

MAST30027 Modern Applied, Statistics Assignment2

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1. Introduction

1.1 Background

This report is about evaluating chimpanzee's prosocial tendency by analyzing and fitting models to the data. The experiment has two options, one is the prosocial option, when human students participate in the experiment, they nearly always choose the prosocial option when another student sits on the opposite side of the table. The question is whether a focal chimpanzee behaves similarly, choosing the prosocial option more often when another animal is present.

This report will analyse the dataset, visualize it, fit models to it and finally gives a conclusion.

1.2 Data

There are four attributes in the raw data. By looking through the dataset, it is found that there are 7 chimpanzees and every chimpanzee has the same number of instances of data (72 for each chimpanzee), therefore it does not tend to bias towards particular a chimpanzee. It should also be noted that the data is also balanced in condition and prosoc_left attribute, which means that each chimpanzee has 16 experiments on each combination of conditions and prosoc_left.

These are the 4 attributes in the raw dataset. actor (1 to 7) condition (0 or 1): prosoc left (0 or 1) pulled left (0 or 1)

```
# Load the dataset
dataset = read.delim("assign2.txt", header = TRUE, sep = " ")
```

2. Preprocessing

2.1 Create a New Attribute

Since the question is whether a focal chimpanzee choosing the prosocial option more often when another animal is present. Therefore, a new attribute "prosocial_action" is created, it means whether prosoc_left and pulled_left are same. If these two attributes are same, chimpanzee performs prosocially and prosocial_action has the value TRUE and otherwise, it has the value FALSE.

```
dataset['prosocial_action'] = (dataset$prosoc_left == dataset$pulled_left)
# print out first 10 rows in the dataset after adding new attribute prosocial_action
dataset[1:10,]
```

| ## | actor | condition | prosoc_left | pulled_left | prosocial_action |
|------|-------|-----------|-------------|-------------|------------------|
| ## 1 | 1 | 0 | 0 | 0 | TRUE |
| ## 2 | 1 | 0 | 0 | 1 | FALSE |
| ## 3 | 1 | 0 | 1 | 0 | FALSE |
| ## 4 | 1 | 0 | 0 | 0 | TRUE |

| | | | | | |
|-------|---|---|---|---|-------|
| ## 5 | 1 | 0 | 1 | 1 | TRUE |
| ## 6 | 1 | 0 | 1 | 1 | TRUE |
| ## 7 | 1 | 0 | 1 | 0 | FALSE |
| ## 8 | 1 | 0 | 1 | 0 | FALSE |
| ## 9 | 1 | 0 | 0 | 0 | TRUE |
| ## 10 | 1 | 0 | 0 | 0 | TRUE |

3. Visualization

3.1 Percentage of prosocial action and other factors

These plots shows how does the percentage of pro_social action depend on condition, actor and prosoc_left.

```
# select the prosocial_action = TRUE data only.
x = xtabs( ~ condition + prosoc_left+ actor, data = dataset[dataset$prosocial_action ==TRUE,])
x=data.frame(x)

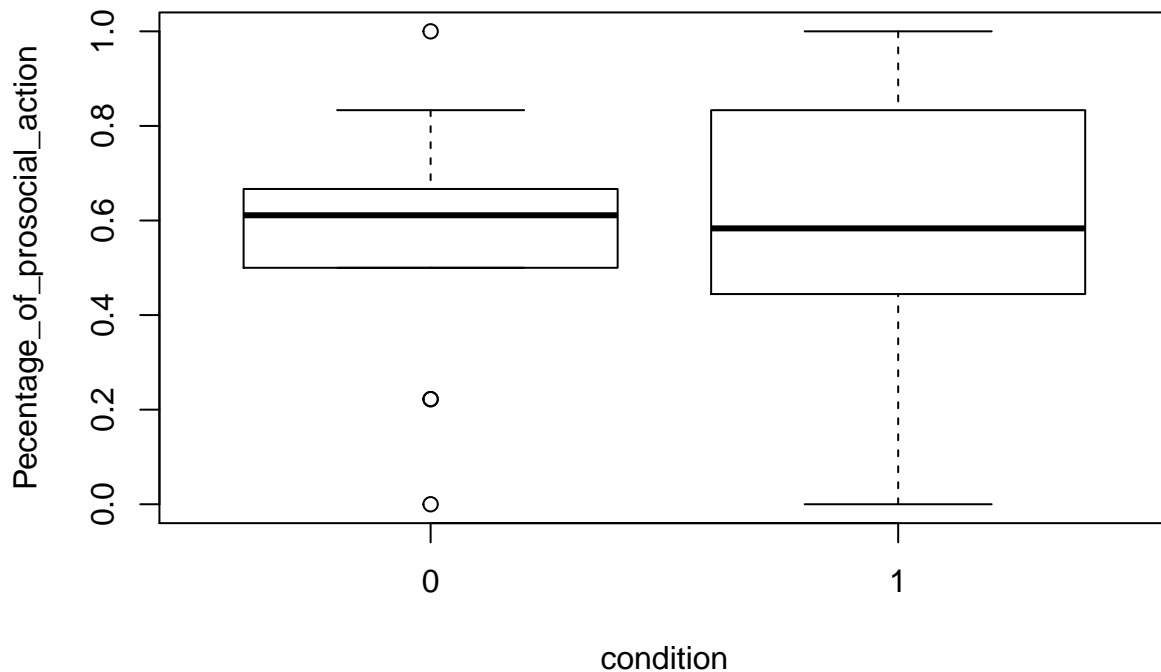
# divid the Freq(count) by total(=18) and plot
x["Percentage_of_prosocial_action"] = x$Freq/18
```

