Modality effects in a signalling game

Intro

This script uses data compiled by *analyseData.R*.

Load libraries

```
library(lme4)
library(sjPlot)
library(ggplot2)
library(lattice)
library(influence.ME)
library(gplots)
```

Load data

Remove non-multimodal turns from multimodal condition.

```
d = read.csv("../../data/FinalSignalData.csv")
turn.d = read.csv("../../data/Final_Turn_data.csv")

multi.turns = turn.d[turn.d$turnModalityType=="multi",]$turnString

d = d[d$modalityCondition!="multi" |
        d$turnString %in% multi.turns,]
```

Work out number of turns in each trial.

```
# Number of turns in each trial
numTurns = tapply(d$turnString, d$trialString,
                  function(X){length(unique(X))})
d$numberOfTurns = numTurns[d$trialString]
```

Variable for length of first T1

```
T1L = tapply(d[d$turnType=="T1",]$turnLength,
             d[d$turnType=="T1",]$trialString, head, n=1)
d$T1Length = T1L[d$trialString]
d$T1Length[is.na(d$T1Length)] = mean(d$T1Length,na.rm=T)
d$T1Length.log = log(d$T1Length)
d$T1Length.log = d$T1Length.log - mean(d$T1Length.log)
```

We don’t need info on every signal in each turn, just the trial time. Keep only 1st signal in each trial.

```
d = d[!duplicated(d$trialString),]
```

Descriptive stats

Here is a graph showing the distribution of trial lengths by conditions:

```r
par(mfrow=c(1,2))
for(stimType in unique(d$condition)){

  plotmeans(trialLength/1000~game,
            data = d[d$modalityCondition=='vocal' & !duplicated(d$trialString)
                     & d$condition==stimType,],
            col=1,barcol = 1,n.label = F,
            ylim=c(0,20),
            xlab="Game",
            ylab="Trial length (s)", las=1)
  plotmeans(trialLength/1000~game,
            data = d[d$modalityCondition=='multi' & !duplicated(d$trialString)
                     & d$condition==stimType,],
            add=T,col=2,barcol = 2,
            xaxt='n',
            n.label = F)
  plotmeans(trialLength/1000~game,
            data = d[d$modalityCondition=='visual' & !duplicated(d$trialString)
                     & d$condition==stimType,],
            add=T,col=3,barcol = 3,n.label = F,
            xaxt='n')
  if(stimType=="Auditory"){
    legend(2.5,20,legend=c('Acoustic','Multimodal','Visual'), col=1:3,lty=1,pch=1)
  }
  title(main=stimType)
}
```

```
## Warning in arrows(x, li, x, pmax(y - gap, li), col = barcol, lwd = lwd, :
## zero-length arrow is of indeterminate angle and so skipped

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## Warning in arrows(x, ui, x, pmin(y + gap, ui), col = barcol, lwd = lwd, :
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```
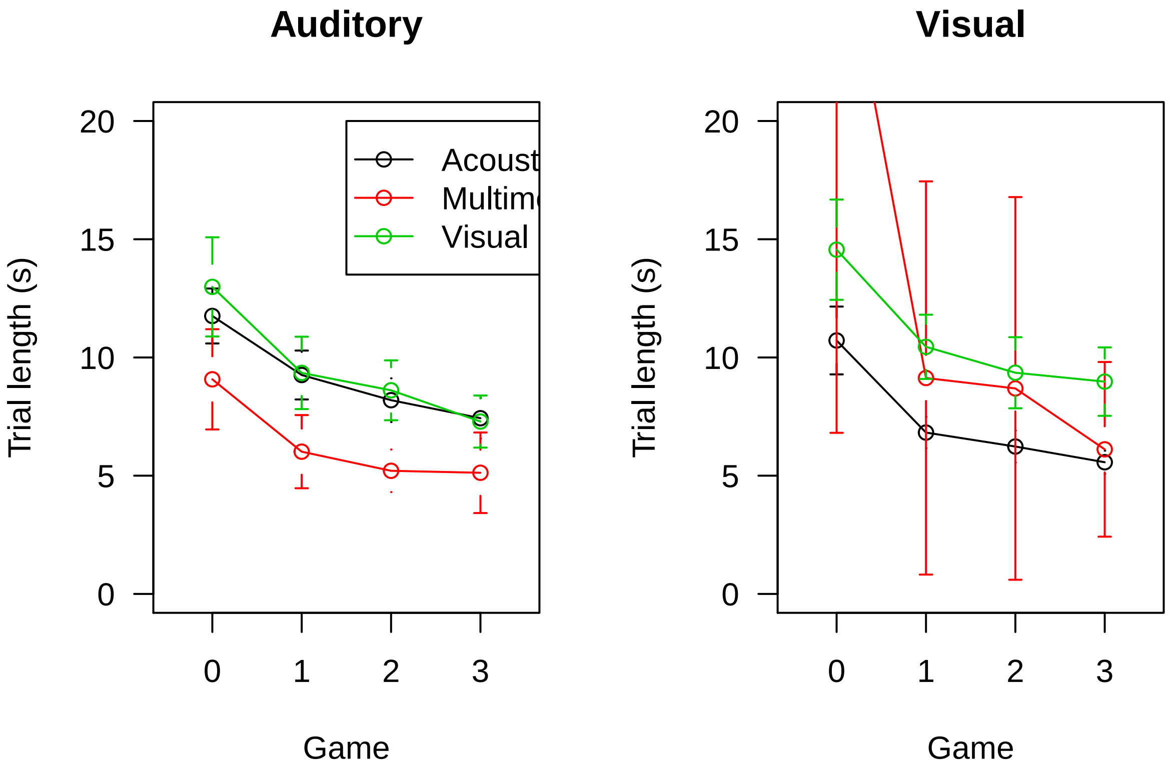
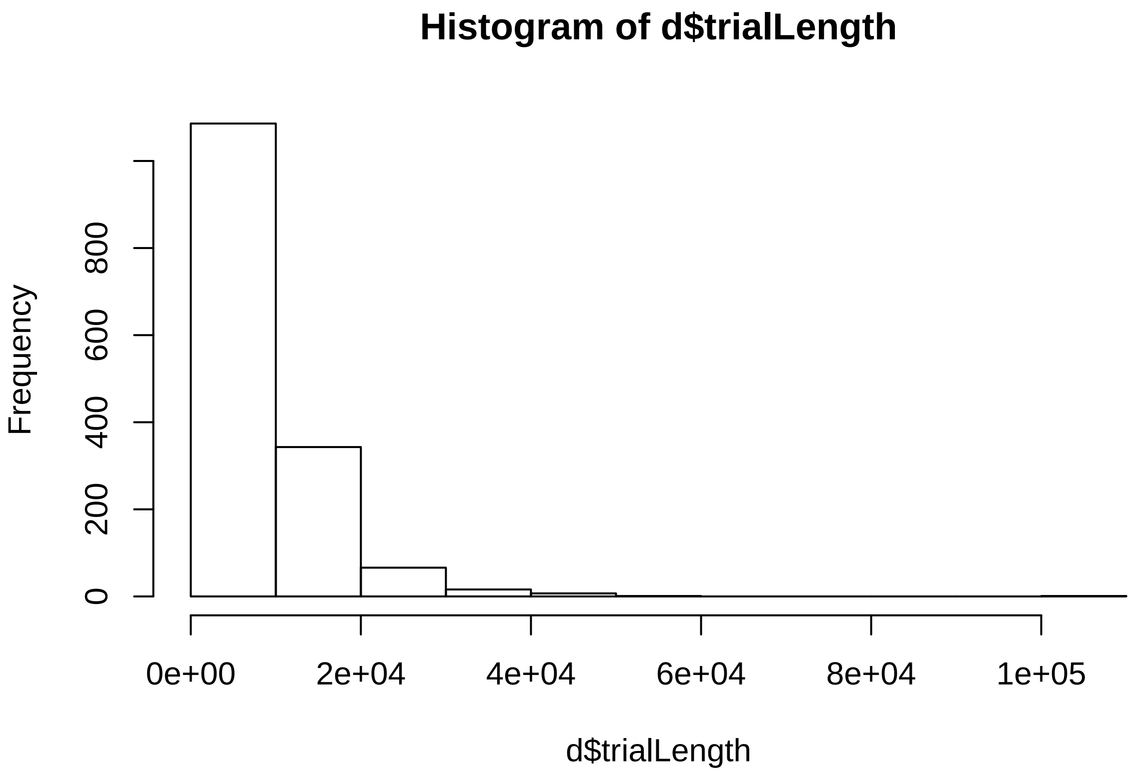



```r
par(mfrow=c(1,1))
```

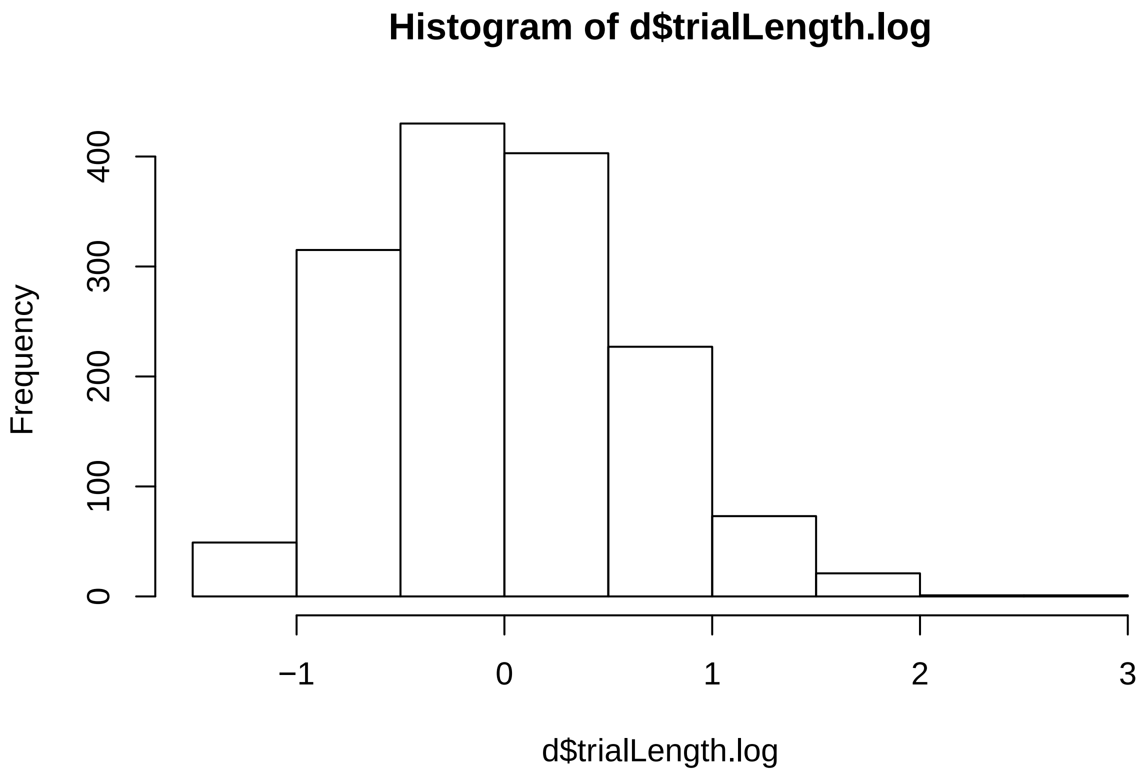
The distribution of trial times is very skewed:

```r
hist(d$trialLength)
```



So we transform it using a log transform, then center the data.

