Colour experiment

Introduction

This analysis looks at the sign variants used in a colour naming game between signers of different sign languages meeting after 1 week of interaction and after 3 weeks of interaction. The data was collected by Kang Suk Byun (Kang-Suk.Byun@mpi.nl).

The analysis tries to predict the relative frequency of each variant within a colour category in week 3, based on measures from week 1.

Load libraries

```
library(ggplot2)
library(lme4)
library(party)
library(Rmisc)
library(dplyr)
```

Load data

```
variants = read.csv('../data/processedData/variants_summary.csv', stringsAsFactors = F)
```

There is only 1 variant for 'white'. Therefore, we remove it from this statistical analysis.

```
variants = variants[variants$colourName!='white',]
```

Transform some variables.

```
variants$Teach = variants$Teach >0

variants$check.any = variants$check>0

variants$freq_week_1.logcenter = log(variants$freq_week_1 + 1)
variants$freq_week_1.logcenter =
  variants$freq_week_1.logcenter - mean(variants$freq_week_1.logcenter)

# cut TryMarking into two categories
variants$TryMarked.cat = cut(variants$TryMarked,
                             c(-Inf,3,Inf),
                             labels = c("Low",'High'))

variants$averageLength_week_1.logcenter = log(variants$averageLength_week_1)
variants$averageLength_week_1.logcenter =
  variants$averageLength_week_1.logcenter -
    mean(variants$averageLength_week_1.logcenter)
```

ANOVA

Perform a straightforward ANOVA analysis:

```
m1 = aov(freq_week_4_withinColour+1 ~
      indexical +
      Teach * TryMarked*check.any+
      freq_week_1.logcenter +
      averageLength_week_1.logcenter+
      inventedBy + colourName,
    data=variants)
summary(m1)
```

```
##                                Df Sum Sq Mean Sq F value   Pr(>F)
## indexical                       2 0.2569  0.1284   7.490  0.00102 **
## Teach                           1 0.0046  0.0046   0.265  0.60780
## TryMarked                       1 0.4342  0.4342  25.320 2.72e-06 ***
## check.any                       1 0.0529  0.0529   3.087  0.08258 .
## freq_week_1.logcenter           1 0.3161  0.3161  18.433 4.69e-05 ***
## averageLength_week_1.logcenter  1 0.0190  0.0190   1.107  0.29574
## inventedBy                      3 0.0117  0.0039   0.227  0.87758
## colourName                      5 0.1344  0.0269   1.568  0.17810
## Teach:TryMarked                 1 0.0337  0.0337   1.964  0.16477
## Teach:check.any                 1 0.1020  0.1020   5.946  0.01686 *
## TryMarked:check.any             1 0.0465  0.0465   2.711  0.10341
## Teach:TryMarked:check.any       1 0.0079  0.0079   0.462  0.49837
## Residuals                      84 1.4404  0.0171
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

LMER models

```
m0 = lmer(freq_week_4_withinColour ~
            1
          + (1 | colourName),
          data=variants)
m1 = lmer(freq_week_4_withinColour ~
            (indexical) +
            + (1 | colourName),
          data=variants)
m2 = lmer(freq_week_4_withinColour ~
            (indexical) +
            (Teach)
          + (1 | colourName),
          data=variants)

m3 = lmer(freq_week_4_withinColour ~
            (indexical) +
            (Teach) + (TryMarked.cat)
          + (1 | colourName),
          data=variants)
```

```
m4 = lmer(freq_week_4_withinColour ~
            (indexical) +
            Teach * TryMarked.cat
          + (1 | colourName),
          data=variants)

m5 = lmer(freq_week_4_withinColour ~
            (indexical) +
            (Teach * TryMarked.cat) +
            freq_week_1.logcenter
          + (1 | colourName),
          data=variants)

m6 = lmer(freq_week_4_withinColour ~
            (indexical) +
            (Teach * TryMarked.cat) +
            freq_week_1.logcenter +
            averageLength_week_1.logcenter
          + (1 | colourName),
          data=variants)

m7 = lmer(freq_week_4_withinColour ~
            (indexical) +
            (Teach * TryMarked.cat) +
            freq_week_1.logcenter +
            averageLength_week_1.logcenter+
            check.any
          + (1 | colourName),
          data=variants)

m8 = lmer(freq_week_4_withinColour ~
            (indexical) +
            (Teach * TryMarked.cat) +
            freq_week_1.logcenter +
            averageLength_week_1.logcenter+
            check.any + inventedBy
          + (1 | colourName),
          data=variants)
```

Results

