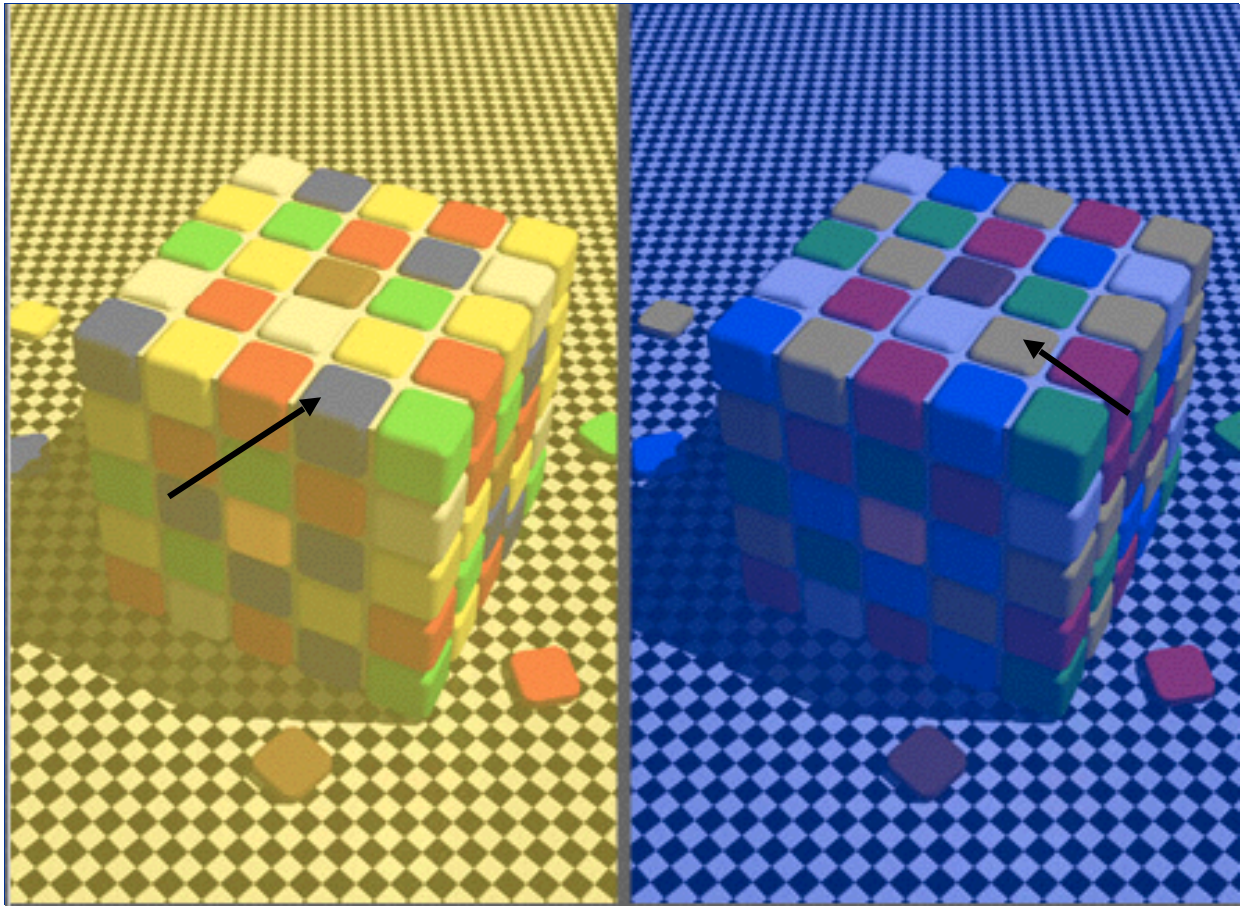


The blue and green colors are actually the same

Pixel color is different from object color

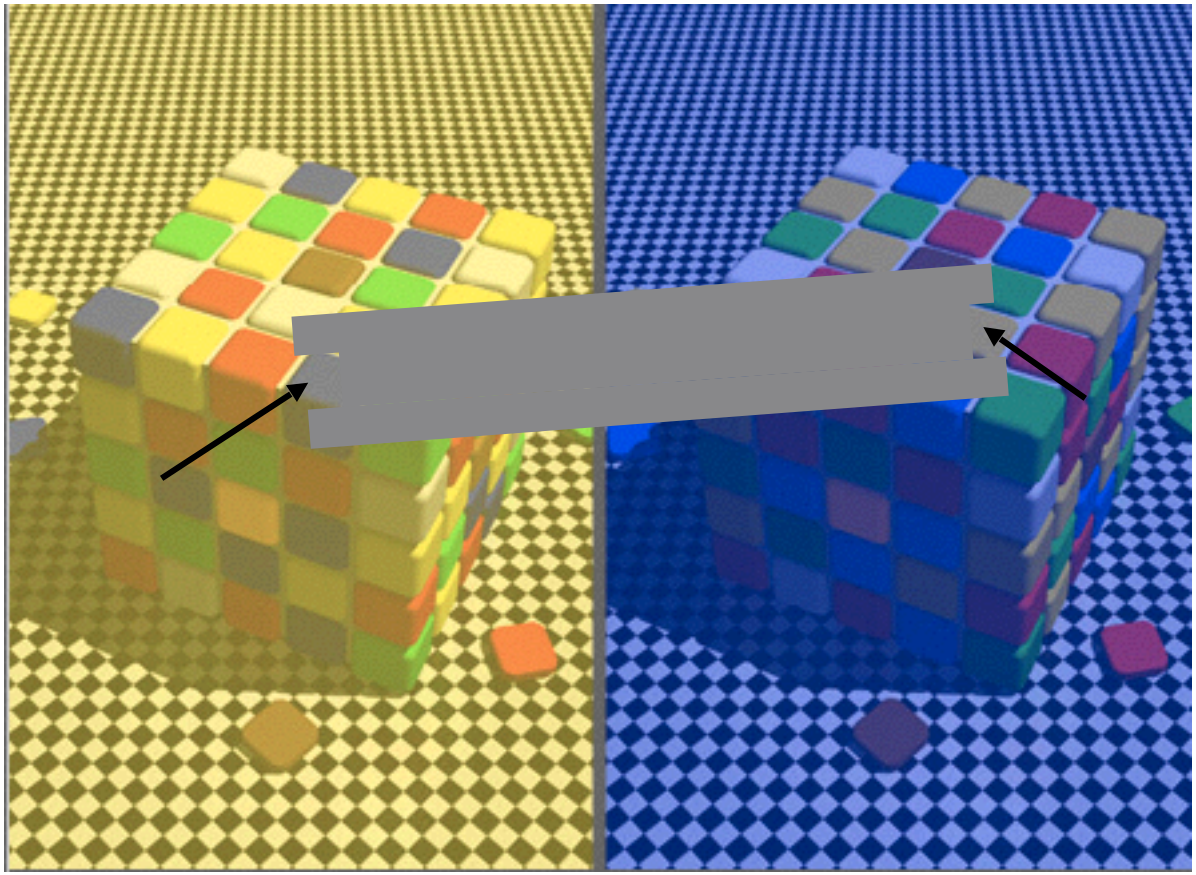
Color constancy is the ability to discount changing in illumination while perceiving stable object color

