How to run the RI-CLPM with Mplus
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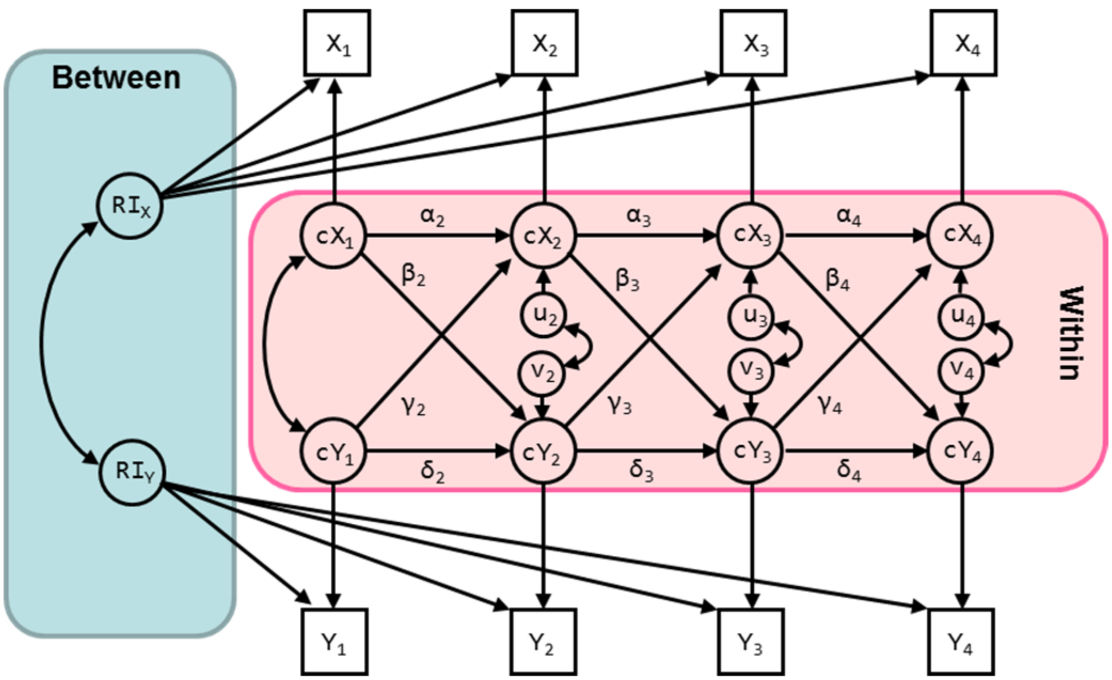
The random intercept cross-lagged panel model (RI-CLPM) as proposed by Hamaker, Kuiper and Grasman (2015, Psychological Methods) is a model that decomposes each observed score into a between-person part and a within-person part. While the terminology is clearly inspired by the multilevel literature (where there is a within-cluster level and a between-cluster level), the RI-CLPM is estimated in wide-format rather than in long-format. This means that if you have two variables measured at T time points, you will have a data file with 2T variables representing these bivariate repeated measures. Estimating the model is based on structural equation modeling (SEM).
The RI-CLPM can be represented like this:



We use this model to simulate data for four time points and 400 cases. For simplicity the lagged parameter values we use are invariant over time (but we will estimate them without this constraint). There specific values are:

$\alpha = 0.5$
$\beta = 0.0$
$\gamma = 0.2$
$\delta = 0.4$

Other parameters are the variances and covariance at the between-person level: variances were set to 2 and the covariance to -1. Furthermore, the within-person residual variances were set to 0.9, and the covariance of these residuals was set to 0.2. The within-person variances at the first wave were set to 1.35 for cX1 and 1.07 for cY1, and a covariance between these terms to 0.36. These parameter values imply it is a stationary process, meaning that the within-person variances and covariance are invariant over time. Hence, the proportions of explained variance at the within level are (1.35-0.9)/1.35=0.33 for x, and (1.07-0.9)/1.07=0.16 for y. Furthermore, the intraclass correlations are 2.00/(2.00+1.35)= 0.60 for x and 2.00/(2.00+1.07)=0.65 for y. The grand means were set to 10 and 8 for x and y respectively.

