semnova: An R package for latent reapeated measures ANOVA

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Preface

About semnova

semnova is an structural equation modeling based `R` package for analysing repeated measures designs. It is an alternative approach to reapeated measures analysis of variances and publicly available on github.com/langenberg/semnnova. To this time, this manual is not a comprehensive description of the software package and the underlying statistical model. This manual is meant to provide early access to applied researchers to this very first release.

Changelog

- 2019-06-13: First Commit

Chapter 1

Installation

semnova is not currently available on CRAN. It is therefore required to install **semnova** via github using, for instance, the **devtools** package. Make sure you installed the package beforehand or simply copy the following code to install both packages in one step.

```r
if (!require("devtools", character.only = T)) {
    install.packages("devtools")
}

devtools::install_github("langenberg/semnova")
```

After running these lines, we are ready to go and perform our first analysis.

Chapter 2

How to use semnova

2.1 Getting some data

```r
if (!require("openxlsx", character.only = T)) {
    install.packages("openxlsx")
}

data <- openxlsx::read.xlsx("https://doi.org/10.1371/journal.pone.0125279.s001")

head(data)
```

```
##   ID        OD Gender AGE    NATION ENGLISH PRCS SUDprecontion1
## 1  1 PP-NP-PN-NN   male  28  Chinese average   10            1.0
## 2  2 NP-PN-NN-PP female  27  Chinese average   14            4.7
## 3  3 PN-NN-PP-NP   male  26  Chinese average   15            7.4
## 4  4 NN-PP-NP-PN   male  30  Chinese average    4            1.0
## 5  5 PP-NP-PN-NN female  29 Romanian average    6            5.0
## 6  6 NP-PN-NN-PP   male  28  Chinese average    6            2.0
##        P1PP       P1NP       P1PN      P1NN       P2PP       P2NP
## 1  0.9132910  0.9132910 -1.2955988 0.1769944  0.5451427  0.9132910
## 2  1.5629185  0.3154624  0.7520721 0.5649537  1.8124097  0.5649537
## 3 -0.5201645  0.6595232 -1.3627986 0.5752598 -0.2252426  0.3224696
## 4  0.6548206  0.3962079  0.6548206 0.3962079  1.0858417  0.6548206
## 5 -0.2694103  0.1197379 -0.2694103 0.1197379 -0.2694103 -0.6585585
## 6  0.8575449 -1.0752498 -1.0752498 0.4630970  0.8575449 -1.1146946
##        P2PN       P2NN       P3PP      P3NP       P3PN       P3NN
## 1 -1.29559884  0.1769944  0.9132910 1.2814393 -1.2955988 -0.9274505
## 2  1.00156329  0.7520721  1.1886817 1.1886817 -1.1814848 -2.4289409
## 3 -1.44706198 -0.1409792  1.1651037 1.4600256 -1.7841156 -1.0257449
```

