Correlational output paper 1

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20/11/2020

General data manipulation

Before we start with the following analyses, we first load the data, check it visually and perform some general preprocessing steps. This includes converting the data from numeric values to factors when required. This conversion is checked visually. Finally, the anova options are specified. We see an overview of the data immediately below.

```
# check if data load worked out
head(df)
```

```
##         RT   RT_log Accuracy_label Accuracy_int Error_int        Theta
## 1 887.1019 2.947973        Correct            1         0 -0.298840850
## 2 726.7696 2.861397          Wrong            0         1  0.023572954
## 3 811.8683 2.909486        Correct            1         0 -0.465039857
## 4 939.2865 2.972798        Correct            1         0 -0.155769481
## 5 592.5244 2.772706        Correct            1         0  0.007509881
## 6 531.3159 2.725353        Correct            1         0 -0.395194816
##         Alpha        Beta Subject_nr Repetitions_overall Repetitions_block
## 1 -0.13613079 -0.06639671          2                   1                 1
## 2 -0.21210035 -0.24449588          2                   2                 2
## 3 -0.29894088 -0.27730979          2                   4                 4
## 4 -0.03231076 -0.25698737          2                   4                 4
## 5 -0.23958405  0.03322169          2                   5                 5
## 6 -0.16080514 -0.25392348          2                   5                 5
##   Block_overall Block_specific Condition Trial_overall Trial_block Response
## 1             1              1     Novel             5           5     Left
## 2             1              1     Novel             7           7     Left
## 3             1              1     Novel            16          16     Left
## 4             1              1     Novel            17          17    Right
## 5             1              1     Novel            21          21    Right
## 6             1              1     Novel            22          22     Left
##   Stimulus_ID
## 1           9
## 2          11
## 3           9
## 4          11
## 5          10
## 6           9
```

Correlation between behavioral- and neural data

In the next step we investigate whether `log(RT)` can be predicted using experimental- and non-experimental parameters. The non-experimental parameters include θ-, α- and β power values recorded during the EEG. The EEG power metrics were calculated by 1) computing the TFR of each trial, and 2) averaging the power in a specific time window based on the results of the permutation test (250 to 400 ms for the θ power, 700 tot 850 ms for both the α- and the β power). Note that the frequency range of interest for θ was 4 to 8 Hz, for *alpha* we looked at the range from 8 to 12 Hz, and for β we looked at the power between 14 and 30 Hz. The experimental parameters include everything that was manipulated during our experiment. This includes the amount of repetitions within an experimental block (`Repetitions_block`, ranges from 1 to 8), the condition-specific block number (`Block_specific`, ranges from 1 to 8), and the binary value condition (`Condition`, either 'Novel' or 'Recurrring'). We also include the interaction between repetitions and condition, and between block number and condition. This concludes the list of all the fixed effects that were included. We additionally included a random intercept for subject (`Subject_nr`, 24 unique IDs), and random slopes for θ, α en β power.