To specify this model in Mplus, we use:

```
TITLE:          Fit the RI-CLPM
DATA:           FILE IS RICLPM.dat;
VARIABLE:       NAMES ARE x1 y1 x2 y2 x3 y3 x4 y4;

MODEL:
        ! Create two individual factors (random intercepts)
        RI_x BY x1@1 x2@1 x3@1 x4@1;
        RI_y BY y1@1 y2@1 y3@1 y4@1;

        ! Create within-person centered variables
        cx1 BY x1@1; cx2 BY x2@1; cx3 BY x3@1; cx4 BY x4@1;
        cy1 BY y1@1; cy2 BY y2@1; cy3 BY y3@1; cy4 BY y4@1;

        ! Constrain the measurement error variances to zero
        x1-y4@0;

        ! Estimate the lagged effects between
        ! the within-person centered variables
        cx2 ON cx1 cy1; cx3 ON cx2 cy2; cx4 ON cx3 cy3;
        cy2 ON cx1 cy1; cy3 ON cx2 cy2; cy4 ON cx3 cy3;

        ! Estimate the covariance between the within-person
        ! centered variables at the first wave
        cx1 WITH cy1;

        ! Estimate the covariances between the residuals of
        ! the within-person centered variables (the innovations)
        cx2 WITH cy2; cx3 WITH cy3; cx4 WITH cy4;

        ! Fix the correlation between the individual factors and the other
        ! exogenous variables to zero (by default these would be estimated)
        RI_x WITH cx1@0 cy1@0;
        RI_y WITH cx1@0 cy1@0;

OUTPUT:         TECH1 STDYX SAMPSTAT;
```

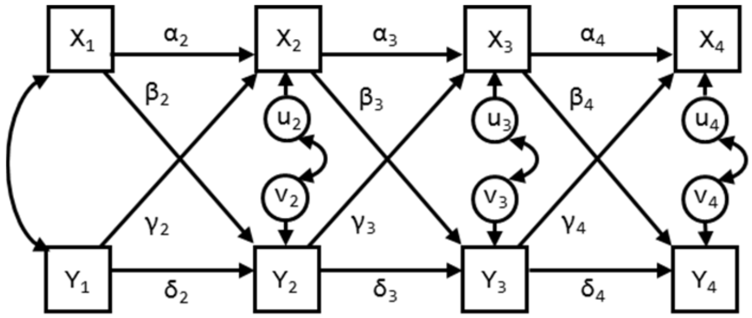
This model leads to a chi-square of 16.178 with 9 df (p=0.063).

Next, we consider a model in which we **constrain the variances of the random intercepts and their covariance to zero**; this implies that there are **no stable between-person differences** in the data.

```
MODEL:
        ! Create two individual factors (random intercepts)
        RI_x BY x1@1 x2@1 x3@1 x4@1;
        RI_y BY y1@1 y2@1 y3@1 y4@1;

        ! Create within-person centered variables
        cx1 BY x1@1; cx2 BY x2@1; cx3 BY x3@1; cx4 BY x4@1;
        cy1 BY y1@1; cy2 BY y2@1; cy3 BY y3@1; cy4 BY y4@1;

        ! Constrain the measurement error variances to zero
        x1-y4@0;

        ! Estimate the lagged effects between
        ! the within-person centered variables
        cx2 ON cx1 cy1; cx3 ON cx2 cy2; cx4 ON cx3 cy3;
        cy2 ON cx1 cy1; cy3 ON cx2 cy2; cy4 ON cx3 cy3;

        ! Estimate the covariance between the within-person
        ! centered variables at the first wave
        cx1 WITH cy1;

        ! Estimate the covariances between thes residuals of
        ! the within-person centered variables (the innovations)
        cx2 WITH cy2;  cx3 WITH cy3;  cx4 WITH cy4;

        ! Fix the correlation between the individual factors and the other
        ! exogenous variables to zero (by default these would be estimated)
        RI_x WITH cx1@0 cy1@0;
        RI_y WITH cx1@0 cy1@0;

        ! Fix the variances and covariance of the random intercepts to zero
        RI_x@0;
        RI_y@0;
        RI_x WITH RI_y@0;
```

This model results in a chi-square of 140.189 with 12 df ($p<.0001$). Note that this model is nested under the RI-CLPM, as we obtained it by fixing three parameters to zero.

