Project 1: The Stroop Effect **Paul Simpson**
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1. The independent variable in this study is the word condition (congruent or incongruent); congruent word lists contain color words that are inked in the colors of the same name, whereas incongruent word lists contain color words that are inked in colors that are of a different name. The dependent variable is the amount of time it takes a participant to name the ink colors of all words in equally-sized lists.
2. Let $\mu_{diff} = \mu_{incongruent} - \mu_{congruent}$, where: $\mu_{congruent}$ is the mean time required to name the ink color of words in congruent trials for the population; and $\mu_{incongruent}$ is the mean time required to name the ink color of words in incongruent trials for the population.
   A suitable set of hypotheses for this study are:
   - H_0: There is no difference in the time taken to name the ink colors of the equally-sized congruent and incongruent lists for the population. ($\mu_{diff} = 0$, or $\mu_{congruent} = \mu_{incongruent}$)
   - H_A: It takes more time to name the ink colors of incongruent lists compared to equally-sized congruent lists for the population. ($0 < \mu_{diff}$, or $\mu_{congruent} < \mu_{incongruent}$)

   To determine whether there is a difference in the times it takes a participant to name the ink colors of the congruent and incongruent lists, I would propose using a paired sample t-test to test the hypotheses outlined above. Paired sample t-tests are great for comparing two sets of measurements that are paired by the subject.
   In order to proceed with this test, the following assumptions must be verified: first, that the differences of the paired measurements are normally distributed; second that there are equal variances in the groups being compared; and third that the measurements are independent

3. Participants in this study required on average 14.05 ± 3.56 seconds to name the ink colors in the trials involving congruent ink and color names (Table 1); whereas in the incongruent trials, participants required 22.02 ± 4.80 seconds to complete the task (Table 1). Looking at the difference in time required to complete the congruent and incongruent trials, participants completed congruent trials 7.97 ± 4.86 seconds faster than the incongruent trials on average. Interestingly, the standard deviation of the difference in time required to complete the two trials, is roughly half the magnitude of the standard deviation of either of the treatment groups (congruent and incongruent).

Table 1 Descriptive statistics for the Stroop Effect study comprising 25 participants.

Group	Mean ± SD (seconds)	Variance ($seconds^2$)	Median (seconds)
Congruent	14.0511 ± 3.5594	12.6690	14.3565
Incongruent	22.0159 ± 4.7971	23.0118	21.0175
Difference	7.9648 ± 4.8648	23.6665	7.6665

4. As is suggested above, the distribution of times required for participants to complete the incongruent ink color naming trials is greater than that for the distribution of times for participants completing the congruent trials – with some overlap in the two distributions (Figure 1). In order to use a paired-sample t-test to see if there is a difference in time for participants to complete the two trials, one must assess whether the differences in time for these trials is normally distributed. Accordingly, when looking at a quantile plot of the full dataset, the data do not appear to be normal as there are significant deviations from the one-to-one line (Figure 2, left

panel); however, when the two outliers are removed, the data fit the normal distribution much better (Figure 2, right panel).

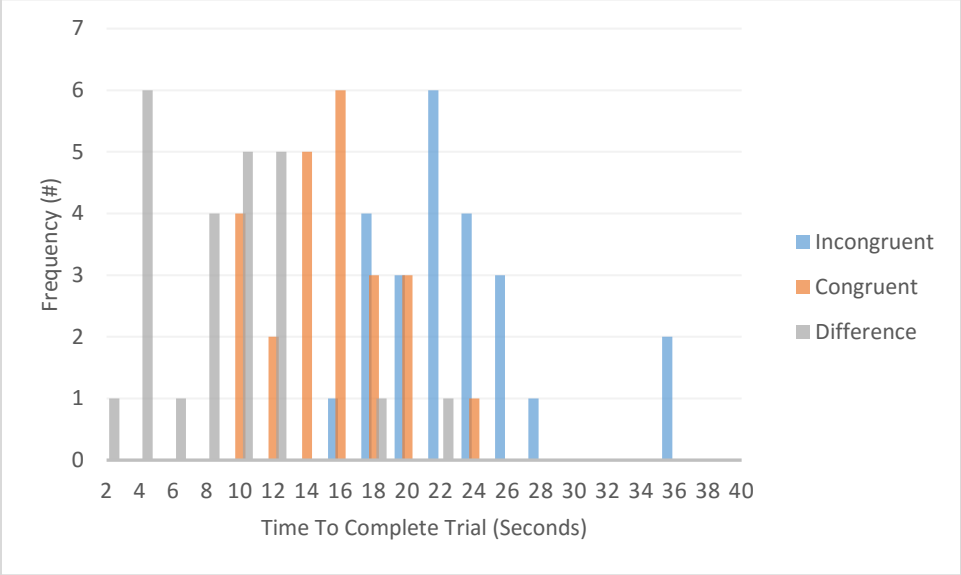

Figure 1: Histogram of the time required for 24 participants of a study examining the Stroop effect to complete incongruent color naming trials (blue bars), congruent color naming trials (red bars) and the difference between these two trials (gray bars) (in seconds).

