Intensive Data Analysis II

Abhilasha Kumar

October 12, 2017

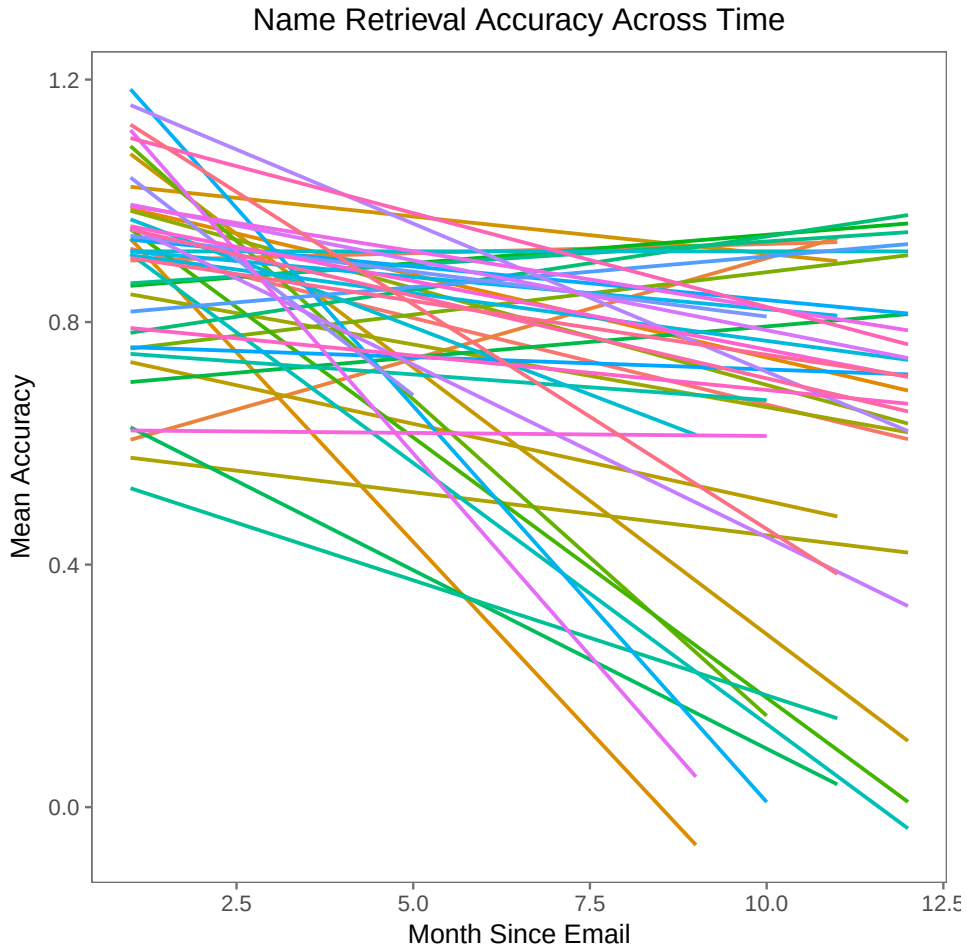
1 Reading the Data

```
> cell_demo = read.csv("cell_demo.csv", header = TRUE, sep = ",")
> cell = read.csv("cell_withitems_complete.csv", header = TRUE, sep = ",")
> cell = merge(cell, cell_demo, by = "ID")
> cell$ID = as.factor(as.character(cell$ID))
```

