

PSYCH 363 - Stroop Effect: Congruency and Response Time

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1 Introduction

Previous studies in the Stroop literature have demonstrated that participants might respond differently based on if Stroop items are congruent with their displayed state and some have found evidence of congruency effects [2]. For example, words that are presented in the same colour that the word is describing (i.e. the word "Red" presented in the colour red) would be known as a congruent trial, whereas words presented in a different colour (i.e. "Red, but presented in the colour blue) would be an incongruent trial.

Rey-Mermet discusses the idea of attentional-control processes, namely, our ability to “activate goal-relevant information and to inhibit irrelevant information” [1]. Our study approaches this idea and seeks to understand if reaction time differences arise when comparing congruent to incongruent trials. A participants goal is to correctly report words that are congruent, while inhibiting the irrelevant information presented during incongruent trials and we hypothesize that ones reaction time should differ as a function of the extended cognitive process one must engage in to correctly make this rejection.

2 Methods

Participants. We utilized our 4 group members, and each completed 20 trials 5 times yielding 100 total trials per person. This gave us enough data to be confident in our results, although with such a small sample size of participants it is clear that these results will struggle to generalize to the broader population more broadly.

Materials. A program was developed for use in our experiment to randomly choose different colour words (i.e. red, blue, green, etc) and an associated colour that the words were written in. The words are presented on a plain solid grey background and participants were instructed to either press "z" or "/" on a keyboard to indicate whether the word and its associated colour were congruent (i.e. the written word

matched the colour of the word) or incongruent (i.e. the written word did not match the colour of the word). After each user response a new word would be randomly generated for them to respond to and once the participant completes 20 trials, the program closes itself, the data is exported and procedure ends. Importantly, the colour and word displayed were all randomly selected, the probability of a participant seeing a congruent trial was set at 25%.

Please see below for a copy of the Python code used in designing the program:

```
from psychopy import visual,core,clock,event
import random as r
import csv
from datetime import datetime

now=datetime.now()
date_time=now.strftime("%Y-%m-%d_%H:%M:%S")
filename="stroop"+date_time+".csv"

keyAssign=["q","z","slash"]
colourOptions=["yellow","red","blue","green"]

probCongruent=0.25

numberTrials=20
RTclock=core.Clock()

win=visual.Window(size=(600,600))

instructionText="Press 'z' for congruent words & colours and '/' when incongruent.
Press any key to start."

showInstruction=visual.TextStim(win,instructionText,color="black",height=0.1)
showInstruction.draw()
win.flip()
event.waitKeys()

for i in range(numberTrials):

    r.shuffle(colourOptions)

    if r.random()<probCongruent:
        writtenColour=colourOptions[0]
        displayColour=colourOptions[0]
        congruent=1
    else:
        writtenColour=colourOptions[0]
        displayColour=colourOptions[1]
        congruent=0

    displayText = visual.TextStim(win,writtenColour,color=displayColour,height=0.2)

    displayText.draw()
    win.flip()
    RTclock.reset()
```

```

key=event.waitKeys(keyList=keyAssign)
rt=RTclock.getTime()
if (key[0]==keyAssign[0]):
core.quit()

with open(filename,'a',newline='') as csvfile:
posnerwrite=csv.writer(csvfile,delimiter=' ')
posnerwrite.writerow([writtenColour] + [displayColour] + [congruent] + [key[0]] + [rt])

core.wait(1)
core.quit()

```

3 Results

```

## Read participant data file
dt <- read.csv("363Stroop_Data_Dec_4.csv")

```

Data structure: This produces an example excerpt from our CSV file (up to 10 trials), there are 400 total across the entire experiment. As you can see, the data is automatically arranged based on if the trial is congruent or not (1 for congruent, 0 for incongruent), the presented colour, the participants response, and their reaction time.

```

## An example of how our data is structured
head(dt, 10)

```

	Trial	Congruent	Colour	Response	Time
1	1	1	blue	z	1.0113984
2	1	0	blue	slash	0.9906640
3	1	0	red	slash	0.7729855
4	1	0	green	slash	0.7496739
5	1	0	green	slash	0.6566195
6	1	1	yellow	z	0.5783305
7	1	0	green	slash	1.0228071
8	1	0	green	slash	1.3865062
9	1	0	yellow	slash	0.7888217
10	1	0	blue	slash	0.9663929

