STAT 158
ANALYSIS OF WEAPON PURCHASING BEHAVIOR
FINAL REPORT

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1 Introduction

Weapon possession has always been a controversial topic in recent years, whereas the decision-making involved in purchasing a lethal weapon is largely driven by a number of socioeconomic factors and personal interest. We are genuinely curious about how much people value about weapons. To find out, we designed an experiment in which we created a hypothetical situation that incorporates budget, job safety, and neighborhood safety as conditions under which subjects will make their purchase. After we designed the experiment and carried out the experiment on our Stat 158 classmates, we found out that people's decision to purchase weapons are more correlated with neighborhood safety than with budget or job safety.

2 Methodology

2.1 Detailed experiment

Our team's project is to run a completely random design CR[3] experiment in which we evaluate the effect of job description, neighborhood location, and budget on weapon purchasing behavior. We used a completely random design CR[3] experiment because it does not make sense to ask any subject to do all 12 combinations of the treatment conditions. Not only will the result be biased (subject will learn through the changing in descriptions and make guess of what we want to study), but also the time is not feasible. Hence, a complete block experiment is not possible here in our situation. A Latin square is not applicable since our experiment have 2*2*3 treatment design. Having unequal numbers of treatment will prevent us from designing a Latin square. Additionally, all conditions are fully crossed and all conditions are only nested within the benchmark (not other factors), so a CR design is reasonable.

Next, to reach the minimum power of 0.75, our power analysis showed that we need a minimum of 5 people in each of our treatment group. Since we have a balanced design, our total population required is 60.

The subjects are told that they will relocate to a large city for a long-term job assignment where the condition of the living place varies. Each participant is given a relocation reimbursement, a description of their housing location, and a description of their job duties. Then they are given 5 categories of spending and asked to allocate their money across the categories. There are 3 experimental factors in this experiment. We will record the gender of each subject at the end of the experiment as a potential interesting factor that we might find useful later in the analysis but we will not treat it as an observational factor. The response is the proportion of money each subject allocated to the weapon/self-defense category. Because we have different budget levels and it doesn't make sense to directly compare the raw amounts.

Budget: The amount of money is one of the main factors that affect people's financial decision making. By putting the restraint on how much money you have, we will see how people value the importance of weapons differently.

Conditions of housing location: The perception of neighborhood safeness may also impact people's desire to purchase a weapon. For instance, walking in the street of Oakland might be considered as "more dangerous" than in Mountain View. We expect higher crime rate in the destination will lead to higher allocation in weapons.

Job title and responsibility: We suspect that if one's job requires engaging in daily dangerous activities, then they will spend more money on self-defense weapon.

Condition 1: Job Description

Level 1: A news reporter which requires frequent interaction with local celebrities and business stakeholders.
Level 2: A criminal investigator which requires you to interact with high-risk population in the city.

Condition 2: Housing Location

Level 1: a dangerous neighborhood with a very high crime rate.
Level 2: a well-developed and secured neighborhood with a low crime rate.

Condition 3: Allocation Budget

Level 1: $800
Level 2: $1200
Level 3: $1600

As for the randomization procedure, we completed the process as follows: first of all, we used R to generated a sequence of random numbers representing the order of 12 treatments in our experiment, with each treatment replicating exactly five times. Then, we printed out 12 survey, each with five copies (so 60 surveys in total), and distributed them on a table. Next, we used the sequence of number generated from R to collect the survey on the table so that we would have our survey randomized in that order. During the experiment, people received the survey in the order that they come because we cannot control the order our subjects come by.

2.2 Potential Error

The main limitation in this experiment is that this is a completely hypothetical situation. The selections participants made on the paper might not truly reflect the choices participants will make in a real-life situation. Even though the scenarios are relatively close to real life experience, for many people, this might still be a bit hard to image or treat seriously. Another limitation is that Stat 158 students comes from diverse cultural and regional backgrounds with different attitude and assumptions toward weapon ownership. For example, around 3 participants asked us if they are allowed to owned guns legally.