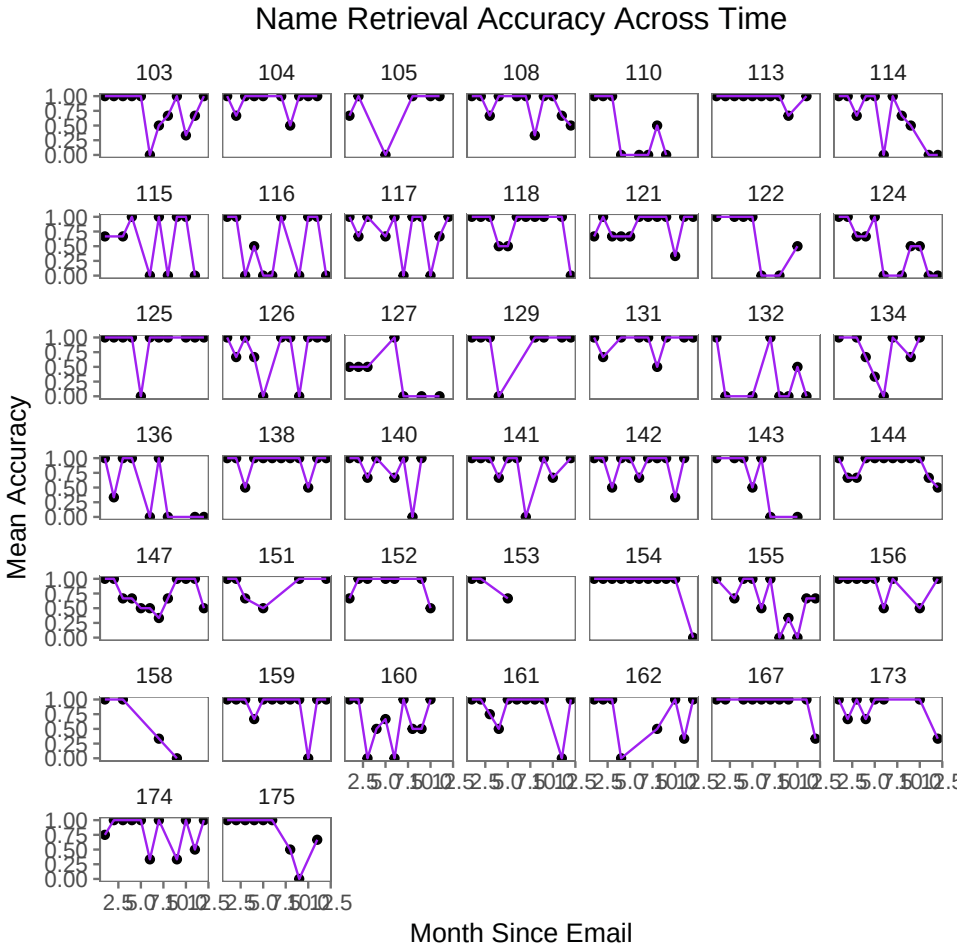
2 Eyeballing the Data

Accuracy for Name Retrieval

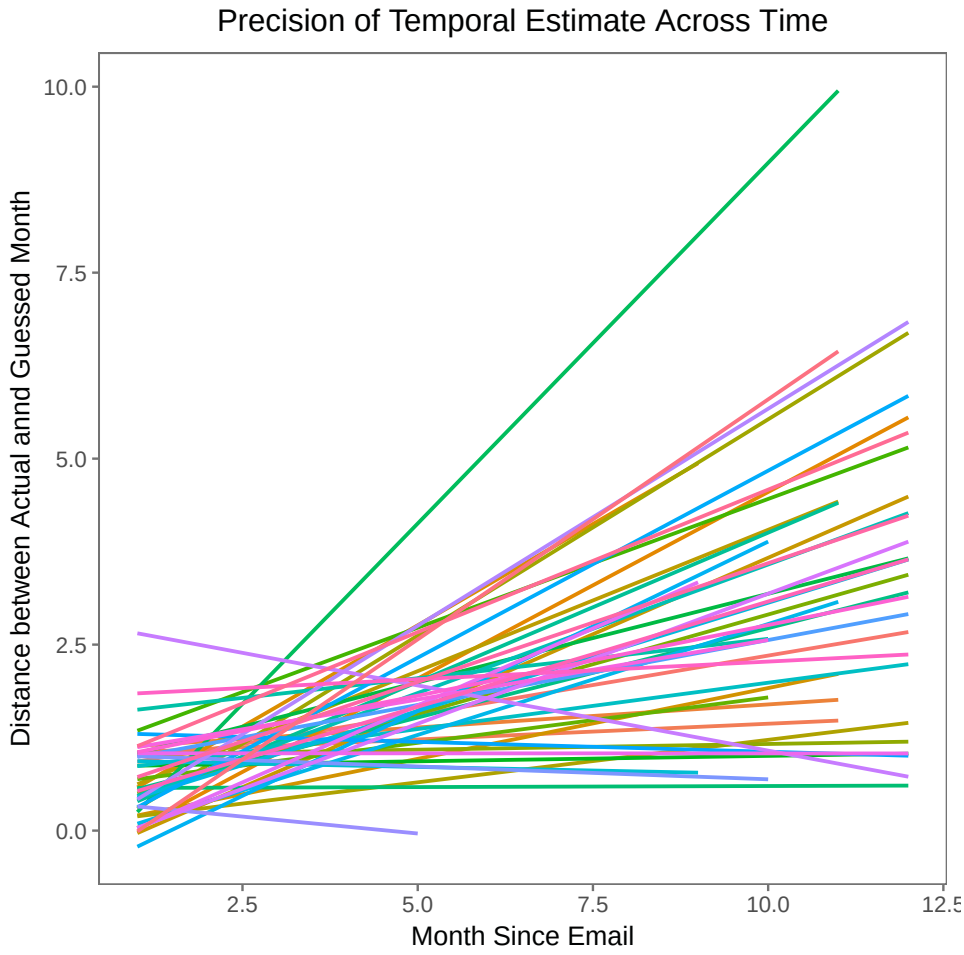
First, we get an average accuracy estimate for each month, per subject to visually examine the data:

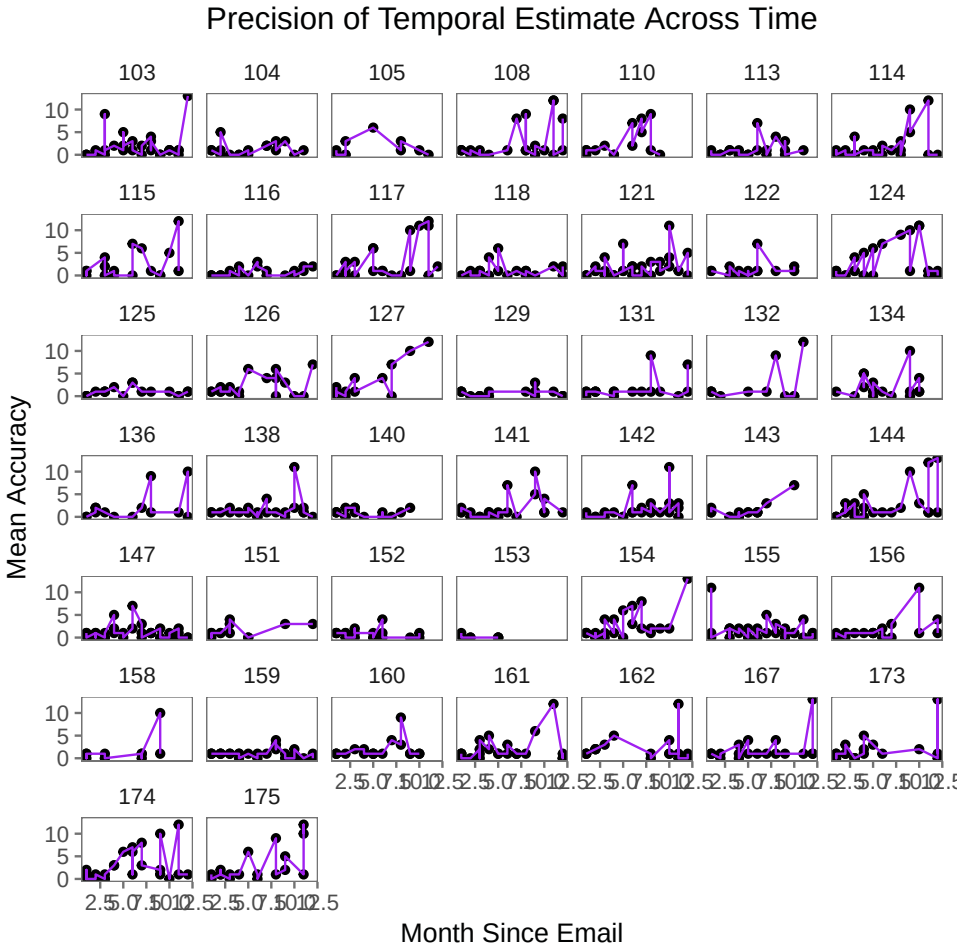


We also look at this at the subject level:


Name Retrieval Accuracy Across Time
103
104
105
108
110
113
114
115
116
117
118
121
122
124
125
126
127
129
131
132
134
136
138
140
141
142
143
144
147
151
152
153
154
155
156
158
159
160
161
162
167
173
174
175
1.00
0.75
0.50
0.25
0.00
2.5
5.0
7.5
10
12.5
Mean Accuracy
Month Since Email

Distance of Temporal Estimate





3 Model 1: Fixed Slope of Time

Name Retrieval Accuracy

```
> library(lme4)
> acc_model_1 = glmer(data = cell, Accuracy ~ Month + (1|ID), family = "binomial")
> summary(acc_model_1)
```

```
Generalized linear mixed model fit by maximum likelihood
  (Laplace Approximation) [glmerMod]
 Family: binomial  ( logit )
Formula: Accuracy ~ Month + (1 | ID)
   Data: cell

     AIC      BIC   logLik deviance df.resid
   867.3    881.6   -430.7    861.3      844

Scaled residuals:
    Min      1Q  Median      3Q     Max
-3.2297  0.2825  0.4001  0.5530  1.0383

Random effects:
 Groups Name        Variance Std.Dev.
 ID     (Intercept) 0.3423   0.5851
Number of obs: 847, groups:  ID, 44
```

```
Fixed effects:
            Estimate Std. Error z value Pr(>|z|)
(Intercept)  2.25612    0.20798  10.848  < 2e-16 ***
Month       -0.16585    0.02515  -6.594 4.29e-11 ***
---
Signif. codes:
0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
      (Intr)
Month -0.796
```

Here, the coefficient b1 for Month, is the predicted change in the logit for a 1-unit change in Month. Thus, these are the odds that Accuracy changes by exp (b1) for a 1-unit change in Month. We can also convert odds to probabilities:

```
> odds = exp(-0.16585)
> prob = odds/(1+odds)
> prob
```

```
[1] 0.4586323
```

Thus, for every 1-unit change in Month, the odds of Accuracy decrease by 16 percent, and the accuracy changes by 0.45.