3.1.1 Percentage of prosocial action and Condition

```
#Mean of prosocial action and condition
prosocial = xtabs(prosocial_action ~ condition, data = dataset)
(prosocial_percentage = transform(prosocial, Freq=Freq/252))

##    condition      Freq
## 1          0 0.5555556
## 2          1 0.5793651

#Boxplot of prosocial action and condition
plot(Pecentage_of_prosocial_action~condition,x)
```



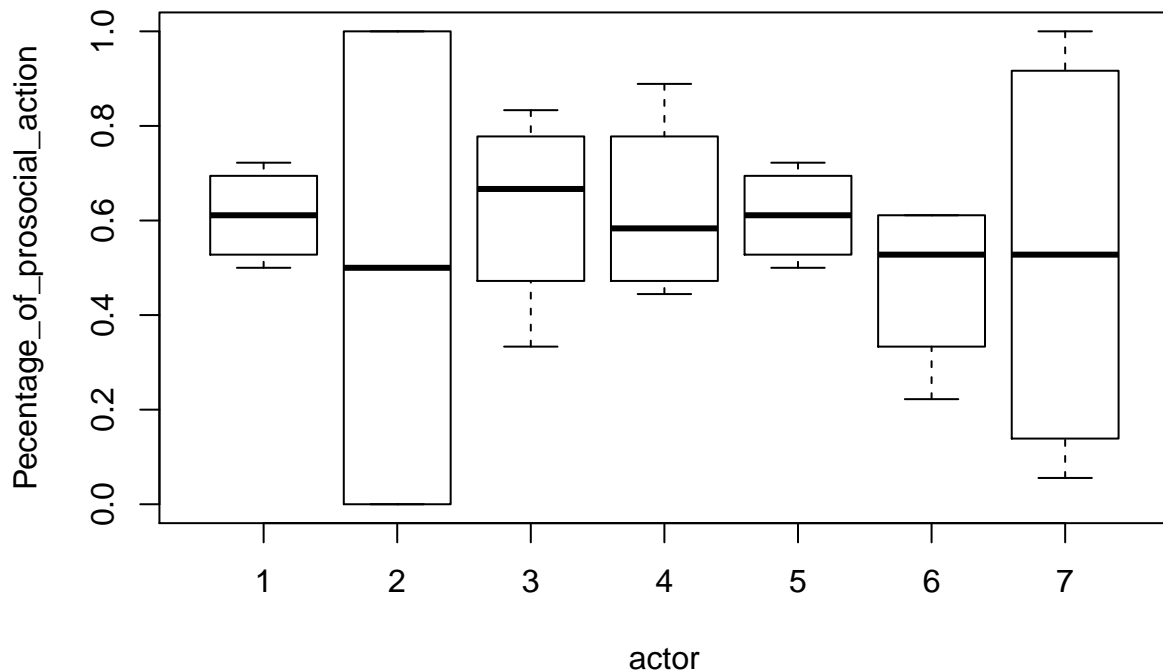
The first plot shows the relationship between condition and prosocial_action. The median decreases, and the variance increases in condition 1. In addition, the mean percentage of choose prosocial increase from 0.5555556 to 0.5793651. On average, chimpanzees choose the prosocial option slightly more frequently in condition 1 (when there is another chimpanzee in opposite). Since the mean increases and the median decrease, the relationship between them is not clear.

3.1.2 Percentage of prosocial action and Actor

```
# It can be seen form the data that the mean prosocial_action for each actor are diffenent.
prosocial = xtabs(prosocial_action ~ actor, data = dataset)
(prosocial_percentage = transform(prosocial, Freq=Freq/72))
```

```
##   actor      Freq
## 1     1 0.6111111
## 2     2 0.5000000
## 3     3 0.6250000
## 4     4 0.6250000
## 5     5 0.6111111
## 6     6 0.4722222
## 7     7 0.5277778
```

```
#Boxplot of prosocial action and condition
plot(Percentage_of_prosocial_action~actor,x)
```



