Statistics: The Science of Decisions Project by Yiyi Tang

Background Information

In a Stroop task, participants are presented with a list of words, with each word displayed in a color of ink. The participant's task is to say out loud the *color of the ink* in which the word is printed. The task has two conditions: a congruent words condition, and an incongruent words condition. In the *congruent words* condition, the words being displayed are color words whose names match the colors in which they are printed: for example RED, BLUE. In the *incongruent words* condition, the words displayed are color words whose names do not match the colors in which they are printed: for example PURPLE, ORANGE. In each case, we measure the time it takes to name the ink colors in equally-sized lists. Each participant will go through and record a time from each condition.

Questions For Investigation

As a general note, be sure to keep a record of any resources that you use or refer to in the creation of your project. You will need to report your sources as part of the project submission.

1. *What is our independent variable? What is our dependent variable?*

   The independent variable is the condition whether the words match the ink colors or not. The dependent variable is the recorded time (reaction time) which participant took to name the ink colors.

2. *What is an appropriate set of hypotheses for this task? What kind of statistical test do you expect to perform? Justify your choices.*

Symbol	Explanation
*H*0	Null Hypothesis
Ha	Alternative Hypothesis

$\mu_{incongruent}$	The population mean of average reaction time in incongruent condition.
$\mu_{congruent}$	The population mean of average reaction time in congruent condition.
μ_{inc}	The sample mean of average reaction time in incongruent condition (sample size 24).
μ_{con}	The sample mean of average reaction time in congruent condition (sample size 24).
S_{incon}	The sample standard deviation of average reaction time in incongruent condition.
S_{con}	The sample standard deviation of average reaction time in congruent condition.

$$H0: \mu_{incongruent} = \mu_{congruent}$$

$$Ha: \mu_{incongruent} > \mu_{congruent}$$

To interpret my set of hypotheses:

The null hypothesis guesses that there will not be evidence to suggest that $\mu_{incongruent}$ and $\mu_{congruent}$ have a significant difference. Which means that the incongruent match of word and ink intervention has no effect on average reaction time, so the result of incongruent and congruent conditions should be approximately the same.

While the alternative hypothesis guesses that there will be evidence to suggest that a significant difference is between $\mu_{incongruent}$ and $\mu_{congruent}$, and the $\mu_{incongruent}$ will be greater than $\mu_{congruent}$. Which means that the incongruent match of word and ink intervention has effect.

In this test, we don't know the population standard deviation or population mean but we did randomly pick a sample size 24 from the population under both congruent and incongruent conditions. So I will use one-tailed t test to see if there's a significant difference between μ_{inc} and μ_{inc} . Based on this sample evidence, I'll test my set of hypotheses, which are related to whether there will be a significant difference between $\mu_{incongruent}$ and $\mu_{congruent}$.

I will use dependent one-tailed t-test because:

- The sample size is less than 30.
- The population standard deviation or population mean are unknown.
- I assume that the distribution is normally distributed.
- I want to predict a direction of this congruent condition effect (*Ha*: $\mu_{incongruent} > \mu_{congruent}$).

3. *Report some descriptive statistics regarding this dataset. Include at least one measure of central tendency and at least one measure of variability.*

Firstly, I expected the distribution of average reaction time in both congruent and incongruent conditions to be normally distributed.

Secondly, I calculated mean, median, sample standard deviation and variance for both conditions. The average reaction time in incongruent condition is bigger than the average reaction time in congruent condition, so does the median.

In addition, about sample standard deviation, I noticed that S_{incon} is greater than S_{con}, so I expected that the normal distribution of incongruent condition would spread much more widely than the distribution of congruent condition.