```
anova(m0,m1,m2,m3,m4,m5, m6,m7,m8)
```

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

```
## Data: variants
## Models:
## m0: freq_week_4_withinColour ~ 1 + (1 | colourName)
## m1: freq_week_4_withinColour ~ (indexical) + +(1 | colourName)
## m2: freq_week_4_withinColour ~ (indexical) + (Teach) + (1 | colourName)
## m3: freq_week_4_withinColour ~ (indexical) + (Teach) + (TryMarked.cat) +
## m3:     (1 | colourName)
```

```
## m4: freq_week_4_withinColour ~ (indexical) + Teach * TryMarked.cat +
## m4:     (1 | colourName)
## m5: freq_week_4_withinColour ~ (indexical) + (Teach * TryMarked.cat) +
## m5:     freq_week_1.logcenter + (1 | colourName)
## m6: freq_week_4_withinColour ~ (indexical) + (Teach * TryMarked.cat) +
## m6:     freq_week_1.logcenter + averageLength_week_1.logcenter +
## m6:     (1 | colourName)
## m7: freq_week_4_withinColour ~ (indexical) + (Teach * TryMarked.cat) +
## m7:     freq_week_1.logcenter + averageLength_week_1.logcenter +
## m7:     check.any + (1 | colourName)
## m8: freq_week_4_withinColour ~ (indexical) + (Teach * TryMarked.cat) +
## m8:     freq_week_1.logcenter + averageLength_week_1.logcenter +
## m8:     check.any + inventedBy + (1 | colourName)
##    Df      AIC     BIC logLik deviance   Chisq Chi Df Pr(>Chisq)
## m0  3  -72.634 -64.701 39.317  -78.634
## m1  5  -78.372 -65.150 44.186  -88.372  9.7379      2  0.0076814 **
## m2  6  -76.554 -60.688 44.277  -88.554  0.1820      1  0.6696992
## m3  7  -86.814 -68.304 50.407 -100.814 12.2606      1  0.0004626 ***
## m4  8  -88.303 -67.148 52.151 -104.303  3.4885      1  0.0617963 .
## m5  9 -112.663 -88.863 65.332 -130.663 26.3600      1  2.833e-07 ***
## m6 10 -111.601 -85.157 65.800 -131.601  0.9379      1  0.3328193
## m7 11 -110.103 -81.014 66.051 -132.103  0.5016      1  0.4787842
## m8 14 -105.424 -68.403 66.712 -133.424  1.3219      3  0.7239414
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
summary(m7)
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula:
## freq_week_4_withinColour ~ (indexical) + (Teach * TryMarked.cat) +
##     freq_week_1.logcenter + averageLength_week_1.logcenter +
##     check.any + (1 | colourName)
##    Data: variants
##
## REML criterion at convergence: -88
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -2.7920 -0.5589  0.0296  0.2283  4.7524
##
## Random effects:
##  Groups     Name        Variance  Std.Dev.
##  colourName (Intercept) 0.0006052 0.0246
##  Residual               0.0175678 0.1325
## Number of obs: 104, groups:  colourName, 6
##
## Fixed effects:
##                               Estimate Std. Error t value
## (Intercept)                    0.06140    0.02376   2.584
## indexicalYes                   0.05931    0.06311   0.940
## indexicalYes-body              0.05158    0.03678   1.402
## TeachTRUE                     -0.05149    0.04810  -1.070
## TryMarked.catHigh              0.11954    0.07712   1.550
## freq_week_1.logcenter          0.17886    0.03396   5.267
```

```
## averageLength_week_1.logcenter -0.01703    0.01638  -1.039
## check.anyTRUE                  -0.02277    0.03126  -0.729
## TeachTRUE:TryMarked.catHigh    -0.18552    0.09334  -1.988
##
## Correlation of Fixed Effects:
##             (Intr) indxcY indxY- TcTRUE TryM.H fr__1. aL__1. c.TRUE
## indexicalYs -0.173
## indxclYs-bd -0.408  0.059
## TeachTRUE   -0.279  0.072  0.068
## TryMrkd.ctH -0.256 -0.004 -0.035  0.134
## frq_wk_1.lg  0.383  0.099 -0.224 -0.184 -0.436
## avrgLng__1. -0.031 -0.173  0.153 -0.045  0.019 -0.138
## chck.nyTRUE -0.508  0.020  0.241  0.101  0.121 -0.325  0.087
## TcTRUE:TM.H  0.158 -0.042 -0.042 -0.490 -0.662  0.027 -0.021 -0.084
```

Random slopes

For each of the predictors, we see if random slopes help improve the model. Random slopes allow the strenght of the effect of a factor to be different for each colour concept.