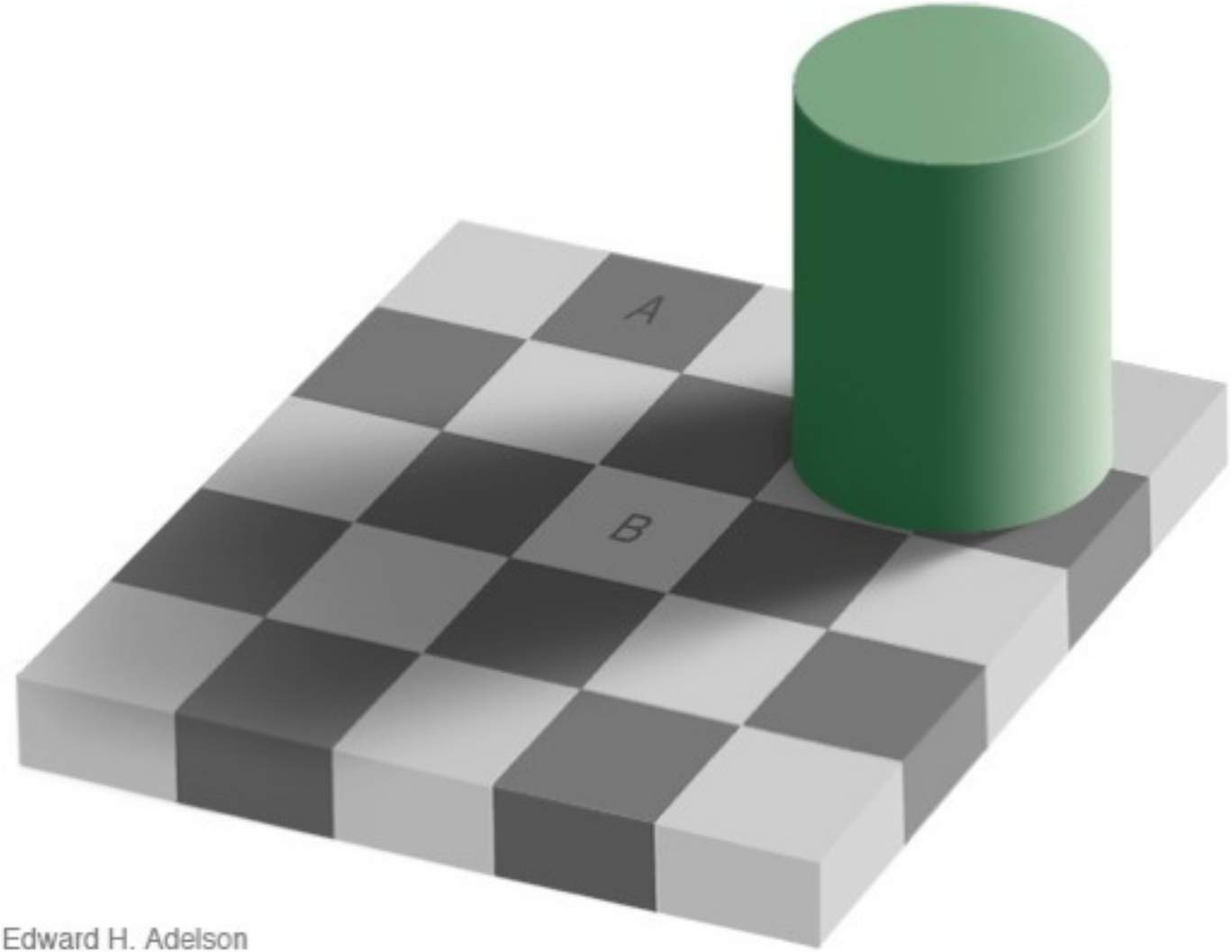
Success of color constancy



Do you see the left or right square as more yellow?

“Discounting of the illuminant”





Edward H. Adelson

We know almost nothing about color constancy beyond objects made with matt and opaque materials!!

Time to move on to Fabrics and other complex materials of everyday life!

Now let’s return to the dress!

A popular believe: the image has very ambitious information about light and surface.
Facing uncertainty, people interoperate the scene illumination differently

But we have no idea why!

Bayesian Framework: people interoperate illumination differently

Ideas are discussed with
Maria Olkkonen at Upenn

Interpretation A:
Is the dress under blue shadow?