The statistical results are as below:
(For calculating process, please see the excel file in the folder)

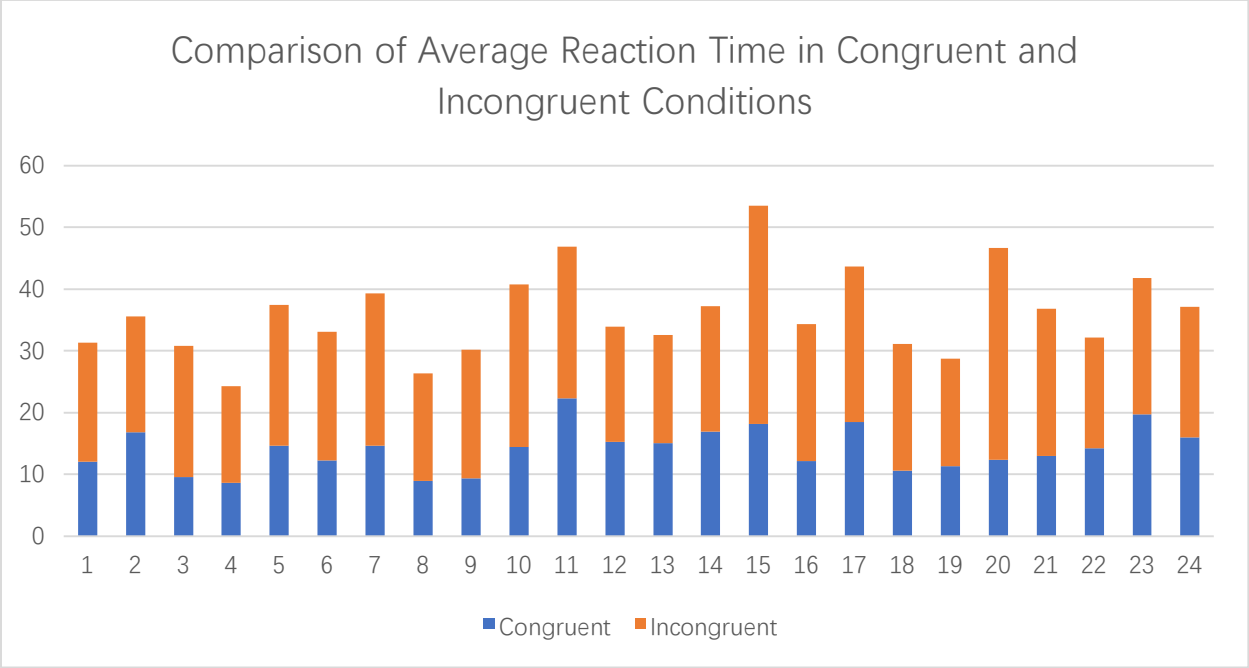
Congruent	squared deviation		median=	14.3565	
12.079	3.889		mean=	14.051	
16.791	7.507		sample standard deviation (Scon)=	3.559	
9.564	20.134		variance=	12.669	
8.63	29.389				
14.669	0.382				
12.238	3.287				
14.692	0.411				
8.987	25.645				
9.401	21.624				
14.48	0.184				
22.328	68.507				
15.298	1.555				
15.073	1.044				
16.929	8.282				
18.2	17.213				
12.13	3.691				
18.495	19.748				
10.639	11.643				
11.344	7.329				
12.369	2.83				
12.944	1.226				
14.233	0.033				
19.71	32.023				
16.004	3.814				

Incongruent	squared deviation		media=	21.0175	
19.278	7.496		mean=	22.016	
18.741	10.725		sample standard deviation (Sincon)=	4.797	
21.214	0.643		variance=	23.012	
15.687	40.055				
22.803	0.62				
20.878	1.295				
24.572	6.534				
17.394	21.362				
20.762	1.572				
26.282	18.199				
24.524	6.29				
18.644	11.37				
17.51	20.303				
20.33	2.842				
35.255	175.273				
22.158	0.02				
25.139	9.754				
20.429	2.518				
17.425	21.077				
34.288	150.604				
23.894	3.527				
17.96	16.45				
22.058	0.002				
21.157	0.738				