```r
d$trialLength.log = log(d$trialLength)
meanLogTrialLength = mean(d$trialLength.log)
d$trialLength.log = d$trialLength.log - meanLogTrialLength
hist(d$trialLength.log)
```



Make a variable to represent proportion of games played:

```
# Make a variable that represents the number of trials played
d$trialTotal = d$trial + (d$game * (max(d$trial)+1))
# Convert to proportion of games played, so that estimates reflect change per game.
d$trialTotal = d$trialTotal / 16
# Center the trialTotal variable so intercept reflects after the first game
d$trialTotal = d$trialTotal - 2
```

Make a variable for which stimuli the players experienced first.

```
firstBlock = tapply(as.character(d$condition),d$dyadNumber,head,n=1)
d$firstBlock = as.factor(firstBlock[match(d$dyadNumber,names(firstBlock))])
```

Reorder some levels so that the intercept reflects the most frequent condition.

```
d$incorrect = !d$correct
```

Variable for whether T1 was a multimodal signal.

```
turnD = read.csv("../../data/Final_Turn_data.csv")
turnD = turnD[turnD$turnType=="T1",]
turnD = turnD[turnD$role == "Director",]
d$multimodal = turnD[match(d$trialString, turnD$trialString),]$turnModalityType == "multi"
d$multimodal[is.na(d$multimodal)] = F
```

Mixed models

Make a series of models with random effects for dyad, director (nested within dyad) and item.

Not all random slopes are appropriate. For example, items are used in only one stimulus condition, so a random slope for condition by item is not appropriate. Similarly, each dyad only plays in one modality condition.

It is reasonable to have a random slope for trial by dyad, but this caused unreliable model convergence, so is not included.

The final random slopes were for condition and incorrectness by dyad/player, and modality condition by item.

```
# No fixed effects
m0 =  lmer(trialLength.log ~ 1 +
            (1 + condition + incorrect |dyadNumber/playerId) +
            (1 + modalityCondition|itemId),
          data=d, REML = FALSE)
```

Now we add a series of possible confounding factors such as the number of turns etc. We add the main experimental factors at the end to ensure that they're really contributing to the model over and above the confounds.

```
# Add number of turns
nTurns = lmer(trialLength.log ~ 1 +
                numberOfTurns +
            (1 + condition + incorrect |dyadNumber/playerId) +
            (1 + modalityCondition|itemId),
          data=d, REML = FALSE)

# Add whether the response was incorrect
incor = lmer(trialLength.log ~ 1 +
            numberOfTurns +
            incorrect +
            (1 + condition + incorrect |dyadNumber/playerId) +
            (1 + modalityCondition|itemId),
          data=d, REML = FALSE)
```

```
# Add multimodal signal

multim = lmer(trialLength.log ~ 1 +
            numberOfTurns +
            incorrect +
            multimodal +
            (1 + condition + incorrect |dyadNumber/playerId) +
            (1 + modalityCondition|itemId),
          data=d, REML = FALSE)

# Add effect of trial

game = lmer(trialLength.log ~ 1 +
            trialTotal +
            numberOfTurns +
            incorrect +
            multimodal +
            (1 + condition + incorrect |dyadNumber/playerId) +
            (1 + modalityCondition|itemId),
          data=d, REML = FALSE)

# Add the quadratic effect of trial
gamQuad = lmer(trialLength.log ~ 1 +
            trialTotal + I(trialTotal^2) +
            numberOfTurns +
            incorrect +
            multimodal +
            (1 + condition + incorrect |dyadNumber/playerId) +
            (1 + modalityCondition|itemId),
          data=d, REML = FALSE)
```

```
# Add modality condition
modality =  lmer(trialLength.log ~ 1 + modalityCondition +
            trialTotal + I(trialTotal^2) +
            numberOfTurns +
            incorrect +
            multimodal +
            (1 + condition + incorrect |dyadNumber/playerId) +
            (1 + modalityCondition|itemId),
          data=d, REML = FALSE)
# Add stimulus condition
cond = lmer(trialLength.log ~ 1 + modalityCondition + condition +
            trialTotal + I(trialTotal^2) +
            numberOfTurns +
            incorrect +
            multimodal +
            (1 + condition + incorrect |dyadNumber/playerId) +
            (1 + modalityCondition|itemId),
          data=d, REML = FALSE)

# Add interaction between modality and stimulus condition
modXcond = lmer(trialLength.log ~ 1 + modalityCondition*condition +
           trialTotal + I(trialTotal^2) +
            numberOfTurns +
            incorrect +
            multimodal +
            (1 + condition + incorrect |dyadNumber/playerId) +
            (1 + modalityCondition|itemId),
          data=d, REML = FALSE)
```

```
# Add interaction between condition and trial
conXgame = lmer(trialLength.log ~ 1 + modalityCondition*condition +
            trialTotal + I(trialTotal^2) +
              condition:trialTotal +
            numberOfTurns +
            incorrect +
            multimodal +
            (1 + condition + incorrect |dyadNumber/playerId) +
            (1 + modalityCondition|itemId),
          data=d, REML = FALSE)
# Add interaction between modality and trial
modXgame = lmer(trialLength.log ~ 1 + modalityCondition*condition +
             trialTotal + I(trialTotal^2) +
              condition:trialTotal + modalityCondition:trialTotal +
            numberOfTurns +
            incorrect +
            multimodal +
            (1 + condition + incorrect |dyadNumber/playerId) +
            (1 + modalityCondition|itemId),
          data=d, REML = FALSE)

# Add 3-way interaction
moXcoXga =  lmer(trialLength.log ~ 1 + modalityCondition*condition*trialTotal +
             I(trialTotal^2) +
            numberOfTurns +
            incorrect +
            multimodal +
            (1 + condition + incorrect |dyadNumber/playerId) +
            (1 + modalityCondition|itemId),
          data=d, REML = FALSE)
```

Interactions

```
# interaction between turns and modality
nTurnXmo = lmer(trialLength.log ~ 1 + modalityCondition*condition*trialTotal +
             I(trialTotal^2) +
            numberOfTurns + numberOfTurns:modalityCondition +
            incorrect +
            multimodal +
            (1 + condition + incorrect |dyadNumber/playerId) +
            (1 + modalityCondition|itemId),
          data=d, REML = FALSE)

nTurnXco = lmer(trialLength.log ~ 1 + modalityCondition*condition*trialTotal +
             I(trialTotal^2) +
            numberOfTurns + numberOfTurns:modalityCondition +
            numberOfTurns:condition +
            incorrect +
            multimodal +
            (1 + condition + incorrect |dyadNumber/playerId) +
            (1 + modalityCondition|itemId),
          data=d, REML = FALSE)

# Turn x modality x condtion
# Note that the acousitc modality had hardly any matcher turns,
#so the factor is dropped

tuXmoXco = lmer(trialLength.log ~ 1 + modalityCondition*condition*trialTotal +
             I(trialTotal^2) +
            numberOfTurns*modalityCondition*condition +
            incorrect +
            multimodal +
            (1 + condition + incorrect |dyadNumber/playerId) +
            (1 + modalityCondition|itemId),
          data=d, REML = FALSE)
```

```
## fixed-effect model matrix is rank deficient so dropping 1 column / coefficient
```

```
# Add the interaction between modality and incorrectness
moXincor =   lmer(trialLength.log ~ 1 + modalityCondition*condition*trialTotal +
             I(trialTotal^2) +
            numberOfTurns*modalityCondition*condition +
            incorrect + incorrect:modalityCondition +
            multimodal +
            (1 + condition + incorrect |dyadNumber/playerId) +
            (1 + modalityCondition|itemId),
          data=d, REML = FALSE)
```

```
## fixed-effect model matrix is rank deficient so dropping 1 column / coefficient
```

```
# Add the interaction between condition and incorrectness
coXincor =  lmer(trialLength.log ~ 1 + modalityCondition*condition*trialTotal +
             I(trialTotal^2) +
            numberOfTurns*modalityCondition*condition +
            incorrect + incorrect:modalityCondition + incorrect:condition +
            multimodal +
            (1 + condition + incorrect |dyadNumber/playerId) +
            (1 + modalityCondition|itemId),
          data=d, REML = FALSE)
```

```
## fixed-effect model matrix is rank deficient so dropping 1 column / coefficient
```

```
# Add the three-way interaction between condition, modality and incorrectness
coXmoXin = lmer(trialLength.log ~ 1 + modalityCondition*condition*trialTotal +
             I(trialTotal^2) +
            numberOfTurns*modalityCondition*condition +
            incorrect *modalityCondition*condition +
            multimodal +
            (1 + condition + incorrect |dyadNumber/playerId) +
            (1 + modalityCondition|itemId),
          data=d, REML = FALSE)
```

```
## fixed-effect model matrix is rank deficient so dropping 1 column / coefficient
```

```
# Interaction between multimodality and condition
multiXco = lmer(trialLength.log ~ 1 + modalityCondition*condition*trialTotal +
             I(trialTotal^2) +
            numberOfTurns*modalityCondition*condition +
            incorrect *modalityCondition*condition +
            multimodal + multimodal:condition +
            (1 + condition + incorrect |dyadNumber/playerId) +
            (1 + modalityCondition|itemId),
          data=d, REML = FALSE)
```

```
## fixed-effect model matrix is rank deficient so dropping 1 column / coefficient
```

```
# Add interaction between quadratic effect of trial and modality
modXgamQ =  lmer(trialLength.log ~ 1 + modalityCondition*condition*trialTotal +
             I(trialTotal^2) +(modalityCondition:I(trialTotal^2)) +
            numberOfTurns*modalityCondition*condition +
            incorrect *modalityCondition*condition +
            multimodal + multimodal:condition +
            (1 + condition + incorrect |dyadNumber/playerId) +
            (1 + modalityCondition|itemId),
          data=d, REML = FALSE)
```

```
## fixed-effect model matrix is rank deficient so dropping 1 column / coefficient
```

Check block has no effect

```
# Add block order
block =  lmer(trialLength.log ~ 1 + modalityCondition*condition*trialTotal +
             I(trialTotal^2) +(modalityCondition:I(trialTotal^2)) +
            numberOfTurns*modalityCondition*condition +
            incorrect *modalityCondition*condition +
            multimodal + multimodal:condition +
            firstBlock +
            (1 + condition + incorrect |dyadNumber/playerId) +
            (1 + modalityCondition|itemId),
          data=d, REML = FALSE)
```

```
## fixed-effect model matrix is rank deficient so dropping 1 column / coefficient
```

```
# Add interaction between block order and modality
blocXmod = lmer(trialLength.log ~ 1 + modalityCondition*condition*trialTotal +
             I(trialTotal^2) +(modalityCondition:I(trialTotal^2)) +
            numberOfTurns*modalityCondition*condition +
            incorrect *modalityCondition*condition +
            multimodal + multimodal:condition +
            firstBlock*modalityCondition +
            (1 + condition + incorrect |dyadNumber/playerId) +
            (1 + modalityCondition|itemId),
          data=d, REML = TRUE)   # Last model is REML to get estimates
```

```
## fixed-effect model matrix is rank deficient so dropping 1 column / coefficient
```

Results

Compare the fit of the models:

```
modelComparison = anova(m0,modality,cond,game,modXcond,conXgame, modXgame,
      moXcoXga,nTurns,nTurnXmo,nTurnXco,tuXmoXco,
      incor,moXincor,coXincor,coXmoXin,
      multim,multiXco,
      gamQuad,modXgamQ,block, blocXmod)
```

