# English Nominal Recursion Study, Part 4:
# Condition by Agegroup, DV is AllTargets: Limit the analysis to kids

```
> #   4. Condition by Agegroup, DV is AllTargets
> # Limit the analysis to just kids and no Item e6
>
> rm(list=ls()); options(scipen=999) # To avoid scientific notation
> # Install packages if necessary. Only need to do this once.
> # install.packages("lme4")
> # install.packages("car")
> # Load packages -- do this every time
> library(lme4) # For lmer function
Loading required package: Matrix
> library(car)  # For F-tests with p-values, Wald chi-squared tests
>
> # Read data into a data frame
> rdata =
read.table("http://www.utstat.toronto.edu/~brunner/workshops/mixed/Recursion.data.txt",
header=T)
> # rdata = read.table("Recursion.data.txt", header=T) # Local copy of the data
> dim(rdata)
[1] 2100   18
> # Eliminate adults and Item e6
> rdata = subset(rdata,Item != 'e6'); rdata = subset(rdata,Group == 'Child')
> dim(rdata)
[1] 1704   18
> # Also eliminate 6 rows with NA for AllTargets and StrictTarget. This reduces
> # headaches later.
> rdata = subset(rdata, !is.na(AllTargets))
> dim(rdata)
[1] 1698   18
>
> head(rdata); attach(rdata)
  Participant AgeinMonths Group Agegroup Condition Item StrictTarget AllTargets
1           1        48.5 Child     4yos         A  a1a            1          1
2           1        48.5 Child     4yos         A  a1b            0          0
3           1        48.5 Child     4yos         A   a2            0          0
4           1        48.5 Child     4yos         A   a3            0          0
5           1        48.5 Child     4yos         A   a4            0          0
7           1        48.5 Child     4yos         A   a6            0          0
  Years Months Days KABC_Hand CELF_SS CELF_WS CELF_EV CELF_Sent PPVT KBIT
1     4      0   14          4      16      13      22        21   92   NA
2     4      0   14          4      16      13      22        21   92   NA
3     4      0   14          4      16      13      22        21   92   NA
4     4      0   14          4      16      13      22        21   92   NA
5     4      0   14          4      16      13      22        21   92   NA
7     4      0   14          4      16      13      22        21   92   NA
> Item = factor(Item); Agegroup = factor(Agegroup) # To eliminate empty levels
> # Effect coding
> contrasts(Agegroup) = contr.sum; contrasts(Condition) = contr.sum
```

```
>
> table5 = table(AllTargets,Condition,Agegroup); table5 # Looks like an interaction
, , Agegroup = 4yos

          Condition
AllTargets   A   B   C   E
         0 141 122 140 120
         1  31  28  10   4

, , Agegroup = 5yos

          Condition
AllTargets   A   B   C   E
         0 139 112 139 121
         1  34  38  11   4

, , Agegroup = 6yos

          Condition
AllTargets   A   B   C   E
         0  82  65  97  84
         1  65  61  29  21

> # Make table of percentages
> prop5.3 = prop.table(table5[,,1],2)
> prop5.5 = prop.table(table5[,,2],2)
> prop5.6 = prop.table(table5[,,3],2)
> PercentRecursion = rbind(prop5.3[2,], prop5.5[2,], prop5.6[2,])
> PercentRecursion = round(100*PercentRecursion,2)
> rownames(PercentRecursion) = c("4yos","5yos","6yos"); PercentRecursion
         A     B     C     E
4yos 18.02 18.67  6.67  3.23
5yos 19.65 25.33  7.33  3.20
6yos 44.22 48.41 23.02 20.00
> round(addmargins(PercentRecursion, FUN=mean, quiet=T),2)
         A     B     C     E  mean
4yos 18.02 18.67  6.67  3.23 11.65
5yos 19.65 25.33  7.33  3.20 13.88
6yos 44.22 48.41 23.02 20.00 33.91
mean 27.30 30.80 12.34  8.81 19.81
>
> # Significance Tests
> model5 = glmer(AllTargets ~ Condition*Agegroup + (1 | Participant),
family=binomial, nAGQ=1)
> Anova(model5, type="III") # p-value for interaction = 0.721
Analysis of Deviance Table (Type III Wald chisquare tests)

Response: AllTargets
                    Chisq Df            Pr(>Chisq)
(Intercept)        169.1986  1 < 0.00000000000000022 ***
Condition           87.5306  3 < 0.00000000000000022 ***
Agegroup            32.2982  2          0.00000009695 ***
Condition:Agegroup   3.6717  6                  0.721
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
>
> # Make a table of estimated population mean log odds
> X = model.matrix(model5) # The X matrix!
