Data Analysis for Punishment is Slower than Cooperation or Defection

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1. Setup

Load required packages

```
library(tidyverse)
library(igraph)
library(lme4)
library(lmerTest)
library(DescTools)
library(data.table)
library(patchwork)
library(stringr)
library(ggpattern)
library(magick)
library(broom.mixed)
library(simr)
```

Load required data

```
## Experiment 1
exp1data = read_csv("~/Documents/Projects/harming_esn/data/final/exp1data_rev3.csv",
                    show_col_types = FALSE)

## Experiment 2
exp2data = read_csv("~/Documents/Projects/harming_esn/data/final/exp2data_rev3.csv",
                    show_col_types = FALSE)
```

Create helper functions

```
mean1 = function(x) {mean(x,na.rm=TRUE)}
median1 = function(x) {median(x, na.rm = TRUE)}
sd1 = function(x) {sd(x, na.rm = TRUE)}
se_mean = function(x) sd1(x)/sqrt(sum(is.na(x) == 0))
```

2. Analysis

Number of observations per experiment

Experiment 1

```
# Experiment 1
exp1data %>%
  filter(round > 0, is.na(behavior) == F) %>%
  nrow()
```

```
[1] 9776
```

Experiment 2

```
# Experiment 2
exp2data %>%
  filter(round > 0, is.na(behavior) == F) %>%
  nrow()
```

```
[1] 10654
```

Per-game characteristics

Experiment 1

```
exp1data %>%
  filter(round >= 1) %>%
  group_by(game) %>%
  select(superid) %>%
  unique() %>%
  nrow()
```

```
[1] 719
```

```
exp1data %>%
  filter(round >= 1) %>%
  group_by(game) %>%
  select(superid) %>%
  unique() %>%
  summarize(n = n()) %>%
  summarize(`Mean Players` = mean(n),
            `Min Players` = min(n),
            `Max Players` = max(n))
```

```
# A tibble: 1 x 3
  `Mean Players` `Min Players` `Max Players`
           <dbl>         <int>         <int>
1           14.4             8            25
```

Experiment 2

```
# Players per game, min, max - Experiment 2
exp2data %>%
  filter(round >=0) %>%
  group_by(game) %>%
  select(superid) %>%
  unique() %>%
  summarize(n = n()) %>%
  summarize(`Mean Players` = mean(n),
            `Min Players` = min(n),
            `Max Players` = max(n))
```

```
# A tibble: 1 x 3
  `Mean Players` `Min Players` `Max Players`
           <dbl>         <int>         <int>
1           14.8             8            20
```

Number of observations in Exp. 2, TP+/TP- settings

```
exp2data %>%
  filter(time_pressure == "Plus", round >= 1, behavior %in% c("C", "D", "P")) %>%
  nrow()
```

```
[1] 5407
```

```
exp2data %>%
  filter(time_pressure == "Minus", round >= 1, behavior %in% c("C", "D", "P")) %>%
  nrow()
```

```
[1] 5247
```

```
# Number of players per condition in Experiment 2
exp2data %>%
  filter(round >= 1, behavior %in% c("C", "D", "P")) %>%
  group_by(time_pressure) %>%
  select(superid) %>%
  unique() %>%
  count()
```

```
Adding missing grouping variables: `time_pressure`

# A tibble: 2 x 2
# Groups:   time_pressure [2]
  time_pressure     n
  <chr>         <int>
1 Minus           366
2 Plus            372
```

Distribution of decision-making

Experiment 1

```
# Decision distribution - Experiment 1
data1_behavior_count = exp1data %>%
  filter(round >= 1) %>%
  group_by(behavior) %>%
  filter(behavior %in% c("C", "D", "P")) %>%
  summarize(count = n()) %>%
  ungroup() %>%
  mutate(proportion = count/sum(count))

# Confidence Intervals
data1_behavior_CI = MultinomCI(x = c(4878, 4336, 562), sides = "two.sided") %>%
  as_tibble()
```

Experiment 2

```
# Decision distribution - Experiment 2
exp2data_count = exp2data %>% filter(round >= 1) %>%
  group_by(behavior) %>%
  filter(behavior %in% c("C", "D", "P")) %>%
  summarize(count = n()) %>%
  ungroup() %>%
  mutate(proportion = count/sum(count))

exp2data_all_CI = MultinomCI(c(4185, 5790, 679), sides = "two.sided")
```

```
exp2data_tp_plus_count = exp2data %>%
  group_by(behavior) %>%
  filter(time_pressure == "Plus", behavior %in% c("C", "D", "P")) %>%
  summarize(count = n()) %>%
  ungroup() %>%
  mutate(proportion = count/sum(count))

exp2data_tp_plus_CI = MultinomCI(c(2172, 2897, 338), sides = "two.sided")

exp2data_tp_plus_times = exp2data %>%
  group_by(behavior) %>%
  filter(time_pressure == "Plus", behavior %in% c("C", "D", "P")) %>%
  summarize(mean_dt = mean1(behaviorTime_sec),
            se_mean_dt = se_mean(behaviorTime_sec),
            LL_mean = mean_dt - 1.96*se_mean_dt,
            UL_mean = mean_dt + 1.96*se_mean_dt)

exp2data_tp_minus_count = exp2data %>%
  group_by(behavior) %>%
  filter(time_pressure == "Minus", behavior %in% c("C", "D", "P")) %>%
  summarize(count = n()) %>%
  ungroup() %>%
  mutate(proportion = count/sum(count))

exp2data_tp_minus_times = exp2data %>%
  group_by(behavior) %>%
  filter(time_pressure == "Minus", behavior %in% c("C", "D", "P")) %>%
  summarize(mean_dt = mean1(behaviorTime_sec),
            se_mean_dt = se_mean(behaviorTime_sec),
            LL_mean = mean_dt - 1.96*se_mean_dt,
            UL_mean = mean_dt + 1.96*se_mean_dt)
```

```
exp2data_tp_minus_CI = MultinomCI(c(2013, 2893, 341), sides = "two.sided")
```

```
# Behavior breakdown - Experiment B, TP-
exp2data_tp_minus_count = exp2data %>%
  group_by(behavior) %>%
  filter(time_pressure == "Minus", behavior %in% c("C", "D", "P")) %>%
  summarize(count = n()) %>%
  ungroup() %>%
  mutate(proportion = count/sum(count))

exp2data_tp_minus_CI = MultinomCI(c(2013, 2893, 341), sides = "two.sided")
```

```
# Behavior breakdown - Experiment B, TP+
exp2data_tp_plus_count = exp2data %>%
  group_by(behavior) %>%
  filter(time_pressure == "Plus", behavior %in% c("C", "D", "P")) %>%
  summarize(count = n()) %>%
  ungroup() %>%
  mutate(proportion = count/sum(count))

exp2data_tp_plus_CI = MultinomCI(c(2172, 2897, 338), sides = "two.sided")
```

Network characteristics

Experiment 1

```
mean1(exp1data$degree)
```

```
[1] 5.911319
```

```
min(exp1data$degree, na.rm = T)
```

```
[1] 1
```

```
max(exp1data$degree, na.rm = T)
```

```
[1] 17
```

Experiment 2

```
mean1(exp2data$degree)
```

```
[1] 5.721265
```

```
min(exp2data$degree, na.rm = T)
```

```
[1] 1
```

```
max(exp2data$degree, na.rm = T)
```

```
[1] 16
```

Decision times

Experiment 1

```
data1_times = exp1data %>%
  group_by(behavior) %>%
  filter(behavior %in% c("C", "D", "P")) %>%
  summarize(mean_dt = mean1(behaviorTime_sec),
            se_mean_dt = se_mean(behaviorTime_sec),
            LL_mean = mean_dt - 1.96*se_mean_dt,
            UL_mean = mean_dt + 1.96*se_mean_dt)
```

```
exp1data %>%
  filter(local_rate_punish_lag > 0.25, behavior %in% c("C", "D", "P")) %>%
  group_by(behavior) %>%
  summarize(mean_dt = mean1(behaviorTime_sec),
            se_mean_dt = se_mean(behaviorTime_sec),
            LL_mean = mean_dt - 1.96*se_mean_dt,
            UL_mean = mean_dt + 1.96*se_mean_dt)
```

```
# A tibble: 3 x 5
  behavior mean_dt se_mean_dt LL_mean UL_mean
  <chr>      <dbl>      <dbl>   <dbl>   <dbl>
1 C           7.19      1.05     5.14    9.24
2 D           4.57      0.298    3.99    5.16
3 P           5.45      1.19     3.12    7.77
```

Experiment 2

```
exp2data %>%
  group_by(behavior, time_pressure) %>%
  filter(behavior %in% c("C", "D", "P")) %>%
  summarize(mean_dt = mean1(behaviorTime_sec),
            se_mean_dt = se_mean(behaviorTime_sec),
            UL_mean = mean_dt + 1.96*se_mean_dt,
            LL_mean = mean_dt - 1.96*se_mean_dt)
```

```
`summarise()` has grouped output by 'behavior'. You can override using the
`.groups` argument.
```

```
# A tibble: 6 x 6
# Groups:   behavior [3]
  behavior time_pressure mean_dt se_mean_dt UL_mean LL_mean
  <chr>    <chr>           <dbl>      <dbl>   <dbl>   <dbl>
1 C        Minus            3.13    0.0537     3.24    3.03
2 C        Plus             2.02    0.00987    2.04    2.00
3 D        Minus            2.85    0.0419     2.93    2.77
4 D        Plus             1.92    0.00826    1.94    1.91
5 P        Minus            3.82    0.203      4.22    3.42
6 P        Plus             2.11    0.0301     2.17    2.05
```

3. Regression Modeling

Punishment vs. time pressure

```
m1 = glmer(behavior_punish ~ time_pressure + round + (1|game) + (1|superid),
           data = exp2data %>% filter(round > 0), family = binomial, nAGQ=0,
           control = glmerControl(optimizer = c("bobyqa"),
                                  optCtrl=list(maxfun=2e5),
                                  calc.derivs=FALSE))
summary(m1)
```

```
Generalized linear mixed model fit by maximum likelihood (Adaptive
  Gauss-Hermite Quadrature, nAGQ = 0) [glmerMod]
 Family: binomial  ( logit )
Formula: behavior_punish ~ time_pressure + round + (1 | game) + (1 | superid)
```

```
   Data: exp2data %>% filter(round > 0)
Control: glmerControl(optimizer = c("bobyqa"), optCtrl = list(maxfun = 2e+05),
    calc.derivs = FALSE)

     AIC      BIC   logLik deviance df.resid
  3639.8   3676.2  -1814.9   3629.8    10742

Scaled residuals:
    Min      1Q  Median      3Q     Max
-2.9801 -0.1020 -0.0884 -0.0793  4.6005

Random effects:
 Groups  Name        Variance Std.Dev.
 superid (Intercept) 6.908    2.6283
 game    (Intercept) 0.641    0.8006
Number of obs: 10747, groups:  superid, 739; game, 50

Fixed effects:
                  Estimate Std. Error z value Pr(>|z|)
(Intercept)       -3.69099    0.25747 -14.335   <2e-16 ***
time_pressurePlus -0.24888    0.34838  -0.714   0.4750
round             -0.02644    0.01120  -2.362   0.0182 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
            (Intr) tm_prP
tm_prssrPls -0.661
round       -0.324 -0.001
```

```
# p = 0.475
```

Cooperation vs. time pressure

```
m1.1 = glmer(behavior_coop ~ time_pressure + round + (1|game) + (1|superid),
             data = exp2data %>% filter(round > 0), family = binomial, nAGQ=0,
             control = glmerControl(optimizer = c("bobyqa"),
                                    optCtrl=list(maxfun=2e5),
                                    calc.derivs=FALSE))
summary(m1.1)
```

```
Generalized linear mixed model fit by maximum likelihood (Adaptive
  Gauss-Hermite Quadrature, nAGQ = 0) [glmerMod]
 Family: binomial  ( logit )
Formula: behavior_coop ~ time_pressure + round + (1 | game) + (1 | superid)
   Data: exp2data %>% filter(round > 0)
Control: glmerControl(optimizer = c("bobyqa"), optCtrl = list(maxfun = 2e+05),
    calc.derivs = FALSE)

     AIC      BIC   logLik deviance df.resid
  6102.1   6138.5  -3046.0   6092.1    10742

Scaled residuals:
    Min      1Q  Median      3Q     Max
-4.2875 -0.1092 -0.0839  0.1164  4.4511

Random effects:
 Groups  Name        Variance Std.Dev.
 superid (Intercept) 27.00    5.196
 game    (Intercept)  2.42    1.556
Number of obs: 10747, groups:  superid, 739; game, 50

Fixed effects:
                   Estimate Std. Error z value Pr(>|z|)
(Intercept)       -0.815089   0.434020  -1.878   0.0604 .
time_pressurePlus  0.265534   0.605401   0.439   0.6609
round             -0.048143   0.008987  -5.357 8.46e-08 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
            (Intr) tm_prP
tm_prssrPls -0.699
round       -0.157 -0.002
```

```
# p = 0.661
```

Power calculation for Experiment 2

We are interested here in the power of Experiment 2 to detect differences in the rate of cooperation. A simulation-based approach for determining power is used due to the hierarchical structure fo the experimental data.

```
# Use model 1.1 as the baseline
m1.1_pwr = m1.1
round(summary(m1.1_pwr)$coef, 4)
```

```
                  Estimate Std. Error z value Pr(>|z|)
(Intercept)        -0.8151     0.4340 -1.8780   0.0604
time_pressurePlus   0.2655     0.6054  0.4386   0.6609
round              -0.0481     0.0090 -5.3571   0.0000
```

We want to estimate the ability of Exp. 2 to determine an 11.7% increase in cooperation relative to the deliberative condition. In this case, the deliberative condition is the TP- setting (the reference group for the time pressure variable in model 1.1).

```
fixef(m1.1_pwr)['time_pressurePlus'] = 0.608
# powerSim(m1.1_pwr, nsim = 1000) #not run
```

Defection vs. time pressure

```
m1.2 = glmer(behavior_defect ~ time_pressure + round + (1|game) + (1|superid),
             data = exp2data %>% filter(round > 0), family = binomial, nAGQ=0,
             control = glmerControl(optimizer = c("bobyqa"),
                                    optCtrl=list(maxfun=2e5),
                                    calc.derivs=FALSE))

summary(m1.2)
```

```
Generalized linear mixed model fit by maximum likelihood (Adaptive
  Gauss-Hermite Quadrature, nAGQ = 0) [glmerMod]
 Family: binomial  ( logit )
Formula: behavior_defect ~ time_pressure + round + (1 | game) + (1 | superid)
   Data: exp2data %>% filter(round > 0)
Control: glmerControl(optimizer = c("bobyqa"), optCtrl = list(maxfun = 2e+05),
    calc.derivs = FALSE)

     AIC      BIC   logLik deviance df.resid
  5658.6   5695.0  -2824.3   5648.6    10742

Scaled residuals:
    Min      1Q  Median      3Q     Max
```

```
-4.5487 -0.1017  0.0728  0.1006  4.4163

Random effects:
 Groups  Name        Variance Std.Dev.
 superid (Intercept) 35.060   5.921
 game    (Intercept)  3.392   1.842
Number of obs: 10747, groups:  superid, 739; game, 50

Fixed effects:
                   Estimate Std. Error z value Pr(>|z|)
(Intercept)        0.034318   0.502767   0.068    0.946
time_pressurePlus -0.216417   0.703294  -0.308    0.758
round              0.055394   0.009602   5.769 7.97e-09 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
            (Intr) tm_prP
tm_prssrPls -0.699
round       -0.147 -0.002
```

```
# p = 0.758
```