Statistical Summary of the Data: This produces some basic descriptive statistics of our experiment. To note a few, there were 88 trials where participants hit the 'z' key (i.e. reported a congruent trial) and 312 instances where they hit the '/' key (i.e. reported an incongruent trial). The mean response time was 0.8997 seconds with the longest response taking 4.5227 seconds and the quickest response taking 0.2039 seconds.

```

summary(dt)

```

	Trial	Congruent	Colour	Response	Time
Min.	: 1.00	Min. :0.0000	blue :110	slash:312	Min. :0.2039
1st Qu.:	5.75	1st Qu.:0.0000	green : 82	z : 88	1st Qu.:0.6608
Median	:10.50	Median :0.0000	red :102		Median :0.7536

Mean	:10.50	Mean	:0.2175	yellow:106	Mean	:0.8997
3rd Qu.	:15.25	3rd Qu.	:0.0000		3rd Qu.	:0.9482
Max.	:20.00	Max.	:1.0000		Max.	:4.5227

Number of rows/trials: This displays the total number of rows in our data file, equivalent to the total number of trials within our experiment.

```
nrow(dt)

[1] 400
```

Linear Regression Model: We completed many different statistical analyses on our data, the first being a linear regression. Our results show that <1% of the total variation in participant response times can be explained by our independent variable, congruency.

```
lmresults <- lm( Time ~ Congruent, data = dt)
summary(lmresults)
```

```
Call:
lm(formula = Time ~ Congruent, data = dt)
```

```
Residuals:
    Min       1Q   Median       3Q      Max
-0.7115 -0.2423 -0.1421  0.0377  3.6073
```

```
Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)  0.91539     0.02736  33.456  <2e-16 ***
Congruent    -0.07234     0.05867  -1.233    0.218
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
Residual standard error: 0.4841 on 398 degrees of freedom
Multiple R-squared:  0.003806, Adjusted R-squared:  0.001303
F-statistic:  1.52 on 1 and 398 DF,  p-value: 0.2183
```

Specialised T-test: The second test we ran was a Welch Two Sample T-test and as we can see from our results that there is not enough evidence to suggest that reaction times are significantly different when presented congruent trials than when presented incongruent trials and we must retain the null hypothesis, $t(241) = 1.646$, $p > .05$.

```
t.test(Time ~ Congruent, mu=0, alt="two.sided", conf=0.95, var.eq=F, paired=F, data = dt)
```

Welch Two Sample t-test

```
data: Time by Congruent
t = 1.6466, df = 241.61, p-value = 0.1009
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -0.01420303  0.15888674
sample estimates:
mean in group 0 mean in group 1
    0.9153860      0.8430441
```

One-Way ANOVA: The third test we ran was a One-Way Analysis of Variance and like the other tests our results do not provide sufficient evidence that reaction times differ significantly under different levels of congruency, $F(1, 398) = 1.52$, $MSE = 0.35$, $p > .05$.

```
anova(lmresults)
```

Analysis of Variance Table

Response: Time

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Congruent	1	0.356	0.35627	1.5205	0.2183
Residuals	398	93.258	0.23432		

More Linear Regression: We decided to further explore the explanatory power between the other variables as well... this really isn't relevant, delete? explanatory power of trial #, response, and colour value? Marked for removal.

```
lmresults2 <- lm( Time ~ Congruent + Trial + Colour + Response, data = dt)
summary(lmresults2)
```

Call:

```
lm(formula = Time ~ Congruent + Trial + Colour + Response, data = dt)
```

Residuals:

	Min	1Q	Median	3Q	Max
	-0.5683	-0.2452	-0.1264	0.0476	3.5778

Coefficients:

	Estimate	Std. Error	t value	Pr(> t)
(Intercept)	0.985707	0.067434	14.617	<2e-16 ***
Congruent	0.727180	0.488648	1.488	0.138
Trial	-0.006801	0.004213	-1.614	0.107
Colourgreen	0.065221	0.070966	0.919	0.359
Colourred	-0.045419	0.066993	-0.678	0.498
Colouryellow	0.004813	0.065793	0.073	0.942
Responsez	-0.799422	0.486281	-1.644	0.101