> summary5 = summary(model5)
> betahat = cbind(summary5$coef[,1]) # Estimated fixed effects as a column vector.
> estlogodds = X %*% betahat # Estimated pop mean log odds for each observation.
>
> aggmeans = aggregate(estlogodds, by = list(Agegroup,Condition), FUN = mean)
> aggmeans
```

```
   Group.1 Group.2          V1
1     4yos       A -1.78883979
2     5yos       A -1.66400533
3     6yos       A -0.26257195
4     4yos       B -1.74671600
5     5yos       B -1.30237792
6     6yos       B -0.06825281
7     4yos       C -3.02596960
8     5yos       C -2.91240497
9     6yos       C -1.37134313
10    4yos       E -3.82377098
11    5yos       E -3.82141335
12    6yos       E -1.57041266
> # aggregate(estlogodds, by = list(Agegroup,Condition), FUN = sd) # All zeros
> treatmeans = aggmeans[,3]
> dim(treatmeans) = c(3,4)
> rownames(treatmeans) = rownames(PercentRecursion)
> colnames(treatmeans) = colnames(PercentRecursion)
> round(addmargins(treatmeans,FUN=mean, quiet=T),2) # With marginal means
         A     B     C     E  mean
4yos -1.79 -1.75 -3.03 -3.82 -2.60
5yos -1.66 -1.30 -2.91 -3.82 -2.43
6yos -0.26 -0.07 -1.37 -1.57 -0.82
mean -1.24 -1.04 -2.44 -3.07 -1.95
> round(addmargins(PercentRecursion, FUN=mean, quiet=T),2) # For comparison
         A     B     C     E  mean
4yos 18.02 18.67  6.67  3.23 11.65
5yos 19.65 25.33  7.33  3.20 13.88
6yos 44.22 48.41 23.02 20.00 33.91
mean 27.30 30.80 12.34  8.81 19.81
>
> # Test pairwise differences between marginal means with a Bonferroni correction
> # First make a combination variable.
>
> # The combination variable AgeCond will have 12 values.
> n = length(AllTargets); n
[1] 1698
> AgeCond = character(n) # A character-valued variable of length n
> for(j in 1:n) AgeCond[j] = paste(Agegroup[j],Condition[j],sep='')
> freq = table(AgeCond); freq
AgeCond
4yosA 4yosB 4yosC 4yosE 5yosA 5yosB 5yosC 5yosE 6yosA 6yosB 6yosC 6yosE
  172   150   150   124   173   150   150   125   147   126   126   105
>
> # Fit a no-intercept model on the combination variable.
> noint = glmer(AllTargets ~ 0+ AgeCond + (1 | Participant), family=binomial)
Warning message:
In checkConv(attr(opt, "derivs"), opt$par, ctrl = control$checkConv,  :
  Model failed to converge with max|grad| = 0.00346365 (tol = 0.001, component 1)
```

```
> nointsum = summary(noint); nointsum
Generalized linear mixed model fit by maximum likelihood (Laplace Approximation) [
glmerMod]
 Family: binomial  ( logit )
Formula: AllTargets ~ 0 + AgeCond + (1 | Participant)

     AIC      BIC   logLik deviance df.resid
  1439.5   1510.2   -706.7   1413.5     1685

Scaled residuals:
    Min      1Q  Median      3Q     Max
-2.1189 -0.4659 -0.2676 -0.1177  5.2976

Random effects:
 Groups      Name        Variance Std.Dev.
