# Exercises Day 4

Your name

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## Exercise 1

a) We are using the cognitive training data set from the previous days.

Please use the final reduced model from Day 3 1c and create three versions with different contrast-coding for the Group variable: * One with treamtent contrasts * One with sum contrasts using -0.5/0.5 * One with sum contrasts using -1/1

How does the model output change between the three version and what does the estimate for Group represent?

```
load("CogTrainingData.RData")

Cog_training_Data1 <-
  Cog_training_Data %>%
  mutate(Group = as.factor(Group))

contrasts(Cog_training_Data1$Group)
```

```
##           Voluntary
## Forced            0
## Voluntary         1
```

```
Model_6 = lmer(RT ~ TrialType*Session*Group + Age + SES + (1| Subject) + (1 | Item), data=Cog_training_
summary(Model_6)
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula: RT ~ TrialType * Session * Group + Age + SES + (1 | Subject) +
##     (1 | Item)
##    Data: Cog_training_Data1
##
## REML criterion at convergence: 422125
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -3.4271 -0.6390 -0.1568  0.4431  5.5324
##
## Random effects:
##  Groups   Name        Variance Std.Dev.
##  Subject  (Intercept)  7194.5   84.82
```

```
##  Item     (Intercept)   129.5   11.38
##  Residual             28683.1  169.36
## Number of obs: 32191, groups:  Subject, 85; Item, 16
##
## Fixed effects:
##                                         Estimate Std. Error t value
## (Intercept)                              479.521     84.860   5.651
## TrialTypeRepeat                          293.179      8.946  32.773
## Session                                  -42.766      3.291 -12.997
## GroupVoluntary                             9.462     20.277   0.467
## Age                                        3.621      3.283   1.103
## SES                                        1.673      6.712   0.249
## TrialTypeRepeat:Session                  -51.986      5.516  -9.424
## TrialTypeRepeat:GroupVoluntary            -6.097     12.782  -0.477
## Session:GroupVoluntary                    -5.601      4.744  -1.181
## TrialTypeRepeat:Session:GroupVoluntary    11.416      7.890   1.447
##
## Correlation of Fixed Effects:
##             (Intr) TrlTyR Sessin GrpVln Age    SES    TrTR:S TTR:GV Sss:GV
## TrialTypRpt -0.036
## Session     -0.059  0.554
## GroupVlntry -0.260  0.150  0.245
## Age         -0.874  0.000  0.000  0.189
## SES         -0.376  0.000  0.000 -0.052 -0.090
## TrlTypRpt:S  0.035 -0.952 -0.596 -0.146  0.000  0.000
## TrlTypRp:GV  0.025 -0.700 -0.387 -0.219  0.000  0.000  0.666
## Sssn:GrpVln  0.041 -0.384 -0.694 -0.353  0.000  0.000  0.413  0.560
## TrlTyR:S:GV -0.025  0.665  0.417  0.212  0.000  0.000 -0.699 -0.951 -0.601
```

```
contrasts(Cog_training_Data1$Group) <-  contr.sum(2)/2
contrasts(Cog_training_Data1$Group)
```

```
##           [,1]
## Forced     0.5
## Voluntary -0.5
```

```
Model_7 = lmer(RT ~ TrialType*Session*Group + Age + SES + (1| Subject) + (1 | Item), data=Cog_training_
summary(Model_7)
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula: RT ~ TrialType * Session * Group + Age + SES + (1 | Subject) +
##     (1 | Item)
##    Data: Cog_training_Data1
##
## REML criterion at convergence: 422125
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -3.4271 -0.6390 -0.1568  0.4431  5.5324
##
## Random effects:
##  Groups   Name        Variance Std.Dev.
##  Subject  (Intercept)  7194.5   84.82
```

```