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.4829 on 393 degrees of freedom

Multiple R-squared: 0.02085, Adjusted R-squared: 0.005901

F-statistic: 1.395 on 6 and 393 DF, p-value: 0.2154

One-Way ANOVA (again? what is this for?): ^^^ see more linear regression comment, same thing but an anova. Marked for removal, not relevant.

```
anova(lmresults2)
```

Analysis of Variance Table

Response: Time

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
--	----	--------	---------	---------	--------

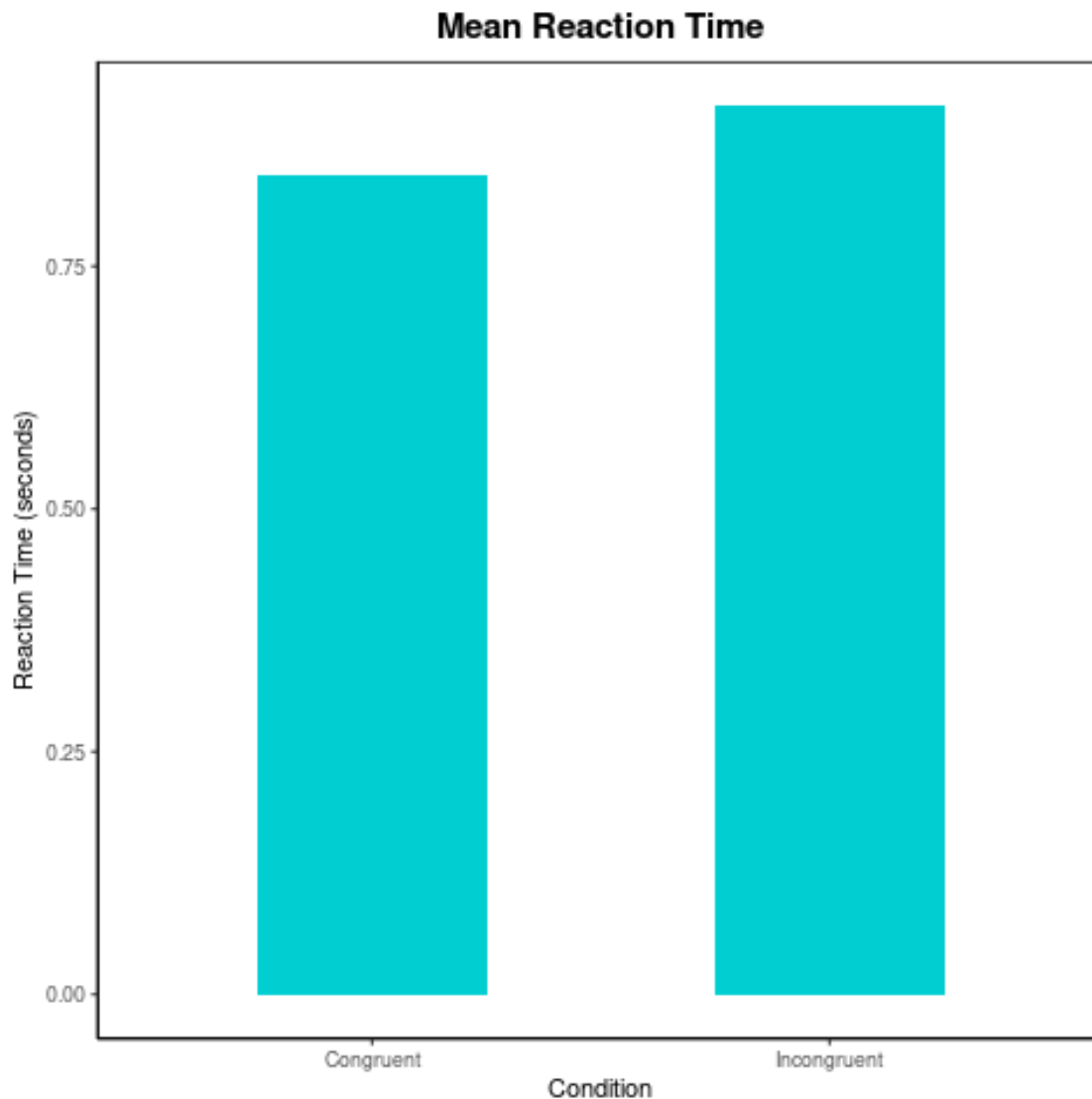
Congruent	1	0.356	0.35627	1.5275	0.2172
Trial	1	0.505	0.50535	2.1667	0.1418
Colour	3	0.460	0.15330	0.6573	0.5788
Response	1	0.630	0.63034	2.7026	0.1010
Residuals	393	91.662	0.23324		