```
## refitting model(s) with ML (instead of REML)
```

```
modelComparison
```

```
## Data: d
## Models:
## m0: trialLength.log ~ 1 + (1 + condition + incorrect | dyadNumber/playerId) +
## m0:     (1 + modalityCondition | itemId)
## nTurns: trialLength.log ~ 1 + numberOfTurns + (1 + condition + incorrect |
## nTurns:     dyadNumber/playerId) + (1 + modalityCondition | itemId)
## incor: trialLength.log ~ 1 + numberOfTurns + incorrect + (1 + condition +
## incor:     incorrect | dyadNumber/playerId) + (1 + modalityCondition |
## incor:     itemId)
## multim: trialLength.log ~ 1 + numberOfTurns + incorrect + multimodal +
## multim:     (1 + condition + incorrect | dyadNumber/playerId) + (1 +
## multim:     modalityCondition | itemId)
## game: trialLength.log ~ 1 + trialTotal + numberOfTurns + incorrect +
## game:     multimodal + (1 + condition + incorrect | dyadNumber/playerId) +
## game:     (1 + modalityCondition | itemId)
## gamQuad: trialLength.log ~ 1 + trialTotal + I(trialTotal^2) + numberOfTurns +
## gamQuad:     incorrect + multimodal + (1 + condition + incorrect | dyadNumber/playerId) +
## gamQuad:     (1 + modalityCondition | itemId)
## modality: trialLength.log ~ 1 + modalityCondition + trialTotal + I(trialTotal^2) +
## modality:     numberOfTurns + incorrect + multimodal + (1 + condition +
## modality:     incorrect | dyadNumber/playerId) + (1 + modalityCondition |
## modality:     itemId)
## cond: trialLength.log ~ 1 + modalityCondition + condition + trialTotal +
## cond:     I(trialTotal^2) + numberOfTurns + incorrect + multimodal +
## cond:     (1 + condition + incorrect | dyadNumber/playerId) + (1 +
## cond:     modalityCondition | itemId)
## modXcond: trialLength.log ~ 1 + modalityCondition * condition + trialTotal +
## modXcond:     I(trialTotal^2) + numberOfTurns + incorrect + multimodal +
## modXcond:     (1 + condition + incorrect | dyadNumber/playerId) + (1 +
## modXcond:     modalityCondition | itemId)
## conXgame: trialLength.log ~ 1 + modalityCondition * condition + trialTotal +
## conXgame:     I(trialTotal^2) + condition:trialTotal + numberOfTurns +
## conXgame:     incorrect + multimodal + (1 + condition + incorrect | dyadNumber/playerId) +
## conXgame:     (1 + modalityCondition | itemId)
## modXgame: trialLength.log ~ 1 + modalityCondition * condition + trialTotal +
## modXgame:     I(trialTotal^2) + condition:trialTotal + modalityCondition:trialTotal +
## modXgame:     numberOfTurns + incorrect + multimodal + (1 + condition +
## modXgame:     incorrect | dyadNumber/playerId) + (1 + modalityCondition |
## modXgame:     itemId)
## moXcoXga: trialLength.log ~ 1 + modalityCondition * condition * trialTotal +
## moXcoXga:     I(trialTotal^2) + numberOfTurns + incorrect + multimodal +
## moXcoXga:     (1 + condition + incorrect | dyadNumber/playerId) + (1 +
## moXcoXga:     modalityCondition | itemId)
## nTurnXmo: trialLength.log ~ 1 + modalityCondition * condition * trialTotal +
## nTurnXmo:     I(trialTotal^2) + numberOfTurns + numberOfTurns:modalityCondition +
## nTurnXmo:     incorrect + multimodal + (1 + condition + incorrect | dyadNumber/playerId) +
## nTurnXmo:     (1 + modalityCondition | itemId)
## nTurnXco: trialLength.log ~ 1 + modalityCondition * condition * trialTotal +
## nTurnXco:     I(trialTotal^2) + numberOfTurns + numberOfTurns:modalityCondition +
## nTurnXco:     numberOfTurns:condition + incorrect + multimodal + (1 + condition +
## nTurnXco:     incorrect | dyadNumber/playerId) + (1 + modalityCondition |
## nTurnXco:     itemId)
## tuXmoXco: trialLength.log ~ 1 + modalityCondition * condition * trialTotal +
## tuXmoXco:     I(trialTotal^2) + numberOfTurns * modalityCondition * condition +
## tuXmoXco:     incorrect + multimodal + (1 + condition + incorrect | dyadNumber/playerId) +
## tuXmoXco:     (1 + modalityCondition | itemId)
## moXincor: trialLength.log ~ 1 + modalityCondition * condition * trialTotal +
## moXincor:     I(trialTotal^2) + numberOfTurns * modalityCondition * condition +
## moXincor:     incorrect + incorrect:modalityCondition + multimodal + (1 +
## moXincor:     condition + incorrect | dyadNumber/playerId) + (1 + modalityCondition |
## moXincor:     itemId)
## coXincor: trialLength.log ~ 1 + modalityCondition * condition * trialTotal +
## coXincor:     I(trialTotal^2) + numberOfTurns * modalityCondition * condition +
## coXincor:     incorrect + incorrect:modalityCondition + incorrect:condition +
## coXincor:     multimodal + (1 + condition + incorrect | dyadNumber/playerId) +
## coXincor:     (1 + modalityCondition | itemId)
## coXmoXin: trialLength.log ~ 1 + modalityCondition * condition * trialTotal +
## coXmoXin:     I(trialTotal^2) + numberOfTurns * modalityCondition * condition +
## coXmoXin:     incorrect * modalityCondition * condition + multimodal +
## coXmoXin:     (1 + condition + incorrect | dyadNumber/playerId) + (1 +
## coXmoXin:     modalityCondition | itemId)
## multiXco: trialLength.log ~ 1 + modalityCondition * condition * trialTotal +
## multiXco:     I(trialTotal^2) + numberOfTurns * modalityCondition * condition +
## multiXco:     incorrect * modalityCondition * condition + multimodal +
## multiXco:     multimodal:condition + (1 + condition + incorrect | dyadNumber/playerId) +
## multiXco:     (1 + modalityCondition | itemId)
## modXgamQ: trialLength.log ~ 1 + modalityCondition * condition * trialTotal +
## modXgamQ:     I(trialTotal^2) + (modalityCondition:I(trialTotal^2)) + numberOfTurns *
## modXgamQ:     modalityCondition * condition + incorrect * modalityCondition *
## modXgamQ:     condition + multimodal + multimodal:condition + (1 + condition +
## modXgamQ:     incorrect | dyadNumber/playerId) + (1 + modalityCondition |
## modXgamQ:     itemId)
## block: trialLength.log ~ 1 + modalityCondition * condition * trialTotal +
## block:     I(trialTotal^2) + (modalityCondition:I(trialTotal^2)) + numberOfTurns *
## block:     modalityCondition * condition + incorrect * modalityCondition *
## block:     condition + multimodal + multimodal:condition + firstBlock +
## block:     (1 + condition + incorrect | dyadNumber/playerId) + (1 +
## block:     modalityCondition | itemId)
## blocXmod: trialLength.log ~ 1 + modalityCondition * condition * trialTotal +
## blocXmod:     I(trialTotal^2) + (modalityCondition:I(trialTotal^2)) + numberOfTurns *
## blocXmod:     modalityCondition * condition + incorrect * modalityCondition *
## blocXmod:     condition + multimodal + multimodal:condition + firstBlock *
## blocXmod:     modalityCondition + (1 + condition + incorrect | dyadNumber/playerId) +
## blocXmod:     (1 + modalityCondition | itemId)
##          Df    AIC    BIC   logLik deviance    Chisq Chi Df Pr(>Chisq)
## m0       20 2064.7 2171.3 -1012.37   2024.7
## nTurns   21 1732.1 1843.9  -845.04   1690.1 334.6602      1  < 2.2e-16 ***
## incor    22 1719.8 1837.0  -837.90   1675.8  14.2934      1  0.0001564 ***
## multim   23 1666.2 1788.7  -810.09   1620.2  55.6033      1  8.867e-14 ***
## game     24 1332.0 1459.8  -642.00   1284.0 336.1928      1  < 2.2e-16 ***
## gamQuad  25 1295.2 1428.4  -622.62   1245.2  38.7502      1  4.817e-10 ***
## modality 27 1285.1 1428.9  -615.54   1231.1  14.1634      2  0.0008404 ***
## cond     28 1287.0 1436.2  -615.52   1231.0   0.0394      1  0.8426975
## modXcond 30 1276.4 1436.2  -608.20   1216.4  14.6330      2  0.0006645 ***
## conXgame 31 1278.4 1443.5  -608.19   1216.4   0.0305      1  0.8614154
## modXgame 33 1273.4 1449.2  -603.69   1207.4   8.9920      2  0.0111537 *
## moXcoXga 35 1273.8 1460.2  -601.91   1203.8   3.5692      2  0.1678615
## nTurnXmo 37 1269.6 1466.7  -597.79   1195.6   8.2329      2  0.0163023 *
## nTurnXco 38 1270.8 1473.2  -597.40   1194.8   0.7828      1  0.3762971
## tuXmoXco 39 1271.5 1479.2  -596.74   1193.5   1.3216      1  0.2503030
## moXincor 41 1271.6 1490.0  -594.80   1189.6   3.8818      2  0.1435747
## coXincor 42 1272.5 1496.2  -594.27   1188.5   1.0647      1  0.3021374
## coXmoXin 44 1274.6 1509.0  -593.30   1186.6   1.9284      2  0.3812949
## multiXco 45 1275.5 1515.2  -592.76   1185.5   1.0758      1  0.2996408
## modXgamQ 47 1274.9 1525.2  -590.43   1180.9   4.6725      2  0.0966904 .
## block    48 1276.7 1532.3  -590.32   1180.7   0.2093      1  0.6472791
## blocXmod 50 1280.4 1546.8  -590.22   1180.4   0.2155      2  0.8978416
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Pick final model for estimates:

```
finalModel = modXgamQ
```

