1 Simultaneous contrast

Our perception of brightness and color of stimulus can be affected by choice of the background on which the stimulus appears. If we for example place uniformly gray stimulus on bright background, it should appear darker than if we place the same gray stimulus on dark background [3].
This phenomenon is called simultaneous brightness contrast. Same holds for color stimulus (simultaneous color contrast).

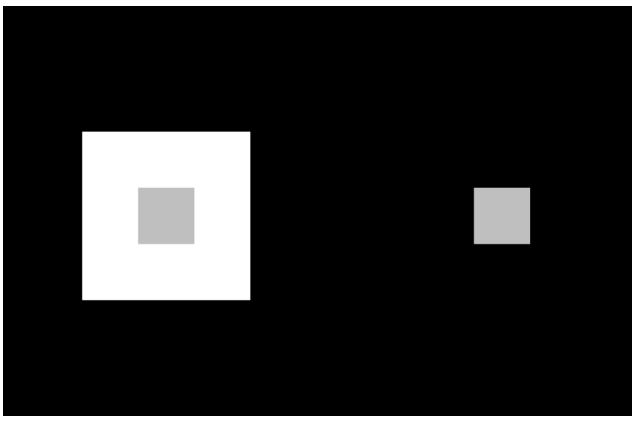

Figure 1: Two rectangles of same color of gray. The one on white background should appear darker than the one on the dark background.

2 Experiment

We tested the effect of simultaneous contrast by two experiments. In first experiment, we displayed two gray squares to our testing subjects where one square was on bright background and other one was on dark background. The square on right had variable brightness and task for the subjects was to decide which one of the two squares is brighter. We tested three individuals (named a,b, and c) on two experiments which will be now further described.

2.1 Chosen color values

In the first experiment, the left square is uniformly gray with 75% brightness on white background (100% brightness), while the one on the right side has variable brightness from 56% to 94% and is placed on black background (0% brightness). Example of such scenario can be seen in figure 1 where the right square has also 75% brightness.
Each subject was asked to decide which one of the two grey squares is brighter. If the subject thinks that the left (right) one is brighter, he/she presses left arrow (right arrow) key. The brightness of the square on right can be one of nine values in interval between 50% and 100% brightness. Because we used software PsychoPy for our experiment which maps values of brightness to interval [-1,1] where -1 is 0% brightness, 0 is 50%, and 1 is 100% brightness, we had to map the used values to this interval. The values which we used in PsychoPy are:
[0.12, 0.27, 0.38, 0.45, 0.50, 0.55, 0.62, 0.73, 0.88].
These values are concentrated more around the supposed value of decision threshold which divides the decision of which square is brighter. Unfortunately my assumption about the position of threshold was not correct as will be described in the results section.
Whole experiment consists of 30 repetitions of randomly chosen sequences of these nine values. Data from these experiments are evaluated in the next section.
In the second experiment, we changed shades of gray to shades of green. This was only difference between the two experiments. It was done by setting red and blue spectrum of the square and background colors to -1 in PsychoPy, while green spectrum was left without change as in first experiment.

Participant	Experiment	Total time	Average time per response	Left responses	Right responses
a	brightness	424 sec	1.57 sec	197	73
b	brightness	518 sec	1.92 sec	184	86
c	brightness	436 sec	1.62 sec	197	73
a	color	438 sec	1.62 sec	205	65
b	color	603 sec	2.23 sec	171	99
c	color	423 sec	1.57 sec	189	81

Table 1: Basic statistics about experiment trials. As can be seen by first glance, the participant b was very thorough with the answer.

2.2 Used setup

We used same conditions for all participants of our experiment. We used display on full brightness with resolution of 1920x1080 pixels and refresh rate of 60 Hz. All subjects were required to leave their smart phones and wearables in different room and the experiment was done in dark room with no light sources other than the laptop on which the experiment was done.