We can also look at the ICC for this model:

```
> reghelper::ICC(acc_model_1) ## why is this 1?
```

```
[1] 1
```

Temporal Distance

```
> time_model_1 = lmer(data = cell, TimeJudgmentDistance ~ Month + (1|ID))
> summary(time_model_1)
```

```
Linear mixed model fit by REML ['lmerMod']
Formula: TimeJudgmentDistance ~ Month + (1 | ID)
   Data: cell

REML criterion at convergence: 3993

Scaled residuals:
    Min      1Q  Median      3Q     Max
-1.5249 -0.5710 -0.2568  0.1874  4.1881

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept) 0.1932   0.4395
 Residual             6.3308   2.5161
Number of obs: 847, groups:  ID, 44

Fixed effects:
```

```
            Estimate Std. Error t value
(Intercept)  0.47150    0.17671   2.668
Month        0.24104    0.02484   9.704

Correlation of Fixed Effects:
      (Intr)
Month -0.783
```

We see a main effect of Month, for every 1-unit change in Month, the temporal distance increase by 0.24 units.

```
> reghelper::ICC(time_model_1)
```

```
[1] 0.02961433
```

4 Model 2: Adding Random Slope for Time

Name Retrieval Accuracy

```
> library(lme4)
> acc_model_2 = glmer(data = cell, Accuracy ~ Month + (Month|ID), family = "binomial")
> summary(acc_model_2)
```

```
Generalized linear mixed model fit by maximum likelihood
  (Laplace Approximation) [glmerMod]
 Family: binomial  ( logit )
Formula: Accuracy ~ Month + (Month | ID)
   Data: cell

     AIC      BIC   logLik deviance df.resid
   868.6    892.3   -429.3    858.6      842

Scaled residuals:
    Min      1Q  Median      3Q     Max
-2.9522  0.3237  0.4052  0.5279  1.2395

Random effects:
 Groups Name        Variance Std.Dev. Corr
 ID     (Intercept) 0.058688 0.24226
        Month       0.003532 0.05943  1.00
Number of obs: 847, groups:  ID, 44

Fixed effects:
            Estimate Std. Error z value Pr(>|z|)
(Intercept)  2.19914    0.19064   11.54  < 2e-16 ***
Month       -0.15994    0.02734   -5.85 4.92e-09 ***
---
Signif. codes:
0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
      (Intr)
Month -0.747
```

```
> anova(acc_model_1, acc_model_2)
```

```
Data: cell
Models:
acc_model_1: Accuracy ~ Month + (1 | ID)
acc_model_2: Accuracy ~ Month + (Month | ID)
            Df    AIC    BIC  logLik deviance  Chisq Chi Df
acc_model_1  3 867.33 881.55 -430.66   861.33
acc_model_2  5 868.56 892.27 -429.28   858.56 2.7648      2
            Pr(>Chisq)
acc_model_1
acc_model_2      0.251
```

```
>
> ## model with random slope is NOT better
```

Temporal Distance

```
> # time_model_2 = lmer(data = cell, TimeJudgmentDistance ~ Month + (Month|ID))
> # summary(time_model_2)
> ## does not converge!
```

5 Model 3: Examining Polynomial Trend

Name Retrieval Accuracy

```
> cell$Month.c = as.numeric(scale(cell$Month, center = TRUE, scale = FALSE))
> #acc_model_3 = glmer(data = cell, Accuracy ~ Month.c + I((Month.c)^2) (1|ID), family = "binomial")
> #summary(acc_model_3)
>
> ## not sure
```

Temporal Distance

```
> time_model_3 = lmer(data = cell, TimeJudgmentDistance ~ Month.c + I((Month.c)^2) + (1|ID))
> summary(time_model_3)
```

```
Linear mixed model fit by REML ['lmerMod']
Formula:
TimeJudgmentDistance ~ Month.c + I((Month.c)^2) + (1 | ID)
   Data: cell

REML criterion at convergence: 4000

Scaled residuals:
    Min      1Q  Median      3Q     Max
-1.4669 -0.5841 -0.2450  0.1944  4.2282

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept) 0.1967   0.4435
```

```
 Residual             6.3306   2.5161
Number of obs: 847, groups:  ID, 44

Fixed effects:
                Estimate Std. Error t value
(Intercept)     1.913343   0.150168  12.741
Month.c         0.248562   0.026304   9.449
I((Month.c)^2) -0.007160   0.008262  -0.867

Correlation of Fixed Effects:
            (Intr) Mnth.c
Month.c      0.230
I((Mnt.)^2) -0.678 -0.329
```

```
> # quadratic term not significant!
```

6 Centering the Data

Centering Time

We first make the 0 for the time variable (Month) meaningful, and see if any of the models change before we add any new predictors.

```
> ## make the 0 for month meaningful
> cell$Month_0 = cell$Month - 1
> acc_model_4 = glmer(data = cell, Accuracy ~ Month_0 + (1|ID), family = "binomial")
> summary(acc_model_4)
```

```
Generalized linear mixed model fit by maximum likelihood
  (Laplace Approximation) [glmerMod]
 Family: binomial  ( logit )
Formula: Accuracy ~ Month_0 + (1 | ID)
   Data: cell

     AIC      BIC   logLik deviance df.resid
   867.3    881.6   -430.7    861.3      844

Scaled residuals:
    Min      1Q  Median      3Q     Max
-3.2297  0.2825  0.4001  0.5530  1.0383

Random effects:
 Groups Name        Variance Std.Dev.
 ID     (Intercept) 0.3423   0.5851
Number of obs: 847, groups:  ID, 44

Fixed effects:
            Estimate Std. Error z value Pr(>|z|)
(Intercept)  2.09028    0.18857  11.085  < 2e-16 ***
Month_0     -0.16585    0.02515  -6.594 4.29e-11 ***
---
Signif. codes:
0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
```

```
        (Intr)
Month_0 -0.745
```

```
> ## model with random slope of Month_0 does not converge. acc_model_4 is new final model.
>
> time_model_4 = lmer(data = cell, TimeJudgmentDistance ~ Month_0 + (1|ID))
> summary(time_model_4)
```

```
Linear mixed model fit by REML ['lmerMod']
Formula: TimeJudgmentDistance ~ Month_0 + (1 | ID)
   Data: cell

REML criterion at convergence: 3993

Scaled residuals:
    Min      1Q  Median      3Q     Max
-1.5249 -0.5710 -0.2568  0.1874  4.1881

Random effects:
 Groups   Name        Variance Std.Dev.
 ID       (Intercept) 0.1932   0.4395
 Residual             6.3308   2.5161
Number of obs: 847, groups:  ID, 44

Fixed effects:
            Estimate Std. Error t value
(Intercept)  0.71254    0.15802   4.509
Month_0      0.24104    0.02484   9.704

Correlation of Fixed Effects:
        (Intr)
Month_0 -0.718
```

```
> time_model_5 = lmer(data = cell, TimeJudgmentDistance ~ Month_0 + (Month_0|ID))
> summary(time_model_5)
```

```
Linear mixed model fit by REML ['lmerMod']
Formula: TimeJudgmentDistance ~ Month_0 + (Month_0 | ID)
   Data: cell

REML criterion at convergence: 3957.1

Scaled residuals:
    Min      1Q  Median      3Q     Max
-2.2200 -0.5532 -0.2003  0.1879  4.1901

Random effects:
 Groups   Name        Variance Std.Dev. Corr
 ID       (Intercept) 0.03442  0.1855
          Month_0     0.02867  0.1693   -1.00
 Residual             5.85977  2.4207
Number of obs: 847, groups:  ID, 44

Fixed effects:
```

```
            Estimate Std. Error t value
(Intercept)  0.70430    0.14134   4.983
Month_0      0.24967    0.03581   6.973

Correlation of Fixed Effects:
        (Intr)
Month_0 -0.679
```

```
> anova(time_model_4, time_model_5)
```

```
Data: cell
Models:
time_model_4: TimeJudgmentDistance ~ Month_0 + (1 | ID)
time_model_5: TimeJudgmentDistance ~ Month_0 + (Month_0 | ID)
             Df    AIC    BIC  logLik deviance  Chisq
time_model_4  4 3992.8 4011.8 -1992.4   3984.8
time_model_5  6 3961.6 3990.0 -1974.8   3949.6 35.256
             Chi Df Pr(>Chisq)
time_model_4
time_model_5      2  2.209e-08 ***
---
Signif. codes:
0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
> ##model 5 with random slope is better.
```