 Participant (Intercept) 0.8784   0.9373
Number of obs: 1698, groups:  Participant, 71

Fixed effects:
             Estimate Std. Error z value           Pr(>|z|)
AgeCond4yosA -1.78928    0.28882  -6.195 0.0000000005826662 ***
AgeCond4yosB -1.74756    0.29745  -5.875 0.0000000042263150 ***
AgeCond4yosC -3.02728    0.39232  -7.716 0.0000000000000120 ***
AgeCond4yosE -3.82506    0.54968  -6.959 0.0000000000034356 ***
AgeCond5yosA -1.66408    0.28286  -5.883 0.0000000040270322 ***
AgeCond5yosB -1.30203    0.28004  -4.649 0.0000033292673787 ***
AgeCond5yosC -2.91164    0.37958  -7.671 0.0000000000000171 ***
AgeCond5yosE -3.82161    0.54872  -6.965 0.0000000000032921 ***
AgeCond6yosA -0.26183    0.27119  -0.965              0.334
AgeCond6yosB -0.06788    0.27994  -0.242              0.808
AgeCond6yosC -1.37091    0.30457  -4.501 0.0000067564687411 ***
AgeCond6yosE -1.57043    0.32995  -4.760 0.0000019399829116 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

> treatmeans # For comparison
              A           B         C         E
4yos -1.7888398 -1.74671600 -3.025970 -3.823771
5yos -1.6640053 -1.30237792 -2.912405 -3.821413
6yos -0.2625719 -0.06825281 -1.371343 -1.570413
> # In spite of the no convergence warning, the estimates are close to
> # the ones based on model5. Go with it.
>
> # Rows of Condmat are contrasts for pairwise comparisons of marginal
> # Condition means
> freq
AgeCond
4yosA 4yosB 4yosC 4yosE 5yosA 5yosB 5yosC 5yosE 6yosA 6yosB 6yosC 6yosE
  172   150   150   124   173   150   150   125   147   126   126   105
> Condmat = rbind(
+ # 4yosA 4yosB 4yosC 4yosE 5yosA 5yosB 5yosC 5yosE 6yosA 6yosB 6yosC 6yosE
+ c(  1,    -1,   0,    0,    1,    -1,   0,    0,    1,    -1,   0,   0),
+ c(  1,     0,  -1,    0,    1,     0,  -1,    0,    1,     0,  -1,   0),
+ c(  1,     0,   0,   -1,    1,     0,   0,   -1,    1,     0,   0,  -1),
+ c(  0,     1,  -1,    0,    0,     1,  -1,    0,    0,     1,  -1,   0),
+ c(  0,     1,   0,   -1,    0,     1,   0,   -1,    0,     1,   0,  -1),
+ c(  0,     0,   1,   -1,    0,     0,   1,   -1,    0,     0,   1,  -1))
> colnames(Condmat) = names(freq)
> rownames(Condmat) = c("AvsB","AvsC","AvsE","BvsC","BvsE","CvsE")
```

```
> Condmat
     4yosA 4yosB 4yosC 4yosE 5yosA 5yosB 5yosC 5yosE 6yosA 6yosB 6yosC 6yosE
AvsB     1    -1     0     0     1    -1     0     0     1    -1     0     0
AvsC     1     0    -1     0     1     0    -1     0     1     0    -1     0
AvsE     1     0     0    -1     1     0     0    -1     1     0     0    -1
BvsC     0     1    -1     0     0     1    -1     0     0     1    -1     0
BvsE     0     1     0    -1     0     1     0    -1     0     1     0    -1
CvsE     0     0     1    -1     0     0     1    -1     0     0     1    -1
> # Rows of Agemat are contrasts for pairwise comparisons of marginal
> # Agegroup means
> Agemat = rbind(
+ # 4yosA 4yosB 4yosC 4yosE 5yosA 5yosB 5yosC 5yosE 6yosA 6yosB 6yosC 6yosE
+ c(  1,     1,    1,    1,   -1,    -1,   -1,   -1,    0,     0,    0,    0),
+ c(  1,     1,    1,    1,    0,     0,    0,    0,   -1,    -1,   -1,   -1),
+ c(  0,     0,    0,    0,    1,     1,    1,    1,   -1,    -1,   -1,   -1))
> colnames(Agemat) = names(freq)
> rownames(Agemat) = c("4vs5","4vs6","5vs6")
> Agemat
     4yosA 4yosB 4yosC 4yosE 5yosA 5yosB 5yosC 5yosE 6yosA 6yosB 6yosC 6yosE
4vs5     1     1     1     1    -1    -1    -1    -1     0     0     0     0
4vs6     1     1     1     1     0     0     0     0    -1    -1    -1    -1
5vs6     0     0     0     0     1     1     1     1    -1    -1    -1    -1
>
> # Make pairwise comparison matrices. Chi-squared test statistics will be in the
> # upper triangle, and unadjusted p-values in the lower triangle.