##  Item     (Intercept)   129.5   11.38
##  Residual             28683.1  169.36
## Number of obs: 32191, groups:  Subject, 85; Item, 16
##
## Fixed effects:
##                                Estimate Std. Error t value
## (Intercept)                     484.252     82.801   5.848
## TrialTypeRepeat                 290.130      6.392  45.391
## Session                         -45.566      2.372 -19.208
## Group1                           -9.462     20.277  -0.467
## Age                               3.621      3.283   1.103
## SES                               1.673      6.712   0.249
## TrialTypeRepeat:Session         -46.278      3.945 -11.730
## TrialTypeRepeat:Group1            6.097     12.782   0.477
## Session:Group1                    5.601      4.744   1.181
## TrialTypeRepeat:Session:Group1  -11.416      7.890  -1.447
##
## Correlation of Fixed Effects:
##             (Intr) TrlTyR Sessin Group1 Age    SES    TrTR:S TTR:G1 Sss:G1
## TrialTypRpt -0.026
## Session     -0.044  0.559
## Group1       0.144  0.009  0.014
## Age         -0.873 -0.001  0.000 -0.189
## SES         -0.392 -0.001  0.000  0.052 -0.090
## TrlTypRpt:S  0.025 -0.951 -0.601 -0.008  0.000  0.000
## TrlTypRp:G1  0.001 -0.020 -0.022 -0.219  0.000  0.000  0.020
## Sessin:Grp1  0.001 -0.022 -0.038 -0.353  0.000  0.000  0.023  0.560
## TrlTyR:S:G1 -0.001  0.020  0.023  0.212  0.000  0.000 -0.022 -0.951 -0.601
```

```
contrasts(Cog_training_Data1$Group) <-  contr.sum(2)
contrasts(Cog_training_Data1$Group)
```

```
##           [,1]
## Forced       1
## Voluntary   -1
```

```
Model_8 = lmer(RT ~ TrialType*Session*Group + Age + SES + (1| Subject) + (1 | Item), data=Cog_training_
summary(Model_8)
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula: RT ~ TrialType * Session * Group + Age + SES + (1 | Subject) +
##     (1 | Item)
##    Data: Cog_training_Data1
##
## REML criterion at convergence: 422130.6
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -3.4271 -0.6390 -0.1568  0.4431  5.5324
##
## Random effects:
##  Groups   Name        Variance Std.Dev.
##  Subject  (Intercept)  7194.5   84.82
```

```
##  Item     (Intercept)   129.5   11.38
##  Residual             28683.1  169.36
## Number of obs: 32191, groups:  Subject, 85; Item, 16
##
## Fixed effects:
##                                 Estimate Std. Error t value
## (Intercept)                      484.252     82.801   5.848
## TrialTypeRepeat                  290.130      6.392  45.391
## Session                          -45.566      2.372 -19.208
## Group1                            -4.731     10.138  -0.467
## Age                                3.621      3.283   1.103
## SES                                1.673      6.712   0.249
## TrialTypeRepeat:Session          -46.278      3.945 -11.730
## TrialTypeRepeat:Group1             3.049      6.391   0.477
## Session:Group1                     2.800      2.372   1.181
## TrialTypeRepeat:Session:Group1    -5.708      3.945  -1.447
##
## Correlation of Fixed Effects:
##             (Intr) TrlTyR Sessin Group1 Age    SES    TrTR:S TTR:G1 Sss:G1
## TrialTypRpt -0.026
## Session     -0.044  0.559
## Group1       0.144  0.009  0.014
## Age         -0.873 -0.001  0.000 -0.189
## SES         -0.392 -0.001  0.000  0.052 -0.090
## TrlTypRpt:S  0.025 -0.951 -0.601 -0.008  0.000  0.000
## TrlTypRp:G1  0.001 -0.020 -0.022 -0.219  0.000  0.000  0.020
## Sessin:Grp1  0.001 -0.022 -0.038 -0.353  0.000  0.000  0.023  0.560
## TrlTyR:S:G1 -0.001  0.020  0.023  0.212  0.000  0.000 -0.022 -0.951 -0.601
```