Decision times vs. time pressure (not useful)

```
model_dt_coop = lmer(behaviorTime_sec ~ time_pressure + round + (1|game) + (1|superid),
                     data = exp2data %>% filter(round > 0, behavior_coop == 1))
summary(model_dt_coop)
```

```
Linear mixed model fit by REML. t-tests use Satterthwaite's method [
lmerModLmerTest]
Formula: behaviorTime_sec ~ time_pressure + round + (1 | game) + (1 |
    superid)
   Data: exp2data %>% filter(round > 0, behavior_coop == 1)

REML criterion at convergence: 13885.1

Scaled residuals:
    Min      1Q  Median      3Q     Max
-3.8000 -0.2551 -0.0807  0.1074 21.7822
```

```
Random effects:
 Groups   Name        Variance Std.Dev.
 superid  (Intercept) 1.15374  1.0741
 game     (Intercept) 0.06439  0.2538
 Residual             2.33938  1.5295
Number of obs: 3588, groups:  superid, 432; game, 50

Fixed effects:
                    Estimate Std. Error         df t value Pr(>|t|)
(Intercept)        3.404e+00  1.107e-01  5.194e+01  30.744  < 2e-16 ***
time_pressurePlus -1.275e+00  1.435e-01  3.649e+01  -8.887 1.17e-10 ***
round             -8.243e-03  6.150e-03  3.285e+03  -1.340     0.18
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
            (Intr) tm_prP
tm_prssrPls -0.627
round       -0.423 -0.014
```

```
model_dt_def = lmer(behaviorTime_sec ~ time_pressure + round + (1|game) + (1|superid),
                    data = exp2data %>% filter(round > 0, behavior_defect == 1))
summary(model_dt_def)
```

```
Linear mixed model fit by REML. t-tests use Satterthwaite's method [
lmerModLmerTest]
Formula: behaviorTime_sec ~ time_pressure + round + (1 | game) + (1 |
    superid)
   Data: exp2data %>% filter(round > 0, behavior_defect == 1)

REML criterion at convergence: 19604.6

Scaled residuals:
    Min      1Q  Median      3Q     Max
-5.6180 -0.2482 -0.0776  0.1050 27.1570

Random effects:
 Groups   Name        Variance Std.Dev.
 superid  (Intercept) 0.945248 0.97224
 game     (Intercept) 0.001146 0.03385
 Residual             2.171540 1.47361
```

```
Number of obs: 5200, groups:  superid, 509; game, 50

Fixed effects:
                    Estimate Std. Error         df t value Pr(>|t|)
(Intercept)        3.162e+00  7.875e-02  7.030e+01  40.155  < 2e-16 ***
time_pressurePlus -1.055e+00  9.991e-02  4.290e+01 -10.564 1.64e-13 ***
round             -1.729e-02  4.853e-03  4.794e+03  -3.563 0.000371 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
            (Intr) tm_prP
tm_prssrPls -0.593
round       -0.489 -0.014
```

```
model_dt_pun = lmer(behaviorTime_sec ~ time_pressure + round + (1|game) + (1|superid),
                    data = exp2data %>% filter(round > 0, behavior_punish == 1))
```

```
boundary (singular) fit: see help('isSingular')
```

```
summary(model_dt_pun)
```

```
Linear mixed model fit by REML. t-tests use Satterthwaite's method [
lmerModLmerTest]
Formula: behaviorTime_sec ~ time_pressure + round + (1 | game) + (1 |
    superid)
   Data: exp2data %>% filter(round > 0, behavior_punish == 1)

REML criterion at convergence: 2607.7

Scaled residuals:
    Min      1Q  Median      3Q     Max
-2.9474 -0.2663 -0.0885  0.0699  9.1708

Random effects:
 Groups   Name        Variance Std.Dev.
 superid  (Intercept) 3.673    1.917
 game     (Intercept) 0.000    0.000
 Residual             6.146    2.479
Number of obs: 525, groups:  superid, 176; game, 49
```

```
Fixed effects:
                   Estimate Std. Error        df t value Pr(>|t|)
(Intercept)         4.17743    0.32280 283.53251  12.941  < 2e-16 ***
time_pressurePlus  -1.87849    0.39484 127.32898  -4.758 5.23e-06 ***
round              -0.01823    0.02866 450.29088  -0.636    0.525
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
            (Intr) tm_prP
tm_prssrPls -0.437
round       -0.637 -0.077
optimizer (nloptwrap) convergence code: 0 (OK)
boundary (singular) fit: see help('isSingular')
```

Punishment mechanisms vs. time pressure

Punishment for copying/retaliation

```r
m2.1 = glmer(punish_type_CR ~ time_pressure + round + (1|game) + (1|superid),
             data = exp2data %>% filter(round > 0), family = binomial, nAGQ=0,
             control = glmerControl(optimizer = c("bobyqa"),
                                    optCtrl=list(maxfun=2e5),
                                    calc.derivs=FALSE))

summary(m2.1)
```

```
Generalized linear mixed model fit by maximum likelihood (Adaptive
  Gauss-Hermite Quadrature, nAGQ = 0) [glmerMod]
 Family: binomial  ( logit )
Formula: punish_type_CR ~ time_pressure + round + (1 | game) + (1 | superid)
   Data: exp2data %>% filter(round > 0)
Control: glmerControl(optimizer = c("bobyqa"), optCtrl = list(maxfun = 2e+05),
    calc.derivs = FALSE)

     AIC      BIC   logLik deviance df.resid
  1559.8   1596.2   -774.9   1549.8    10742

Scaled residuals:
    Min      1Q  Median      3Q     Max
-1.1200 -0.1048 -0.0669 -0.0467  6.6001
```

```
Random effects:
 Groups  Name        Variance Std.Dev.
 superid (Intercept) 2.722    1.650
 game    (Intercept) 2.117    1.455
Number of obs: 10747, groups:  superid, 739; game, 50

Fixed effects:
                  Estimate Std. Error z value Pr(>|z|)
(Intercept)       -5.15894    0.38747 -13.315   <2e-16 ***
time_pressurePlus -0.07021    0.50659  -0.139     0.89
round              0.02031    0.01840   1.104     0.27
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
            (Intr) tm_prP
tm_prssrPls -0.647
round       -0.392  0.000
```

```
# p = 0.89
```

Punishment for negative reinforcement

```
m2.2 = glmer(punish_type_NR ~ time_pressure + round + (1|game) + (1|superid),
             data = exp2data %>% filter(round > 0), family = binomial, nAGQ=0,
             control = glmerControl(optimizer = c("bobyqa"),
                                    optCtrl=list(maxfun=2e5),
                                    calc.derivs=FALSE))

summary(m2.2)
```

```
Generalized linear mixed model fit by maximum likelihood (Adaptive
  Gauss-Hermite Quadrature, nAGQ = 0) [glmerMod]
 Family: binomial  ( logit )
Formula: punish_type_NR ~ time_pressure + round + (1 | game) + (1 | superid)
   Data: exp2data %>% filter(round > 0)
Control: glmerControl(optimizer = c("bobyqa"), optCtrl = list(maxfun = 2e+05),
    calc.derivs = FALSE)

     AIC      BIC   logLik deviance df.resid
```

```
  2747.8   2784.2  -1368.9   2737.8    10742

Scaled residuals:
    Min      1Q  Median      3Q     Max
-1.5280 -0.1039 -0.0845 -0.0722  5.0321

Random effects:
 Groups  Name        Variance Std.Dev.
 superid (Intercept) 4.903    2.214
 game    (Intercept) 1.007    1.004
Number of obs: 10747, groups:  superid, 739; game, 50

Fixed effects:
                  Estimate Std. Error z value Pr(>|z|)
(Intercept)       -4.55764    0.29037 -15.696   <2e-16 ***
time_pressurePlus -0.18463    0.38230  -0.483   0.6291
round              0.03579    0.01325   2.702   0.0069 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
            (Intr) tm_prP
tm_prssrPls -0.647
round       -0.384  0.000
```

```
# p = 0.629
```

Punishment for inequality aversion

```
m2.3 = glmer(punish_type_IA ~ time_pressure + round + (1|game) + (1|superid),
             data = exp2data %>% filter(round > 0), family = binomial, nAGQ=0,
             control = glmerControl(optimizer = c("bobyqa"),
                                    optCtrl=list(maxfun=2e5),
                                    calc.derivs=FALSE))
summary(m2.3)
```

```
Generalized linear mixed model fit by maximum likelihood (Adaptive
  Gauss-Hermite Quadrature, nAGQ = 0) [glmerMod]
 Family: binomial  ( logit )
Formula: punish_type_IA ~ time_pressure + round + (1 | game) + (1 | superid)
   Data: exp2data %>% filter(round > 0)
```

```
Control: glmerControl(optimizer = c("bobyqa"), optCtrl = list(maxfun = 2e+05),
    calc.derivs = FALSE)

     AIC      BIC   logLik deviance df.resid
  2697.2   2733.6  -1343.6   2687.2    10742

Scaled residuals:
    Min      1Q  Median      3Q     Max
-1.3832 -0.0838 -0.0767 -0.0709  4.6221

Random effects:
 Groups  Name        Variance Std.Dev.
 superid (Intercept) 6.9558   2.6374
 game    (Intercept) 0.4017   0.6338
Number of obs: 10747, groups:  superid, 739; game, 50

Fixed effects:
                  Estimate Std. Error z value Pr(>|z|)
(Intercept)       -4.56425    0.25976 -17.571   <2e-16 ***
time_pressurePlus -0.26515    0.33947  -0.781   0.4348
round              0.02203    0.01332   1.654   0.0981 .
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
            (Intr) tm_prP
tm_prssrPls -0.630
round       -0.420 -0.001
```

```
# p = 0.435
```

Unclassified punishment

```
m2.4 = glmer(punish_type_U ~ time_pressure + round + (1|game) + (1|superid),
             data = exp2data %>% filter(round > 0), family = binomial, nAGQ=0,
             control = glmerControl(optimizer = c("bobyqa"),
                                    optCtrl=list(maxfun=2e5),
                                    calc.derivs=FALSE))
summary(m2.4)
```

```
Generalized linear mixed model fit by maximum likelihood (Adaptive
```

```
  Gauss-Hermite Quadrature, nAGQ = 0) [glmerMod]
 Family: binomial  ( logit )
Formula: punish_type_U ~ time_pressure + round + (1 | game) + (1 | superid)
   Data: exp2data %>% filter(round > 0)
Control: glmerControl(optimizer = c("bobyqa"), optCtrl = list(maxfun = 2e+05),
    calc.derivs = FALSE)

     AIC      BIC   logLik deviance df.resid
  1220.2   1256.6   -605.1   1210.2    10742

Scaled residuals:
    Min      1Q  Median      3Q     Max
-1.4674 -0.0904 -0.0623 -0.0419 11.0773

Random effects:
 Groups  Name        Variance Std.Dev.
 superid (Intercept) 3.919    1.9798
 game    (Intercept) 0.358    0.5984
Number of obs: 10747, groups:  superid, 739; game, 50

Fixed effects:
                  Estimate Std. Error z value Pr(>|z|)
(Intercept)       -3.86428    0.26454 -14.607  < 2e-16 ***
time_pressurePlus -0.15285    0.33542  -0.456    0.649
round             -0.18400    0.02469  -7.452  9.2e-14 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
            (Intr) tm_prP
tm_prssrPls -0.614
round       -0.471  0.000
```

```
# p = 0.649
```

Decision time as the outcome

Exp 1 - Cooperation as reference

```
m4 = lmer(behaviorTime_sec ~ behavior + round + (1|game) + (1|superid),
          data = exp1data %>%
```

```
            filter(round > 0))

summary(m4)
```

```
Linear mixed model fit by REML. t-tests use Satterthwaite's method [
lmerModLmerTest]
Formula: behaviorTime_sec ~ behavior + round + (1 | game) + (1 | superid)
   Data: exp1data %>% filter(round > 0)

REML criterion at convergence: 69452.7

Scaled residuals:
    Min      1Q  Median      3Q     Max
-2.9109 -0.3656 -0.1566  0.0373 10.4105

Random effects:
 Groups   Name        Variance Std.Dev.
 superid  (Intercept) 11.789   3.434
 game     (Intercept)  1.824   1.350
 Residual             64.809   8.050
Number of obs: 9776, groups:  superid, 719; game, 50

Fixed effects:
             Estimate Std. Error         df t value Pr(>|t|)
(Intercept)   6.79184    0.30462  110.40898  22.296  < 2e-16 ***
behaviorD     0.30411    0.23036 5471.24286   1.320  0.18684
behaviorP     1.21569    0.42149 9059.09346   2.884  0.00393 **
round        -0.16708    0.01916 9287.78481  -8.719  < 2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
          (Intr) behvrD behvrP
behaviorD -0.322
behaviorP -0.180  0.263
round     -0.460 -0.058  0.023
```

Exp 1 - Defection as reference

```r
m4_1 = lmer(behaviorTime_sec ~ factor(behavior, levels = c("D", "C", "P")) +
              round + (1|game) + (1|superid), data = exp1data)
summary(m4_1)
```

```
Linear mixed model fit by REML. t-tests use Satterthwaite's method [
lmerModLmerTest]
Formula: behaviorTime_sec ~ factor(behavior, levels = c("D", "C", "P")) +
    round + (1 | game) + (1 | superid)
   Data: exp1data

REML criterion at convergence: 69452.7

Scaled residuals:
    Min      1Q  Median      3Q     Max
-2.9109 -0.3656 -0.1566  0.0373 10.4105

Random effects:
 Groups   Name        Variance Std.Dev.
 superid  (Intercept) 11.789   3.434
 game     (Intercept)  1.824   1.350
 Residual             64.809   8.050
Number of obs: 9776, groups:  superid, 719; game, 50

Fixed effects:
                                             Estimate Std. Error         df
(Intercept)                                   7.09595    0.31735  125.30780
factor(behavior, levels = c("D", "C", "P"))C -0.30411    0.23036 5471.24286
factor(behavior, levels = c("D", "C", "P"))P  0.91157    0.42392 8963.54750
round                                        -0.16708    0.01916 9287.78482
                                            t value Pr(>|t|)
(Intercept)                                  22.360   <2e-16 ***
factor(behavior, levels = c("D", "C", "P"))C -1.320   0.1868
factor(behavior, levels = c("D", "C", "P"))P  2.150   0.0316 *
round                                        -8.719   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
                     (Intr) f(,l=c("D","C","P"))C f(,l=c("D","C","P"))P
f(,l=c("D","C","P"))C -0.417
f(,l=c("D","C","P"))P -0.209  0.282
round                 -0.484  0.058                0.054
```

Exp 1 - Comparing the punishment mechanisms - CR punishment is the reference

```
m4_2 = lmer(behaviorTime_sec ~ punish_type_NR + punish_type_IA + punish_type_U +
              round + (1|game) + (1|superid),
            data = exp1data %>% filter(behavior_punish == 1))
summary(m4_2)
```

```
Linear mixed model fit by REML. t-tests use Satterthwaite's method [
lmerModLmerTest]
Formula: behaviorTime_sec ~ punish_type_NR + punish_type_IA + punish_type_U +
    round + (1 | game) + (1 | superid)
   Data: exp1data %>% filter(behavior_punish == 1)

REML criterion at convergence: 3686.3

Scaled residuals:
    Min      1Q  Median      3Q     Max
-1.7665 -0.4121 -0.1780  0.0855  6.0832

Random effects:
 Groups   Name        Variance Std.Dev.
 superid  (Intercept) 23.47    4.845
 game     (Intercept) 11.29    3.360
 Residual             64.44    8.028
Number of obs: 508, groups:  superid, 174; game, 48

Fixed effects:
               Estimate Std. Error       df t value Pr(>|t|)
(Intercept)      6.2481     1.5349 329.3702   4.071 5.88e-05 ***
punish_type_NR   0.5307     1.1866 487.8494   0.447   0.6549
punish_type_IA   1.5698     1.1200 424.9994   1.402   0.1618
punish_type_U    3.7815     1.6083 494.5013   2.351   0.0191 *
round           -0.1209     0.1023 479.7367  -1.182   0.2377
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
            (Intr) pn__NR pn__IA pns__U
pnsh_typ_NR -0.485
pnsh_typ_IA -0.531  0.084
punsh_typ_U -0.608  0.501  0.464
round       -0.364 -0.197 -0.061 -0.070
```