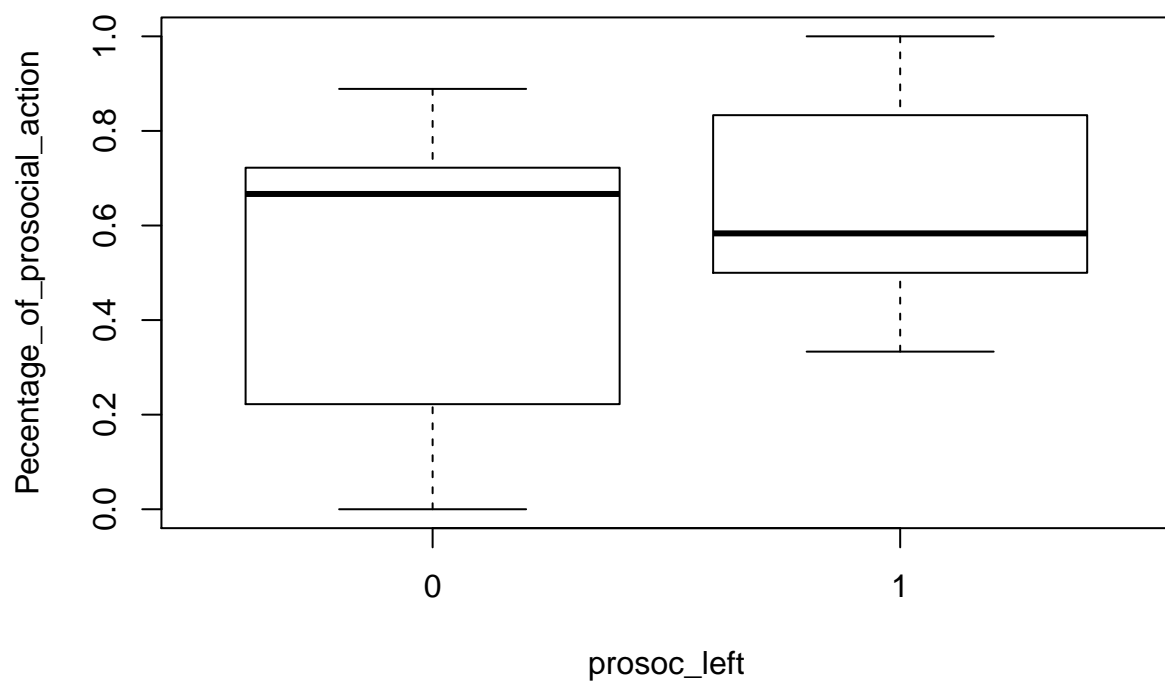
The second plot shows that each actor has different responses in the test. The prosocial_action is depended on actor. For example, the second actor has the largest variance and actor 1 and 5 have relatively higher median and low variance. The trend is meaningless in this plot because actor is not an ordinal class.

3.1.3 Percentage of prosocial action and Prosoc_left

```
prosocal = xtabs(prosocial_action ~ prosoc_left, data = dataset)
(prosocial_percentage = transform(prosocal, Freq=Freq/252))
```

```
##   prosoc_left    Freq
## 1           0 0.4880952
## 2           1 0.6468254
```

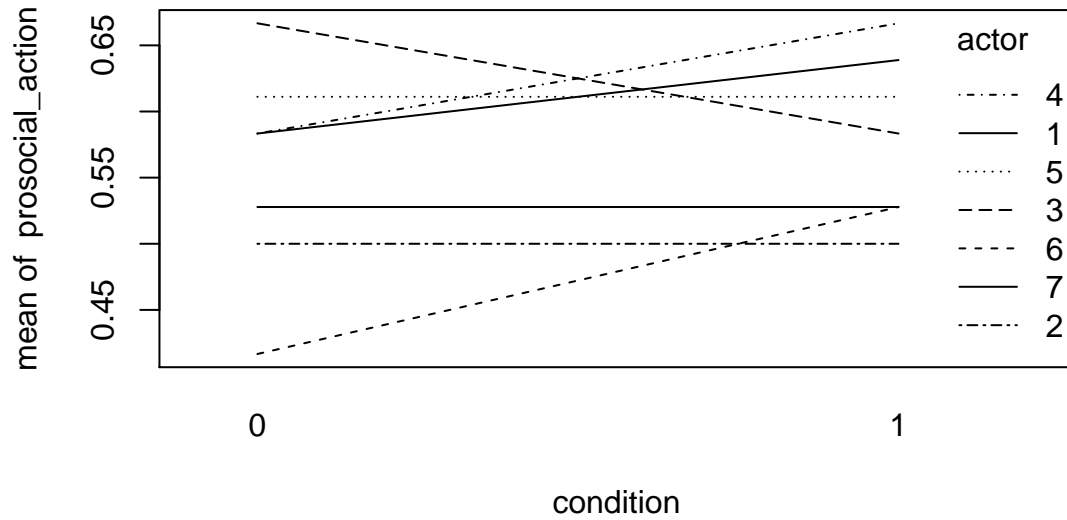
```
#Boxplot of prosocial action and prosoc_left
plot(Percentage_of_prosocial_action~prosoc_left,x)
```



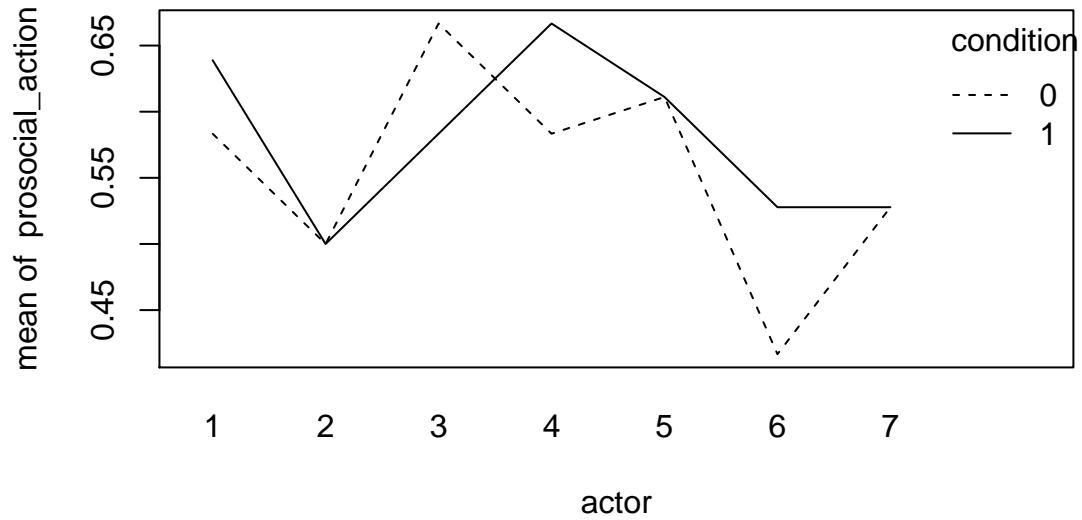
The third plot shows the relationship between `prosoc_left` and `prosocial_action`. It can be seen the left and right have different result on `prosocial_action`. When the prosocial option is at right, chimpanzees have 0.4880952 to choose it, but when it is at left, chimpanzees have 0.6468254 probability to choose it.