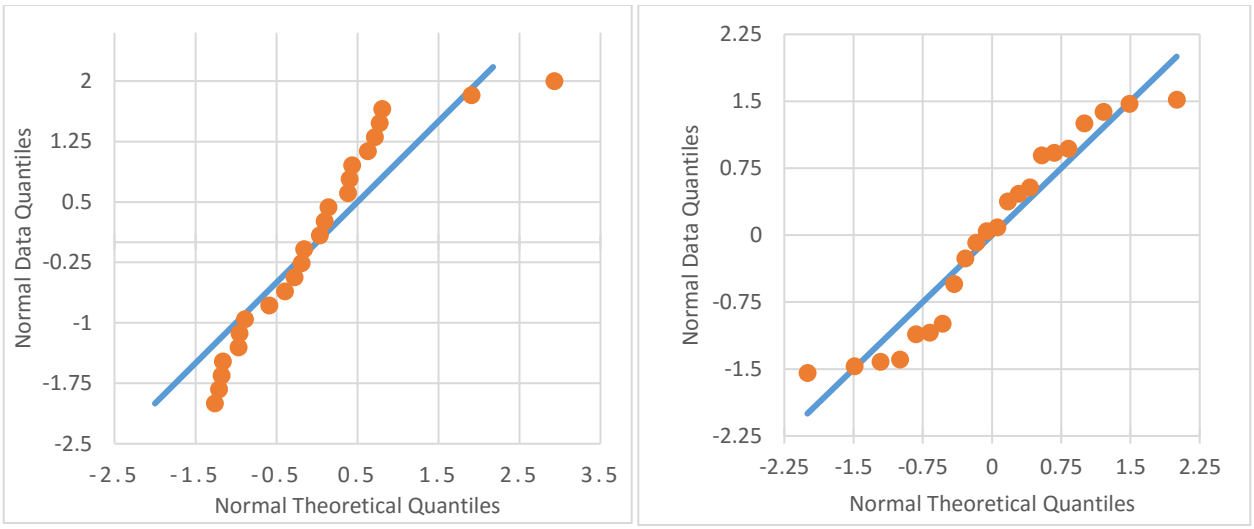

Figure 2: Normal quantile plots of the difference in time it takes a participant in the Stroop study to complete the ink naming task in the congruent and incongruent conditions. The left plot is for the full data-set (n=24), whereas the right plot is for the data with outliers removed (n=22). Orange circles denote data points, the blue line represents a one-to-one line demonstrating the expected value of the data quantiles, if they were drawn from a normal distribution.

5. The critical t value for this test given 23 degrees of freedom, and an alpha of 0.05, corresponding to a confidence level of 0.95 (or 95%), is $t_{23}^{*} = 1.7139$. The test statistic for the full data set is t = 7.8518, which is greater than our critical t value $t_{23}^{*} = 1.7139$; accordingly, one must reject the null hypothesis, and conclude that participants required significantly more time to complete the incongruent trials, than the congruent trials.

6. Response automaticity, wherein people are able to complete tasks without occupying their minds – as a form of automatic response is a possible explanation for this phenomenon (see: Stirling 1979). When participants complete the congruent color trials they are engaging in automatic reading of words, the association with color does not require participants to pay closer attention to the task at hand; whereas when participants took part in the incongruent color trials, it became necessary to pay greater attention to color processing (Monahan 2001). Similar interference could arise from bilingual individuals told to read (or to translate passages) in one language they are familiar with, or passages that comprise a mix of the two languages they are familiar with.

Literature

Monahan, J.S. (2001). Coloring single Stroop elements: Reducing automaticity or slowing color processing. *Journal of General Psychology.* **128**:98-112.

Stirling, N. (1979). Stroop interference: An input and output phenomenon. *Quarterly Journal of Experimental Psychology.* **31**:121-132.