Exp 1 - Comparing copying/retaliation punishment vs. all others

```
m4_2_1 = lmer(behaviorTime_sec ~ punish_type_CR + round + (1|game) + (1|superid),
              data = exp1data %>%
  filter(behavior_punish == 1))
summary(m4_2_1)
```

```
Linear mixed model fit by REML. t-tests use Satterthwaite's method [
lmerModLmerTest]
Formula: behaviorTime_sec ~ punish_type_CR + round + (1 | game) + (1 |
    superid)
   Data: exp1data %>% filter(behavior_punish == 1)

REML criterion at convergence: 3690.5

Scaled residuals:
    Min      1Q  Median      3Q     Max
-1.7020 -0.4204 -0.1869  0.0978  6.1235

Random effects:
 Groups   Name        Variance Std.Dev.
 superid  (Intercept) 23.89    4.887
 game     (Intercept) 10.43    3.229
 Residual             64.10    8.006
Number of obs: 508, groups:  superid, 174; game, 48

Fixed effects:
               Estimate Std. Error       df t value Pr(>|t|)
(Intercept)      9.1691     1.1074 169.5893   8.280 3.54e-14 ***
punish_type_CR  -2.4355     0.9306 483.1002  -2.617  0.00914 **
round           -0.1489     0.1003 479.6408  -1.484  0.13842
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
            (Intr) pn__CR
pnsh_typ_CR -0.308
round       -0.693  0.113
```

Exp 1 - Comparing unclassified punishment vs. all others

```
m4_2_2 = lmer(behaviorTime_sec ~ punish_type_U + round + (1|game) + (1|superid),
              data = exp1data %>%
  filter(behavior_punish == 1))
summary(m4_2_2)
```

```
Linear mixed model fit by REML. t-tests use Satterthwaite's method [
lmerModLmerTest]
Formula: behaviorTime_sec ~ punish_type_U + round + (1 | game) + (1 |
    superid)
   Data: exp1data %>% filter(behavior_punish == 1)

REML criterion at convergence: 4089.8

Scaled residuals:
    Min      1Q  Median      3Q     Max
-1.9010 -0.4359 -0.1943  0.0883  6.0749

Random effects:
 Groups   Name        Variance Std.Dev.
 superid  (Intercept) 24.642   4.964
 game     (Intercept)  8.374   2.894
 Residual             67.666   8.226
Number of obs: 560, groups:  superid, 184; game, 49

Fixed effects:
               Estimate Std. Error        df t value Pr(>|t|)
(Intercept)     7.80336    1.06843 157.29632   7.304 1.32e-11 ***
punish_type_U   2.10507    1.02123 549.35836   2.061   0.0397 *
round          -0.09103    0.09612 538.05539  -0.947   0.3440
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
            (Intr) pns__U
punsh_typ_U -0.464
round       -0.695  0.304
```

Exp 1 - Regression model with and without punishment in round t-1

```
m13 = lmer(behaviorTime_sec ~ round + last_punished + (1|game) + (1|superid),
           data = exp1data %>% filter(behavior_punish == 1))
```

```
summary(m13)
```

```
Linear mixed model fit by REML. t-tests use Satterthwaite's method [
lmerModLmerTest]
Formula: behaviorTime_sec ~ round + last_punished + (1 | game) + (1 |
    superid)
   Data: exp1data %>% filter(behavior_punish == 1)

REML criterion at convergence: 3690.5

Scaled residuals:
    Min      1Q  Median      3Q     Max
-1.7020 -0.4204 -0.1869  0.0978  6.1235

Random effects:
 Groups   Name        Variance Std.Dev.
 superid  (Intercept) 23.89    4.887
 game     (Intercept) 10.43    3.229
 Residual             64.10    8.006
Number of obs: 508, groups:  superid, 174; game, 48

Fixed effects:
              Estimate Std. Error       df t value Pr(>|t|)
(Intercept)     9.1691     1.1074 169.5893   8.280 3.54e-14 ***
round          -0.1489     0.1003 479.6408  -1.484  0.13842
last_punished  -2.4355     0.9306 483.1002  -2.617  0.00914 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
            (Intr) round
round       -0.693
last_punshd -0.308  0.113
```

Exp 2 - Controlling for time pressure

Time pressure +

```r
exp2_tp_plus = exp2data %>% filter(time_pressure == "Plus")
exp2_tp_minus = exp2data %>% filter(time_pressure == "Minus")

m5a = lmer(behaviorTime_sec ~ behavior + round + (1|game) + (1|superid),
           data = exp2_tp_plus %>% filter(round > 0))
summary(m5a)
```

```
Linear mixed model fit by REML. t-tests use Satterthwaite's method [
lmerModLmerTest]
Formula: behaviorTime_sec ~ behavior + round + (1 | game) + (1 | superid)
   Data: exp2_tp_plus %>% filter(round > 0)

REML criterion at convergence: 2356.9

Scaled residuals:
    Min      1Q  Median      3Q     Max
-3.2207 -0.6608 -0.0951  0.5662  4.8321

Random effects:
 Groups   Name        Variance Std.Dev.
 superid  (Intercept) 0.07370  0.27147
 game     (Intercept) 0.00315  0.05613
 Residual             0.08420  0.29018
Number of obs: 4066, groups:  superid, 367; game, 25

Fixed effects:
             Estimate Std. Error         df t value Pr(>|t|)
(Intercept)  2.090e+00  2.348e-02  6.115e+01  88.999  < 2e-16 ***
behaviorD   -5.140e-02  1.966e-02  2.483e+03  -2.614  0.00899 **
behaviorP    1.155e-01  2.799e-02  4.043e+03   4.128 3.73e-05 ***
round       -6.124e-03  1.091e-03  3.751e+03  -5.611 2.15e-08 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
          (Intr) behvrD behvrP
behaviorD -0.456
behaviorP -0.206  0.315
round     -0.358 -0.043 -0.001
```

Time pressure -

```r
m5b = lmer(behaviorTime_sec ~ behavior + round + (1|game) + (1|superid),
           data = exp2_tp_minus %>% filter(round > 0))

summary(m5b)
```

```
Linear mixed model fit by REML. t-tests use Satterthwaite's method [
lmerModLmerTest]
Formula: behaviorTime_sec ~ behavior + round + (1 | game) + (1 | superid)
   Data: exp2_tp_minus %>% filter(round > 0)

REML criterion at convergence: 23330.5

Scaled residuals:
    Min      1Q  Median      3Q     Max
-3.7670 -0.2960 -0.1224  0.0783 19.2939

Random effects:
 Groups   Name        Variance Std.Dev.
 superid  (Intercept) 1.58559  1.2592
 game     (Intercept) 0.08172  0.2859
 Residual             4.38568  2.0942
Number of obs: 5247, groups:  superid, 366; game, 25

Fixed effects:
             Estimate Std. Error         df t value Pr(>|t|)
(Intercept)  3.330e+00  1.228e-01  6.772e+01  27.117  < 2e-16 ***
behaviorD   -2.740e-01  1.069e-01  2.005e+03  -2.562  0.01048 *
behaviorP    4.700e-01  1.475e-01  5.177e+03   3.185  0.00145 **
round       -2.073e-02  6.745e-03  4.913e+03  -3.074  0.00213 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
          (Intr) behvrD behvrP
behaviorD -0.491
behaviorP -0.253  0.357
round     -0.412 -0.037  0.009
```

Supplementary Analyses for Verification

Testing interaction between punishing environment and punishment decision making (Table S6)

```
exp1data = exp1data %>%
  mutate(local_rate_punish_lag_binary =
           case_when(local_rate_punish_lag == 0 ~ 'Low',
                     local_rate_punish_lag != 0 ~ 'High'))

m4_no_int = lmer(behaviorTime_sec ~ behavior_punish + local_rate_punish_lag +
                   round + (1|game) + (1|superid),
                 data = exp1data %>% filter(round > 1))

m4_int = lmer(behaviorTime_sec ~ behavior_punish*local_rate_punish_lag +
                   round + (1|game) + (1|superid),
                 data = exp1data %>% filter(round > 1))

summary(m4_int)
```

```
Linear mixed model fit by REML. t-tests use Satterthwaite's method [
lmerModLmerTest]
Formula: behaviorTime_sec ~ behavior_punish * local_rate_punish_lag +
    round + (1 | game) + (1 | superid)
   Data: exp1data %>% filter(round > 1)

REML criterion at convergence: 63408.5

Scaled residuals:
    Min      1Q  Median      3Q     Max
-3.0493 -0.3578 -0.1520  0.0321 10.7635

Random effects:
 Groups   Name        Variance Std.Dev.
 superid  (Intercept) 11.076   3.328
 game     (Intercept)  1.554   1.247
 Residual             59.983   7.745
Number of obs: 9020, groups:  superid, 713; game, 50

Fixed effects:
                                    Estimate Std. Error        df t value
(Intercept)                           6.5745     0.2951  116.7952  22.276
```

```
behavior_punish                            1.2756     0.4545 8494.5666   2.806
local_rate_punish_lag                     -0.6620     0.8331 8724.9751  -0.795
round                                     -0.1310     0.0206 8489.2586  -6.360
behavior_punish:local_rate_punish_lag     -4.0876     2.4373 8772.9935  -1.677
                                         Pr(>|t|)
(Intercept)                               < 2e-16 ***
behavior_punish                           0.00502 **
local_rate_punish_lag                     0.42684
round                                     2.12e-10 ***
behavior_punish:local_rate_punish_lag     0.09356 .
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
            (Intr) bhvr_p lcl___ round
behavr_pnsh -0.114
lcl_rt_pns_ -0.196  0.102
round       -0.584  0.041  0.086
bhvr_pn:___  0.059 -0.418 -0.309 -0.019
```

Regression analysis for the effect of low initial wealth allocation on decision time (Tables S7, S8)

```
summary(lmer(behaviorTime_sec ~ initial_score_low + behavior + round + (1|game)
             + (1|superid), data = exp1data))
```

```
Linear mixed model fit by REML. t-tests use Satterthwaite's method [
lmerModLmerTest]
Formula: behaviorTime_sec ~ initial_score_low + behavior + round + (1 |
    game) + (1 | superid)
   Data: exp1data

REML criterion at convergence: 69452.7

Scaled residuals:
    Min      1Q  Median      3Q     Max
-2.9146 -0.3656 -0.1562  0.0382 10.4141

Random effects:
 Groups   Name        Variance Std.Dev.
 superid  (Intercept) 11.806   3.436
```

```
 game     (Intercept)  1.826   1.351
 Residual             64.809   8.050
Number of obs: 9776, groups:  superid, 719; game, 50

Fixed effects:
                    Estimate Std. Error         df t value Pr(>|t|)
(Intercept)          6.66573    0.38930  253.32765  17.122  < 2e-16 ***
initial_score_low    0.17879    0.34334  603.94338   0.521  0.60275
behaviorD            0.30663    0.23045 5479.92156   1.331  0.18339
behaviorP            1.21876    0.42156 9060.96987   2.891  0.00385 **
round               -0.16710    0.01916 9287.58879  -8.719  < 2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
            (Intr) intl__ behvrD behvrP
intl_scr_lw -0.622
behaviorD   -0.265  0.022
behaviorP   -0.150  0.015  0.263
round       -0.358 -0.003 -0.058  0.023
```

```
summary(lmer(behaviorTime_sec ~ initial_score_low + behavior + round +
               (1|game) + (1|superid),
             data = exp2data %>% filter(time_pressure == 'Minus')))
```

```
Linear mixed model fit by REML. t-tests use Satterthwaite's method [
lmerModLmerTest]
Formula: behaviorTime_sec ~ initial_score_low + behavior + round + (1 |
    game) + (1 | superid)
   Data: exp2data %>% filter(time_pressure == "Minus")

REML criterion at convergence: 23332

Scaled residuals:
    Min      1Q  Median      3Q     Max
-3.7773 -0.2968 -0.1225  0.0778 19.2842

Random effects:
 Groups   Name        Variance Std.Dev.
 superid  (Intercept) 1.58849  1.2604
 game     (Intercept) 0.08541  0.2922
 Residual             4.38547  2.0942
```

```
Number of obs: 5247, groups:  superid, 366; game, 25

Fixed effects:
                    Estimate Std. Error         df t value Pr(>|t|)
(Intercept)        3.272e+00  1.640e-01  1.616e+02  19.952  < 2e-16 ***
initial_score_low  8.524e-02  1.583e-01  3.379e+02   0.538  0.59060
behaviorD         -2.749e-01  1.070e-01  2.007e+03  -2.570  0.01025 *
behaviorP          4.687e-01  1.476e-01  5.176e+03   3.176  0.00150 **
round             -2.072e-02  6.745e-03  4.913e+03  -3.072  0.00214 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
            (Intr) intl__ behvrD behvrP
intl_scr_lw -0.658
behaviorD   -0.363 -0.008
behaviorP   -0.182 -0.011  0.357
round       -0.310  0.003 -0.037  0.009
```

```
summary(lmer(behaviorTime_sec ~ behavior + initial_score_low + round + (1|game)
             + (1|superid), data = exp2data %>% filter(time_pressure == 'Plus')))
```

```
Linear mixed model fit by REML. t-tests use Satterthwaite's method [
lmerModLmerTest]
Formula: behaviorTime_sec ~ behavior + initial_score_low + round + (1 |
    game) + (1 | superid)
   Data: exp2data %>% filter(time_pressure == "Plus")

REML criterion at convergence: 2361.6

Scaled residuals:
    Min      1Q  Median      3Q     Max
-3.2220 -0.6618 -0.0931  0.5661  4.8309

Random effects:
 Groups   Name        Variance Std.Dev.
 superid  (Intercept) 0.073843 0.27174
 game     (Intercept) 0.003195 0.05653
 Residual             0.084201 0.29017
Number of obs: 4066, groups:  superid, 367; game, 25

Fixed effects:
```

```
                   Estimate Std. Error         df t value Pr(>|t|)
(Intercept)        2.076e+00  3.285e-02  1.733e+02  63.197  < 2e-16 ***
behaviorD         -5.128e-02  1.967e-02  2.484e+03  -2.607  0.00918 **
behaviorP          1.158e-01  2.799e-02  4.041e+03   4.138 3.58e-05 ***
initial_score_low  2.027e-02  3.296e-02  3.489e+02   0.615  0.53909
round             -6.126e-03  1.091e-03  3.751e+03  -5.613 2.13e-08 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
            (Intr) behvrD behvrP intl__
behaviorD   -0.330
behaviorP   -0.158  0.315
intl_scr_lw -0.698  0.005  0.016
round       -0.255 -0.043 -0.001 -0.001
```

```
summary(lmer(behaviorTime_sec ~ punish_type_NR + punish_type_IA + punish_type_U
             + initial_score_low +
              round + (1|game) + (1|superid),
            data = exp1data %>% filter(behavior_punish == 1)))
```

```
Linear mixed model fit by REML. t-tests use Satterthwaite's method [
lmerModLmerTest]
Formula: behaviorTime_sec ~ punish_type_NR + punish_type_IA + punish_type_U +
    initial_score_low + round + (1 | game) + (1 | superid)
   Data: exp1data %>% filter(behavior_punish == 1)

REML criterion at convergence: 3683.3

Scaled residuals:
    Min      1Q  Median      3Q     Max
-1.8090 -0.4179 -0.1820  0.0792  6.0808

Random effects:
 Groups   Name        Variance Std.Dev.
 superid  (Intercept) 24.29    4.928
 game     (Intercept) 11.12    3.335
 Residual             64.20    8.013
Number of obs: 508, groups:  superid, 174; game, 48

Fixed effects:
                  Estimate Std. Error       df t value Pr(>|t|)
```

```
(Intercept)         5.7683     1.6748 290.7348   3.444 0.000657 ***
punish_type_NR      0.5899     1.1890 484.0219   0.496 0.620008
punish_type_IA      1.2323     1.2123 469.3862   1.017 0.309910
punish_type_U       3.7892     1.6085 493.0342   2.356 0.018876 *
initial_score_low   1.0097     1.3814 120.4577   0.731 0.466256
round              -0.1250     0.1024 478.1856  -1.221 0.222565
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
            (Intr) pn__NR pn__IA pns__U intl__
pnsh_typ_NR -0.469
pnsh_typ_IA -0.299  0.053
punsh_typ_U -0.555  0.499  0.431
intl_scr_lw -0.399  0.064 -0.379 -0.006
round       -0.315 -0.200 -0.039 -0.070 -0.046
```

```
summary(lmer(behaviorTime_sec ~ punish_type_NR + punish_type_IA + punish_type_U
             + initial_score_low +
              round + (1|game) + (1|superid),
            data = exp2data %>%
              filter(behavior_punish == 1, time_pressure == 'Minus')))
```

```
boundary (singular) fit: see help('isSingular')

Linear mixed model fit by REML. t-tests use Satterthwaite's method [
lmerModLmerTest]
Formula: behaviorTime_sec ~ punish_type_NR + punish_type_IA + punish_type_U +
    initial_score_low + round + (1 | game) + (1 | superid)
   Data: exp2data %>% filter(behavior_punish == 1, time_pressure == "Minus")

REML criterion at convergence: 1826.1

Scaled residuals:
    Min      1Q  Median      3Q     Max
-2.5741 -0.2987 -0.1420  0.0779  7.4304

Random effects:
 Groups   Name        Variance Std.Dev.
 superid  (Intercept) 6.570    2.563
 game     (Intercept) 0.000    0.000
 Residual             9.037    3.006
```

```
Number of obs: 341, groups:  superid, 100; game, 25

Fixed effects:
                   Estimate Std. Error        df t value Pr(>|t|)
(Intercept)         4.10574    0.88082 190.10165   4.661  5.9e-06 ***
punish_type_NR      1.03461    0.50453 307.49181   2.051   0.0411 *
punish_type_IA     -0.14245    0.59177 334.70019  -0.241   0.8099
punish_type_U       0.37886    0.71566 278.32617   0.529   0.5970
initial_score_low  -0.57891    0.73529  59.19624  -0.787   0.4342
round              -0.03548    0.04477 297.16389  -0.792   0.4287
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
            (Intr) pn__NR pn__IA pns__U intl__
pnsh_typ_NR -0.422
pnsh_typ_IA -0.398  0.049
punsh_typ_U -0.593  0.467  0.574
intl_scr_lw -0.568  0.018 -0.140  0.011
round       -0.299 -0.107 -0.127  0.046  0.032
optimizer (nloptwrap) convergence code: 0 (OK)
boundary (singular) fit: see help('isSingular')
```

```
summary(lmer(behaviorTime_sec ~ punish_type_NR + punish_type_IA + punish_type_U
             + initial_score_low +
              round + (1|game) + (1|superid),
            data = exp2data %>%
              filter(behavior_punish == 1, time_pressure == 'Plus')))
```

```
Linear mixed model fit by REML. t-tests use Satterthwaite's method [
lmerModLmerTest]
Formula: behaviorTime_sec ~ punish_type_NR + punish_type_IA + punish_type_U +
    initial_score_low + round + (1 | game) + (1 | superid)
   Data: exp2data %>% filter(behavior_punish == 1, time_pressure == "Plus")

REML criterion at convergence: 174.3

Scaled residuals:
     Min       1Q   Median       3Q      Max
-1.83298 -0.55507  0.02874  0.60241  2.32159

Random effects:
```

```
 Groups   Name        Variance Std.Dev.
 superid  (Intercept) 0.11062  0.33260
 game     (Intercept) 0.00683  0.08265
 Residual             0.07639  0.27638
Number of obs: 184, groups:  superid, 76; game, 24

Fixed effects:
                    Estimate Std. Error         df t value Pr(>|t|)
(Intercept)         2.185287   0.116628 124.848840  18.737   <2e-16 ***
punish_type_NR      0.024358   0.068415 146.332603   0.356    0.722
punish_type_IA     -0.025223   0.074085 155.102352  -0.340    0.734
punish_type_U      -0.001092   0.097554 137.910560  -0.011    0.991
initial_score_low   0.019143   0.102787  74.808561   0.186    0.853
round              -0.004240   0.006033 126.423327  -0.703    0.483
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
            (Intr) pn__NR pn__IA pns__U intl__
pnsh_typ_NR -0.442
pnsh_typ_IA -0.303  0.103
punsh_typ_U -0.532  0.558  0.451
intl_scr_lw -0.464 -0.072 -0.296 -0.088
round       -0.457 -0.035 -0.053  0.156  0.087
```