Final model estimates:

```
summary(finalModel)
```

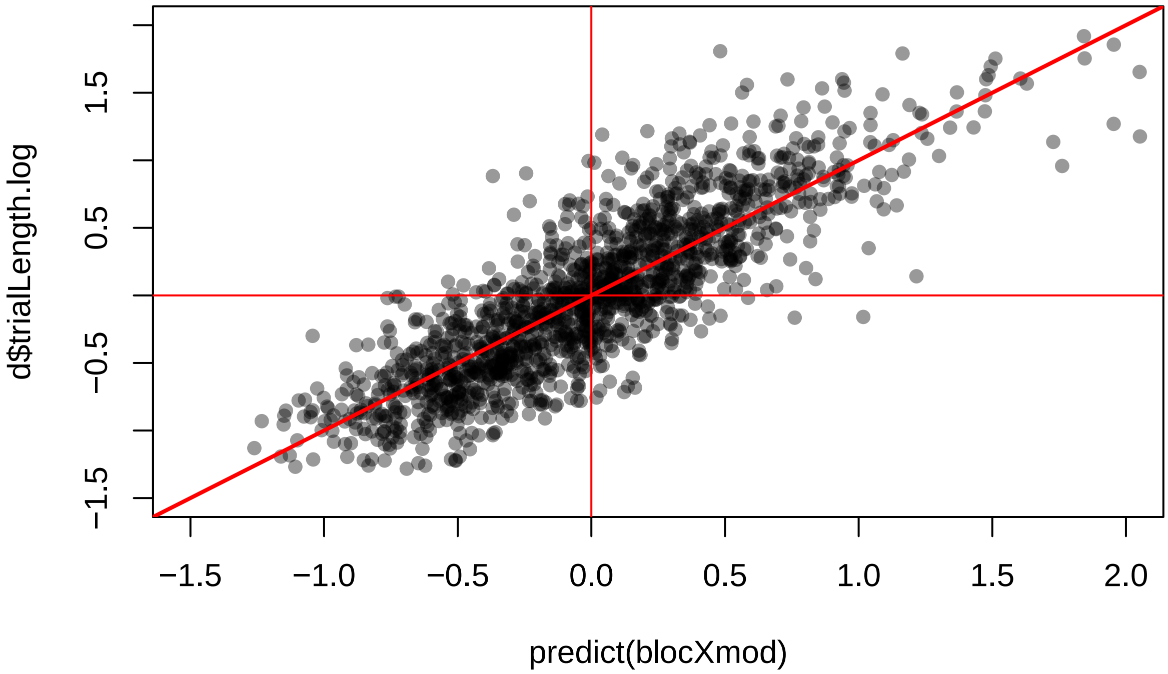
```
## Linear mixed model fit by maximum likelihood  ['lmerMod']
## Formula:
## trialLength.log ~ 1 + modalityCondition * condition * trialTotal +
##     I(trialTotal^2) + (modalityCondition:I(trialTotal^2)) + numberOfTurns *
##     modalityCondition * condition + incorrect * modalityCondition *
##     condition + multimodal + multimodal:condition + (1 + condition +
##     incorrect | dyadNumber/playerId) + (1 + modalityCondition |
##     itemId)
##    Data: d
##
##      AIC      BIC   logLik deviance df.resid
##   1274.9   1525.2   -590.4   1180.9     1473
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -3.5944 -0.6360 -0.0285  0.5758  4.0047
##
## Random effects:
##  Groups              Name                   Variance  Std.Dev. Corr
##  playerId:dyadNumber (Intercept)            4.724e-02 0.217348
##                      conditionVisual        2.773e-02 0.166512 -0.52
##                      incorrectTRUE          1.464e-02 0.120992 -0.58
##  itemId              (Intercept)            1.843e-02 0.135750
##                       modalityConditionvisual 9.539e-03 0.097668 0.52
##                       modalityConditionvocal  1.025e-02 0.101229 0.13
##  dyadNumber           (Intercept)             5.746e-02 0.239705
##                       conditionVisual         3.218e-04 0.017938 -1.00
##                       incorrectTRUE           1.724e-05 0.004152  1.00
##  Residual                                     1.104e-01 0.332260
##
##
##
##   0.05
##
##
##  0.40
##
##
##  -1.00
##
## Number of obs: 1520, groups:
## playerId:dyadNumber, 29; itemId, 16; dyadNumber, 15
##
## Fixed effects:
##                                                          Estimate
## (Intercept)                                             0.3133528
## modalityConditionvisual                                -0.7945485
## modalityConditionvocal                                 -0.6852690
## conditionVisual                                        -0.1301797
## trialTotal                                             -0.1752599
## I(trialTotal^2)                                         0.0591269
## numberOfTurns                                           0.4898436
## incorrectTRUE                                           0.2354254
## multimodalTRUE                                         -1.2550761
## modalityConditionvisual:conditionVisual                 0.3370008
## modalityConditionvocal:conditionVisual                 -0.1647026
## modalityConditionvisual:trialTotal                      0.0394102
## modalityConditionvocal:trialTotal                       0.0255431
## conditionVisual:trialTotal                             -0.0619726
## modalityConditionvisual:I(trialTotal^2)                -0.0322265
## modalityConditionvocal:I(trialTotal^2)                 -0.0004019
## modalityConditionvisual:numberOfTurns                  -0.0936616
## modalityConditionvocal:numberOfTurns                   -0.0970190
## conditionVisual:numberOfTurns                           0.0368211
## modalityConditionvisual:incorrectTRUE                  -0.0765185
## modalityConditionvocal:incorrectTRUE                   -0.1892731
## conditionVisual:incorrectTRUE                           0.3228754
## conditionVisual:multimodalTRUE                          0.3808349
## modalityConditionvisual:conditionVisual:trialTotal      0.0756274
## modalityConditionvocal:conditionVisual:trialTotal       0.0439746
## modalityConditionvisual:conditionVisual:numberOfTurns -0.0877391
## modalityConditionvisual:conditionVisual:incorrectTRUE -0.3389112
## modalityConditionvocal:conditionVisual:incorrectTRUE  -0.2399253
##                                                        Std. Error t value
## (Intercept)                                             0.3905191   0.802
## modalityConditionvisual                                 0.4118226  -1.929
## modalityConditionvocal                                  0.4446196  -1.541
## conditionVisual                                       0.4240834  -0.307
## trialTotal                                            0.0199802  -8.772
## I(trialTotal^2)                                       0.0178266   3.317
## numberOfTurns                                         0.0492266   9.951
## incorrectTRUE                                         0.1047503   2.247
## multimodalTRUE                                        0.3587690  -3.498
## modalityConditionvisual:conditionVisual               0.4286870   0.786
## modalityConditionvocal:conditionVisual                0.4064755  -0.405
## modalityConditionvisual:trialTotal                    0.0259772   1.517
## modalityConditionvocal:trialTotal                     0.0260024   0.982
## conditionVisual:trialTotal                            0.0594229  -1.043
## modalityConditionvisual:I(trialTotal^2)               0.0210939  -1.528
## modalityConditionvocal:I(trialTotal^2)                0.0210877  -0.019
## modalityConditionvisual:numberOfTurns                 0.0590461  -1.586
## modalityConditionvocal:numberOfTurns                  0.1785406  -0.543
## conditionVisual:numberOfTurns                         0.1290953   0.285
## modalityConditionvisual:incorrectTRUE                 0.1291345  -0.593
## modalityConditionvocal:incorrectTRUE                  0.1313271  -1.441
## conditionVisual:incorrectTRUE                         0.2035345   1.586
## conditionVisual:multimodalTRUE                        0.3911493   0.974
## modalityConditionvisual:conditionVisual:trialTotal    0.0638784   1.184
## modalityConditionvocal:conditionVisual:trialTotal     0.0638859   0.688
## modalityConditionvisual:conditionVisual:numberOfTurns 0.1356342  -0.647
## modalityConditionvisual:conditionVisual:incorrectTRUE 0.2227195  -1.522
## modalityConditionvocal:conditionVisual:incorrectTRUE  0.2196350  -1.092
```

```
##
## Correlation matrix not shown by default, as p = 28 > 12.
## Use print(x, correlation=TRUE)  or
##     vcov(x)        if you need it
```

```
## fit warnings:
## fixed-effect model matrix is rank deficient so dropping 1 column / coefficient
```

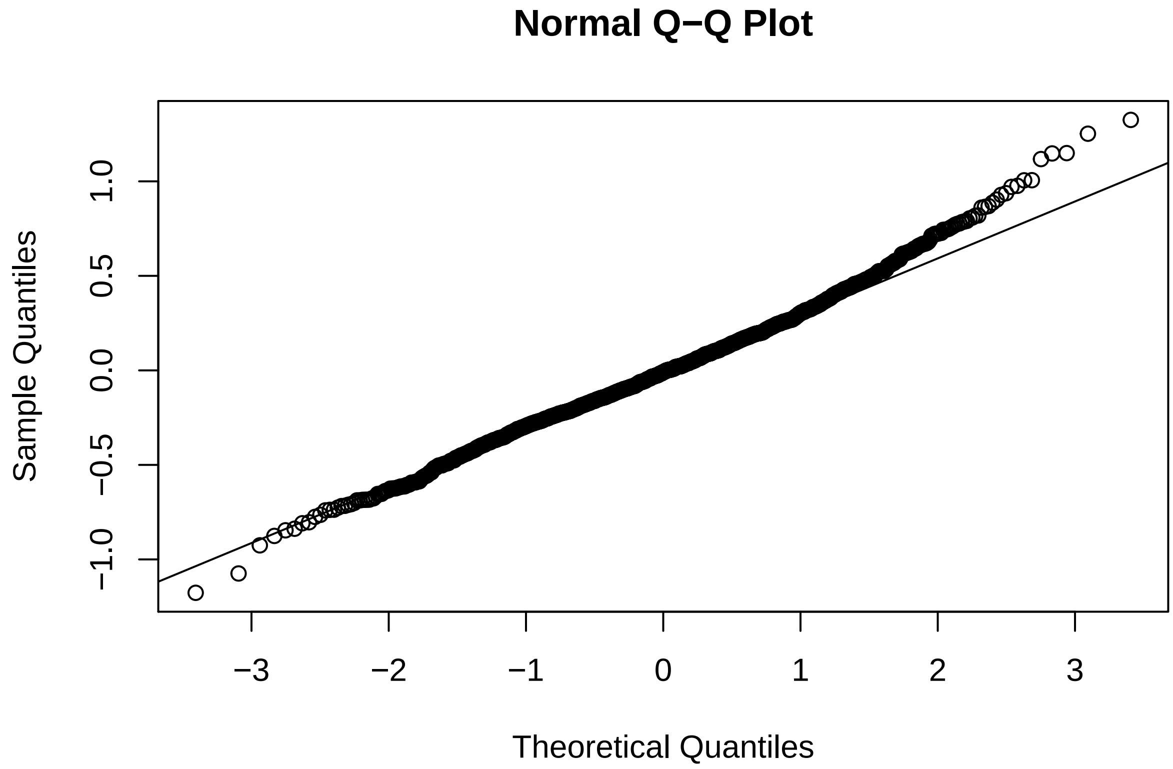
Check model predictions. The model predictions are in the right range and direction, fitting linear quite well:

```
plot(predict(blocXmod),d$trialLength.log, pch=16, col=rgb(0,0,0,0.4),
     ylim=c(-1.5,2),xlim=c(-1.5,2))
abline(a=0,b=1, col=2, lwd=2)
abline(h=0, col=2)
abline(v=0, col=2)
```



The residuals are ok, though it tends to do worse at higher values. This is expected from using the log scale.

```
qqnorm(resid(blocXmod))
qqline(resid(blocXmod))
```



