

Revised Regression

Evan Dragich

Last compiled on 2021-12-27

Data Cleaning

Mass Analysis

Omnibus ANOVA

```
mass <- mass %>%
  mutate(rating = factor(rating, ordered = TRUE))

mass_clmm <- clmm(rating ~ blooms_level * task + year + (1 | student_id), data = mass)

summary(mass_clmm)
```

```
## Cumulative Link Mixed Model fitted with the Laplace approximation
##
## formula: rating ~ blooms_level * task + year + (1 | student_id)
## data:    mass
##
## link threshold nobs logLik   AIC      niter      max.grad cond.H
## logit flexible  2668 -3204.95 6467.90 4687(18753) 1.26e-03 1.2e+03
##
## Random effects:
## Groups      Name      Variance Std.Dev.
## student_id (Intercept) 1.566    1.252
## Number of groups:  student_id 90
##
## Coefficients:
##
##               Estimate Std. Error z value Pr(>|z|)
## blooms_levelunderstand    0.55051   0.28832   1.909  0.05622 .
## blooms_levelanalyze     -1.31682   0.28375  -4.641 3.47e-06 ***
## blooms_levelapply       -1.22389   0.28091  -4.357 1.32e-05 ***
## blooms_levelevaluate    -1.87272   0.28485  -6.574 4.88e-11 ***
## blooms_levelcreate      -2.77720   0.29524  -9.406 < 2e-16 ***
## taskicp                 -0.12316   0.28721  -0.429  0.66805
## taskhw                   0.48298   0.29046   1.663  0.09634 .
## taskpbl                 -1.37448   0.24985  -5.501 3.77e-08 ***
## year2020                -0.51974   0.27589  -1.884  0.05958 .
## blooms_levelunderstand:taskicp -0.11151  0.40643  -0.274  0.78381
## blooms_levelanalyze:taskicp   1.09333  0.39622   2.759  0.00579 **
## blooms_levelapply:taskicp    1.71607  0.39980   4.292 1.77e-05 ***
## blooms_levelevaluate:taskicp  0.99320  0.39883   2.490  0.01276 *
## blooms_levelcreate:taskicp   0.62510  0.40634   1.538  0.12396
```

```

## blooms_levelunderstand:taskhw -0.35728    0.41285   -0.865    0.38682
## blooms_levelanalyze:taskhw    1.05436    0.40420    2.609    0.00909 **
## blooms_levelapply:taskhw      2.00345    0.41634    4.812  1.49e-06 ***
## blooms_levelevaluate:taskhw   0.92013    0.40537    2.270    0.02322 *
## blooms_levelcreate:taskhw     0.70755    0.41599    1.701    0.08897 .
## blooms_levelunderstand:taskpbl 0.01264    0.34873    0.036    0.97108
## blooms_levelanalyze:taskpbl    2.76783    0.35074    7.892  2.99e-15 ***
## blooms_levelapply:taskpbl      2.88040    0.35009    8.228 < 2e-16 ***
## blooms_levelevaluate:taskpbl   3.49730    0.35479    9.858 < 2e-16 ***
## blooms_levelcreate:taskpbl     4.99270    0.37088   13.462 < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Threshold coefficients:
##      Estimate Std. Error z value
## 1|2  -5.2848     0.3173 -16.657
## 2|3  -3.1013     0.2933 -10.572
## 3|4  -1.3877     0.2870  -4.835
## 4|5   0.3534     0.2856   1.237
## (32 observations deleted due to missingness)
Anova.clmm(mass_clmm)

## Analysis of Deviance Table (Type II tests)
##
## Response: rating
##              LR Chisq Df Pr(>Chisq)
## blooms_level      91.50  5    < 2e-16 ***
## task             110.77  3    < 2e-16 ***
## year               3.46  1    0.06282 .
## blooms_level:task  428.58 15    < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
# null model to test significance of random effects
mass_null <- clm(rating ~ blooms_level * task, data = mass)
anova(mass_clmm, mass_null)

## Likelihood ratio tests of cumulative link models:
##
##      formula:                                link:
## mass_null rating ~ blooms_level * task          logit
## mass_clmm rating ~ blooms_level * task + year + (1 | student_id) logit
##      threshold:
## mass_null flexible
## mass_clmm flexible
##
##      no.par    AIC  logLik LR.stat df Pr(>Chisq)
## mass_null      27 7142.2 -3544.1
## mass_clmm      29 6467.9 -3205.0  678.29  2 < 2.2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

```

Marginal Means and Contrasts

```
# split by task, then compares pairs of blooms levels
mass_emm_t <- emmeans(mass_clmm, specs = pairwise ~ blooms_level | task, mode = "mean.class")

mass_task_means <- mass_emm_t$emmeans %>%
  summary(infer = TRUE, null = mean(as.numeric(mass$rating), na.rm = TRUE), level = 0.99)
mass_task_contrasts <- mass_emm_t$contrasts %>%
  summary(infer = TRUE, level = 0.99)

# split by blooms level, then compares pairs of tasks
mass_emm_bl <- emmeans(mass_clmm, specs = pairwise ~ task | blooms_level, mode = "mean.class")

mass_bl_means <- mass_emm_bl$emmeans %>%
  summary(infer = TRUE, null = mean(as.numeric(mass$rating), na.rm = TRUE), level = 0.99)
mass_bl_contrasts <- mass_emm_bl$contrasts %>%
  summary(infer = TRUE, level = 0.99)
```

