This part notes why having an illuminated surface produces better results:

Okay, let's break down why illuminating the colored surface gives you "better" results (higher R, G, B values that correspond more clearly to the perceived color) when using the Adafruit APDS9960 sensor with your Arduino code.

The Core Principle: Color Sensing Measures Reflected Light

The APDS9960, when in color sensing mode (as enabled by `apds.enableColor(true);`), doesn't produce its own light to measure color. Instead, it relies on the ambient light surrounding it. Here's how it works:

1. **Ambient Light Hits the Surface:** Light from the room (or any external source) hits the colored surface you are trying to measure.
2. **Selective Reflection:** The colored surface absorbs certain wavelengths (colors) of light and reflects others. For example:
    - A **red** surface absorbs most green and blue light and reflects primarily red light.
    - A **green** surface absorbs most red and blue light and reflects primarily green light.
    - A **white** surface reflects most red, green, and blue light fairly evenly.
    - A **black** surface absorbs most light and reflects very little.
3. **Sensor Detects Reflected Light:** The APDS9960 sensor has photodiodes (light sensors) behind different color filters (Red, Green, Blue) and one clear filter (no color filter, measures overall intensity). These photodiodes detect the light *that has reflected off the surface* and reached the sensor.
4. **Output Values:** The amount of light detected by each filtered photodiode is converted into the `r`, `g`, `b`, and `c` values you read in your code.

Why Illumination Improves Results

Now, consider the two scenarios:

1. **Without Extra Illumination (Dim Ambient Light):**
    - There isn't much light hitting the colored surface in the first place.
    - Therefore, even though the surface reflects certain colors, the *amount* of reflected light is very low.
    - The sensor's photodiodes detect only a weak signal for each color channel (R, G, B) and overall intensity (C).
    - This results in low numerical values for `r`, `g`, `b`, and `c`. While the *ratio* might hint at the color (e.g., `r` might be slightly higher than `g` and `b` for a red object), the low numbers make it harder to distinguish colors clearly, and the readings are more susceptible to noise or slight variations in the dim ambient light.
2. **With Extra Illumination (Bright Light Directed at Surface):**
    - You are providing a strong source of light directly onto the colored surface. Ideally, this light source is somewhat "white," containing a good mix of red, green, and blue wavelengths.
    - The colored surface still absorbs and reflects light based on its color, but now there is *much more* incident light available.

    - Consequently, the *amount* of light reflected towards the sensor is significantly higher. A red surface reflects a much stronger red signal, a green surface reflects a much stronger green signal, etc.
    - The sensor's photodiodes detect a strong signal for the reflected colors.
    - This results in higher numerical values for `r`, `g`, `b`, and `c`. These higher values provide a clearer, less noisy indication of the color being measured. The differences between the channels become more pronounced, making it easier to identify the dominant color and its intensity.

In Summary:

The APDS9960 measures the *intensity* of Red, Green, Blue, and Clear light *reflecting off a surface*. When you add illumination:

- You increase the amount of light hitting the surface.
- This increases the amount of light reflecting off the surface.
- The sensor detects this stronger reflected light signal.
- This leads to higher R, G, B, and C values, providing a clearer, stronger, and more representative measurement of the surface's color characteristics under that specific illumination.

Think of it like taking a photograph: pictures taken in bright light are generally clearer, more vibrant, and show colors more accurately than pictures taken in very dim light. The color sensor works on a similar principle of needing sufficient light to accurately capture the color information.

That's an interesting observation! If the green (`g`) reading isn't increasing significantly when you add illumination to a green surface, while other colors respond as expected on their respective surfaces, here are the most likely reasons:

1. **The Spectrum of Your Added Light Source:**
    - **Problem:** The extra light you are adding might be deficient in the green wavelengths that your specific green object reflects and that the sensor's green filter is most sensitive to.
    - **Explanation:** Not all "white" light sources are created equal.
        - **LEDs:** Many white LEDs (especially cheaper ones) create "white" light by using a blue LED chip coated with phosphors. This can lead to strong peaks in the blue and yellow/red parts of the spectrum, but potentially a dip or weaker output in the specific green wavelengths the sensor is looking for.
        - **Incandescent:** Usually have a broad spectrum but are very heavy on red/infrared and weaker on blue/green.
        - **Fluorescent:** Have distinct spectral peaks and troughs.
    - **Result:** If your light source is weak in the green part of the spectrum, adding more of that light won't significantly increase the amount of *green* light reflecting off the surface, even if the overall brightness (and maybe the `c` value) goes up.

    - **Test:** Try a different type of light source if possible (e.g., if using an LED, try an incandescent bulb, or a different brand/color temperature LED, or even filtered sunlight if you can make it consistent).
2. **Sensor's Green Channel Sensitivity (Spectral Response):**
    - **Problem:** The APDS9960's green filter and photodiode might inherently be less sensitive than its red or blue channels, or its peak sensitivity might be slightly offset from the green wavelength your object reflects most strongly.
    - **Explanation:** Each color channel in the sensor has its own sensitivity curve across the light spectrum.[1] It's possible the green channel requires more incident green light to produce the same numerical output increase compared to the red or blue channels. You can sometimes find spectral response graphs in the sensor's datasheet, which might show differences in peak sensitivity or bandwidth for R, G, and B.
    - **Result:** Even with ample green light reflecting, the sensor's internal conversion might yield a smaller numerical increase for green compared to other colors under similar conditions.
3. **Nature of the Green Surface:**
    - **Problem:** The specific green object you are testing might not be a very efficient reflector of green light, or it might reflect a very narrow or unusual shade of green.
    - **Explanation:** Some pigments or dyes might absorb more light overall, even in their primary color. A very dark green, for instance, will reflect less light than a bright, vibrant green. Also, if the green has hints of other colors (like a yellowish-green or bluish-green), the reflected light might be spread across sensor channels.
    - **Test:** Try measuring different green objects (different shades, different materials).
4. **Green Channel Saturation (Less Likely, but Possible):**
    - **Problem:** Is it possible the green channel is already getting a relatively high reading in ambient light and is getting close to its maximum value (`65535`) when you add more light?
    - **Explanation:** If the reading is already near the maximum, adding more light won't increase the number much further because it's "saturated" or "clipped."
    - **Test:** Check the raw `g` value. Is it very high (e.g., > 60000) even before adding extra light, perhaps due to strong green component in your ambient room lighting?
5. **IR Sensitivity / Filtering:**
    - **Problem:** While the sensor has an IR block filter, some IR can leak through, especially from IR-rich sources like incandescent bulbs. Green objects *can* reflect IR differently than red or blue objects. It's *possible* that interactions between the green filter's passband and IR light are behaving unexpectedly, although typically IR affects all channels or the clear channel most.

Troubleshooting Steps:

1. **Quantify "Doesn't Change Much":** Record the `r, g, b, c` values for the green object *without* added light and *with* added light. Do the same for a red object and a blue object. Compare the *absolute* and *percentage* increases for each channel. Is green truly static, or just increasing less dramatically than R or B did on their respective objects?

2. **Try Different Light Sources:** This is often the easiest and most revealing test.
3. **Try Different Green Objects:** See if the behavior is specific to one object.
4. **Check for Saturation:** Look at the raw `g` values.

Most often, the issue lies with the spectral output of the added light source not matching well with the combined reflection properties of the surface and the sensor's green filter sensitivity.