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```
## 4   0.31000366   0.6117185   0.3100037 1.5168628 -0.6382428 -0.9399576
## 5   0.11973791   0.5088861 -0.6585585 0.1197379 -0.6585585  0.1197379
## 6   0.06864911   0.4630970   0.8575449 0.8575449  0.4630970 -2.2980383
##          P4PP        P4NP        P4PN        P4NN       P5PP       P5NP
## 1   0.9132910   0.5451427 -0.19115393 -0.19115393  0.9132910  1.2814393
## 2   0.2530896   0.1283440 -0.05877437 -0.86962082  1.1886817  1.3758001
## 3  -0.9414815   0.6595232 -1.40493028  0.65952321  1.1651037  1.4600256
## 4   0.6979227  -0.1210175  0.22379943  0.48241212  1.1720459  1.5599650
## 5   0.1197379  -1.4368549  0.11973791  0.11973791 -0.2694103  0.5088861
## 6   0.8575449   0.8575449 -1.90359040  0.06864911  0.8575449 -1.1146946
##          P5PN        P5NN       P6PP      P6NP       P6PN       P6NN
## 1  -1.6637471 -0.9274505  0.9132910 0.9132910 -1.2955988  0.1769944
## 2  -1.3062304 -1.3062304  0.1907168 0.5649537  0.1283440 -0.4953840
## 3  -1.9105107 -1.1521401  0.1960745 0.2803379 -1.0257449  0.2382062
## 4  -1.4140809 -0.9830597 -0.3796302 0.2669015 -0.5951407 -0.1210175
## 5  -0.2694103 -0.2694103 -1.0477067 -0.6585585  0.1197379  0.1197379
## 6  -0.3257988 -1.9035904  0.8575449 -2.2585935 -1.0752498 -1.1146946
##          P7PP       P7NP        P7PN        P7NN       P8PP       P8NP
## 1 0.8519329 1.1587232 -1.11152469 -0.06843783 0.9132910  1.2814393
## 2 0.3986262 0.5545582  0.22190324 -0.48498853 1.0015633  1.1263089
## 3 0.8280500 1.1861695 -1.35577662 -0.84317423 0.3224696  1.0808402
## 4 0.6763716 1.1792296  0.26690155  0.53988160 0.6117185  0.3100037
## 5 0.5737442 0.6386022  0.63860219  0.63860219 0.1197379  0.1197379
## 6 0.8575449 0.5354125  0.06864911  0.20013174 0.8575449 -1.9035904
##          P8PN        P8NN      P9PP       P9NP       P9PN       P9NN
## 1  -0.9274505   0.5451427 -1.663747 -1.6637471 -0.9274505 -0.5593022
## 2   1.1886817   0.7520721 -1.493349  1.1886817 -0.2458928 -1.1191120
## 3  -1.4891937   0.3646013 -1.025745 -1.4049303  1.6706841 -0.2252426
## 4  -0.1641196   0.2669015 -1.069264 -0.1210175 -0.5089365 -0.1210175
## 5   0.1197379   0.1197379 -2.993448 -2.9934477 -2.9934477 -2.9934477
## 6  -0.3257988  -1.1146946 -2.298038 -0.2863540 -1.1146946 -1.9035904
##          P10PP       P10NP       P10PN       P10NN        S1PP       S1NP
## 1   0.3681483   0.3681483 1.4725932  0.7362966   0.9132910 0.17699438
## 2  -0.0623728   1.4345745 0.4366096  0.0000000   0.7520721 1.56291852
## 3  -2.4436388  -2.6121656 0.5898439 -1.3060828   0.2382062 0.23820617
## 4   0.1724085   0.8620423 0.9913486  1.5516761  -1.5433872 1.47376072
## 5  -1.9457410   0.0000000 0.0000000  0.0000000  -0.2694103 0.11973791
## 6  -0.4733375   2.0116843 0.0000000 -0.8283406   0.4630970 0.06864911
##          S1PN        S1NN       S2PP      S2NP       S2PN        S2NN
## 1  -0.9274505 -0.92745054  0.9132910 0.1769944 -0.9274505 -0.92745054
## 2   0.1283440 -1.80521287  0.5649537 0.9391905 -0.2458928 -2.11707689
## 3  -1.3206669  0.02754765  0.6595232 0.2382062 -1.4891937 -0.68869131
## 4   1.0858417  1.60306707 -0.5520386 1.0858417  0.6548206  1.51686284
## 5  -0.2694103  0.11973791 -0.2694103 0.1197379 -0.2694103  0.50888612
## 6   0.1080939  0.85754491  0.4630970 0.8575449  0.4630970  0.06864911
##          S3PP       S3NP       S3PN       S3NN      S4PP      S4NP      S4PN
```