Plot the fixed effects

Relabel the effects:

```
feLabels = matrix(c(
"(Intercept)"              ,"Intercept"      , NA,
"modalityConditionvisual" ,"Visual modality", "modality",
"modalityConditionvocal"  , "Acoustic modality", "modality",
"conditionVisual" , "Visual stimuli","cond",
"trialTotal"              , "Game","game",
"modalityConditionvisual:conditionVisual"  , "Visual modality:Visual stimuli", "modXcond",
"modalityConditionvocal:conditionVisual" , "Acoustic modality:Visual stimuli","modXcond",
"modalityConditionvisual:trialTotal"    , "Visual modality:Game","modXgame",
"modalityConditionvocal:trialTotal"     , "Acoustic modality:Game", "modXgame",
"conditionVisual:trialTotal"             , "Visual stimuli:Game","conXgame",
"modalityConditionvisual:conditionVisual:trialTotal", "Visual modality:Visual stimuli:Game", "moXcoXga"
"modalityConditionvocal:conditionVisual:trialTotal", "Acoustic modality:Visual stimuli:Game", "moXcoXga
"incorrectTRUE","Inorrect","incor",
"modalityConditionvisual:incorrectTRUE","Visual modality:Incorrect","moXincor",
"modalityConditionvocal:incorrectTRUE","Acoustic modality:Incorrect","moXincor",
"modalityConditionvisual:I(trialTotal^2)", "Visual modality:Game^2","modXgamQ",
"modalityConditionvocal:I(trialTotal^2)", "Acoustic modality:Game^2","modXgamQ",
"I(trialTotal^2)","Game^2","gamQuad",
"firstBlockVisual","Visual stims first","block",
"modalityConditionvisual:firstBlockVisual","Visual modality:Visual stim first","blocXmod",
"modalityConditionvocal:firstBlockVisual","Acoustic modality:Visual stim first","blocXmod",
"conditionVisual:incorrectTRUE","Visual stimuli:incorrect","coXincor",
"modalityConditionvisual:conditionVisual:incorrectTRUE","Visual modality:Visual stimuli:incorrect","coX
"modalityConditionvocal:conditionVisual:incorrectTRUE","Acoustic modality:Visual stimuli:incorrect","co

"modalityConditionvisual:conditionVisual:numberOfTurns","VisualModality:Visual stim:NumTurns","tuXmoXco
"modalityConditionvocal:conditionVisual:numberOfTurns","Vocal Modality:Visual stim:NumTurns","tuXmoXco"
"conditionVisual:numberOfTurns","Visual stim:NumTurns","nTurnXco",
"modalityConditionvisual:numberOfTurns","VisualModality:NumTurns","nTurnXmo",
"modalityConditionvocal:numberOfTurns","Vocal Modality:NumTurns","nTurnXmo",
"numberOfTurns","Number of turns","nTurns",
"multimodalTRUE","Multimodal T1","multim",
"conditionVisual:multimodalTRUE","VisualStim:MultimodalT1","multiXco"
), ncol=3, byrow = T)

feLabels2 = as.vector(feLabels[match(names(fixef(finalModel)),feLabels[,1]),2])
feModel = as.vector(feLabels[match(names(fixef(finalModel)),feLabels[,1]),3])

sig = modelComparison$`Pr(>Chisq)`
names(sig) = rownames(modelComparison)

sig.data = data.frame(estimate = fixef(finalModel),
                      y=1:length(fixef(finalModel)),
                      sig=sig[feModel])

cols= c("black",'red')
sig.data$pointCol = cols[1]
sig.data$pointCol[!is.na(sig.data$sig)] =
  cols[1 + (sig.data$sig[!is.na(sig.data$sig)] < 0.05)]
```

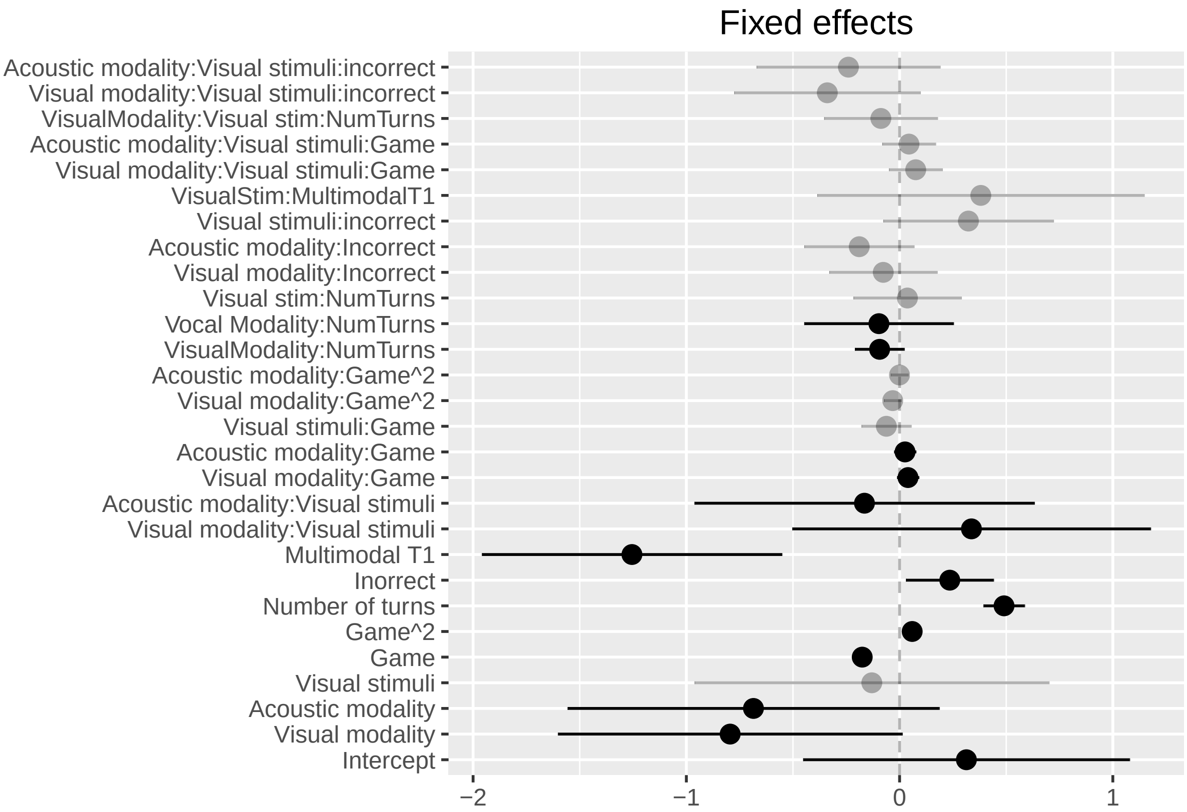
```
# Mark marginal effects
#sig.data$pointCol[!is.na(sig.data$sig) &
#                     sig.data$sig < 0.1 &
#                     sig.data$sig >=0.05] = "orange"

sig.data$fade = sig.data$sig > 0.05
```

Plot the strength of the fixed effects:

```
x = sjp.lmer(finalModel, 'fe',
         show.intercept = T,
         sort.est=NULL,
         axis.labels = feLabels2[2:length(feLabels2)],
         xlab="Trial time (log ms)",
         geom.colors = c(1,1),
         show.p=F,
         show.values = F,
         p.kr = FALSE,
         string.interc="Intercept",
         prnt.plot = F)
```

```
## Computing p-values via Wald-statistics approximation (treating t as Wald z).
```

```
x$plot.list[[1]]$data$fade = sig.data$fade

x$plot.list[[1]]
```



Attempt plot with axes in milliseconds.

```
convertEst = function(X){
  exp(meanLogTrialLength+X) - exp(meanLogTrialLength)
}

x$plot.list[[1]]$data$estimate =convertEst(x$plot.list[[1]]$data$estimate)
x$plot.list[[1]]$data$conf.low = convertEst(x$plot.list[[1]]$data$conf.low)
x$plot.list[[1]]$data$conf.high =  convertEst(x$plot.list[[1]]$data$conf.high)

sig.data2 = sig.data
sig.data2$estimate = x$plot.list[[1]]$data$estimate
sig.data2$estimate.lower = x$plot.list[[1]]$data$conf.low
sig.data2$estimate.upper = x$plot.list[[1]]$data$conf.high

x$plot.list[[1]]$data$fade = sig.data2$fade

x$plot.list[[1]] +
  scale_y_continuous(name="Difference (ms)") +
  scale_x_discrete(labels=feLabels2) +
  #geom_point(data=sig.data2,aes(y=estimate,x=y,fade=fade), color=sig.data$pointCol) +
  coord_flip(ylim=c(-5000,10000))
```

```
## Scale for 'x' is already present. Adding another scale for 'x', which
## will replace the existing scale.
```

