Study 1: Reinforcement-Punishment Analysis

Debbie Yee

3/18/2018

Study 1: Punishment Effects of Monetary and Liquid Incentives

This is an analysis of the subject performance of study 1 of reinforcement and punishment effects of liquid feedback with monetary gains and losses. In the study, subjects perform the cued task-switching paradigm, where they have classify a letter (vowel/consonant) or digit (odd/even). During the baseline runs, they don't receive any feedback and are told to respond "as quickly and accurate as possible." During the incentive runs, they receive a drop of liquid (2 mL) to indicate successful attainment of monetary reward in a single trial. Each subject performs 3 incentive runs in which they must respond accurately and faster than a criterion RT to earn monetary reward. Liquid feedback (blocked) signaled failure to attain monetary reward (opportunity cost). Criterion RT is calculated on subject performance during the baseline run (25%) (CHECK THIS), and is the same for both reinforcement and punishment conditions.

Loading relevant packages

```
library(ggplot2)
library(gridExtra)
library(dplyr)
library(tidyr)
library(lme4)
library(lmerTest)
library(sjPlot)
library(pander)
source("summarySEwithin2.R")
```

Path Directories of Data Input/Output

```
# data directories
data.path<-paste0("/Users/debbieyee/Dropbox/CCPLabProjects/Liquid_Feedback/",
                  "Reinforce-Punish_Combined/Study1/Data/SubjectData/TrimmedData/",
                  "NewCT/Study1_RewardData.csv")
runkey.path<-paste0("/Users/debbieyee/Dropbox/CCPLabProjects/Liquid_Feedback/",
                    "Reinforce-Punish_Combined/Study1/Data/SubjectData/TrimmedData/",
                    "NewCT/Study1_runkey.csv")
figure.path<-paste0("/Users/debbieyee/Dropbox/CCPLabProjects/Liquid_Feedback/",
                    "Reinforce-Punish_Combined/Study1/Analysis/Figures/")
```

Format the Data For Analysis

```r
# Read in the data
data<-read.csv(data.path,header = TRUE) %>% select(-X)
runkey<-read.csv(runkey.path, header = TRUE) %>% select(-X)

# Formatting incentive data
incentive<- data %>% inner_join(y = runkey, by = c("subID","block"))  %>%
  mutate(subRewarded=(RT<critRT & ACC==1)*1,
         ERR=ifelse(ACC==0,1,0),
         block=factor(block, levels=c(7,8,9), labels=c(1,2,3)),
         money=factor(rewType, levels=c("Reward1","Reward2","Reward4"), labels=c("$","$$","$$$$")),
         moneyCode=factor(rewType, levels=c("Reward1","Reward2","Reward4"), labels=c(-1,0,1)),
         liqCode=factor(liquid, levels=c("saltwater","neutral","juice"), labels=c(-1,0,1)),
         liqCodeJvN=factor(liquid, levels=c("saltwater","neutral","juice"), labels=c(0,-1,1)),
         liqCodeSvN=factor(liquid, levels=c("saltwater","neutral","juice"), labels=c(-1,1,0)))
incentive$moneyCode<-as.numeric(levels(incentive$moneyCode)[incentive$moneyCode])
incentive$liqCode<-as.numeric(levels(incentive$liqCode)[incentive$liqCode])
incentive$liqCodeJvN<-as.numeric(levels(incentive$liqCodeJvN)[incentive$liqCodeJvN])
incentive$liqCodeSvN<-as.numeric(levels(incentive$liqCodeSvN)[incentive$liqCodeSvN])
```

Summarise/Consolidate Incentive Data

```r
# summarise means by monetary reward only
rewRT.means = incentive %>% group_by(subID, money) %>%
  filter(!is.na(subRewarded), ACC==1) %>% filter(!is.na(subRewarded), ACC==1) %>%
  summarise(n=n(),meanRT = mean(RT))
rew.means = incentive %>% group_by(subID,money) %>% filter(!is.na(subRewarded)) %>%
  summarise(n=n(), meanRR = mean(subRewarded), meanACC = mean(ACC), meanERR = mean(ERR))

# summarise means by liquid incentive type only
liqRT.means = incentive %>% group_by(subID, liquid) %>% filter(!is.na(subRewarded), ACC==1) %>%
  summarise(meanRT = mean(RT))
liq.means=incentive %>% group_by(subID, liquid) %>% filter(!is.na(subRewarded)) %>%
  summarise(n=n(), meanRR = mean(subRewarded), meanACC = mean(ACC), meanERR = mean(ERR))

# summarise the means of the incentive data for each subject, grouped by condition
incentive9RT.means <- incentive %>% group_by(subID, liquid, money) %>%
  filter(!is.na(subRewarded), ACC==1) %>% summarise(n=n(), meanRT = mean(RT)) %>%
  mutate(moneycode = as.numeric(as.character(factor(money,levels=c("$","$$","$$$$"),
                                          labels=c(-1,0,1)))),
         liqcode = as.numeric(as.character(factor(liquid,levels=c("saltwater","neutral","juice"),
                                          labels=c(-1,0,1))))) %>%
  ungroup(subID) %>% mutate(subID=as.factor(subID))
incentive9.means = incentive %>% group_by(subID, liquid, money) %>% filter(!is.na(subRewarded)) %>%
  summarise(n = n(), meanRR = mean(subRewarded), meanACC = mean(ACC), meanERR = mean(ERR)) %>%
  mutate(moneycode = as.numeric(as.character(factor(money,levels=c("$","$$","$$$$"),
                                          labels=c(-1,0,1)))),
         liqcode = as.numeric(as.character(factor(liquid,levels=c("saltwater","neutral","juice"),
                                          labels=c(-1,0,1))))) %>%
  ungroup(subID) %>% mutate(subID=as.factor(subID))
```

Reward Rate Plots

Plot: mean reward rate by monetary reward level

```r
RR.sum=summarySEwithin2(data=rew.means, measurevar = "meanRR", withinvars = c("money"),
                        idvar = "subID")
```

```
##
## Attaching package: 'data.table'

## The following objects are masked from 'package:dplyr':
##
##      between, first, last
```

```r
pandoc.table(RR.sum)
```

```
##
## ---------------------------------------------------------------
## money   N    meanRR   meanRRNormed    sd        se         ci
## ------- ---- -------- -------------- --------- ---------- ---------
##    $     39   0.668       0.668      0.05132   0.008218   0.01664
##
##   $$     39   0.6787      0.6787     0.04878   0.007811   0.01581
##
##  $$$$    39   0.7236      0.7236     0.05154   0.008252   0.01671
## ---------------------------------------------------------------
```

```r
p.RR.1<-ggplot(RR.sum, aes(x=money, y=meanRR)) +
  geom_bar(position=position_dodge(width=0.8), color="black",
           fill='darkmagenta', stat="identity", width=0.8) +
  geom_errorbar(position=position_dodge(width=0.8),
                aes(ymin=meanRR-se, ymax=meanRR+se), width=.2) +
  xlab("Monetary Reward") + ylab("Reward Rate") +
  ggtitle("Task Performance Across Money") +
  coord_cartesian(ylim=c(.5,.85)) +
  scale_fill_discrete(name="Monetary Reward") +
  theme(#plot.title=element_text(size=22,face="bold", vjust=2),
        axis.title=element_text(size=12,face = "bold"),
        axis.text=element_text(size=14),
        legend.position="none",
        strip.text.x = element_text(size = 12))
p.RR.1
```

