A new online tool to detect color misconceptions

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Abstract

In this work, we present an online test designed to ascertain what type of misconceptions people may have about color perception. It is noteworthy that only 15.7% of the over 20,000 respondents answered correctly, and that the vast majority (78.2%) of incorrect response patterns on our test matched to just four sequences, corresponding with four types of misconceptions.

Keywords: Color, misconceptions, online test, learning

Introduction

Our research group has previously worked on identifying misconceptions about concepts of optics in general. One important finding was that over 80% of the people studied had misconceptions concerning the concept of color. Most individuals seem to arrive spontaneously (mostly in childhood) to a type of subconscious explanation about how science works [1-3], which is further developed into misconceptions. In most cases, these misconceptions persist throughout life; even at the highest level of university, sometimes instruction is not enough to make misconceptions about color disappear [4].

In a previous study, we designed a test aimed at obtaining information about the misconceptions people may have concerning color [5]. In the present work we have further developed this test, and now it can be accessed online [6].

Method: design of the online test

To avoid the influence that the interpretation of textual language may have in inducing specific erroneous responses, we have created a set of symbols, shown in Figure 1. Using this set of symbols, we developed a 9-item test. On every item, the scene statements were presented using figures: an apple of one of the three primary colors was illuminated by a light

bulb of one of those primary colors. The overall scenes are illuminated by a white light lamp, which will be turned off. The question asked in the test is always the same: *"What color will the apple look once the white light lamp is turned off?"*

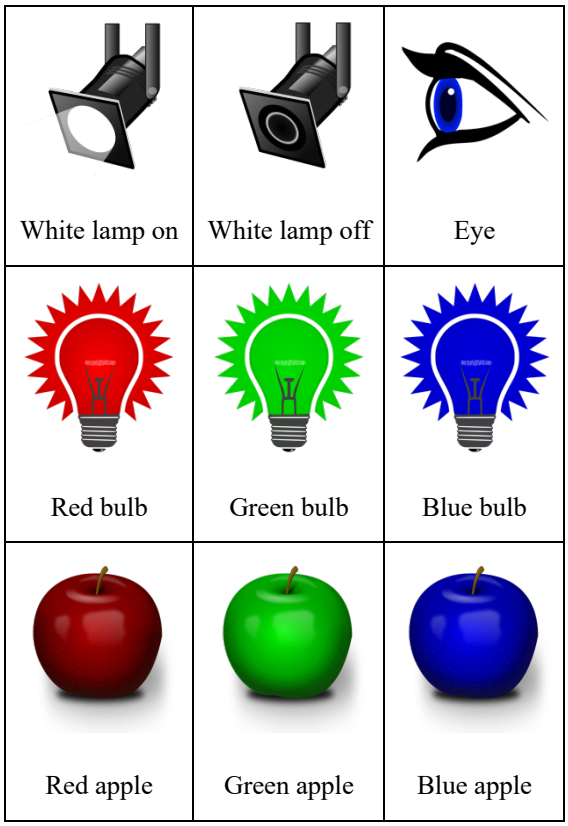


Figure 1: Symbols used in the test

In the following images (Figures 2 and 3), we show two of the nine questions of the online test, followed with their corresponding right answers (in the test the answers are only showed to the respondents once they have completed it).

