Measuring the Stroop Effect

The goal is to determine if there is a Stroop Effect when people read the colour of the 'colour' words, which are the same colour as the word, compared to when they read the 'colour' of the words, which are in a different colour. Simply put, do people read these congruent words:

faster than these incongruent words:

My hypothesis is that people read the colour of the congruent words (top box) faster than they they read the colour of the incongruent words (bottom box).

Null Hypothesis (H_0): $\mu_C \geq \mu_I$
There is no difference in the reading speed between the congruent population mean (μ_C), and the incongruent population mean (μ_I).

Alternative Hypothesis (H_1): $\mu_C < \mu_I$
The congruent population mean (μ_C) is less than the incongruent population mean (μ_I), thus people read the colour of the congruent words faster.

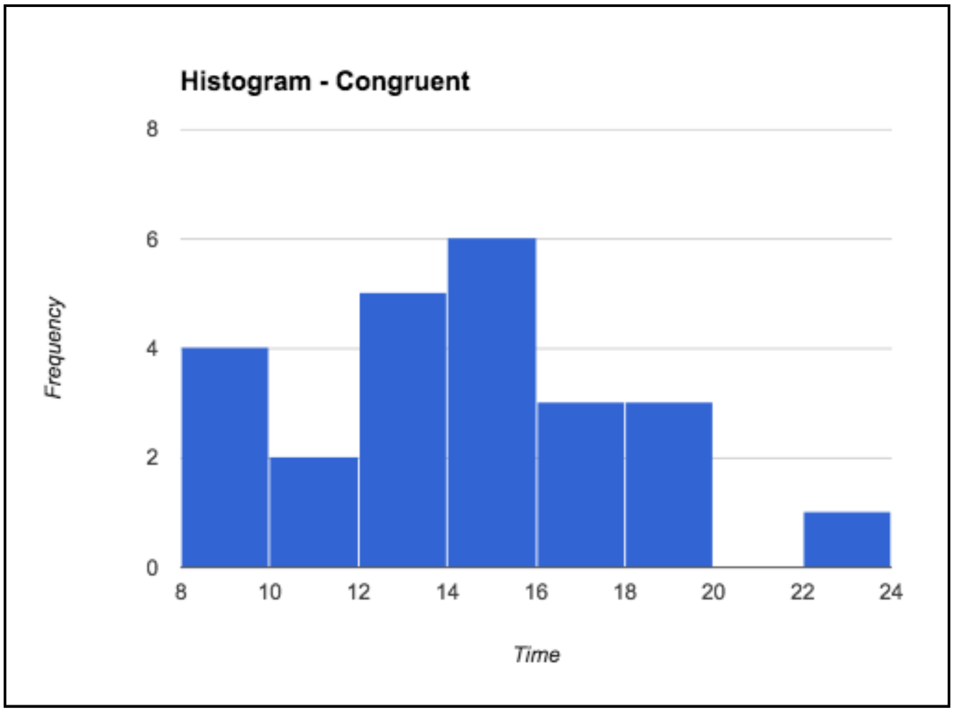
Independent Variable: Condition of the words - congruent or incongruent.
Dependent Variable: The amount of time to read the colour of the words.

We will measure the difference in reading speed by performing a dependent one-tailed t-test for paired samples. The reasons for this test are as followed:

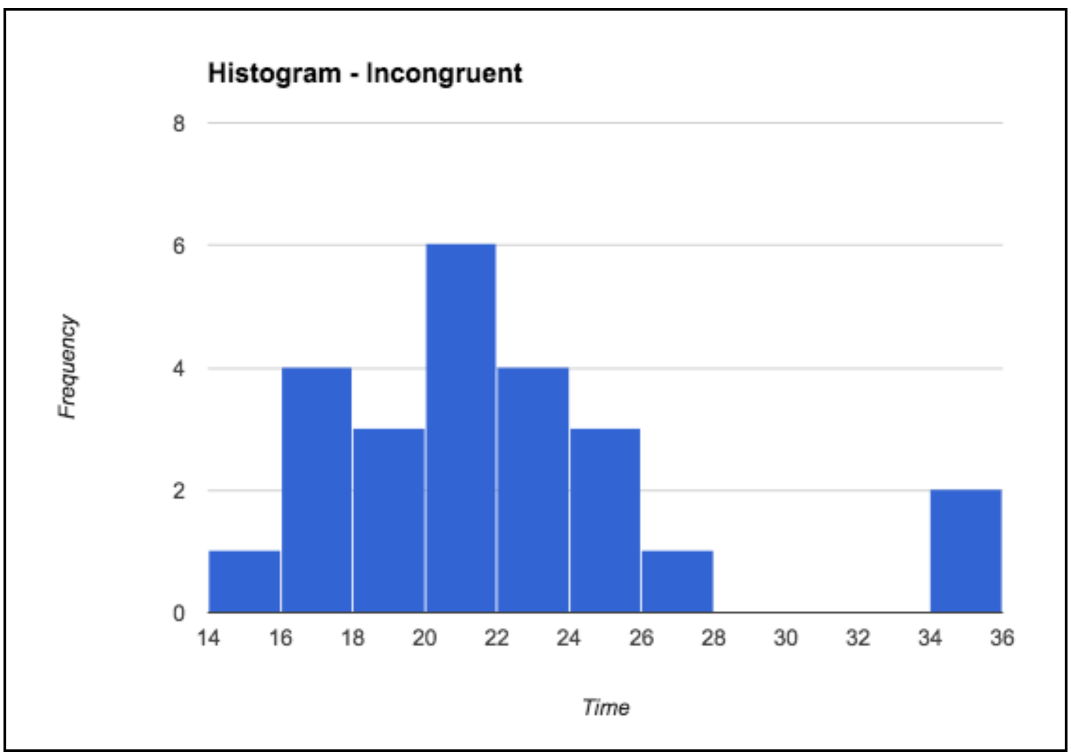
- ‘dependent’: The same subjects have taken the test twice.
- ‘one-tailed’: I am assuming that people will read the congruent words fastest than the incongruent words. Therefore, we only have to look in one direction = one-tailed.
- ‘t-test’: The sample size is small, n < 30.
- ’t-test’: The population mean and standard deviation is unknown.
- ‘paired samples’: We will be measuring the difference in the participants’ reading speed between their first test (congruent words) and second test (incongruent words).

Let’s begin by looking at the data:

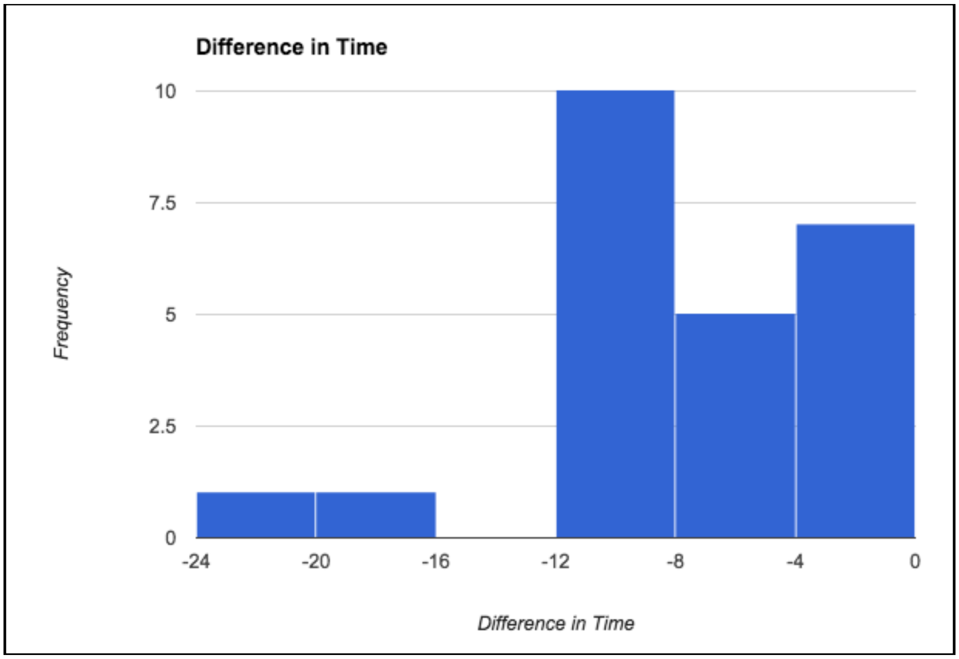
	A	B	C
1	Congruent	Incongruent	Difference
2	8.63	15.687	-7.057
3	8.987	17.394	-8.407
4	9.401	20.762	-11.361
5	9.564	21.214	-11.65
6	10.639	20.429	-9.79
7	11.344	17.425	-6.081
8	12.079	19.278	-7.199
9	12.13	22.158	-10.028
10	12.238	20.878	-8.64
11	12.369	34.288	-21.919
12	12.944	23.894	-10.95
13	14.233	17.96	-3.727
14	14.48	26.282	-11.802
15	14.669	22.803	-8.134
16	14.692	24.572	-9.88
17	15.073	17.51	-2.437
18	15.298	18.644	-3.346
19	16.004	21.157	-5.153
20	16.791	18.741	-1.95
21	16.929	20.33	-3.401
22	18.2	35.255	-17.055
23	18.495	25.139	-6.644
24	19.71	22.058	-2.348
25	22.328	24.524	-2.196