3.2 Interactions Between Two Factors

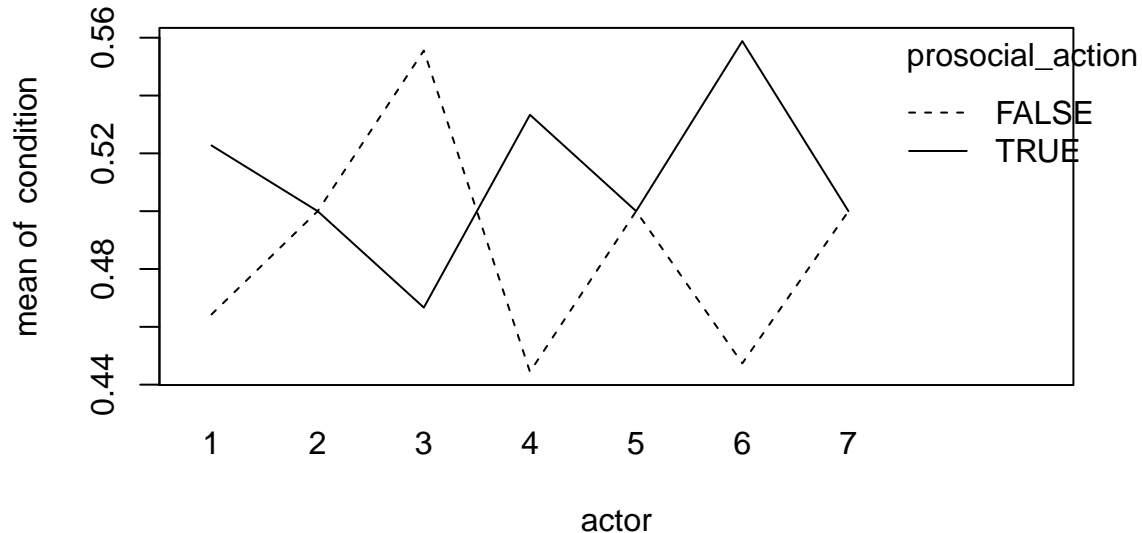
```
with(dataset, interaction.plot(condition,actor,prosocial_action))
```



```
with(dataset, interaction.plot(actor,condition,prosocial_action))
```



```
with(dataset, interaction.plot(actor, prosocial_action, condition))
```



It seems that there are some interaction between actor and prosocial_action, all actors have different mean of prosocial_action.

3.3 Outlier Detection

From the previous plots, the second chimpanzee (actor 2) shows a strange result. In both conditions, it chooses prosocial_action option at exactly 0.5 probability. By looking back to the raw dataset. It can be found that it always chooses the left one regardless of any other factors. There is no similar behavior like this among other chimpanzees thus it might be an outlier.

```
# Second chimpanzee always pulled the left lever
xtabs(~prosoc_left+pulled_left, data = dataset[dataset$actor == 2,])
```

```
##           pulled_left
## prosoc_left  1
##           0 36
##           1 36
```

```
# Other chimpanzees pulled both left and right lever
# for example chimpanzees 1
xtabs(~prosoc_left+pulled_left, data = dataset[dataset$actor == 1,])
```

```
##           pulled_left
## prosoc_left  0  1
##           0 25 11
##           1 17 19
```

This might be an error in the data collection process and might be normal behavior of chimpanzee species. Based on the data, I cannot decide which one it should be. This problem should be checked with the zoologist and experts with domain knowledge to decide whether to remove data from chimpanzee 2.

4. Contingency Table

Use contingency table to test the dependency of prosocial_action, condition. Poisson regression is used because poisson regression with log link will give chi-square distribution.

H0 = prosocial_action & condition are independent

H1 = prosocial_action & condition are not independent

```
x = xtabs( ~ condition + prosocial_action, data = dataset)
(x = data.frame(x))
```

```
##   condition prosocial_action Freq
## 1         0             FALSE  112
## 2         1             FALSE  106
## 3         0              TRUE  140
## 4         1              TRUE  146
```

The cell counts need to be at least 5 for the deviance to have chi-square distribution as described in the lecture. From the data count above, it can be seen that the minimum count is 106.

```
#fit poisson model
model0 = glm(Freq ~ condition + prosocial_action, family = poisson, data = x)
#deviance of the poisson regression model
deviance(model0)
```

```
## [1] 0.2910418
```

```
#degrees of freedom
df.residual(model0)
```

```
## [1] 1
```

```
# calculate the p-value
pchisq(deviance(model0), df = df.residual(model0), lower.tail = FALSE)
```

```
## [1] 0.5895537
```

