Sensation and Perception Assignment

Aim: Performing experiment to plot psychometric curve for a sensory quantity for multiple subjects

Abstract: For the sensory quantity, I have chosen the brightness of a primary color (out of RGB) present in a single pixel of my laptop's screen. RGB color scheme for a single pixel on an electronic screen is encoded as (R,G,B), where the intensity of one color varies from 0 to 255. For my experiment, I started from a background of (100,0,100), which is dark pink in color, and incremented either red, or blue color in small steps, present as randomized spots on the screen of a certain size. For initial plotting of psychometric curve, intensity of red was varied. Further analysis was also conducted by incrementing the intensity of blue.

Experimental methods: For all practical purposes, python scripts were used to generate the stimuli images and perform the experiment. The images generated had a background color dark pink (100, 0, 100), to ensure a uniformity between red and blue stimulus. The stimulus was present in one of the four direction (up, down, left, or right), which ensures that the subject does not develop a bias for the position of the stimuli. The position of the stimulus was randomized for the sequence of one trial, and for replicates as well. The stimulus (spot) occurred at time point 0.5 seconds and for a duration of 0.2 seconds (*Fig 2a*), while the background was present for a total of 1.2 seconds. After the trial was done for a particular spot RGP color coding, a black screen was shown to ensure fatigue/adaptation does not occur over time. The black screen had 4 arrows corresponding to locations, and a 0 at the center (*Fig 2b*). 15 images were generated per subject, with the increment (ΔI) in spot color coding decided after a small pseudo trial (This was necessary to see a clear psychometric curve, due to the high varianc e in subject's age and capabilities).

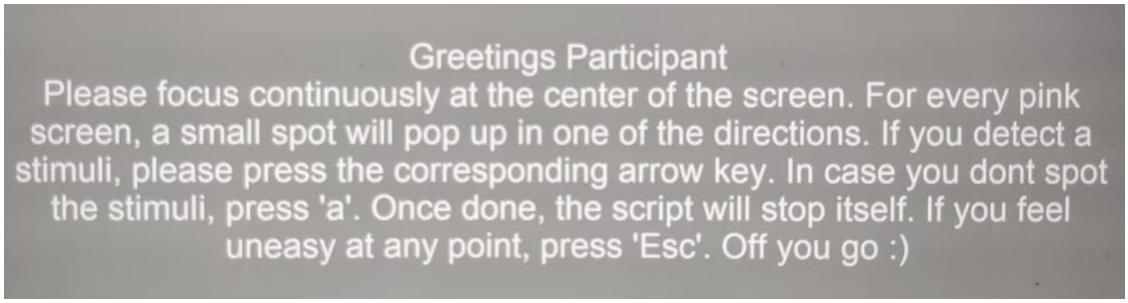

Fig 1: Instructions screen for every replicate

For the initial analysis, the size of the spot was kept constant (0.05 times the height of the screen). Once the images were generated based on the subject's sensitivity levels, the experiment script was used. The python script for the experiment was made using Psychopy module. There is an initial set of instructions (*Fig 1*) that made the experimental details clear to the subject. The subject must press the corresponding arrow keys based on the spot position (if detected), and 'a' if not detected. For one trial, 15 images occurred in which the spot was randomized in location and in the increment in intensity for red for every image, in a shuffled order. 20 such trials constituted one replicate for a subject. 3 replicates were performed per subject for one set of variables (for current purposes, increment in intensity of red diode in a pixel). *Table 1* gives an idea about the data obtained at the end of all three replicates.

