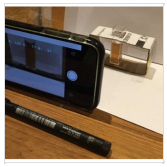

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Mobile Phone Spectrophotometer Setup [Tea experiment version]

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Katharine Hubbard

Katharine E Hubbard

ABSTRACT

This protocol allows you to turn a mobile phone (smart phone) into a colorimeter/spectrophotometer. It goes through how to set up your phone and workspace, making up a dilution series, constructing a calibration curve and making measurements.

This version of the protocol is used to test the hypothesis "Two different brands of tea bags will produce different strengths of tea". There are therefore no chemicals required, so the protocol is suitable for performing in a domestic kitchen.

The protocol could be adapted for other experiments e.g. comparing chlorophyll concentrations, comparing the solubility of spices in water vs vodka vs vegetable oil.

The protocol is inspired by and adapted from this video - smartphone spectrophotometer

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PROTOCOL CITATION

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KEYWORDS

null, mobile phone, smartphone, smart phone, spectrophotometer, colorimeter, at home experiments

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MATERIALS TEXT

Mobile phone with camera
White card
1 cm path length cuvettes
50 mL centrifuge (falcon) tubes
3 mL plastic pipettes (pastettes)
Scissors
Sellotape
Marker pen
[optional] table lamp
Cuvette holder template cuvette holder design.pdf

SAFETY WARNINGS

Take care with boiling water!

Setting up your phone

1 You first need to set up your phone to act as a colorimeter - video Instructions for this section are availabile: Setting up Your Mobile Phone as a Colorimeter

2 Choose a well lit space to work in. This protocol works better during the day under natural light. If you are doing the experiments after dark you might want to position a lamp near your set-up so you have fewer shadows and greater contrast in your images.

3 Fully charge your phone! Unplug your phone from it's charger and put the charger away to reduce the risk of electrocution while handling liquids.

4 Install a colour picker app on your phone - you need one that gives you numerical Red Green Blue (RGB) values. I recommend 'ColorPicker' for iPhones, and 'ColorGrab' for Android.

5 Download the template and make the cuvette holder - you will need sellotape to fix it together.
cuvette holder design.pdf

6 Sellotape the cuvette holder to the table/workshop where you are going to work. Place a piece of white card behind the cuvette holder. You might want to tape this into place too.

7 Open the colour picker app. Position your phone so that you are pointing the colour picker pointer in the middle of your cuvette. I would recommend resting your phone against something (e.g. a mug/box) so that it stays in the same position for each of your measurements.

My set-up is shown below.

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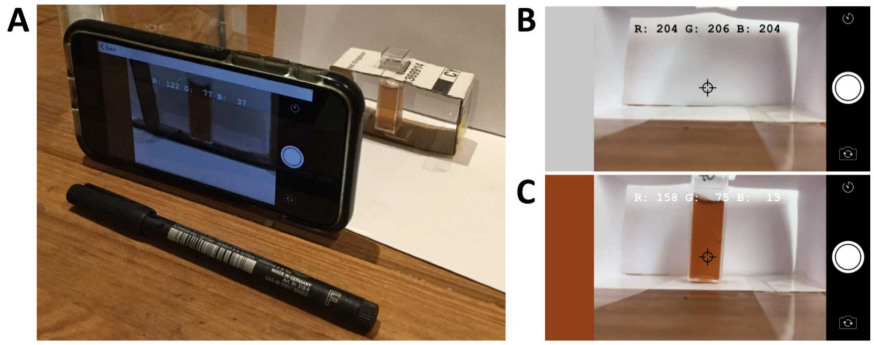

A: Relative positions of the phone, cuvette holder and cuvette. B: Screenshot of the setup without a cuvette (R:204,G:206,B:204). C: Screenshot of the setup with a cuvette of 50% diluted tea (R:158,G:75,B:13).

Calibration curve (tea bag experiment)

8 To test that your phone is able to measure different concentrations you will need to set up a calibration curve. For this you will construct a dilution series of different concentrations, and measure the RGB values for each concentration. You then plot this on a graph to determine if there is a relationship between concentration and RGB.

For the tea experiment, you only need to do this for one of the brands of tea. The calibration curve is to test whether or not the phone is able to measure a relationship between concentration and RGB values - it is a test of your phone, not of the tea.

Video instructions for the calibration curve

9 Boil some water and measure out approximately 50 mL boiling water into a clean mug/cup.

Take care with boiling water

Put a teabag into the water and allow to brew for 1 minute - the tea should be a dark brown colour. Allow the tea to cool.