We observed of 3 potential errors/complications during the execution of the experiment that will further influence the results. First, we noticed that some participants attempted to guess the true intention of the experiment by either asking the experimenters before they start the survey or while some other participants are filling out the survey. We also observed that there are at least two people who intentionally put 0 on the weapon category. We noticed this because they specifically tell us that they put down 0 for the weapon category. Secondly, during the morning session, we observed that people who are taking the surveys together will look at each others' surveys and compare their conditions and tried inferred the "true" purpose of this experiment. Thirdly, we also overheard participants who finished the survey telling the next participant who haven't started about the content of the survey.

2.3 Data Collection

Table 1: Data collection

Budgets	Job	Neighborhood	Medication	Cloth	Enter	Weapon	goods	Sex
1600	Dangerous	Dangerous	100	300	100	900	200	m
1200	Safe	Dangerous	150	500	300	50	200	f
800	Dangerous	Safe	100	250	250	100	100	f
800	Safe	Safe	10	300	400	0	90	m
1200	Dangerous	Safe	50	600	250	0	300	m
1600	Safe	Safe	100	200	300	100	700	f
1200	Safe	Dangerous	100	300	300	400	100	f
1600	Dangerous	Safe	200	500	200	500	200	f
1600	Dangerous	Dangerous	20	300	780	400	100	m
1600	Safe	Safe	20	500	60	20	1000	m
1200	Safe	Dangerous	150	450	200	100	300	m
1600	Dangerous	Safe	300	250	450	200	400	f
1600	Dangerous	Safe	200	700	600	0	100	m
1600	Safe	Safe	100	800	500	0	200	m
800	Safe	Dangerous	50	200	150	200	200	m
1600	Dangerous	Safe	100	200	600	0	700	f
1200	Dangerous	Dangerous	420	400	300	0	80	m
800	Safe	Safe	200	200	100	100	200	f
800	Safe	Dangerous	100	200	200	200	100	m
1200	Dangerous	Safe	300	200	50	600	50	m
1200	Dangerous	Safe	100	380	200	200	350	f
800	Safe	Dangerous	100	200	100	200	200	f
1600	Safe	Dangerous	300	200	400	400	300	f
1600	Safe	Safe	100	400	100	200	800	f
800	Safe	Dangerous	100	200	200	200	100	f
1200	Dangerous	Dangerous	150	300	300	150	300	f
1200	Safe	Dangerous	100	300	480	20	300	m
1200	Safe	Dangerous	100	600	200	100	200	m
800	Dangerous	Safe	50	200	50	150	350	f
1600	Dangerous	Dangerous	50	500	0	1000	50	f
800	Dangerous	Dangerous	100	400	200	0	100	f
1600	Safe	Safe	200	600	500	0	300	m
800	Safe	Safe	100	300	150	50	200	m
1200	Dangerous	Dangerous	100	500	200	200	200	f
800	Safe	Dangerous	200	300	50	100	150	f
1600	Safe	Dangerous	200	600	300	0	500	m
800	Dangerous	Dangerous	0	200	200	150	250	m
1200	Dangerous	Dangerous	200	200	200	300	300	m
1600	Dangerous	Dangerous	300	200	600	300	200	f
800	Safe	Safe	100	400	200	0	100	m
800	Dangerous	Safe	200	50	50	300	200	f
800	Dangerous	Dangerous	0	80	105	600	15	m
800	Dangerous	Dangerous	200	200	200	100	100	m
1200	Safe	Safe	250	250	250	200	250	m
1600	Safe	Dangerous	0	0	0	1600	0	m
1600	Dangerous	Safe	100	500	500	0	500	m
800	Dangerous	Dangerous	50	500	20	100	80	f
1600	Dangerous	Dangerous	400	800	200	50	150	f
800	Safe	Safe	100	100	200	0	400	f
1200	Safe	Safe	300	200	300	300	100	m
1200	Dangerous	Safe	200	200	200	400	200	f
1200	Dangerous	Safe	500	300	300	0	100	m
1200	Safe	Safe	100	200	400	200	300	m
1600	Safe	Dangerous	400	250	200	500	250	f
1600	Safe	Dangerous	200	50	50	110	200	f
1200	Safe	Safe	200	600	150	50	200	f
1200	Safe	Safe	100	400	200	100	400	f
800	Dangerous	Safe	100	200	300	200	0	m
800	Dangerous	Safe	50	150	200	300	100	m
1200	Dangerous	Dangerous	100	100	200	600	200	m