As shown in section 3.3, actor2 might be an outlier, so we can remove it and do the contingency table again to see whether the result is different.

```
#remove outlier (Actor 2)
x = xtabs( ~ condition + prosocial_action, data = dataset[dataset$actor!=2,])
(x = data.frame(x))
```

```
##   condition prosocial_action Freq
## 1         0             FALSE   94
## 2         1             FALSE   88
## 3         0              TRUE  122
## 4         1              TRUE  128
```

```
#fit poisson model
model0 = glm(Freq ~ condition + prosocial_action, family = poisson, data = x)
#deviance of the poisson regression model
deviance(model0)
```

```
## [1] 0.3418519
```



```
#degrees of freedom  
df.residual(model0)
```

```
## [1] 1
```

```
# calculate the p-value
```

```
pchisq(deviance(model0), df = df.residual(model0), lower.tail = FALSE)
```

```
## [1] 0.5587622
```

The p-value is 0.5895537 (or 0.5587622 if remove outlier), both of them are much larger than 0.05, thus we cannot reject H_0 and prosocial_action & condition are independent. Since they are already independent, there is no need to check for confounding factors.

Our interest is whether prosocial_action is related to the condition (whether there is another chimpanzee on another side), from the result we can say that prosocial_action is independent of condition. And chimpanzee doesn't behave similarly as humans.

5. Binomial Regression

5.1 Fitting data with binomial regression

If we let the count be response variable, and all four factors (condition, prosoc_left, pulled_left, actor) as explanation variable. The count has a binomial distribution with n equals to 18 and p is the probability of choosing the prosocial_action. Since the n is only 18 and p is large, we cannot use poisson distribution to approximate the binomial distribution.

5.1.1 Fit binomial model

```
x = xtabs( ~ condition + prosoc_left + pulled_left + actor, data = dataset)
x = data.frame(x)
#set last column to n = 18
x["total"] = 18
(x = x[x$prosoc_left == x$pulled_left,])
```

| ## | condition | prosoc_left | pulled_left | actor | Freq | total |
|-------|-----------|-------------|-------------|-------|------|-------|
| ## 1 | 0 | 0 | 0 | 1 | 12 | 18 |
| ## 2 | 1 | 0 | 0 | 1 | 13 | 18 |
| ## 7 | 0 | 1 | 1 | 1 | 9 | 18 |
| ## 8 | 1 | 1 | 1 | 1 | 10 | 18 |
| ## 9 | 0 | 0 | 0 | 2 | 0 | 18 |
| ## 10 | 1 | 0 | 0 | 2 | 0 | 18 |
| ## 15 | 0 | 1 | 1 | 2 | 18 | 18 |
| ## 16 | 1 | 1 | 1 | 2 | 18 | 18 |
| ## 17 | 0 | 0 | 0 | 3 | 13 | 18 |
| ## 18 | 1 | 0 | 0 | 3 | 15 | 18 |
| ## 23 | 0 | 1 | 1 | 3 | 11 | 18 |
| ## 24 | 1 | 1 | 1 | 3 | 6 | 18 |
| ## 25 | 0 | 0 | 0 | 4 | 12 | 18 |
| ## 26 | 1 | 0 | 0 | 4 | 16 | 18 |
| ## 31 | 0 | 1 | 1 | 4 | 9 | 18 |
| ## 32 | 1 | 1 | 1 | 4 | 8 | 18 |
| ## 33 | 0 | 0 | 0 | 5 | 12 | 18 |
| ## 34 | 1 | 0 | 0 | 5 | 13 | 18 |
| ## 39 | 0 | 1 | 1 | 5 | 10 | 18 |
| ## 40 | 1 | 1 | 1 | 5 | 9 | 18 |
| ## 41 | 0 | 0 | 0 | 6 | 4 | 18 |
| ## 42 | 1 | 0 | 0 | 6 | 8 | 18 |
| ## 47 | 0 | 1 | 1 | 6 | 11 | 18 |
| ## 48 | 1 | 1 | 1 | 6 | 11 | 18 |
| ## 49 | 0 | 0 | 0 | 7 | 4 | 18 |
| ## 50 | 1 | 0 | 0 | 7 | 1 | 18 |
| ## 55 | 0 | 1 | 1 | 7 | 15 | 18 |
| ## 56 | 1 | 1 | 1 | 7 | 18 | 18 |

```
#the data have 28 rows
dim(x)
```

```
## [1] 28 6
```

```
#fit binomial regression model
```

```
fullmodel = glm(cbind(total-Freq,Freq) ~ (condition + prosoc_left +actor)^2, family = binomial, data = )
```

5.1.2 Model selction

```
#use AIC to select model
finalmodel = step(fullmodel)

## Start: AIC=127.33
## cbind(total ~ Freq, Freq) ~ (condition + prosoc_left + actor)^2
##
##           Df Deviance   AIC
## - condition:actor      6   13.193 117.30
## - condition:prosoc_left  1   13.017 127.12
## <none>                  11.231 127.33
## - prosoc_left:actor     6  173.039 277.14
##
## Step: AIC=117.3
## cbind(total ~ Freq, Freq) ~ condition + prosoc_left + actor +
##   condition:prosoc_left + prosoc_left:actor
##
##           Df Deviance   AIC
## - condition:prosoc_left  1   15.002 117.11
## <none>                  13.193 117.30
## - prosoc_left:actor     6  175.035 267.14
##
## Step: AIC=117.1
## cbind(total ~ Freq, Freq) ~ condition + prosoc_left + actor +
##   prosoc_left:actor
##
##           Df Deviance   AIC
## - condition              1   15.414 115.52
## <none>                   15.002 117.11
## - prosoc_left:actor     6  176.199 266.30
##
## Step: AIC=115.52
## cbind(total ~ Freq, Freq) ~ prosoc_left + actor + prosoc_left:actor
##
##           Df Deviance   AIC
## <none>                  15.414 115.52
## - prosoc_left:actor     6  176.502 264.61
```