This latter model is actually **statistically identical to the traditional CLPM**, which can be represented as:



This model can be specified quite simply in Mplus as:

```
MODEL:
        ! Estimate the lagged effects between
        ! the observed variables
        x2 ON x1 y1; x3 ON x2 y2; x4 ON x3 y3;
        y2 ON x1 y1; y3 ON x2 y2; y4 ON x3 y3;

        ! Estimate the covariance between the
        ! observed variables at the first wave
        x1 WITH y1;

        ! Estimate the covariances between the
        ! residuals of the observed variables
        x2 WITH y2;
        x3 WITH y3;
        x4 WITH y4;
```

When using this code to estimate the CLPM, we also obtained a chi-square of 140.189 with 12 df ($p<.0001$), which illustrates **these latter two models are statistically equivalent**. Moreover, the lagged parameter estimates they produce are exactly the same, as shown below.

The lagged parameters from the **RI-CLPM in which the variances and covariance of the random intercepts are fixed to zero** are:

```
CX2      ON
    CX1                 0.799      0.031     26.063      0.000
    CY1                -0.053      0.031     -1.715      0.086

 CX3      ON
    CX2                 0.810      0.030     27.185      0.000
    CY2                -0.018      0.030     -0.580      0.562

 CX4      ON
    CX3                 0.779      0.028     27.892      0.000
    CY3                -0.045      0.029     -1.563      0.118
```

```
 CY2       ON
    CX1               -0.171      0.029     -5.854      0.000
    CY1                0.767      0.030     25.965      0.000

 CY3       ON
    CX2               -0.150      0.028     -5.346      0.000
    CY2                0.766      0.029     26.850      0.000

 CY4       ON
    CX3               -0.131      0.028     -4.614      0.000
    CY3                0.788      0.029     27.012      0.000
```

The lagged parameters from the **traditional CLPM** are:

```
X2        ON
    X1                 0.799      0.031     26.063      0.000
    Y1                -0.053      0.031     -1.714      0.086

 X3        ON
    X2                 0.810      0.030     27.186      0.000
    Y2                -0.018      0.030     -0.580      0.562

 X4        ON
    X3                 0.779      0.028     27.892      0.000
    Y3                -0.045      0.029     -1.563      0.118

 Y2        ON
    X1                -0.171      0.029     -5.854      0.000
    Y1                 0.767      0.030     25.964      0.000

 Y3        ON
    X2                -0.150      0.028     -5.346      0.000
    Y2                 0.766      0.029     26.850      0.000

 Y4        ON
    X3                -0.131      0.028     -4.614      0.000
    Y3                 0.788      0.029     27.012      0.000
```

This shows that the traditional CLPM and the RI-CLPM in which the variances of the random intercepts are fixed to zero lead to **identical lagged parameters**.

However, these lagged parameter estimates **differ starkly** from the ones obtained with the **RI-CLPM**:

```
CX2       ON
    CX1                0.482      0.088      5.450      0.000
    CY1                0.239      0.087      2.759      0.006

 CX3       ON
```

```
    CX2                     0.548       0.074       7.360       0.000
    CY2                     0.263       0.099       2.662       0.008

 CX4       ON
    CX3                     0.526       0.060       8.713       0.000
    CY3                     0.190       0.077       2.456       0.014

 CY2       ON
    CX1                     0.087       0.074       1.173       0.241
    CY1                     0.234       0.099       2.371       0.018

 CY3       ON
    CX2                    -0.055       0.069      -0.789       0.430
    CY2                     0.332       0.110       3.018       0.003

 CY4       ON
    CX3                     0.012       0.066       0.181       0.856
    CY3                     0.301       0.088       3.408       0.001
```

The most notable differences between the estimates obtained with the RI-CLPM and the ones obtained with the traditional CLPM are:

- the **autoregressive parameters in the traditional CLPM are higher** than the ones in the RI-CLPM; this results is often observed when comparing these models and stems from the fact that the traditional CLPM confounds trait-like stability and moment-to-moment stability, whereas the RI-CLPM separates these two forms of stability;
- the effect from Y on X is significant and positive in the RI-CLPM, while it is non-significant (and negative) in the traditional CLPM; and
- the effect from X to Y is nonsignificant in the RI-CLPM (it was 0 in the data-generating RI-CLPM), while it is significant and negative in the traditional CLPM.

