**Spoon Reflections**

- **Answer:**
  - When you look into the inside of a spoon (the concave part), light is reflected in, light rays cross, and you get back an image that is smaller and upside-down.
  - When you look into the outside of a spoon (the convex part), light is reflected out, and you get back an image that is larger and right side up.
  - In the diagram below, the large black arrow is the object being reflected, and the thin red arrow is the resulting reflection.
  - *Also, if you look close enough (before the cross-over), even the reflection off of the concave surface will look right-side-up.

![Diagram of spoon reflections](image)

**Tapping Into What a Deer Sees, and Doesn’t**

By John Tierney


- For now, thanks to decades of research into ungulate vision combined with the latest in military concealment technology, hunters can don a computer-generated camouflage with fractal designs that look nothing like a shrub or a tree, at least not to the human eye. Named Optifade, it’s being introduced this fall by W.L. Gore (the makers of the breathable Gore-Tex rain gear) and promoted as the first camouflage scientifically designed to make hunters invisible to deer.

The deer, as usual, are not available for comment, so these claims of invisibility cannot be directly verified. But the psychologists who worked with Gore to develop it — Jay Neitz, an animal-vision expert at the Medical College of Wisconsin, and Timothy O’Neill, who pioneered the United States Army’s digital camouflage as a researcher at West Point — say they’re confident the deer will be fooled.

“A camouflage that makes a person look like a tree can work if you’re in a place where other trees look like that,” Dr. Neitz says. “But what if you’re somewhere else, or if the deer sees you move? This new camouflage is a totally different approach. It fools the deer’s vision system at its roots, so that it doesn’t recognize the person as anything.”
At Dr. Neitz’s laboratory, he tests some animals’ vision by training them to press touch screens, but the deer weren’t quite ready for the computer age. He and researchers at the University of Georgia showed them three cards at a time and rewarded them with food pellets when they picked out the right pattern by pushing a button with their noses.

“We can measure in animals anything you can measure in a human being and every bit as accurate,” Dr. Neitz says. “The difference is that a vision test that might take 10 minutes in a human can take six months.” The research revealed that deer vision is a little blurrier than human vision — about 20/40 — and that deer see the world roughly like a human with red-green colorblindness. Their eyes have only two color receptors (unlike the three in the human eye). Fortunately for hunters, they have a hard time seeing blaze orange.

White-headed langur
Color Perception

- Color perception is a great example of the continuity between physics, physiology, and psychology.
- The physical properties of light, together with the physiology and architecture of our nervous system, produce the colorful perceptual world we experience.
Light varies in intensity and wavelength
Spectral sensitivity curves....
The Spectral Power Distribution (SPD) of an object is the amount of light of each wavelength that an object reflects.

**“Rainbow” Spectrum**

- Newton was the first to show this by passing sunlight through a prism. Light passed through a prism is broken down into a "rainbow" spectrum. Why is that?
Because lights of different wavelengths have different refractive properties. Long-wavelength (red) light is bent least by passing through a prism, while short-wavelength (blue) light is bent most.

By adding a second, up-side-down prism to the set up, all the different colors of light can be recombined into white light.

A drawing Isaac Newton made of the prism experiment he conducted in his dorm room in Cambridge.
There is an important difference between lights and pigments…

Lights are additive

Pigments are subtractive

blue paint  yellow paint  blue + yellow paint
Are wavelengths colored?

- Newton wrote "The Rays to speak properly are not coloured. In them there is nothing else than a certain Power and Disposition to stir up a Sensation of this or that Colour..."

- What this means is that the colors we see associated with different wavelengths are not contained in the light itself. Rather, they are created by our perceptual system in response to these wavelengths.

Achromatic Color:

Black, white, and the shades of gray in between are achromatic colors. Achromatic colors have approximately equal power across all the wavelengths in the visible range (check out the SPDs of white and black paper below).

In dim light, we only see achromatic colors.
Chromatic Colors

• Blue, red, green, and yellow are all examples of chromatic colors
• These are the colors we see in good light using our cones
• For ease of reference, we’ll call blue, red, yellow, etc., "colors" and black, white and gray "achromatic colors"

How many colors are there?

• People can distinguish about 2 million different colors (200 colors in the visible spectrum X 500 steps in brightness X 20 steps in saturation).
• Brightness is our perception of the intensity of light.
• And intensity, remember, is the amplitude of a sinusoidal wave.
• Saturation is inversely related to the amount of whiteness in a color (the more saturated a color, the less whiteness it contains; for example, red is more saturated than pink).
The Crayola challenge

Did you ever have trouble arranging your crayons by color? I always tried to make a rainbow, but then would get stuck on the purples. Do they go with the reds or with the blues?
The Crayola challenge

It turns out, I'm not alone. If you ask people to rate the similarity of a whole bunch of pure colors to one another, what you get is a color circle, not a line.

The physical qualities and associated psychological qualities of color processing

<table>
<thead>
<tr>
<th>Physical Attribute</th>
<th>Psychological</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wavelength</td>
<td>Hue</td>
</tr>
<tr>
<td>Purity</td>
<td>Saturation</td>
</tr>
<tr>
<td>Intensity</td>
<td>Brightness</td>
</tr>
</tbody>
</table>
Two major ways researchers have organized the color stimulus...

- **Color Wheel**
  - like colors (in spectrum) are near each other on circle
  - non-spectral hues
    - dotted line at the top

Add to this brightness and saturation, and you get a 3-dimensional color solid (or a "color spindle")
Color Constancy

- Puzzle: Sometimes lights of the same wavelength are perceived differently…