Statistical results from data analysis :			
Congruent		Incongruent	
Mean	14.051125	Mean	22.0159167
Standard Error	0.7265509	Standard Error	0.97919519
Median	14.3565	Median	21.0175
Mode	#N/A	Mode	#N/A
Standard Deviation	3.55935796	Standard Deviation	4.79705712
Sample Variance	12.6690291	Sample Variance	23.011757
Kurtosis	-0.2052248	Kurtosis	2.6889002
Skewness	0.41689987	Skewness	1.54759003
Range	13.698	Range	19.568
Minimum	8.63	Minimum	15.687
Maximum	22.328	Maximum	35.255
Sum	337.227	Sum	528.382
Count	24	Count	24

4. Provide one or two visualizations that show the distribution of the sample data. Write one or two sentences noting what you observe about the plot or plots.

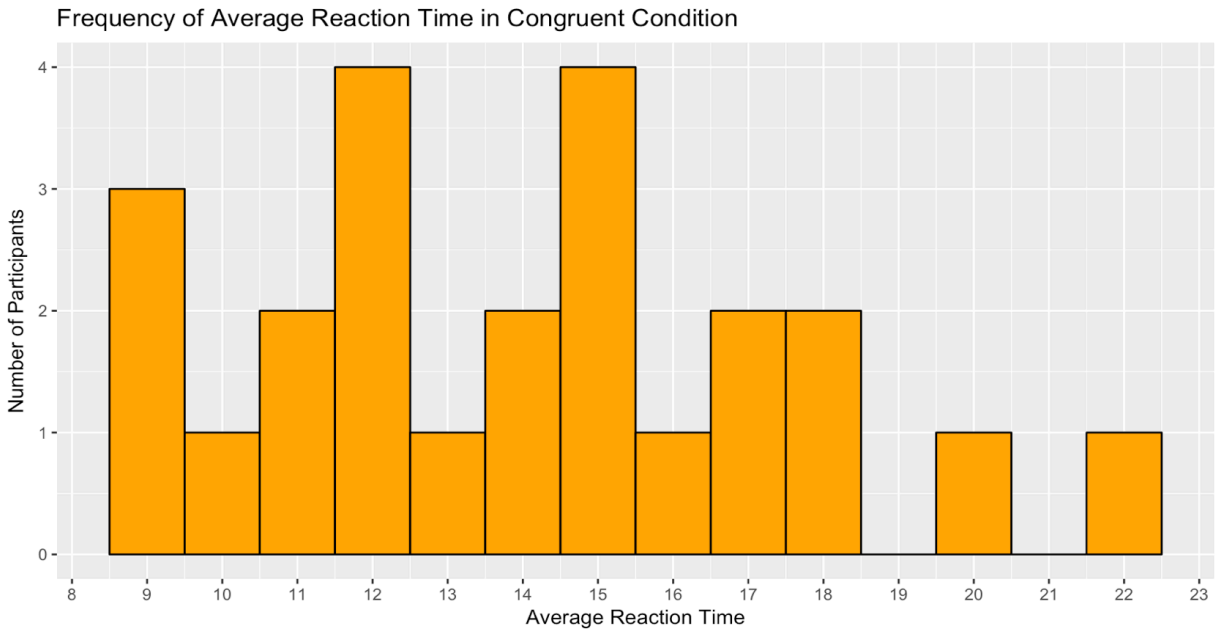
- Plot 1:

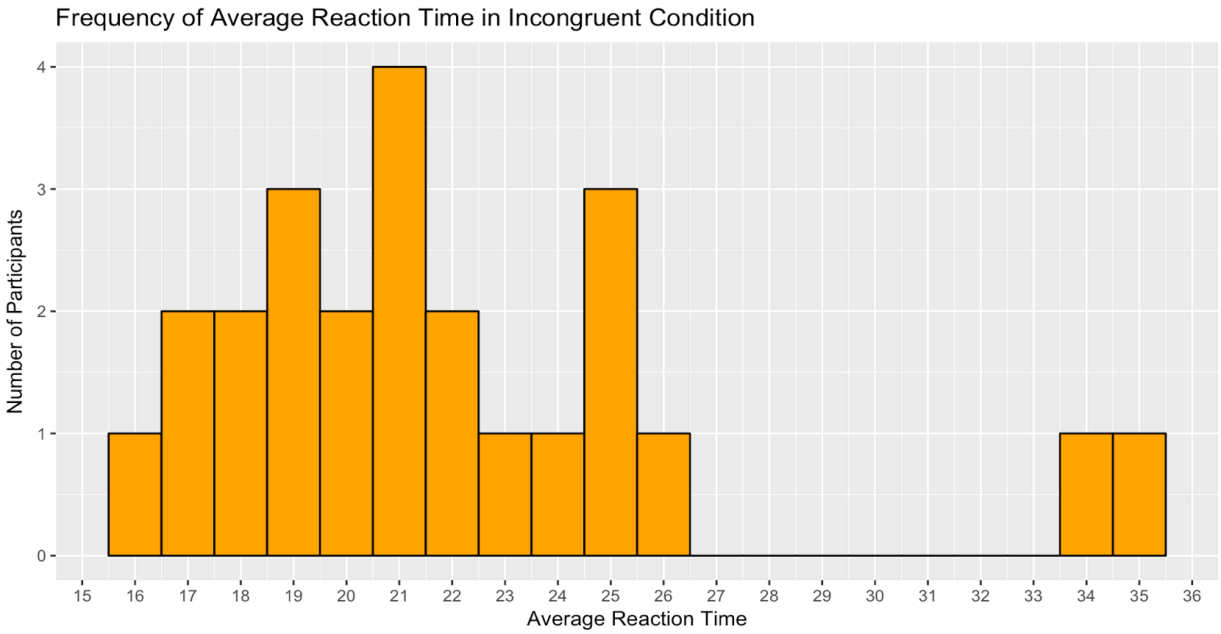


I can easily see that average reaction time in incongruent condition is much greater than the average reaction time in congruent condition.

- Plot 2:

(Please see the R markdown file in the folder for detailed codes)





Surprisingly, I found out that the distribution of average reaction time in both congruent and incongruent conditions are not normally distributed. This may have reasons with the small limited size of the sample (sample size = 24). If the sample size increased to, let's say 300, I believe the distributions will tend to be normally distributed.

In the histogram of congruent condition, there're 3 peaks in the distribution at 9, 12 and 15. A gap existed in the distribution at 19 and 21.

In the histogram of incongruent condition, I firstly noticed a long gap between 27 and 33. Maybe the gap would be filled if we increase the sample size. Also, there're 3 peaks in the distribution at 19, 21 and 25.

5. *Now, perform the statistical test and report your results. What is your confidence level and your critical statistic value? Do you reject the null hypothesis or fail to reject it? Come to a conclusion in terms of the experiment task. Did the results match up with your expectations?*

I'll perform this using dependent one-tailed t-test:

confidence level = 95%

critical value (t critical value) = 1.714

critical region >1.714

df = 23

Dependent one-tailed t test									
	Congruent	Incongruent							
Mean	14.051125	22.0159167							
Variance	12.6690291	23.011757							
Observations	24	24							
Pearson Correlation	0.35181953								
Hypothesized Mean Difference	0								
df	23								
t Stat	-8.0207069			critical region > 1.714		so if t statistical value is greater than 1.714,			
P(T<=t) one-tail	2.05E-08					then we reject the null hypothesis.			
t Critical one-tail	1.71387153					Otherwise, we failed to reject the null hypothesis.			
P(T<=t) two-tail	4.10E-08			Conclusion:					
t Critical two-tail	2.06865761			1. p-value < 0.05 so we failed to reject the null hypothesis.					
				2. t stat < t critical (one-tail) , which means t statistical value is not in the					
				critical region, so we failed to reject the null hypothesis.					