3 Results

3.1 Checking Model Assumption

Before we dig into the ANOVA table analysis, we want to check assumptions for independent error and normal distributed data. As we observe from the residual vs. fitted plot (Figure 1), there is an uneven distribution of all the dots under each treatment: the treatment "budget 1600 + dangerous neighborhood + safe job" has the most spread out distribution whereas the treatment "budget 800 + safe neighborhood + safe job" has the least spread out distribution. The uneven spread has an observable pattern: the variance of the residual increases as the fitted value increases. The spread is not constant and we observed disparity. Considering that the homoscedasticity assumption of the ANOVA model is not satisfied, we will use transformations to pre-process our data to make the constant variance assumption valid.

The first transformation we tried is the log transformation. One problem we encountered was that our data contain 13 0's in the response and to use the log transformation we need to add 1 to the proportion column as a padding. After we performed log transformation on the data, we observe that the fitted vs residual plot still look like it has non-constant variance with variance increasing as the fitted value increases. Next, we tried the 1/y transformation, with the padded data, the resulting fitted vs residual plot has variance that decrease as fitted values increase. So that didn't work as well.

Finally, we tried the Box Cox transformation. We choose this transformation because we learned from lecture that it's a power transformation method that's known to be useful for stabilizing variance and normalizing distribution. Similar to the log transformation case, we added 1 to the proportion column as padding before the transformation. The resulting fitted vs residual plot no longer contain an obvious increasing for decreasing relationship between variance and fitted value. The points look like they are randomly spread out and have relatively constant variance.

With the Box Cox transformed data, we now satisfy the homoscedasticity assumption of the ANOVA model and are ready to move on to the next step.