> ConditionPairwise = diag(4)
> rownames(ConditionPairwise) = colnames(ConditionPairwise) = c("A","B","C","E")
>
> # Look at one test to see what's going on
> L = Condmat[1,] # Row 1
> testtest = linearHypothesis(noint,L) # Testing H0: L beta = 0
> testtest
Linear hypothesis test

Hypothesis:
AgeCond4yosA - AgeCond4yosB  + AgeCond5yosA - AgeCond5yosB  + AgeCond6yosA -
AgeCond6yosB = 0

Model 1: restricted model
Model 2: AllTargets ~ 0 + AgeCond + (1 | Participant)

  Df  Chisq Pr(>Chisq)
1
2  1 1.4925     0.2218
> c(testtest[2,2], testtest[2,3])
[1] 1.4924858 0.2218312
```

```
>
> # Fill the ConditionPairwise matrix
> rowno = 0
> for(i in 1:3)
+     {
+     for(j in (i+1):4)
+         {
+         rowno=rowno+1
+         L = Condmat[rowno,]
+         Ltest = linearHypothesis(noint,L) # Testing H0: L beta = 0
+         ConditionPairwise[i,j] = Ltest[2,2] # Test statistic
+         ConditionPairwise[j,i] = Ltest[2,3] # p-value
+         } # Next j
+     } # Next i
> AgePairwise = diag(3)
> rownames(AgePairwise) = colnames(AgePairwise) = c("4yos","5yos","6yos")
> rowno = 0
> for(i in 1:2)
+     {
+     for(j in (i+1):3)
+         {
+         rowno=rowno+1
+         L = Agemat[rowno,]
+         Ltest = linearHypothesis(noint,L) # Testing H0: L beta = 0
+         AgePairwise[i,j] = Ltest[2,2] # Test statistic
+         AgePairwise[j,i] = Ltest[2,3] # p-value
+         } # Next j
+     } # Next i
>
> # Here are the tables of means again.
> round(addmargins(treatmeans,FUN=mean, quiet=T),2) # Estimated population mean log
odds of recursion
         A     B     C     E  mean
4yos -1.79 -1.75 -3.03 -3.82 -2.60
5yos -1.66 -1.30 -2.91 -3.82 -2.43
6yos -0.26 -0.07 -1.37 -1.57 -0.82
mean -1.24 -1.04 -2.44 -3.07 -1.95
> round(addmargins(PercentRecursion, FUN=mean, quiet=T),2) # Percent recursion
         A     B     C     E  mean
4yos 18.02 18.67  6.67  3.23 11.65
5yos 19.65 25.33  7.33  3.20 13.88
6yos 44.22 48.41 23.02 20.00 33.91
mean 27.30 30.80 12.34  8.81 19.81
> # Pairwise comparisons between Condition means A, B, C, E
> ConditionPairwise
                      A                        B           C         E
A 1.00000000000000000 1.4924857721928317389 34.18923054 43.367609
B 0.22183117846160316 1.0000000000000000000 45.18013910 52.437336
C 0.00000000500049219 0.0000000000179718473  1.00000000  4.358665
E 0.00000000004536355 0.0000000000004441983  0.03682115  1.000000
> # Pairwise comparisons between Agegroup means 4,5,6 yrs old
> AgePairwise
                4yos           5yos     6yos
4yos 1.0000000000000 0.221685065362 25.54517
5yos 0.6377589717567 1.000000000000 21.24834
6yos 0.0000004321467 0.000004034592  1.00000
> # To protect all 9 tests with a Bonferroni correction, compare p-values to
> 0.05/9
[1] 0.005555556
```

```
>
> # Try continuous age
>
> model6a = glmer( AllTargets ~ AgeinMonths + Condition + (1 | Participant),
+                  family=binomial, nAGQ=1,
+                  contrasts = list(Condition="contr.treatment") )
> summary(model6a) # Pretty nice
Generalized linear mixed model fit by maximum likelihood (Laplace Approximation) [
glmerMod]
 Family: binomial  ( logit )
Formula: AllTargets ~ AgeinMonths + Condition + (1 | Participant)

     AIC      BIC   logLik deviance df.resid
  1429.2   1461.9   -708.6   1417.2     1692

Scaled residuals:
    Min      1Q  Median      3Q     Max
-2.2811 -0.4611 -0.2809 -0.1364  4.8863

Random effects:
 Groups      Name        Variance Std.Dev.