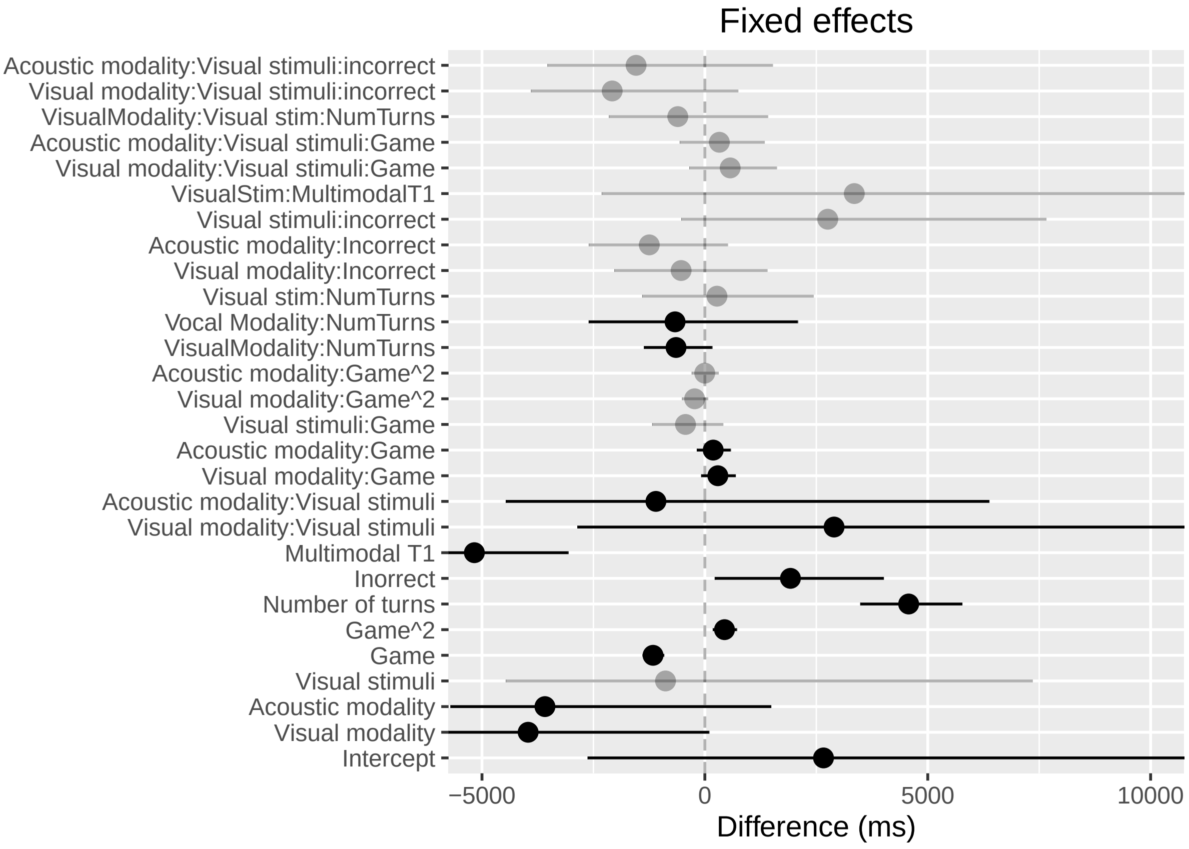


Table for paper

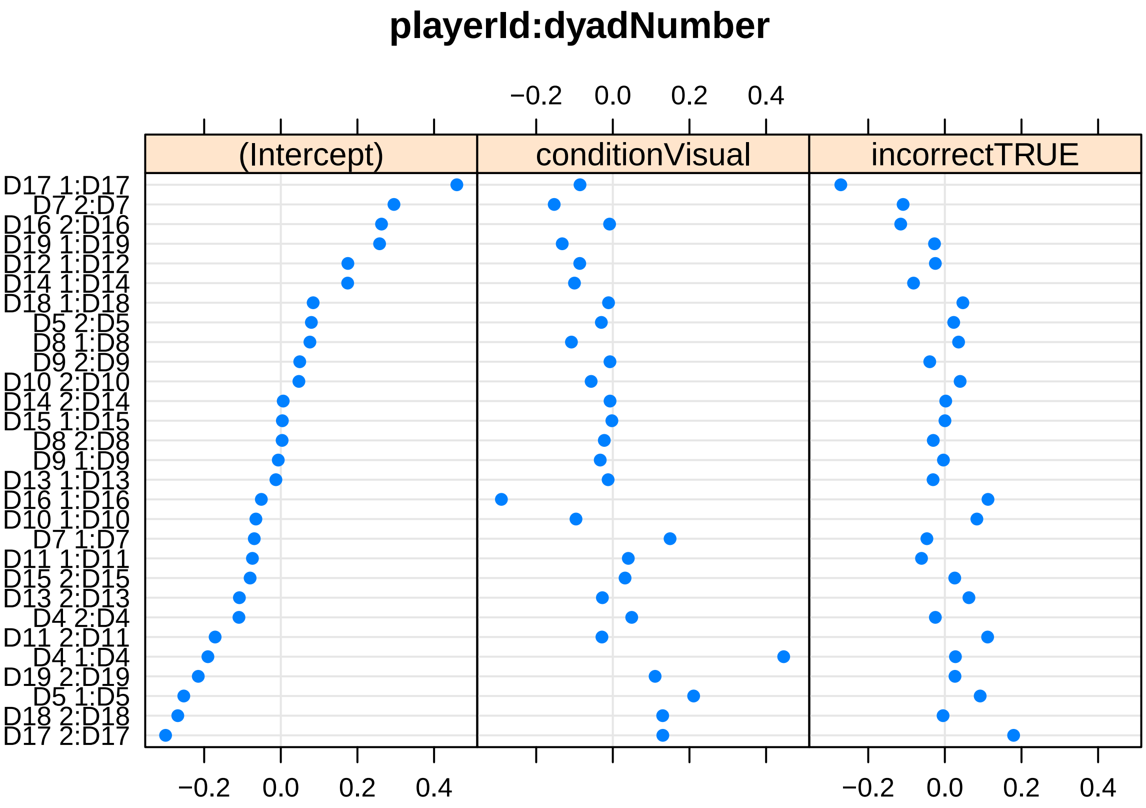
```
outdata = x$plot.list[[1]]$data[,c("estimate","conf.low",'conf.high')]

outdata$estimate = round(outdata$estimate)
outdata$conf.low = round(outdata$conf.low)
outdata$conf.high = round(outdata$conf.high)
#outdata = outdata[2:nrow(outdata),]

xd = as.data.frame(summary(finalModel)$coef)
#xd = xd[2:nrow(xd),]
outdata$wald.t = xd$`t value`

sig = modelComparison$`Pr(>Chisq)`
names(sig) = rownames(modelComparison)
sigx = sig[feModel]
#sigx = sigx[2:length(sigx)]

outdata$model.comparison.p = sigx
outdata$estimate = paste(
  c("","+")[1+(outdata$estimate>0)],
  as.character(outdata$estimate),sep='')

outdata$label = feLabels2

outdata = outdata[,c("label","estimate","conf.low",
                     "conf.high","wald.t",
                     "model.comparison.p")]

write.csv(outdata[2:nrow(outdata),],file="../../results/tables/Efficiency_FixedEffects.csv")
```

Random effects

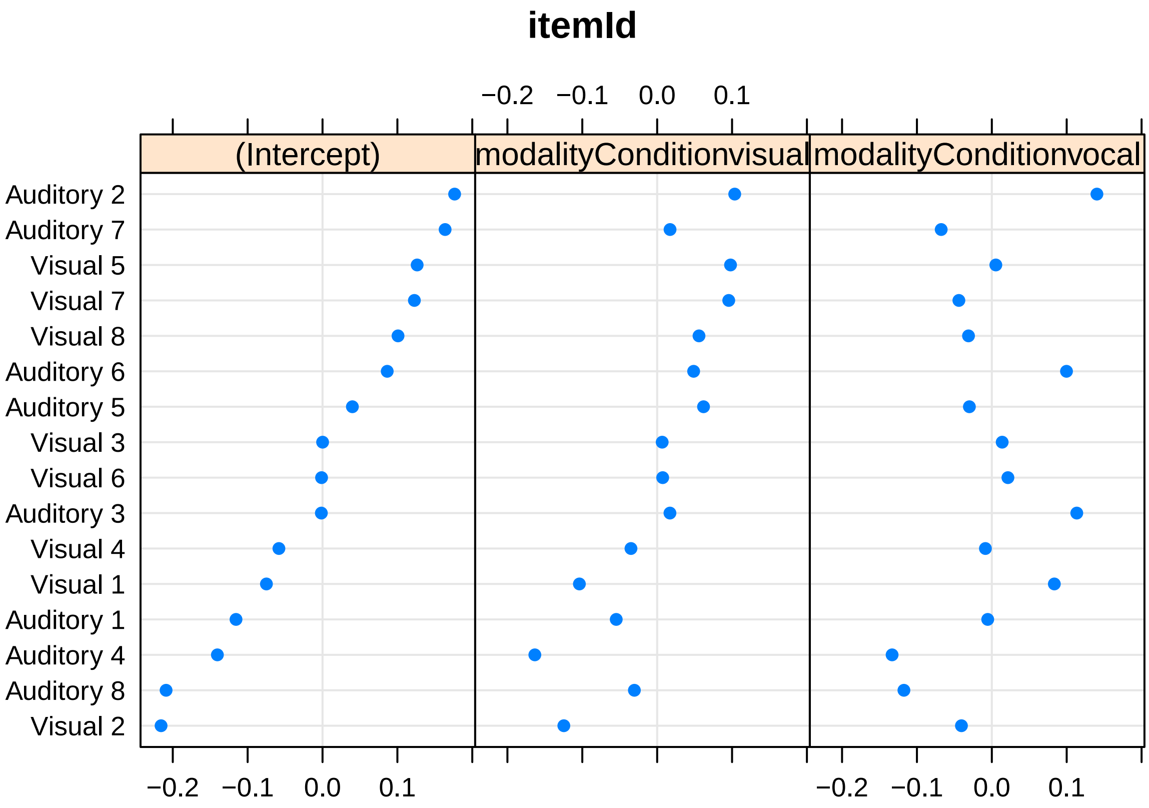
There is a reasonable amount of variaition in the random effects, suggesting that dyads and players differ. This justifies the use of mixed effects modelling.

```
dotplot(ranef(finalModel))
```

```
## $`playerId:dyadNumber`
```

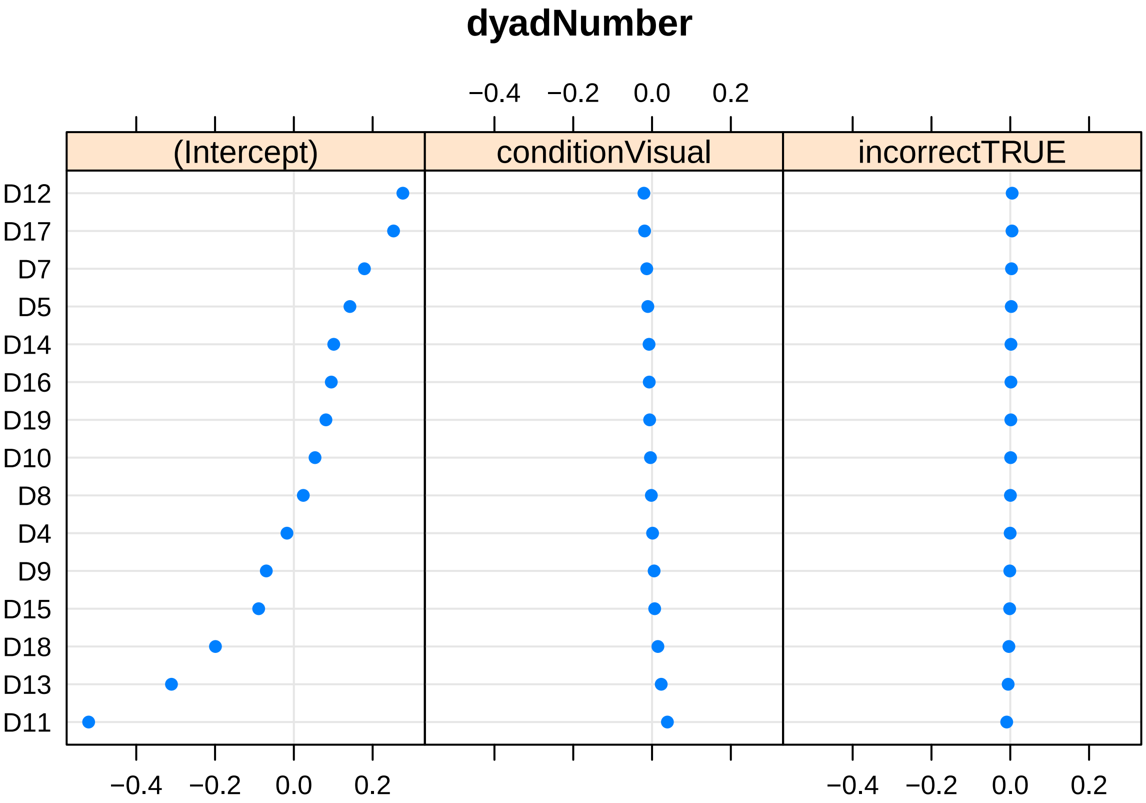

playerId:dyadNumber
(Intercept)
conditionVisual
incorrectTRUE
D17 1:D17
D7 2:D7
D16 2:D16
D19 1:D19
D12 1:D12
D14 1:D14
D18 1:D18
D5 2:D5
D8 1:D8
D9 2:D9
D10 2:D10
D14 2:D14
D15 1:D15
D8 2:D8
D9 1:D9
D13 1:D13
D16 1:D16
D10 1:D10
D7 1:D7
D11 1:D11
D15 2:D15
D13 2:D13
D4 2:D4
D11 2:D11
D4 1:D4
D19 2:D19
D5 1:D5
D18 2:D18
D17 2:D17
−0.2
0.0
0.2
0.4

```
##
## $itemId
```


itemId
(Intercept)
modalityConditionvisual
modalityConditionvocal
Auditory 2
Auditory 7
Visual 5
Visual 7
Visual 8
Auditory 6
Auditory 5
Visual 3
Visual 6
Auditory 3
Visual 4
Visual 1
Auditory 1
Auditory 4
Auditory 8
Visual 2
−0.2
−0.1
0.0
0.1

```
##
```