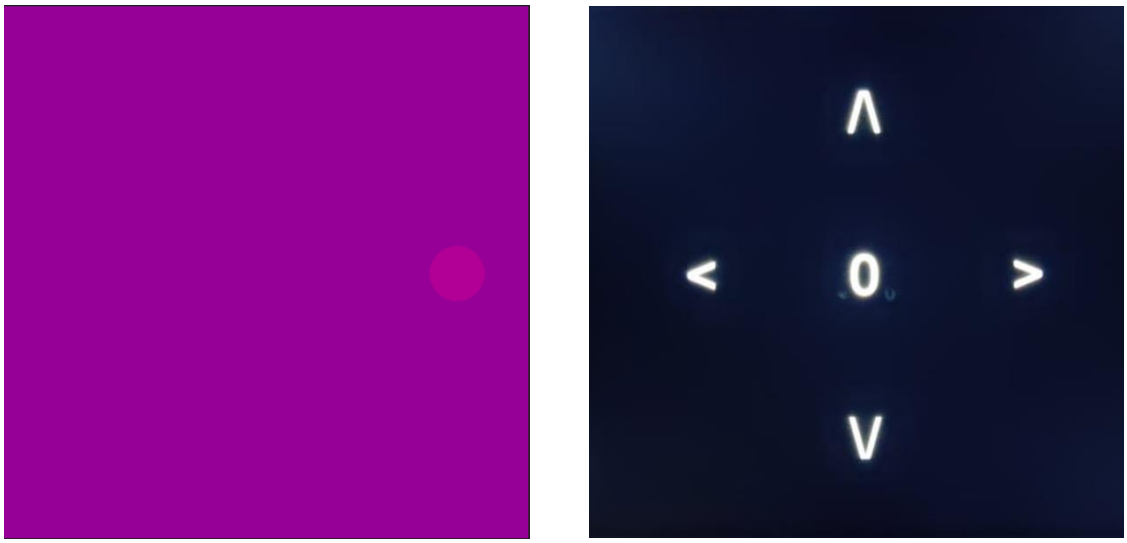

Fig 2: a) Sample spot on the right, b) black screen acting as a buffer and input screen

Since for each unique spot, we had 20 trials, %correct guesses could be i*5% (where i is a whole number ranging from 0 to 20). Granting a human error of one wrong click/attention loss for a single spot, I used 95% correct guess accuracy as the threshold for my sensory modality (as a minimal of 5% error occurs for one mistrial). So, the ΔI which was accounted as a threshold was the first value at which the threshold was greater than or equal to 95%. It is important to note that the laptop was kept at maximum brightness for the duration of trial, and the subjects were kept a constant distance of 60 cm from the screen and was supervised by the researcher during the entire trial. Subjects were requested to keep their gaze at the center of the screen, aided by the presence of the '0' in the buffer screen. Due to the high dependence of the experiment on screen specifications, unfortunately the script could not be outsourced to distant volunteers, despite presence of scripts. The laptop used is a HP Spectre x360. The subjects were kept in a dark room for 10 minutes before the experiment (and through the experiment) to ensure no adverse errors from external light conditions.

ΔI (Red)	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
%correct (rep 1)	0	0	0	0.25	0.25	0.75	0.95	0.9	1	0.95	1	0.95	1	1	1
%correct (rep 2)	0	0	0	0.25	0.45	0.85	0.95	1	1	1	1	1	1	1	1
%correct (rep 3)	0	0	0	0.25	0.55	0.8	0.95	1	1	0.95	1	1	0.95	1	1
mean	0	0	0	0.25	0.42	0.8	0.95	0.97	1	0.97	1	0.98	0.98	1	1

Table 1: Data for increment in red intensity for the spot (subject 1).

NOTE: For their valuable input and time, each subject was treated to a Domino's pizza (highly recommended, the experiment gets tedious after a point). All the codes for the experiment are available on GitHub (link provided in the end). Analysis and plotting were done using SciDavis and Excel software.

Results: For our preliminary testing conditions (radius = 0.05 times height of screen, increase in red intensity, spot centers at [+/- 0.35, +/- 0.035]), the graphs obtained are attached below. The graphs were fitted to the sigmoid function, formula given below (with additional parameters):