```
## 1   0.9132910  1.2814393 -1.2955988 -0.9274505  0.9132910  1.2814393 -1.663747
## 2   0.1907168  1.5005457 -0.9943664 -2.5536865  1.3134273  1.5005457 -1.306230
## 3   0.1960745  0.6173915 -1.7419839 -0.6465596  1.5021573  1.7970792 -1.952642
## 4  -0.1210175  0.6117185  1.0858417  1.8185776  1.1289438  1.6030671 -1.414081
## 5   0.5088861  0.1197379 -1.0477067  0.1197379  0.5088861  0.5088861 -1.826003
## 6   0.8575449  0.8575449  0.8575449 -1.5091425  0.8575449  0.8575449 -1.114695
##          S4NN       T1PP       T1NP       T1PN       T1NN       T2PP
## 1  -0.9274505  0.9132910  0.5451427 -1.29559884 -0.1911539  0.91329099
## 2  -2.1794497 -0.3082656  0.4402081 -0.43301119 -1.2438576 -0.05877437
## 3  -0.9414815  0.2382062  0.6173915 -0.09884746  0.5752598  0.15394276
## 4  -1.4140809 -1.1123661 -1.0261619 -0.98305974 -0.9830597 -1.32787665
## 5   0.1197379  0.5088861  0.1197379  0.50888612  0.5088861  0.50888612
## 6  -3.0869341  0.8575449  0.8575449  0.85754491  0.8575449  0.85754491
##          T2NP       T2PN       T2NN       T3PP       T3NP       T3PN
## 1   0.5451427 -1.2955988  0.1769944  0.91329099  0.9132910 -1.29559884
## 2   0.7520721 -0.8696208 -1.1191120 -0.05877437  0.5649537 -1.43097605
## 3   0.6173915 -1.0678766 -0.6044279  0.19607447  0.2803379 -1.02574494
## 4  -0.1641196 -0.9399576 -0.8106513 -1.45718299 -0.5520386 -1.41408088
## 5   0.1197379  0.1197379  0.1197379  0.89803432  0.8980343  0.89803432
## 6   0.8575449  0.8575449  0.4630970  0.85754491  0.8575449  0.06864911
##          T3NN       T4PP        T4NP       T4PN       T4NN  PresencePP
## 1  -0.55930223  0.91329099  0.91329099 -1.6637471 -0.1911539  0.7905749
## 2  -1.74284007 -0.37063839 -0.05877437 -0.6825024 -0.8072480  0.1075531
## 3  -0.09884746  0.19607447  1.03870854  0.1960745 -0.6044279  0.6033476
## 4  -1.24167242 -1.45718299 -0.59514072 -1.4571830 -1.2416724 -1.0405292
## 5   0.89803432  0.11973791  0.11973791  0.8980343  0.5088861  0.2494540
## 6   0.85754491  0.06864911  0.06864911  0.4236522  0.4630970 -0.3257988
##     PresenceNP   PresencePN PresenceNN DialoglengthfirstquestionPP
## 1   0.66785878  0.054278276  0.1769944                       10.13
## 2   0.29467151 -0.141938111  0.1491350                       14.42
## 3   0.85613783 -0.534208399  0.3365135                        9.16
## 4  -0.85375340 -1.011794483  0.4249426                        8.46
## 5   0.76831825 -0.009978159  0.5088861                       12.97
## 6   0.08179737  0.186983476 -0.1943162                       44.04
##    DialoglengthfirstquestionNP DialoglengthfirstquestionPN
## 1                        15.52                        6.28
## 2                        12.46                        9.12
## 3                         0.00                       21.26
## 4                        14.06                        8.34
## 5                         6.93                       15.63
## 6                        16.54                       25.18
##    DialoglengthfirstquestionNN DialoglengthtotalPP DialoglengthtotalNP
## 1                        13.39               57.30            50.93000
## 2                        14.48               70.86            65.64000
## 3                         5.28               45.67            49.47667
## 4                         8.01               50.41            49.62000
```