Kinetics Analysis

Omnibus ANOVA

```
kinetics <- kinetics %>%
  mutate(rating = factor(rating, ordered = TRUE))

kinetics_clmm <- clmm(rating ~ blooms_level * task + year + (1 | student_id), data = kinetics)

summary(kinetics_clmm)

## Cumulative Link Mixed Model fitted with the Laplace approximation
##
## formula: rating ~ blooms_level * task + year + (1 | student_id)
## data: kinetics
##
## link threshold nobs logLik AIC niter max.grad cond.H
## logit flexible 2141 -2586.52 5231.04 4475(22349) 1.84e-03 8.4e+02
##
## Random effects:
## Groups Name Variance Std.Dev.
## student_id (Intercept) 2.409 1.552
## Number of groups: student_id 90
##
## Coefficients:
## Estimate Std. Error z value Pr(>|z|)
## blooms_levelunderstand 0.0259 0.2866 0.090 0.927999
## blooms_levelanalyze -1.0350 0.2799 -3.698 0.000217 ***
## blooms_levelapply -1.0260 0.2782 -3.688 0.000226 ***
## blooms_levelevaluate -1.6599 0.2812 -5.902 3.59e-09 ***
## blooms_levelcreate -2.3911 0.2881 -8.300 < 2e-16 ***
## taskicp 0.1406 0.2818 0.499 0.617743
## taskhw 0.5414 0.2938 1.843 0.065355 .
## taskpbl -0.5729 0.2943 -1.946 0.051609 .
## year2020 -0.7565 0.3397 -2.227 0.025940 *
```

```
## blooms_levelunderstand:taskicp 0.2168 0.4000 0.542 0.587930
## blooms_levelanalyze:taskicp 0.5714 0.3913 1.460 0.144277
## blooms_levelapply:taskicp 1.0087 0.3931 2.566 0.010281 *
## blooms_levelevaluate:taskicp 0.4311 0.3907 1.103 0.269816
## blooms_levelcreate:taskicp 0.2486 0.3970 0.626 0.531183
## blooms_levelunderstand:taskhw -0.0702 0.4124 -0.170 0.864829
## blooms_levelanalyze:taskhw 0.7228 0.4046 1.787 0.073981 .
## blooms_levelapply:taskhw 1.4440 0.4086 3.534 0.000410 ***
## blooms_levelevaluate:taskhw 0.7946 0.4048 1.963 0.049668 *
## blooms_levelcreate:taskhw 0.4822 0.4093 1.178 0.238674
## blooms_levelunderstand:taskpbl 0.0342 0.4137 0.083 0.934122
## blooms_levelanalyze:taskpbl 2.0617 0.4181 4.931 8.19e-07 ***
## blooms_levelapply:taskpbl 2.1544 0.4189 5.143 2.70e-07 ***
## blooms_levelevaluate:taskpbl 2.4275 0.4186 5.799 6.69e-09 ***
## blooms_levelcreate:taskpbl 3.4622 0.4291 8.068 7.15e-16 ***
```

```
## ---
```

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

```
##
```

```
## Threshold coefficients:
```

```
## Estimate Std. Error z value
```

```
## 1|2 -5.0780 0.3468 -14.644
```

```
## 2|3 -3.1506 0.3276 -9.619
```

```
## 3|4 -1.3550 0.3210 -4.222
```

```
## 4|5 0.5846 0.3199 1.827
```

```
## (19 observations deleted due to missingness)
```

```
Anova.clmm(kinetics_clmm)
```

```
## Analysis of Deviance Table (Type II tests)
```

```
##
```

```
## Response: rating
```

```
## LR Chisq Df Pr(>Chisq)
```

```
## blooms_level 164.799 5 < 2e-16 ***
```

```
## task 113.278 3 < 2e-16 ***
```

```
## year 4.824 1 0.02806 *
```

```
## blooms_level:task 141.597 15 < 2e-16 ***
```

```
## ---
```

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

```
# null model to test significance of fixed effects
```

```
kinetics_null <- clm(rating ~ blooms_level * task + year, data = kinetics)
```

```
anova(kinetics_clmm, kinetics_null)
```

```
## Likelihood ratio tests of cumulative link models:
```

```
##
```

```
## formula:
```

```
link:
```

```
## kinetics_null rating ~ blooms_level * task + year
```

```
logit
```

```
## kinetics_clmm rating ~ blooms_level * task + year + (1 | student_id)
```

```
## threshold:
```

```
## kinetics_null flexible
```

```
## kinetics_clmm flexible
```

```
##
```

```
## no.par AIC logLik LR.stat df Pr(>Chisq)
```

```
## kinetics_null 28 5980.2 -2962.1
```

```
## kinetics_clmm 29 5231.0 -2586.5 751.18 1 < 2.2e-16 ***
```

```
## ---
```