6.1 Adding New Predictors

We have 2 predictors that could potentially influence our DVs. The number of messages sent to the recipient over the year (a level-1 predictor), and the vividness for the email conversation (level 1 predictor). We will now try to include these variables.

Uncentered Messages

```
> acc_pred_1  = glmer(data = cell, Accuracy ~ Month_0 + Messages + (1|ID), family = "binomial")
> summary(acc_pred_1)
```

```
Generalized linear mixed model fit by maximum likelihood
  (Laplace Approximation) [glmerMod]
 Family: binomial  ( logit )
Formula: Accuracy ~ Month_0 + Messages + (1 | ID)
   Data: cell

     AIC      BIC   logLik deviance df.resid
   846.6    865.6   -419.3    838.6      843

Scaled residuals:
    Min      1Q  Median      3Q     Max
-7.3552  0.0430  0.4053  0.5598  1.2609

Random effects:
 Groups Name        Variance Std.Dev.
 ID     (Intercept) 0.3533   0.5944
```

```
Number of obs: 847, groups:  ID, 44

Fixed effects:
            Estimate Std. Error z value Pr(>|z|)
(Intercept)  1.51985    0.22530   6.746 1.52e-11 ***
Month_0     -0.13782    0.02610  -5.281 1.29e-07 ***
Messages     0.06158    0.01692   3.640 0.000273 ***
---
Signif. codes:
0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
         (Intr) Mnth_0
Month_0  -0.706
Messages -0.517  0.135
```

```
> anova(acc_model_4, acc_pred_1) ## this is a better model
```

```
Data: cell
Models:
acc_model_4: Accuracy ~ Month_0 + (1 | ID)
acc_pred_1: Accuracy ~ Month_0 + Messages + (1 | ID)
            Df    AIC    BIC  logLik deviance  Chisq Chi Df
acc_model_4  3 867.33 881.55 -430.66   861.33
acc_pred_1   4 846.64 865.61 -419.32   838.64 22.687      1
            Pr(>Chisq)
acc_model_4
acc_pred_1   1.907e-06 ***
---
Signif. codes:
0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
> time_pred_1 = lmer(data = cell, TimeJudgmentDistance ~ Month_0 + Messages + (Month_0|ID))
> summary(time_pred_1)
```

```
Linear mixed model fit by REML ['lmerMod']
Formula:
TimeJudgmentDistance ~ Month_0 + Messages + (Month_0 | ID)
   Data: cell

REML criterion at convergence: 3966.4

Scaled residuals:
    Min      1Q  Median      3Q     Max
-2.2178 -0.5530 -0.2001  0.1877  4.1876

Random effects:
 Groups   Name        Variance Std.Dev. Corr
 ID       (Intercept) 0.03454  0.1859
          Month_0     0.02868  0.1693   -1.00
 Residual             5.86701  2.4222
Number of obs: 847, groups:  ID, 44

Fixed effects:
```

```
             Estimate Std. Error t value
(Intercept)  0.7064800  0.1569244   4.502
Month_0      0.2494711  0.0363674   6.860
Messages    -0.0001207  0.0037629  -0.032

Correlation of Fixed Effects:
         (Intr) Mnth_0
Month_0  -0.678
Messages -0.433  0.173
```

```
> anova(time_model_5, time_pred_1) ## not a better model
```

```
Data: cell
Models:
time_model_5: TimeJudgmentDistance ~ Month_0 + (Month_0 | ID)
time_pred_1: TimeJudgmentDistance ~ Month_0 + Messages + (Month_0 | ID)
             Df    AIC    BIC  logLik deviance Chisq Chi Df
time_model_5  6 3961.6 3990.0 -1974.8   3949.6
time_pred_1   7 3963.6 3996.8 -1974.8   3949.6 9e-04      1
             Pr(>Chisq)
time_model_5
time_pred_1      0.9756
```

Uncentered Vividness

```
> # acc_pred_2  = glmer(data = cell, Accuracy ~ Month_0 + Vividness + (1|ID), family = "binomial")
> # summary(acc_pred_2) ## does not converge
> #
> # time_pred_2 = lmer(data = cell, TimeJudgmentDistance ~ Month_0 + Vividness + (Month_0|ID))
> # summary(time_pred_2) ## does not converge
```

Within-Person and Grand Mean Centering

```
> library(dplyr)
> ## aggregate per subject all IVs and DVs
> cell_agg = cell %>% group_by(ID) %>%
+   summarize(acc_mean = mean(Accuracy, na.rm = TRUE),
+             time_mean = mean(TimeJudgmentDistance, na.rm = TRUE),
+             messages_mean = mean(Messages, na.rm = TRUE),
+             vividness_mean = mean(Vividness, na.rm = TRUE))
> head(cell_agg)
```

```
# A tibble: 6 x 5
      ID  acc_mean time_mean messages_mean vividness_mean
  <fctr>     <dbl>     <dbl>         <dbl>          <dbl>
1    103 0.7666667 1.7666667      5.633333       8.000000
2    104 0.8823529 1.2352941      7.941176       8.000000
3    105 0.8181818 1.3636364      5.181818       6.545455
4    108 0.7727273 2.7727273      9.681818       7.000000
5    110 0.4285714 2.6428571     37.928571       6.142857
6    113 0.9565217 0.9565217      7.652174       8.130435
```

```
> ## merge aggregate info with long data
> cell = merge(cell, cell_agg, by = "ID", all.x = T)
> ## person and grand-mean centered scores using original and aggregate
> library(dplyr)
> cell = cell %>% mutate(acc_pc = Accuracy - acc_mean,
+                  time_pc = TimeJudgmentDistance - time_mean,
+                  messages_pc = Messages - messages_mean,
+                  vividness_pc = Vividness - vividness_mean)
```