b) You are interested in the threeway interaction between TrialType, Session and Group in your model and want to understand the underlying comparisons and estimated marginal means for each coefficent combination. How would you get this information?

```
emmeans(Model_6, specs = pairwise ~ TrialType:Session:Group)
```

```
## Note: D.f. calculations have been disabled because the number of observations exceeds 3000.
## To enable adjustments, add the argument 'pbkrtest.limit = 32191' (or larger)
## [or, globally, 'set emm_options(pbkrtest.limit = 32191)' or larger];
## but be warned that this may result in large computation time and memory use.
```

```
## Note: D.f. calculations have been disabled because the number of observations exceeds 3000.
## To enable adjustments, add the argument 'lmerTest.limit = 32191' (or larger)
## [or, globally, 'set emm_options(lmerTest.limit = 32191)' or larger];
## but be warned that this may result in large computation time and memory use.
```

```
## $emmeans
##  TrialType Session Group     emmean   SE  df asymp.LCL asymp.UCL
##  pure            1 Forced       530 13.4 Inf       504       557
##  Repeat          1 Forced       771 13.6 Inf       745       798
##  pure            2 Forced       488 13.4 Inf       461       514
##  Repeat          2 Forced       677 13.5 Inf       650       703
##  pure            1 Voluntary    534 13.9 Inf       507       561
##  Repeat          1 Voluntary    781 14.1 Inf       753       808
```

```
##  pure            2 Voluntary    486 13.9 Inf       458       513
##  Repeat          2 Voluntary    692 14.0 Inf       664       719
##
## Degrees-of-freedom method: asymptotic
## Confidence level used: 0.95
##
## $contrasts
##  contrast                                              estimate    SE  df
##  pure Session1 Forced - Repeat Session1 Forced         -241.19  4.07 Inf
##  pure Session1 Forced - pure Session2 Forced             42.77  3.29 Inf
##  pure Session1 Forced - Repeat Session2 Forced         -146.44  3.75 Inf
##  pure Session1 Forced - pure Session1 Voluntary          -3.86 19.12 Inf
##  pure Session1 Forced - Repeat Session1 Voluntary      -250.37 19.26 Inf
##  pure Session1 Forced - pure Session2 Voluntary          44.51 19.12 Inf
##  pure Session1 Forced - Repeat Session2 Voluntary      -161.44 19.20 Inf
##  Repeat Session1 Forced - pure Session2 Forced          283.96  4.05 Inf
##  Repeat Session1 Forced - Repeat Session2 Forced         94.75  4.43 Inf
##  Repeat Session1 Forced - pure Session1 Voluntary       237.33 19.27 Inf
##  Repeat Session1 Forced - Repeat Session1 Voluntary      -9.18 19.41 Inf
##  Repeat Session1 Forced - pure Session2 Voluntary       285.70 19.26 Inf
##  Repeat Session1 Forced - Repeat Session2 Voluntary      79.76 19.35 Inf
##  pure Session2 Forced - Repeat Session2 Forced         -189.21  3.73 Inf
##  pure Session2 Forced - pure Session1 Voluntary         -46.63 19.12 Inf
##  pure Session2 Forced - Repeat Session1 Voluntary      -293.14 19.26 Inf
##  pure Session2 Forced - pure Session2 Voluntary          1.74 19.11 Inf
##  pure Session2 Forced - Repeat Session2 Voluntary      -204.20 19.20 Inf
##  Repeat Session2 Forced - pure Session1 Voluntary       142.58 19.21 Inf
##  Repeat Session2 Forced - Repeat Session1 Voluntary    -103.93 19.34 Inf
##  Repeat Session2 Forced - pure Session2 Voluntary       190.95 19.20 Inf
##  Repeat Session2 Forced - Repeat Session2 Voluntary     -15.00 19.28 Inf
##  pure Session1 Voluntary - Repeat Session1 Voluntary   -246.51  4.15 Inf
##  pure Session1 Voluntary - pure Session2 Voluntary       48.37  3.42 Inf
##  pure Session1 Voluntary - Repeat Session2 Voluntary   -157.58  3.86 Inf
##  Repeat Session1 Voluntary - pure Session2 Voluntary    294.88  4.12 Inf
##  Repeat Session1 Voluntary - Repeat Session2 Voluntary   88.94  4.49 Inf
##  pure Session2 Voluntary - Repeat Session2 Voluntary   -205.94  3.83 Inf
##  z.ratio p.value
##  -59.299  <.0001
##   12.997  <.0001
##  -39.045  <.0001
##   -0.202  1.0000
##  -12.999  <.0001
##    2.328  0.2782
##   -8.407  <.0001
##   70.076  <.0001
##   21.390  <.0001
##   12.316  <.0001
##   -0.473  0.9998
##   14.830  <.0001
##    4.122  0.0010
##  -50.707  <.0001
##   -2.439  0.2227
##  -15.222  <.0001
##    0.091  1.0000
```

```
##  -10.636  <.0001
##    7.424  <.0001
##   -5.374  <.0001
##    9.945  <.0001
##   -0.778  0.9943
##  -59.455  <.0001
##   14.151  <.0001
##  -40.826  <.0001
##   71.580  <.0001
##   19.812  <.0001
##  -53.763  <.0001
##
## Degrees-of-freedom method: asymptotic
## P value adjustment: tukey method for comparing a family of 8 estimates
```