Task Performance Across Money
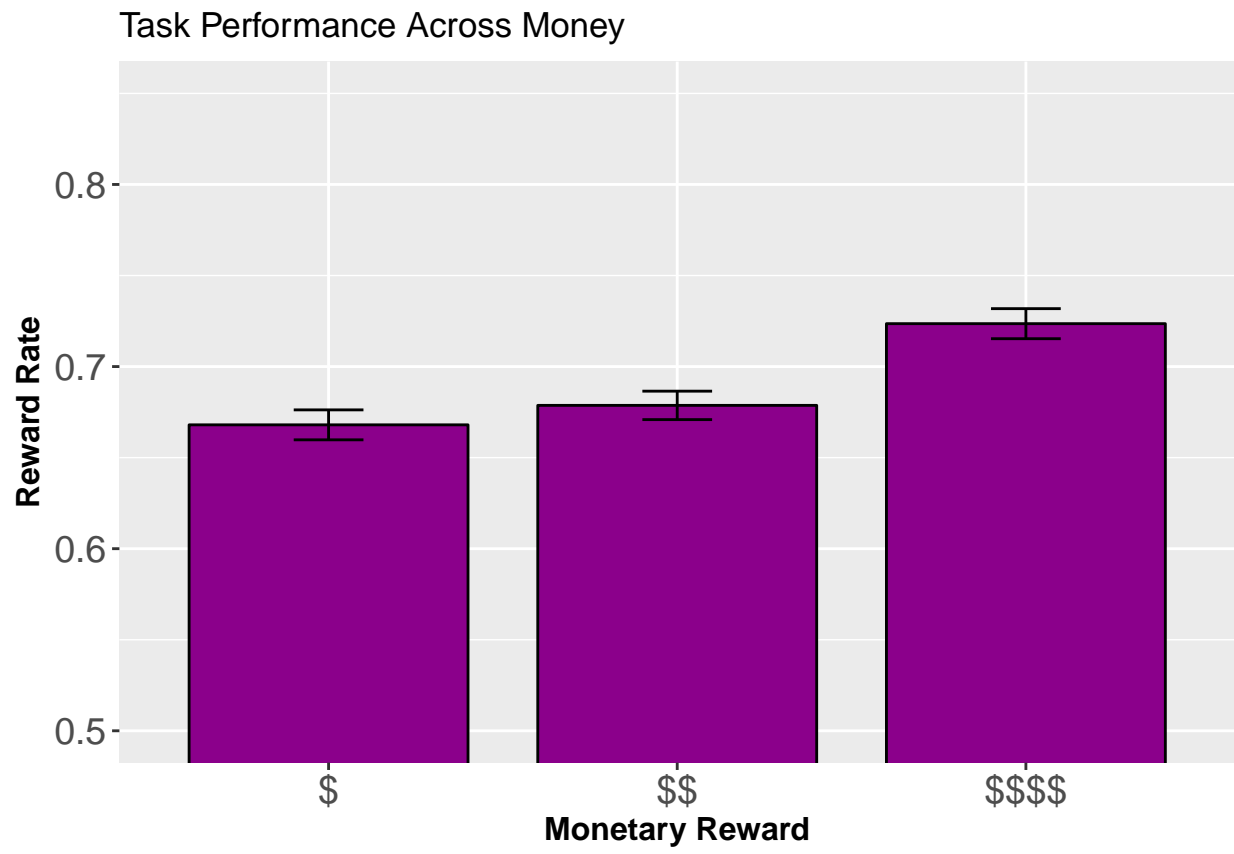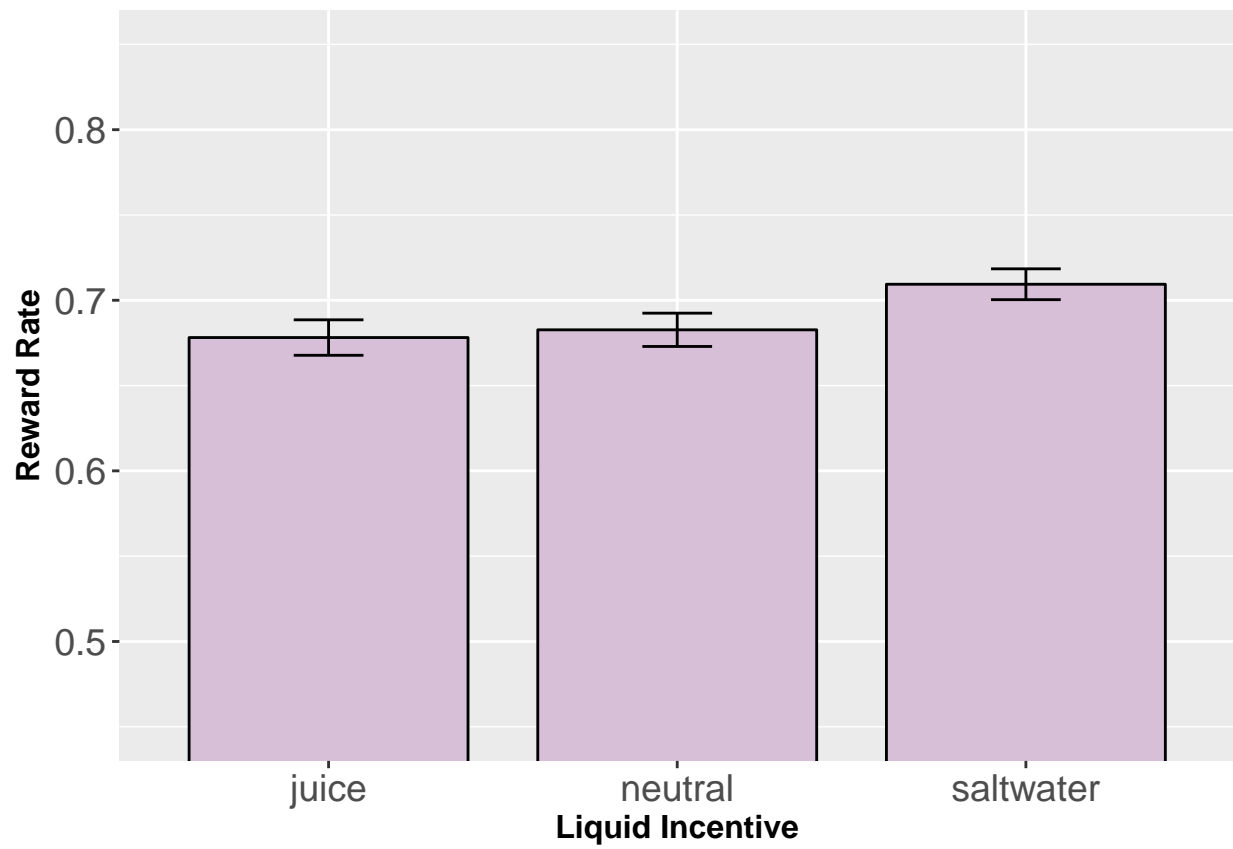
Plot: mean reward rate by liquid type

```
RR.sum=summarySEwithin2(data=liq.means, measurevar = "meanRR", withinvars = c("liquid"),
                        idvar = "subID")
pandoc.table(RR.sum)
```

```
## 
## ----------------------------------------------------------------------
##    liquid    N    meanRR    meanRRNormed    sd        se         ci
## ----------- ---- -------- -------------- --------- ---------- ---------
##    juice     39   0.6782      0.6782      0.06493    0.0104    0.02105
## 
##   neutral    39   0.6827      0.6827      0.06098   0.009765   0.01977
## 
##  saltwater   39   0.7094      0.7094      0.05644   0.009038    0.0183
## ----------------------------------------------------------------------
```

```
p.RR.2<-ggplot(RR.sum, aes(x=liquid, y=meanRR)) +
  geom_bar(position=position_dodge(width=0.8), color="black", fill='thistle',
           stat="identity", width=0.8) +
  geom_errorbar(position=position_dodge(width=0.8),
                aes(ymin=meanRR-se, ymax=meanRR+se), width=.2) +
  xlab("Liquid Incentive") + ylab("Reward Rate") +
  #ggtitle("Task Performance Across Liquid Type") +
  coord_cartesian(ylim=c(.45,.85)) +
  scale_fill_discrete(name="Monetary Reward") +
  theme(#plot.title=element_text(size=22,face="bold", vjust=2),
        axis.title=element_text(size=12,face = "bold"),
        axis.text=element_text(size=14),
        legend.position="none",
        strip.text.x = element_text(size = 12))
p.RR.2
```
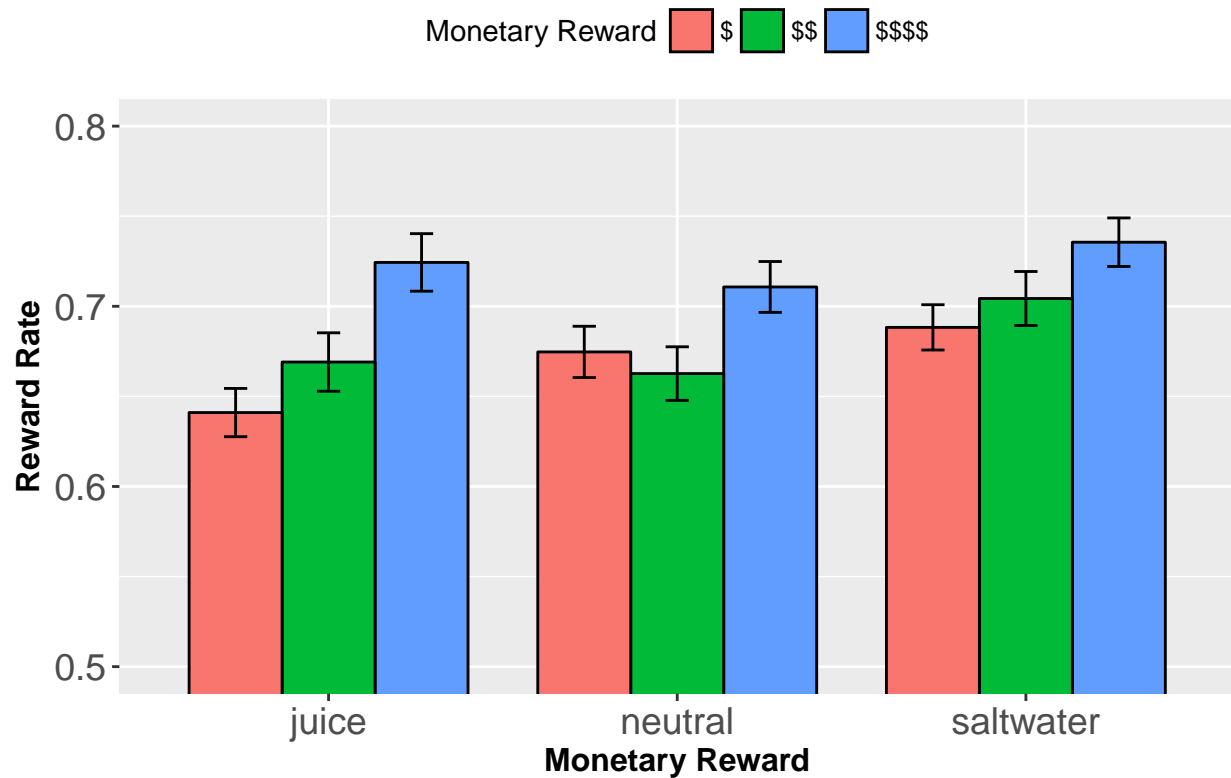
Plot: mean reward rate by money and liquid type

```
RR.sum=summarySEwithin2(data=incentive9.means, measurevar = "meanRR",
                        withinvars = c("money","liquid"), idvar = "subID")
pandoc.table(RR.sum)
```

```
## 
## --------------------------------------------------------------------------
##  money     liquid     N    meanRR    meanRRNormed     sd        se        ci
## -------  ----------  ----  --------  --------------  --------  ---------  ---------
##    $       juice      39    0.641        0.641       0.08364   0.01339    0.02711
## 
##    $      neutral     39    0.6747       0.6747      0.08896   0.01424    0.02884
## 
##    $      saltwater   39    0.6883       0.6883      0.07842   0.01256    0.02542
## 
##   $$       juice      39    0.6691       0.6691      0.1012    0.01621    0.03281
## 
##   $$      neutral     39    0.6627       0.6627      0.09277   0.01486    0.03007
## 
##   $$      saltwater   39    0.7043       0.7043      0.09359   0.01499    0.03034
## 
##  $$$$      juice      39    0.7244       0.7244      0.09967   0.01596    0.03231
## 
##  $$$$     neutral     39    0.7107       0.7107      0.08814   0.01411    0.02857
## 
##  $$$$     saltwater   39    0.7356       0.7356      0.08412   0.01347    0.02727
## --------------------------------------------------------------------------
```

```r
# first plot
p.RR.3<-ggplot(RR.sum, aes(x=liquid, y=meanRR, fill=money)) +
  geom_bar(position=position_dodge(width=0.8), color="black",
           stat="identity", width=0.8) +
  geom_errorbar(position=position_dodge(width=0.8),
                aes(ymin=meanRR-se, ymax=meanRR+se), width=.2) +
  xlab("Monetary Reward") + ylab("Reward Rate") +
  ggtitle("Punishment Avoidance Across Money and Liquid Type") +
  coord_cartesian(ylim=c(.5,.8)) +
  scale_fill_discrete(name="Monetary Reward") +
  theme(#plot.title=element_text(size=22,face="bold", vjust=2),
        axis.title=element_text(size=12,face = "bold"),
        axis.text=element_text(size=14),
        legend.position="top",
        strip.text.x = element_text(size = 12))
p.RR.3
```
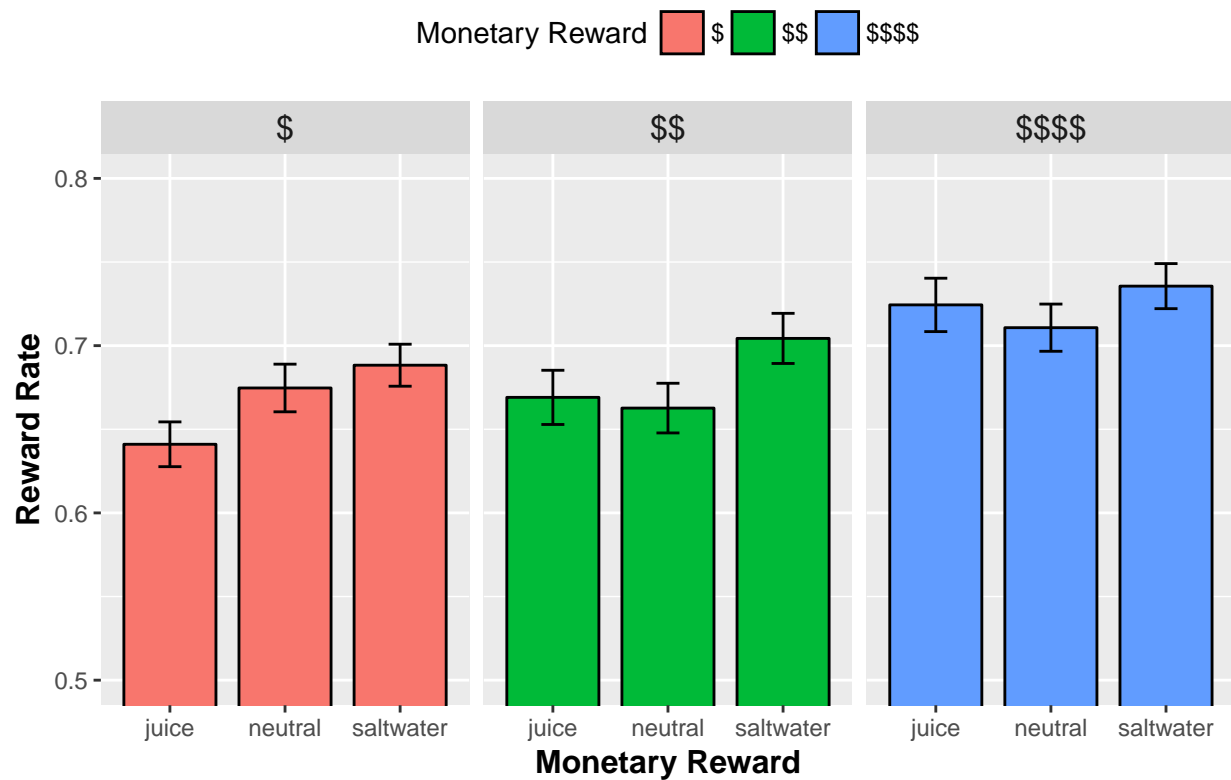
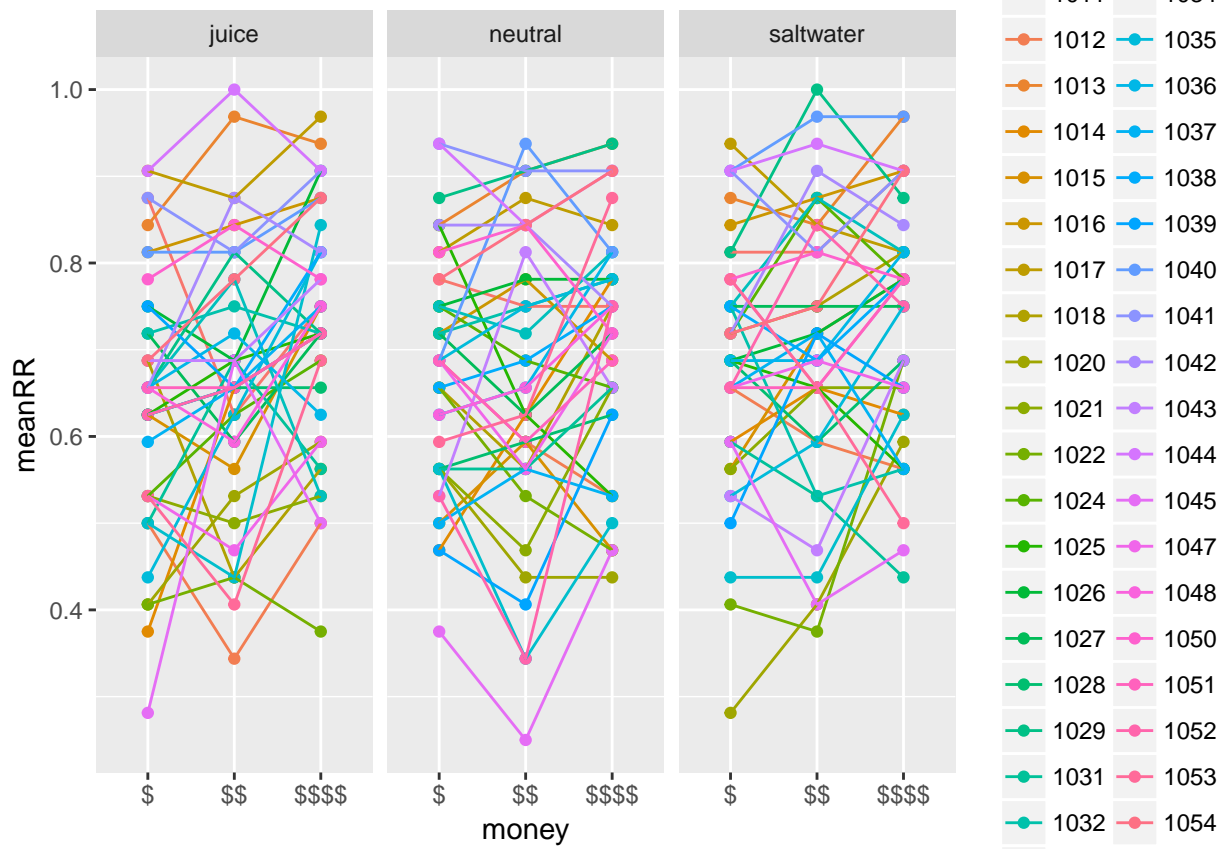## Punishment Avoidance Across Money and Liquid Type


```r
# second plot
p.RR.4<-ggplot(RR.sum, aes(x=liquid, y=meanRR, fill=money)) +
  geom_bar(position=position_dodge(width=0.8), color="black", stat="identity", width=0.8) +
  geom_errorbar(position=position_dodge(width=0.8), aes(ymin=meanRR-se, ymax=meanRR+se), width=.2) +
  facet_wrap(~money) +
  xlab("Monetary Reward") + ylab("Reward Rate") +
  ggtitle("Task Performance Across Money and Liquid Type") +
  coord_cartesian(ylim=c(.5,.8)) +
  scale_fill_discrete(name="Monetary Reward") +
  theme(#plot.title=element_text(size=22,face="bold", vjust=2),
        axis.title=element_text(size=12,face = "bold"),
        #axis.text=element_text(size=14),
        legend.position="top",
        strip.text.x = element_text(size = 12))
p.RR.4
```