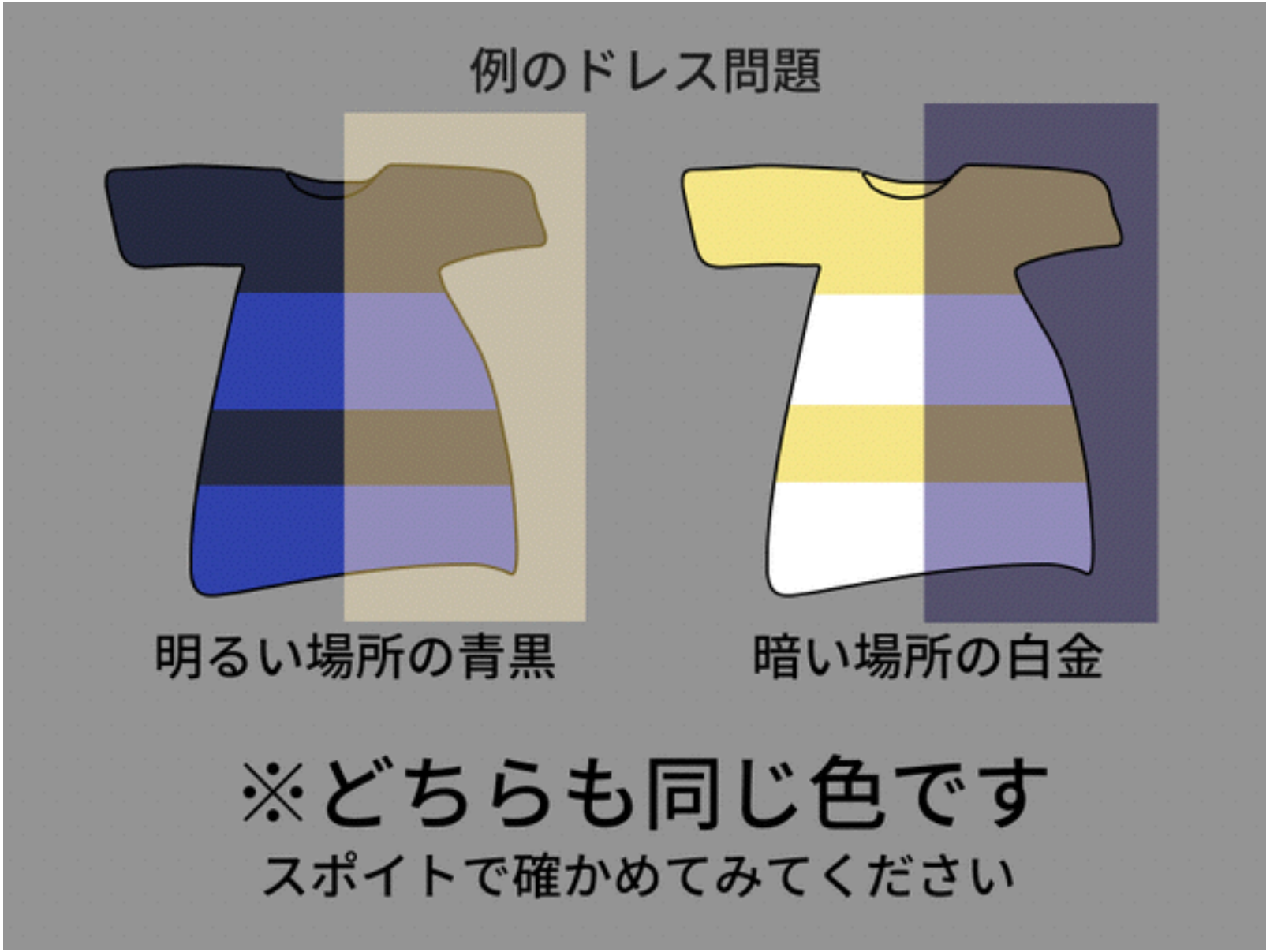
dress is white/gold

Interpretation B:

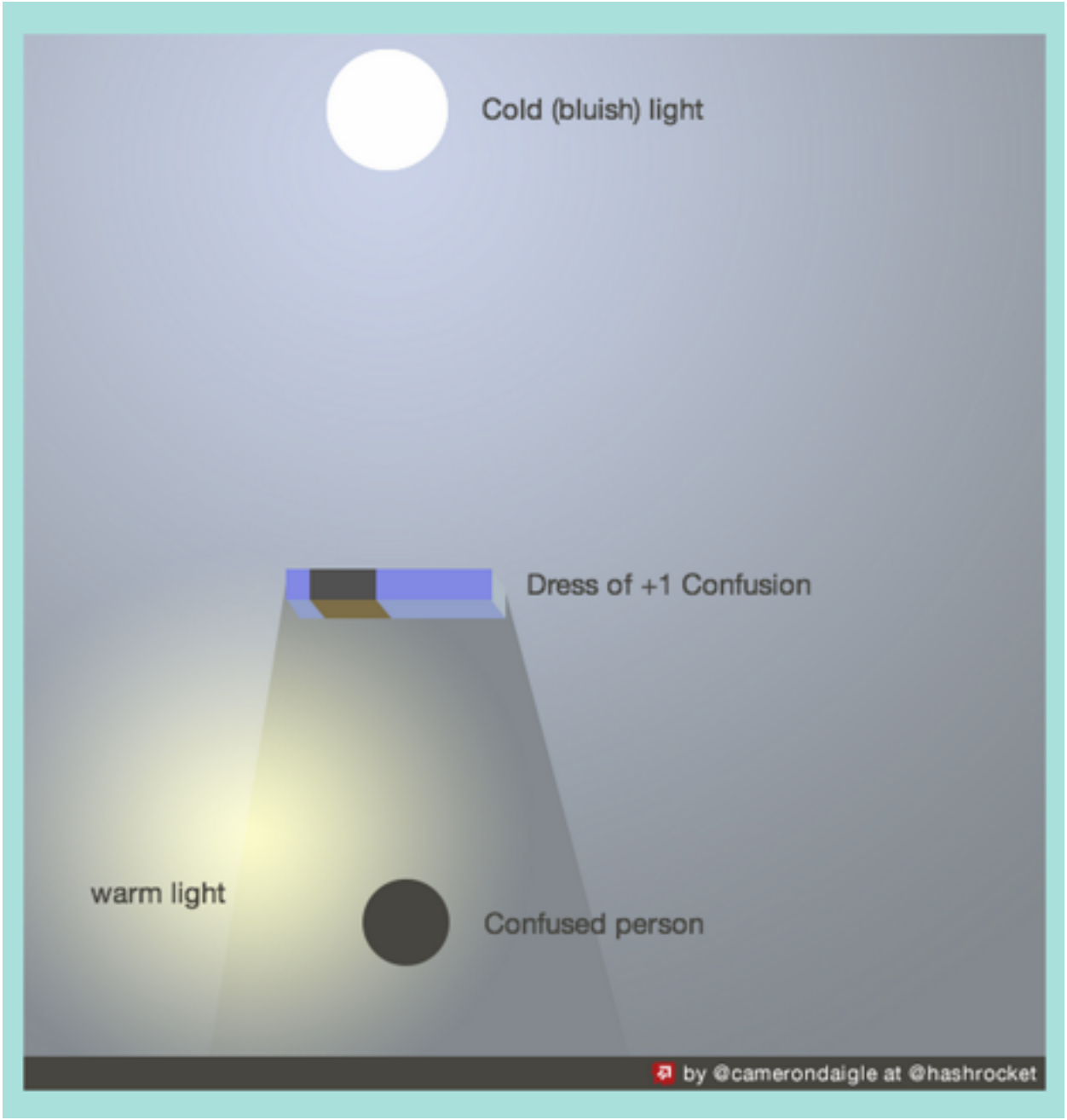
or is it under bright yellow light?