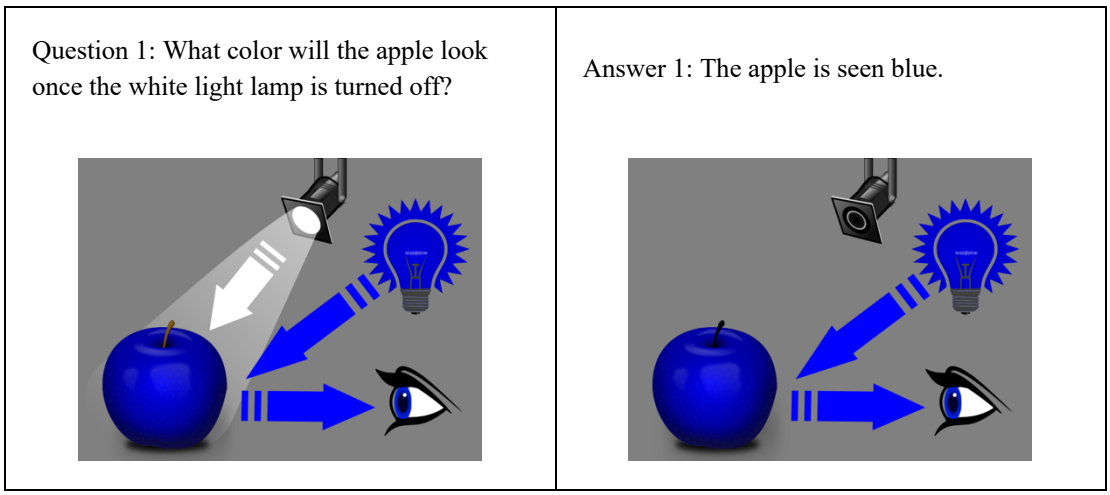


Figure 2: Question 1 and its correct answer

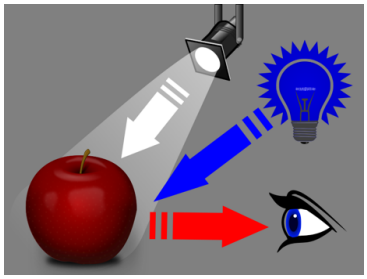
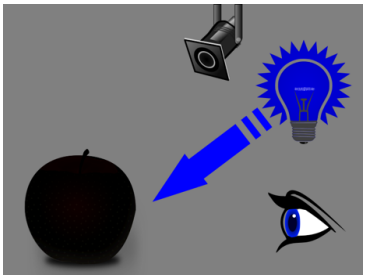
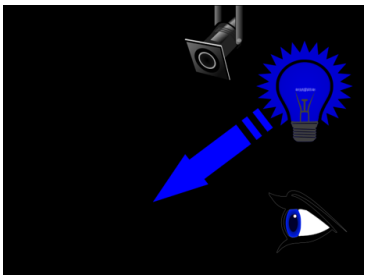
Question 2: What color will the apple look once the white light lamp is turned off?	Answer 2: The apple is no longer seen.	Answer 2: The apple is no longer seen.
		

Figure 3: Question 2 and its correct answer

Although apparently in Figure 3 (middle) the apple is seen black, what really happens is that we notice the contrast with the grey background. The background is grey to see more clearly the eye, the bulb and the white lamp. In Figure 3 (right) we have again the solution of Question 2 with a black background.

While it is true that objects in real life in most cases will not appear pure black as depicted, we avoided using responses as gray, dark gray, greenish gray, etc., because on pilot tests the respondents felt inclined to choose them as a "do not know/no answer" card, thus losing valuable information about the underlying misconceptions. Thus, the online test was designed as simple as possible, as this was essential to use the test with a large sample of people (from primary education to university level).

Results: the main misconceptions about color found

From the responses to our test (over 20,000 respondents), we found out that the misconceptions were structured in the form of authentic implicit theories: the vast majority of incorrect response patterns on our test corresponded to just four sequences, reflecting the existence of four respective mini-theories about color, with a high internal consistency.

The detected misconceptions about color were as follows:

- Misconception 1: Bodies "emit" their color, which reaches the eye of the observer together with the color of the light from the illuminant, so that the color finally perceived by the observer is the sum of the two.
- Misconception 2: Color is a property of bodies (similar to their mass)—a body "is" a certain color and will always be perceived as that color. The typical use of the verb "to be" to describe the color of an object adds greatly to this misconception.
- Misconception 3: The color that an object appears to be depends only on the light that illuminates it. Objects behave in a "neutral" fashion with respect to how they reflect the light that reaches them and will always be seen to have the color of the illuminant.
- Misconception 4: When the space surrounding an object is "full" of the color of the illuminant, and an object of that same color is located within that space, then that object will not be seen, because of the lack of contrast. This misconception can coexist with any of the previous three misconceptions.

After the completion of the test, all the respondents were shown a message with their results, and they were invited to follow a link with the correct answers and a concept map proposed to correct their misconceptions. Most of the people who took the test held one of the misconceptions described (78.2%), or a coexistence of the fourth misconception with any of the previous three. Only 15.7% of the respondents answered correctly. Table 1 shows the percentages of the results obtained.

Table 1. Percentages of the results obtained.

Correct	15.7 %
Misconception 1	50.1 %
Misconception 2	18.7 %
Misconception 3	6.6 %
Misconception 4	2.8 %
Others	6.1 %

The origin of these misconceptions comes from usual observations in which the illuminant is white sunlight. When we extrapolate to other situations in which the illuminant has changed and does not contain the full range of colors, mistakes arise. When we use the verb *"to be"* to indicate the color of an object, we are implicitly assuming that the object is being illuminated by typical daylight. The expression *"the grass is green"* really means *"the grass is green when illuminated by sunlight,"* but the last part of the sentence is generally dropped.

Discussion

We will further elaborate on the misconceptions found.

Misconception 1: Color is the sum of the color of the object plus the color of the light.