$$f(x) = \frac{A1 - A2}{1 + e^{-b(x-x0)}} + A2$$

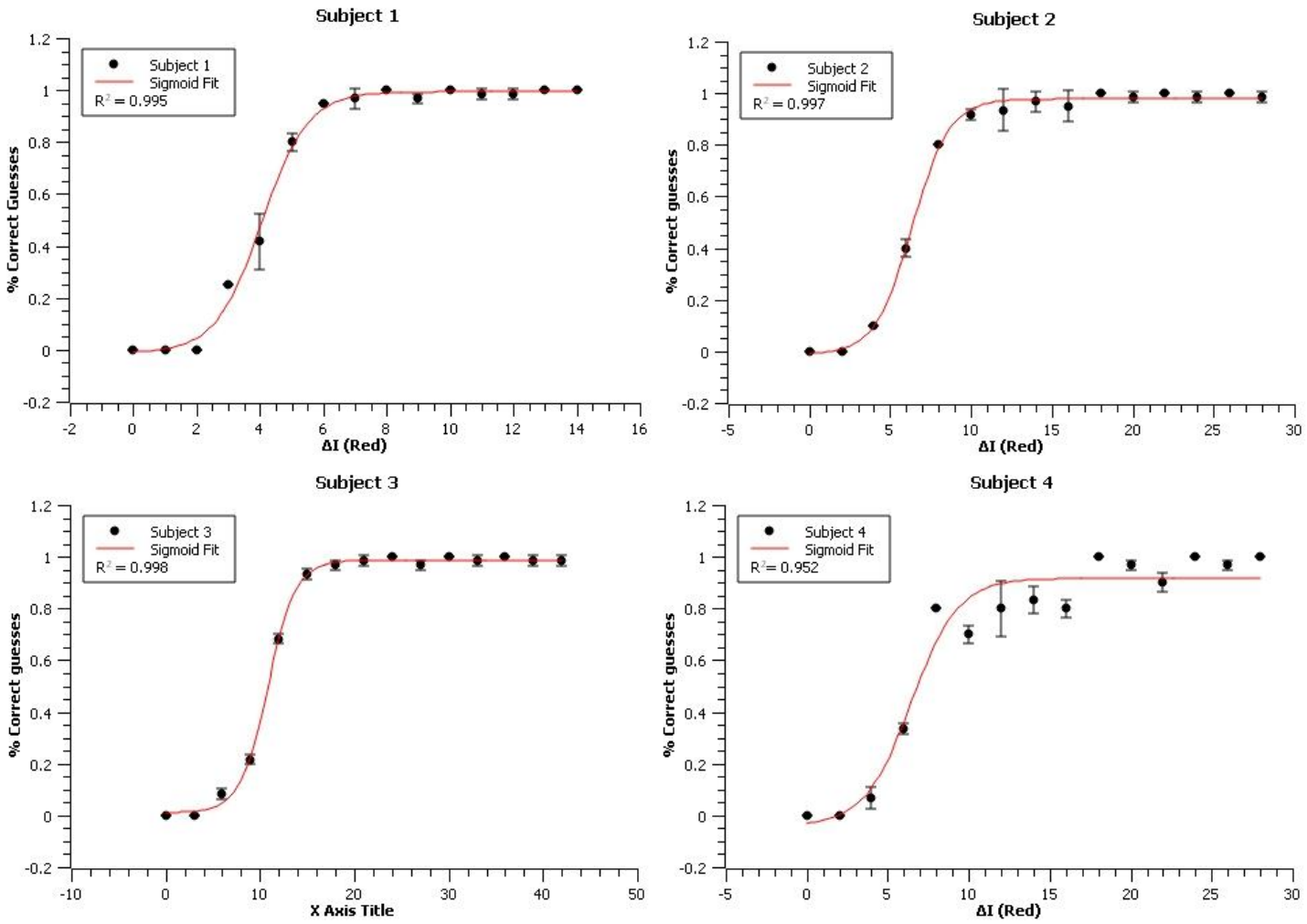

Fig 3: Sigmoid fitted data for 4 subjects, for increment in intensity of red for stimuli, for a background (100,0,100)

	Subject 1	Subject 2	Subject 3	Subject 4	mean	Std dev
Threshold (≥ 95% correct)	6 units	14 units	18 units	18 units	14 units	4.89 units

Table 2: Average threshold across subjects, as defined above

Table 2 and Fig 3 represent the data obtained for four subjects for preliminary testing conditions described earlier. Complete data for all replicates for the subjects are given in the curated _data.xlsx file in the GitHub repository . As can be seen, the threshold varies vastly across the subjects. This can, in 3 of the cases be explained by an age factor. Subject 1 is a 20-year-old male, with clear vision, and has the lowest threshold at 6 units. Subject 2 is a 48-year-old female and has an average threshold of 14 units. Further, Subject 3 is a 63-year-old female, and has the highest observable threshold at 18 units. A very infuriating thing observed with subject 4 was lack of adherence to instructions. Subject 4 is a 21-year-old male. In his own words, "I thought this was competitive in nature, and hence I utilized removal by error. I focused on one side of the screen, which helped me focus on three sides better, and a lack of stimulus might mean a stimulus on the fourth side". This was observed as large error bars and a non-sequential increase in percent correct guesses. An increased error was also observed for spots that should have been clearly visible. Even discarding subject 4, we see a marked variance in the threshold across the three viable subjects, which was, to a high degree correlated to age.