3.1 Plots

3.1.1 Mean Reaction Time: Congruent vs Incongruent Trials

```
p <- ggplot(overall, aes(x = cond, y = rt)) + geom_bar(fill = "darkturquoise", stat = "identity",
width = 0.5) + labs(title = "Mean Reaction Time", x = "Condition",
y = "Reaction Time (seconds)") + theme_classic() +
theme(plot.title = element_text(hjust = 0.5, size = 15, face = "bold"),
panel.background = element_blank(), panel.grid = element_blank(),
panel.border = element_rect(colour = "black", fill = NA, size = 0.75))
```

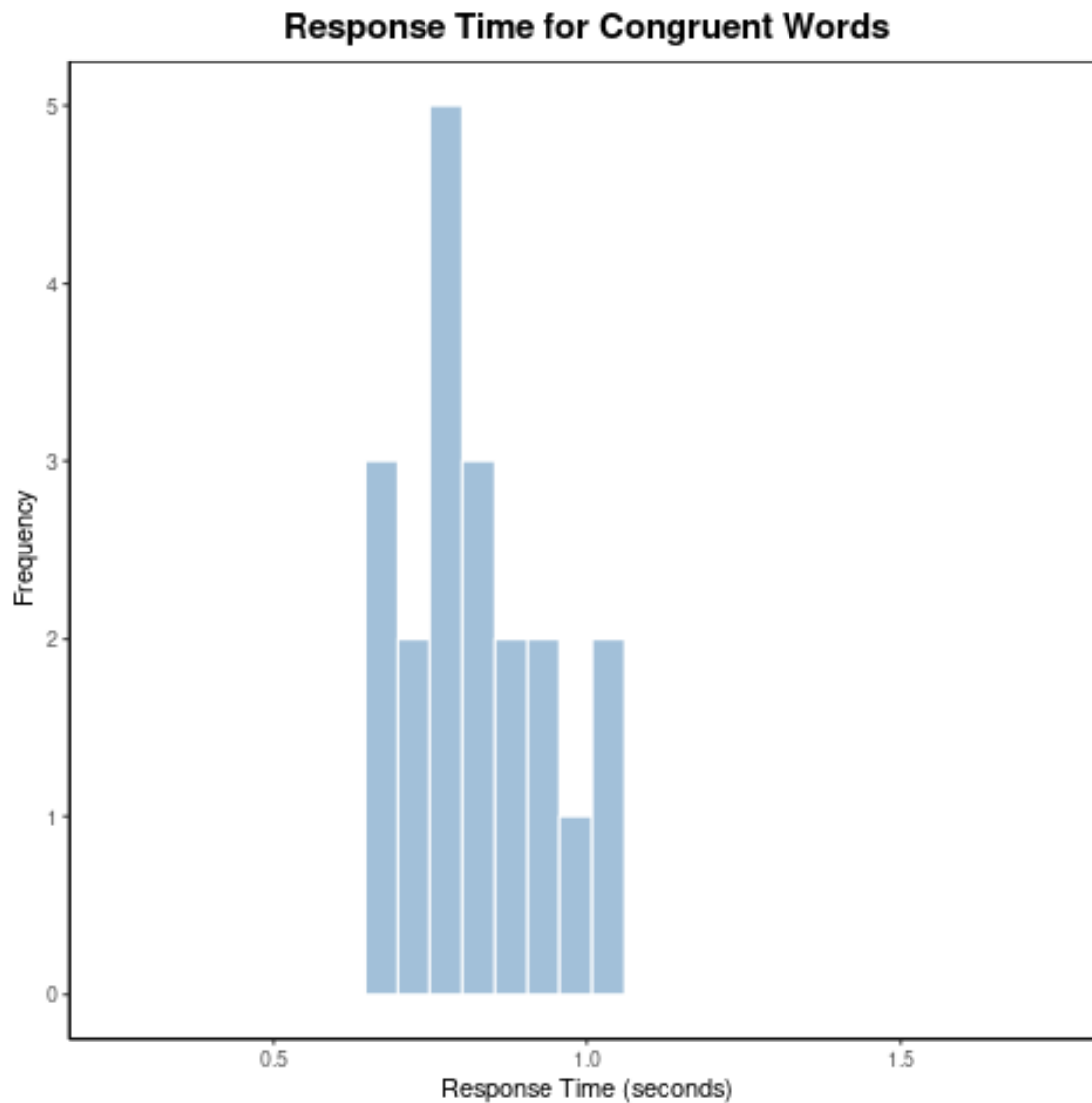
p



3.1.2 RT Values for Congruent Trials

```
RT_congruent <- ggplot(df, aes(x = Congruent)) + geom_histogram(alpha = 0.5, fill = "steelblue",  
color = "white") + labs(title = "Response Time for Congruent Words", x = "Response Time (seconds)",  
y = "Frequency") + theme_classic() + theme(plot.title = element_text(hjust = 0.5, size = 15,  
face = "bold"), panel.background = element_blank(), panel.grid = element_blank(),  
panel.border = element_rect(colour = "black",  
fill = NA, size = 0.75)) + xlim(0.25, 1.75) + ylim(0, 5)
```