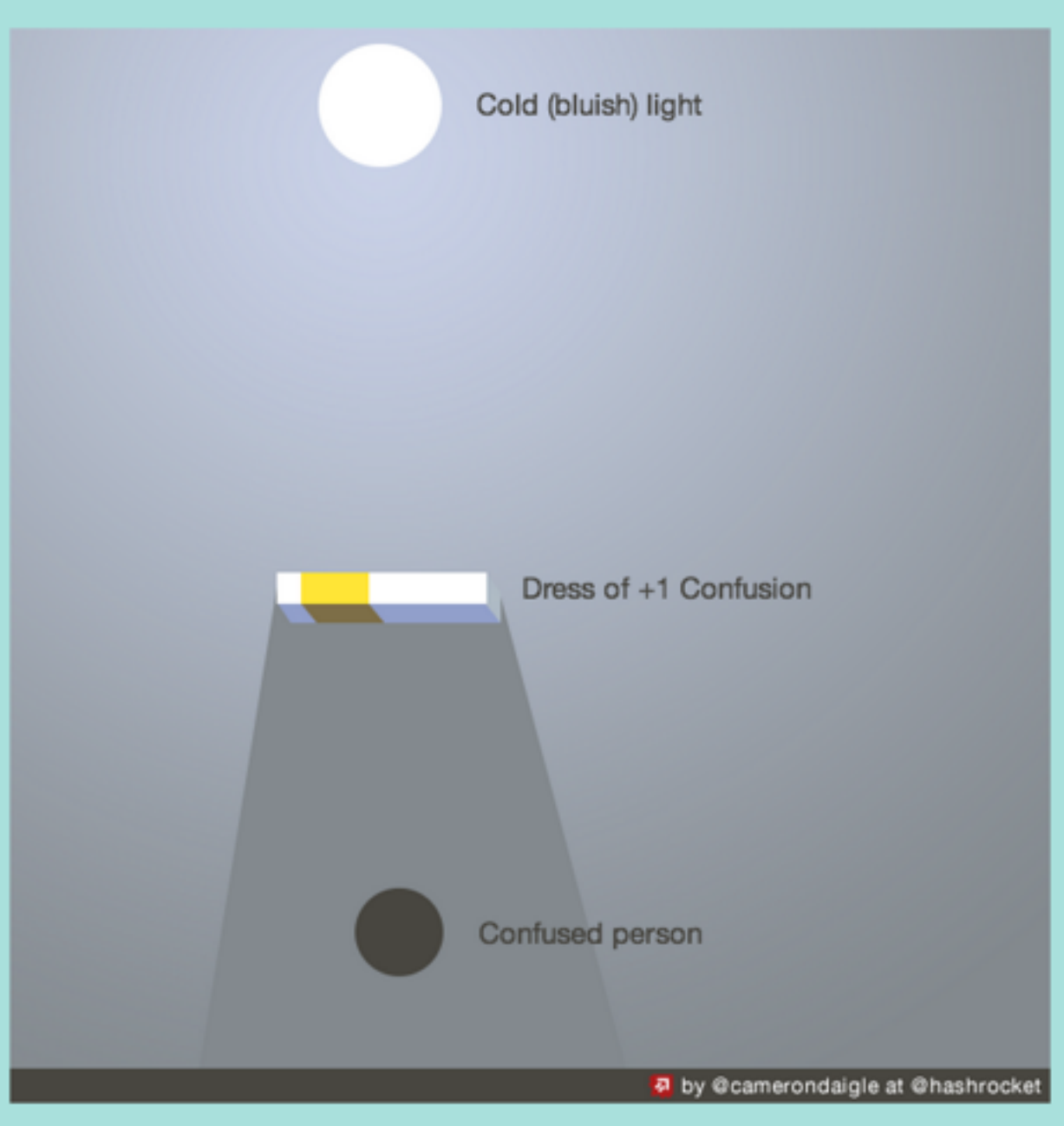
dress is blue/black

Some nice illustrations

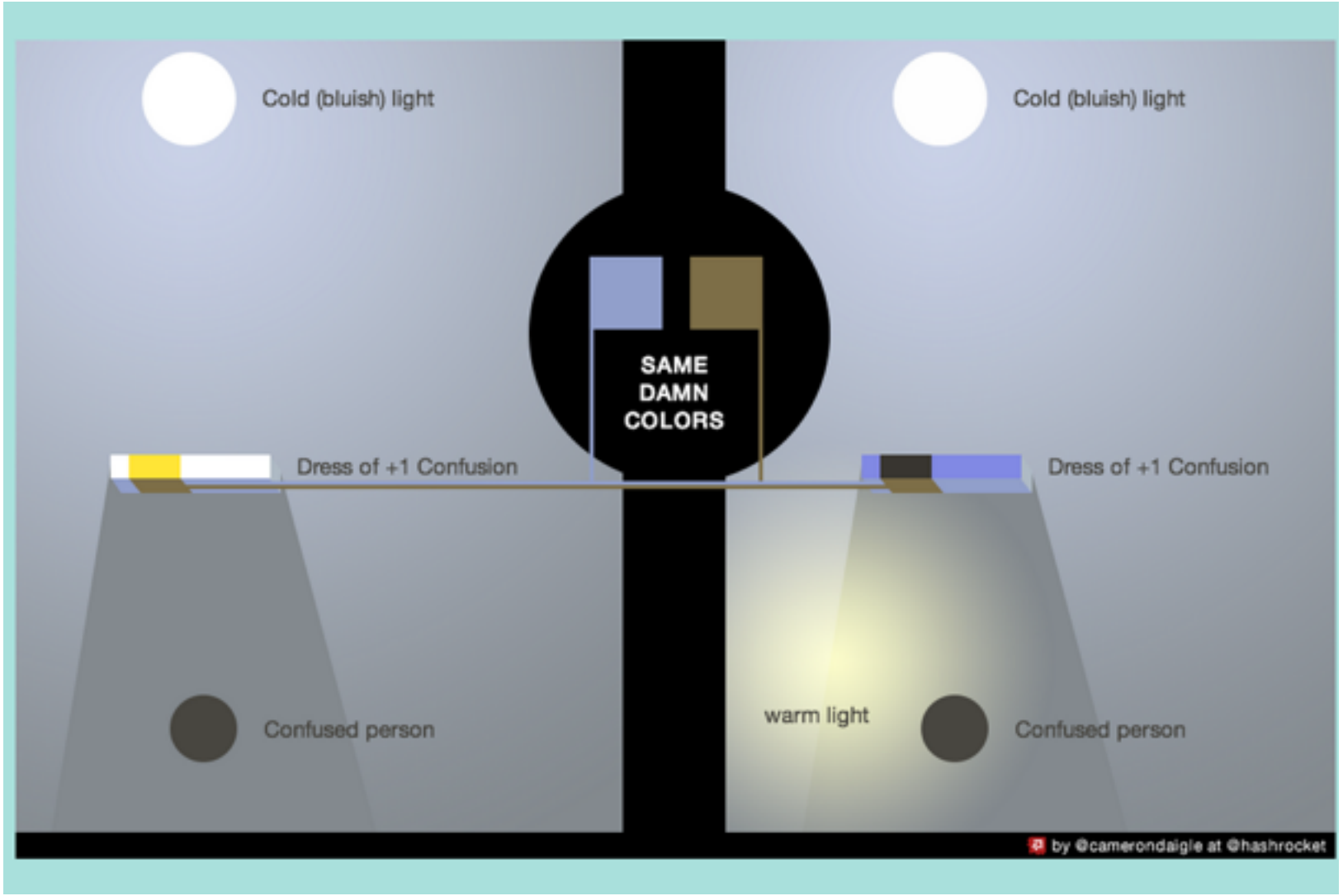


http://hashrocket.com/blog/posts/the-tale-of-the-color-shifting-dress




Cold (bluish) light
Dress of +1 Confusion
Confused person
by @camerondaigle at @hashrocket