7 Centered Multiple Predictors

Time and Messages

```
> acc_pred_3 = glmer(data = cell, Accuracy ~ Month_0 + messages_mean +
+                                                  messages_pc + (1|ID), family = "binomial")
> summary(acc_pred_3)
```

```
Generalized linear mixed model fit by maximum likelihood
  (Laplace Approximation) [glmerMod]
 Family: binomial  ( logit )
Formula:
Accuracy ~ Month_0 + messages_mean + messages_pc + (1 | ID)
   Data: cell

     AIC      BIC   logLik deviance df.resid
   846.3    870.0   -418.2    836.3      842

Scaled residuals:
    Min      1Q  Median      3Q     Max
-7.4906  0.0416  0.4054  0.5648  1.3510

Random effects:
 Groups Name        Variance Std.Dev.
 ID     (Intercept) 0.3116   0.5582
Number of obs: 847, groups:  ID, 44

Fixed effects:
             Estimate Std. Error z value Pr(>|z|)
(Intercept)   1.78568    0.28474   6.271 3.58e-10 ***
Month_0      -0.13781    0.02610  -5.280 1.29e-07 ***
messages_mean  0.03696    0.02297   1.609 0.107566
messages_pc    0.06331    0.01692   3.741 0.000184 ***
---
Signif. codes:
0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
            (Intr) Mnth_0 mssgs_m
Month_0     -0.576
messages_mn -0.721  0.117
messages_pc -0.359  0.132  0.680
```

```
> ## Accuracy increases if the number of sent messages is over and above the person's sending
> ## behaviour in general. IMPORTANT!
>
```

```
> time_pred_3 = lmer(data = cell, TimeJudgmentDistance ~ Month_0 + messages_mean +
+                                                    messages_pc + (Month_0|ID))
> summary(time_pred_3)
```

```
Linear mixed model fit by REML ['lmerMod']
Formula:
TimeJudgmentDistance ~ Month_0 + messages_mean + messages_pc +
    (Month_0 | ID)
   Data: cell

REML criterion at convergence: 3972.6

Scaled residuals:
    Min      1Q  Median      3Q     Max
-2.2124 -0.5531 -0.2050  0.1772  4.1834

Random effects:
 Groups   Name        Variance Std.Dev. Corr
 ID       (Intercept) 0.03383  0.1839
          Month_0     0.02855  0.1690   -1.00
 Residual             5.87189  2.4232
Number of obs: 847, groups:  ID, 44

Fixed effects:
              Estimate Std. Error t value
(Intercept)    0.620365   0.210361   2.949
Month_0        0.248359   0.036375   6.828
messages_mean  0.008254   0.014131   0.584
messages_pc   -0.001029   0.004044  -0.255

Correlation of Fixed Effects:
            (Intr) Mnth_0 mssgs_m
Month_0     -0.472
messages_mn -0.728 -0.001
messages_pc -0.058  0.179 -0.104
```

```
>
> ## Still no effect of messages
```

Time and Vividness

```
> # acc_pred_4 = glmer(data = cell, Accuracy ~ Month_0 + vividness_mean +
> #                                                vividness_pc + (1|ID), family = "binomial")
> # summary(acc_pred_4) ## does not converge
> #
> # time_pred_4 = lmer(data = cell, TimeJudgmentDistance ~ Month_0 + vividness_mean +
> #                                                vividness_pc + (Month_0|ID))
> # summary(time_pred_4) ## does not converge
```

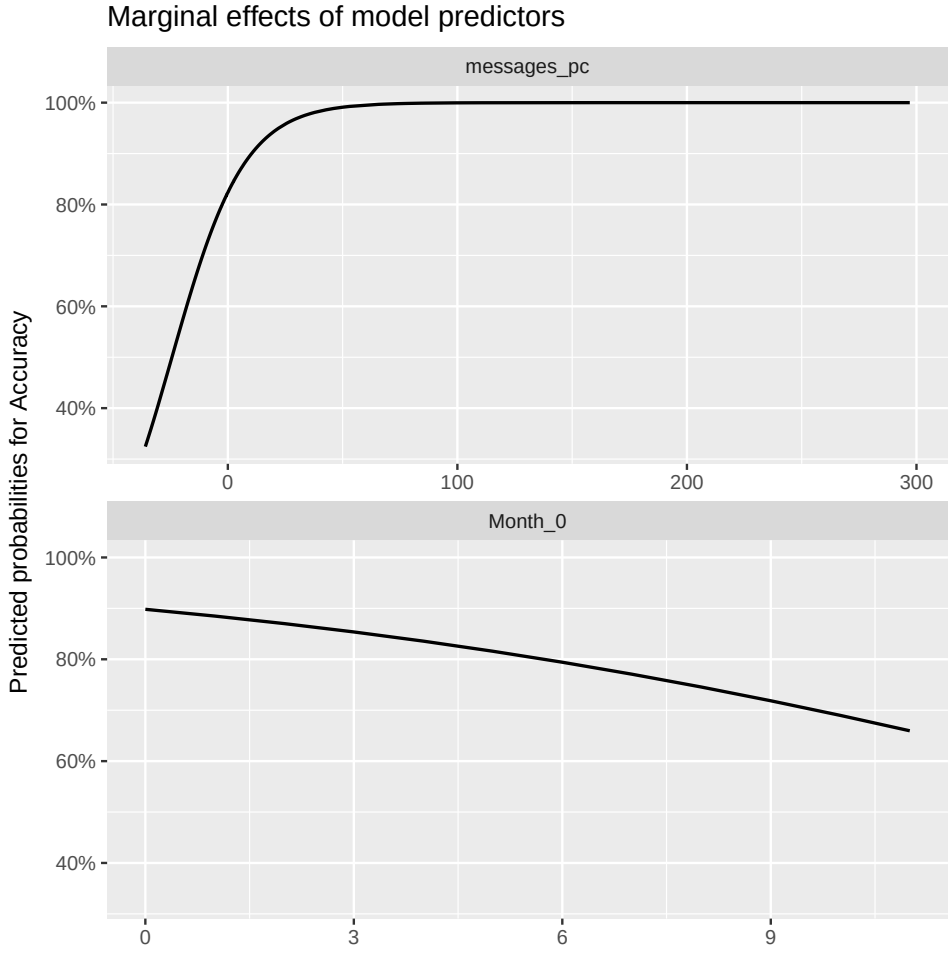
Time and Messages Interaction

```
> # acc_pred_5 = glmer(data = cell, Accuracy ~ Month_0 + messages_mean +
> #                                                messages_pc + Month_0*messages_pc +
> #                                                    (1|ID), family = "binomial")
```

```
> # summary(acc_pred_5) ## does not converge
>
> # time_pred_5 = lmer(data = cell, TimeJudgmentDistance ~ Month_0 + messages_mean +
> #                                                    messages_pc + Month_0*messages_pc +
> #                                                              (Month_0|ID))
> # summary(time_pred_5) ## no effect
>
```