Note that the latter two differences have major consequences for the substantive interpretation of the model. However, such dramatic differences are not necessarily observed when comparing these two models; it may also be the case that the traditional CLPM and the RI-CLPM lead to very similar (substantive) conclusions. Another noteworthy difference is that the standard errors in the RI-CLPM are larger than the ones in the traditional CLPM. This is typically the case and results from the fact that the RI-CLPM is a more flexible model with more parameters, and as a result there is more uncertainty about parameter estimates. This means larger sample sizes are needed, both in terms of number of cases (N) and number of time points (T); simulation studies need to show which of these is more beneficial in terms of increasing power and efficiency.

Because the models are nested, we can compare them using a chi-square test, although we should adjust this test for the fact that two of the three parameters that are constrained, are constrained at the boundary of the parameter space (i.e., the two variances are constrained to zero). As indicated in Hamaker et al. (2015), the usual chi-square test is conservative, which means that if it is significant, we are certain that the correct test would also be significant.

Furthermore, we can add constraints to the RI-CLPM to make the lagged parameters invariant over time; this is often done in practice, but note that it only makes sense when the intervals between the observations are (more or less) equal over time. In that case we can specify the lagged effects as

```
! Constraining the lagged effects between
! the within-person centered variables
cx2 ON cx1 cy1 (a g);
cx3 ON cx2 cy2 (a g);
cx4 ON cx3 cy3 (a g);
cy2 ON cx1 cy1 (b d);
cy3 ON cx2 cy2 (b d);
cy4 ON cx3 cy3 (b d);
```

This results in

```
CX2      ON
    CX1                  0.500      0.055      9.031      0.000
    CY1                  0.244      0.051      4.800      0.000

 CX3      ON
    CX2                  0.500      0.055      9.031      0.000
    CY2                  0.244      0.051      4.800      0.000

 CX4      ON
    CX3                  0.500      0.055      9.031      0.000
    CY3                  0.244      0.051      4.800      0.000

 CY2      ON
    CX1                  0.020      0.045      0.441      0.659
    CY1                  0.278      0.054      5.155      0.000

 CY3      ON
    CX2                  0.020      0.045      0.441      0.659
    CY2                  0.278      0.054      5.155      0.000

 CY4      ON
    CX3                  0.020      0.045      0.441      0.659
    CY3                  0.278      0.054      5.155      0.000
```

Furthermore, the **grand means** can be **constrained over time**, using

```
! Constrain the grand means over time
[x1 x2 x3 x4] (mx);
[y1 y2 y3 y4] (my);
```

Again, we can do chi-square difference tests to see whether these constraints are tenable.

Data that were used (with columns representing x1, y1, x2 y2 x3 y3 x4 y4; rows representing 400 separate cases):