Results:

1. t statistical value (which equals -8.021) is less than critical value, so it is not in the critical region.
2. p-value is less than 0.05

Conclusions:

At confidence level 95%, we failed to reject the null hypothesis and cannot accept the alternative hypothesis based on our sample test. That is, we failed to reject that there's no significant difference between $\mu_{incongruent}$ and $\mu_{congruent}$. Because the t statistical value is less than critical value, and p-value is also less than 0.05.

This result does not match my expectations since I believe that the incongruent conditions will certainly slower the reaction time people naming the ink color. But I think this result may have reason with my set of the alternative hypothesis.

I believe if my null hypothesis is the same, and my alternative hypothesis is that $\mu_{incongruent}$ does not equal to $\mu_{congruent}$. The result might match my expectation. Let's test this <u>new set</u> of hypotheses using <u>dependent two-tailed t test:</u>

Dependent one-tailed t test					
	Congruent	Incongruent			
Mean	14.051125	22.0159167			
Variance	12.6690291	23.011757			
Observations	24	24			
Pearson Correlation	0.35181953				
Hypothesized Mean Difference	0				
df	23				
t Stat	-8.0207069		critical region > 2.069 or <-0.2069		so if t statistical value is in the critical region,
P(T<=t) one-tail	2.05E-08				then we reject the null hypothesis.
t Critical one-tail	1.71387153				Otherwise, we failed to reject the null hypothesis.
P(T<=t) two-tail	4.10E-08			Conclusion:	
t Critical two-tail	2.06865761			1. p-value < 0.05 so we failed to reject the null hypothesis.	
				2. t stat < t critical , which means t statistical value is in the	
				critical region, so we reject the null hypothesis.	

As above, we can see that if my null hypothesis is the same, and my alternative hypothesis is

that $\mu_{incongruent}$ does not equal to $\mu_{congruent}$. Then the conclusion is that based on our sample test, we reject the null hypothesis, and accept the alternative hypothesis. That means the incongruent match of word and ink intervention has effect on average reaction time.

6. *Optional: What do you think is responsible for the effects observed? Can you think of an alternative or similar task that would result in a similar effect? Some research about the problem will be helpful for thinking about these two questions!*

   After my research, I learned that these effects are related to brain imaging techniques. To be specific, the differences of reaction time between congruent condition and incongruent condition are related to "brain speed of processing and executive functions with working memory and cognitive development".

   Depending on my research, I think it is interesting to compare two groups of people (one group ages younger and the other group ages older) to test the average reaction time in both congruent and incongruent conditions. This can be a similar task that would result in a similar effect, but more related to psychology side. Because the brain "speed of processing increases with age, and cognitive control becomes increasingly efficient".

Reference：

https://en.wikipedia.org/wiki/Stroop_effect

http://support.minitab.com/en-us/minitab/17/topic-library/basic-statistics-and-graphs/hypothesis-tests/tests-of-means/why-use-paired-t/

http://demonstrations.wolfram.com/SamplingDistributionOfTheSampleMean/

https://www.r-bloggers.com/visualizing-sampling-distributions/

https://en.wikipedia.org/wiki/Student%27s_t-test#Assumptions

http://stattrek.com/hypothesis-test/difference-in-means.aspx?Tutorial=AP

https://onlinecourses.science.psu.edu/stat500/node/51

http://www.statisticshowto.com/when-to-use-a-t-score-vs-z-score/

http://support.minitab.com/en-us/minitab/17/topic-library/basic-statistics-and-graphs/hypothesis-tests/tests-of-means/types-of-t-tests/

https://discussions.udacity.com/t/lesson-8-estimation-what-does-this-mean/184871/4