http://hashrocket.com/blog/posts/the-tale-of-the-color-shifting-dress



People believe the image has different exposure

Interpretation A:
not overexposed

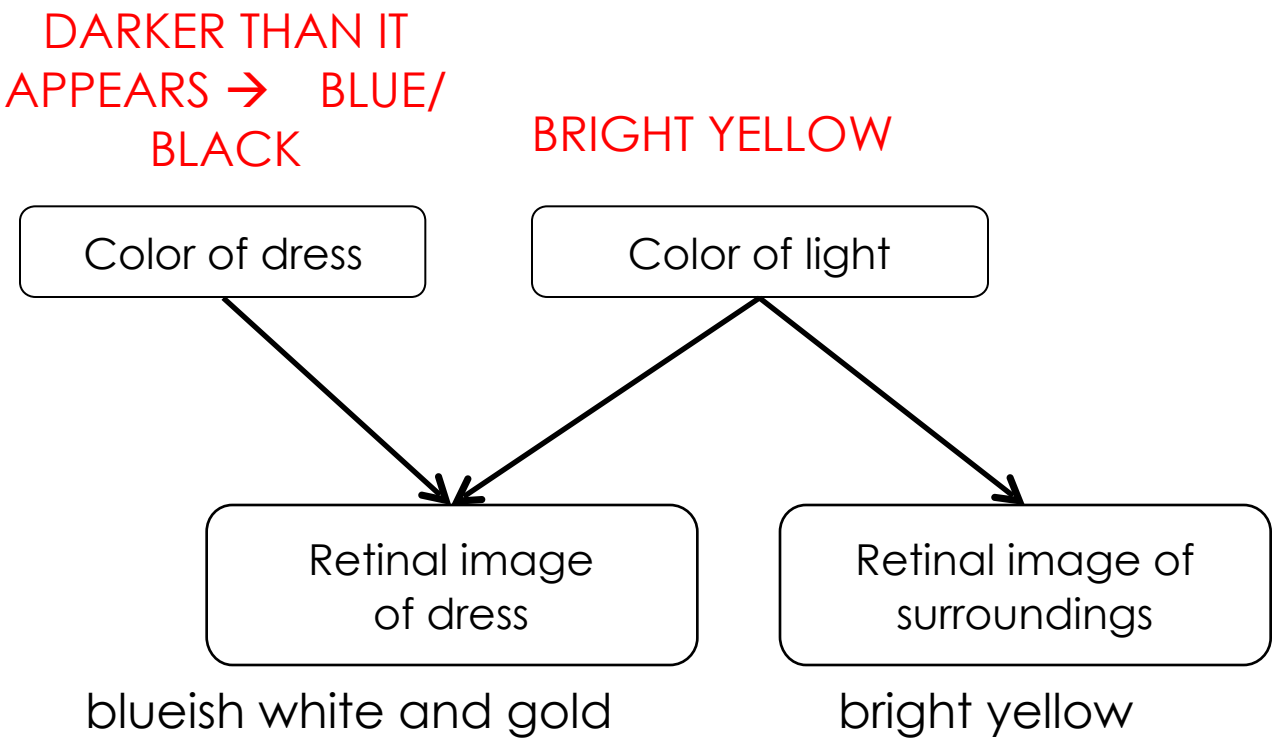
dress is white/gold

Interpretation B:
overexposed

dress is blue/black

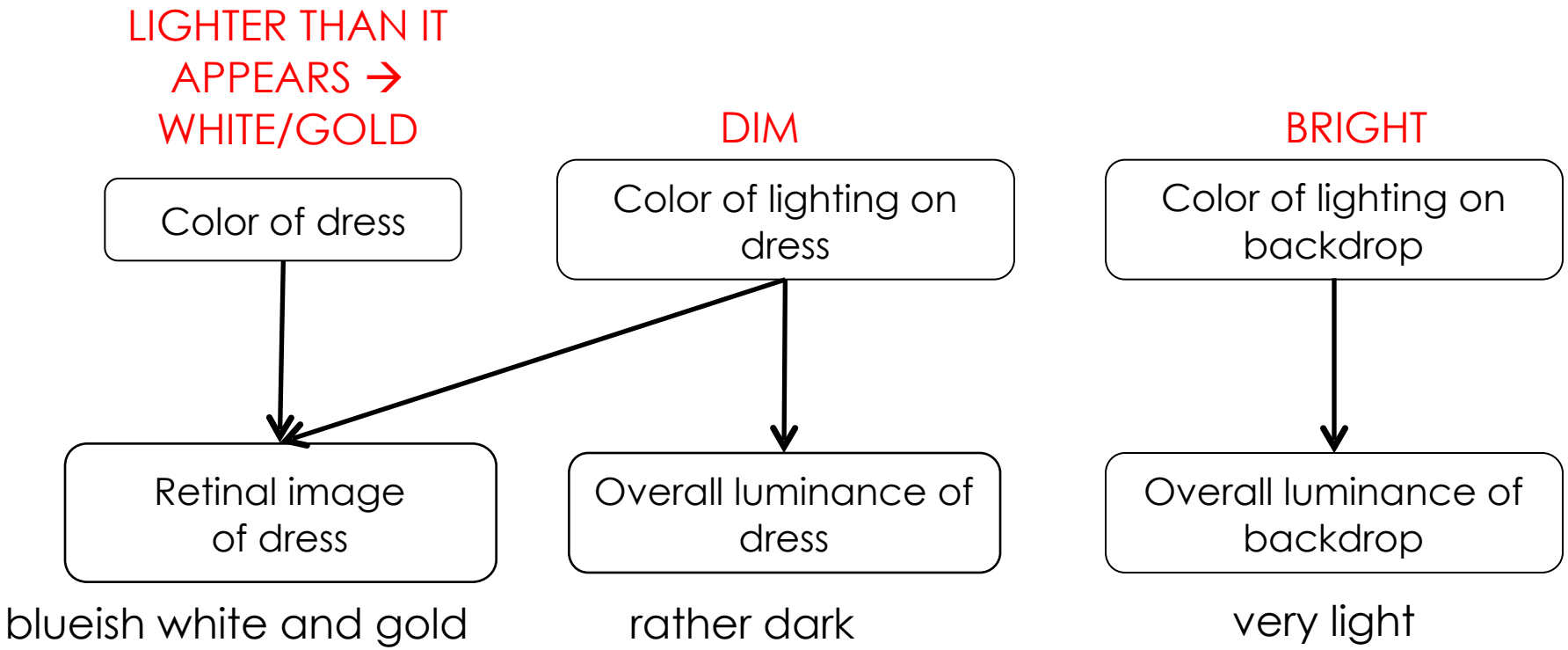
Ideas are borrowed from Weiji Ma (NYU)