10 Put 5 mL of the tea into a 50 mL centrifuge tube, and dilute with 45 mL of water. Label this tube as '10% tea'.

11 Using a plastic disposable pipette, set up a dilution series of different concentrations of tea in the cuvettes. I suggest you make up cuvettes with the following concentrations. Make sure you label your cuvettes clearly at the top or on the frosted side.

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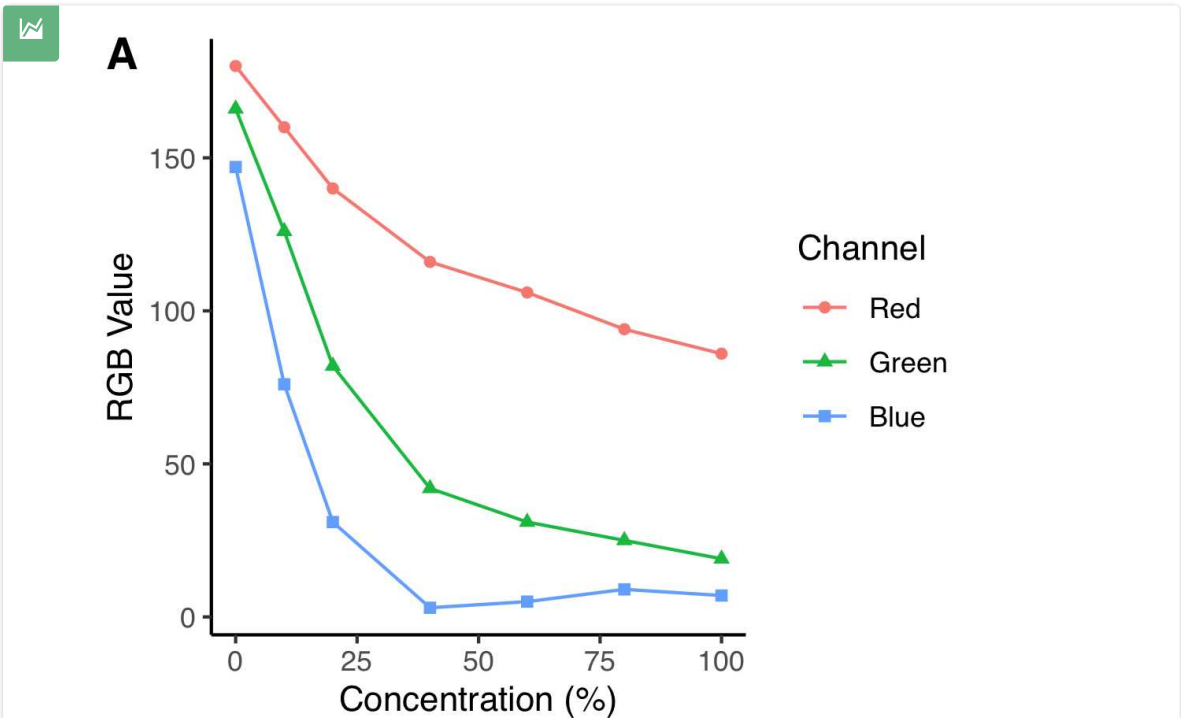
A	B	C
Concentration of tea	Volume of original tea solution	Volume of water
100%	3 mL	0 mL
80%	2 mL	0.5 mL
60%	1.5 mL	1 mL
40%	1 mL	1.5 mL
20%	0.5 mL	2 mL
	Volume of 10% tea solution	Volume of water
10%	3 mL	0 mL
5%	1.5 mL	1.5 mL
0%	0 mL	3 mL

12 Place the 100% cuvette into the cuvette holder with the transparent side facing towards you. [Note that the cuvettes have a clear side and a frosted side]

13 Load up the color picker on your phone and record the RGB Values for the 100% cuvette.

14 Repeat for each of your dilutions.

15 Plot a calibration curve with concentration on the x-axis and measured RGB value on the y-axis. Mine is shown below - you will notice that there is a negative relationship between RGB and concentration. This is because on the RGB scale white = 255 and black = 0.