The fianl model after model selection is $y \sim \text{prosoc_left} + \text{actor} + \text{prosoc_left}:\text{actor}$

```
summary(finalmodel)

##
## Call:
## glm(formula = cbind(total ~ Freq, Freq) ~ prosoc_left + actor +
##   prosoc_left:actor, family = binomial, data = x)
##
## Deviance Residuals:
##      Min       1Q   Median       3Q      Max
## -1.7699  -0.2581   0.0000   0.2538   1.1946
##
## Coefficients:
##              Estimate Std. Error z value Pr(>|z|)
## (Intercept)    -8.210e-01  3.618e-01  -2.269  0.02326 *
```

```
## prosoc_left1      7.098e-01  4.923e-01   1.442  0.14939
## actor2           2.247e+01  5.089e+03   0.004  0.99648
## actor3          -4.318e-01  5.400e-01  -0.800  0.42396
## actor4          -4.318e-01  5.400e-01  -0.800  0.42396
## actor5          -1.555e-15  5.117e-01   0.000  1.00000
## actor6           1.514e+00  5.059e-01   2.993  0.00276 **
## actor7           2.646e+00  6.026e-01   4.390  1.13e-05 ***
## prosoc_left1:actor2 -4.402e+01  7.197e+03  -0.006  0.99512
## prosoc_left1:actor3  6.542e-01  7.173e-01   0.912  0.36173
## prosoc_left1:actor4  6.542e-01  7.173e-01   0.912  0.36173
## prosoc_left1:actor5  9.103e-16  6.962e-01   0.000  1.00000
## prosoc_left1:actor6 -1.855e+00  6.959e-01  -2.666  0.00769 **
## prosoc_left1:actor7 -4.932e+00  9.156e-01  -5.387  7.16e-08 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
## Null deviance: 197.206 on 27 degrees of freedom
## Residual deviance: 15.414 on 14 degrees of freedom
## AIC: 115.52
##
## Number of Fisher Scoring iterations: 18
```

```
deviance(finalmodel)
```

```
## [1] 15.4145
```

```
df.residual(finalmodel)
```

```
## [1] 14
```

```
pchisq(deviance(finalmodel), df = df.residual(finalmodel), lower.tail = FALSE)
```

```
## [1] 0.3504197
```

```
anova(finalmodel,fullmodel,test = "Chisq")
```

```
## Analysis of Deviance Table
```

```
##
```

```
## Model 1: cbind(total ~ Freq, Freq) ~ prosoc_left + actor + prosoc_left:actor
```

```
## Model 2: cbind(total ~ Freq, Freq) ~ (condition + prosoc_left + actor)^2
```

```
## Resid. Df Resid. Dev Df Deviance Pr(>Chi)
```

```
## 1      14      15.415
```

```
## 2       6      11.231  8    4.1838  0.8402
```

The model comparison test between full model and final model gives p-value = 0.8402, thus the final model is adequate.

The final model after model selection is $y \sim \text{prosoc_left} + \text{actor} + \text{prosoc_left}:\text{actor}$. Therefore the number of times choosing prosocial action does depend on condition because it is not in the final model.