```
## 5                               15.43              58.78             64.03000
## 6                                6.04              96.60             63.22000
##   DialoglengthtotalPN DialoglengthtotalNN
## 1              36.28               54.42
## 2              31.94               51.24
## 3              84.76               31.13
## 4              42.71               45.55
## 5              84.54               45.56
## 6              77.91               76.88
##   DialoglengthfirstquestionPPzScore DialoglengthfirstquestionNPzScore
## 1                          -0.29771                           1.03949
## 2                           0.71571                          -0.06362
## 3                           0.02600                          -0.98731
## 4                          -0.43343                           1.49677
## 5                           0.05668                          -1.43181
## 6                           1.31064                          -0.39835
##   DialoglengthfirstquestionPNzScore DialoglengthfirstquestionNNzScore
## 1                          -1.25285                           0.51106
## 2                          -1.39167                           0.73957
## 3                           1.36453                          -0.40322
## 4                          -0.47480                          -0.58854
## 5                           0.71221                           0.66292
## 6                           0.13858                          -1.05087
##   DialoglengthtotalPPzScore DialoglengthtotalNPzScore
## 1                   0.81032                   0.12823
## 2                   0.91491                   0.61530
## 3                  -0.31163                  -0.14417
## 4                   0.92592                   0.70675
## 5                  -0.27463                   0.04955
## 6                   1.30899                  -1.12556
##   DialoglengthtotalPNzScore DialoglengthtotalNNzScore HeartRatephase1PP
## 1                  -1.44048                   0.50193              80.3
## 2                  -1.31899                  -0.21122              76.7
## 3                   1.40650                  -0.95071              74.1
## 4                  -1.21028                  -0.42238              75.4
## 5                   1.31603                  -1.09096              68.3
## 6                  -0.05415                  -0.12928              69.8
##   HeartRatephase1NP HeartRatephase1PN HeartRatephase1NN HeartRatephase2PP
## 1              81.1              78.3              76.4              83.0
## 2              82.2              77.1              76.0              73.6
## 3              72.6              71.5              75.2              65.7
## 4              74.5              72.7              80.4              76.1
## 5              67.8              71.2              66.2              71.0
## 6              68.9              69.4              70.0              68.1
##   HeartRatephase2NP HeartRatephase2PN HeartRatephase2NN GSRphase1PP
## 1              85.0              77.7              78.2    7.31e-06
```