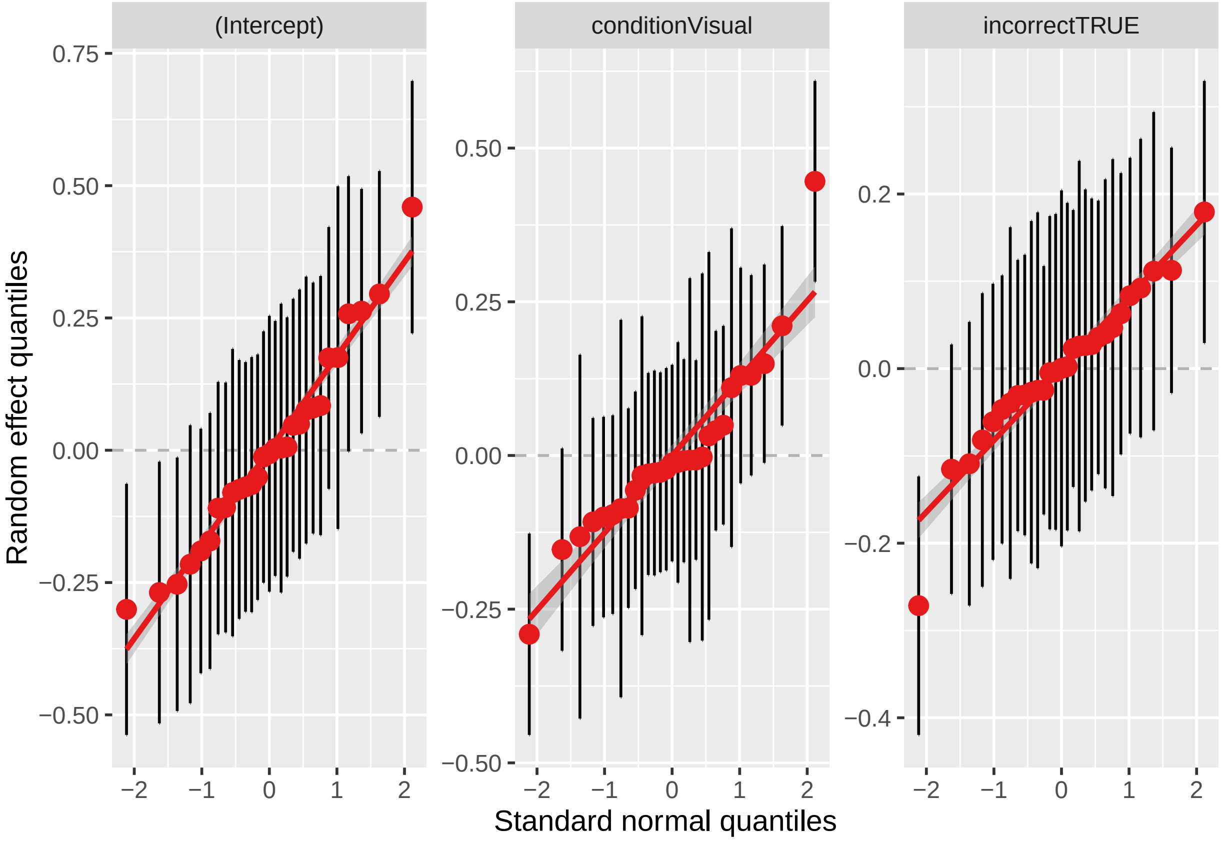
```
## $dyadNumber
```



qq-plots of random effects

```
sjp.lmer(finalModel, type = "re.qq")
```

```
## Testing for normal distribution. Dots should be plotted along the line.
```



Relevel factors to see other comparisons

```
d2 = d
d2$condition = relevel(d2$condition,"Visual")
fm2 = update(finalModel, data=d2)
```

```
## fixed-effect model matrix is rank deficient so dropping 1 column / coefficient
```

```
summary(fm2)
```

```
## Linear mixed model fit by maximum likelihood  ['lmerMod']
## Formula:
## trialLength.log ~ 1 + modalityCondition * condition * trialTotal +
##     I(trialTotal^2) + (modalityCondition:I(trialTotal^2)) + numberOfTurns *
##     modalityCondition * condition + incorrect * modalityCondition *
##     condition + multimodal + multimodal:condition + (1 + condition +
##     incorrect | dyadNumber/playerId) + (1 + modalityCondition |
##     itemId)
##    Data: d2
##
##      AIC      BIC   logLik deviance df.resid
##   1274.9   1525.2   -590.4   1180.9     1473
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -3.5944 -0.6360 -0.0285  0.5758  4.0047
```

```
##
## Random effects:
##  Groups              Name                    Variance  Std.Dev. Corr
##  playerId:dyadNumber (Intercept)             3.733e-02 0.193202
##                      conditionAuditory       2.773e-02 0.166512 -0.28
##                      incorrectTRUE           1.464e-02 0.120992 -0.61
##  itemId              (Intercept)             1.843e-02 0.135751
##                      modalityConditionvisual 9.539e-03 0.097668 0.52
##                      modalityConditionvocal  1.025e-02 0.101229 0.13
##  dyadNumber          (Intercept)             4.918e-02 0.221767
##                      conditionAuditory       3.218e-04 0.017939 1.00
##                      incorrectTRUE           1.724e-05 0.004152 1.00
##  Residual                                    1.104e-01 0.332260
##
##
##
##  -0.05
##
##
##  0.40
##
##
##  1.00
##
## Number of obs: 1520, groups:
## playerId:dyadNumber, 29; itemId, 16; dyadNumber, 15
##
## Fixed effects:
##                                                            Estimate
## (Intercept)                                               0.1831728
## modalityConditionvisual                                  -0.4575475
## modalityConditionvocal                                   -0.8499715
## conditionAuditory                                         0.1301799
## trialTotal                                               -0.2372325
## I(trialTotal^2)                                           0.0591269
## numberOfTurns                                             0.5266647
## incorrectTRUE                                             0.5583009
## multimodalTRUE                                           -0.8742412
## modalityConditionvisual:conditionAuditory                -0.3370009
## modalityConditionvocal:conditionAuditory                  0.1647026
## modalityConditionvisual:trialTotal                        0.1150377
## modalityConditionvocal:trialTotal                         0.0695178
## conditionAuditory:trialTotal                              0.0619726
## modalityConditionvisual:I(trialTotal^2)                  -0.0322265
## modalityConditionvocal:I(trialTotal^2)                   -0.0004019
## modalityConditionvisual:numberOfTurns                    -0.1814007
## modalityConditionvocal:numberOfTurns                     -0.0970190
## conditionAuditory:numberOfTurns                          -0.0368211
## modalityConditionvisual:incorrectTRUE                    -0.4154298
## modalityConditionvocal:incorrectTRUE                     -0.4291984
## conditionAuditory:incorrectTRUE                          -0.3228755
## conditionAuditory:multimodalTRUE                         -0.3808349
## modalityConditionvisual:conditionAuditory:trialTotal    -0.0756274
## modalityConditionvocal:conditionAuditory:trialTotal     -0.0439747
## modalityConditionvisual:conditionAuditory:numberOfTurns  0.0877391
## modalityConditionvisual:conditionAuditory:incorrectTRUE  0.3389113
## modalityConditionvocal:conditionAuditory:incorrectTRUE   0.2399254
##                                                         Std. Error t value
## (Intercept)                                              0.2394390   0.765
## modalityConditionvisual                                  0.2671386  -1.713
## modalityConditionvocal                                   0.2963412  -2.868
## conditionAuditory                                        0.4240834   0.307
## trialTotal                                               0.0558909  -4.245
## I(trialTotal^2)                                          0.0178266   3.317
## numberOfTurns                                            0.1195101   4.407
## incorrectTRUE                                            0.1837540   3.038
## multimodalTRUE                                           0.1501194  -5.824
## modalityConditionvisual:conditionAuditory                0.4286870  -0.786
## modalityConditionvocal:conditionAuditory                 0.4064756   0.405
## modalityConditionvisual:trialTotal                       0.0582899   1.974
## modalityConditionvocal:trialTotal                        0.0582913   1.193
## conditionAuditory:trialTotal                             0.0594229   1.043
## modalityConditionvisual:I(trialTotal^2)                  0.0210939  -1.528
## modalityConditionvocal:I(trialTotal^2)                   0.0210877  -0.019
## modalityConditionvisual:numberOfTurns                    0.1223561  -1.483
## modalityConditionvocal:numberOfTurns                     0.1785406  -0.543
## conditionAuditory:numberOfTurns                          0.1290953  -0.285
## modalityConditionvisual:incorrectTRUE                    0.1977337  -2.101
## modalityConditionvocal:incorrectTRUE                     0.1933937  -2.219
## conditionAuditory:incorrectTRUE                          0.2035345  -1.586
## conditionAuditory:multimodalTRUE                         0.3911493  -0.974
## modalityConditionvisual:conditionAuditory:trialTotal     0.0638784  -1.184
## modalityConditionvocal:conditionAuditory:trialTotal      0.0638859  -0.688
## modalityConditionvisual:conditionAuditory:numberOfTurns  0.1356342   0.647
## modalityConditionvisual:conditionAuditory:incorrectTRUE  0.2227195   1.522
## modalityConditionvocal:conditionAuditory:incorrectTRUE   0.2196350   1.092
```

```
##
## Correlation matrix not shown by default, as p = 28 > 12.
## Use print(x, correlation=TRUE)  or
##   vcov(x)     if you need it
```