8 Graphing the Models

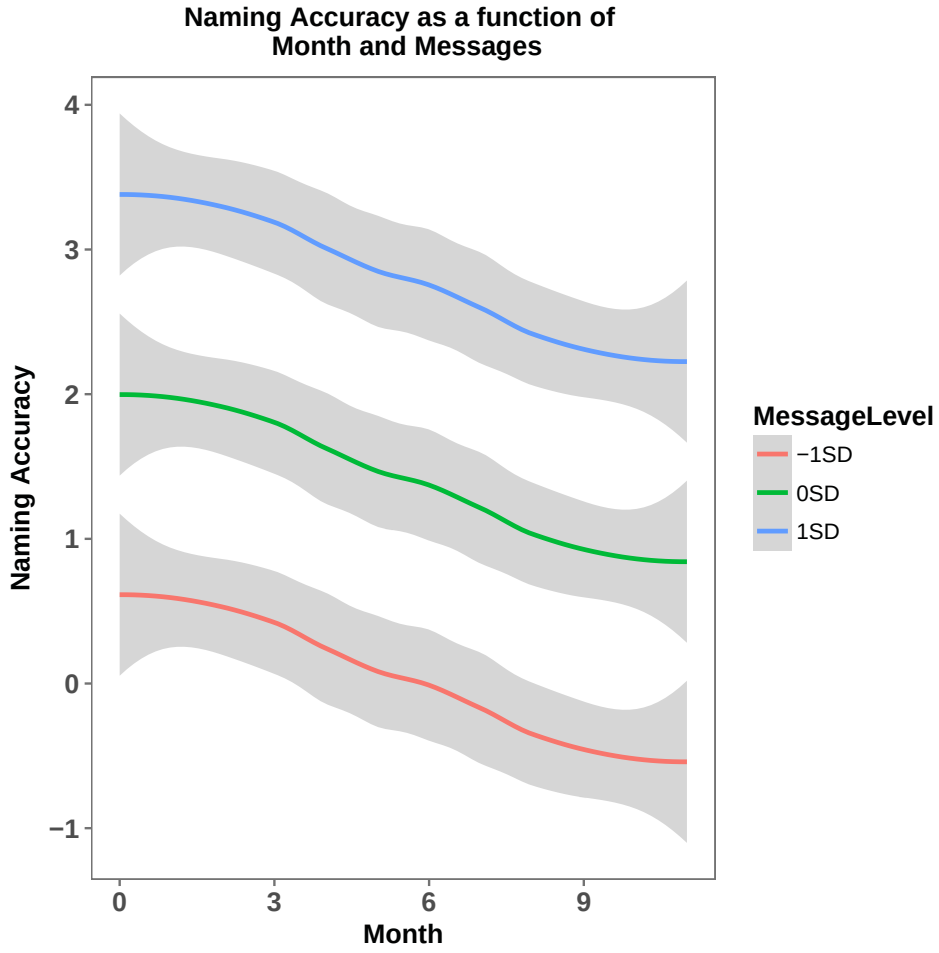
Naming Accuracy



The final model for accuracy is $\text{acc}_p red_3, with time and messages. We are going to try and plot the fitted values from this mo$

Table 1: Naming Accuracy Regression Table

	Naming Accuracy	
term	b	CI
Fixed		
(Intercept)	1.79	(1.54, 2.36)
Month_0	-0.14	(-0.19, -0.11)
messages_mean	0.04	(0.01, 0.09)
messages_pc	0.06	(0.04, 0.11)
Random		
τ_{00}	0.31	(0.26, 0.47)
Summary		
ICC	1.00	NA
R^2_m	0.41	NA
R^2_c	0.46	NA



9 Regression Table

Storing Table into a Dataframe

Making the Table

10 Naming Accuracy as a Factor

```
> ##creatng a factor term for naming accuracy
> cell$acc_fac = as.factor(as.character(cell$Accuracy))
> time_model_6 = lmer(data = cell, TimeJudgmentDistance ~ Month_0 +
+                                     acc_fac + (Month_0|ID))
> summary(time_model_6)
```

```
Linear mixed model fit by REML ['lmerMod']
Formula:
TimeJudgmentDistance ~ Month_0 + acc_fac + (Month_0 | ID)
   Data: cell

REML criterion at convergence: 3884.4

Scaled residuals:
    Min      1Q  Median      3Q     Max
-2.7857 -0.4778 -0.2026  0.2238  4.6923

Random effects:
 Groups   Name        Variance Std.Dev. Corr
 ID       (Intercept) 0.03674  0.1917
          Month_0     0.02397  0.1548   -1.00
 Residual             5.39870  2.3235
Number of obs: 847, groups:  ID, 44

Fixed effects:
            Estimate Std. Error t value
(Intercept)  2.30899    0.22743  10.153
Month_0      0.19567    0.03406   5.745
acc_fac1    -1.78491    0.20269  -8.806

Correlation of Fixed Effects:
         (Intr) Mnth_0
Month_0  -0.554
acc_fac1 -0.801  0.180
```

```
> ## adding interaction term
> time_model_7 = lmer(data = cell, TimeJudgmentDistance ~ Month_0 +
+                                     acc_fac + Month_0*acc_fac + (Month_0|ID))
> summary(time_model_7)
```

```
Linear mixed model fit by REML ['lmerMod']
Formula:
TimeJudgmentDistance ~ Month_0 + acc_fac + Month_0 * acc_fac +
    (Month_0 | ID)
   Data: cell

REML criterion at convergence: 3871.9
```

```
Scaled residuals:
    Min      1Q  Median      3Q     Max
-3.1481 -0.4549 -0.1793  0.1818  4.8774

Random effects:
 Groups   Name        Variance Std.Dev. Corr
 ID       (Intercept) 0.02999  0.1732
          Month_0     0.02183  0.1478   -1.00
 Residual             5.31142  2.3047
Number of obs: 847, groups:  ID, 44

Fixed effects:
                 Estimate Std. Error t value
(Intercept)       1.18163    0.35765   3.304
Month_0           0.38789    0.05781   6.710
acc_fac1         -0.45771    0.38400  -1.192
Month_0:acc_fac1 -0.24345    0.05996  -4.060

Correlation of Fixed Effects:
            (Intr) Mnth_0 acc_f1
Month_0     -0.836
acc_fac1    -0.926  0.753
Mnth_0:cc_1  0.777 -0.819 -0.852
```

```
> anova(time_model_5, time_model_6)
```

```
Data: cell
Models:
time_model_5: TimeJudgmentDistance ~ Month_0 + (Month_0 | ID)
time_model_6: TimeJudgmentDistance ~ Month_0 + acc_fac + (Month_0 | ID)
             Df    AIC    BIC  logLik deviance  Chisq
time_model_5  6 3961.6 3990.0 -1974.8   3949.6
time_model_6  7 3889.2 3922.4 -1937.6   3875.2 74.347
             Chi Df Pr(>Chisq)
time_model_5
time_model_6      1  < 2.2e-16 ***
---
Signif. codes:
0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
> anova(time_model_6, time_model_7)
```