```
m7R = lmer(freq_week_4_withinColour ~
            (indexical) +
            (Teach * TryMarked.cat) +
            freq_week_1.logcenter +
            averageLength_week_1.logcenter+
            check.any
          + (1 | colourName),
          data=variants)

m7R.indexical = lmer(freq_week_4_withinColour ~
            (indexical) +
            (Teach * TryMarked.cat) +
            freq_week_1.logcenter +
            averageLength_week_1.logcenter+
            check.any
          + (1 + indexical | colourName),
          data=variants)

anova(m7R,m7R.indexical)
```

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

```
## Data: variants
## Models:
## m7R: freq_week_4_withinColour ~ (indexical) + (Teach * TryMarked.cat) +
## m7R:     freq_week_1.logcenter + averageLength_week_1.logcenter +
## m7R:     check.any + (1 | colourName)
## m7R.indexical: freq_week_4_withinColour ~ (indexical) + (Teach * TryMarked.cat) +
## m7R.indexical:     freq_week_1.logcenter + averageLength_week_1.logcenter +
## m7R.indexical:     check.any + (1 + indexical | colourName)
##               Df     AIC     BIC logLik deviance Chisq Chi Df Pr(>Chisq)
## m7R           11 -110.10 -81.014 66.051  -132.10
## m7R.indexical 16 -114.54 -72.232 73.271  -146.54 14.44      5    0.01304 *
## ---
```

```
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
m7R.Teach = lmer(freq_week_4_withinColour ~
            (indexical) +
            (Teach * TryMarked.cat) +
            freq_week_1.logcenter +
            averageLength_week_1.logcenter+
            check.any
          + (1 + Teach| colourName),
          data=variants)
anova(m7R,m7R.Teach)
```

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

```
## Data: variants
## Models:
## m7R: freq_week_4_withinColour ~ (indexical) + (Teach * TryMarked.cat) +
## m7R:     freq_week_1.logcenter + averageLength_week_1.logcenter +
## m7R:     check.any + (1 | colourName)
## m7R.Teach: freq_week_4_withinColour ~ (indexical) + (Teach * TryMarked.cat) +
## m7R.Teach:     freq_week_1.logcenter + averageLength_week_1.logcenter +
## m7R.Teach:     check.any + (1 + Teach | colourName)
##           Df     AIC     BIC logLik deviance  Chisq Chi Df Pr(>Chisq)
## m7R       11 -110.10 -81.014 66.051  -132.10
## m7R.Teach 13 -106.26 -71.880 66.129  -132.26 0.1546      2     0.9256
```

```
m7R.TryMark = lmer(freq_week_4_withinColour ~
            (indexical) +
            (Teach * TryMarked.cat) +
            freq_week_1.logcenter +
            averageLength_week_1.logcenter+
            check.any
          + (1 + TryMarked.cat| colourName),
          data=variants)
anova(m7R,m7R.TryMark)
```

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

```
## Data: variants
## Models:
## m7R: freq_week_4_withinColour ~ (indexical) + (Teach * TryMarked.cat) +
## m7R:     freq_week_1.logcenter + averageLength_week_1.logcenter +
## m7R:     check.any + (1 | colourName)
## m7R.TryMark: freq_week_4_withinColour ~ (indexical) + (Teach * TryMarked.cat) +
## m7R.TryMark:     freq_week_1.logcenter + averageLength_week_1.logcenter +
## m7R.TryMark:     check.any + (1 + TryMarked.cat | colourName)
##             Df     AIC     BIC logLik deviance  Chisq Chi Df Pr(>Chisq)
## m7R         11 -110.10 -81.014 66.051  -132.10
## m7R.TryMark 13 -109.31 -74.929 67.653  -135.31 3.2035      2     0.2015
```