 Participant (Intercept) 0.8524   0.9233
Number of obs: 1698, groups:  Participant, 71

Fixed effects:
            Estimate Std. Error z value         Pr(>|z|)
(Intercept) -6.19773    0.91381  -6.782 0.00000000001183 ***
AgeinMonths  0.07574    0.01367   5.542 0.00000002984295 ***
ConditionB   0.20885    0.16256   1.285            0.199
ConditionC  -1.18535    0.19702  -6.017 0.00000000178162 ***
ConditionE  -1.63912    0.23432  -6.995 0.00000000000265 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Correlation of Fixed Effects:
            (Intr) AgnMnt CndtnB CndtnC
AgeinMonths -0.984
ConditionB  -0.101  0.015
ConditionC  -0.019 -0.048  0.391
ConditionE  -0.003 -0.053  0.328  0.296
>
> # One could include interaction terms (products), but the test would be for
> # departure from proportional odds; it's too strange.
>
> Anova(model6a, type="III")
Analysis of Deviance Table (Type III Wald chisquare tests)

Response: AllTargets
             Chisq Df            Pr(>Chisq)
(Intercept) 45.999  1      0.00000000001183 ***
AgeinMonths 30.718  1      0.00000002984295 ***
Condition   95.500  3 < 0.00000000000000022 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
> 5.542^2
[1] 30.71376
> # Right, it's a Wald test: for df=1, Chi-square = Z-squared
>
```

```
> # Include the tests as covariates -- except KBIT (too many NAs)
> # This is very nice. You could have time-varying covariates,
> # Like concentration of ADHD drug in the kid's bloodstream if it were a
> # longitudinal study.
> model6b = glmer( AllTargets ~ AgeinMonths + KABC_Hand + CELF_SS + CELF_WS +
+                  CELF_EV + CELF_Sent + PPVT +
+                  Condition + (1 | Participant), family=binomial, nAGQ=1,
+                  contrasts = list(Condition="contr.treatment") )
Warning messages:
1: In checkConv(attr(opt, "derivs"), opt$par, ctrl = control$checkConv,  :
  Model failed to converge with max|grad| = 0.1301 (tol = 0.001, component 1)
2: In checkConv(attr(opt, "derivs"), opt$par, ctrl = control$checkConv,  :
  Model is nearly unidentifiable: very large eigenvalue
 - Rescale variables?;Model is nearly unidentifiable: large eigenvalue ratio
 - Rescale variables?
>
> # Failure to converge, with suggestions about re-scaling ...
> # Max gradient does not look good.
>
> # Are the independent variables too highly correlated?