Evaluating effect of past round defection rate on inequality aversion punishment (Table S9)

```
IA_data_e1 = exp1data %>% filter(punish_type_IA == T) %>%
  mutate(high_defect_rate_lag = ifelse(local_rate_defect_lag > 0.5,
                                       'Defect rate > 0.5', "Defect rate <= 0.5"))

summary(lmer(behaviorTime_sec ~ high_defect_rate_lag + round + (1|game) +
               (1|superid), data = IA_data_e1))
```

```
boundary (singular) fit: see help('isSingular')

Linear mixed model fit by REML. t-tests use Satterthwaite's method [
lmerModLmerTest]
Formula: behaviorTime_sec ~ high_defect_rate_lag + round + (1 | game) +
    (1 | superid)
```

```
   Data: IA_data_e1

REML criterion at convergence: 2039

Scaled residuals:
    Min      1Q  Median      3Q     Max
-2.1463 -0.4384 -0.2147  0.0979  5.9454

Random effects:
 Groups   Name        Variance Std.Dev.
 superid  (Intercept)  0.00    0.000
 game     (Intercept) 29.43    5.425
 Residual             66.96    8.183
Number of obs: 283, groups:  superid, 119; game, 43

Fixed effects:
                                        Estimate Std. Error        df t value
(Intercept)                              7.00558    1.52616 128.04269   4.590
high_defect_rate_lagDefect rate > 0.5    1.76945    1.28524 276.37411   1.377
round                                   -0.07426    0.14125 278.96536  -0.526
                                       Pr(>|t|)
(Intercept)                            1.04e-05 ***
high_defect_rate_lagDefect rate > 0.5      0.170
round                                      0.599
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
            (Intr) h__r>0
hg___Dr>0.5 -0.272
round       -0.577 -0.291
optimizer (nloptwrap) convergence code: 0 (OK)
boundary (singular) fit: see help('isSingular')
```

```
IA_data_e2 = exp2data %>%
  filter(punish_type_IA == T) %>%
  mutate(high_defect_rate_lag = ifelse(local_rate_defect_lag > 0.5,
                                       'Defect rate > 0.5',
                                       "Defect rate <= 0.5"))

summary(lmer(behaviorTime_sec ~ high_defect_rate_lag + round + (1|game) +
               (1|superid),
```

```
            data = IA_data_e2 %>% filter(time_pressure == 'Minus')))
```

```
Linear mixed model fit by REML. t-tests use Satterthwaite's method [
lmerModLmerTest]
Formula: behaviorTime_sec ~ high_defect_rate_lag + round + (1 | game) +
    (1 | superid)
   Data: IA_data_e2 %>% filter(time_pressure == "Minus")

REML criterion at convergence: 1192.2

Scaled residuals:
    Min      1Q  Median      3Q     Max
-2.0322 -0.3084 -0.1641  0.0425  6.4899

Random effects:
 Groups   Name        Variance  Std.Dev.
 superid  (Intercept)  6.414773 2.53274
 game     (Intercept)  0.009413 0.09702
 Residual             12.457652 3.52954
Number of obs: 211, groups:  superid, 75; game, 25

Fixed effects:
                                     Estimate Std. Error        df t value
(Intercept)                           3.52903    0.74703 149.44054   4.724
high_defect_rate_lagDefect rate > 0.5  1.25054    0.59541 188.67712   2.100
round                                -0.03702    0.07108 183.67433  -0.521
                                    Pr(>|t|)
(Intercept)                         5.28e-06 ***
high_defect_rate_lagDefect rate > 0.5    0.037 *
round                                    0.603
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
            (Intr) h__r>0
hg___Dr>0.5 -0.407
round       -0.662 -0.162
```

```
summary(lmer(behaviorTime_sec ~ high_defect_rate_lag +
               round + (1|game) + (1|superid),
             data = IA_data_e2 %>% filter(time_pressure == 'Plus')))
```

```
boundary (singular) fit: see help('isSingular')

Linear mixed model fit by REML. t-tests use Satterthwaite's method [
lmerModLmerTest]
Formula: behaviorTime_sec ~ high_defect_rate_lag + round + (1 | game) +
    (1 | superid)
   Data: IA_data_e2 %>% filter(time_pressure == "Plus")

REML criterion at convergence: 109

Scaled residuals:
     Min       1Q   Median       3Q      Max
-1.71800 -0.55936  0.07293  0.51427  2.17703

Random effects:
 Groups   Name        Variance Std.Dev.
 superid  (Intercept) 0.12424  0.3525
 game     (Intercept) 0.00000  0.0000
 Residual             0.06913  0.2629
Number of obs: 113, groups:  superid, 55; game, 22

Fixed effects:
                                      Estimate Std. Error         df t value
(Intercept)                           2.116992   0.098005 109.456692  21.601
high_defect_rate_lagDefect rate > 0.5  0.095327   0.066173  85.348506   1.441
round                                -0.002140   0.008578  83.358857  -0.249
                                     Pr(>|t|)
(Intercept)                            <2e-16 ***
high_defect_rate_lagDefect rate > 0.5   0.153
round                                   0.804
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
            (Intr) h__r>0
hg___Dr>0.5 -0.353
round       -0.701 -0.111
optimizer (nloptwrap) convergence code: 0 (OK)
boundary (singular) fit: see help('isSingular')
```

Evaluating the effect of wealth visibility on inequality aversion punishment

```r
summary(glmer(punish_type_IA ~ showScore + round + (1|game) + (1|superid),
              data = exp1data %>% filter(round > 0),
              family = 'binomial', nAGQ=0,
      control = glmerControl(optimizer = c("bobyqa"),
                                    optCtrl=list(maxfun=2e5),
                                    calc.derivs=FALSE)))
```

```
Generalized linear mixed model fit by maximum likelihood (Adaptive
  Gauss-Hermite Quadrature, nAGQ = 0) [glmerMod]
 Family: binomial  ( logit )
Formula: punish_type_IA ~ showScore + round + (1 | game) + (1 | superid)
   Data: exp1data %>% filter(round > 0)
Control: glmerControl(optimizer = c("bobyqa"), optCtrl = list(maxfun = 2e+05),
    calc.derivs = FALSE)

     AIC      BIC   logLik deviance df.resid
  2115.4   2151.4  -1052.7   2105.4     9928

Scaled residuals:
    Min      1Q  Median      3Q     Max
-1.6785 -0.0963 -0.0821 -0.0726  4.9926

Random effects:
 Groups  Name        Variance Std.Dev.
 superid (Intercept) 4.6454   2.1553
 game    (Intercept) 0.6706   0.8189
Number of obs: 9933, groups:  superid, 719; game, 50

Fixed effects:
             Estimate Std. Error z value Pr(>|z|)
(Intercept) -4.626329   0.285225 -16.220   <2e-16 ***
showScore    0.233556   0.356549   0.655    0.512
round       -0.003266   0.015790  -0.207    0.836
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
          (Intr) shwScr
showScore -0.656
round     -0.424  0.000
```

```r
summary(lmer(behaviorTime_sec ~ showScore + round + (1|game) + (1|superid),
             data = exp1data %>% filter(punish_type_IA == 1)))
```

```
boundary (singular) fit: see help('isSingular')

Linear mixed model fit by REML. t-tests use Satterthwaite's method [
lmerModLmerTest]
Formula: behaviorTime_sec ~ showScore + round + (1 | game) + (1 | superid)
   Data: exp1data %>% filter(punish_type_IA == 1)

REML criterion at convergence: 2074.9

Scaled residuals:
    Min      1Q  Median      3Q     Max
-2.0380 -0.4550 -0.2361  0.1051  5.8411

Random effects:
 Groups   Name        Variance Std.Dev.
 superid  (Intercept)  0.00    0.000
 game     (Intercept) 25.92    5.092
 Residual             71.95    8.482
Number of obs: 286, groups:  superid, 120; game, 43

Fixed effects:
             Estimate Std. Error        df t value Pr(>|t|)
(Intercept)   7.16246    1.78256  67.67375   4.018  0.00015 ***
showScore     1.09465    1.99383  35.39306   0.549  0.58644
round        -0.01564    0.13893 281.94491  -0.113  0.91043
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
          (Intr) shwScr
showScore -0.573
round     -0.576 -0.043
optimizer (nloptwrap) convergence code: 0 (OK)
boundary (singular) fit: see help('isSingular')
```

Testing the reciprocal effect of defection for defection decisions

```
# Reciprocation occurs when previous round local rate is >0

exp1data = exp1data %>% mutate(any_defectors_lag =
                                  ifelse(local_rate_defect_lag > 0, 1, 0))
exp2data = exp2data %>% mutate(any_defectors_lag =
                                  ifelse(local_rate_defect_lag > 0, 1, 0))
```

```
summary(lmer(behaviorTime_sec ~ any_defectors_lag + round +
               (1|game) + (1|superid),
             data = exp1data %>% filter(behavior_defect == 1, round > 0)))
```

```
Linear mixed model fit by REML. t-tests use Satterthwaite's method [
lmerModLmerTest]
Formula: behaviorTime_sec ~ any_defectors_lag + round + (1 | game) + (1 |
    superid)
   Data: exp1data %>% filter(behavior_defect == 1, round > 0)

REML criterion at convergence: 28985.1

Scaled residuals:
    Min      1Q  Median      3Q     Max
-2.9714 -0.3557 -0.1635  0.0010  9.8659

Random effects:
 Groups   Name        Variance Std.Dev.
 superid  (Intercept) 15.0762  3.8828
 game     (Intercept)  0.8647  0.9299
 Residual             70.6379  8.4046
Number of obs: 4017, groups:  superid, 532; game, 50

Fixed effects:
                    Estimate Std. Error         df t value Pr(>|t|)
(Intercept)          7.37080    0.61965 1108.55638  11.895  < 2e-16 ***
any_defectors_lag   -0.44426    0.53732 3371.01222  -0.827 0.408406
round               -0.12143    0.03459 3880.05350  -3.511 0.000452 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
```

```
            (Intr) any_d_
any_dfctrs_ -0.771
round       -0.467  0.003
```

```
summary(lmer(behaviorTime_sec ~ any_defectors_lag + round + (1|game) +
               (1|superid),
             data = exp2data %>% filter(behavior_defect == 1, round > 0,
                                        time_pressure == 'Minus')))
```

```
boundary (singular) fit: see help('isSingular')

Linear mixed model fit by REML. t-tests use Satterthwaite's method [
lmerModLmerTest]
Formula: behaviorTime_sec ~ any_defectors_lag + round + (1 | game) + (1 |
    superid)
   Data: exp2data %>% filter(behavior_defect == 1, round > 0, time_pressure ==
    "Minus")

REML criterion at convergence: 11007.6

Scaled residuals:
    Min      1Q  Median      3Q     Max
-3.2771 -0.3082 -0.1322  0.0909 16.1598

Random effects:
 Groups   Name        Variance Std.Dev.
 superid  (Intercept) 1.460    1.208
 game     (Intercept) 0.000    0.000
 Residual             2.951    1.718
Number of obs: 2693, groups:  superid, 259; game, 25

Fixed effects:
                    Estimate Std. Error         df t value Pr(>|t|)
(Intercept)        3.082e+00  1.933e-01  1.798e+03  15.947   <2e-16 ***
any_defectors_lag -5.897e-03  1.662e-01  2.671e+03  -0.035   0.9717
round             -1.464e-02  8.403e-03  2.472e+03  -1.742   0.0816 .
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
            (Intr) any_d_
any_dfctrs_ -0.820
```

```
round       -0.408  0.050
optimizer (nloptwrap) convergence code: 0 (OK)
boundary (singular) fit: see help('isSingular')
```

```
summary(lmer(behaviorTime_sec ~ any_defectors_lag + round + (1|game) +
               (1|superid),
             data = exp2data %>% filter(behavior_defect == 1, round > 0,
                                        time_pressure == 'Plus')))
```

```
Linear mixed model fit by REML. t-tests use Satterthwaite's method [
lmerModLmerTest]
Formula: behaviorTime_sec ~ any_defectors_lag + round + (1 | game) + (1 |
    superid)
   Data: exp2data %>% filter(behavior_defect == 1, round > 0, time_pressure ==
    "Plus")

REML criterion at convergence: 1190.8

Scaled residuals:
    Min      1Q  Median      3Q     Max
-2.4325 -0.6629 -0.0777  0.5550  3.7395

Random effects:
 Groups   Name        Variance Std.Dev.
 superid  (Intercept) 0.07516  0.2742
 game     (Intercept) 0.01126  0.1061
 Residual             0.07867  0.2805
Number of obs: 2174, groups:  superid, 247; game, 25

Fixed effects:
                    Estimate Std. Error         df t value Pr(>|t|)
(Intercept)        2.040e+00  4.621e-02  1.518e+02  44.135  < 2e-16 ***
any_defectors_lag -5.518e-04  3.486e-02  2.146e+03  -0.016    0.987
round             -7.010e-03  1.541e-03  1.972e+03  -4.550 5.69e-06 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
            (Intr) any_d_
any_dfctrs_ -0.722
round       -0.329  0.057
```