Task Performance Across Money and Liquid Type


```
ggplot(data = incentive9.means, mapping = aes(x = money, y = meanRR, col=subID, group=subID)) +
  facet_grid(~liquid) +
  geom_point() +
  geom_line()
```

Generalized Linear Mixed Effects Models of Reward Rate Effects by Condition (Money, Liquid)

Reward Rate by money (1,2,4) and liquid (juice,neutral,saltwater).

```
# omnibus model: reward rate by liquid and money
m.RR.null<-glmer(formula = subRewarded ~ (1+moneyCode+liqCode|subID),
                 data = incentive, family=binomial)
```

```
## Warning in checkConv(attr(opt, "derivs"), opt$par, ctrl = control
## $checkConv, : unable to evaluate scaled gradient

## Warning in checkConv(attr(opt, "derivs"), opt$par, ctrl = control
## $checkConv, : Model failed to converge: degenerate Hessian with 1 negative
## eigenvalues
```

```
m.RR.1<-glmer(formula = subRewarded ~ moneyCode*liqCode +(1+moneyCode+liqCode|subID),
              data = incentive, family=binomial)
```

```
## Warning in checkConv(attr(opt, "derivs"), opt$par, ctrl = control
## $checkConv, : Model failed to converge with max|grad| = 0.340106 (tol =
## 0.001, component 1)
```

```
summary(m.RR.1)
```

```
## Generalized linear mixed model fit by maximum likelihood (Laplace
##    Approximation) [glmerMod]
##  Family: binomial  ( logit )
## Formula: subRewarded ~ moneyCode * liqCode + (1 + moneyCode + liqCode |
##     subID)
##    Data: incentive
##
##      AIC      BIC   logLik deviance df.resid
##  13236.1  13309.4  -6608.1  13216.1    11222
##
## Scaled residuals:
##    Min     1Q Median     3Q    Max
## -3.479 -1.093  0.498  0.713  1.200
##
## Random effects:
##  Groups Name        Variance Std.Dev. Corr
##  subID  (Intercept) 0.408597 0.63922
##         moneyCode   0.004809 0.06934   0.16
##         liqCode     0.019613 0.14005  -0.23  0.58
## Number of obs: 11232, groups:  subID, 39
##
## Fixed effects:
##                   Estimate Std. Error z value Pr(>|z|)
## (Intercept)        0.88715    0.10488   8.458  < 2e-16 ***
## moneyCode          0.14726    0.02928   5.030 4.91e-07 ***
## liqCode           -0.08298    0.03519  -2.358   0.0184 *
## moneyCode:liqCode  0.04317    0.03187   1.354   0.1756
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
```

```
## Correlation of Fixed Effects:
##            (Intr) monyCd liqCod
## moneyCode    0.080
## liqCode     -0.151  0.147
## monyCd:lqCd  0.001 -0.026  0.036
## convergence code: 0
## Model failed to converge with max|grad| = 0.340106 (tol = 0.001, component 1)
```