```
m7R.Freq = lmer(freq_week_4_withinColour ~
            (indexical) +
            (Teach * TryMarked.cat) +
            freq_week_1.logcenter +
            averageLength_week_1.logcenter+
            check.any
          + (1 + averageLength_week_1.logcenter| colourName),
```

```
          data=variants)
anova(m7R,m7R.Freq)
```

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

```
## Data: variants
## Models:
## m7R: freq_week_4_withinColour ~ (indexical) + (Teach * TryMarked.cat) +
## m7R:     freq_week_1.logcenter + averageLength_week_1.logcenter +
## m7R:     check.any + (1 | colourName)
## m7R.Freq: freq_week_4_withinColour ~ (indexical) + (Teach * TryMarked.cat) +
## m7R.Freq:     freq_week_1.logcenter + averageLength_week_1.logcenter +
## m7R.Freq:     check.any + (1 + averageLength_week_1.logcenter | colourName)
##          Df     AIC     BIC logLik deviance  Chisq Chi Df Pr(>Chisq)
## m7R      11 -110.10 -81.014 66.051  -132.10
## m7R.Freq 13 -107.64 -73.260 66.819  -133.64 1.5346      2     0.4643
```

```
m7R.Length = lmer(freq_week_4_withinColour ~
            (indexical) +
            (Teach * TryMarked.cat) +
            freq_week_1.logcenter +
            averageLength_week_1.logcenter+
            check.any
          + (1 + averageLength_week_1.logcenter| colourName),
          data=variants)
anova(m7R,m7R.Length)
```

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

```
## Data: variants
## Models:
## m7R: freq_week_4_withinColour ~ (indexical) + (Teach * TryMarked.cat) +
## m7R:     freq_week_1.logcenter + averageLength_week_1.logcenter +
## m7R:     check.any + (1 | colourName)
## m7R.Length: freq_week_4_withinColour ~ (indexical) + (Teach * TryMarked.cat) +
## m7R.Length:     freq_week_1.logcenter + averageLength_week_1.logcenter +
## m7R.Length:     check.any + (1 + averageLength_week_1.logcenter | colourName)
##            Df     AIC     BIC logLik deviance  Chisq Chi Df Pr(>Chisq)
## m7R        11 -110.10 -81.014 66.051  -132.10
## m7R.Length 13 -107.64 -73.260 66.819  -133.64 1.5346      2     0.4643
```

```
m7R.Check = lmer(freq_week_4_withinColour ~
            (indexical) +
            (Teach * TryMarked.cat) +
            freq_week_1.logcenter +
            averageLength_week_1.logcenter+
            check.any
          + (1 + check.any| colourName),
          data=variants)
anova(m7R,m7R.Check)
```

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

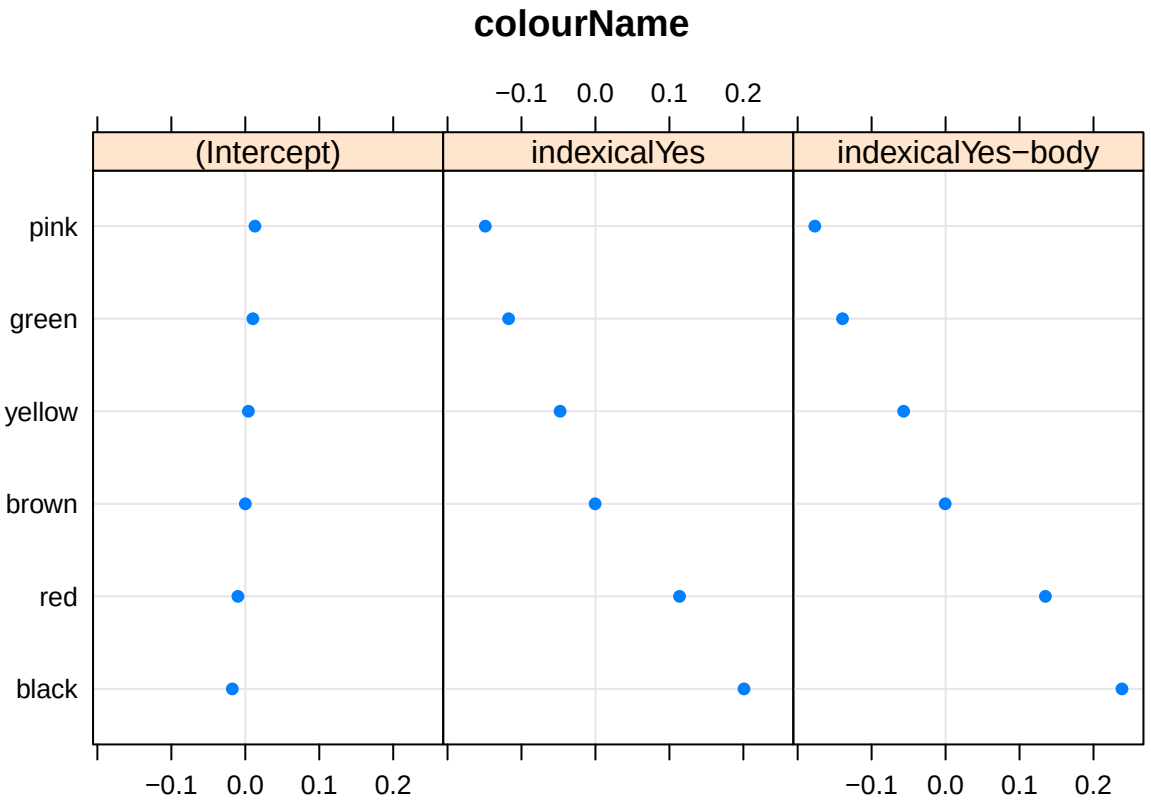
```
## Data: variants
## Models:
## m7R: freq_week_4_withinColour ~ (indexical) + (Teach * TryMarked.cat) +
## m7R:     freq_week_1.logcenter + averageLength_week_1.logcenter +
```