Possibility 1: You believe foreground and background were taken under the same lighting



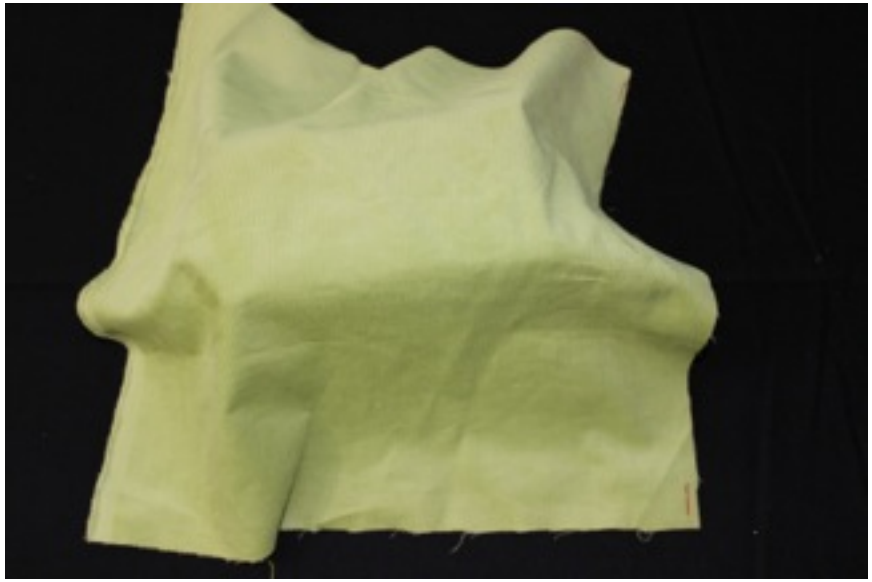
Ideas are borrowed from Weiji Ma (NYU)

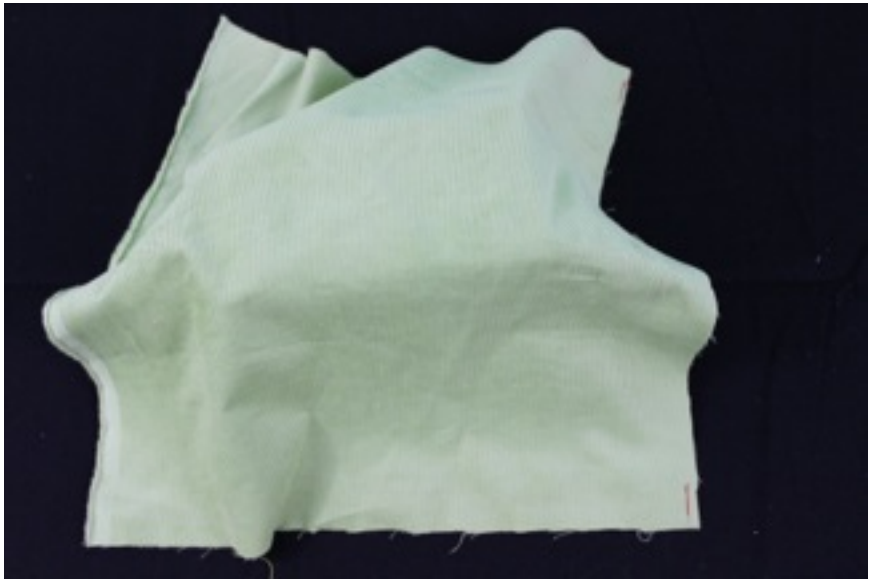
Possibility 2: You use the overall luminance difference between foreground and background to infer that the dress was lit dimly



Color interacts with material properties!!