Evaluating the effect of choosing punishment on rewiring

```
## Regression for punishment and rewiring, Exp. 1 ------------------------------
model_e1_rwr = glmer(rewired ~ behavior_punish + round + (1|game) + (1|superid),
                     data = exp1data %>% filter(round > 0,
                                                behavior %in% c("C", "D", "P")),
                     family = 'binomial', nAGQ=0,
                     control = glmerControl(optimizer = c("bobyqa"),
                                            optCtrl=list(maxfun=2e5),
                                            calc.derivs=FALSE))
tidy(model_e1_rwr, exponentiate = T) %>% as.data.frame()
```

```
    effect   group            term  estimate   std.error   statistic
1    fixed    <NA>     (Intercept) 5.2864841 0.578111067  15.2268437
2    fixed    <NA> behavior_punish 0.9535831 0.114125479  -0.3971294
3    fixed    <NA>           round 0.9001853 0.005162444 -18.3360179
4 ran_pars superid sd__(Intercept) 0.8038238          NA          NA
5 ran_pars    game sd__(Intercept) 0.6347083          NA          NA
       p.value
1 2.346492e-52
2 6.912721e-01
3 4.269490e-75
4           NA
5           NA
```

```
## Regression for punishment and rewiring, Exp. 2 (TP-) ------------------------
model_e2_rwr_minus = glmer(rewired ~ behavior_punish + round + (1|game) +
                             (1|superid),
              data = exp2data %>% filter(round > 0,
                                         behavior %in% c('C', 'D', 'P'),
                                         time_pressure == 'Minus'),
              family = 'binomial', nAGQ=0,
              control = glmerControl(optimizer = c("bobyqa"),
                                     optCtrl=list(maxfun=2e5),
                                     calc.derivs=FALSE))
tidy(model_e2_rwr_minus, exponentiate = T) %>% as.data.frame()
```

```
    effect   group            term  estimate   std.error statistic      p.value
1    fixed    <NA>     (Intercept) 8.1130162 1.085044141 15.653145 3.161973e-55
2    fixed    <NA> behavior_punish 1.3454189 0.265622835  1.502857 1.328759e-01
```

```
3    fixed    <NA>           round 0.9448068 0.008581793 -6.250589 4.089089e-10
4 ran_pars superid sd__(Intercept) 1.4596213          NA        NA           NA
5 ran_pars    game sd__(Intercept) 0.3159409          NA        NA           NA
```

```
## Regression for punishment and rewiring, Exp. 2 (TP+) ------------------------
model_e2_rwr_plus = glmer(rewired ~ behavior_punish + round + (1|game) +
                            (1|superid),
              data = exp2data %>% filter(round > 0,
                                         behavior %in% c('C', 'D', 'P'),
                                         time_pressure == 'Plus'),
              family = 'binomial', nAGQ=0,
              control = glmerControl(optimizer = c("bobyqa"),
                                     optCtrl=list(maxfun=2e5),
                                     calc.derivs=FALSE))
tidy(model_e2_rwr_plus, exponentiate = T) %>% as.data.frame()
```

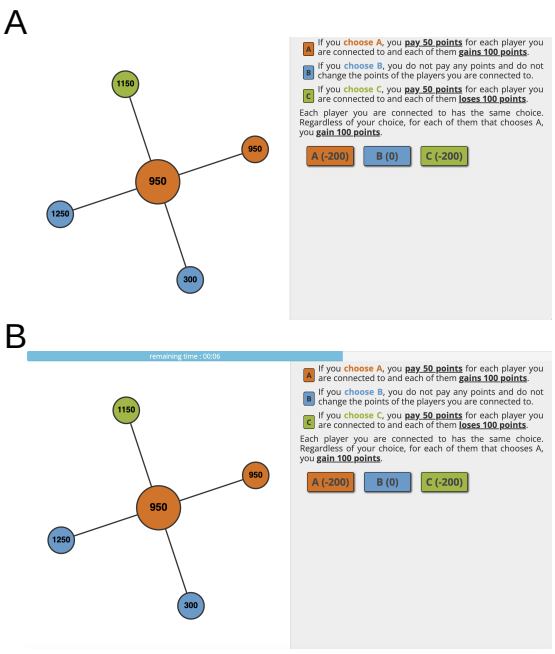
```
    effect   group            term  estimate   std.error  statistic
1    fixed    <NA>     (Intercept) 9.2522425 1.739726644 11.8323182
2    fixed    <NA> behavior_punish 1.1247841 0.248119669  0.5330676
3    fixed    <NA>           round 0.9408296 0.008932311 -6.4243497
4 ran_pars superid sd__(Intercept) 1.6406728          NA         NA
5 ran_pars    game sd__(Intercept) 0.6893328          NA         NA
       p.value
1 2.657009e-32
2 5.939868e-01
3 1.324345e-10
4           NA
5           NA
```

4. Figures

Figure 1 - Example of Player's Screen

```
example_fig1 = image_read('~/Documents/Projects/harming_esn/figures/fig1A.png') %>%
  image_ggplot() +
  labs(tag = 'A')
example_fig2 = image_read('~/Documents/Projects/harming_esn/figures/fig1B.png') %>%
  image_ggplot() +
  labs(tag = 'B')
```

```
example_fig1 / example_fig2
```

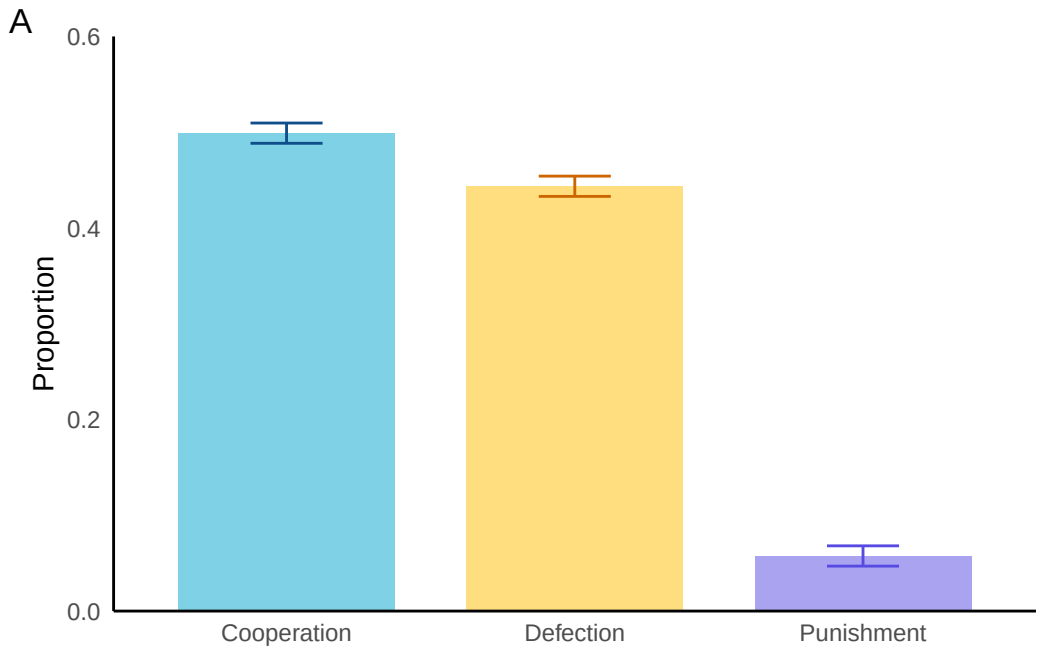



```
# ggsave(filename = "~/Documents/Projects/harming_esn/figures/fig1combined.png",
#       width = 8, height = 8, units = "in")
```

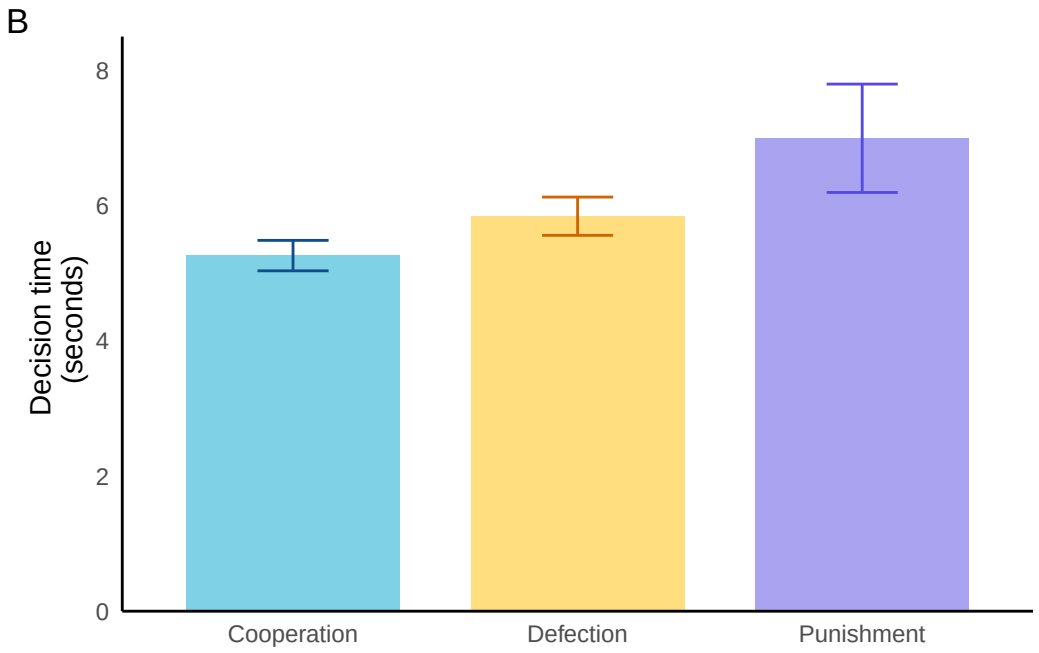
Figure 2 - Behavior Distribution, Decision Times, and Punishment Mechanisms, Experiment 1

```
# Fig 1A
exp1_fig1_data = bind_cols(data1_behavior_count, data1_behavior_CI, data1_times)[-7]

names(exp1_fig1_data) = c("behavior", "count", "crude_prop", "adjusted_prop",
                          "LL_prop", "UL_prop", "mean_dt", "se_mean_dt",
                          "UL_mean_dt", "LL_mean_dt")
exp1_fig1_data = exp1_fig1_data %>%
  mutate(behavior = case_match(behavior,
                               "C" ~ "Cooperation",
                               "D" ~ "Defection",
                               "P" ~ "Punishment"))
```

```r
exp1_fig1_A = exp1_fig1_data %>%
  ggplot() +
  aes(x = behavior, y = adjusted_prop, fill = behavior) +
  geom_bar(stat = "identity", width = 0.75, alpha = 0.5) +
  geom_errorbar(aes(ymin = LL_prop, ymax = UL_prop, color = factor(behavior)),
                width = 0.25) +
  theme_classic() +
  scale_y_continuous(limits = c(0, 0.6), breaks = seq(0, 0.6, by = 0.2),
                     expand = c(0, 0)) +
  ylab("Proportion") +
  scale_fill_manual(values = c("#00A5CF", "#FFBF00", "#574AE2")) +
  scale_color_manual(values = c("dodgerblue4", "darkorange3", "#574AE2")) +
  labs(tag = "A") +
  theme(panel.grid.minor = element_blank(),
        panel.grid.major = element_blank(),
        legend.position = "none",
        axis.text.x = element_text(size = 9),
        axis.title.x = element_blank(),
        axis.ticks.x = element_blank(),
        axis.ticks.y = element_blank())
exp1_fig1_A
```



```r
exp1_fig1_B = exp1_fig1_data %>%
  ggplot() +
  aes(x = behavior, y = mean_dt, fill = behavior) +
  geom_bar(stat = "identity", width = 0.75, alpha = 0.5) +
  geom_errorbar(aes(ymin = mean_dt - 1.96*se_mean_dt,
                    ymax = mean_dt + 1.96*se_mean_dt,
                    color = factor(behavior)), width = 0.25) +
  theme_classic() +
  scale_y_continuous(limits = c(0, 8.5), breaks = seq(0, 8, by = 2),
                     expand = c(0, 0)) +
  ylab("Decision time \n (seconds)")+
  scale_fill_manual(values = c("#00A5CF", "#FFBF00", "#574AE2")) +
  scale_color_manual(values = c("dodgerblue4", "darkorange3", "#574AE2")) +
  labs(tag = "B") +
  theme(panel.grid.minor = element_blank(),
        panel.grid.major = element_blank(),
        legend.position = "none",
        axis.text.x = element_text(size = 9),
        axis.title.x = element_blank(),
        axis.ticks.x = element_blank(),
        axis.ticks.y = element_blank())
exp1_fig1_B
```



```
exp1data_NR = exp1data %>%
  group_by(punish_type_NR) %>%
  count() %>%
  ungroup() %>%
  mutate(punish_type = "NR",
         total = sum(n),
         perc = n/sum(n),
         se_perc = sqrt((perc*(1-perc))/total)) %>%
  filter(punish_type_NR == 1)  %>%
  select(punish_type, n, total, perc, se_perc)

exp1data_IA = exp1data %>%
  group_by(punish_type_IA) %>%
  count() %>%
  ungroup() %>%
  mutate(punish_type = "IA",
         total = sum(n),
         perc = n/sum(n),
         se_perc = sqrt((perc*(1-perc))/total)) %>%
  filter(punish_type_IA == 1)  %>%
  select(punish_type, n, total, perc, se_perc)

exp1data_CR = exp1data %>%
  group_by(punish_type_CR) %>%
  count() %>%
  ungroup() %>%
  mutate(punish_type = "CR",
         total = sum(n),
         perc = n/sum(n),
         se_perc = sqrt((perc*(1-perc))/total)) %>%
  filter(punish_type_CR == 1)  %>%
  select(punish_type, n, total, perc, se_perc)

exp1data_U = exp1data %>%
  group_by(punish_type_U) %>%
  count() %>%
  ungroup() %>%
  mutate(punish_type = "U",
         total = sum(n),
         perc = n/sum(n),
         se_perc = sqrt((perc*(1-perc))/total)) %>%
  filter(punish_type_U == 1)  %>%
```

