P1: Test a Perceptual Phenomenon
Statistics
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Stroop Effect

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

In psychology, the Stroop effect is a demonstration of interference in the reaction time of a task. (Wikipedia, 2017) With the following data investigation, it will be indicated that naming the colour of the incongruent words condition takes longer and is more prone to errors than when the colour of the ink matches the name of the colour. This effect is named after John Ridley Stroop, who first published the effect in English in 1935. The effect has been used to create a psychological test (Stroop test) that is widely used in clinical practice and investigation.

Investigation of a Stroop Experiment

1. Experimental Variables

The independent variable in this experiment is whether the colour word name and the font colour are the same or different; congruent or incongruent words.

The dependent variable is the reaction time that a participant needs to name the font colour in equally-sized lists.

2. Hypotheses and Statistical Test

Our intention is to examine if there will be a difference in the reaction time between the two congruent and incongruent words conditions. An appropriate statistical test for this case can be considered a one-tailed hypothesis t-test, because we are expecting a reduced performance after the interference applied by the incongruent words condition. This is a dependent sample's design with two conditions, because the same subject is exposed to two conditions and tested for each ("within-subjects"). Additionally, we have chosen t-test over z-test, because population parameters are unknown. Our hypotheses are as follow:

a. Null hypothesis claims that there is no difference or increase in reaction time after the interference. The subscripts "c" and "i" used as symbols for the congruent and incongruent conditions respectively and "μ" represents the population mean.

$$H_0: \mu_c \geq \mu_i$$

Alternative hypothesis supports that there is a significant increase in the reaction time for the incongruent words condition.

$$H_A: \mu_c < \mu_i$$

b. Our data meets the following 4 assumptions that are required for a dependent t-test to give a valid result. (Laerd Statistics, 2013)

   i. The dependent variable (reaction time in our case) is measured on a continuous scale.
   ii. The independent variable consists of two categorical, "related groups" or "matched pairs" (congruent and incongruent tasks).
   iii. There are no significant outliers in the differences between the two related groups.
   iv. The distribution of the differences in the dependent variable between the two related groups is approximately normally distributed.

3. Descriptive Statistics

Mean

$$\bar{X}_c = 14.05$$

$$\bar{X}_i = 22.02$$

Median

$$\tilde{X}_c = 14.36$$

$$\tilde{X}_i = 21.02$$

Mean difference

$$\bar{X} = \bar{X}_i - \bar{X}_c = 7.97$$

Standard Deviation for each category

$$S_c = 3.56$$

$$S_i = 4.80$$

Standard Deviation of the differences

$$S = \sqrt{\frac{\sum(X_c - X_i - \bar{X})^2}{n-1}} = 4.87$$

Cohen's d

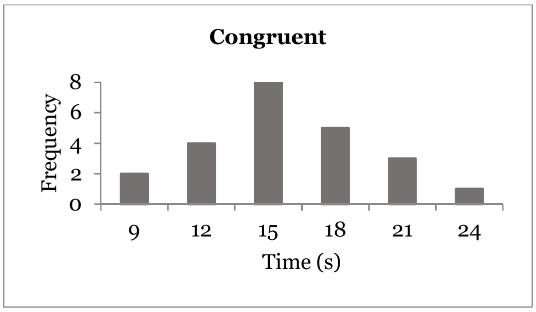
$$d = \frac{\bar{X}}{S} = \frac{7.97}{4.87} = 1.64$$

hence, the two means are 1.64 standard deviations apart.

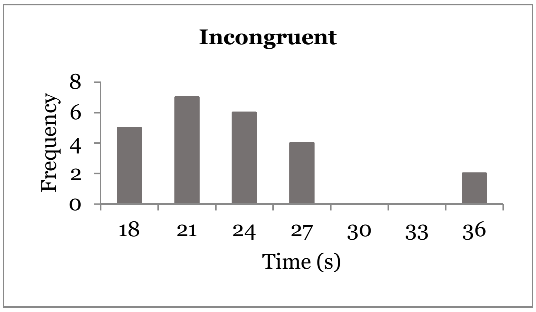
4. Visualizing the data

Histograms of the data distributions

a.



b.