> cor(rdata[,c(2,12:17)])
            AgeinMonths KABC_Hand   CELF_SS   CELF_WS   CELF_EV CELF_Sent      PPVT
AgeinMonths   1.0000000 0.5412701 0.5341597 0.5775873 0.4491584 0.5511442 0.7372568
KABC_Hand     0.5412701 1.0000000 0.4944667 0.4625104 0.2813629 0.3725062 0.6203403
CELF_SS       0.5341597 0.4944667 1.0000000 0.7048561 0.5013098 0.6266722 0.7193117
CELF_WS       0.5775873 0.4625104 0.7048561 1.0000000 0.6186514 0.7858615 0.7133241
CELF_EV       0.4491584 0.2813629 0.5013098 0.6186514 1.0000000 0.4885895 0.6537793
CELF_Sent     0.5511442 0.3725062 0.6266722 0.7858615 0.4885895 1.0000000 0.6997446
PPVT          0.7372568 0.6203403 0.7193117 0.7133241 0.6537793 0.6997446 1.0000000
> # Looks quite nice
> # Try standardizing age and the test scores -- 7 of them
> zAgeinMonths = (AgeinMonths-mean(AgeinMonths))/sd(AgeinMonths)
> zKABC_Hand = (KABC_Hand-mean(KABC_Hand))/sd(KABC_Hand)
> zCELF_SS = (CELF_SS-mean(CELF_SS))/sd(CELF_SS)
> zCELF_WS = (CELF_WS-mean(CELF_WS))/sd(CELF_WS)
> zCELF_EV = (CELF_EV-mean(CELF_EV))/sd(CELF_EV)
> zCELF_Sent = (CELF_Sent-mean(CELF_Sent))/sd(CELF_Sent)
> zPPVT = (PPVT-mean(PPVT))/sd(PPVT)
>
> model6b = glmer( AllTargets ~ zAgeinMonths + zKABC_Hand + zCELF_SS + zCELF_WS +
+                  zCELF_EV + zCELF_Sent + zPPVT +
+                  Condition + (1 | Participant), family=binomial, nAGQ=1,
+                  contrasts = list(Condition="contr.treatment") )
Warning message:
In checkConv(attr(opt, "derivs"), opt$par, ctrl = control$checkConv,  :
  Model failed to converge with max|grad| = 0.0103166 (tol = 0.001, component 1)
> # The maximum gradient element is still above tolerance but it's much better.
>
> # I wonder about a no-intercept model
>
> model6c = glmer( AllTargets ~ 0 + zAgeinMonths + zKABC_Hand + zCELF_SS +
+                  zCELF_WS + zCELF_EV + zCELF_Sent + zPPVT +
+                  Condition + (1 | Participant), family=binomial, nAGQ=1)
> # Hoho!
> summary(model6c)
```

```
Generalized linear mixed model fit by maximum likelihood (Laplace Approximation) [
glmerMod]
 Family: binomial  ( logit )
Formula: AllTargets ~ 0 + zAgeinMonths + zKABC_Hand + zCELF_SS + zCELF_WS +
    zCELF_EV + zCELF_Sent + zPPVT + Condition + (1 | Participant)

     AIC      BIC   logLik deviance df.resid
  1395.4   1460.6   -685.7   1371.4     1686

Scaled residuals:
    Min      1Q  Median      3Q     Max
-2.0537 -0.4768 -0.2721 -0.0978  7.7211

Random effects:
 Groups      Name        Variance Std.Dev.
 Participant (Intercept) 0.2895   0.5381
Number of obs: 1698, groups:  Participant, 71

Fixed effects:
             Estimate Std. Error z value             Pr(>|z|)
zAgeinMonths -0.004526   0.153270  -0.030             0.976442
zKABC_Hand   -0.188966   0.126655  -1.492             0.135705
zCELF_SS      0.254474   0.164264   1.549             0.121339
zCELF_WS      0.183961   0.208588   0.882             0.377812
zCELF_EV     -0.024733   0.157811  -0.157             0.875464
zCELF_Sent    0.690782   0.193351   3.573             0.000353 ***
zPPVT         0.365971   0.233511   1.567             0.117055
ConditionA   -1.378051   0.141966  -9.707 < 0.0000000000000002 ***
ConditionB   -1.170641   0.144448  -8.104 0.00000000000000531 ***
ConditionC   -2.555724   0.188686 -13.545 < 0.0000000000000002 ***
ConditionE   -3.004410   0.228419 -13.153 < 0.0000000000000002 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Correlation of Fixed Effects:
            zAgnMn zKABC_ zCELF_SS zCELF_W zCELF_E zCELF_Sn zPPVT  CndtnA CndtnB
zKABC_Hand -0.086