The use of randomized positions of stimuli and a fifth key for missed stimuli decreased the chances of cheating/guesses by the subjects. Even if the subject did guess, the chance of it being counted as correct would be 0.25, which is a marked reduction from a binary choice. In cases where said cheating/guessing did occur (subject 4), the data is clearly variant and displays the guesswork done. Further, a stimuli bias was removed by shuffling the order in which the stimuli was shown, ie, not in an increasing order of intensity.

One very intriguing thing to me was the fact that the physiological frequency response curve of the cone cells does NOT peak at the emission frequencies of the RGB pixel coding on a screen (Fig 4). Since in preliminary testing, we increased only the intensity of red spectra, I wanted to find out what would happen if I increased blue independently of red for the same background (100, 0, 100). For this, I increased the intensity of blue spectra in a virtually identical experiment. Since this experiment was already north of 45 minutes now, and I was running out of pocket money to buy pizzas, I chose to perform only one replicate on subject 1 for this analysis. As one would expect, I found the curves to be nearly identical (Fig 5).

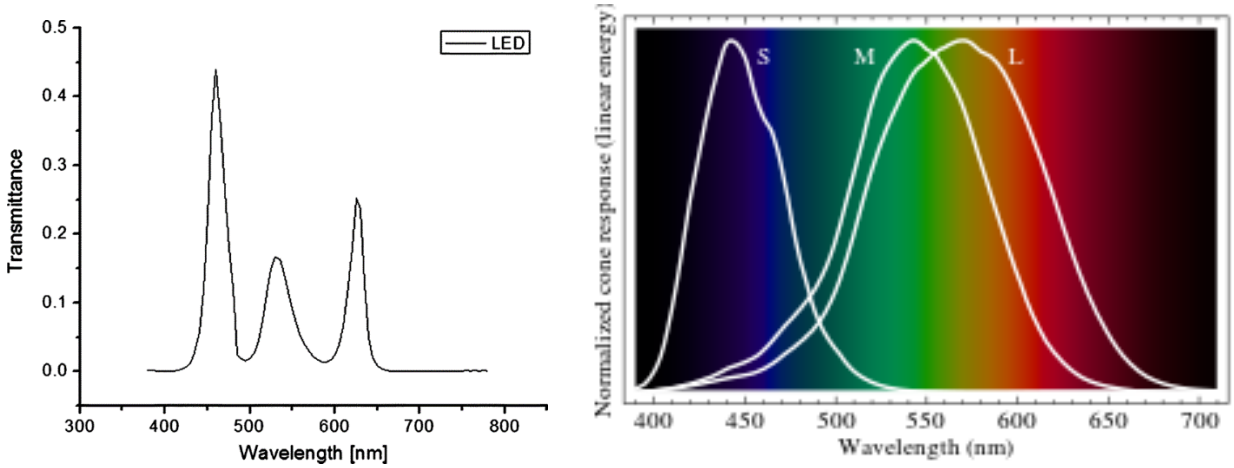

Fig 4: emission spectra for typical RGB LED, and response curve for cone cells.