3 Results

All three individuals completed both experiments which consisted of 270 iterations of the choice of brighter square. Basic statistic about the experiment can be found in the table 1. As can be seen the participant *b* was very patient with answers. In comparison with other two participants, it took him/her in simultaneous brightness contrast experiment on average 0.3 second more time to give response than the other two participants. In second experiment with simultaneous green color contrast it took him/her 0.6 second more on average to respond in comparison with the second slowest participant.
We can also see that the ratio between responses that left square is brighter than the right square (see fig. 1) is in favor of left square. More precisely, the ratio is 2.4:1 in favor of left square. We have chosen the brightness values of the right square before reading any literature about it. We supposed that the threshold will be close to the brightness of the left square. This is not correct assumption as will be seen in the graphs. Unfortunately, in times of Corona, I had only one chance to do the experiments and could not do another round with better arrangement of brightness values.

As can be seen in both figures 2 and 3, the approximated thresholds where probability of choosing left or right square as the brightest one are not close to the 50% of brightness as we wrongly assumed while choosing the brightness values of the right square, but are shifted towards lower values of brightness of the right square on darker background. This is caused by the Simultaneous contrast described in the first section. The grey square on light background appears darker than square of same color on darker background.
In case of the simultaneous color contrast (fig. 3) we can see that the thresholds of participants *b* and *c* are closer to the 50% brightness than in case of simultaneous brightness contrast. On the other hand, the threshold of participant *a* is shifted away from the 50% brightness.
The threshold of the participant *b* is shifted to the higher values of brightness in comparison with other participants. As was described above, the participant *b* spent on average the most time of all participants on each response. One possible explanation of this shift can be explained by the experiments done in the article [2]. Authors describe that the brightness contrast was stronger when the stimulus was shown only for short duration of time. Exactly 58 ms was duration at which the simultaneous brightness contrast was the strongest. As our stimulus duration is in orders of seconds, this seems like weak connection and could be wrong.
Another explanation could be that participant *a* has poor sight and strong astigmatism, while other two participants have perfect sight. Also, individuals *a* and *c* are both males while individual *b* is a female. Some women can have four cone pigments or generally better recognition of colors and brightness. However, these differences between thresholds are not that significant to be caused by such rare oddity as four cone pigments, but are more likely caused by variability in another conditions. As we have only three participants these are only speculations not backed up by larger dataset.

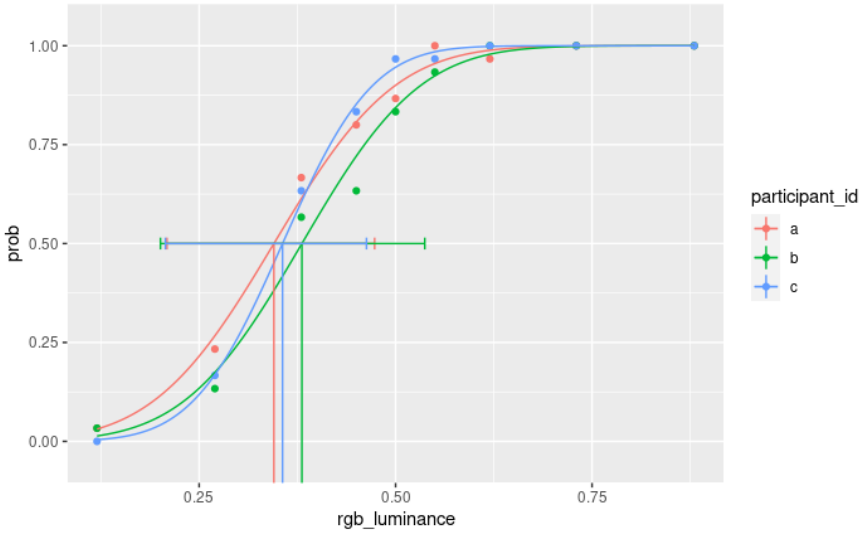

Figure 2: Psychometric curves fitted to the data of three participants in the simultaneous brightness contrast experiment.