Reward Rate separated by Monetary Reward

The omnibus model reveals a significant main effect of reward. When broken down by monetary reward level, it is evident that these task performance differences are driven by a parametric relationship of liquid in the low monetary reward condition. In low monetary reward conditions, there is a significant monetary reward effect. In medium monetary reward conditions, the liquid effect is weaker, but still significant. In high monetary reawrd conditions, there is no difference in task performance in liquids. Thus, it seems to be the case that that differences in task performance across monetary reward levels depended on liquid valence when reward offers were low, and participants seemed to not care as much about the liquid valence during high reward trials.

```r
# Monetary Reward Effect
m.RR.1.money <-glmer(formula = subRewarded ~ moneyCode + (1+moneyCode|subID),
        data = incentive, family = binomial)
summary(m.RR.1.money)
```

```
## Generalized linear mixed model fit by maximum likelihood (Laplace
##   Approximation) [glmerMod]
##  Family: binomial  ( logit )
## Formula: subRewarded ~ moneyCode + (1 + moneyCode | subID)
##    Data: incentive
##
##      AIC      BIC   logLik deviance df.resid
##  13245.4  13282.0  -6617.7  13235.4    11227
##
## Scaled residuals:
##     Min      1Q  Median      3Q      Max
## -3.2969 -1.0958  0.5006  0.7131  1.1615
##
## Random effects:
##  Groups Name        Variance Std.Dev. Corr
##  subID  (Intercept) 0.384207 0.61984
##         moneyCode   0.006252 0.07907  0.09
## Number of obs: 11232, groups:  subID, 39
##
## Fixed effects:
##             Estimate Std. Error z value Pr(>|z|)
## (Intercept)  0.87744    0.10168   8.630  < 2e-16 ***
## moneyCode    0.14101    0.02972   4.745 2.08e-06 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##           (Intr)
## moneyCode 0.049
```

```r
# Money $ (Low)
m.RR.1.money.rew1 <-glmer(formula = subRewarded ~ liqCode + (1+liqCode|subID),
        data = subset(incentive,moneyCode==-1), family = binomial)
summary(m.RR.1.money.rew1)
```

```
## Generalized linear mixed model fit by maximum likelihood (Laplace
##   Approximation) [glmerMod]
##  Family: binomial  ( logit )
## Formula: subRewarded ~ liqCode + (1 + liqCode | subID)
```

```
##     Data: subset(incentive, moneyCode == -1)
##
##      AIC      BIC   logLik deviance df.resid
##   4598.5   4629.6  -2294.2   4588.5     3739
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -2.8898 -1.0972  0.5548  0.7210  1.1730
##
## Random effects:
##  Groups Name        Variance  Std.Dev. Corr
##  subID  (Intercept) 0.3412307 0.584150
##         liqCode     0.0000835 0.009138 -1.00
## Number of obs: 3744, groups:  subID, 39
##
## Fixed effects:
##             Estimate Std. Error z value Pr(>|z|)
## (Intercept)  0.75829    0.10057   7.540 4.69e-14 ***
## liqCode     -0.11562    0.04503  -2.568   0.0102 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##         (Intr)
## liqCode -0.045
```

```r
# Money $$ (Medium)
m.RR.1.money.rew2 <-glmer(formula = subRewarded ~ liqCode + (1+liqCode|subID),
         data = subset(incentive,moneyCode==0), family = binomial)
summary(m.RR.1.money.rew2)
```

```
## Generalized linear mixed model fit by maximum likelihood (Laplace
##   Approximation) [glmerMod]
##  Family: binomial  ( logit )
## Formula: subRewarded ~ liqCode + (1 + liqCode | subID)
##    Data: subset(incentive, moneyCode == 0)
##
##      AIC      BIC   logLik deviance df.resid
##   4481.0   4512.1  -2235.5   4471.0     3739
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -3.1746 -1.0368  0.4716  0.7211  1.1776
##
## Random effects:
##  Groups Name        Variance Std.Dev. Corr
##  subID  (Intercept) 0.47453  0.6889
##         liqCode     0.04082  0.2020   -0.17
## Number of obs: 3744, groups:  subID, 39
##
## Fixed effects:
##             Estimate Std. Error z value Pr(>|z|)
## (Intercept)  0.83915    0.11682   7.183 6.81e-13 ***
## liqCode     -0.09574    0.05697  -1.680   0.0929 .
## ---
```

```
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##         (Intr)
## liqCode -0.105
```

```r
# Money $$$$ (High)
m.RR.1.money.rew4 <-glmer(formula = subRewarded ~ liqCode + (1+liqCode|subID),
        data = subset(incentive,moneyCode==1), family = binomial)
summary(m.RR.1.money.rew4)
```

```
## Generalized linear mixed model fit by maximum likelihood (Laplace
##   Approximation) [glmerMod]
##  Family: binomial  ( logit )
## Formula: subRewarded ~ liqCode + (1 + liqCode | subID)
##    Data: subset(incentive, moneyCode == 1)
##
##      AIC      BIC   logLik deviance df.resid
##   4276.2   4307.3  -2133.1   4266.2     3739
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -3.3836 -1.1024  0.5072  0.6415  1.0061
##
## Random effects:
##  Groups Name        Variance Std.Dev. Corr
##  subID  (Intercept) 0.34947  0.5912
##         liqCode     0.02703  0.1644   -0.20
## Number of obs: 3744, groups:  subID, 39
##
## Fixed effects:
##             Estimate Std. Error z value Pr(>|z|)
## (Intercept)  1.04232    0.10259  10.160   <2e-16 ***
## liqCode     -0.03836    0.05493  -0.698    0.485
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##         (Intr)
## liqCode -0.098
```

Reward Rate separated by liquid types (Two models)

Model 1 (Juice vs Neutral):

The first model examines whether monetary reward effects are present with only Juice and Neutral liquids. The GLMM reveals a marginal effect of monetary reward and a marginal interaction between money and liquid. Post-hoc analyses reveal that when omit low reward trials (medium and high), you see a main effect of monetary reward only ($$ >$ task performance). When you omit the medium reward trials (low and high present only), the main effect of money and interaction are present. In other words, the difference between the money trials increased in the Juice vs Neutral trials. When you omit the high reward trials, there are no significant main effects.

Specifically, this reveals that subjects perform worst on the Juice$ trials, and we want to test whether they are performing more comission errors on these trials.

```
# Liquid Effect: Juice vs Neutral
m.RR.1.JvN <-glmer(formula = subRewarded ~ moneyCode*liqCode + (1+moneyCode+liqCode|subID),
          data = subset(incentive,liqCode!=-1), family=binomial)
summary(m.RR.1.JvN)
```

```
## Generalized linear mixed model fit by maximum likelihood (Laplace
##   Approximation) [glmerMod]
##  Family: binomial  ( logit )
## Formula: subRewarded ~ moneyCode * liqCode + (1 + moneyCode + liqCode |
##     subID)
##    Data: subset(incentive, liqCode != -1)
##
##      AIC      BIC   logLik deviance df.resid
##   8973.6   9042.8  -4476.8   8953.6     7478
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -3.3969 -1.0838  0.5191  0.7087  1.2913
##
## Random effects:
##  Groups Name        Variance Std.Dev. Corr
##  subID  (Intercept) 0.406205 0.63734
##         moneyCode   0.009484 0.09738   0.04
##         liqCode     0.090300 0.30050  -0.28  0.38
## Number of obs: 7488, groups:  subID, 39
##
## Fixed effects:
##                   Estimate Std. Error z value Pr(>|z|)
## (Intercept)        0.84252    0.10886   7.740 9.96e-15 ***
## moneyCode          0.09129    0.04805   1.900   0.0574 .
## liqCode           -0.02048    0.07186  -0.285   0.7757
## moneyCode:liqCode  0.11853    0.06322   1.875   0.0608 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##             (Intr) monyCd liqCod
## moneyCode    0.024
## liqCode     -0.357  0.071
## monyCd:lqCd -0.007 -0.659  0.034
```

```r
m.RR.1.JvN.omitrew1 <-glmer(formula = subRewarded ~ moneyCode*liqCode + (1+moneyCode+liqCode|subID),
          data = subset(incentive,liqCode!=-1 & moneyCode!=-1), family=binomial)
summary(m.RR.1.JvN.omitrew1)
```

```
## Generalized linear mixed model fit by maximum likelihood (Laplace
##   Approximation) [glmerMod]
##  Family: binomial  ( logit )
## Formula: subRewarded ~ moneyCode * liqCode + (1 + moneyCode + liqCode |
##     subID)
##    Data: subset(incentive, liqCode != -1 & moneyCode != -1)
##
##      AIC      BIC   logLik deviance df.resid
##   5899.2   5964.3  -2939.6   5879.2     4982
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -3.2021 -1.0577  0.5003  0.7016  1.2322
##
## Random effects:
##  Groups Name        Variance Std.Dev. Corr
##  subID  (Intercept) 0.54096  0.7355
##         moneyCode   0.03119  0.1766   -0.67
##         liqCode     0.09988  0.3160   -0.34 -0.08
## Number of obs: 4992, groups:  subID, 39
##
## Fixed effects:
##                   Estimate Std. Error z value Pr(>|z|)
## (Intercept)        0.76449    0.13442   5.687 1.29e-08 ***
## moneyCode          0.21691    0.09616   2.256   0.0241 *
## liqCode            0.02331    0.10387   0.224   0.8224
## moneyCode:liqCode  0.03514    0.12791   0.275   0.7835
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##            (Intr) monyCd liqCod
## moneyCode  -0.489
## liqCode    -0.438  0.383
## monyCd:lqCd 0.230 -0.662 -0.595
```

```r
m.RR.1.JvN.omitrew2 <-glmer(formula = subRewarded ~ moneyCode*liqCode + (1+moneyCode+liqCode|subID),
          data = subset(incentive,liqCode!=-1 & moneyCode!=0), family=binomial)
summary(m.RR.1.JvN.omitrew2)
```

```
## Generalized linear mixed model fit by maximum likelihood (Laplace
##   Approximation) [glmerMod]
##  Family: binomial  ( logit )
## Formula: subRewarded ~ moneyCode * liqCode + (1 + moneyCode + liqCode |
##     subID)
##    Data: subset(incentive, liqCode != -1 & moneyCode != 0)
##
##      AIC      BIC   logLik deviance df.resid
##   5984.8   6049.9  -2982.4   5964.8     4982
##
```

```
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -3.0703 -1.1202  0.5546  0.6906  1.3247
##
## Random effects:
##  Groups Name        Variance Std.Dev. Corr
##  subID  (Intercept) 0.312528 0.55904
##         moneyCode   0.009804 0.09901  -0.01
##         liqCode     0.100766 0.31744  -0.10  0.32
## Number of obs: 4992, groups:  subID, 39
##
## Fixed effects:
##                   Estimate Std. Error z value Pr(>|z|)
## (Intercept)        0.87557    0.10072   8.693   <2e-16 ***
## moneyCode          0.08976    0.04811   1.866   0.0621 .
## liqCode           -0.03264    0.08273  -0.395   0.6931
## moneyCode:liqCode  0.12047    0.06352   1.896   0.0579 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##            (Intr) monyCd liqCod
## moneyCode    0.012
## liqCode     -0.311  0.050
## monyCd:lqCd -0.011 -0.658  0.045
```

```r
m.RR.1.JvN.omitrew4 <-glmer(formula = subRewarded ~ moneyCode*liqCode + (1+moneyCode+liqCode|subID),
        data = subset(incentive,liqCode!=-1 & moneyCode!=1), family=binomial)
summary(m.RR.1.JvN.omitrew4)
```

```
## Generalized linear mixed model fit by maximum likelihood (Laplace
##   Approximation) [glmerMod]
##  Family: binomial  ( logit )
## Formula: subRewarded ~ moneyCode * liqCode + (1 + moneyCode + liqCode |
##     subID)
##    Data: subset(incentive, liqCode != -1 & moneyCode != 1)
##
##      AIC      BIC   logLik deviance df.resid
##   6127.9   6193.1  -3054.0   6107.9     4982
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -3.1233 -1.0681  0.5159  0.7517  1.2852
##
## Random effects:
##  Groups Name        Variance Std.Dev. Corr
##  subID  (Intercept) 0.52416  0.7240
##         moneyCode   0.04109  0.2027    0.66
##         liqCode     0.07158  0.2675   -0.29  0.26
## Number of obs: 4992, groups:  subID, 39
##
## Fixed effects:
##                   Estimate Std. Error z value Pr(>|z|)
## (Intercept)        0.76283    0.13275   5.746 9.12e-09 ***
## moneyCode         -0.03126    0.09571  -0.327    0.744
```

```
## liqCode              0.02562   0.10010   0.256    0.798
## moneyCode:liqCode  0.19412   0.12459   1.558    0.119
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##            (Intr) monyCd liqCod
## moneyCode    0.519
## liqCode     -0.414 -0.375
## monyCd:lqCd -0.240 -0.660  0.638
```

Model 2 (Saltwater vs Neutral):

The second model whether monetary reward effects are present with saltwater and neutral liquids. the GLMM reveals a significant effect of money and significant effect of liquid, but no interaction. Post hoc analyes reveal that omitting low reward trials result in stronger significant effect of money, and a significant liquid effect. Omitting medium reward trials maintains significant monetary reward effect, but the liquid effect is weaker. Omitting high reward trials eradicate the monetary reward effects but keep the liquid effects.