RT_congruent

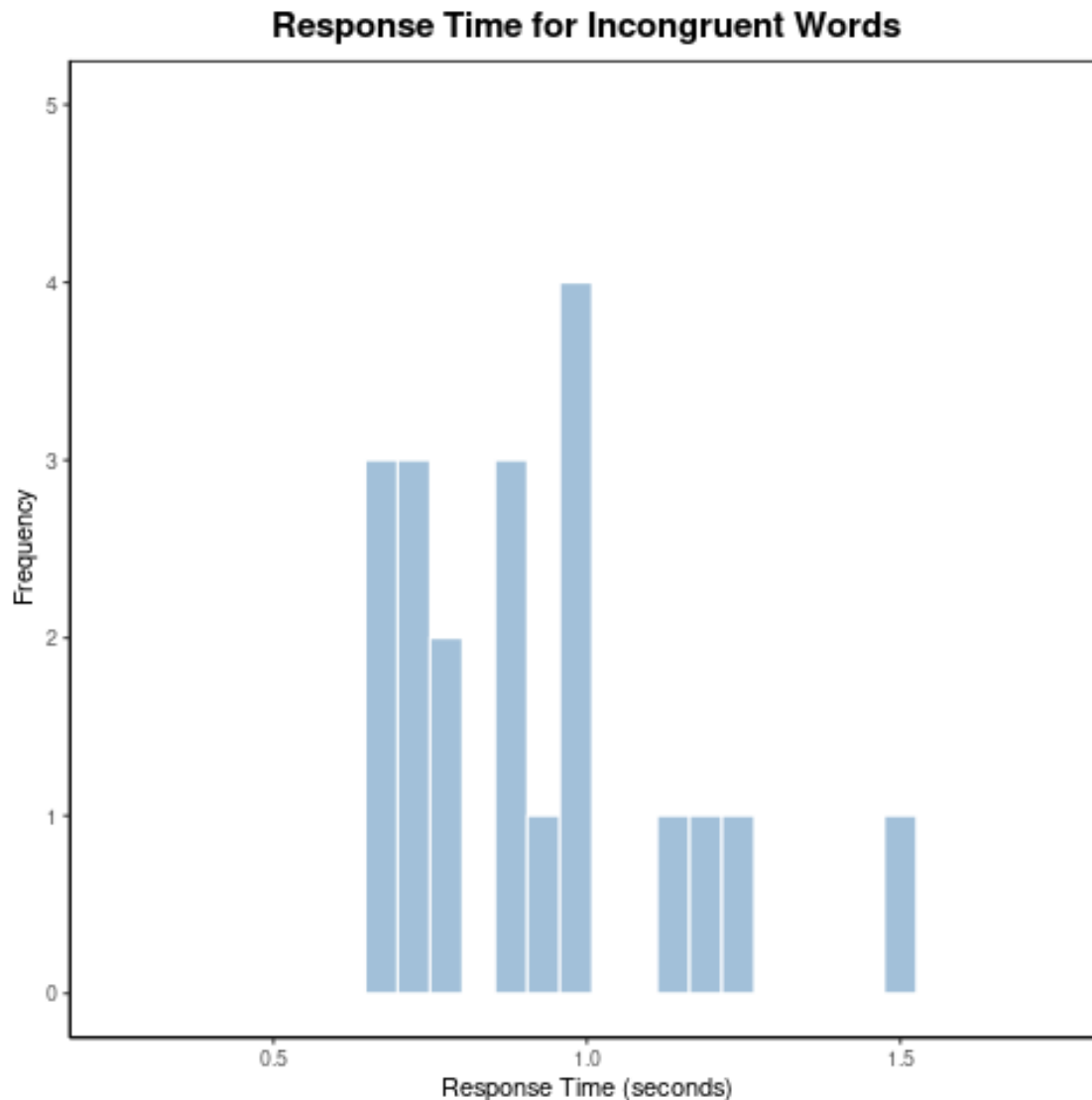


3.1.3 RT Values for Incongruent Trials

```
RT_incongruent <- ggplot(df, aes(x = Incongruent)) + geom_histogram(alpha = 0.5, fill = "steelblue",  
color = "white") + labs(title = "Response Time for Incongruent Words", x = "Response Time (seconds)",  
y = "Frequency") + theme_classic() + theme(plot.title = element_text(hjust = 0.5, size = 15,
```

```
face = "bold"), panel.background = element_blank(), panel.grid = element_blank(),
panel.border = element_rect(colour = "black",
fill = NA, size = 0.75)) + xlim(0.25, 1.75) + ylim(0, 5)
```