```
## m7R:     check.any + (1 | colourName)
## m7R.Check: freq_week_4_withinColour ~ (indexical) + (Teach * TryMarked.cat) +
## m7R.Check:     freq_week_1.logcenter + averageLength_week_1.logcenter +
## m7R.Check:     check.any + (1 + check.any | colourName)
##           Df     AIC     BIC logLik deviance  Chisq Chi Df Pr(>Chisq)
## m7R       11 -110.10 -81.014 66.051  -132.10
## m7R.Check 13 -109.36 -74.978 67.677  -135.35 3.2523      2     0.1967
```

We see that only indexicality improves the model as a random slope. This means that for some colours, indexicality matters more than for others. We can plot the random slopes below:

```
dotplot(ranef(m7R.indexical))
```

```
## $colourName
```



We see that indexicality is a better predictor of selection for black and red, but is a very weak predictor for pink and green.

Summary

Choose a final model for the beta values:

```
finalModel = m7R.indexical
```

There was a significant main effect of try marking (beta = 0.13 , std.err = 0.071 , Wald t = 1.8 ; log likelihood difference = 6.1 , df = 1 , Chi Squared = 12.26 , p = 0.00046).

There was a marginal interaction between try marking and teaching (beta = -0.16 , std.err = 0.086 , Wald t = -1.8 ; log likelihood difference = 1.7 , df = 1 , Chi Squared = 3.49 , p = 0.062).