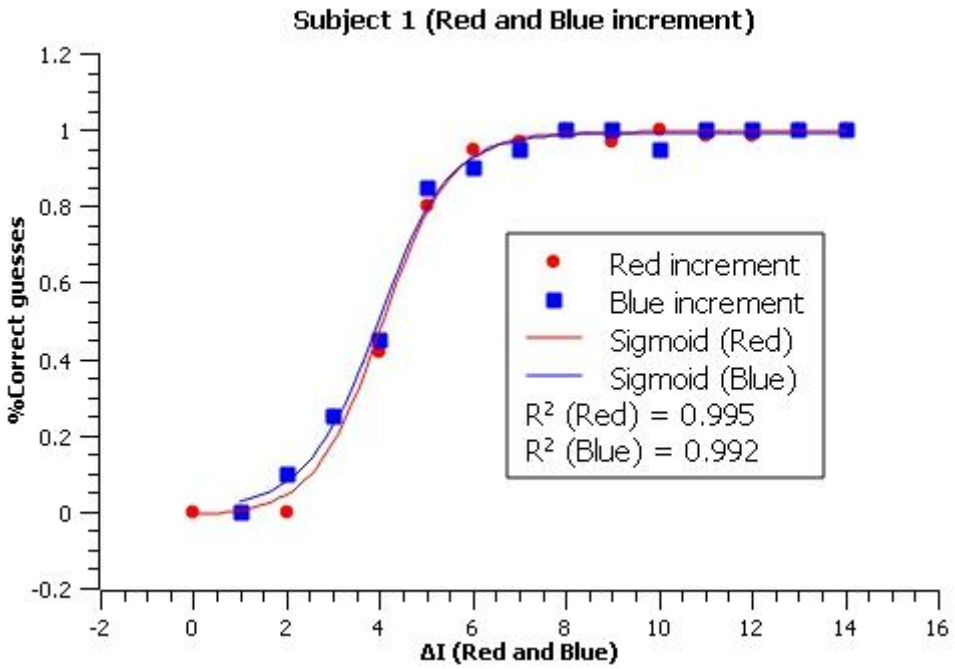

Fig 5: Data (3 replicates for red, error bars not shown, 1 replicate for blue) with the fitted curves for subject 1.

Discussion: Based on the experiment done and the data collected, I was able to plot the psychometric curve for the subjects and able to show it largely follows a sigmoidal trend (even for subject 4, $R^2 = 0.952$, despite no heed paid to instructions). I also have reported the thresholds for the various subjects, which showed a correlation with age of the subject for the first three subjects. This pattern was however broken by subject 4, who virtually had the same threshold as subject 3. Another important observation was the similar curved obtained for increase in blue and red intensity independently, suggesting limited role of cone cells in detecting brightness of colors, which was to be expected. However, one cannot say this with confidence since there is a difference in the transmittance of the three spectra in an RGB LED. Moreover, many more tests with independent pairs of colors (including green), and mixed testing (varying 2 or more primary colors in various steps need to be done) to lay the above said claim.

There was limited noise in my data for 3 of the subjects. Subject 4 had quite some noise in the data, which was evident based on the rational followed by the subject. This also proved the efficacy of using randomized positions in detecting guesswork by the participant. One very interesting fact to note was the less noise for subject 3, which is quite surprising considering the elderly age of the subject (63 years). The possible sources of the noise could be external light, or personal bias of the individual to various intensities of light and the type of electronic screen used in daily life. Less attention by the participant could be another source of error, in addition to the least error of the stimulus increment and limited number of replicates. I decided to sacrifice precision in threshold (ie only 15 stimuli) for precision in percent correct guesses (20 trials) to obtain smoother curves. Replicating the results should be able easy, as three different replicates resulted in close results. Moreover, the experimental conditions and priming in a dark room ensured static conditions, which would support my claim that we can replicate the results obtained.

Changing variables such as distance from screen, radius of spot size and location of spot size would significantly alter the data obtained. In some pilot trials done to judge these (data and figures not attached, very rudimentary analyses), it was observed that these things did indeed affect the data seen. A closer location of the stimuli to the center resulted in a higher detection of the stimuli. Similarly, a larger radius of the stimuli resulted in greater detection of stimuli. However, these claims cannot be conclusively stated, due to lack of data and replicates. Also, keeping in mind the randomness of the trials, I believe that I can act as a subject despite my knowledge of the internal working of the experiment, provided I follow all the instructions as followed by the rest of the subjects. I would like to hint in the end that rods are responsible for the brightness detection, irrespective of color, although there are many more experiments needed to prove that.

Reference: All rudimentary codes and compiled data are available on the repository at the link https://github.com/Lakshya3141/ns201_psychometric_curves.git

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