Thus, for low and medium monetary reward values, we see a boost in punishment avoidance based on liquid type, but no significant differences between low and monetary reward rates.

```r
# Liquid Effect: Salt vs Neutral
m.RR.1.SvN<-glmer(formula = subRewarded ~ moneyCode*liqCode + (1+liqCode|subID),
          data = subset(incentive,liqCode!=1), family=binomial)
summary(m.RR.1.SvN)
```

```
## Generalized linear mixed model fit by maximum likelihood (Laplace
##   Approximation) [glmerMod]
##  Family: binomial  ( logit )
## Formula: subRewarded ~ moneyCode * liqCode + (1 + liqCode | subID)
##    Data: subset(incentive, liqCode != 1)
##
##      AIC      BIC   logLik deviance df.resid
##   8758.0   8806.4  -4372.0   8744.0     7481
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -3.2201 -1.0819  0.5002  0.6952  1.2481
##
## Random effects:
##  Groups Name        Variance Std.Dev. Corr
##  subID  (Intercept) 0.39694  0.6300
##         liqCode     0.05346  0.2312   0.03
## Number of obs: 7488, groups:  subID, 39
##
## Fixed effects:
##                   Estimate Std. Error z value Pr(>|z|)
## (Intercept)        0.83918    0.10771   7.791 6.63e-15 ***
## moneyCode          0.08960    0.04459   2.009   0.0445 *
## liqCode           -0.14615    0.06578  -2.222   0.0263 *
## moneyCode:liqCode -0.03432    0.06394  -0.537   0.5914
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##            (Intr) monyCd liqCod
## moneyCode   0.009
## liqCode     0.214  0.015
## monyCd:lqCd 0.006  0.697  0.028
```

```r
m.RR.1.SvN.omitrew1<-glmer(formula = subRewarded ~ moneyCode*liqCode + (1+liqCode|subID),
          data = subset(incentive,liqCode!=1 & moneyCode!=-1), family=binomial)
summary(m.RR.1.SvN.omitrew1)
```

```
## Generalized linear mixed model fit by maximum likelihood (Laplace
##   Approximation) [glmerMod]
```

```
##  Family: binomial  ( logit )
## Formula: subRewarded ~ moneyCode * liqCode + (1 + liqCode | subID)
##    Data: subset(incentive, liqCode != 1 & moneyCode != -1)
##
##      AIC      BIC   logLik deviance df.resid
##   5768.5   5814.1  -2877.2   5754.5     4985
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -3.5383 -1.0528  0.4848  0.6751  1.3140
##
## Random effects:
##  Groups Name        Variance Std.Dev. Corr
##  subID  (Intercept) 0.4581   0.6768
##         liqCode     0.1008   0.3175   0.12
## Number of obs: 4992, groups:  subID, 39
##
## Fixed effects:
##                   Estimate Std. Error z value Pr(>|z|)
## (Intercept)        0.74896    0.12564   5.961  2.5e-09 ***
## moneyCode          0.24322    0.09001   2.702  0.00689 **
## liqCode           -0.21992    0.10507  -2.093  0.03634 *
## moneyCode:liqCode  0.07460    0.12932   0.577  0.56404
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##            (Intr) monyCd liqCod
## moneyCode   -0.342
## liqCode      0.357 -0.409
## monyCd:lqCd -0.238  0.696 -0.590
```

```r
m.RR.1.SvN.omitrew2<-glmer(formula = subRewarded ~ moneyCode*liqCode + (1+liqCode|subID),
         data = subset(incentive,liqCode!=1 & moneyCode!=0), family=binomial)
summary(m.RR.1.SvN.omitrew2)
```

```
## Generalized linear mixed model fit by maximum likelihood (Laplace
##   Approximation) [glmerMod]
##  Family: binomial  ( logit )
## Formula: subRewarded ~ moneyCode * liqCode + (1 + liqCode | subID)
##    Data: subset(incentive, liqCode != 1 & moneyCode != 0)
##
##      AIC      BIC   logLik deviance df.resid
##   5859.4   5905.0  -2922.7   5845.4     4985
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -3.1607 -1.1038  0.5240  0.6737  1.0795
##
## Random effects:
##  Groups Name        Variance Std.Dev. Corr
##  subID  (Intercept) 0.315569 0.56176
##         liqCode     0.002614 0.05113  -1.00
## Number of obs: 4992, groups:  subID, 39
##
```

```
## Fixed effects:
##                  Estimate Std. Error z value Pr(>|z|)
## (Intercept)       0.87506    0.10105   8.659   <2e-16 ***
## moneyCode         0.08983    0.04466   2.011   0.0443 *
## liqCode          -0.11103    0.06665  -1.666   0.0958 .
## moneyCode:liqCode -0.03339    0.06391  -0.522   0.6013
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##             (Intr) monyCd liqCod
## moneyCode   0.015
## liqCode     0.204  0.024
## monyCd:lqCd 0.011  0.699  0.043
```

```r
m.RR.1.SvN.omitrew4<-glmer(formula = subRewarded ~ moneyCode*liqCode + (1+liqCode|subID),
        data = subset(incentive,liqCode!=1 & moneyCode!=1), family=binomial)
summary(m.RR.1.SvN.omitrew4)
```

```
## Generalized linear mixed model fit by maximum likelihood (Laplace
##   Approximation) [glmerMod]
## Family: binomial  ( logit )
## Formula: subRewarded ~ moneyCode * liqCode + (1 + liqCode | subID)
##    Data: subset(incentive, liqCode != 1 & moneyCode != 1)
##
##      AIC      BIC   logLik deviance df.resid
##   5955.1   6000.7  -2970.6   5941.1     4985
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -2.9838 -1.0739  0.4955  0.7068  1.2931
##
## Random effects:
##  Groups Name        Variance Std.Dev. Corr
##  subID  (Intercept) 0.42429  0.6514
##         liqCode     0.09798  0.3130   0.16
## Number of obs: 4992, groups:  subID, 39
##
## Fixed effects:
##                  Estimate Std. Error z value Pr(>|z|)
## (Intercept)       0.74389    0.12197   6.099 1.07e-09 ***
## moneyCode        -0.05884    0.08840  -0.666   0.5056
## liqCode          -0.21419    0.10417  -2.056   0.0398 *
## moneyCode:liqCode -0.14121    0.12656  -1.116   0.2645
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##             (Intr) monyCd liqCod
## moneyCode   0.359
## liqCode     0.380  0.420
## monyCd:lqCd 0.250  0.698  0.610
```

Error Comission Rate

Plot: mean error rate by monetary reward level

```
ERR.sum=summarySEwithin2(data=rew.means, measurevar = "meanERR", withinvars = c("money"),
                         idvar = "subID")
pandoc.table(ERR.sum)
```

```
##
## ----------------------------------------------------------------------
##  money   N    meanERR   meanERRNormed     sd        se         ci
## ------- ---- --------- --------------- --------- ---------- ----------
##    $     39   0.1581       0.1581       0.03351   0.005365   0.01086
##
##   $$     39   0.148        0.148        0.02785   0.004459   0.009027
##
##  $$$$    39   0.1368       0.1368       0.02937   0.004703   0.00952
## ----------------------------------------------------------------------
```

```
p.ERR.2<-ggplot(ERR.sum, aes(x=money, y=meanERR)) +
  geom_bar(position=position_dodge(width=0.8), color="black",
           fill='darkmagenta', stat="identity", width=0.8) +
  geom_errorbar(position=position_dodge(width=0.8),
                aes(ymin=meanERR-se, ymax=meanERR+se), width=.2) +
  xlab("Monetary Reward") + ylab("Error Rate") +
  ggtitle("Task Performance Across Money") +
  coord_cartesian(ylim=c(0,.25)) +
  scale_fill_discrete(name="Monetary Reward") +
  theme(#plot.title=element_text(size=22,face="bold", vjust=2),
        axis.title=element_text(size=12,face = "bold"),
        axis.text=element_text(size=14),
        legend.position="none",
        strip.text.x = element_text(size = 12))
p.ERR.2
```

Task Performance Across Money
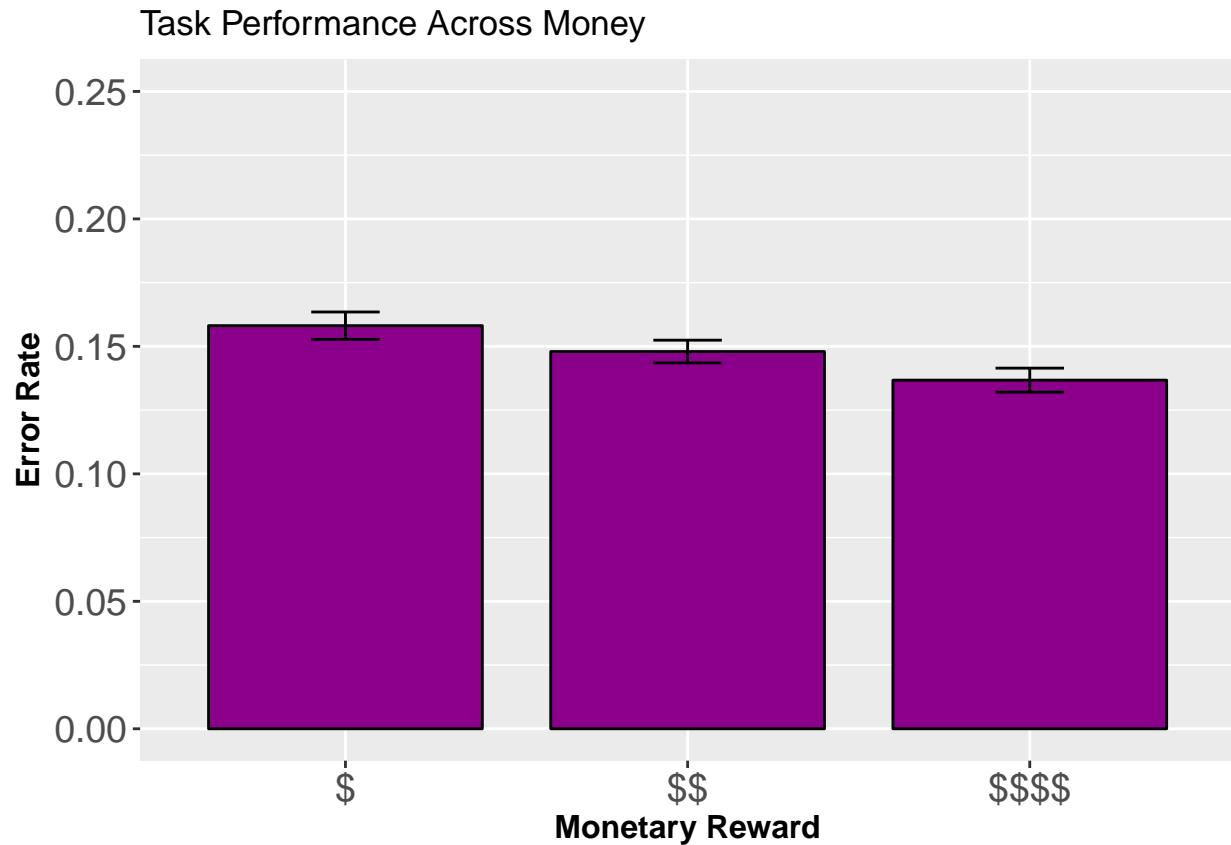
Plot: mean error rate by liquid

```
ERR.sum=summarySEwithin2(data=liq.means, measurevar = "meanERR", withinvars = c("liquid"),
                        idvar = "subID")
pandoc.table(ERR.sum)
```

```
##
## ---------------------------------------------------------------------------
##    liquid     N    meanERR    meanERRNormed      sd        se         ci
## ----------- ---- --------- --------------- --------- ---------- ---------
##    juice     39    0.1504        0.1504       0.03798   0.006081   0.01231
##
##    neutral   39    0.1474        0.1474       0.04502   0.007208   0.01459
##
##  saltwater   39    0.145         0.145        0.05085   0.008143   0.01648
## ---------------------------------------------------------------------------
```

```
p.ERR.2<-ggplot(ERR.sum, aes(x=liquid, y=meanERR)) +
  geom_bar(position=position_dodge(width=0.8), color="black",
          fill='darkmagenta', stat="identity", width=0.8) +
  geom_errorbar(position=position_dodge(width=0.8),
              aes(ymin=meanERR-se, ymax=meanERR+se), width=.2) +
  xlab("Monetary Reward") + ylab("Error Rate") +
  ggtitle("Task Performance Across Liquid Incentive") +
  coord_cartesian(ylim=c(0,.25)) +
  scale_fill_discrete(name="Monetary Reward") +
```

```
theme(#plot.title=element_text(size=22,face="bold", vjust=2),
      axis.title=element_text(size=12,face = "bold"),
      axis.text=element_text(size=14),
      legend.position="none",
      strip.text.x = element_text(size = 12))
p.ERR.2
```