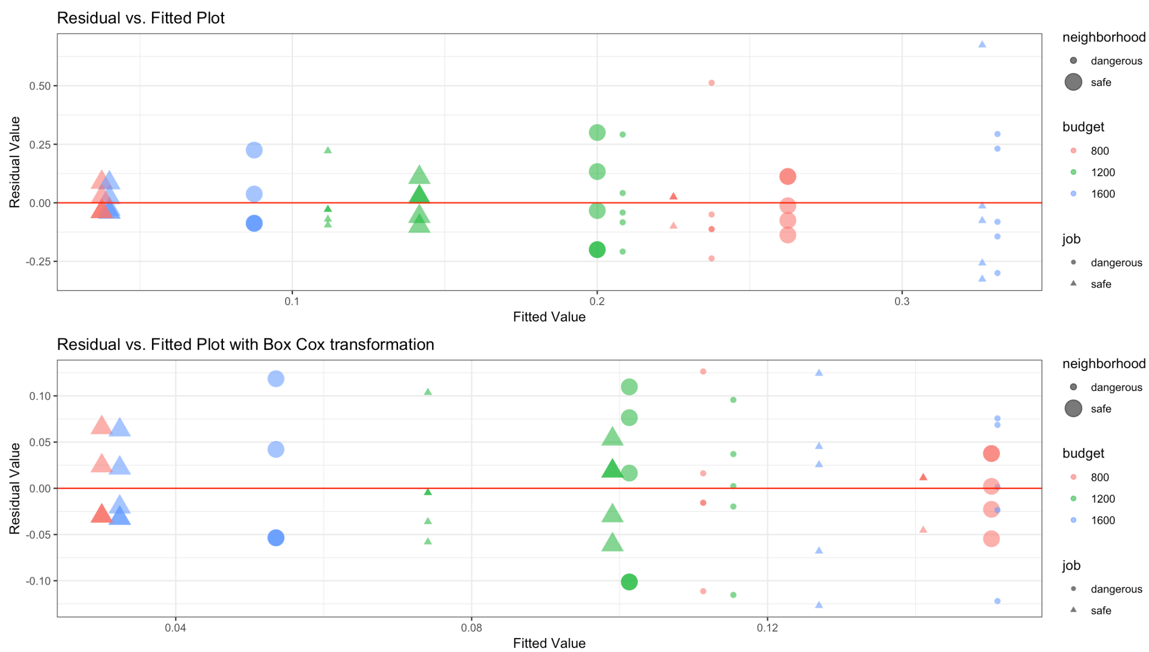

Figure 1: Fitted vs Residual Plot with Log transformation

3.2 Checking Data Normality

In addition to checking assumptions about variance, we also want to check the normality of the data itself. We plot the Q-Q plot before and after the Box Cox transformation. With the transformation, the original violation has been corrected.

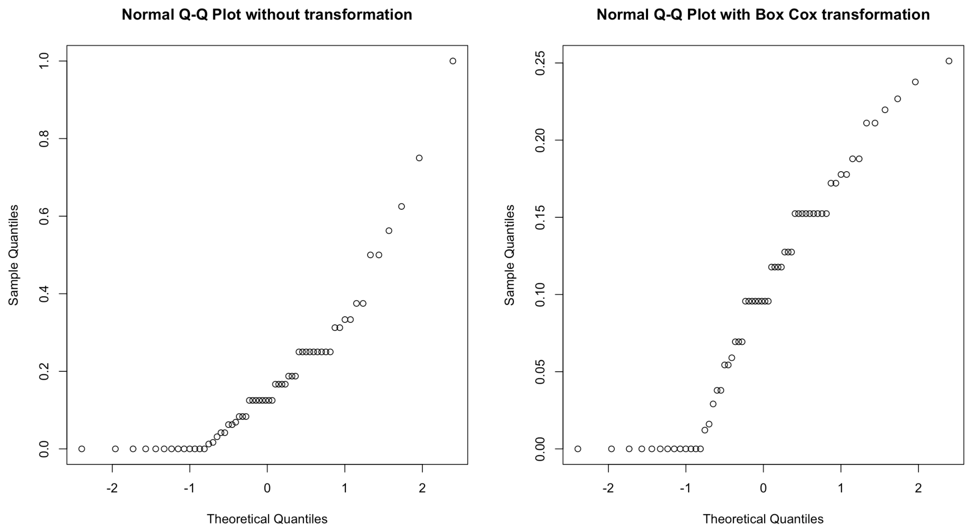

Figure 2: Q-Q Plot

3.3 Main Effect Plot (parallel dot chart)

We use the main effects plot to display the means for each group within each level of our categorical variable.