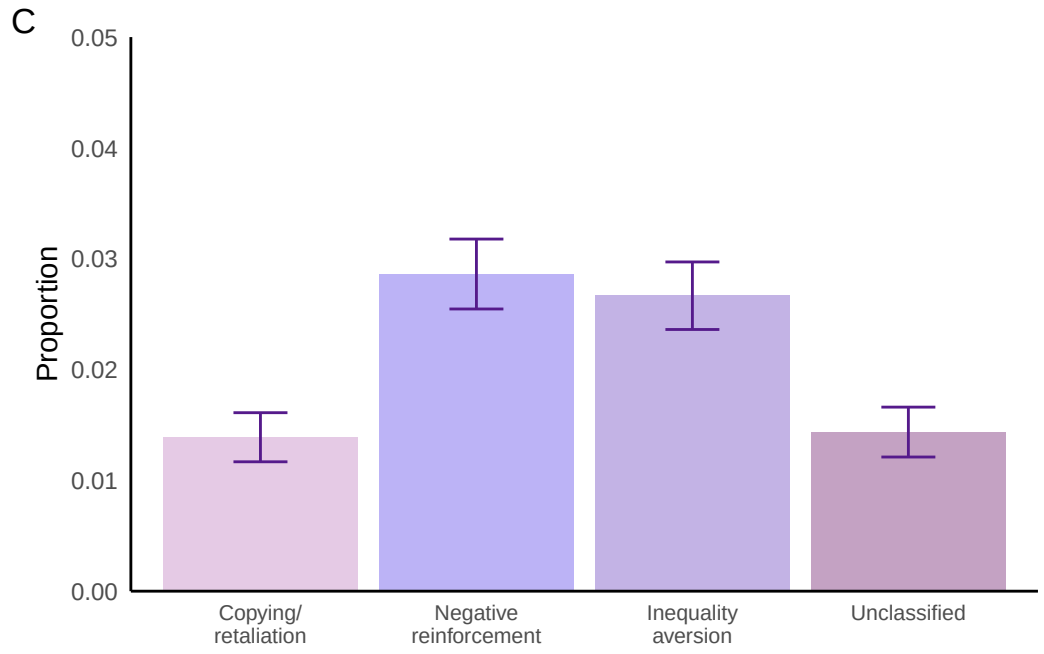
```
  select(punish_type, n, total, perc, se_perc)

figS1data = bind_rows(exp1data_CR, exp1data_IA, exp1data_NR, exp1data_U)

figS1data = figS1data %>%
  mutate(perc_LL = perc - 1.96*se_perc,
         perc_UL = perc + 1.96*se_perc)
```

```
# Decision times by punish type

exp1data_NR_times = exp1data %>%
  filter(punish_type_NR == 1, behavior_punish == 1) %>%
  summarize(mean_dt = mean1(behaviorTime_sec),
            se_mean_dt = se_mean(behaviorTime_sec)) %>%
  mutate(punish_type = "NR",
         mean_LL = mean_dt - 1.96*se_mean_dt,
         mean_UL = mean_dt + 1.96*se_mean_dt)

exp1data_IA_times = exp1data %>%
  filter(punish_type_IA == 1, behavior_punish == 1) %>%
  summarize(mean_dt = mean1(behaviorTime_sec),
            se_mean_dt = se_mean(behaviorTime_sec),
) %>%
  mutate(punish_type = "IA",   mean_LL = mean_dt - 1.96*se_mean_dt,
         mean_UL = mean_dt + 1.96*se_mean_dt)

exp1data_CR_times = exp1data %>%
  filter(punish_type_CR == 1, behavior_punish == 1) %>%
  summarize(mean_dt = mean1(behaviorTime_sec),
            se_mean_dt = se_mean(behaviorTime_sec)) %>%
  mutate(punish_type = "CR",
           mean_LL = mean_dt - 1.96*se_mean_dt,
         mean_UL = mean_dt + 1.96*se_mean_dt)

exp1data_U_times = exp1data %>%
  filter(punish_type_U == 1, behavior_punish == 1) %>%
  summarize(mean_dt = mean1(behaviorTime_sec),
            se_mean_dt = se_mean(behaviorTime_sec)) %>%
  mutate(punish_type = "U",
         mean_LL = mean_dt - 1.96*se_mean_dt,
         mean_UL = mean_dt + 1.96*se_mean_dt)
```

```
exp1data_punish_types_times = bind_rows(exp1data_NR_times,
                                        exp1data_CR_times,
                                        exp1data_IA_times,
                                        exp1data_U_times) %>%
  select(punish_type, mean_dt, se_mean_dt, mean_LL, mean_UL)

fig1data = figS1data %>%
  left_join(exp1data_punish_types_times, by = "punish_type") %>%
  mutate(punish_type = case_match(punish_type,
              "CR" ~ "Copying/retaliation",
              "IA" ~ "Inequality aversion",
              "NR" ~ "Negative reinforcement",
              "U" ~ "Unclassified")) %>%
  mutate(punish_type_fct = factor(punish_type, levels = c("Copying/retaliation", "Negative re
```

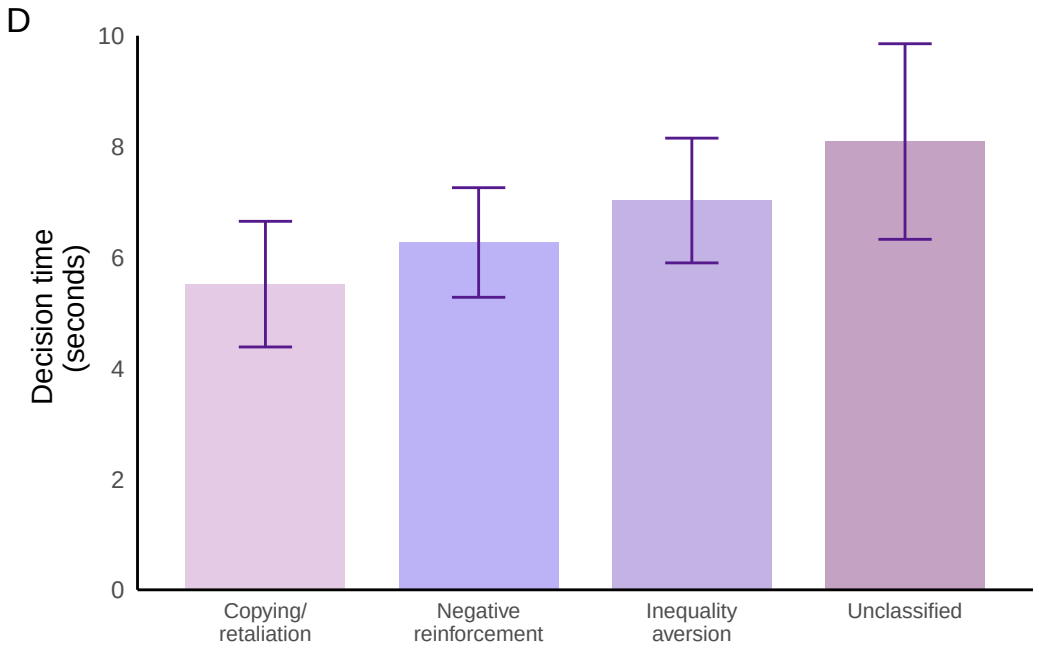
```
exp1_fig1_C = fig1data %>%
  ggplot(aes(x = punish_type_fct, y = perc, fill = punish_type_fct)) +
  geom_bar(position = "dodge", stat = "identity", alpha = 0.5, show.legend = F) +
  geom_errorbar(aes(ymin = perc + 1.96*se_perc,
                    ymax = perc - 1.96*se_perc,
                    width = 0.25),
                color = "purple4",
                position = position_dodge(.9),
                show.legend = F) +
  scale_fill_manual(values = c("Copying/retaliation" = "plum3",
                               "Negative reinforcement" = "mediumslateblue",
                               "Inequality aversion" = "mediumpurple3",
                               "Unclassified" = "orchid4"), guide = "none") +
  scale_color_manual(guide = "none") +
  scale_x_discrete(labels = c("Copying/\nretaliation", "Negative\nreinforcement",
                              "Inequality\naversion", "Unclassified")) +
  scale_y_continuous(limits = c(0, 0.05), expand = c(0, 0)) +
  ylab("Proportion") +
  xlab("") +
  labs(tag = "C") +
  theme_classic() +
  theme(panel.grid.minor = element_blank(),
        panel.grid.major = element_blank(),
        legend.position = "bottom",
        legend.title = element_blank(),
        axis.text.x = element_text(size = 8),
        axis.title.x = element_blank(),
```

```
        axis.ticks.x = element_blank(),
        axis.ticks.y = element_blank())
exp1_fig1_C
```



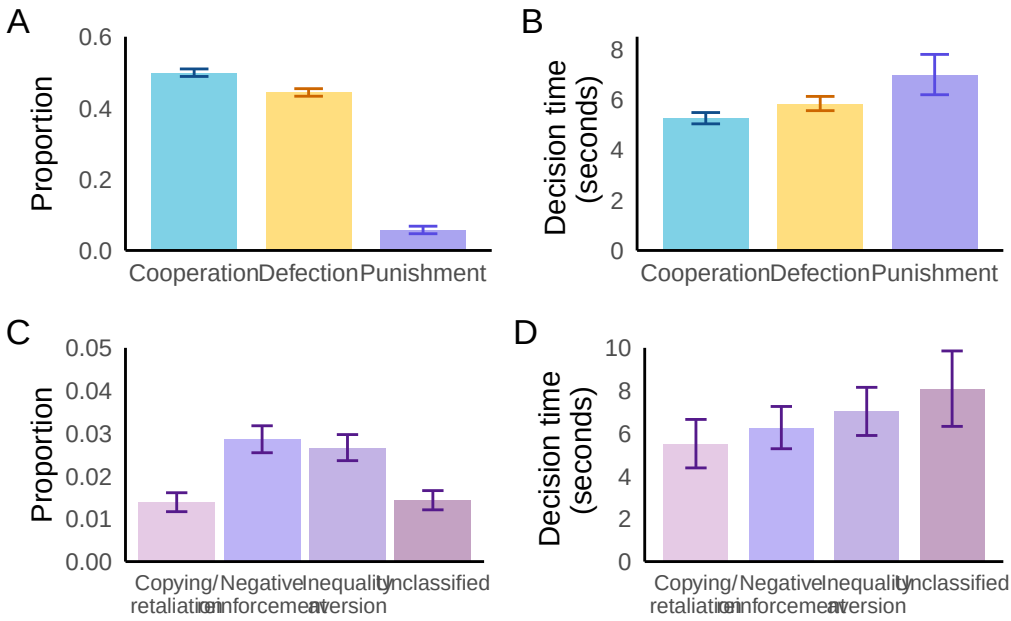

```
exp1_fig1_D = fig1data %>%
  ggplot(aes(x = punish_type_fct, y = mean_dt, fill = punish_type_fct)) +
  geom_bar(stat = "identity", width = 0.75,  alpha = 0.5) +
  geom_errorbar(aes(ymin = mean_LL,
                    ymax = mean_UL),
                color = "purple4", width = 0.25) +
  theme_classic() +
  scale_y_continuous(limits = c(0, 10), breaks = seq(0, 10, by = 2), expand = c(0, 0)) +
  ylab("Decision time \n (seconds)")+
  scale_fill_manual(values = c("Copying/retaliation" = "plum3",
                               "Negative reinforcement" = "mediumslateblue",
                               "Inequality aversion" = "mediumpurple3",
                               "Unclassified" = "orchid4"), guide = "none") +
  scale_x_discrete(labels = c("Copying/\nretaliation", "Negative\nreinforcement",
                              "Inequality\naversion", "Unclassified")) +
  scale_color_manual(guide = "none") +
  theme_classic() +
  labs(tag = "D") +
```

```
  theme(panel.grid.minor = element_blank(),
        panel.grid.major = element_blank(),
        legend.position = "none",
        axis.text.x = element_text(size = 8),
        axis.title.x = element_blank(),
        axis.ticks.x = element_blank(),
        axis.ticks.y = element_blank())
exp1_fig1_D
```



Main

```
(exp1_fig1_A + exp1_fig1_B)/ (exp1_fig1_C + exp1_fig1_D)
```




```
# ggsave(filename = "~/Documents/Projects/harming_esn/figures/fig2.png",
#        width = 8, height = 8, units = "in")
```

Figure 3 - Behavior Distribution, Decision Times, and Punishment Mechanisms, Experiment 2

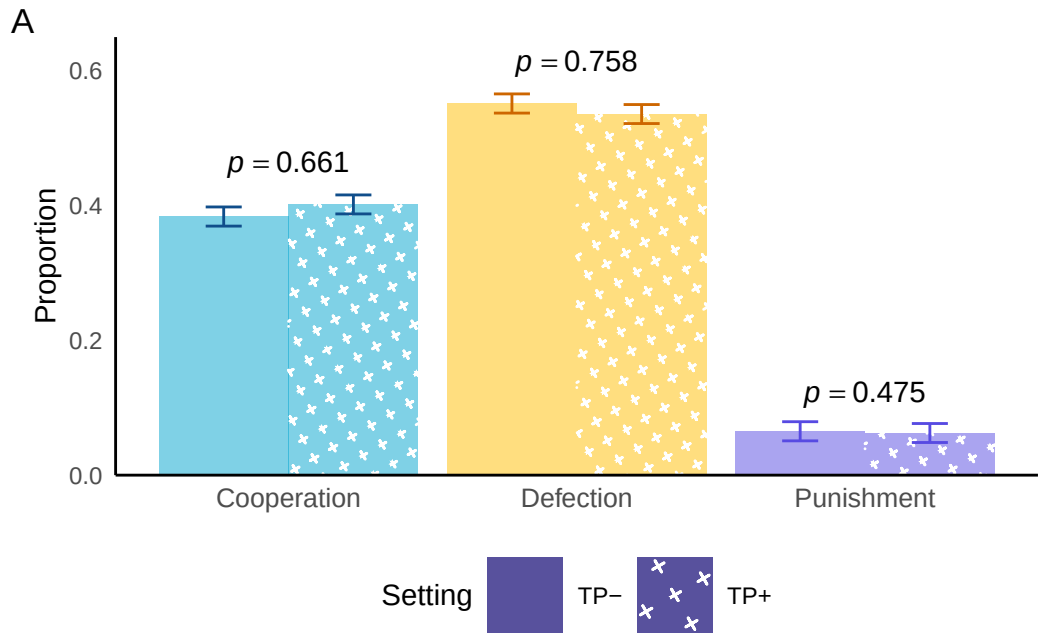
```
exp2_tp_plus_fig3_data = bind_cols(exp2data_tp_plus_count, exp2data_tp_plus_CI,
                                   exp2data_tp_plus_times)[-7]
names(exp2_tp_plus_fig3_data) = c("behavior", "count", "crude_prop",
                                  "adjusted_prop", "LL_prop", "UL_prop", "mean_dt",
                                  "se_mean_dt", "LL_mean_dt", "UL_mean_dt")
exp2_tp_plus_fig3_data$setting = "TP+"

exp2_tp_minus_fig3_data = bind_cols(exp2data_tp_minus_count, exp2data_tp_minus_CI,
                                    exp2data_tp_minus_times)[-7]
names(exp2_tp_minus_fig3_data) = c("behavior", "count", "crude_prop",
                                   "adjusted_prop", "LL_prop", "UL_prop", "mean_dt",
                                   "se_mean_dt", "LL_mean_dt", "UL_mean_dt")

exp2_tp_minus_fig3_data$setting = "TP-"
```

```r
fig3data = bind_rows(exp2_tp_minus_fig3_data, exp2_tp_plus_fig3_data)

fig3data = fig3data %>%
  mutate(behavior = case_match(behavior, "C" ~ "Cooperation",
                               "D" ~ "Defection", "P" ~ "Punishment"))
```

Main

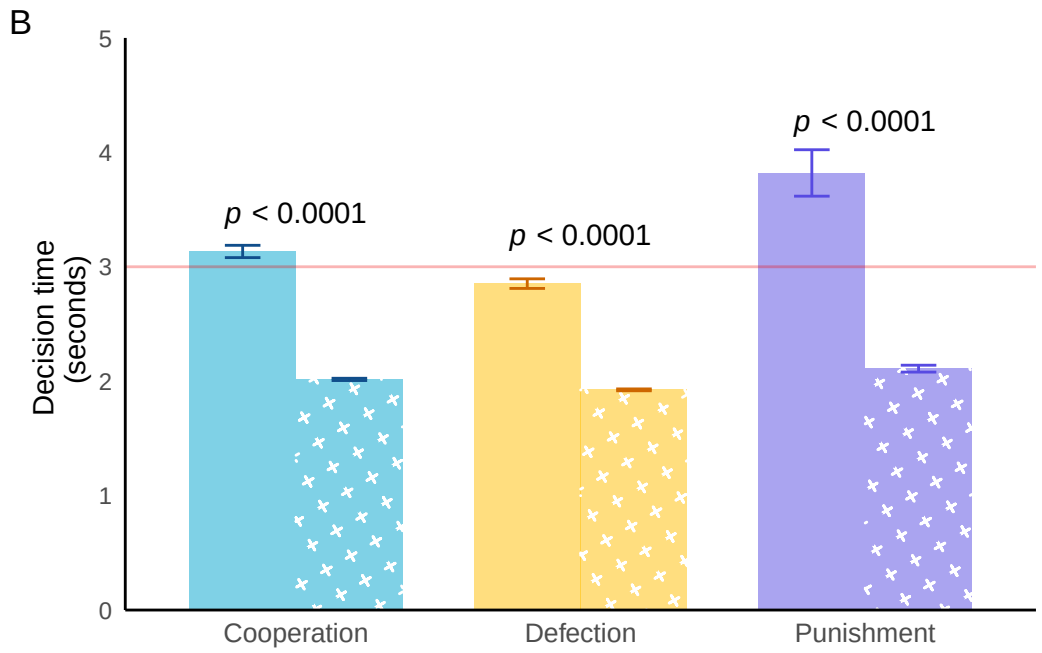
```r
fig3A = fig3data %>%
  ggplot(aes(x = behavior, y = adjusted_prop, fill = behavior, pattern = setting)) +
  geom_bar_pattern(position = "dodge", stat = "identity", alpha = 0.5,
                   pattern_density = 0.4, pattern_color = "white",
                   pattern_shape = 3) +
  geom_errorbar(aes(ymin = LL_prop,
                    ymax = UL_prop,
                    color = behavior,
                    width = 0.25),
                position = position_dodge(.9),
                show.legend = F) +
  scale_pattern_manual(values = c("none", "pch")) +
  scale_fill_manual(values = c("Cooperation" = "#00A5CF", "Defection" = "#FFBF00",
                               "Punishment" = "#574AE2")) +
  scale_color_manual(values = c("dodgerblue4", "darkorange3", "#574AE2")) +
  scale_y_continuous(limits = c(0, 0.65), expand = c(0, 0)) +
  guides(color = "none", fill = "none", pattern = guide_legend(title = "Setting")) +
  ylab("Proportion") +
  xlab("") +
  theme_classic() +
  labs(tag = "A") +
  theme(panel.grid.minor = element_blank(),
        panel.grid.major = element_blank(),
        axis.text.x = element_text(size = 10),
        axis.title.x = element_blank(),
        axis.ticks.x = element_blank(),
        axis.ticks.y = element_blank(),
        legend.position = "bottom",
        legend.key.size = unit(1, "cm"),
        legend.key = element_rect(fill = "#574AE2", color = NA)) +
  annotate("text", x = 1:3,
           y = c(0.46, 0.61, 0.12),
```

```
            label = c("italic(p) == 0.661", "italic(p) == 0.758", "italic(p) == 0.475"),
            parse = T)
fig3A
```