## Exercise 2

Using the cognitive training data set, you came up with a new hypothesis regarding age. You predict that there might be no quantitative, but qualitative differences between different age groups. Specifically, you predict that "middle-age" people show faster reaction times in the Pure-Block condition compared to the non-pure block condition, while "young" and "old" people show slower reaction times.

Create a new categorical variable with three levels for "young" (20 to 24), "middle-aged" (25 to 29) and "old" people (30 to 33).

Create a new model to test your hypothesis. How would you dummy-code the new age variable in order to test your hypothesis?

```
Cog_training_Data4 <-
  Cog_training_Data %>%
  mutate(AgeGroup = ifelse(Age < 25, "Young", ifelse(Age < 30, "Middle", "Old"))) %>%
  mutate(AgeGroup.n = ifelse(AgeGroup == "Middle", 0.5, -0.5))

Model_7 = lmer(RT ~ TrialType*AgeGroup.n + (1+TrialType| Subject) + (1+AgeGroup| Item), data=Cog_traini
```

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

```
summary(Model_7)
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula: RT ~ TrialType * AgeGroup.n + (1 + TrialType | Subject) + (1 +
##     AgeGroup | Item)
##    Data: Cog_training_Data4
##
## REML criterion at convergence: 422366.8
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -3.8159 -0.6357 -0.1629  0.4530  6.0355
##
## Random effects:
##  Groups   Name            Variance Std.Dev. Corr
```

```
##  Subject  (Intercept)      5931.79  77.018
##           TrialTypeRepeat  4835.67  69.539  0.13
##  Item     (Intercept)       192.43  13.872
##           AgeGroupOld        82.83   9.101   0.15
##           AgeGroupYoung      79.40   8.911  -0.69  0.62
##  Residual                 28673.26 169.332
## Number of obs: 32191, groups:  Subject, 85; Item, 16
##
## Fixed effects:
##                             Estimate Std. Error t value
## (Intercept)                  517.683     10.931  47.360
## TrialTypeRepeat              219.591      9.738  22.550
## AgeGroup.n                    28.319     21.209   1.335
## TrialTypeRepeat:AgeGroup.n   21.448     19.476   1.101
##
## Correlation of Fixed Effects:
##             (Intr) TrlTyR AgGrp.
## TrialTypRpt 0.095
## AgeGroup.n  0.587  0.059
## TrlTypR:AG. 0.057  0.599  0.098
## optimizer (nloptwrap) convergence code: 0 (OK)
## boundary (singular) fit: see help('isSingular')
```