Udacity DAND, P1 – The Stroop effect

In this text we will take a look at a classic phenomena from experimental psychology, the Stroop effect. After a short description about the effect we will present some data and then proceed with calculating some statistics and performing a test to see if there are any difference in response time while naming colors from to different lists out loud.

Background

The effect is named after an American psychologist named John Ridley Stroop. His findings were published in 1935. The Stroop effect (*https://en.wikipedia.org/wiki/Stroop_effect*) itself is about interference in reaction times demonstrated by measuring time and error frequency when subjects named colors listed in two different lists. In the first list the color of the font corresponded to the word written. In the second list the font and written colors do not correspond to each other and the subject has to name the color of the font. From here on the first list will be described as congruent and the second list as incongruent.

Variables, Hypotheses, and Test type

We will proceed by doing a statistical test to see if the reaction time is changed significantly between the two types of lists using a small sample of data. We start by defining our variables for the test.

The independent variable is the type of list, which we change in between the two times the subject performs the test. The dependent variable is the measured time to complete reading through the lists.

We are interested in seeing if the dependent variable (measured time) is affected by our independent variable (type of list) and therefore define the below two hypotheses based on the population mean μ for congruent(c) and incongruent (i) list reading time:

$$H_0: \mu_i = \mu_c (The\ measured\ \ reading\ time\ is\ unchanged\ between\ list\ types)$$

$$H_A: \mu_i \neq \mu_c (The\ measured\ reading\ time\ do\ change\ between\ list\ types)$$

Since we won't have any access to information about the population as a whole, just two rather small samples, we will perform a t-test (https://en.wikipedia.org/wiki/Student%27s_t-test) suitable for this sample size. We will use the standard deviation and mean of our sample to evaluate if there is any statistically significant change between the two reading times. With a larger sample size and data about the population standard deviation we could have opted for a z-test (https://en.wikipedia.org/wiki/Z-test) instead.

By choosing to do a t-test we make the following assumptions about our test data:

- The reading time are randomly sampled from the whole population.

- The reading time are normally distributed when looking at the population as a whole.
- The values for our sample data follow a continuous scale.

Further, for a paired sample t-test the following assumptions are made as well:

- Just as the original reading times are, the difference in seconds between the two reading times are also normally distributed.
- The two samples are linked with each other due to the measurement being repeated two times for each subject.

Source for the t-test assumptions at:
http://www.psychology.emory.edu/clinical/bliwise/Tutorials/TOM/meanstests/assump.htm

We will compare two samples (measured time) where each test subject are present in both samples (once for the congruent and once more for the incongruent list), so the sample data sets will be dependent on each other. This means we can perform a paired sample t-test where we look at the difference between the two list types reading times. This will gives us the following equations for our t-statistic($t_{statistic}$) and degrees of freedom(df):

$$t_{statistic} = \frac{\overline{X_i} - \overline{X_c}}{S/\sqrt{n}}$$

$$df = n - 1$$

X is the mean of the sample for the congruent(c) and incongruent(i) lists reading times, S is the standard deviation for the differences in reading times between the two list types, and n is the sample size.

Data

To be able to perform any calculations the following existing data set will be used. I have added my own times for the two lists on the last row and also calculated the differences in reading time as written in the third column. If you are curious about the test yourself, please feel free to check it out via this link (https://faculty.washington.edu/chudler/java/ready.html&sa=D&ust=1488102478313000&usg=AFQjCNHd2BV4nKVqCBQzVq35xzESJHA1QA).

Reading times (in seconds)

Congruent(X_c)	Incongruent(X_i)	Difference($X_d = X_i - X_c$)
12.079	19.278	7.199
16.791	18.741	1.950
9.564	21.214	11.65
8.630	15.687	7.057
14.669	22.803	8.134

12.238	20.878	8.640
14.692	24.572	9.880
8.987	17.394	8.407
9.401	20.762	11.361
14.480	26.282	11.802
22.328	24.524	2.196
15.298	18.644	3.346
15.073	17.510	2.437
16.929	20.330	3.401
18.200	35.255	17.055
12.130	22.158	10.028
18.495	25.139	6.644
10.639	20.429	9.790
11.344	17.425	6.081
12.369	34.288	21.919
12.944	23.894	10.950
14.233	17.960	3.727
19.710	22.058	2.348
16.004	21.157	5.153
11.940	15.650	3.710