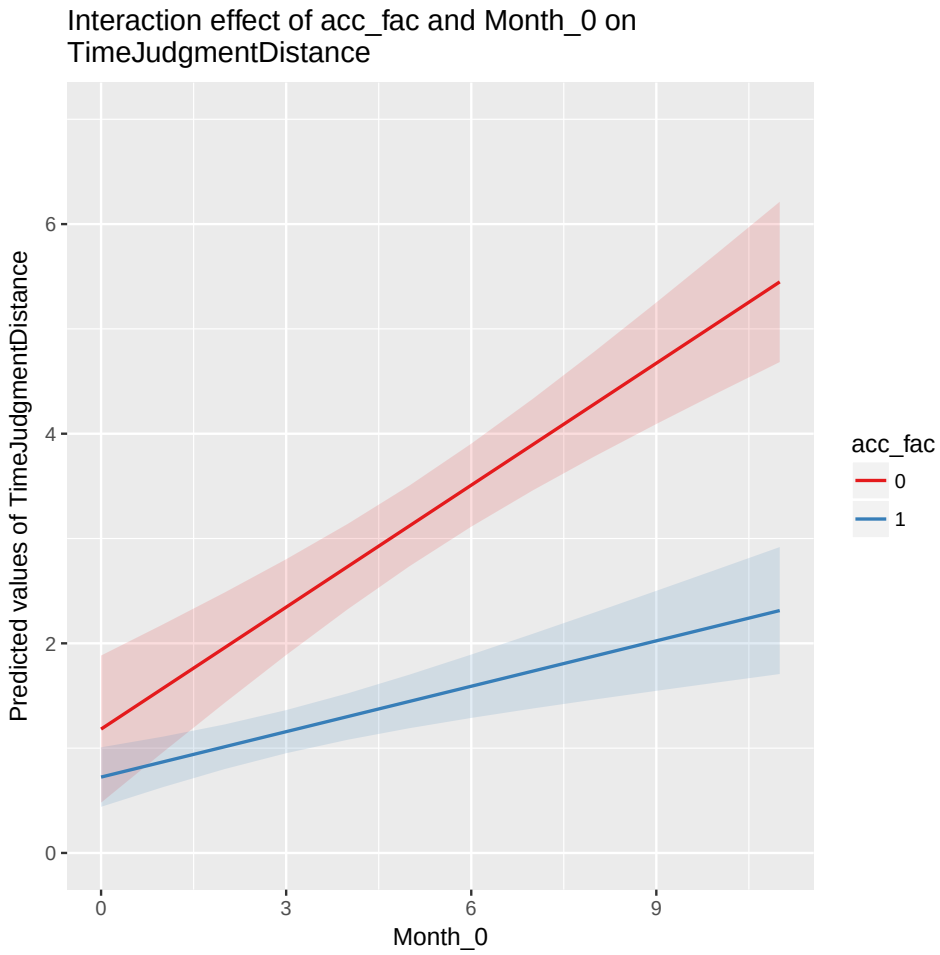
```
Data: cell
Models:
time_model_6: TimeJudgmentDistance ~ Month_0 + acc_fac + (Month_0 | ID)
time_model_7: TimeJudgmentDistance ~ Month_0 + acc_fac + Month_0 * acc_fac +
time_model_7:     (Month_0 | ID)
             Df    AIC    BIC  logLik deviance  Chisq
time_model_6  7 3889.2 3922.4 -1937.6   3875.2
time_model_7  8 3874.8 3912.8 -1929.4   3858.8 16.401
             Chi Df Pr(>Chisq)
time_model_6
time_model_7      1  5.126e-05 ***
---
```

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

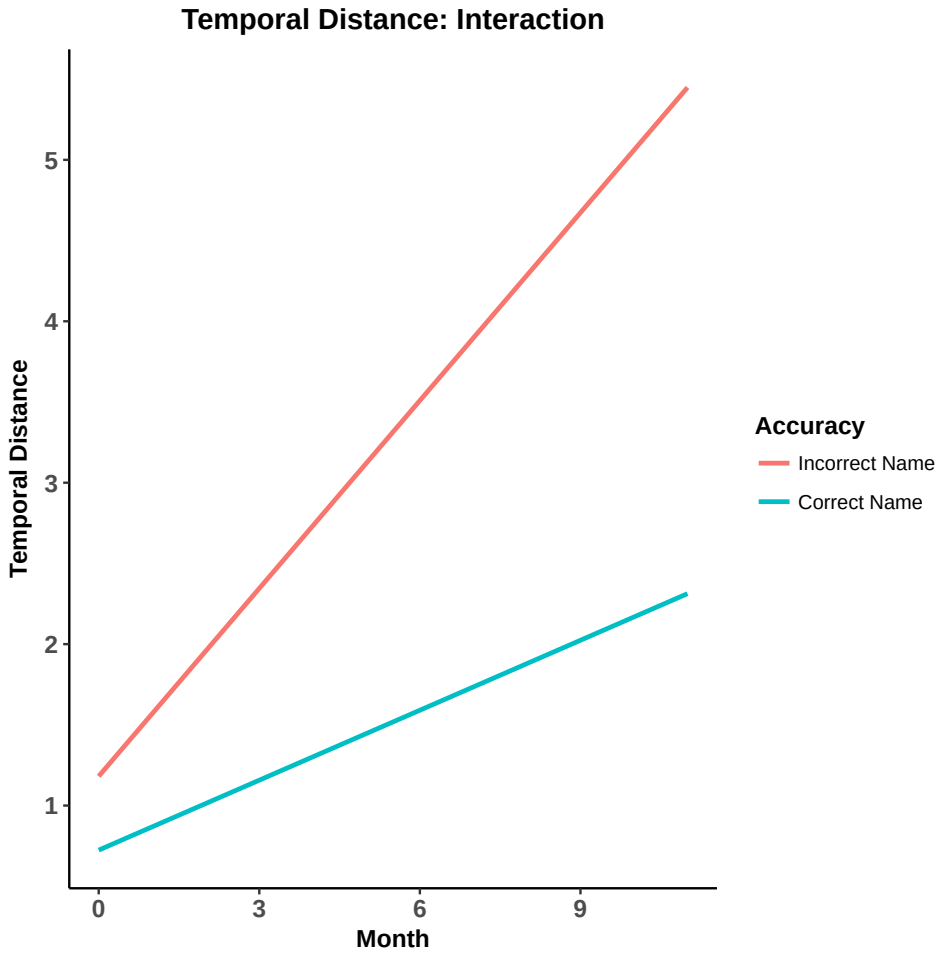
```
>
> ## thus, time_model_7 is a better model
```

Plotting The Temporal Distance Model

Using sjPlot



Using predict()