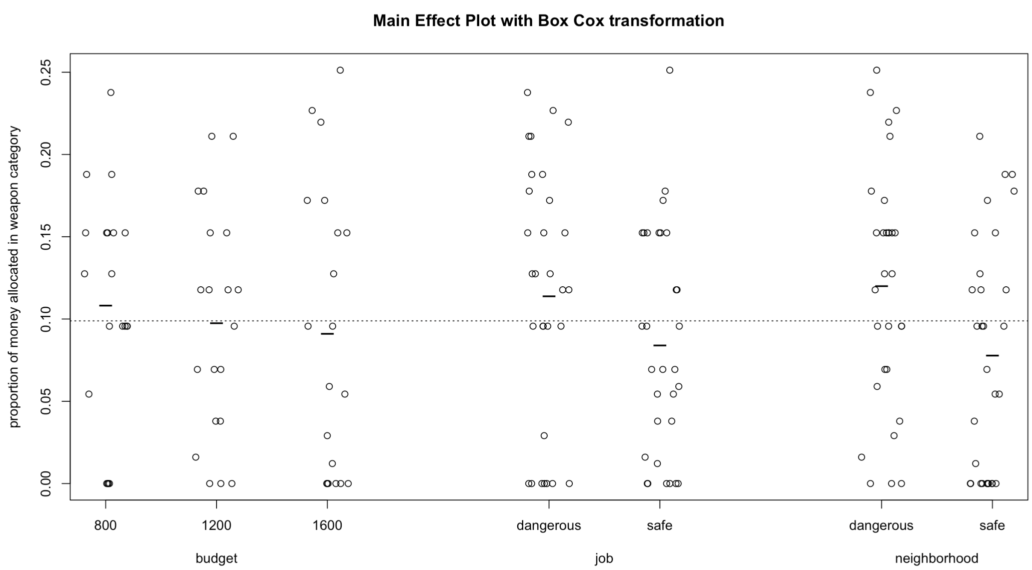

Figure 3: The Main effect plot

The main effect plot shows that the spreads of each group are relatively even and the ranges of each group are relatively equivalent. Also, the group means, represented in the plot by short black bars, are very close to the benchmark which is represented by the long dashed line, and evenly distribution on two sides of the benchmark. This suggests that the data doesn't violate the zero sum constraint between group means.

3.4 Interaction Plot

To inspect the three way interaction, we generated 4 plots (Figure 4) comparing the interaction between the job factor and the neighborhood factor for the average value and different levels of the budget factor. At a glance, we observed that the slopes of two interaction lines are generally not parallel but close to parallel across all 4 plots except for the last where the lines looks like they are parallel. This suggest of a small interaction effect between neighborhood factor and job factor. We also noticed that the slopes of both interaction lines varies, slightly, across all 4 plots, suggesting a small interaction effect between the neighborhood factor and budget factor and between job factor and budget factor. In conclusion, from the variation of the slope of the interaction lines across 4 plots and 3 factors we can assume there exist 3-way interaction between the 3 factors. Because now we know about the existence of the interaction effects, to satisfy the additive model assumption, we included the interaction terms in the ANOVA model.