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

Estimated Marginal Means and Contrasts

```
kinetics_emm_t <- emmeans(kinetics_clmm, specs = pairwise ~ blooms_level | task, mode = "mean.class")

kinetics_task_means <- kinetics_emm_t$emmeans %>%
  summary(infer = TRUE, null = mean(as.numeric(kinetics$rating), na.rm = TRUE), level = 0.99)
kinetics_task_contrasts <- kinetics_emm_t$contrasts %>%
  summary(infer = TRUE, level = 0.99)

kinetics_emm_bl <- emmeans(kinetics_clmm, specs = pairwise ~ task | blooms_level, mode = "mean.class")

kinetics_bl_means <- kinetics_emm_bl$emmeans %>%
  summary(infer = TRUE, null = mean(as.numeric(kinetics$rating), na.rm = TRUE), level = 0.99)
kinetics_bl_contrasts <- kinetics_emm_bl$contrasts %>%
  summary(infer = TRUE, level = 0.99)
```

Write results to xlsx

```
write_xlsx(list("Mass by Bloom's - Mean Classes" = mass_bl_means,
               "Mass by Bloom's - Contrasts" = mass_bl_contrasts,
               "Mass by Task - Mean Classes" = mass_task_means,
               "Mass by Task - Contrasts" = mass_task_contrasts,
               "Kinetics by Bloom's - Mean Classes" = kinetics_bl_means,
               "Kinetics by Bloom's - Contrasts" = kinetics_bl_contrasts,
               "Kinetics by Task - Mean Classes" = kinetics_task_means,
               "Kinetics by Task - Contrasts" = kinetics_task_contrasts),
           "clmm_anova_output.xlsx")
```

```
# information about this R session:
sessionInfo()
```

```
## R version 4.1.2 (2021-11-01)
## Platform: x86_64-apple-darwin17.0 (64-bit)
## Running under: macOS Big Sur 10.16
##
## Matrix products: default
## BLAS:   /Library/Frameworks/R.framework/Versions/4.1/Resources/lib/libRblas.0.dylib
## LAPACK: /Library/Frameworks/R.framework/Versions/4.1/Resources/lib/libRlapack.dylib
##
## locale:
## [1] en_US.UTF-8/en_US.UTF-8/en_US.UTF-8/C/en_US.UTF-8/en_US.UTF-8
##
## attached base packages:
## [1] stats      graphics  grDevices  utils      datasets  methods   base
##
## other attached packages:
## [1] emmeans_1.7.1-1      RVAideMemoire_0.9-81 ordinal_2019.12-10
## [4] forcats_0.5.1        stringr_1.4.0        dplyr_1.0.7
## [7] purrr_0.3.4          readr_2.1.1          tidyr_1.1.4
## [10] tibble_3.1.6         ggplot2_3.3.5        tidyverse_1.3.1
## [13] writexl_1.4.0        readxl_1.3.1
```

```
##
## loaded via a namespace (and not attached):
## [1] httr_1.4.2          jsonlite_1.7.2      splines_4.1.2
## [4] here_1.0.1          modelr_0.1.8        ucminf_1.1-4
## [7] assertthat_0.2.1    cellranger_1.1.0    yaml_2.2.1
## [10] numDeriv_2016.8-1.1 pillar_1.6.4         backports_1.4.0
## [13] lattice_0.20-45     glue_1.5.1          digest_0.6.29
## [16] rvest_1.0.2         colorspace_2.0-2    sandwich_3.0-1
## [19] htmltools_0.5.2     Matrix_1.3-4        pkgconfig_2.0.3
## [22] broom_0.7.10        haven_2.4.3         xtable_1.8-4
## [25] mvtnorm_1.1-3       scales_1.1.1        tzdb_0.2.0
## [28] generics_0.1.1      ellipsis_0.3.2      TH.data_1.1-0
## [31] withr_2.4.3         cli_3.1.0           survival_3.2-13
## [34] magrittr_2.0.1      crayon_1.4.2        estimability_1.3
## [37] evaluate_0.14       fs_1.5.2            fansi_0.5.0
## [40] MASS_7.3-54         xml2_1.3.3          tools_4.1.2
## [43] hms_1.1.1           lifecycle_1.0.1     multcomp_1.4-17
## [46] munsell_0.5.0       reprex_2.0.1        compiler_4.1.2
## [49] rlang_0.4.12        grid_4.1.2          rstudioapi_0.13
## [52] rmarkdown_2.11      gtable_0.3.0        codetools_0.2-18
## [55] DBI_1.1.1           R6_2.5.1            zoo_1.8-9
## [58] lubridate_1.8.0     knitr_1.36          fastmap_1.1.0
## [61] utf8_1.2.2          rprojroot_2.0.2     stringi_1.7.6
## [64] Rcpp_1.0.7          vctrs_0.3.8         dbplyr_2.1.1
## [67] tidyselect_1.1.1    xfun_0.28
```