Comparing the two histograms it can be deduced that the distributions looks normal with a higher mean and a more spread out shape for the incongruent one. Incongruent distribution depicts also a positive skew contrary to the neutral skewness of congruent, but to be sure more sample data are needed.

5. Statistical Test and Results

For a sample with size $n = 24$ the following statistics were calculated:

Degrees of freedom

$$df = n - 1 = 24 - 1 = 23$$

Standard Error of the Mean

$$SE = \frac{S}{\sqrt{n}} = \frac{4.87}{\sqrt{24}} = 0.99$$

From a t-table for $df = 23$, $\alpha\text{-}level = .05$ and a one-tailed t-test it is found that

$$t_{critical} = 1.714$$

$t_{statistic}$ is calculated as following

$$t_{statistic} = \frac{\bar{X}}{SE} = \frac{7.97}{0.99} = 8.02$$

Since $t_{statistic}$ is past the critical value, it falls in the critical region and the probability is

$$p < .05$$

Summing up, it was found that

$$t(23) = 8.02, p < .05, positive\ direction$$

So, the null hypothesis can be rejected and these results are statistically significant. This means that participants need more time to say out loud the colour of the ink in incongruent words, an outcome that was expected before doing the experiment. Assuming this as an experimental design, the type of words condition has a causal effect on the reaction time.

The Confidence Interval CI on the mean difference for confidence level 95% is

$$CI = \bar{X} \pm Margin\ of\ Error = \bar{X} \pm t_{critical} \cdot SE = 7.97 \pm 1.714 \cdot 0.99$$

$$95\%\ CI = (6.26, 9.67)$$

Thus, participants on average will make around 6 to 10 more seconds to react after the interference in the words.

Finally, the Coefficient of Determination, r^2 is

$$r^2 = \frac{t_{statistic}^2}{t_{statistic}^2 + df} = \frac{8.02^2}{8.02^2 + 23} = .74$$

Or 74% of the differences in reaction time for the sample of 24 people are due to interference.

The following table contains a summarized report of the statistical values.

Table 1. Summarized statistical data

Statistical Parameters	**Values**
Sample size	$n = 24$
Degrees of freedom	$df = 23$
Null hypothesis	$H_0: \mu_c \geq \mu_i$
Alternative hypothesis	$H_A: \mu_c < \mu_i$
Mean of differences	$\bar{X} = 7.97$
Standard Deviation of the differences	$S = 4.87$
t critical value if a-level = .05	$t_{critical} = 1.714$
t statistical value	$t_{statistic} = 8.02$
Probability	$p < .05$
Confidence Interval	$95\%\ CI = (6.26, 9.67)$
Cohen's d	$d = 1.64$
Coefficient of Determination	$r^2 = .74$

6. **Extending the investigation…**

Stroop experimental results showed that people are more practiced at word reading than naming colours. (CloudDeakin, 2017) In other words, there is less interference with word reading than there is with naming colours. Research shows that the 'Stroop effect' affects most people who try to identify words quicker than colours. There are two theories that may explain the Stroop effect: (Chudler, 2017)

- Speed of Processing Theory: the interference occurs because words are read faster than colours are named.
- Selective Attention Theory: the interference occurs because naming colours requires more attention than reading words.

More experiments to try, could be the following: (Chudler, 2017)

- Turn the words upside down or rotate them 90 degrees.
- Turn the words "inside out."
- Use non-colour words such as "dog" or "house."
- Use nonsense words such as "kiw" or "thoz."
- Compare long words to short words.
- Use emotional words such as "sad" or "happy" or "depressed" or "angry."
- Colour only half of the word or colour only the first and last letter of each word.

References

Chudler, E. H. (2017). Retrieved from Neuroscience For Kids - stroop effect: https://faculty.washington.edu/chudler/words.html

CloudDeakin. (2017). *The Stroop effect*. Retrieved from https://d2l.deakin.edu.au/d2l/eP/presentations/presentation_preview_popup.d2l?presId=67655

Laerd Statistics. (2013). *Dependent T-Test using SPSS Statistics*. Retrieved from https://statistics.laerd.com/spss-tutorials/dependent-t-test-using-spss-statistics.php

Wikipedia. (2017). *Stroop effect*. Retrieved from https://en.wikipedia.org/wiki/Stroop_effect