5.1.3 Check overdispersion

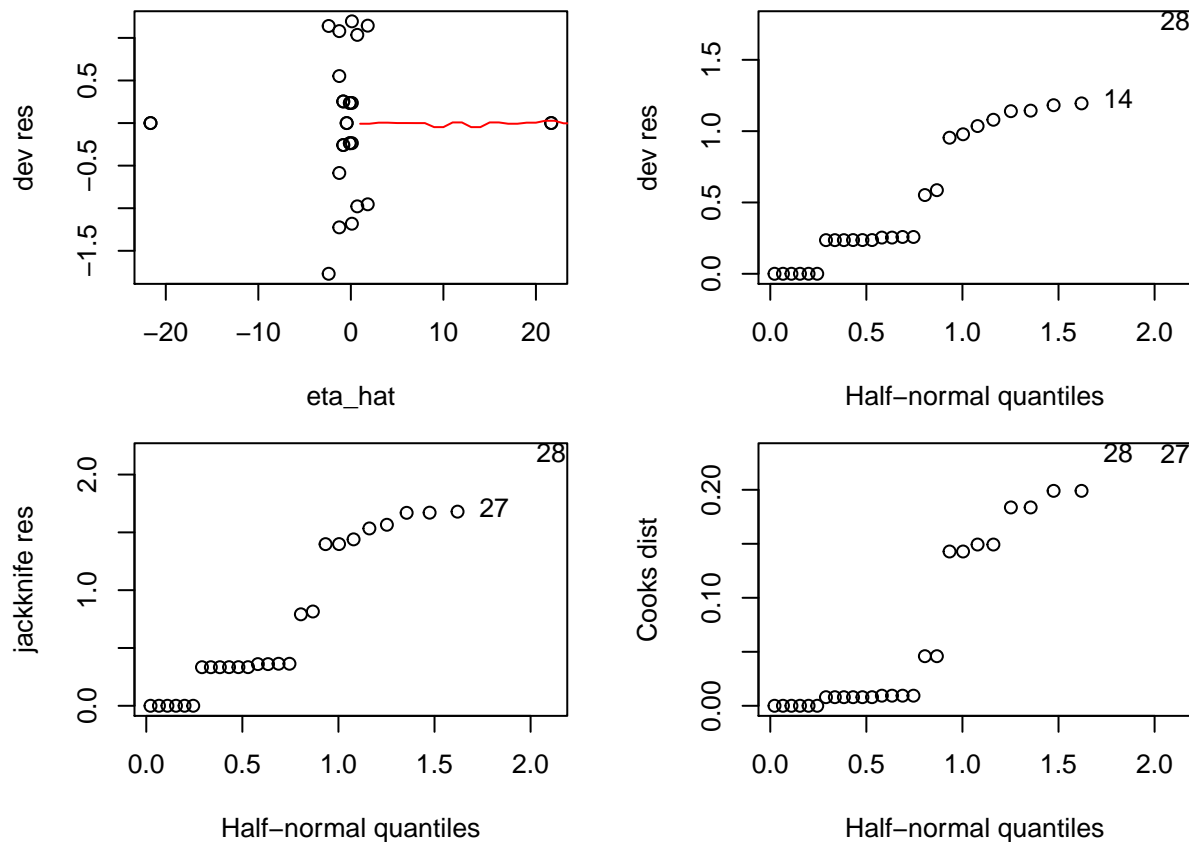
```
(phi_hat = sum(residuals(finalmodel,type = "pearson")^2)/finalmodel$df.residual)
```

```
## [1] 0.9971355
```

The $\hat{\phi}$ is 0.9971355. It is close to 1 and there is no overdispersion or underdispersion exist.

5.1.4 Diagnostic plot

```
library(faraway) # for halfnorm function
D_res <- residuals(finalmodel)
P_res <- residuals(finalmodel, type="pearson")
leverage <- influence(finalmodel)$hat
J_res <- rstudent(finalmodel)
Cooks <- cooks.distance(finalmodel)
eta_hat <- predict(finalmodel, type="link")
par(mfrow=c(2,2))
par(mar=c(4,4,1,2))
plot(eta_hat, D_res, ylab="dev res")
lines(predict(loess(D_res ~ eta_hat)), col="red")
halfnorm(D_res, ylab="dev res")
halfnorm(J_res, ylab="jackknife res")
halfnorm(Cooks, ylab="Cooks dist")
```



The first plot has some data points has extremely small and large η_{hat} values. From the η_{hat} data, it can be found that it is due to the second actor always choose the left lever. In section 3.3, it is mentioned that actor 2 might be an outlier, and we can remove it and see whether it influence our model.

Beside this, all other points have reasonable cooks distance and residual.