Task Performance Across Liquid Incentive
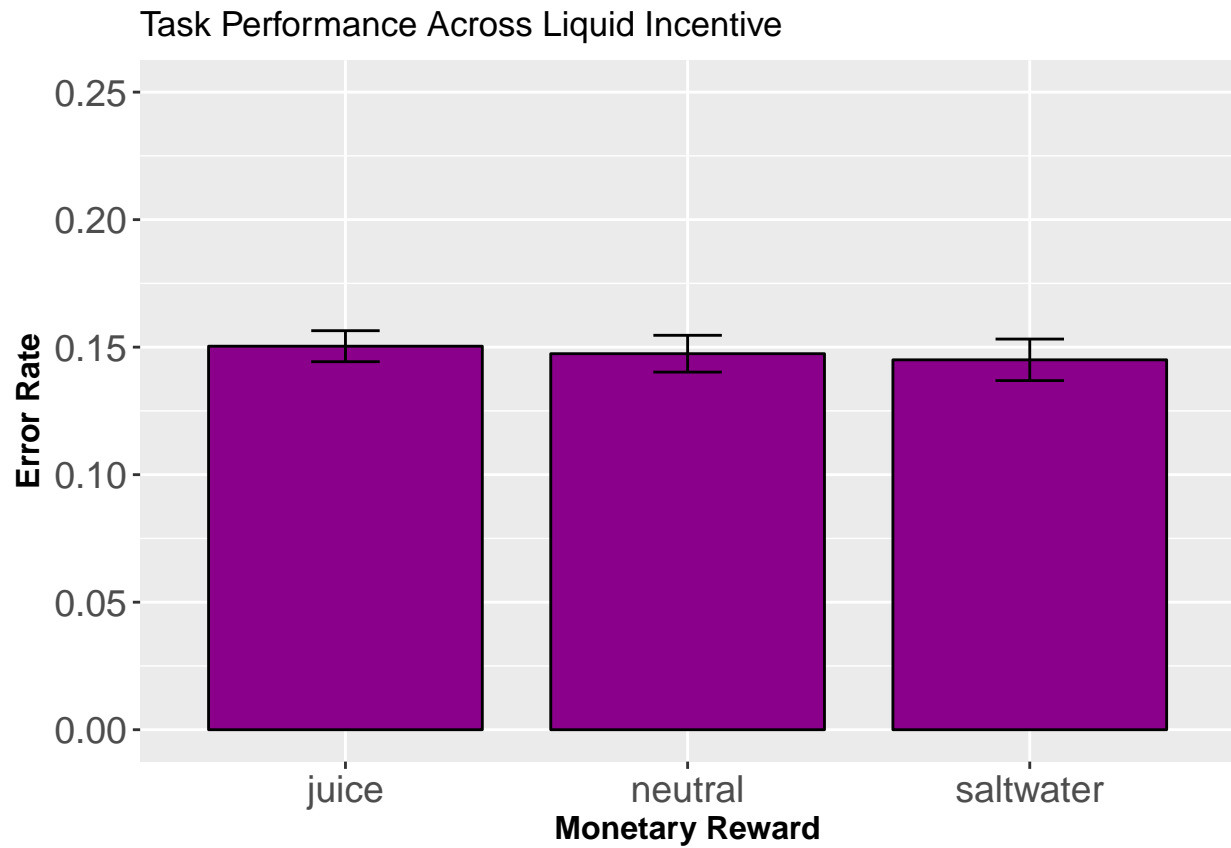
Response Times

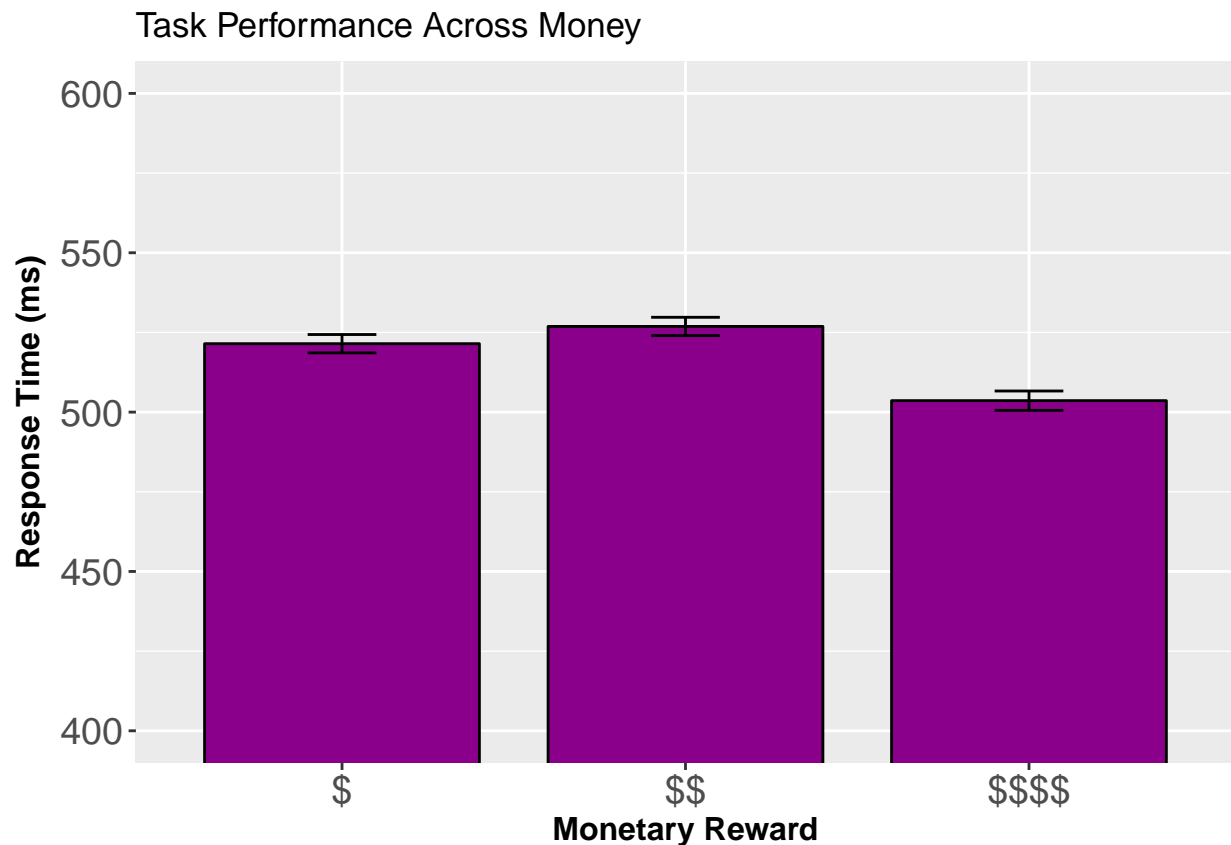## Plot: mean response time by monetary reward level

```
RT.sum=summarySEwithin2(data=rewRT.means, measurevar = "meanRT", withinvars = c("money"),
                        idvar = "subID")
pandoc.table(RT.sum)
```

```
##
## ----------------------------------------------------------
##  money   N    meanRT   meanRTNormed    sd      se     ci
## ------- ---- -------- -------------- ------- ------- -------
##    $     39   521.5       521.5      17.96   2.876   5.821
##
##   $$     39   526.9       526.9      17.95   2.874   5.818
##
##  $$$$    39   503.6       503.6      18.93   3.032   6.137
## ----------------------------------------------------------
```

```
p.RT.1<-ggplot(RT.sum, aes(x=money, y=meanRT)) +
  geom_bar(position=position_dodge(width=0.8), color="black",
           fill='darkmagenta', stat="identity", width=0.8) +
  geom_errorbar(position=position_dodge(width=0.8),
                aes(ymin=meanRT-se, ymax=meanRT+se), width=.2) +
  xlab("Monetary Reward") + ylab("Response Time (ms)") +
  ggtitle("Task Performance Across Money") +
  coord_cartesian(ylim=c(400,600)) +
  scale_fill_discrete(name="Monetary Reward") +
  theme(#plot.title=element_text(size=22,face="bold", vjust=2),
        axis.title=element_text(size=12,face = "bold"),
        axis.text=element_text(size=14),
        legend.position="none",
        strip.text.x = element_text(size = 12))
p.RT.1
```