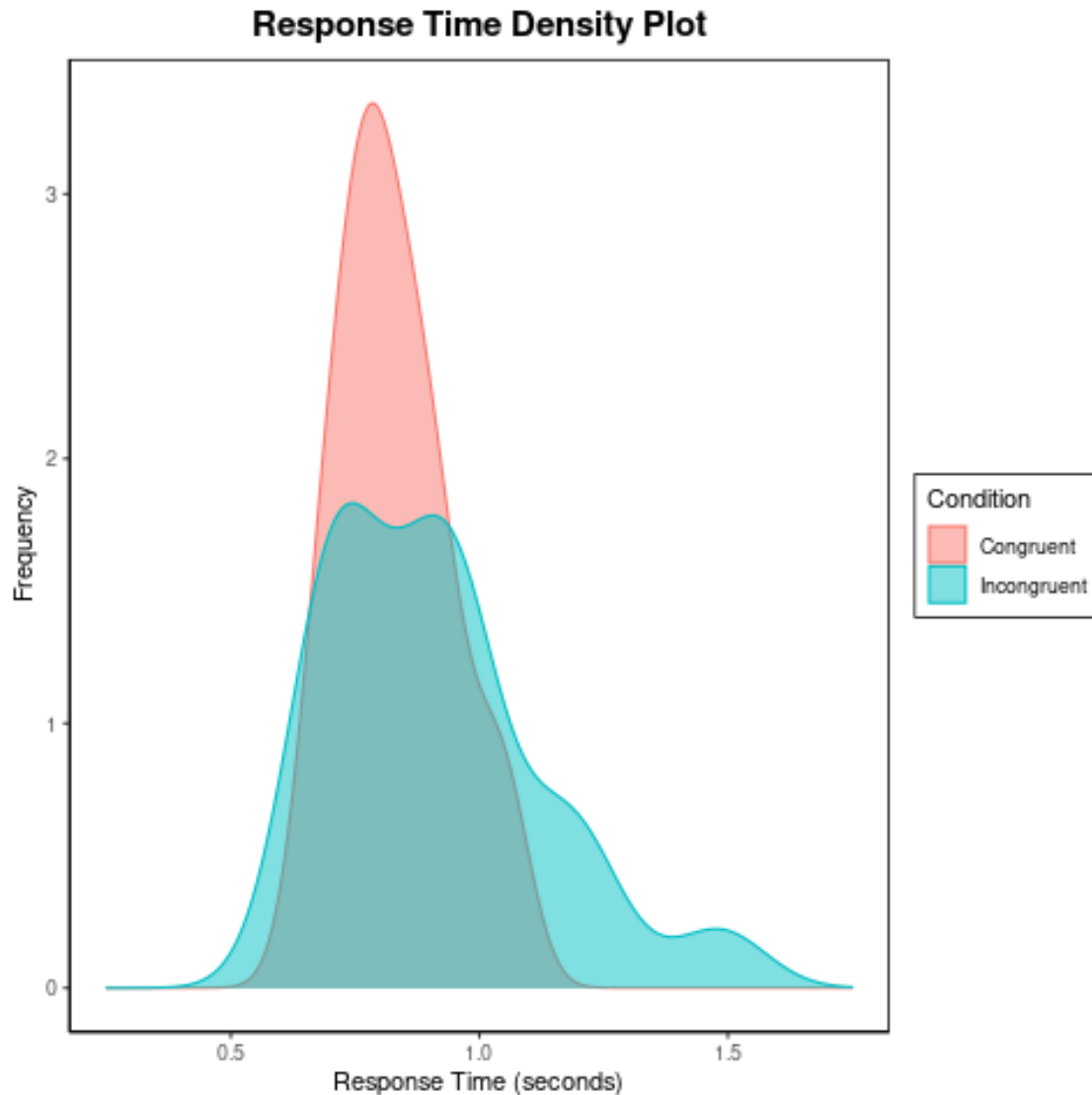
RT_incongruent



3.1.4 Response Time Density Plot

```
density_plot <- ggplot(cond_rt_df, aes(x = RT, color = Condition, fill = Condition)) +
geom_density(alpha = 0.5) + labs(title = "Response Time Density Plot", x = "Response Time (seconds)",
y = "Frequency") + theme_classic() + theme(plot.title = element_text(hjust = 0.5, size = 15,
face = "bold"), legend.position = "right", legend.background = element_blank(),
legend.box.background = element_rect(colour = "black"), panel.background = element_blank(),
panel.grid = element_blank(), panel.border = element_rect(colour = "black",
fill = NA, size = 0.75)) + xlim(0.25, 1.75)
```


density_plot



4 Discussion

Our study originally hypothesized that there should be a difference in participant reaction time due to the increased cognitive effort one must expend to inhibit irrelevant information (i.e. in this case, incongruent trials) when compared to trials where they presumably would have to expend less effort (i.e. during congruent trials). We believed therefore that incongruent trials should lead to participants taking longer to complete and congruent trials should be relatively quicker due to one not having to bypass the barrier of the required extra processing to make a correct rejection on false targets (i.e. incongruent trials). Spinelli and Lupker found in a 2020 study a significant result indicating faster response times for congruent trials than incongruent trials [3]. Our