```
## 2                     81.4            73.8            76.6    1.35e-06
## 3                     70.3            72.1            66.8    9.43e-06
## 4                     73.6            74.6            80.2    2.26e-06
## 5                     67.7            70.5            69.0    1.84e-06
## 6                     68.9            72.2            70.6    4.73e-06
##    GSRphase1NP GSRphase1PN GSRphase1NN GSRphase2PP GSRphase2NP GSRphase2PN
## 1     8.05e-06     7.30e-06     5.91e-06     7.23e-06     7.99e-06     7.10e-06
## 2     3.98e-06     3.28e-06     2.78e-06     1.13e-06     4.37e-06     2.36e-06
## 3     9.25e-06     7.20e-06     8.82e-06     9.09e-06     9.15e-06     7.93e-06
## 4     2.58e-06     2.33e-06     2.02e-06     2.80e-06     2.11e-06     2.73e-06
## 5     1.71e-06     2.58e-06     2.20e-06     2.14e-06     1.41e-06     1.81e-06
## 6     4.02e-06     4.04e-06     4.48e-06     3.64e-06     4.67e-06     4.04e-06
##    GSRphase2NN GSRphase1PPzScore GSRphase1NPzScore GSRphase1PNzScore
## 1     5.66e-06         0.2782361         1.1277856         0.2655563
## 2     1.72e-06        -1.0586347         1.1328518         0.5474547
## 3     9.09e-06         0.8862400         0.6553149        -2.0003240
## 4     2.69e-06        -0.5895321         0.4805148        -0.3782062
## 5     1.99e-06        -0.3312885        -0.7192075         1.7555459
## 6     5.08e-06         0.8306492        -0.6637847        -0.6176084
##    GSRphase1NNzScore GSRphase2PPzScore GSRphase2NPzScore GSRphase2PNzScore
## 1        -1.33440940         0.1871718         1.0632337         0.03501366
## 2         0.12967129        -1.2429264         1.4580724        -0.21723068
## 3         0.09616474         0.4425524         0.5281763        -1.05067686
## 4        -1.40129177         1.2084150        -1.1128152         0.96354533
## 5         0.66540854         0.5210007        -1.5460130        -0.42472886
## 6         0.29752247        -1.4550790         0.6942191        -0.63439977
##    GSRphase2NNzScore      P1ppnn      P1nppn      P2ppnn      P2nppn      P3ppnn
## 1        -1.62258765 0.54213270 4.87919429 0.135533174 4.8791943   3.3883294
## 2        -0.74925823 0.99593385 0.19062796 1.124315955 0.1906280 13.0871933
## 3         0.44255242 1.19995439 4.08978540 0.007100322 3.1312419   4.7998176
## 4         0.82937017 0.06688052 0.06688052 0.224792854 0.1188987   1.5624032
## 5         0.07928272 0.15143633 0.15143633 0.605745306 0.6057453   0.6057453
## 6         1.54848115 0.15558915 0.00000000 0.155589146 1.4003023   9.9577054
##        P3nppn     P4ppnn    P4nppn   P5ppnn      P5nppn     P6ppnn    P6nppn
## 1  6.6411256 1.2197986 0.5421327 3.388329  8.6741232 0.54213270 4.8791943
## 2  5.6176894 1.2604788 0.0350133 6.224587  7.1932879 0.47073436 0.1906280
## 3 10.5244521 2.5632162 4.2619682 5.369618 11.3605150 0.00177508 1.7058523
## 4  4.6444805 0.0464448 0.1188987 4.644480  8.8449486 0.06688052 0.7431169
## 5  0.6057453 0.0000000 2.4229812 0.000000  0.6057453 1.36292694 0.6057453
## 6  0.1555891 0.6223566 7.6238682 7.623868  0.6223566 3.88972866 1.4003023
##         P7ppnn    P7nppn     P8ppnn      P8nppn     S1ppnn      S1nppn
## 1 0.847082342 5.1540255 0.13553317 4.879194294 3.38832937 1.219798575
## 2 0.780774968 0.1106593 0.06224587 0.003890367 6.53970629 2.058003942
## 3 2.792990502 6.4614901 0.00177508 6.605074427 0.04437701 2.430085161
## 4 0.018629527 0.8323425 0.11889870 0.224792854 9.90017454 0.150481167
## 5 0.004206565 0.0000000 0.00000000 0.000000000 0.15143633 0.151436327
```

```
## 6 0.432192073 0.2178680 3.88972866 2.489426342 0.15558915 0.001555891
##         S2ppnn     S2nppn    S3ppnn    S3nppn     S4ppnn     S4nppn     T1ppnn
## 1 3.3883294 1.2197986 3.3883294 6.6411256   3.3883294   8.674123 1.21979857
## 2 7.1932879 1.4044223 7.5317498 6.2245866 12.2001897   7.877992 0.87533249
## 3 1.8176824 2.9839103 0.7100322 5.5666523   5.9713707 14.060412 0.11360515
## 4 4.2803532 0.1857792 3.7620292 0.2247929   6.4669746   9.103182 0.01672013
## 5 0.6057453 0.1514363 0.1514363 1.3629269   0.1514363   5.451708 0.00000000
## 6 0.1555891 0.1555891 5.6012093 0.0000000 15.5589146   3.889729 0.00000000
##          T1nppn    T2ppnn    T2nppn     T3ppnn    T3nppn     T4ppnn     T4nppn
## 1 3.388329369 0.5421327 3.3883294 2.16853079 4.8791943 1.2197986 6.6411256
## 2 0.762511859 1.1243160 2.6298878 2.83607727 3.9837354 0.1906280 0.3890367
## 3 0.512998255 0.5751261 2.8401287 0.08697894 1.7058523 0.6408040 0.7100322
## 4 0.001857792 0.2675221 0.6019247 0.04644480 0.7431169 0.0464448 0.7431169
## 5 0.151436326 0.1514363 0.0000000 0.00000000 0.0000000 0.1514363 0.6057453
## 6 0.000000000 0.1555891 0.0000000 0.00000000 0.6223566 0.1555891 0.1260272
```