We start from the full model, and use a model selection procedure to determine the best possible model. The procedure we use is the `step` function from the library `lmerTest`. This procedure uses a backwards procedure to determine the best model. When this procedure is concluded, we determine the final model and print the associated p-values.

```r
# are theta and alpha predictors of RT?
# caveat: this is the full data, so correlation exists between repetitions_block and block
rt.all = lmer(RT_log  ~ (1 + Theta + Alpha + Beta|Subject_nr) +
                             Theta + Alpha + Beta +
                             Repetitions_block + Repetitions_block:Condition +
                             Block_specific * Condition,
                             data = df)

# select the best subset of variables that also leads to decent performance
rt_all.selected = lmerTest::step(rt.all)
rt_all.selected
```

```
## Backward reduced random-effect table:
##
##                                                    Eliminated npar logLik    AIC
## <none>                                                          44  10706 -21324
## Theta in (1 + Theta + Alpha + Beta | Subject_nr)            0   40  10691 -21302
## Alpha in (1 + Theta + Alpha + Beta | Subject_nr)            0   40  10685 -21289
## Beta in (1 + Theta + Alpha + Beta | Subject_nr)             0   40  10686 -21293
##                                                       LRT Df Pr(>Chisq)
## <none>
## Theta in (1 + Theta + Alpha + Beta | Subject_nr) 30.026  4  4.834e-06 ***
## Alpha in (1 + Theta + Alpha + Beta | Subject_nr) 42.465  4  1.336e-08 ***
## Beta in (1 + Theta + Alpha + Beta | Subject_nr)  39.199  4  6.336e-08 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Backward reduced fixed-effect table:
## Degrees of freedom method: Satterthwaite
##
##                               Eliminated  Sum Sq  Mean Sq NumDF   DenDF F value
## Theta                                  0 0.06717 0.067173     1    22.7  9.9179
## Alpha                                  0 0.03847 0.038470     1    21.2  5.6799
```

```
## Beta                                0 0.07774 0.077738     1    23.5 11.4778
## Repetitions_block:Condition          0 0.67178 0.095968     7 10065.6 14.1694
## Condition:Block_specific             0 0.67957 0.097081     7 10074.2 14.3337
##                                Pr(>F)
## Theta                        0.004542 **
## Alpha                        0.026572 *
## Beta                         0.002476 **
## Repetitions_block:Condition < 2.2e-16 ***
## Condition:Block_specific    < 2.2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Model found:
## RT_log ~ (1 + Theta + Alpha + Beta | Subject_nr) + Theta + Alpha + Beta + Repetitions_block + Repeti
```

```r
rt_all.final    = lmerTest::get_model(rt_all.selected)
anova(rt_all.final)
```

```
## Type III Analysis of Variance Table with Satterthwaite's method
##                             Sum Sq Mean Sq NumDF   DenDF  F value    Pr(>F)
## Theta                       0.0672  0.0672     1    22.7   9.9179  0.004542 **
## Alpha                       0.0385  0.0385     1    21.2   5.6799  0.026572 *
## Beta                        0.0777  0.0777     1    23.5  11.4778  0.002476 **
## Repetitions_block           2.6203  0.3743     7 10071.8  55.2678 < 2.2e-16 ***
## Block_specific              1.3437  0.1920     7 10075.3  28.3428 < 2.2e-16 ***
## Condition                   4.0184  4.0184     1 10090.4 593.3052 < 2.2e-16 ***
## Repetitions_block:Condition 0.6718  0.0960     7 10065.2  14.1694 < 2.2e-16 ***
## Condition:Block_specific    0.6796  0.0971     7 10074.6  14.3337 < 2.2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
summary(rt_all.final)
```

```
## Linear mixed model fit by REML. t-tests use Satterthwaite's method [
## lmerModLmerTest]
## Formula: RT_log ~ (1 + Theta + Alpha + Beta | Subject_nr) + Theta + Alpha +
##     Beta + Repetitions_block + Repetitions_block:Condition +
##     Block_specific * Condition
##    Data: df
##
## REML criterion at convergence: -21411.7
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -4.5411 -0.5790 -0.0400  0.5428  4.1730
##
## Random effects:
##  Groups     Name        Variance  Std.Dev. Corr
##  Subject_nr (Intercept) 0.0014824 0.03850
##             Theta       0.0004925 0.02219   0.34
##             Alpha       0.0005651 0.02377  -0.63 -0.60
##             Beta        0.0020374 0.04514   0.39 -0.10 -0.40
##  Residual               0.0067729 0.08230
```

```