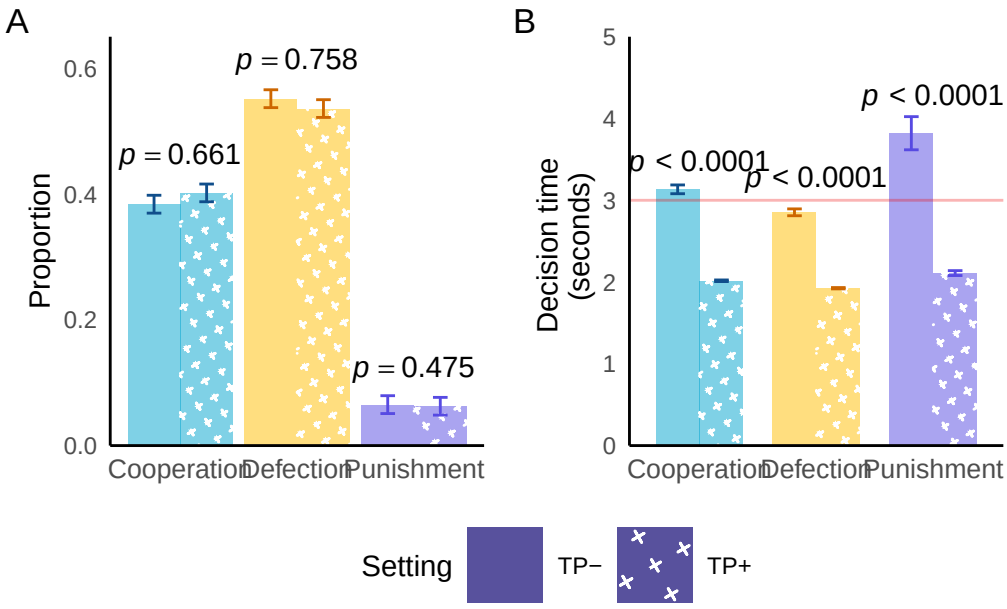



```
fig3B = fig3data %>%
  ggplot() +
  aes(x = behavior, y = mean_dt, fill = behavior, pattern = setting) +
  geom_bar_pattern(stat = "identity", width = 0.75, alpha = 0.5,
                   position = "dodge",
                   pattern_density = 0.4,
                   pattern_color = "white",
                   pattern_shape = 3, show.legend = F) +
  geom_errorbar(aes(ymin = mean_dt - se_mean_dt,
                    ymax = mean_dt + se_mean_dt,
                    color = factor(behavior)),
                    position = position_dodge(0.75),
                    width = 0.25,
                show.legend = F) +
  geom_hline(yintercept = 3, color = "red2", alpha = 0.3) +
  theme_classic() +
  scale_pattern_manual(values = c("none", "pch")) +
  scale_y_continuous(limits = c(0, 5), expand = c(0, 0)) +
```

```
  scale_x_discrete(limits = c("Cooperation", "Defection", "Punishment")) +
  ylab("Decision time \n (seconds)")+
  scale_fill_manual(values = c("#00A5CF", "#FFBF00", "#574AE2")) +
  scale_color_manual(values = c("dodgerblue4", "darkorange3", "#574AE2")) +
  labs(tag = "B") +
  theme(panel.grid.minor = element_blank(),
        panel.grid.major = element_blank(),
        legend.position = "none",
        axis.text.x = element_text(size = 10),
        axis.title.x = element_blank(),
        axis.ticks.x = element_blank(),
        axis.ticks.y = element_blank()) +
    annotate("text", x = 1:3,
             y = c(3.45, 3.25, 4.25),
             label = c(rep(expression(paste(italic("p")," < 0.0001")), 3)))

fig3B
```




```
fig3A + fig3B +
  plot_annotation(tag_levels = c("A", "B")) +
  plot_layout(guides = "collect") &
  theme(legend.position = "bottom")
```




```
#ggsave(filename = "~/Documents/Projects/harming_esn/figures/fig3.png",
#width =  7, height = 5, units = "in")
```

Figure 4 - Punishment Mechanism Decision Times, Experiment 2

```
# Get the frequencies stratified by TP status and by punishment type
exp2data = exp2data %>%
  mutate(punish_type_U =
           ifelse(is.na(punish_type_CR) == 1 & is.na(punish_type_NR) == 1 |
                    is.na(punish_type_IA) == 1 & is.na(punish_type_U) == 1,
                  1, punish_type_U),
         punish_type_CR = ifelse(punish_type_U == 1, 0, punish_type_CR),
         punish_type_NR = ifelse(punish_type_U == 1, 0, punish_type_NR),
         punish_type_IA = ifelse(punish_type_U == 1, 0, punish_type_IA))

fig4_tp_minus_CR = exp2data %>%
  filter(time_pressure == "Minus") %>%
  group_by(punish_type_CR) %>%
  count() %>%
  ungroup() %>%
  mutate(setting = "TP-",
```

```
          punish_type = "CR",
          total = sum(n),
          perc = n/sum(n),
          se_perc = sqrt((perc*(1-perc))/total)) %>%
  filter(punish_type_CR == 1)  %>%
  select(setting, punish_type, n, total, perc, se_perc)

fig4_tp_minus_IA = exp2data %>%
  filter(time_pressure == "Minus") %>%
  group_by(punish_type_IA) %>%
  count() %>%
  ungroup() %>%
  mutate(setting = "TP-",
          punish_type = "IA",
          total = sum(n),
          perc = n/sum(n),
          se_perc = sqrt((perc*(1-perc))/total)) %>%
  filter(punish_type_IA == 1)  %>%
  select(setting, punish_type, n, total, perc, se_perc)

fig4_tp_minus_NR = exp2data %>%
  filter(time_pressure == "Minus") %>%
  group_by(punish_type_NR) %>%
  count() %>%
  ungroup() %>%
  mutate(setting = "TP-",
          punish_type = "NR",
          total = sum(n),
          perc = n/sum(n),
          se_perc = sqrt((perc*(1-perc))/total)) %>%
  filter(punish_type_NR == 1)  %>%
  select(setting, punish_type, n, total, perc, se_perc)

fig4_tp_minus_U = exp2data %>%
  filter(time_pressure == "Minus") %>%
  group_by(punish_type_U) %>%
  count() %>%
  ungroup() %>%
  mutate(setting = "TP-",
          punish_type = "U",
          total = sum(n),
          perc = n/sum(n),
```

```
         se_perc = sqrt((perc*(1-perc))/total)) %>%
  filter(punish_type_U == 1)  %>%
  select(setting, punish_type, n, total, perc, se_perc)

fig4_tp_minus_data = bind_rows(fig4_tp_minus_CR, fig4_tp_minus_IA,
                               fig4_tp_minus_NR, fig4_tp_minus_U)
```

```
fig4_tp_Plus_CR = exp2data %>%
  filter(time_pressure == "Plus") %>%
  group_by(punish_type_CR) %>%
  count() %>%
  ungroup() %>%
  mutate(setting = "TP+",
         punish_type = "CR",
         total = sum(n),
         perc = n/sum(n),
         se_perc = sqrt((perc*(1-perc))/total)) %>%
  filter(punish_type_CR == 1)  %>%
  select(setting, punish_type, n, total, perc, se_perc)

fig4_tp_Plus_IA = exp2data %>%
  filter(time_pressure == "Plus") %>%
  group_by(punish_type_IA) %>%
  count() %>%
  ungroup() %>%
  mutate(setting = "TP+",
         punish_type = "IA",
         total = sum(n),
         perc = n/sum(n),
         se_perc = sqrt((perc*(1-perc))/total)) %>%
  filter(punish_type_IA == 1)  %>%
  select(setting, punish_type, n, total, perc, se_perc)

fig4_tp_Plus_NR = exp2data %>%
  filter(time_pressure == "Plus") %>%
  group_by(punish_type_NR) %>%
  count() %>%
  ungroup() %>%
  mutate(setting = "TP+",
         punish_type = "NR",
         total = sum(n),
         perc = n/sum(n),
```

```
         se_perc = sqrt((perc*(1-perc))/total)) %>%
  filter(punish_type_NR == 1)  %>%
  select(setting, punish_type, n, total, perc, se_perc)

fig4_tp_Plus_U = exp2data %>%
  filter(time_pressure == "Plus") %>%
  group_by(punish_type_U) %>%
  count() %>%
  ungroup() %>%
  mutate(setting = "TP+",
         punish_type = "U",
         total = sum(n),
         perc = n/sum(n),
         se_perc = sqrt((perc*(1-perc))/total)) %>%
  filter(punish_type_U == 1)  %>%
  select(setting, punish_type, n, total, perc, se_perc)

fig4_tp_Plus_data = bind_rows(fig4_tp_Plus_CR, fig4_tp_Plus_IA,
                              fig4_tp_Plus_NR, fig4_tp_Plus_U)

exp2data_combined = bind_rows(fig4_tp_minus_data, fig4_tp_Plus_data)
```

```
exp2data_plus_NR_times = exp2data %>%
  filter(punish_type_NR == 1,
         behavior_punish == 1,
         time_pressure == "Plus") %>%
  summarize(mean_dt = mean1(behaviorTime_sec),
            se_mean_dt = se_mean(behaviorTime_sec)) %>%
  mutate(punish_type = "NR",
         setting = "TP+",
           mean_LL = mean_dt - 1.96*se_mean_dt,
         mean_UL = mean_dt + 1.96*se_mean_dt)

exp2data_plus_CR_times = exp2data %>%
  filter(punish_type_CR == 1,
         behavior_punish == 1,
         time_pressure == "Plus") %>%
  summarize(mean_dt = mean1(behaviorTime_sec),
            se_mean_dt = se_mean(behaviorTime_sec)) %>%
  mutate(punish_type = "CR",
         setting = "TP+",
         mean_LL = mean_dt - 1.96*se_mean_dt,
```

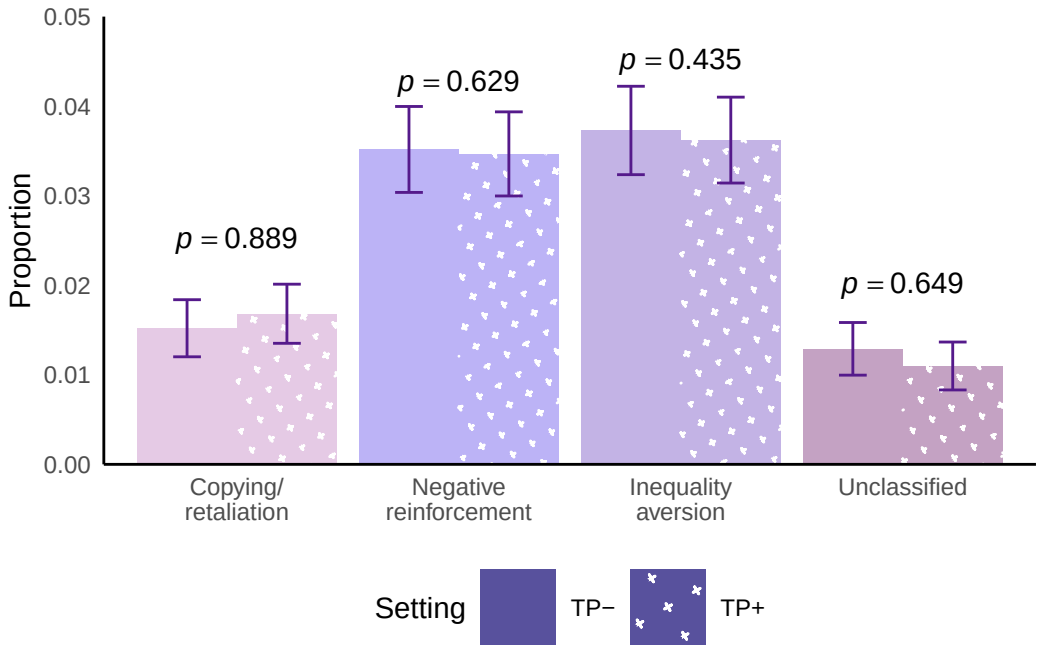
```
         mean_UL = mean_dt + 1.96*se_mean_dt)

exp2data_plus_IA_times = exp2data %>%
  filter(punish_type_IA == 1,
         behavior_punish == 1,
         time_pressure == "Plus") %>%
  summarize(mean_dt = mean1(behaviorTime_sec),
            se_mean_dt = se_mean(behaviorTime_sec)) %>%
  mutate(punish_type = "IA",
                  setting = "TP+",
           mean_LL = mean_dt - 1.96*se_mean_dt,
         mean_UL = mean_dt + 1.96*se_mean_dt)

exp2data_plus_U_times = exp2data %>%
  filter(punish_type_U == 1,
         behavior_punish == 1,
         time_pressure == "Plus") %>%
  summarize(mean_dt = mean1(behaviorTime_sec),
            se_mean_dt = se_mean(behaviorTime_sec)) %>%
  mutate(punish_type = "U",
         setting = "TP+",
         mean_LL = mean_dt - 1.96*se_mean_dt,
         mean_UL = mean_dt + 1.96*se_mean_dt)

exp2data_minus_NR_times = exp2data %>%
  filter(punish_type_NR == 1,
         behavior_punish == 1,
         time_pressure == "Minus") %>%
  summarize(mean_dt = mean1(behaviorTime_sec),
            se_mean_dt = se_mean(behaviorTime_sec)) %>%
  mutate(punish_type = "NR",
                  setting = "TP-",
           mean_LL = mean_dt - 1.96*se_mean_dt,
         mean_UL = mean_dt + 1.96*se_mean_dt)

exp2data_minus_CR_times = exp2data %>%
  filter(punish_type_CR == 1,
         behavior_punish == 1,
         time_pressure == "Minus") %>%
  summarize(mean_dt = mean1(behaviorTime_sec),
            se_mean_dt = se_mean(behaviorTime_sec)) %>%
  mutate(punish_type = "CR",
```

```
         setting = "TP-",
        mean_LL = mean_dt - 1.96*se_mean_dt,
         mean_UL = mean_dt + 1.96*se_mean_dt)

exp2data_minus_IA_times = exp2data %>%
  filter(punish_type_IA == 1,
         behavior_punish == 1,
         time_pressure == "Minus") %>%
  summarize(mean_dt = mean1(behaviorTime_sec),
            se_mean_dt = se_mean(behaviorTime_sec)) %>%
  mutate(punish_type = "IA",
         setting = "TP-",
         mean_LL = mean_dt - 1.96*se_mean_dt,
         mean_UL = mean_dt + 1.96*se_mean_dt)

exp2data_minus_U_times = exp2data %>%
  filter(punish_type_U == 1,
         behavior_punish == 1,
         time_pressure == "Minus") %>%
  summarize(mean_dt = mean1(behaviorTime_sec),
            se_mean_dt = se_mean(behaviorTime_sec)) %>%
  mutate(punish_type = "U",
         setting = "TP-",
         mean_LL = mean_dt - 1.96*se_mean_dt,
         mean_UL = mean_dt + 1.96*se_mean_dt)

exp2data_times = bind_rows(exp2data_minus_CR_times, exp2data_minus_IA_times,
                           exp2data_minus_NR_times, exp2data_minus_U_times,
                           exp2data_plus_CR_times, exp2data_plus_IA_times,
                           exp2data_plus_NR_times, exp2data_plus_U_times)
```