There was a significant main effect of frequency in week 1 (beta = 0.16 , std.err = 0.031 , Wald t = 5.1 ; log likelihood difference = 13 , df = 1 , Chi Squared = 26.36 , p = 2.8e-07).

There was a significant main effect of indexicality (beta = 0.14 , std.err = 0.085 , Wald t = 1.7 ; log likelihood difference = 4.9 , df = 2 , Chi Squared = 9.74 , p = 0.0077).

There was no significant main effect of sign length (beta = -0.018 , std.err = 0.014 , Wald t = -1.3 ; log likelihood difference = 0.47 , df = 1 , Chi Squared = 0.94 , p = 0.33).

There was no significant main effect of checking (beta = -0.021 , std.err = 0.028 , Wald t = -0.76 ; log likelihood difference = 0.25 , df = 1 , Chi Squared = 0.5 , p = 0.48).

There was no significant main effect of first user (inventedBy) (log likelihood difference = 0.66 , df = 3 , Chi Squared = 1.32 , p = 0.72).

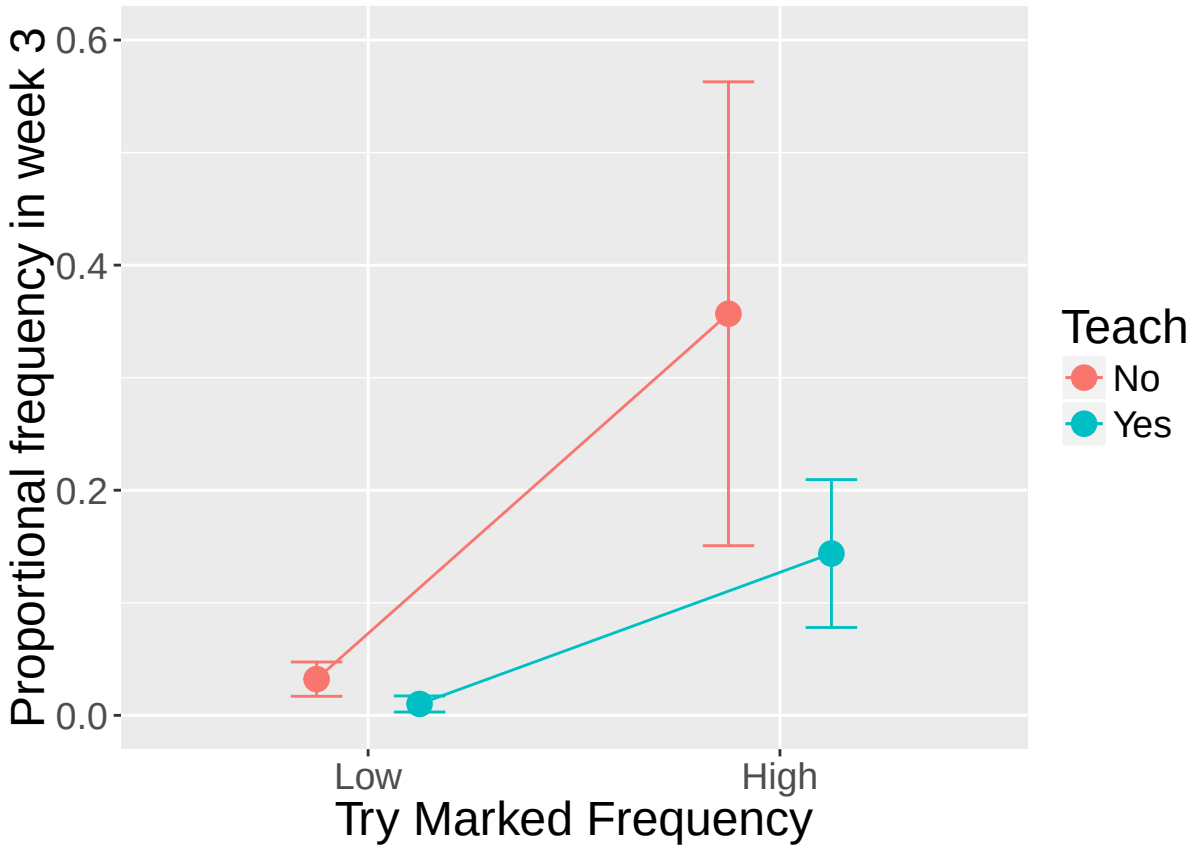
Graphs

Plot the interaction between teaching and try marking.

```
sumStats2 = summarySE(variants, measurevar="freq_week_4_withinColour",
                      groupvars=c("TryMarked.cat","Teach"))

dodge <- position_dodge(width=0.5)