After the completion of the test, the respondents who had this misconception were shown the following message: *"The results show the existence of a misconception (MIS1). You have answered reasoning that the color the eye will see will be the sum of the color from the bulb (reflected by the apple) plus the color emitted from the apple itself. This way of thinking is wrong, but it is widespread (50.1% of over 20,000 respondents from primary to university professors), as it is very intuitive. Go to see the correct solution and the conceptual map proposed to try to correct your misconception."*

The top right picture of Figure 4 shows an image of the wrong reasoning behind this misconception.

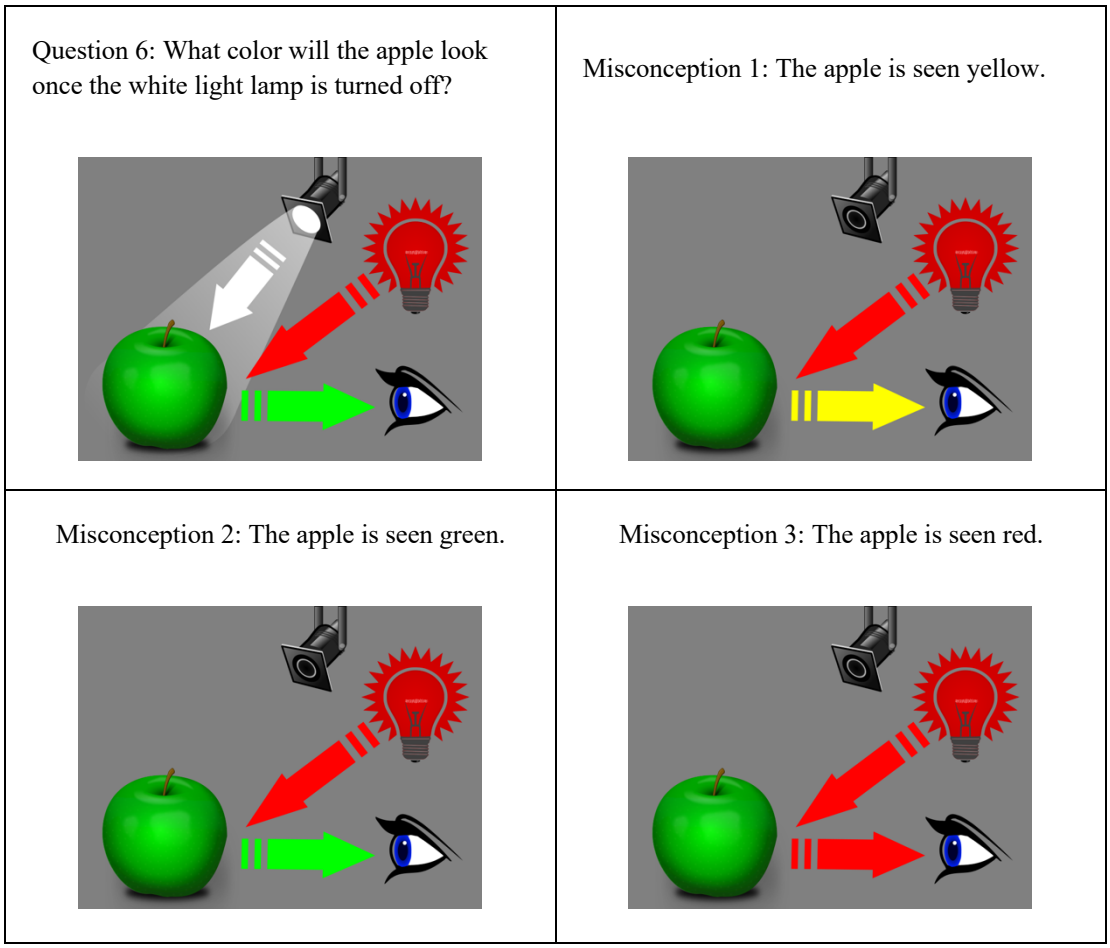


Figure 4: Question 6 and the wrong answers depicting Misconception 1 (top right), Misconception 2 (bottom left), and Misconception 3 (bottom right).

This misconception implies that there is an additive color mixing. As we state in the online test, many respondents requested us to provide them with an additive color mixing chart. The subject thinks that the apple "emits its color," and then it is mixed with the color of the light. This is consistent with previous studies [4], where it was detected a general belief that the color of an object is a property of the object that remains unchanged under white light, but can be changed by colored light.

Misconception 2: Color is a property of bodies.

After the completion of the test, the respondents who had this misconception were shown the following message: *"The results show the existence of a misconception (MIS2). You have answered reasoning that the color the eye will see will be the color of the apple: the apple is that color and that color will always be, regardless of the color of the illuminating light. This way of thinking is wrong, but is widespread (18.7% of over 20,000 respondents from primary to university professors), as it is very intuitive. Go to see the correct solution and the conceptual map proposed to try to correct your misconception."*

The bottom left picture of Figure 4 shows an image of the wrong reasoning behind this misconception.