11 Naming Accuracy and Vividness as IVs

```
> time_model_8 = lmer(data = cell, TimeJudgmentDistance ~ Month_0 +
+                                     acc_fac + Month_0*acc_fac +
+                                       Vividness  +
+                                           (Month_0|ID))
> summary(time_model_8)
```

```
Linear mixed model fit by REML ['lmerMod']
Formula:
TimeJudgmentDistance ~ Month_0 + acc_fac + Month_0 * acc_fac +
    Vividness + (Month_0 | ID)
   Data: cell

REML criterion at convergence: 3806.3

Scaled residuals:
    Min      1Q  Median      3Q     Max
-2.7998 -0.5159 -0.1245  0.2745  4.7145

Random effects:
 Groups   Name        Variance Std.Dev. Corr
 ID       (Intercept) 0.01803  0.1343
```

```
          Month_0     0.02755  0.1660   -1.00
 Residual             4.81913  2.1953
Number of obs: 847, groups:  ID, 44

Fixed effects:
                 Estimate Std. Error t value
(Intercept)       2.68530    0.38191   7.031
Month_0           0.33148    0.05720   5.795
acc_fac1          0.61168    0.38683   1.581
Vividness        -0.28266    0.03253  -8.689
Month_0:acc_fac1 -0.23567    0.05739  -4.107

Correlation of Fixed Effects:
            (Intr) Mnth_0 acc_f1 Vvdnss
Month_0     -0.770
acc_fac1    -0.640  0.654
Vividness   -0.451  0.108 -0.321
Mnth_0:cc_1  0.697 -0.793 -0.802 -0.010
```

```
> anova(time_model_7, time_model_8)
```

```
Data: cell
Models:
time_model_7: TimeJudgmentDistance ~ Month_0 + acc_fac + Month_0 * acc_fac +
time_model_7:     (Month_0 | ID)
time_model_8: TimeJudgmentDistance ~ Month_0 + acc_fac + Month_0 * acc_fac +
time_model_8:     Vividness + (Month_0 | ID)
             Df    AIC    BIC  logLik deviance  Chisq
time_model_7  8 3874.8 3912.8 -1929.4   3858.8
time_model_8  9 3806.2 3848.8 -1894.1   3788.2 70.678
             Chi Df Pr(>Chisq)
time_model_7
time_model_8      1  < 2.2e-16 ***
---
Signif. codes:
0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
> #3-way interaction
>
> time_model_9 = lmer(data = cell, TimeJudgmentDistance ~ Month_0 +
+                                     acc_fac + Month_0*acc_fac +
+                                       Vividness +  Month_0*acc_fac*Vividness +
+                                           (Month_0|ID))
> summary(time_model_9)
```

```
Linear mixed model fit by REML ['lmerMod']
Formula:
TimeJudgmentDistance ~ Month_0 + acc_fac + Month_0 * acc_fac +
    Vividness + Month_0 * acc_fac * Vividness + (Month_0 | ID)
   Data: cell

REML criterion at convergence: 3760.7

Scaled residuals:
```

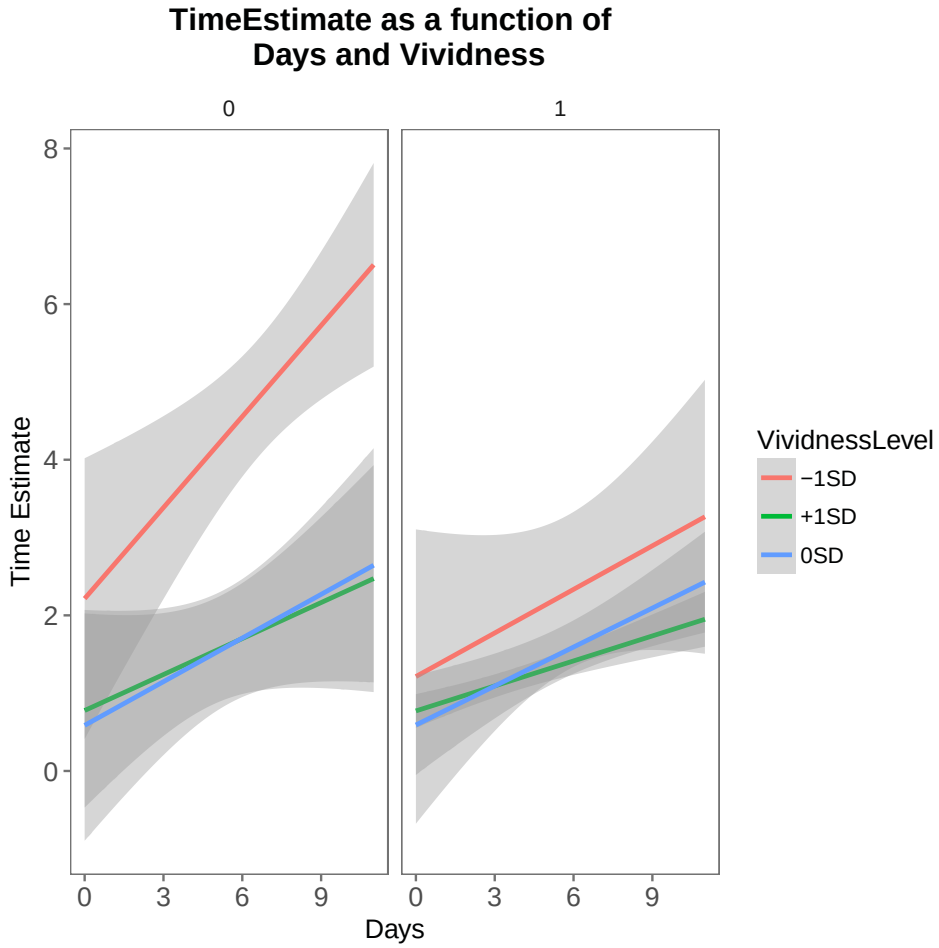
```
    Min      1Q  Median      3Q     Max
-3.3588 -0.4816 -0.0740  0.3379  4.6726

Random effects:
 Groups   Name        Variance Std.Dev. Corr
 ID       (Intercept) 0.06673  0.2583
          Month_0     0.03680  0.1918   -1.00
 Residual             4.45260  2.1101
Number of obs: 847, groups:  ID, 44

Fixed effects:
                           Estimate Std. Error t value
(Intercept)                 1.85695    0.54652   3.398
Month_0                     0.63136    0.08526   7.405
acc_fac1                   -1.00127    0.80033  -1.251
Vividness                  -0.06419    0.09082  -0.707
Month_0:acc_fac1           -0.25510    0.12330  -2.069
Month_0:Vividness          -0.08284    0.01509  -5.490
acc_fac1:Vividness          0.05574    0.11130   0.501
Month_0:acc_fac1:Vividness  0.05171    0.01855   2.787

Correlation of Fixed Effects:
            (Intr) Mnth_0 acc_f1 Vvdnss Mn_0:_1 Mn_0:V
Month_0     -0.852
acc_fac1    -0.679  0.566
Vividness   -0.795  0.680  0.542
Mnth_0:cc_1  0.565 -0.601 -0.842 -0.464
Mnth_0:Vvdn  0.639 -0.732 -0.437 -0.844  0.497
acc_fc1:Vvd  0.648 -0.555 -0.855 -0.815  0.732   0.688
Mnth_0:_1:V -0.516  0.588  0.678  0.682 -0.836  -0.805
            ac_1:V
Month_0
acc_fac1
Vividness
Mnth_0:cc_1
Mnth_0:Vvdn
acc_fc1:Vvd
Mnth_0:_1:V -0.825
```

```
> anova(time_model_8, time_model_9)
```

```
Data: cell
Models:
time_model_8: TimeJudgmentDistance ~ Month_0 + acc_fac + Month_0 * acc_fac +
time_model_8:     Vividness + (Month_0 | ID)
time_model_9: TimeJudgmentDistance ~ Month_0 + acc_fac + Month_0 * acc_fac +
time_model_9:     Vividness + Month_0 * acc_fac * Vividness + (Month_0 | ID)
             Df    AIC    BIC  logLik deviance  Chisq
time_model_8  9 3806.2 3848.8 -1894.1   3788.2
time_model_9 12 3748.9 3805.8 -1862.5   3724.9 63.234
             Chi Df Pr(>Chisq)
time_model_8
time_model_9      3  1.197e-13 ***
---
Signif. codes:
0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
>
> ## Thus the 3-way model is better. This is the final model for Temporal Distance.
```

12 Plotting Final Temporal Model



Using predict()