study finds quite the opposite and we believe this opens up the body of research for continued study and investigation. However, there are some glaringly clear limitations to our study and earlier attempts at these studies as we have seen from Spinelli and the like should not be discarded. Firstly, our study had an extremely small sample size of only 4 participants, all of which had a hand in deciding the study and this could negatively bias our results. By proxy we had a very small set of trials, 400 is acceptable with 100 per

person, but given that there were again only 4 people this is a clear limitation. Lastly, our study was not conducted in a controlled lab setting and this could skew our results as a consequence.

References

- [1] Alodie Rey-Mermet. Finding an interaction between stroop congruency and flanker congruency requires a large congruency effect: A within-trial combination of conflict tasks. *Attention, perception psychophysics*, 82(5):2271–2301, 2020.
- [2] Giacomo Spinelli, Kesheni Krishna, Jason R Perry, and Stephen J Lupker. Working memory load dissociates contingency learning and item-specific proportion-congruent effects. *Journal of experimental psychology. Learning, memory, and cognition*, 46(11):2007–2033, 2020.
- [3] Giacomo Spinelli and Stephen J Lupker. Item-specific control of attention in the stroop task: Contingency learning is not the whole story in the item-specific proportion-congruent effect. *Memory cognition*, 48(3):426–435, 2020.