Same fabric under different illumination!





We observe that fabrics tend to have poor color constancy due to complex surface reflections and sub-surface scattering properties! Light interacts with fabrics in a complex way so we are worse at color constancy.

People believe the material properties of the dress differently

Interpretation A:
Dress is shinny

dress is white/gold

Interpretation B:
Dress is matt

dress is blue/black

People use different straggly of scene parsing

Individual differences in color constancy

1. Few works have explored individual difference on color constancy! A great opportunity for a potential PhD thesis and project!
2. A recent recent study, for example, showed that working memory predicts individual differences color constancy (Allen et al. 2012, Josa A).
3. But in terms of this dress? Is working memory needed?
4. How about color naming and categorization?
5. When context information is removed, color constancy becomes worse and the uncertain amplified the difference in perception is amplified.

Individual differences in color constancy

Let ’s rule out a few less complex possibilities

- Color naming
- Color categorization and material properties
- Display device difference

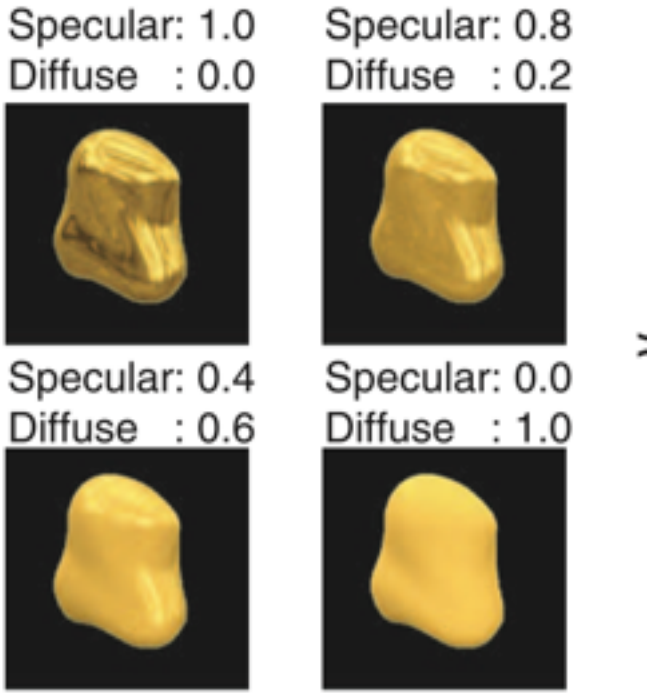
Color perception depends on culture and language: Russian blues reveal effects of language on color discrimination

Different languages divide color space differently. For example, the English term “blue” can be used to describe all of the colors in the figure. Unlike English, Russian makes an obligatory distinction between lighter blues (“goluboy”) and darker blues (“siniy”).

Russian speakers distinguish blue faster than English speakers!

http://www.pnas.org/content/104/19/7780.full

Is “gold” a valid color category?



A recent study has shown “gold” only becomes a valid color category if the surface is shinny!!

Okazawa et al. (2011) Journal of Vision.

Is “gold” a valid color category?