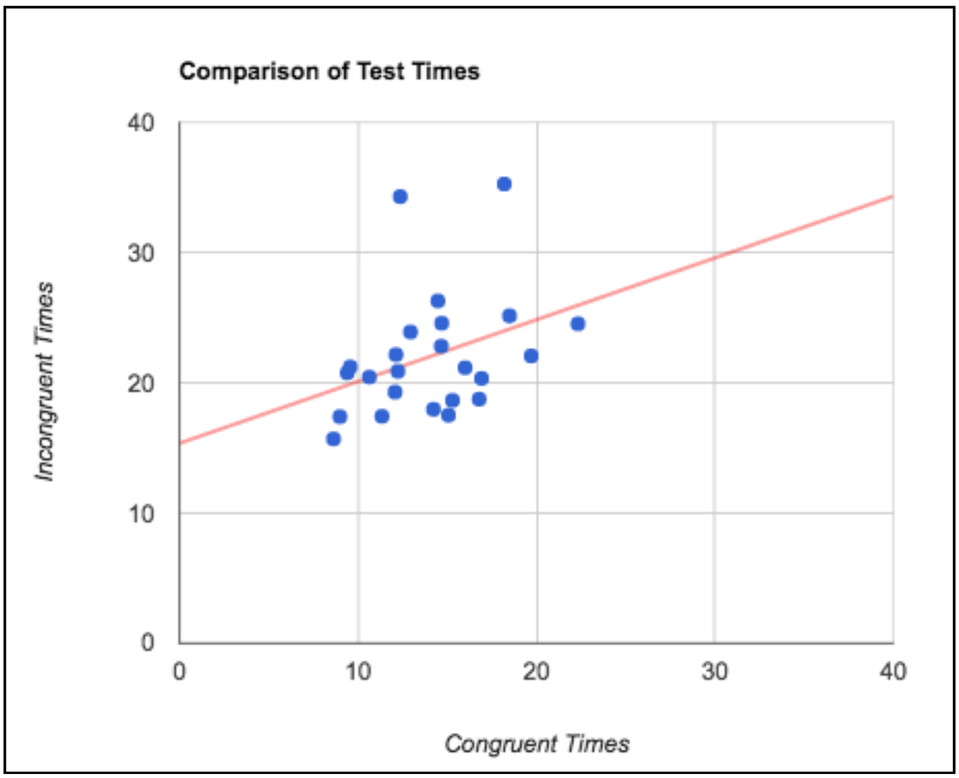


Congruent Words:
Wc_{Mean}: 14.05 seconds.
Wc_{SD}, with 23 degrees of freedom: 3.56 seconds.



Incongruent Words:
Wi_{Mean}: 22.02 seconds.
Wi_{SD}, with 23 degrees of freedom: 4.80 seconds.





Difference in Reading Times:
DIF_{Mean}: -7.96 seconds.
DIF_{SD} ,with 23 degrees of freedom: 4.86 seconds.

From these plots, it appears that applicants typical read the congruent words about 8 seconds faster than they read the incongruent words. The difference in the fastest and slowest times also varies a great deal:

	Congruent	Incongruent	Difference
Fastest	8.63	15.687	-7.057 seconds, 55.01%
Slowest	22.328	35.255	-12.927 seconds, 63.33%

Now let's calculate the t-statistic to show how great the difference is:

$t = DIF_{Mean} / (DIF_{SD} / sqrt(n))$
$t = -7.96 / (4.86 / sqrt(24))$
$t = -8.02$

Compare this to the t-critical value to see if the results are statistically significant:

One-tail, $\alpha = 0.05$, $df = 23$
t-critical = -1.714

Table B *t* distribution critical values

	Tail probability *p*											
df	.25	.20	.15	.10	.05	.025	.02	.01	.005	.0025	.001	.0005
1	1.000	1.376	1.963	3.078	6.314	12.71	15.89	31.82	63.66	127.3	318.3	636.6
2	.816	1.061	1.386	1.886	2.920	4.303	4.849	6.965	9.925	14.09	22.33	31.60
3	.765	.978	1.250	1.638	2.353	3.182	3.482	4.541	5.841	7.453	10.21	12.92
4	.741	.941	1.190	1.533	2.132	2.776	2.999	3.747	4.604	5.598	7.173	8.610
5	.727	.920	1.156	1.476	2.015	2.571	2.757	3.365	4.032	4.773	5.893	6.869
6	.718	.906	1.134	1.440	1.943	2.447	2.612	3.143	3.707	4.317	5.208	5.959
7	.711	.896	1.119	1.415	1.895	2.365	2.517	2.998	3.499	4.029	4.785	5.408
8	.706	.889	1.108	1.397	1.860	2.306	2.449	2.896	3.355	3.833	4.501	5.041
9	.703	.883	1.100	1.383	1.833	2.262	2.398	2.821	3.250	3.690	4.297	4.781
10	.700	.879	1.093	1.372	1.812	2.228	2.359	2.764	3.169	3.581	4.144	4.587
11	.697	.876	1.088	1.363	1.796	2.201	2.328	2.718	3.106	3.497	4.025	4.437
12	.695	.873	1.083	1.356	1.782	2.179	2.303	2.681	3.055	3.428	3.930	4.318
13	.694	.870	1.079	1.350	1.771	2.160	2.282	2.650	3.012	3.372	3.852	4.221
14	.692	.868	1.076	1.345	1.761	2.145	2.264	2.624	2.977	3.326	3.787	4.140
15	.691	.866	1.074	1.341	1.753	2.131	2.249	2.602	2.947	3.286	3.733	4.073
16	.690	.865	1.071	1.337	1.746	2.120	2.235	2.583	2.921	3.252	3.686	4.015
17	.689	.863	1.069	1.333	1.740	2.110	2.224	2.567	2.898	3.222	3.646	3.965
18	.688	.862	1.067	1.330	1.734	2.101	2.214	2.552	2.878	3.197	3.611	3.922
19	.688	.861	1.066	1.328	1.729	2.093	2.205	2.539	2.861	3.174	3.579	3.883
20	.687	.860	1.064	1.325	1.725	2.086	2.197	2.528	2.845	3.153	3.552	3.850
21	.686	.859	1.063	1.323	1.721	2.080	2.189	2.518	2.831	3.135	3.527	3.819
22	.686	.858	1.061	1.321	1.717	2.074	2.183	2.508	2.819	3.119	3.505	3.792
23	.685	.858	1.060	1.319	1.714	2.069	2.177	2.500	2.807	3.104	3.485	3.768
24	.685	.857	1.059	1.318	1.711	2.064	2.172	2.492	2.797	3.091	3.467	3.745
25	.684	.856	1.058	1.316	1.708	2.060	2.167	2.485	2.787	3.078	3.450	3.725

Therefore, we can reject H_0, because the t-statistic is less than the t-critical value, which means that there is a Stroop Effect and people read the colour of the congruent words faster than the colour of the incongruent words. $-8.02 < -1.714$

To expand on this analysis, we can calculate the effect size's measure, Cohen's d:
= DIF_{Mean} / DIF_{SD}
= -7.96 / 4.86
= -1.64

Therefore, the typical difference in the time it took a participant to read the congruent list vs the incongruent list, was 1.64 standard deviations faster, or simply put, about 8 seconds.

We can be a little more specific, by putting the difference of reading speed inside a 95% confidence interval:

CI = DIF_{Mean} ± t-critical * (DIF_{SD} / sqrt(n))
CI = -7.96 ± (-1.714) * (4.86 / sqrt(24))
CI = (-9.67, -6.26)

We can see that a similar sample will, 95% of the time, read a list of congruent words 6.26 - 9.67 seconds faster than a list of incongruent words.

Additional Notes:

I believe this effect is a result of people's natural tendency to read a word when presented before them, therefore people have to override or avoid making full-eye contact with the words, to read them as quickly as possible. For example, I looked at the bottom-left corner of the word, which helped me to only focus on the colour of the word, and not the letters.

I expect a similar effect would be created by this list of words:

RED	**GEREN**	**BULE**	**YLOELW**	**PNIK**
OGNARE	**BULE**	**GEERN**	**BULE**	**WITHE**
GEREN	**YLLOEW**	**OGARNE**	**BULE**	**WHTIE**
BWRON	**RED**	**BULE**	**YOELLW**	**GEREN**
PNIK	**YLELOW**	**GEERN**	**BULE**	**RED**

*the first and last letters are in the correct location, the middle letters are mixed up.

I'm not sure if this would have as large of an effect as the ink colour, I suppose it could be something worth testing. However, I assume that it could slow people's reading speed a little.