Dark Adaptation **15 January 2001**

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The purpose of this exercise is to test the hypothesis that red light is less stressful to a dark-adapted eye than blue light, thus requiring much less readjustment time.

Each group designated a “guinea pig,” a card-holder, and a timer. The guinea pig sat facing the front of the room where the instructor displayed the colored lights. The card-holder and timer sat facing the guinea pig but not in the line of sight to the front of the room. The classroom was darkened as much as possible while allowing just enough light to read black numbers on white cards after full dark-adaptation. The groups waited for approximately 10 minutes for the guinea pigs’ eyes to fully adapt to the darkness.

Then the instructor turned on a blue light, which the guinea pigs stared towards for 15 seconds. Immediately after the instructor shut off the light, the card-holder held up one of the cards and the timer started a stopwatch. These actions must be simultaneous. If not, you must scrap the trial and wait for the next one.

The stopwatch ran until the guinea pig was finished reading the numbers on the card (as indicated by the guinea pig), at which point it was stopped and the time recorded.

Then the card-holder changed cards and we waited until everyone had dark-adapted again (about 7–8 minutes) before repeating the procedure using a red light. We continued this process, alternating the red and blue lights, until we had taken six measurements with each color.

In our group, Orson was the guinea pig while Jacques held the cards and I timed Orson’s responses. One thing we immediately noticed was that there was probably too much ambient light in the room. It was a difficult balance to maintain because we needed enough light so the guinea pig could read the cards, but not so much to spoil the dark-adaptation in the first place. We also noticed that the instructor did not time the light intervals with a timepiece, but counted out loud instead. Undoubtedly, this has introduced some error into our measurements, but as this is a random error (just as likely to be too fast as it is too slow), we can’t formally correct for it. We were also concerned that (a) the distance between the guinea pig and the cards wasn’t necessarily the same each time and (b) the two bulbs were of different wattages, which may have affected the results.

We calculated averages and standard deviations for both sets of times. The average and standard deviation for the blue data was calculated by hand (see sample below). We then input our data into an Excel spreadsheet and, after verifying that it gave the same answers as the two calculations we did by hand, we used its built-in functions to complete the calculations.

Trial	Blue Light (sec)	Red Light (sec)
1	21.40	N/A
2	7.20	4.03
3	18.94	7.60
4	10.30	5.08
5	8.98	5.15
6	39.77	17.96
avg	17.77	7.96
σ	12.19	5.74
avg*	11.36	5.47
σ*	5.21	1.51

$$\bar{x} = \frac{1}{N}\sum_{i=1}^{N} x_i = \frac{1}{6}(x_1 + x_2 + x_3 + x_4 + x_5 + x_6)$$

$$\bar{x} = \left(\frac{21.40+7.20+18.94+10.30+8.98+39.77}{6}\right) = 17.77\ \mathrm{s}$$

$$\sigma = \sqrt{\frac{\sum_{i=1}^{N}(x_i - \bar{x})^2}{N-1}}$$

*These numbers were calculated excluding trials 1 and 6.

$$\sigma = \sqrt{\frac{(21.40-17.77)^2+(7.20-17.77)^2+(18.94-17.77)^2+(10.30-17.77)^2+(8.98-17.77)^2+(39.77-17.77)^2}{6-1}}$$

$$\sigma = \sqrt{\frac{(3.63)^2+(-10.57)^2+(1.17)^2+(-7.47)^2+(-8.79)^2+(22.00)^2}{5}}$$

$$\sigma = \sqrt{\frac{13.1769+111.7249+1.3689+55.8009+77.2641+484}{5}} = \sqrt{\frac{743.3357}{5}} = \sqrt{148.66714} = 12.19\ s$$

In trial #1, we messed up with the stopwatch and didn't get to make a reading in the red light. In trial #6, we got much larger times than previous trials. We believe the instructor didn't wait long enough to dark-adapt after trial #5. This is why we made two sets of calculations, one using all available data, and another excluding what we believe may be erroneous data (trial #6 for reasons stated above and trial #1 was excluded because there was no comparison data in the other color).

In both cases, the guinea pig's eyes recovered from the red light more quickly than from the blue. Additionally, the standard deviations of the red measurements are not enough to raise the averages to those of the blue light, leading us to believe that the difference is real. The standard deviations of the blue light measurements, however, are quite high and are enough to bring them down to the red light values. The standard deviation of the red light data that includes all trials is also very high compared to the average.

It is important to note that these large standard deviations relative to the averages are a consequence of many sources of error, some which were previously stated: eye-card distance, readjustment time between trials, actual exposure time not counted precisely, etc. We should also say that the handwriting on the cards could have been a factor, but this is probably a small contribution compared to that from the other sources of error. Other sources of errors are human response time in operating the stopwatch, and the guinea pig blinking or closing his eyes for longer intervals later into the experiment as the his eyes got more tired.

Nevertheless, looking only at the case where the bad data were excluded, it seems safe to state that the eye definitely recovered more quickly and consistently from the red light exposure. The standard deviation of the blue data is roughly 46% of the average while that of the red data is only about 28% of its average. Likewise, the blue light average is more than twice as long as that of the red light data. It seems unlikely that the quality of the blue light data could differ that radically from the quality of the red light data (see procedural description). Therefore, we conclude the difference is real.

In summary, we tested and confirmed the hypothesis that red light is easier on the eyes than blue light. It would be interesting to repeat the experiment with tighter controls on the sources of error mentioned (leakage of ambient light into the room, writing on the cards, using a different guinea pig each time, bulb wattages, etc.). It might be worth experimenting with other colors of light and/or various types of bulbs though we suspect the results would again be confirmed since red light is of lower energy than any other color in the visible spectrum.

Discussion Questions:

1. The guinea pig's eyes recovered quicker from the red light.
2. Red photons have lower energy than blue photons. Lower energy photons apparently cause less stress on the eye. It is less work for the ocular muscles to readjust to the darkness after being in red light than it is after being in [higher energy] blue light.
3. These results support using a red light to see while observing, just as expected.
4. There are a variety of reasons that all trials of a given color weren't the same: those listed above plus the fact that the eyes were getting more tired as time progressed. This is evident in the data where, in general, the times increased in later trials. Also, the guinea pig wasn't reading the same number each time, which may have accounted for different response times.