5.2 After removing the outlier, fitting data with binomial regression

```
#remove actor2
x = xtabs( ~ condition + prosoc_left + pulled_left+ actor, data = dataset[dataset$actor !=2,])
x = data.frame(x)
#set last column to n = 18

x["total"] = 18
x = x[x$prosoc_left == x$pulled_left,]

#the data have 24 rows
dim(x)

## [1] 24 6

#fit binomial regression model
fullmodel = glm(cbind(total-Freq,Freq) ~ (condition + prosoc_left +actor)^2, family = binomial, data = x)

#use AIC to select model
finalmodel = step(fullmodel)

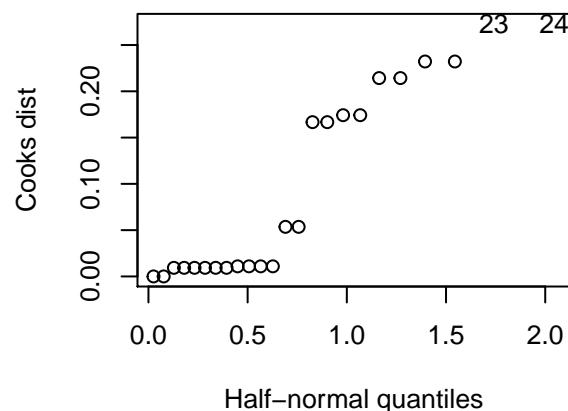
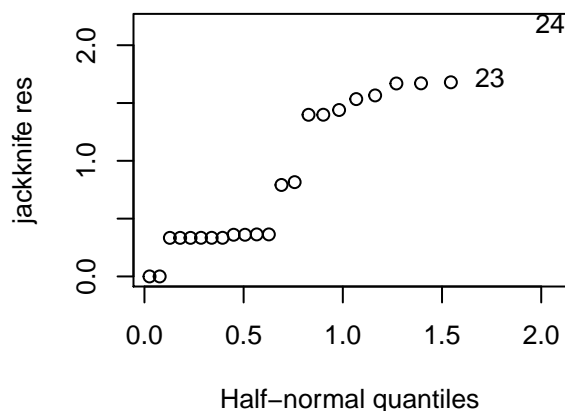
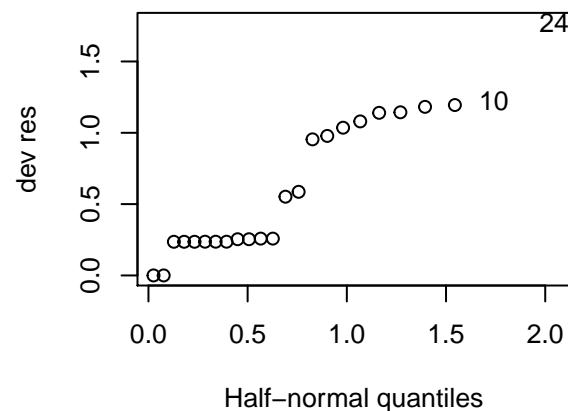
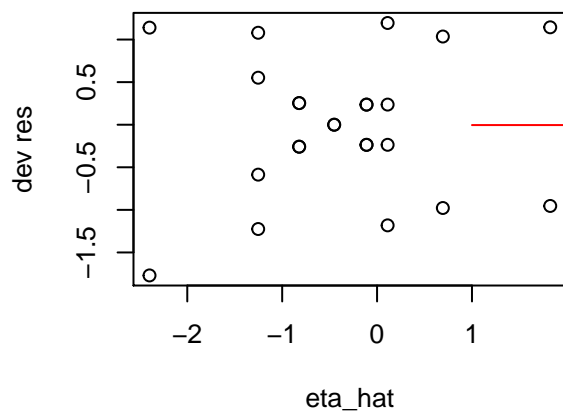
## Start: AIC=121.33
## cbind(total - Freq, Freq) ~ (condition + prosoc_left + actor)^2
##
##              Df Deviance    AIC
## - condition:actor      5   13.193 113.30
## - condition:prosoc_left  1   13.017 121.12
## <none>                  11.231 121.33
## - prosoc_left:actor      5   86.140 186.24
##
## Step: AIC=113.3
## cbind(total - Freq, Freq) ~ condition + prosoc_left + actor +
##   condition:prosoc_left + prosoc_left:actor
##
##              Df Deviance    AIC
## - condition:prosoc_left  1   15.002 113.11
## <none>                  13.193 113.30
## - prosoc_left:actor      5   88.002 178.10
##
## Step: AIC=113.1
## cbind(total - Freq, Freq) ~ condition + prosoc_left + actor +
##   prosoc_left:actor
##
##              Df Deviance    AIC
## - condition              1   15.414 111.52
## <none>                    15.002 113.11
## - prosoc_left:actor      5   89.383 177.49
##
## Step: AIC=111.52
## cbind(total - Freq, Freq) ~ prosoc_left + actor + prosoc_left:actor
##
##              Df Deviance    AIC
## <none>                  15.414 111.52
## - prosoc_left:actor      5   89.730 175.83
```

The model after remove outlier does not change. It is still $y \sim \text{prosoc_left} + \text{actor} + \text{prosoc_left:actor}$.

```
(phi_hat = sum(residuals(finalmodel,type = "pearson")^2)/finalmodel$df.residual)
```

```
## [1] 1.163325
```

```
library(faraway) # for halfnorm function
D_res <- residuals(finalmodel)
P_res <- residuals(finalmodel, type="pearson")
lever <- influence(finalmodel)$hat
J_res <- rstudent(finalmodel)
Cooks <- cooks.distance(finalmodel)
eta_hat <- predict(finalmodel, type="link")
par(mfrow=c(2,2))
par(mar=c(4,4,1,2))
plot(eta_hat, D_res, ylab="dev res")
lines(predict(loess(D_res ~ eta_hat)), col="red")
halfnorm(D_res, ylab="dev res")
halfnorm(J_res, ylab="jackknife res")
halfnorm(Cooks, ylab="Cooks dist")
```



```
deviance(finalmodel)
```

```
## [1] 15.4145
```

```
df.residual(finalmodel)
```

```
## [1] 12
```

```
pchisq(deviance(finalmodel), df = df.residual(finalmodel), lower.tail = FALSE)
```

```
## [1] 0.2195474
```

```
anova(finalmodel,fullmodel,test = "Chisq")
```

```
## Analysis of Deviance Table
```

```
##
```

```
## Model 1: cbind(total ~ Freq, Freq) ~ prosoc_left + actor + prosoc_left:actor
```

```
## Model 2: cbind(total ~ Freq, Freq) ~ (condition + prosoc_left + actor)^2
```

```
##   Resid. Df Resid. Dev Df Deviance Pr(>Chi)
```

```
## 1         12      15.415
```

```
## 2          5      11.231  7    4.1838  0.7584
```

The removal of outlier dose not change out model, the model is still $y \sim \text{prosoc_left} + \text{actor} + \text{prosoc_left}:\text{actor}$, although our p-value decrease from 0.8402 to 0.7584. Since the model does not change, we can sill conclude that the number of times choosing prosocial action does dependent on condition.

6.Conclusion

In this report, section 2 adds a new attribute “prosocal_action”, section 3 plots the relationships and interactions between factors, section 4 shows the prosocial action and condition are independent using contingency table and section 5 shows the number of times choosing prosocial action only dependent on actor and prosoc_left. Thus focal chimpanzee do not behaving like human that choose the prosocial option more often when another animal is present.

As described in section 3.3, actor 2 might be an outlier because it always chooses the left lever and is not influence by any other factor. This require some domain knowledge to decided whether it should be removed. However, whether it is removed or not does not change the result.