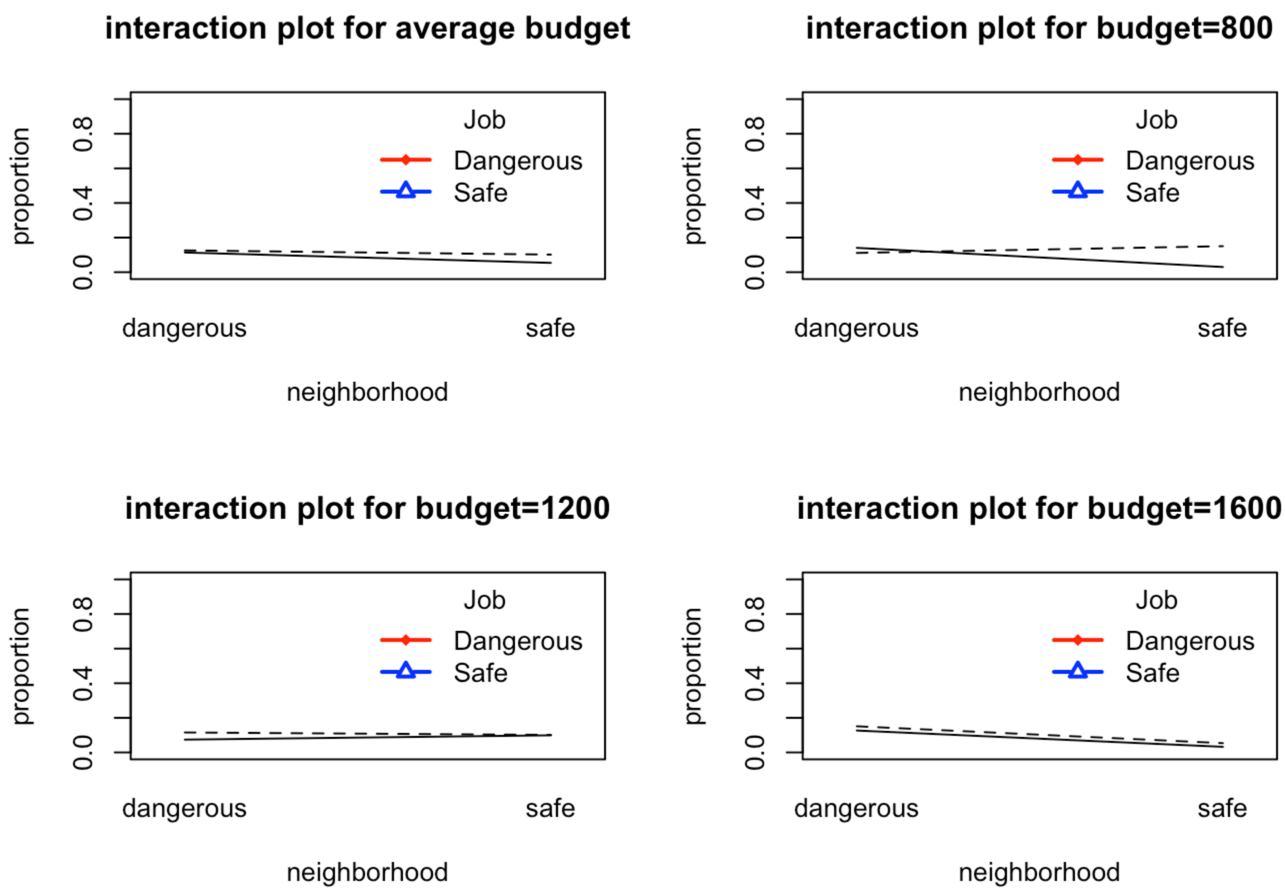

Figure 4: Three Way interaction

3.5 ANOVA table

We want to get a quantitative measure of how well the weapon purchasing behavior can be explained by the ANOVA model.

```
                        Df  Sum Sq  Mean Sq F value Pr(>F)
job                      1 0.01340 0.013397   2.816 0.0998 .
neighborhood             1 0.02672 0.026718   5.617 0.0219 *
budget                   2 0.00300 0.001501   0.315 0.7310
job:neighborhood         1 0.00486 0.004860   1.022 0.3172
job:budget               2 0.00177 0.000887   0.186 0.8305
neighborhood:budget      2 0.02602 0.013012   2.735 0.0750 .
job:neighborhood:budget  2 0.02518 0.012591   2.647 0.0812 .
Residuals               48 0.22833 0.004757
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Figure 5: Anova Table Analysis

The result of the ANOVA analysis (with the Box Cox transformed data) shows that there is only 1 significant factor under 95% significance level. That is the neighborhood factors with p value of 0.0219. This result rejects the null hypothesis that neighborhood factor has no influence and suggested that the neighborhood safety factor has a significant impact on people's decision to purchase weapon. However, under 90% significance level, we can reject an addition of 3 more factors: the job factor (p-value = 0.0998), the neighborhood and budget 2-way interaction factor (p-value = 0.0750), and the job and neighborhood and budget 3-way interaction factor (p-value = 0.0812). This shows those three addition factors also have important effect on the weapon purchasing, just not as significant as the neighborhood factor. Furthermore, out of curiosity, we performed the ANOVA analysis on the untransformed raw data and got similar result (See Appendix). The ANOVA result for the untransformed data also have the neighborhood factor as the only significant factor (with p-value 0.0308) under 95% significance level. This suggests that the data transformation we performed didn't change the outcome of the model.

3.6 Contrasts

In this section we will perform **three** hypothesis testings and account for multiple testing by using the Bonferroni correction which controls for the strong family-wise error rates. The significant level of each test will be controlled at α = 0.05/3 = 0.01667

Contrast 1: Low budget (800) vs. rest of the budget (1200 & 1600)

Contrast vector:

$$w = (1, 1, 1, 1, -\frac{1}{2}, -\frac{1}{2}, -\frac{1}{2}, -\frac{1}{2}, -\frac{1}{2}, -\frac{1}{2}, -\frac{1}{2}, -\frac{1}{2})$$

We will test H_0: w(μ) = 0 against the alternative H_1: w(μ) < 0; since we assume that subjects with low budget tend to spend less than subjects with medium or high budget.

Purpose of null hypothesis: to test whether subjects that had low budget would have the same proportion of spending in weapons than subjects that had medium or high budget. If we consider having a budget of 800 as "low" and having budget of 1200 or 1600 as "normal", this is more of a straightforward comparison between low vs normal group.

From the ANOVA table above we know that the mean square error of residual is 0.03786 and the degree of freedom is 48. The t-value is 0.1299112 and the p-value is 0.44 which is too large so we fail to reject the null hypothesis and conclude that there is no significant evidence that subjects with low budget would spend less than subjects with normal budget.