zCELF_SS    0.003 -0.075
zCELF_WS   -0.100 -0.190 -0.275
zCELF_EV    0.075  0.233  0.106   -0.380
zCELF_Sent -0.165  0.154  0.067   -0.456   0.061
zPPVT      -0.462 -0.349 -0.336    0.054  -0.418  -0.186
ConditionA  0.105  0.041 -0.096   -0.043   0.031  -0.181   -0.047
ConditionB  0.109  0.041 -0.092   -0.038   0.034  -0.172   -0.047  0.346
ConditionC  0.074  0.048 -0.082   -0.036   0.028  -0.163   -0.055  0.312  0.293
ConditionE  0.059  0.043 -0.069   -0.031   0.024  -0.139   -0.051  0.265  0.249
            CndtnC
zKABC_Hand
zCELF_SS
zCELF_WS
zCELF_EV
zCELF_Sent
zPPVT
ConditionA
ConditionB
ConditionC
ConditionE  0.246
```

```
> Anova(model6c, type="III")
Analysis of Deviance Table (Type III Wald chisquare tests)

Response: AllTargets
               Chisq Df            Pr(>Chisq)
zAgeinMonths   0.0009  1             0.9764417
zKABC_Hand     2.2260  1             0.1357053
zCELF_SS       2.4000  1             0.1213389
zCELF_WS       0.7778  1             0.3778120
zCELF_EV       0.0246  1             0.8754637
zCELF_Sent    12.7641  1             0.0003533 ***
zPPVT          2.4563  1             0.1170552
Condition    302.8184  4 < 0.00000000000000022 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
> # Test for condition is undesirable.
>
> # Model 6b was not too bad.
> summary(model6b)
Generalized linear mixed model fit by maximum likelihood (Laplace Approximation) [
glmerMod]
 Family: binomial  ( logit )
Formula: AllTargets ~ zAgeinMonths + zKABC_Hand + zCELF_SS + zCELF_WS +
    zCELF_EV + zCELF_Sent + zPPVT + Condition + (1 | Participant)

     AIC      BIC   logLik deviance df.resid
  1395.4   1460.6   -685.7   1371.4     1686

Scaled residuals:
    Min      1Q  Median      3Q     Max
-2.0533 -0.4770 -0.2722 -0.0977  7.7325

Random effects:
 Groups      Name        Variance Std.Dev.
 Participant (Intercept) 0.2896   0.5382
Number of obs: 1698, groups:  Participant, 71

Fixed effects:
             Estimate Std. Error z value             Pr(>|z|)
(Intercept)  -1.378220   0.141984  -9.707 < 0.0000000000000002 ***
zAgeinMonths -0.005213   0.153291  -0.034             0.972870
zKABC_Hand   -0.188511   0.126663  -1.488             0.136676
zCELF_SS      0.253675   0.164275   1.544             0.122538
zCELF_WS      0.186115   0.208632   0.892             0.372355
zCELF_EV     -0.025301   0.157833  -0.160             0.872645
zCELF_Sent    0.690732   0.193376   3.572             0.000354 ***
zPPVT         0.365566   0.233541   1.565             0.117508
ConditionB    0.207371   0.163751   1.266             0.205377
ConditionC   -1.176929   0.197613  -5.956     0.00000000258932 ***
ConditionE   -1.626274   0.234765  -6.927     0.00000000000429 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

```
Correlation of Fixed Effects:
            (Intr) zAgnMn zKABC_ zCELF_SS zCELF_W zCELF_E zCELF_Sn zPPVT  CndtnB
zAgeinMnths  0.106
zKABC_Hand   0.041 -0.086
zCELF_SS    -0.096  0.003 -0.075
zCELF_WS    -0.043 -0.100 -0.190 -0.275
zCELF_EV     0.031  0.076  0.233  0.106   -0.380
zCELF_Sent  -0.181 -0.165  0.154  0.067   -0.455   0.060
zPPVT       -0.047 -0.462 -0.349 -0.336    0.054  -0.418  -0.186
ConditionB  -0.561  0.005  0.001  0.002    0.004   0.003   0.005   -0.001
ConditionC  -0.421 -0.005  0.016 -0.009   -0.004   0.005  -0.026   -0.019  0.393
ConditionE  -0.346 -0.007  0.017 -0.009   -0.005   0.005  -0.025   -0.021  0.329
            CndtnC
zAgeinMnths
zKABC_Hand
zCELF_SS
zCELF_WS
zCELF_EV
zCELF_Sent
zPPVT
ConditionB
ConditionC
ConditionE   0.297