## Number of obs: 10157, groups:  Subject_nr, 24
##
## Fixed effects:
##                                 Estimate Std. Error         df t value Pr(>|t|)
## (Intercept)                    2.714e+00  7.976e-03  2.291e+01 340.301  < 2e-16
## Theta                         -1.725e-02  5.476e-03  2.268e+01  -3.149 0.004542
## Alpha                          1.338e-02  5.612e-03  2.123e+01   2.383 0.026572
## Beta                          -3.653e-02  1.078e-02  2.352e+01  -3.388 0.002476
## Repetitions_block1             3.384e-02  2.311e-03  1.009e+04  14.647  < 2e-16
## Repetitions_block2             1.809e-02  2.198e-03  1.007e+04   8.230  < 2e-16
## Repetitions_block3             5.506e-03  2.173e-03  1.007e+04   2.534 0.011285
## Repetitions_block4            -3.902e-03  2.156e-03  1.006e+04  -1.810 0.070338
## Repetitions_block5            -9.284e-03  2.140e-03  1.008e+04  -4.338 1.45e-05
## Repetitions_block6            -1.056e-02  2.147e-03  1.007e+04  -4.917 8.94e-07
## Repetitions_block7            -1.567e-02  2.145e-03  1.007e+04  -7.306 2.97e-13
## Block_specific1                2.495e-02  2.224e-03  1.009e+04  11.221  < 2e-16
## Block_specific2                9.378e-03  2.166e-03  1.008e+04   4.330 1.51e-05
## Block_specific3                4.781e-03  2.131e-03  1.008e+04   2.243 0.024908
## Block_specific4               -7.820e-04  2.161e-03  1.007e+04  -0.362 0.717387
## Block_specific5               -8.191e-03  2.147e-03  1.006e+04  -3.815 0.000137
## Block_specific6               -9.734e-03  2.214e-03  1.008e+04  -4.396 1.11e-05
## Block_specific7               -8.644e-03  2.152e-03  1.007e+04  -4.017 5.93e-05
## Condition1                     2.014e-02  8.269e-04  1.009e+04  24.358  < 2e-16
## Repetitions_block1:Condition1  1.578e-02  2.281e-03  1.007e+04   6.917 4.88e-12
## Repetitions_block2:Condition1  8.557e-03  2.187e-03  1.006e+04   3.914 9.14e-05
## Repetitions_block3:Condition1  3.263e-03  2.171e-03  1.006e+04   1.503 0.132874
## Repetitions_block4:Condition1 -5.658e-04  2.155e-03  1.006e+04  -0.263 0.792848
## Repetitions_block5:Condition1 -1.495e-03  2.135e-03  1.006e+04  -0.700 0.483788
## Repetitions_block6:Condition1 -8.283e-03  2.143e-03  1.008e+04  -3.866 0.000112
## Repetitions_block7:Condition1 -7.024e-03  2.141e-03  1.007e+04  -3.281 0.001039
## Condition1:Block_specific1    -1.496e-02  2.218e-03  1.008e+04  -6.744 1.62e-11
## Condition1:Block_specific2    -1.199e-02  2.163e-03  1.007e+04  -5.543 3.05e-08
## Condition1:Block_specific3    -6.241e-04  2.130e-03  1.008e+04  -0.293 0.769528
## Condition1:Block_specific4     2.666e-03  2.160e-03  1.008e+04   1.234 0.217149
## Condition1:Block_specific5     8.943e-03  2.146e-03  1.006e+04   4.167 3.11e-05
## Condition1:Block_specific6     8.079e-03  2.214e-03  1.008e+04   3.650 0.000264
## Condition1:Block_specific7     3.936e-03  2.154e-03  1.008e+04   1.828 0.067626
##
## (Intercept)                   ***
## Theta                         **
## Alpha                         *
## Beta                          **
## Repetitions_block1            ***
## Repetitions_block2            ***
## Repetitions_block3            *
## Repetitions_block4            .
## Repetitions_block5            ***
## Repetitions_block6            ***
## Repetitions_block7            ***
## Block_specific1               ***
## Block_specific2               ***
## Block_specific3               *
## Block_specific4
## Block_specific5               ***
```

```
## Block_specific6               ***
## Block_specific7               ***
## Condition1                    ***
## Repetitions_block1:Condition1 ***
## Repetitions_block2:Condition1 ***
## Repetitions_block3:Condition1
## Repetitions_block4:Condition1
## Repetitions_block5:Condition1
## Repetitions_block6:Condition1 ***
## Repetitions_block7:Condition1 **
## Condition1:Block_specific1    ***
## Condition1:Block_specific2    ***
## Condition1:Block_specific3
## Condition1:Block_specific4
## Condition1:Block_specific5    ***
## Condition1:Block_specific6    ***
## Condition1:Block_specific7    .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
##
## Correlation matrix not shown by default, as p = 33 > 12.
## Use print(x, correlation=TRUE)  or
##     vcov(x)        if you need it
```

Collinearity issues in our dataset?

A final step is to print the Variance Inflation Factor (VIF) to assess collinearity in the dataset. We note that a VIF of 1 means that there is no correlation at all. Different definitions of 'problematic VIF values' exist, but we argue that our VIFs would not be considered problematic.

```
all_vifs = car::vif(rt_all.final)
print(all_vifs)
```

```
##                                GVIF Df GVIF^(1/(2*Df))
## Theta                      1.457998  1        1.207476
## Alpha                      1.748878  1        1.322451
## Beta                       1.370560  1        1.170709
## Repetitions_block          1.019724  7        1.001396
## Block_specific             1.008438  7        1.000600
## Condition                  1.007826  1        1.003905
## Repetitions_block:Condition 1.012364  7        1.000878
## Condition:Block_specific   1.007464  7        1.000531
```