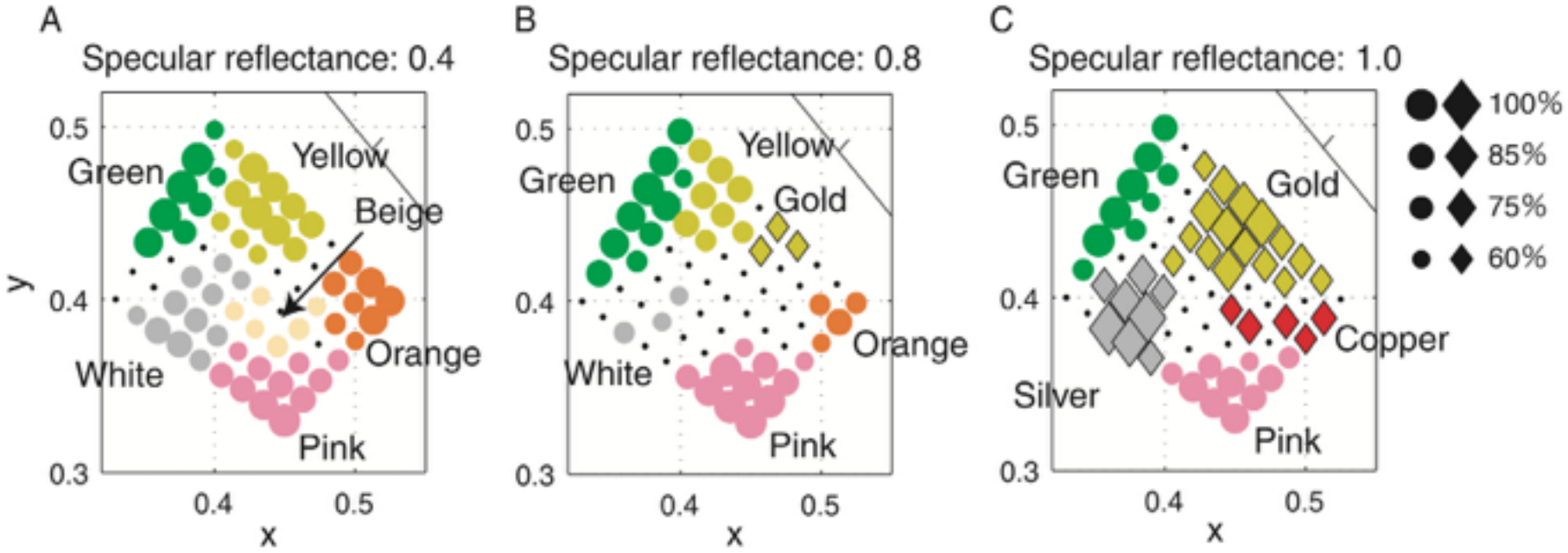


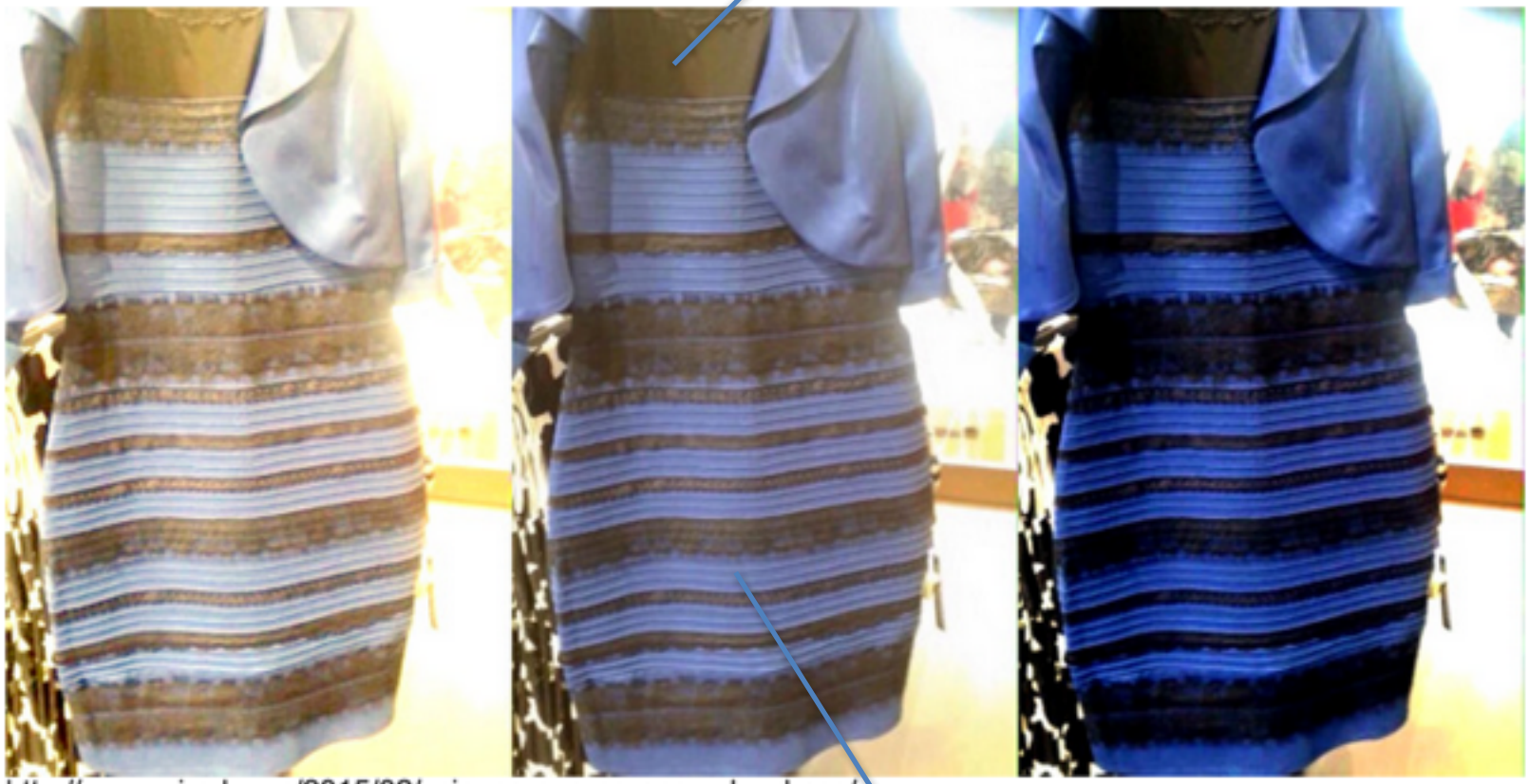
Figure 3. Results from categorical color-naming tasks in which stimuli had specular reflectances of (A) 0.4, (B) 0.8, and (C) 1.0. The conventions are the same as in Figure 2.

“Gold” becomes a valid name for color category as the surface becomes more glossy!

Okazawa et al. (2011) Journal of Vision.

Is “gold” a valid color category?

Is this “gold” or “brown”



http://www.wired.com/2015/02/science-one-agrees-color-dress/

Is this “blue”

Deeper question: What is the origin of individual differences in color perception?

1. Biological difference. Studies has found that the distribution of red, blue, green cones (photo receptors) distribution in human retina has a huge differences! But we roughly see similar colors!!
2. Genetics. Well, this is well known since there are mutations to the genes that cause color blindness. But it seems very trivial for normal-visioned people.
3. Culture (see the Russian blues study). But this could be small.
4. Experiences (interactions with different materials). We might see different amount of gloss in the dress!
5. Prior about wavelength?
6. Last and but not the least, we all use different kinds of displays to view images (iPAD, iPHONE, computer monitors, etc). Device certainly has different dynamic range.

Interesting things to pursue

1. Do a study using color matching task instead of color naming. You can ask subjects to pick up a patch that looks similar to a patch on the dress. Can you still have the same size of individual differences? This will eliminate the effect of color naming.
2. Try this experiment with different materials. Try very opaque material (linen) and very transparent one (lace) and glossy vs. on-glossy.
3. Do a color constancy experiment with Fabrics. Fast while the heat is on!
4. Test different priors of illumination.

Experiment 1: color matching

1. load the dress into Photoshop.
2. make color swatches from different parts of the dress
3. Make a few color swatches of different hues of yellow, blue, white, and black.
4. Paste them on a gray background
5. Ask your classmates to select color watches that match best to different regions of the dress.

What to do?

1. Make an experiment of color matching and collect some data from your friends. It will be great to make it into an app
2. Do the above experiment using the dress without the background.
3. Compare with a normal stripy dress or another gold dress (shoot your own photo)
4. Write a report of your own research and if you changed your percept, also report how you changed.
5. Turn it in either as a webpage or a document. We will collage it together and share with the public.

Long-term questions to pursue

1. Measure individual difference in interoperating scene illumination (e.g.which part of the regions is under shadow). Under what circumstance does it happen?
2. Does this depends on material perception?
3. Independent of scene illumination, what about individual differences in material perception?