Contrast 2: Dangerous job + dangerous neighborhood vs. the rest.

Contrast vector:

$$w = (1, 1, 1, -\frac{1}{3}, -\frac{1}{3}, -\frac{1}{3}, -\frac{1}{3}, -\frac{1}{3}, -\frac{1}{3}, -\frac{1}{3}, -\frac{1}{3}, -\frac{1}{3})$$

We will test H_0: w(μ) = 0 against the alternative H_1: w(μ) > 0; since we assume that subjects with dangerous job and dangerous neighborhood treatment tend to spend more than subjects with other treatments(less dangerous)

Purpose of null hypothesis: to test whether subjects that had dangerous treatment setting would have the same proportion of spending in weapons than subjects that had less dangerous conditions.

The t-statistic is 1.76 and we calculate the p-value as 0.0423 > 0.01667. Therefore, there is no significant evidence showing that subjects with dangerous treatments would spend more purchasing weapons than those with less dangerous treatments.

Contrast 3: Safe job + safe neighborhood + Budget 800 vs. the rest

Contrast vector:

$$w = (-\frac{1}{11}, -\frac{1}{11}, -\frac{1}{11}, 1, -\frac{1}{11}, -\frac{1}{11}, -\frac{1}{11}, -\frac{1}{11}, -\frac{1}{11}, -\frac{1}{11}, -\frac{1}{11}, -\frac{1}{11})$$

We will test H_0: w(μ) = 0 against the alternative H_1: w(μ) < 0; since we assume that subjects with safe job, safe neighborhood and low budget tend to spend less than subjects with other treatments.

Purpose of null hypothesis: to test whether subjects that had relatively safer treatment conditions and lower budget would have the same in purchasing weapons than subjects that had more dangerous conditions and more money.

The t-statistic is 0.52 and the p-value is 0.3027 > 0.01667. We fail to reject the null hypothesis and there is no significant evidence showing that subjects with safe job, safe neighborhood and low budget would spend less purchasing weapons than those with dangerous treatments and medium to high budget.

4 Discussion/Conclusion

In a word, the neighborhood safety factor has the most significant effect on people's weapon purchasing behavior while job, interaction between neighborhood and budget, and the three way interaction between all factors have less significant effect.

Another noticeable result is that the budget factor has a p-value of 0.7310 which suggest that the budget factor has negligible effect on weapon purchasing behavior. This goes against our original hypothesis that higher budget will result in more money spend in weapon. Turns out, Stat 158 students' decision to purchase weapon depend more on the safeness of their neighborhood and job and much less on how much money they have.

One further thing to do with this experiment is to carry out the experiment with a more random population with larger samples. So this way we can eliminate bias in our population and increase our confidence levels. Another possible improvement will be to plan out the execution of the experiment more carefully to avoid the unwanted cases such as subjects comparing their surveys to figure out the purpose of the experiment. In the new execution, experimenters should try to isolate each participant and minimize their interaction and discussion of the survey.