main.plot <- ggplot(sumStats2,
    aes(x = TryMarked.cat, y = freq_week_4_withinColour, colour=Teach)) +
  geom_point(position=dodge, size=4) + geom_line(aes(group=Teach),position=dodge) +
  geom_errorbar(aes(ymax=freq_week_4_withinColour+se, ymin=freq_week_4_withinColour-se), width=0.25,posi
  xlab("Try Marked Frequency") +
  ylab("Proportional frequency in week 3") +
  coord_cartesian(ylim=c(0,0.6)) +
  scale_color_discrete(breaks=c(FALSE,TRUE),
                       labels=c("No","Yes"),
                       name="Teach") +
  theme(text=element_text(size=18))
main.plot
```



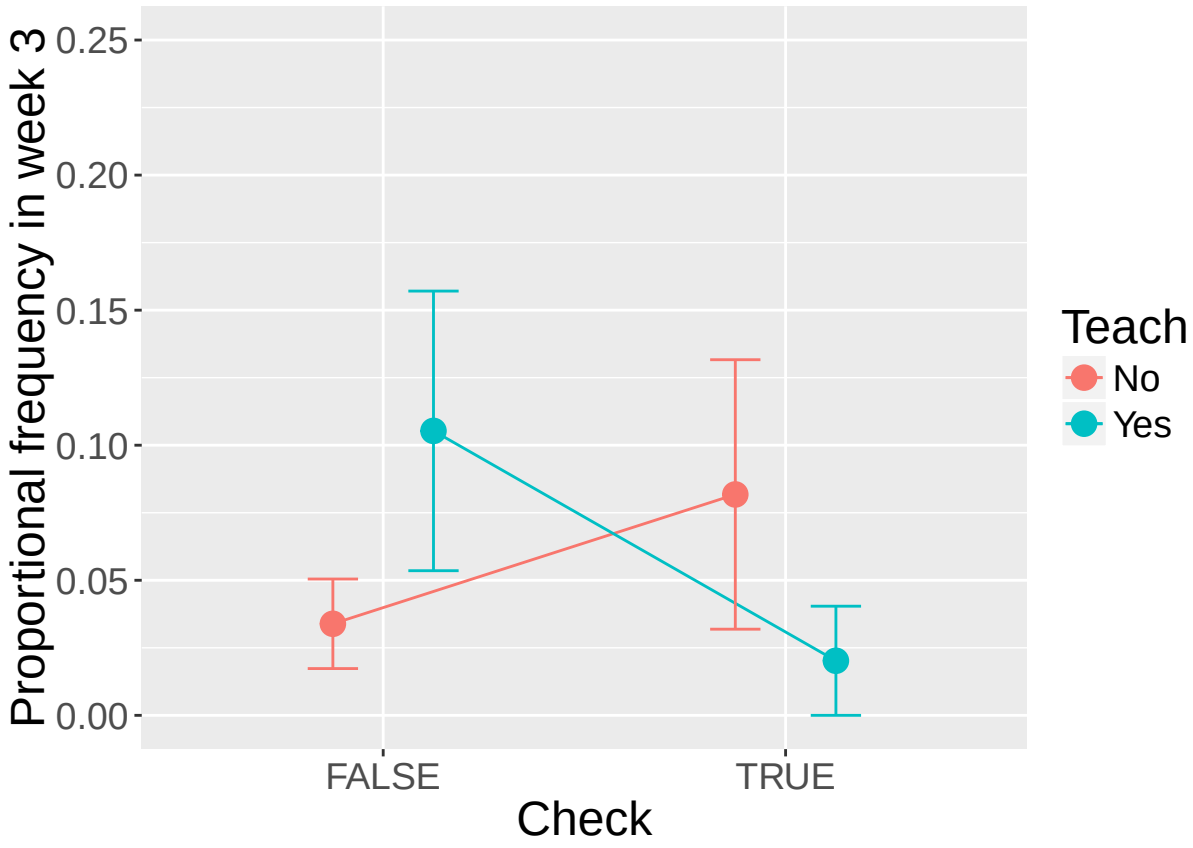

```
## pdf
##   2
```

Plot the interaction between teaching and checking.

```
sumStats2 = summarySE(variants, measurevar="freq_week_4_withinColour",
                      groupvars=c("Teach","check.any"))

dodge <- position_dodge(width=0.5)

main.plot2 <- ggplot(sumStats2,
    aes(x = check.any, y = freq_week_4_withinColour, colour=Teach)) +
  geom_point(position=dodge, size=4) + geom_line(aes(group=Teach),position=dodge) +
  geom_errorbar(aes(ymax=freq_week_4_withinColour+se, ymin=freq_week_4_withinColour-se), width=0.25,pos
  xlab("Check") +
  ylab("Proportional frequency in week 3") +
  coord_cartesian(ylim=c(0,0.25)) +
  scale_color_discrete(breaks=c(FALSE,TRUE),
                       labels=c("No","Yes"),
                       name="Teach") +
  theme(text=element_text(size=18))
main.plot2
```


Proportional frequency in week 3
0.25
0.20
0.15
0.10
0.05
0.00
FALSE
TRUE
Check
Teach
No
Yes

```
## pdf
##   2
```