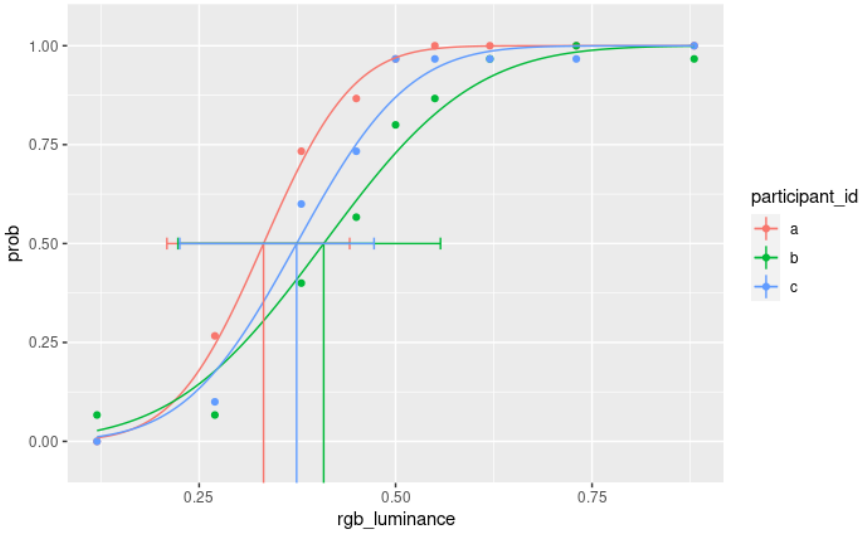

Figure 3: Psychometric curves fitted to the data of three participants in the simultaneous color contrast experiment with green color.

4 Conclusions

We have explained what is simultaneous contrast. Two experiments with three participants were done. Each participant was asked to leave all possible distractions in other room and the experiment was done in dark room with no other source of light other than the laptop with experiment. The values of brightness for the experiments could have been more densely packed around the area of 35% brightness as the thresholds were located around this area, but current lockdown situation did not allow us to repeat the experiment in person with all three participants.

The thresholds at 35%, rather than at 50% brightness which is brightness of the gray square on the white background, is caused by the simultaneous contrast phenomena described in the articles [1, 2]. There were also some interesting but not statistically significant differences between the participants thresholds. For example, participant b had in both experiments threshold around 3% higher then other two participants. We speculated that this can be caused by the longer average response time or the fact that it the participant sex is female with perfect sight while other two participants are males, where the individual *a* has very poor sight. We could see that the difference between the three participants is even larger in case of the second experiment with simultaneous green color contrast.

It would be ideal to use anonymised data collected by other students who have done same experiment as it would allow us to analyze larger dataset with less speculation and less biases. It would be also interesting to try also strictly chosen duration of stimulus rather than free viewing of the stimuli. As is described in article

Participant	Experiment	threshold value
a	brightness	0.345
b	brightness	0.381
c	brightness	0.356
a	color	0.332
b	color	0.409
c	color	0.374

Table 2: Approximated thresholds where probability that participant choose left or right square as brighter is equal.

[2], with shorter duration of stimulus the effect of simultaneous contrast is stronger.

Bibliography

[1] Kaneko, S., Murakami, I., Kuriki, I., & Peterzell, D. H. (2018). Individual variability in simultaneous contrast for color and brightness: Small sample factor analyses reveal separate induction processes for short and long flashes. i-Perception, 9(5), 1–22. doi: 10.1177/2041669518800507.

[2] Sae Kaneko, Ikuya Murakami; Flashed stimulation produces strong simultaneous brightness and color contrast. Journal of Vision 2012;12(12):1. doi: https://doi.org/10.1167/12.12.1.

[3] HEINEMANN EG. Simultaneous brightness induction as a function of inducing and test-field luminances. J Exp Psychol. 1955 Aug;50(2):89-96. doi: 10.1037/h0040919. PMID: 13242747.