Task Performance Across Money
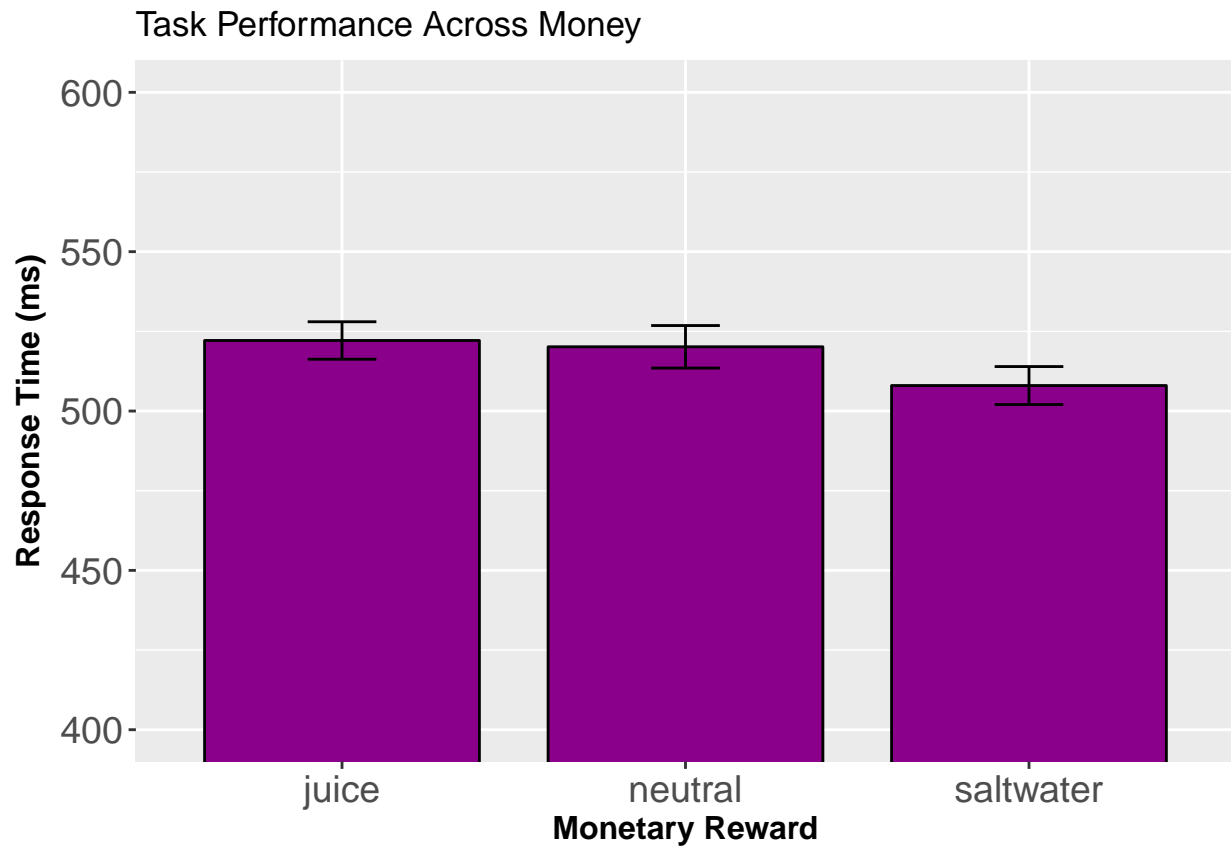

Plot: mean response time by liquid

```
RT.sum=summarySEwithin2(data=liqRT.means, measurevar = "meanRT", withinvars = c("liquid"),
                         idvar = "subID")
pandoc.table(RT.sum)
```

```
##
## -----------------------------------------------------------------
##    liquid    N    meanRT    meanRTNormed    sd      se      ci
## ----------- ---- -------- -------------- ------- ------- -------
##    juice     39   522.1        522.1       36.69   5.875   11.89
##
##   neutral    39   520.2        520.2       41.67   6.673   13.51
##
##  saltwater   39    508          508        37.24   5.963   12.07
## -----------------------------------------------------------------
```

```
p.RT.2<-ggplot(RT.sum, aes(x=liquid, y=meanRT)) +
  geom_bar(position=position_dodge(width=0.8), color="black",
           fill='darkmagenta', stat="identity", width=0.8) +
  geom_errorbar(position=position_dodge(width=0.8),
                aes(ymin=meanRT-se, ymax=meanRT+se), width=.2) +
  xlab("Monetary Reward") + ylab("Response Time (ms)") +
  ggtitle("Task Performance Across Money") +
  coord_cartesian(ylim=c(400,600)) +
  scale_fill_discrete(name="Monetary Reward") +
```

```
    theme(#plot.title=element_text(size=22,face="bold", vjust=2),
          axis.title=element_text(size=12,face = "bold"),
          axis.text=element_text(size=14),
          legend.position="none",
          strip.text.x = element_text(size = 12))
p.RT.2
```


Task Performance Across Money

Plot: mean response time by money and liquid

```
RT.sum=summarySEwithin2(data=incentive9RT.means, measurevar = "meanRT", withinvars = c("money","liquid")
                        idvar = "subID")
pandoc.table(RT.sum)
```

```
##
## ---------------------------------------------------------------------------
## money     liquid     N     meanRT    meanRTNormed     sd       se      ci
## -------   ---------- ----  --------  --------------  -------  -------  -------
##    $        juice     39     528         528         42.23    6.762    13.69
##
##    $        neutral   39    522.7       522.7        43.57    6.977    14.12
##
##    $       saltwater  39    511.9       511.9        33.33    5.337    10.8
##
##   $$        juice     39    529.9       529.9        47.19    7.557    15.3
##
```

```
##   $$      neutral   39    534.6        534.6          60.86  9.746  19.73
##
##   $$    saltwater   39    514.8        514.8          42.95  6.878  13.92
##
##  $$$$      juice    39    509.3        509.3          35.83  5.737  11.61
##
##  $$$$     neutral   39    503.4        503.4          29.52  4.726  9.568
##
##  $$$$   saltwater   39     498          498           42.36  6.783  13.73
## --------------------------------------------------------------------
```

```r
p.RT.3<-ggplot(RT.sum, aes(x=liquid, y=meanRT, fill=money)) +
  geom_bar(position=position_dodge(width=0.8), color="black",
        stat="identity", width=0.8) +
  geom_errorbar(position=position_dodge(width=0.8),
             aes(ymin=meanRT-se, ymax=meanRT+se), width=.2) +
  xlab("Monetary Reward") + ylab("Response Time (ms)") +
  #ggtitle("Response Time (ms)") +
  coord_cartesian(ylim=c(400,600)) +
  scale_fill_discrete(name="Monetary Reward") +
  theme(#plot.title=element_text(size=22,face="bold", vjust=2),
        axis.title=element_text(size=12,face = "bold"),
        axis.text=element_text(size=14),
        legend.position="none",
        strip.text.x = element_text(size = 12))
p.RT.3
```


29
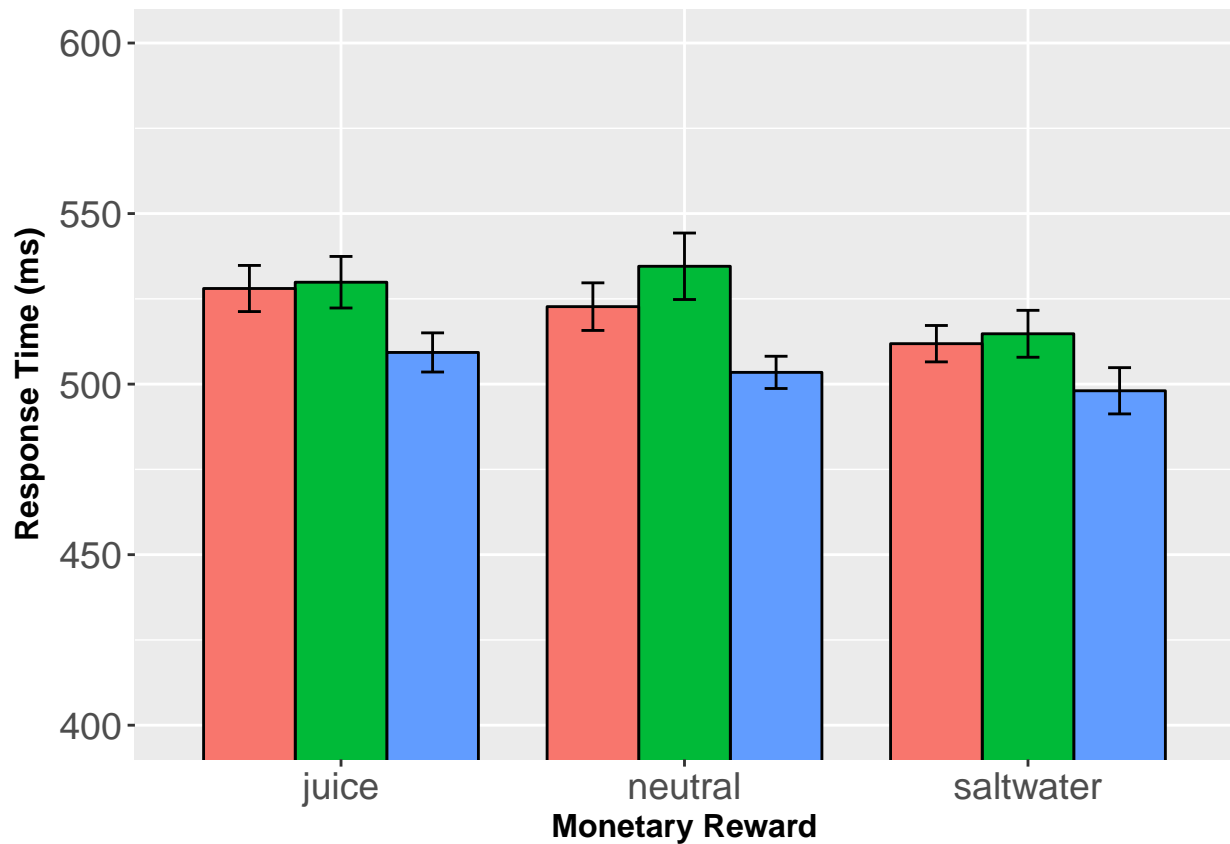
GLM RT

Running a general linear model on the response time reveal a significant effect of monetary reward (no surprise), and a marginal effect of liquid. RT appears to be slightly faster in the saltwater condition, and it appears that the presence of saltwater increase motivation in the low and medium reward value trials, whereas the motivational vigor is more disparate with the other liquids.

```
# omnibus model: reward rate by liquid and money
incentive.RT<-filter(incentive, ACC==1)
m.RT.1<-lmer(formula = RT ~ moneyCode*liqCode + (1+moneyCode+liqCode|subID),
             data = incentive.RT,REML=FALSE)
summary(m.RT.1)
```

```
## Linear mixed model fit by maximum likelihood t-tests use Satterthwaite
##   approximations to degrees of freedom [lmerMod]
## Formula: RT ~ moneyCode * liqCode + (1 + moneyCode + liqCode | subID)
##    Data: incentive.RT
##
##      AIC      BIC   logLik deviance df.resid
## 123087.5 123166.4 -61532.8 123065.5     9563
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -2.5036 -0.5737 -0.1775  0.3287  9.2812
##
## Random effects:
##  Groups   Name        Variance Std.Dev. Corr
##  subID    (Intercept)  7506.73  86.64
##           moneyCode      35.76   5.98   -0.42
##           liqCode       476.31  21.82    0.25 -0.24
##  Residual            21837.58 147.78
## Number of obs: 9574, groups:  subID, 39
##
## Fixed effects:
##                   Estimate Std. Error       df t value Pr(>|t|)
## (Intercept)        517.211     13.956   39.000  37.059  < 2e-16 ***
## moneyCode           -8.549      2.085   38.000  -4.101 0.000207 ***
## liqCode              6.959      3.957   39.000   1.758 0.086465 .
## moneyCode:liqCode   -1.025      2.268 9488.000  -0.452 0.651309
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##             (Intr) monyCd liqCod
## moneyCode   -0.195
## liqCode      0.217 -0.099
## monyCd:lqCd  0.000  0.004 -0.006
```