convergence code: 0
Model failed to converge with max|grad| = 0.0103166 (tol = 0.001, component 1)

> Anova(model6b, type="III")
Analysis of Deviance Table (Type III Wald chisquare tests)

Response: AllTargets
               Chisq Df            Pr(>Chisq)
(Intercept)  94.2230  1 < 0.00000000000000022 ***
zAgeinMonths  0.0012  1             0.9728699
zKABC_Hand    2.2150  1             0.1366756
zCELF_SS      2.3846  1             0.1225382
zCELF_WS      0.7958  1             0.3723552
zCELF_EV      0.0257  1             0.8726451
zCELF_Sent   12.7589  1             0.0003543 ***
zPPVT         2.4502  1             0.1175078
Condition    93.6799  3 < 0.00000000000000022 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

> # Look how close the z statistics are to Model 6c.  It looks like CELF_Sent
> # is doing something even controlling for the  other covariates. Age and
> # some of the other tests may be washing out each other's effects. Note that
> # this regression model is can't be correct. Age influences maturation, a
> # latent variable that is reflected in the test scores as well as use of
> # sophisticated grammar. Anyway, let's see if the other test scores are
> # significantly related to AllTargets when we control for age, CELF_Sent
> # and Condition. We could get a Wald test with linearHypothesis, but how
> # about a nice likelihood ratio test? Fit a restricted model without
> # zKABC_Hand + zCELF_SS + zCELF_WS + zCELF_EV + zPPVT
>

> restricted = glmer( AllTargets ~ 0 + zAgeinMonths + zCELF_Sent +
+                  Condition + (1 | Participant), family=binomial, nAGQ=1)
> anova(restricted,model6c)
```

```
Data: NULL
Models:
restricted: AllTargets ~ 0 + zAgeinMonths + zCELF_Sent + Condition + (1 |
restricted:     Participant)
model6c: AllTargets ~ 0 + zAgeinMonths + zKABC_Hand + zCELF_SS + zCELF_WS +
model6c:     zCELF_EV + zCELF_Sent + zPPVT + Condition + (1 | Participant)
           Df    AIC    BIC logLik deviance  Chisq Chi Df Pr(>Chisq)
restricted  7 1396.2 1434.3 -691.1   1382.2
model6c    12 1395.4 1460.7 -685.7   1371.4 10.796      5    0.05559 .
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
> summary(restricted)
Generalized linear mixed model fit by maximum likelihood (Laplace Approximation) [
glmerMod]
 Family: binomial  ( logit )
Formula: AllTargets ~ 0 + zAgeinMonths + zCELF_Sent + Condition + (1 |
    Participant)

     AIC      BIC   logLik deviance df.resid
  1396.2   1434.3   -691.1   1382.2     1691

Scaled residuals:
    Min      1Q  Median      3Q     Max
-2.0219 -0.4900 -0.2810 -0.1198  6.0955

Random effects:
 Groups      Name        Variance Std.Dev.
 Participant (Intercept) 0.4021   0.6341
Number of obs: 1698, groups:  Participant, 71

Fixed effects:
             Estimate Std. Error z value             Pr(>|z|)
zAgeinMonths   0.2236     0.1261   1.773               0.0762 .
zCELF_Sent     0.9788     0.1661   5.894   0.0000000037603410 ***
ConditionA    -1.3533     0.1458  -9.280 < 0.0000000000000002 ***
ConditionB    -1.1450     0.1482  -7.724   0.0000000000000113 ***
ConditionC    -2.5336     0.1914 -13.239 < 0.0000000000000002 ***
ConditionE    -2.9828     0.2305 -12.943 < 0.0000000000000002 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Correlation of Fixed Effects:
           zAgnMn zCELF_ CndtnA CndtnB CndtnC
zCELF_Sent -0.567
ConditionA  0.041 -0.249
ConditionB  0.050 -0.233  0.381
ConditionC  0.012 -0.236  0.338  0.320
ConditionE  0.003 -0.205  0.288  0.272  0.264
> # Humm, what do you think?
>
>
```