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My calibration curve for the tea experiment, using raw RGB values from the phone

16 To give a positive relationship between concentration and RGB I recommend that you normalise your data as follows:

$$normalised.value = 1 - (RGBvalue/255)$$

For example, if you measured R as 86, you would calculate your normalised value as:

$$normalised.value = 1 - (86/255) = 1 - 0.337 = 0.663$$

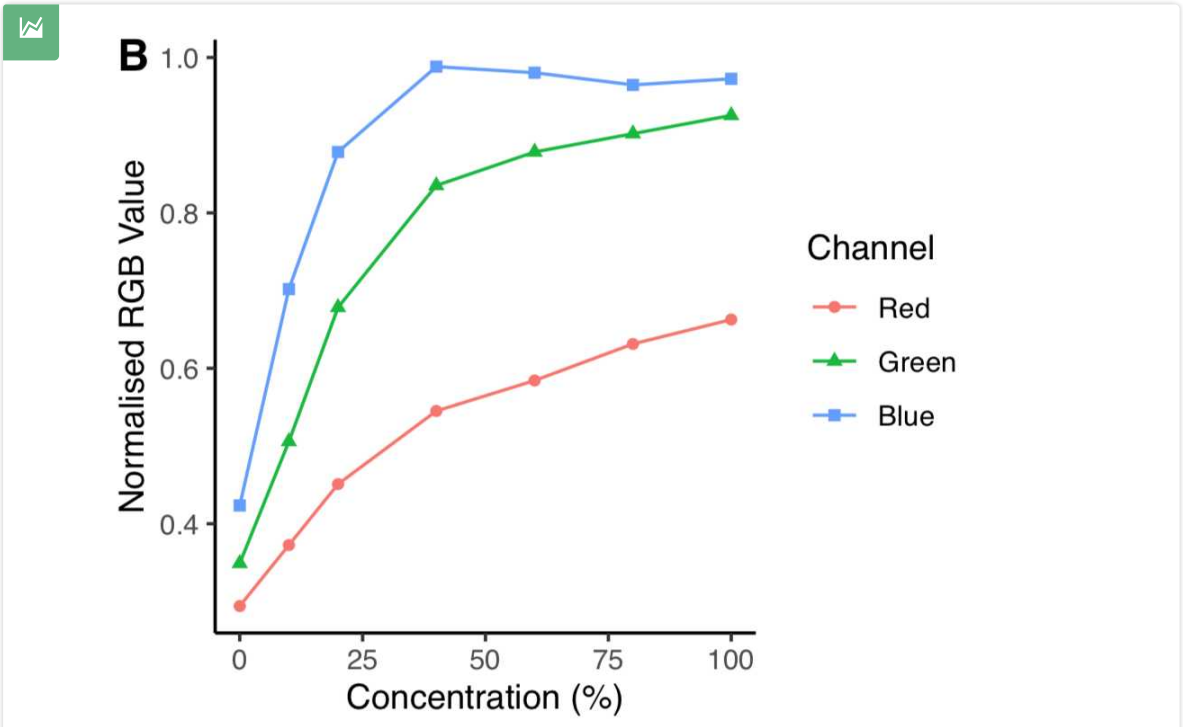
Alternatively, you could calculate this relative to a blank (empty) cuvette, which would be a better approximation for a spectrophotometer. This would be calculated as follows:

$$normalised.value = 1 - (sample.RGBvalue/blank.RGBvalue)$$

For example, if you measured B as 120 for your sample, and 190 for your blank you would calculate the normalised value as:

$$normalised.value = 1 - (120/190) = 1 - 0.631 = 0.368$$

17 Plot a second calibration curve with the normalised values. Mine is below using the basic normalisation calculation. - You will see that this normalisation has given a positive relationship between concentration and normalised RGB. Normalised RGB is now scaled so that 0 = white and 1 = black.



My normalised calibration curve

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Methodology Decisions

18 **Decide which colour channel you are going to use for the rest of your experiments.** Pick the channel which gives the best relationship between concentration and RGB. For example, in my experiment I would pick the Green channel - the Red channel doesn't change as much, and the Blue saturates quite quickly (i.e. the curve flattens off at ~40% concentration).

19 **Decide which concentration you are going to use for the rest of your experiments.**

- On the Green curve above graph you can see that there isn't much difference between the RGB values once you go above 40% strength, which means that it will be difficult to measure any differences at that concentration. This is known as saturation, i.e. the assay is unable to detect changes in concentration above a certain point.
- You should pick a concentration that is in the middle of the linear part of the curve (i.e. the straight line), as this is the most sensitive part of the assay. For my curve above this would be 20% concentration .

Experimental Measurements

20 Boil a tea bag in 50 mL boiling water for 1 minute - the tea should be a dark brown colour. Allow the tea to cool.

21 Dilute the tea to 20% strength in a cuvette (0.5 mL tea, 2.0 mL water). *[Note this is an experimental choice based on my calibration curve - see step 18]*

22 Measure the RGB for your chosen colour channel [see step 17] using the colour picker app, and record your data.

23 Repeat for all replicates in your experiment. If you want to perform a t-test, you will need at least 5 replicates of each sample (i.e. 5 tea bags of one brand, 5 tea bags of another brand)

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