This misconception implies that color is a physical property of a body, similar to its mass. The object "is" of one color, and always will be. These results agree with previous studies that found that a high percentage of children believed that color was a property of the object viewed [7]. When children observe colored objects under a white light, they usually consider color to be a quality of the object, independent of the source of light or the receiver [8]. This misconception may persist even at university levels [9].

A comment about color constancy must be addressed: while it is true that in real life experiences the color from the apple sometimes will be recognized as being the same under different illuminant lights, in our test we did not ask about the color *recognized*, but about the color the apple *appears* to be. Due to the simplicity of the online test the mechanisms of color constancy can be neglected.

A recent example of color being thought as a property of bodies can be found in the question asked in a viral photo, which recently became popular over the Internet [10]. It consisted on a washed-out photograph of a two-color dress, with the question "What color is the dress?" There is an on-going dispute over whether the dress pictured is blue and black, or white and gold, but we want to point out that Misconception 2 affects the question itself. The dress cannot "be" of one color or other. It is a matter of perception, and the neutral proper question should be "What color do you see the dress?" The best thing about this question is that there is not a right or wrong answer, as every individual will perceive the colors differently, or even change their perception over time.

Misconception 3: Color depends only on the illuminating light.

After the completion of the test, the respondents who had this misconception were shown the following message: *"The results show the existence of a misconception (MIS3). You have answered reasoning that the color the eye will see will be the color from the bulb. If the bulb is the only light source the apple should be perceived with that color, regardless of the characteristics of the apple. This way of thinking is wrong, but is widespread (6.6% of over 20,000 respondents from primary to university professors), as it is quite intuitive. Go to see the correct solution and the conceptual map proposed to try to correct your misconception."*

The bottom right picture of Figure 4 shows an image of the wrong reasoning behind this misconception.

This misconception implies that the color in which the apple is seen is the color of the light emitted by the bulb, regardless of the nature of the apple. This way of thinking indicates that the apple just reflects the incoming light from the bulb unaltered in color.

Misconception 4: Color fills the space around objects.

After the completion of the test, the respondents who had this misconception were shown the following message: *"The results show the existence of a misconception (MIS4). You have answered reasoning that the bulb fills the space with light of a certain color, and if the color of the apple is the same it will be no longer seen for lack of contrast. This way of thinking is wrong, but is used by 2.8% of the 20,000 respondents (from primary to university professors). Go to see the correct solution and the conceptual map proposed to try to correct your misconception."*

Figure 5 shows an image of the wrong reasoning behind this misconception:

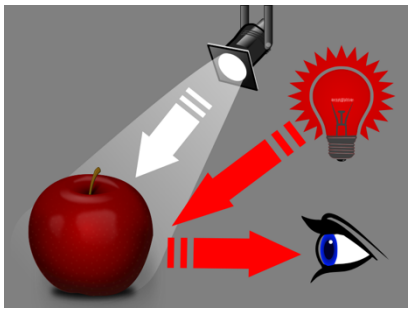
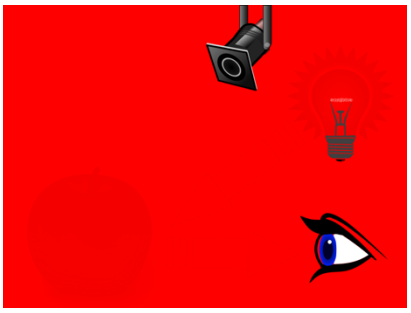
Question 5: What color will the apple look once the white light lamp is turned off?	Misconception 4: The apple is not seen.
	

Figure 5: Question 5 (left) and the wrong answer depicting Misconception 4 (right).

The first three misconceptions occur when the colors from the bulb and the apple are different, and are exclusive of one another. In Misconception 4, however, both colors are the same. This misconception implies that light is something tangible that fills the surrounding space. These respondents believe that if there is a red light that is filling the space surrounding a red apple, the apple will not be seen, because of the lack of any contrast. This misconception may coexist with any of the other three.

Conclusions

Online test results are consistent with those obtained previously. About 78.2% of the respondents held misconceptions about colored objects under colored illumination. Only 15.7% had a clear understanding of the subtractive mixing nature of the phenomenon: the object just reflects part of the illuminating light and absorbs the rest. The remaining 6.1% correspond to a combination of the fourth misconception with any of the first three (3.6%), or random or non-fitting sequences.

The online nature of the test allows the respondent, anywhere in the world, to establish what kind of misconceptions he or she may have about color perception. In addition, the test and online content provided offers further guidance on the subject, trying to correct any existing misconception.

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