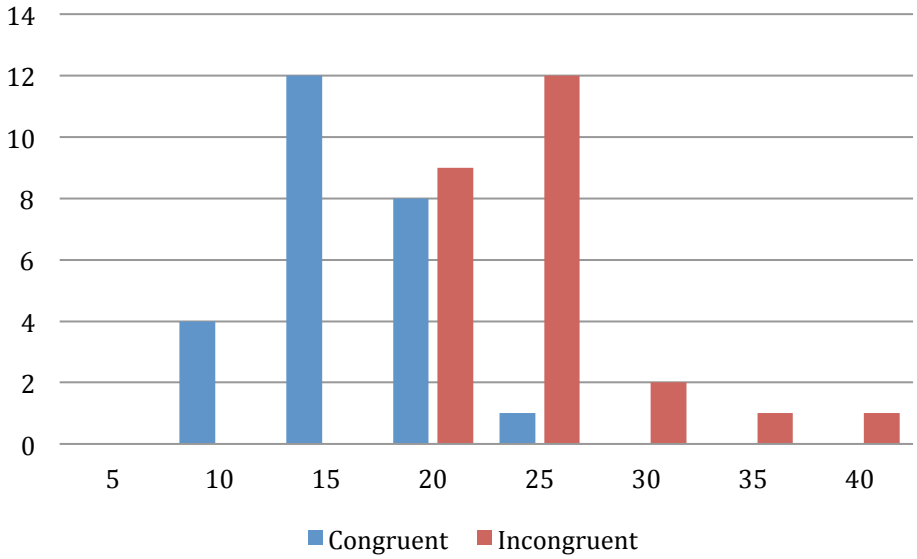
From the above data we are also able to calculate following descriptive measurements:

$$\overline{X_c} = \frac{\sum X_c}{n} = 13.967, \qquad \overline{X_i} = 21.761, \qquad S = \sqrt{\frac{\sum(X_d - \overline{X_d})^2}{n-1}} = 4.838, \qquad n = 25$$

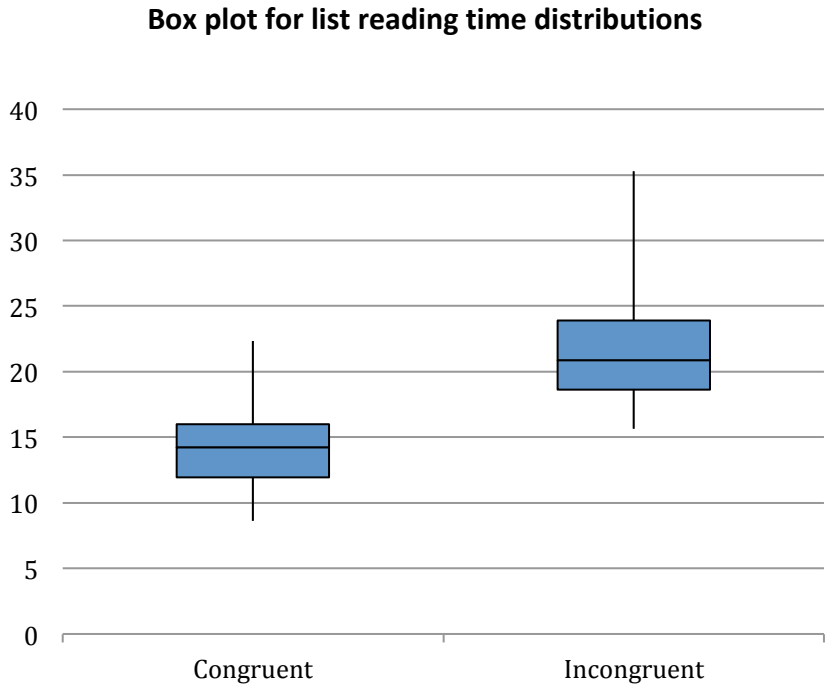
Visual analysis

Before we start the testing let's have a look at our data to see if there is something we have missed. We begin with a simple histogram showing the number of occurences for different reading times.

Reading times (occurrences)



Judging from the above bin plot it do seem like the incongruent list type increases the reading time, but we will wait until a little bit later to see if the observed difference in our samples have any statistical significance. For now I believe it is okay to just observe that both shapes looks to be bell shaped and that we will not have any trouble proceeding with our planned t-test.



Another way to visualize the data is to use a box plot, as the one seen above. Here once again we see that the reading times for the incongruent list are increased in comparison to the congruent list. Compared to the previous bin plot we can see that there is less overlap between the two sample groups for values in the 15 to 20 second interval than one might first think. The reason being that most of the reading times for the congruent list is in the lower and while the incongruent list times are in the higher end of the interval of the bin in the previous plot.

t-Test and conclusion

Now let's proceed to testing our hypotheses with a double sided t-test and a confidence level of 95%. Together with the information we have gathered so far this gives us the following degrees of freedom and critical value for t.

$$df = n - 1 = 25 - 1 = 24$$

$$t_{critical}(24) = 2.064$$

To continue, we input the measures we obtained from our data into the equation for our $t_{statistic}$ and get the following:

$$t_{statistic} = \frac{\overline{X_i} - \overline{X_c}}{S/\sqrt{n}} = \frac{21.761 - 13.967}{4.838/5} = 8.055, with\ P < 0.0001$$

Since our $t_{statistic} > t_{critical}$ we reject the null hypothesis, there are significant change in reading time between the two list types.

I believe this comes as no surprise to anyone that actually tried to do the test with the link I provided in the beginning. There is a noticeable difference in the concentration necessary for reading the second incongruent word list in comparing with the first congruent list.

As why this is the case I can only speculate, but after a quick visit to Wikipedia (https://en.wikipedia.org/wiki/Stroop_effect) and some reading it seems that a possible explanation are that both the font color and the written color are being processed at the same time in the brain causing the two signals to interfere with each other influencing the response time and failure rate.

The Stroop test seems like it is still being used in research even today to measure attention capacity and processing speed of the human brain among other things.