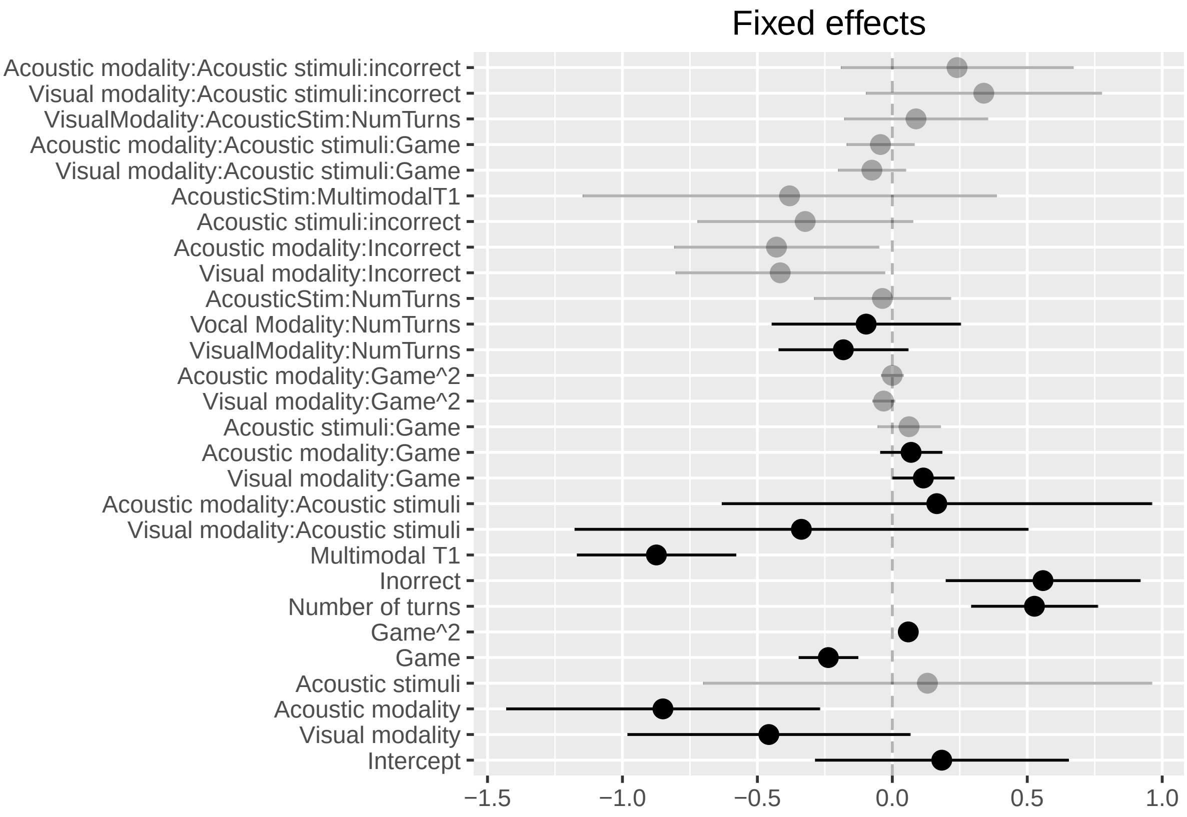
```
## fit warnings:
## fixed-effect model matrix is rank deficient so dropping 1 column / coefficient
```

```
feLabelsB = feLabels2
feLabelsB = gsub("Visual stimuli","Acoustic stimuli",feLabelsB)
feLabelsB = gsub("VisualStim","AcousticStim",feLabelsB)
feLabelsB = gsub("Visual stim","AcousticStim",feLabelsB)

x2 = sjp.lmer(fm2, 'fe',
        show.intercept = T,
        sort.est=NULL,
        axis.labels = feLabelsB[2:length(feLabelsB)],
        xlab="Trial time (log ms)",
        geom.colors = c(1,1),
        show.p=F,
        show.values = F,
        p.kr = FALSE,
        string.interc="Intercept",
        prnt.plot = F)
```

```
## Computing p-values via Wald-statistics approximation (treating t as Wald z).
```

```
## Warning: Deprecated, use tibble::rownames_to_column() instead.
```

```
x2$plot.list[[1]]$data$fade = sig.data$fade

x2$plot.list[[1]]
```



```
d2 = d
d2$modalityCondition = relevel(d2$modalityCondition,"visual")
fm2 = update(finalModel, data=d2)
```

```
## fixed-effect model matrix is rank deficient so dropping 1 column / coefficient
```

```
summary(fm2)
```

```
## Linear mixed model fit by maximum likelihood  ['lmerMod']
## Formula:
## trialLength.log ~ 1 + modalityCondition * condition * trialTotal +
##     I(trialTotal^2) + (modalityCondition:I(trialTotal^2)) + numberOfTurns *
##     modalityCondition * condition + incorrect * modalityCondition *
##     condition + multimodal + multimodal:condition + (1 + condition +
##     incorrect | dyadNumber/playerId) + (1 + modalityCondition |
##     itemId)
##    Data: d2
##
##      AIC      BIC   logLik deviance df.resid
##   1274.9   1525.2   -590.4   1180.9     1473
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -3.5944 -0.6360 -0.0285  0.5758  4.0047
##
## Random effects:
##  Groups              Name                   Variance  Std.Dev. Corr
##  playerId:dyadNumber (Intercept)            4.724e-02 0.217347
##                      conditionVisual        2.773e-02 0.166512 -0.52
##                      incorrectTRUE          1.464e-02 0.120992 -0.58  0.05
##  itemId              (Intercept)            4.173e-02 0.204291
##                      modalityConditionmulti 9.539e-03 0.097668 -0.82
##                      modalityConditionvocal 1.188e-02 0.109004 -0.48  0.52
##  dyadNumber          (Intercept)            5.746e-02 0.239705
##                      conditionVisual        3.218e-04 0.017939 -1.00
##                      incorrectTRUE          1.724e-05 0.004152  1.00 -1.00
##  Residual                                   1.104e-01 0.332260
## Number of obs: 1520, groups:
## playerId:dyadNumber, 29; itemId, 16; dyadNumber, 15
##
## Fixed effects:
##                                                       Estimate Std. Error
## (Intercept)                                          -0.481196   0.152876
## modalityConditionmulti                                0.794549   0.411823
## modalityConditionvocal                                0.109279   0.256722
## conditionVisual                                       0.206821   0.128413
## trialTotal                                           -0.135850   0.016636
## I(trialTotal^2)                                       0.026900   0.011274
## numberOfTurns                                         0.396182   0.032653
## incorrectTRUE                                         0.158907   0.076294
## multimodalTRUE                                       -1.255076   0.358769
## modalityConditionmulti:conditionVisual               -0.337001   0.428687
## modalityConditionvocal:conditionVisual               -0.413964   0.102073
## modalityConditionmulti:trialTotal                    -0.039410   0.025977
## modalityConditionvocal:trialTotal                    -0.013867   0.023532
## conditionVisual:trialTotal                            0.013655   0.023757
## modalityConditionmulti:I(trialTotal^2)                0.032226   0.021094
## modalityConditionvocal:I(trialTotal^2)                0.031825   0.015937
## modalityConditionmulti:numberOfTurns                  0.093662   0.059046
## modalityConditionvocal:numberOfTurns                 -0.003357   0.174796
## conditionVisual:numberOfTurns                        -0.050918   0.041780
## modalityConditionmulti:incorrectTRUE                  0.076518   0.129134
## modalityConditionvocal:incorrectTRUE                 -0.112755   0.110064
## conditionVisual:incorrectTRUE                        -0.016036   0.092100
## conditionVisual:multimodalTRUE                        0.380835   0.391149
## modalityConditionmulti:conditionVisual:trialTotal    -0.075627   0.063878
## modalityConditionvocal:conditionVisual:trialTotal    -0.031653   0.033404
## modalityConditionmulti:conditionVisual:numberOfTurns  0.087739   0.135634
## modalityConditionmulti:conditionVisual:incorrectTRUE  0.338911   0.222720
## modalityConditionvocal:conditionVisual:incorrectTRUE  0.098986   0.123897
##                                                      t value
## (Intercept)                                           -3.148
## modalityConditionmulti                                 1.929
## modalityConditionvocal                                  0.426
## conditionVisual                                         1.611
## trialTotal                                             -8.166
## I(trialTotal^2)                                         2.386
## numberOfTurns                                          12.133
## incorrectTRUE                                           2.083
## multimodalTRUE                                         -3.498
## modalityConditionmulti:conditionVisual                 -0.786
## modalityConditionvocal:conditionVisual                 -4.056
## modalityConditionmulti:trialTotal                      -1.517
## modalityConditionvocal:trialTotal                      -0.589
## conditionVisual:trialTotal                              0.575
## modalityConditionmulti:I(trialTotal^2)                  1.528
## modalityConditionvocal:I(trialTotal^2)                  1.997
## modalityConditionmulti:numberOfTurns                    1.586
## modalityConditionvocal:numberOfTurns                   -0.019
## conditionVisual:numberOfTurns                          -1.219
## modalityConditionmulti:incorrectTRUE                    0.593
## modalityConditionvocal:incorrectTRUE                   -1.024
## conditionVisual:incorrectTRUE                          -0.174
## conditionVisual:multimodalTRUE                          0.974
## modalityConditionmulti:conditionVisual:trialTotal     -1.184
## modalityConditionvocal:conditionVisual:trialTotal     -0.948
## modalityConditionmulti:conditionVisual:numberOfTurns   0.647
## modalityConditionmulti:conditionVisual:incorrectTRUE   1.522
## modalityConditionvocal:conditionVisual:incorrectTRUE   0.799
```

```
##
## Correlation matrix not shown by default, as p = 28 > 12.
## Use print(x, correlation=TRUE)  or
##   vcov(x)     if you need it
```

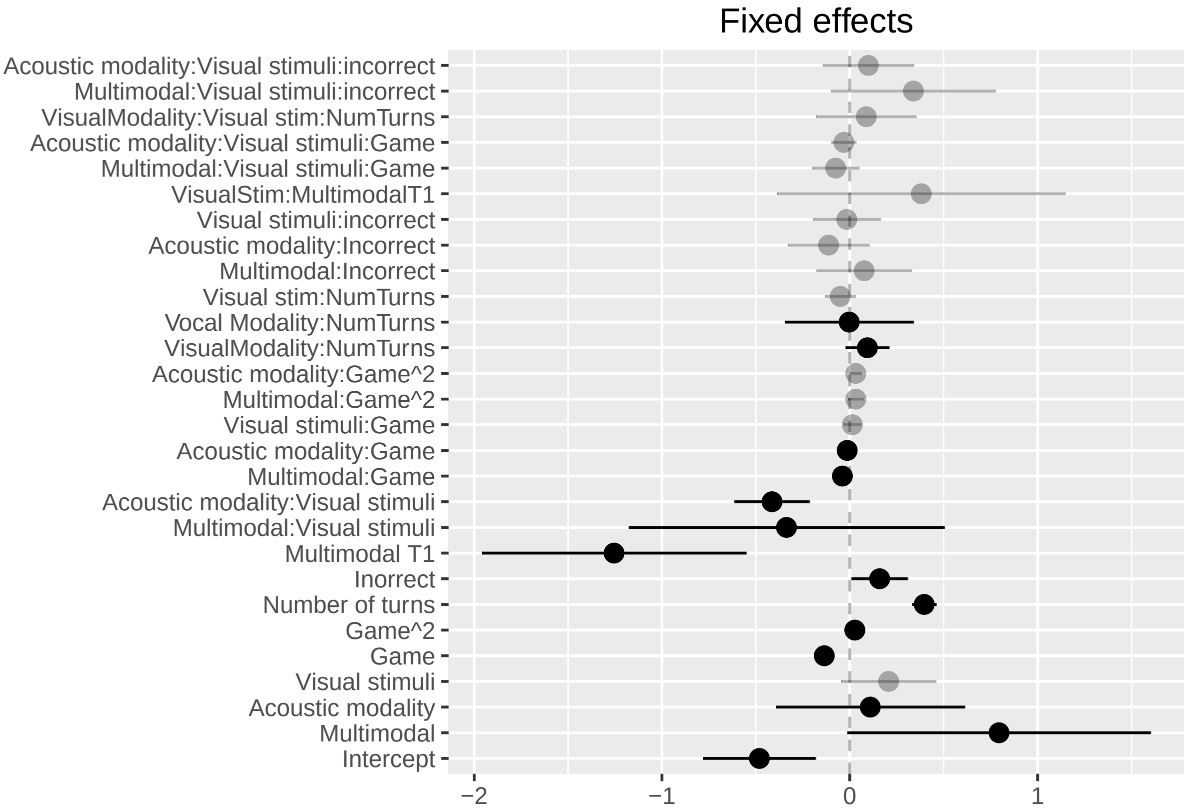
```
## fit warnings:
## fixed-effect model matrix is rank deficient so dropping 1 column / coefficient
```

```
feLabelsB = feLabels2
feLabelsB = gsub("Visual modality","Multimodal",feLabelsB)


x2 = sjp.lmer(fm2, 'fe',
         show.intercept = T,
         sort.est=NULL,
         axis.labels = feLabelsB[2:length(feLabelsB)],
         xlab="Trial time (log ms)",
         geom.colors = c(1,1),
         show.p=F,
         show.values = F,
         p.kr = FALSE,
         string.interc="Intercept",
         prnt.plot = F)
```

```
## Computing p-values via Wald-statistics approximation (treating t as Wald z).
```

```
## Warning: Deprecated, use tibble::rownames_to_column() instead.
```

```
x2$plot.list[[1]]$data$fade = sig.data$fade

x2$plot.list[[1]]
```


Fixed effects
Acoustic modality:Visual stimuli:incorrect
Multimodal:Visual stimuli:incorrect
VisualModality:Visual stim:NumTurns
Acoustic modality:Visual stimuli:Game
Multimodal:Visual stimuli:Game
VisualStim:MultimodalT1
Visual stimuli:incorrect
Acoustic modality:Incorrect
Multimodal:Incorrect
Visual stim:NumTurns
Vocal Modality:NumTurns
VisualModality:NumTurns
Acoustic modality:Game^2
Multimodal:Game^2
Visual stimuli:Game
Acoustic modality:Game
Multimodal:Game
Acoustic modality:Visual stimuli
Multimodal:Visual stimuli
Multimodal T1
Inorrect
Number of turns
Game^2
Game
Visual stimuli
Acoustic modality
Multimodal
Intercept