Switch Cost Effects

Plotting the Switch Costs

```
data.switch<-incentive %>% group_by(subID,money,taskSwitch) %>%
  filter(!is.na(subRewarded),trial!=1) %>%
  summarise(meanRT=mean(RT)) %>%
  mutate(taskSwitch=factor(taskSwitch, levels=c(0,1), labels=c("taskrepeat","taskswitch"))) %>%
  spread(key = taskSwitch, value=meanRT) %>%
  mutate(meanRT=taskswitch-taskrepeat)

RT.sum=summarySEwithin2(data=data.switch, measurevar = "meanRT", withinvars = c("money"),
                        idvar = "subID")
pandoc.table(RT.sum)
```

```
##
## -----------------------------------------------------------
##  money   N    meanRT    meanRTNormed    sd      se      ci
## ------- ---- --------- -------------- ------- ------- -------
##    $     39   19.95        19.95       28.88   4.625   9.362
##
##    $$    39   9.968        9.968       37.47   6.001   12.15
##
##  $$$$    39   7.042        7.042       33.8    5.413   10.96
## -----------------------------------------------------------
```

```
p.switch.1<-ggplot(RT.sum, aes(x=money, y=meanRT)) +
  geom_bar(position=position_dodge(width=0.8), color="black",stat="identity", width=0.8) +
  geom_errorbar(position=position_dodge(width=0.8),
                aes(ymin=meanRT-se, ymax=meanRT+se), width=.2) +
  #facet_grid(.~money) +
  xlab("Monetary Reward") + ylab("Response Time") +
  ggtitle("Task Switch Costs") +
  #coord_cartesian(ylim=c(400,600)) +
  scale_fill_discrete(name="Task Switch") +
  theme(#plot.title=element_text(size=22,face="bold", vjust=2),
        axis.title=element_text(size=12,face = "bold"),
        axis.text=element_text(size=14),
        #legend.position="none",
        strip.text.x = element_text(size = 12))
p.switch.1
```
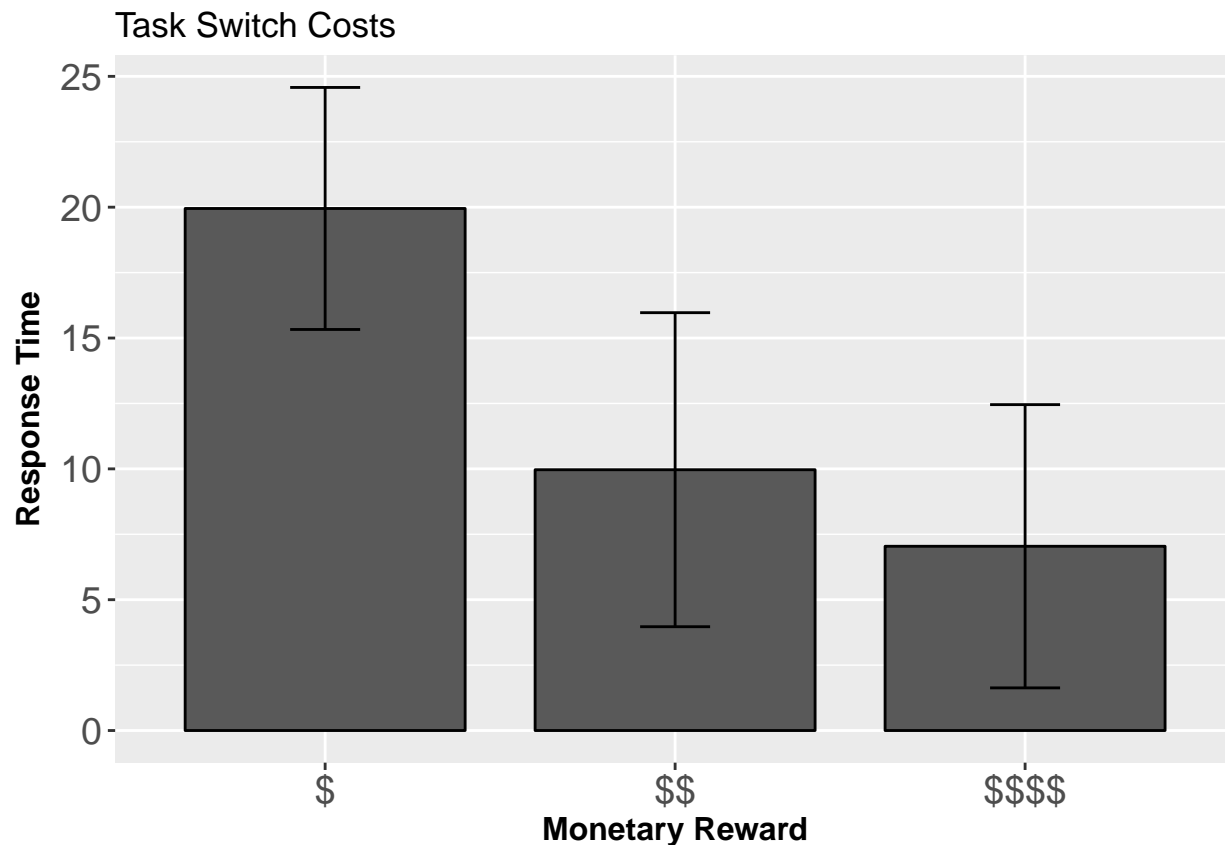
GLMM on the Switch Costs

It appears that switch costs are modulated by task switches, monetary reward, as well as an tineraction between the two

```
# Is Reward Rate predicted by task switches? yes.
m.switch.1<-glmer(formula = subRewarded ~ taskSwitch + (1|subID),
                  data = incentive, family = binomial)
summary(m.switch.1)
```

```
## Generalized linear mixed model fit by maximum likelihood (Laplace
##   Approximation) [glmerMod]
##  Family: binomial  ( logit )
## Formula: subRewarded ~ taskSwitch + (1 | subID)
##    Data: incentive
##
##      AIC      BIC   logLik deviance df.resid
##  13253.3  13275.3  -6623.7  13247.3    11229
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -3.2182 -1.1042  0.5056  0.7198  1.1392
##
## Random effects:
##  Groups Name        Variance Std.Dev.
##  subID  (Intercept) 0.3824   0.6184
```

```
## Number of obs: 11232, groups:  subID, 39
##
## Fixed effects:
##             Estimate Std. Error z value Pr(>|z|)
## (Intercept)  0.96503    0.10373   9.303  < 2e-16 ***
## taskSwitch  -0.17908    0.04222  -4.242 2.22e-05 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##           (Intr)
## taskSwitch -0.210
```

```r
#Full Model (money,liquid,task switch)
m.switch.2<-glmer(formula = subRewarded ~ taskSwitch*moneyCode*liqCode + (1+moneyCode+liqCode|subID),
                  data = incentive, family = binomial)
summary(m.switch.2)
```

```
## Generalized linear mixed model fit by maximum likelihood (Laplace
##   Approximation) [glmerMod]
## Family: binomial  ( logit )
## Formula:
## subRewarded ~ taskSwitch * moneyCode * liqCode + (1 + moneyCode +
##     liqCode | subID)
##    Data: incentive
##
##      AIC      BIC   logLik deviance df.resid
##  13219.0  13321.6  -6595.5  13191.0    11218
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -3.3875 -1.0691  0.4987  0.7052  1.3288
##
## Random effects:
##  Groups Name        Variance Std.Dev. Corr
##  subID  (Intercept) 0.388903 0.62362
##         moneyCode   0.006218 0.07885   0.08
##         liqCode     0.019069 0.13809  -0.22  0.45
## Number of obs: 11232, groups:  subID, 39
##
## Fixed effects:
##                           Estimate Std. Error z value Pr(>|z|)
## (Intercept)               0.971050   0.104615   9.282  < 2e-16 ***
## taskSwitch               -0.176227   0.042414  -4.155 3.25e-05 ***
## moneyCode                 0.089062   0.040042   2.224   0.0261 *
## liqCode                  -0.067031   0.044009  -1.523   0.1277
## taskSwitch:moneyCode      0.100396   0.051985   1.931   0.0535 .
## taskSwitch:liqCode       -0.032598   0.051974  -0.627   0.5305
## moneyCode:liqCode        -0.009129   0.045642  -0.200   0.8415
## taskSwitch:moneyCode:liqCode 0.100688 0.063692   1.581   0.1139
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##             (Intr) tskSwt monyCd liqCod tskSwtch:mC tskSwtch:lC mnyC:C
```

33

```
## taskSwitch  -0.209
## moneyCode    0.033 -0.016
## liqCode     -0.114  0.014  0.069
## tskSwtch:mC -0.005  0.034 -0.669  0.003
## tskSwtch:lC  0.005 -0.023  0.003 -0.609  0.005
## monyCd:lqCd -0.001  0.002 -0.024  0.024  0.017    -0.019
## tskSwtc:C:C  0.001  0.005  0.015 -0.014 -0.023     0.034     -0.715
```

```r
# Money and Task Switching
m.switch.3<-glmer(formula = subRewarded ~ taskSwitch*moneyCode + (1+moneyCode|subID),
                  data = incentive, family = binomial)
summary(m.switch.3)
```

```
## Generalized linear mixed model fit by maximum likelihood (Laplace
##   Approximation) [glmerMod]
##  Family: binomial  ( logit )
## Formula: subRewarded ~ taskSwitch * moneyCode + (1 + moneyCode | subID)
##    Data: incentive
##
##      AIC      BIC   logLik deviance df.resid
##  13227.5  13278.7  -6606.7  13213.5    11225
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -3.3588 -1.0951  0.5041  0.7095  1.2461
##
## Random effects:
##  Groups Name        Variance Std.Dev. Corr
##  subID  (Intercept) 0.385673 0.62103
##         moneyCode   0.006321 0.07951  0.08
## Number of obs: 11232, groups:  subID, 39
##
## Fixed effects:
##                     Estimate Std. Error z value Pr(>|z|)
## (Intercept)          0.96743    0.10415   9.289   <2e-16 ***
## taskSwitch          -0.17664    0.04233  -4.173    3e-05 ***
## moneyCode            0.08854    0.04002   2.212   0.0269 *
## taskSwitch:moneyCode 0.10204    0.05187   1.967   0.0492 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##             (Intr) tskSwt monyCd
## taskSwitch  -0.209
## moneyCode    0.032 -0.016
## tskSwtch:mC -0.005  0.036 -0.668
```