Main

```
# Create the combined figure
exp2data_combined = exp2data_combined %>%
         mutate(punish_type_fct = factor(punish_type,
                                         levels = c("CR", "NR", "IA", "U")))

exp2data_combined %>%
  ggplot(aes(x = punish_type_fct, y = perc, fill = punish_type_fct,
```

```
            pattern = setting)) +
geom_bar_pattern(position = "dodge", stat = "identity", alpha = 0.5,
                 pattern_density = 0.25, pattern_color = "white",
                 pattern_shape = 3) +
geom_errorbar(aes(ymin = perc + 1.96*se_perc,
                  ymax = perc - 1.96*se_perc,
                  width = 0.25),
                  color = "purple4",
              position = position_dodge(.9),
              show.legend = F) +
scale_pattern_manual(values = c("none", "pch")) +
guides(color = "none", fill = "none",
       pattern = guide_legend(title = "Setting")) +
annotate("text", x = 1:4,
         y = c(0.025, 0.0425, 0.045, 0.02),
         label = c("italic(p) == 0.889", "italic(p) == 0.629",
                   "italic(p) == 0.435", "italic(p) == 0.649"),
         parse = T) +
scale_fill_manual(values = c("CR" = "plum3",
                             "NR" = "mediumslateblue",
                             "IA" = "mediumpurple3",
                             "U" = "orchid4"),
                  limits = c("CR", "NR", "IA", "U"),
                  guide = "none") +
scale_x_discrete(labels = c("Copying/\nretaliation", "Negative\nreinforcement",
                            "Inequality\naversion", "Unclassified")) +
scale_y_continuous(limits = c(0, 0.05), expand = c(0, 0)) +
ylab("Proportion") +
xlab("") +
theme_classic() +
theme(panel.grid.minor = element_blank(),
      panel.grid.major = element_blank(),
      legend.position = "bottom",
      legend.key.size = unit(1, "cm"),
      legend.key = element_rect(fill = "#574AE2", color = NA),
      axis.title.x = element_blank(),
      axis.ticks.x = element_blank(),
      axis.ticks.y = element_blank())
```

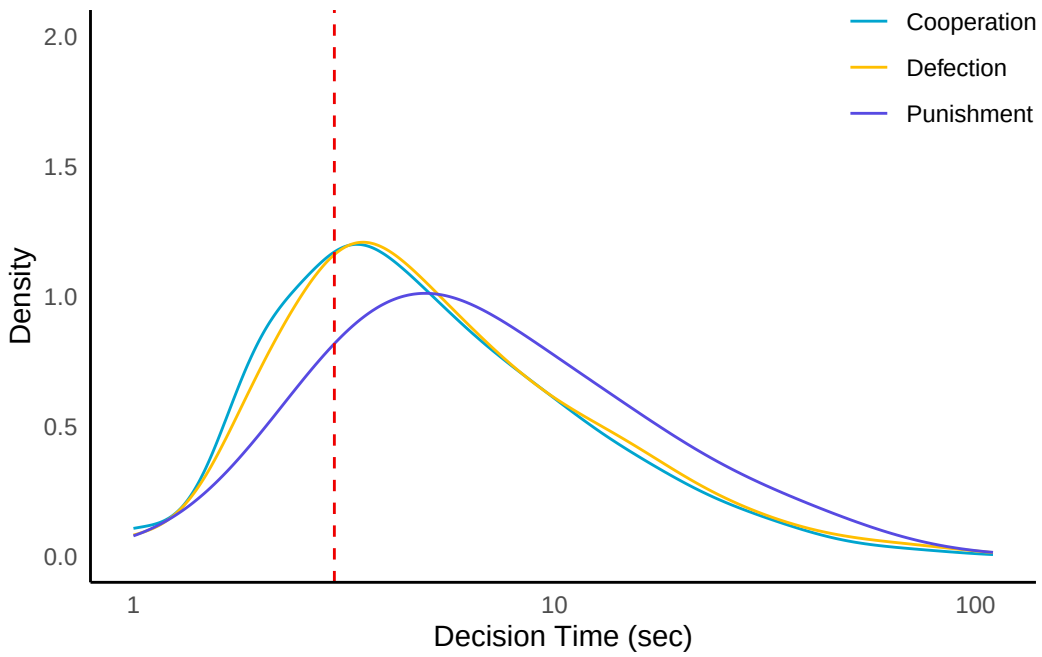



```
# ggsave(filename = "~/Documents/Projects/harming_esn/figures/fig4.png",
# width = 7, height = 5, units = "in")
```

Figure S2 - Distribution of Decision Times, Experiment 1

```
exp1data %>%
  filter(is.na(behaviorTime_prompt/1000) == 0, behavior %in% c("C", "D", "P")) %>%
  ggplot(aes(x = behaviorTime_prompt/1000, color = behavior)) +
  geom_density(adjust = 2, key_glyph = "path") +
  geom_vline(xintercept = 3, color = "red2", linetype = "dashed") +
  theme_classic() +
  labs(color = "Behavior") +
  xlab("Decision Time (sec)") +
  scale_x_log10(limits = c(1, 110),breaks = c(1, 10, 100),
                name = "Decision Time (sec)") +
  scale_y_continuous(limits = c(0, 2), name = "Density") +
  scale_color_manual(labels = c("Cooperation", "Defection", "Punishment"),
                     values = c("#00A5CF", "#FFBF00", "#574AE2"), guide = "none") +
  guides(colour=guide_legend(title = NULL)) +
  theme(panel.grid.minor = element_blank(),
        panel.grid.major = element_blank(),
```

```
        legend.position = c(0.9, 0.9),
        legend.title = element_blank(),
        axis.ticks.x = element_blank(),
        axis.ticks.y = element_blank())
```




```
# ggsave(filename = "~/Documents/Projects/harming_esn/figures/figS2.png",
# width = 7, height = 5, units = "in")
```

Figure S3 - Sensitivity Analysis for Invisible Wealth Games Only (Exp. 1)

```
exp1data_invis_only = exp1data %>% filter(showScore == 0)

exp1data_invis_only_NR = exp1data_invis_only %>%
  group_by(punish_type_NR) %>%
  count() %>%
  ungroup() %>%
  mutate(punish_type = "NR",
         total = sum(n),
         perc = n/sum(n),
         se_perc = sqrt((perc*(1-perc))/total)) %>%
```

```
  filter(punish_type_NR == 1)  %>%
  select(punish_type, n, total, perc, se_perc)

exp1data_invis_only_IA = exp1data_invis_only %>%
  group_by(punish_type_IA) %>%
  count() %>%
  ungroup() %>%
  mutate(punish_type = "IA",
         total = sum(n),
         perc = n/sum(n),
         se_perc = sqrt((perc*(1-perc))/total)) %>%
  filter(punish_type_IA == 1)  %>%
  select(punish_type, n, total, perc, se_perc)

exp1data_invis_only_CR = exp1data_invis_only %>%
  group_by(punish_type_CR) %>%
  count() %>%
  ungroup() %>%
  mutate(punish_type = "CR",
         total = sum(n),
         perc = n/sum(n),
         se_perc = sqrt((perc*(1-perc))/total)) %>%
  filter(punish_type_CR == 1)  %>%
  select(punish_type, n, total, perc, se_perc)

exp1data_invis_only_U = exp1data_invis_only %>%
  group_by(punish_type_U) %>%
  count() %>%
  ungroup() %>%
  mutate(punish_type = "U",
         total = sum(n),
         perc = n/sum(n),
         se_perc = sqrt((perc*(1-perc))/total)) %>%
  filter(punish_type_U == 1)  %>%
  select(punish_type, n, total, perc, se_perc)

figS1data_invis_only =
  bind_rows(exp1data_invis_only_CR, exp1data_invis_only_IA,
            exp1data_invis_only_NR, exp1data_invis_only_U)

figS1data_invis_only = figS1data_invis_only %>%
  mutate(perc_LL = perc - 1.96*se_perc,
```

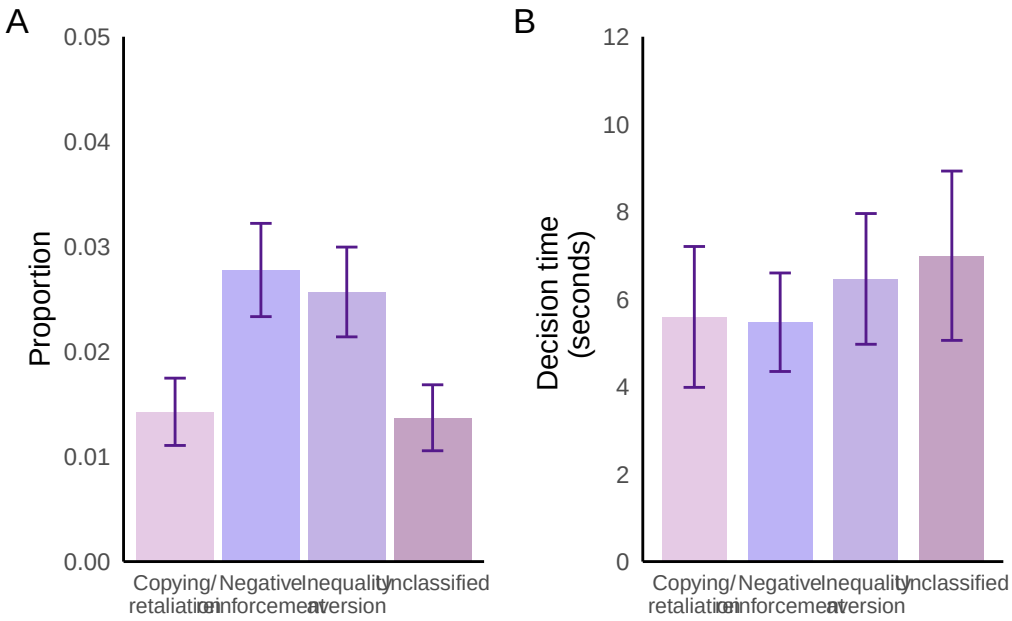
```
         perc_UL = perc + 1.96*se_perc)

exp1data_invis_only_NR_times = exp1data_invis_only %>%
  filter(punish_type_NR == 1, behavior_punish == 1) %>%
  summarize(mean_dt = mean1(behaviorTime_sec),
            se_mean_dt = se_mean(behaviorTime_sec)) %>%
  mutate(punish_type = "NR",
         mean_LL = mean_dt - 1.96*se_mean_dt,
         mean_UL = mean_dt + 1.96*se_mean_dt)

exp1data_invis_only_IA_times = exp1data_invis_only %>%
  filter(punish_type_IA == 1, behavior_punish == 1) %>%
  summarize(mean_dt = mean1(behaviorTime_sec),
            se_mean_dt = se_mean(behaviorTime_sec),
) %>%
  mutate(punish_type = "IA",   mean_LL = mean_dt - 1.96*se_mean_dt,
         mean_UL = mean_dt + 1.96*se_mean_dt)

exp1data_invis_only_CR_times = exp1data_invis_only %>%
  filter(punish_type_CR == 1, behavior_punish == 1) %>%
  summarize(mean_dt = mean1(behaviorTime_sec),
            se_mean_dt = se_mean(behaviorTime_sec)) %>%
  mutate(punish_type = "CR",
           mean_LL = mean_dt - 1.96*se_mean_dt,
         mean_UL = mean_dt + 1.96*se_mean_dt)

exp1data_invis_only_U_times = exp1data_invis_only %>%
  filter(punish_type_U == 1, behavior_punish == 1) %>%
  summarize(mean_dt = mean1(behaviorTime_sec),
            se_mean_dt = se_mean(behaviorTime_sec)) %>%
  mutate(punish_type = "U",
         mean_LL = mean_dt - 1.96*se_mean_dt,
         mean_UL = mean_dt + 1.96*se_mean_dt)

exp1data_invis_only_punish_types_times = bind_rows(exp1data_invis_only_NR_times,
                                        exp1data_invis_only_CR_times,
                                        exp1data_invis_only_IA_times,
                                        exp1data_invis_only_U_times) %>%
  select(punish_type, mean_dt, se_mean_dt, mean_LL, mean_UL)

fig2_data_invis_only = figS1data_invis_only %>%
  left_join(exp1data_invis_only_punish_types_times, by = "punish_type") %>%
```

```
  mutate(punish_type = case_match(punish_type,
              "CR" ~ "Copying/retaliation",
              "IA" ~ "Inequality aversion",
              "NR" ~ "Negative reinforcement",
              "U" ~ "Unclassified")) %>%
  mutate(punish_type_fct = factor(punish_type,
                                  levels = c("Copying/retaliation",
                                             "Negative reinforcement",
                                             "Inequality aversion",
                                             "Unclassified")))
figS3_A = fig2_data_invis_only %>%
  ggplot(aes(x = punish_type_fct, y = perc, fill = punish_type_fct)) +
  geom_bar(position = "dodge", stat = "identity", alpha = 0.5, show.legend = F) +
  geom_errorbar(aes(ymin = perc + 1.96*se_perc,
                    ymax = perc - 1.96*se_perc,
                    width = 0.25),
                color = "purple4",
                position = position_dodge(.9),
                show.legend = F) +
  scale_fill_manual(values = c("Copying/retaliation" = "plum3",
                               "Negative reinforcement" = "mediumslateblue",
                               "Inequality aversion" = "mediumpurple3",
                               "Unclassified" = "orchid4"), guide = "none") +
  scale_color_manual(guide = "none") +
  scale_x_discrete(labels = c("Copying/\nretaliation", "Negative\nreinforcement",
                              "Inequality\naversion", "Unclassified")) +
  scale_y_continuous(limits = c(0, 0.05), expand = c(0, 0)) +
  ylab("Proportion") +
  xlab("") +
  labs(tag = "A") +
  theme_classic() +
  theme(panel.grid.minor = element_blank(),
        panel.grid.major = element_blank(),
        legend.position = "bottom",
        legend.title = element_blank(),
        axis.text.x = element_text(size = 8),
        axis.title.x = element_blank(),
        axis.ticks.x = element_blank(),
        axis.ticks.y = element_blank())
```

```
figS3_B = fig2_data_invis_only %>%
  ggplot(aes(x = punish_type_fct, y = mean_dt, fill = punish_type_fct)) +
```

```
  geom_bar(stat = "identity", width = 0.75,  alpha = 0.5) +
  geom_errorbar(aes(ymin = mean_LL,
                    ymax = mean_UL),
                color = "purple4", width = 0.25) +
  theme_classic() +
  scale_y_continuous(limits = c(0, 12), breaks = seq(0, 12, by = 2), expand = c(0, 0)) +
  ylab("Decision time \n (seconds)")+
  scale_fill_manual(values = c("Copying/retaliation" = "plum3",
                               "Negative reinforcement" = "mediumslateblue",
                               "Inequality aversion" = "mediumpurple3",
                               "Unclassified" = "orchid4"), guide = "none") +
  scale_x_discrete(labels = c("Copying/\nretaliation", "Negative\nreinforcement",
                              "Inequality\naversion", "Unclassified")) +
  scale_color_manual(guide = "none") +
  theme_classic() +
  labs(tag = "B") +
  theme(panel.grid.minor = element_blank(),
        panel.grid.major = element_blank(),
        legend.position = "none",
        axis.text.x = element_text(size = 8),
        axis.title.x = element_blank(),
        axis.ticks.x = element_blank(),
        axis.ticks.y = element_blank())
```

```
figS3_A + figS3_B
```




```
# ggsave(filename = "~/Documents/Projects/harming_esn/figures/figS3.png",
#      width = 8, height = 5, units = "in")
```