7.556 8.836 7.237 8.976 7.813 10.573 8.654 9.791
9.832 6.074 12.033 6.974 13.843 6.675 13.552 6.78
11.574 5.543 12.21 6.066 13.818 5.607 12.461 3.904
9.572 5.765 9.913 6.527 9.819 5.389 12.102 7.05
6.699 11.792 8.008 12.095 8.858 10.958 8.385 11.479
10.202 7.068 11.745 7.615 11.55 7.764 10.39 6.65
12.905 6.635 11.714 5.858 12.443 7.33 13.34 4.719
9.808 7.467 8.74 6.855 7.468 6.406 10.162 7.39
10.084 5.412 9.812 5.964 8.625 5.267 8.519 6.744
14.275 7.618 14.877 7.326 16.421 6.721 14.217 7.913
11.509 7.906 11.375 6.923 9.139 5.764 8.821 7.508
10.13 5.101 10.383 5.624 8.128 3.421 8.869 4.957
11.571 6.774 12.731 5.784 11.737 3.953 9.78 4.553
11.362 7.32 11.18 7.379 7.747 6.044 10.846 6.971
10.271 9.462 9.797 8.513 9.025 10.731 9.755 9.987
10.9 7.941 10.187 7.31 10.43 7.235 9.025 6.642
9.928 8.421 9.55 9.777 9.393 9.998 9.988 9.161
10.519 11.779 11.605 10.345 10.696 10.892 9.438 9.804
7.707 8.072 8.15 6.945 9.852 8.658 10.089 8.924
9.638 7.312 11.258 8.58 10.531 7.583 10.719 8.345
11.337 8.74 10.864 9.438 13.238 8.878 10.952 8.489
8.65 5.346 9.428 4.979 7.194 5.67 8.2 5.74
13.872 3.204 11.283 4.258 11.463 5.005 13.341 4.759
8.308 7.157 9.577 7.833 10.259 7.3 8.41 7.73
9.1 6.864 8.896 6.506 8.22 9.632 8.93 9.056
11.313 5.598 9.911 5.224 9.536 5.766 8.739 5.017
9.028 7.546 10.639 9.835 10.778 8.807 11.027 7.899
10.945 7.569 10.908 5.976 12.26 6.16 11.375 5.256
9.127 8.641 6.051 8.112 7.959 10.2 9.022 10.184
9.373 9.791 8.917 11.981 8.119 12.121 7.794 9.85
10.526 5.525 11.792 6.426 11.885 7.16 11.372 7.518
9.416 8.559 8.226 9.659 7.917 10.168 8.953 9.488
8.87 7.485 10.4 7.023 10.386 8.718 10.226 7.471
11.833 6.374 13.074 7.746 14.066 6.927 14.312 6.543
13.765 6.903 14.214 6.587 13.174 5.171 13.208 3.848
11.538 9.644 11.026 7.953 11.379 9.697 10.062 6.837
10.405 8.575 9.842 6.834 9.611 6.433 10.7 7.408
11.309 5.546 9.706 7.117 11.093 7.02 10.279 7.238
7.296 11.494 7.578 10.188 9.122 10.5 8.536 9.867
9.013 9.919 10.245 10.588 9.971 8.997 10.699 8.064
7.988 8.214 9.057 8.805 9.481 11.233 10.554 9.047
8.83 9.969 9.352 9.818 8.515 9.857 8.634 10.021
12.278 10.587 13.705 10.096 12.898 7.726 11.243 7.273
7.38 6.781 8.549 8.524 7.654 8.121 8.255 9.121
7.851 10.041 7.203 10.471 7.959 8.98 7.769 9.966
10.209 9.269 12.199 9.359 11.364 8.377 9.505 7.997
9.041 8.962 8.204 10.123 8.332 9.45 8.547 8.976
8.174 10.884 7.188 10.994 6.28 9.48 7.506 11.728
9.629 9.621 9.242 7.293 10.217 8.198 10.733 7.785
7.67 11.057 8.086 10.231 8.912 9.318 7.696 8.523
9.7 4.694 11.04 6.404 13.315 6.089 12.51 6.148

8.037 6.748 9.052 8.058 9.581 7.62 10.873 8.983
10.171 9.096 11.066 7.935 9.715 6.896 9.044 8.403
8.242 8.831 8.306 9.095 9.302 9.981 9.82 9.652
8.278 10.794 7.541 10.734 6.596 9.688 6.784 10.11
10.461 9.323 10.745 7.202 11.97 7.755 10.98 5.471
3.788 9.306 5.203 9.213 4.563 9.985 5.672 10.617
10.534 8.655 11.314 9.338 10.745 7.068 9.351 8.789
12.825 9.253 12.057 7.693 11.571 8.616 10.597 7.6
10.328 6.1 10.509 4.684 10.347 5.093 10.974 6.714
6.485 9.809 6.166 9.898 6.126 10.634 6.257 9.497
9.217 6.452 8.241 7.93 10.437 9.059 11.024 9.484
8.075 7.916 8.938 7.93 9.552 8.14 9.176 8.152
9.268 11.087 8.974 10.026 9.48 12.046 9.849 11.637
10.043 6.684 8.855 6.931 10.475 7.283 12.239 9.39
11.07 9.71 10.762 8.406 10.147 9.327 11.029 7.883
13.079 5.576 13.256 5.22 14.612 6.892 13.881 8.182
10.177 12.255 9.699 9.752 10.161 9.327 9.782 8.698
7.403 8.999 8.276 9.387 8.575 9.081 9.088 8.279
10.197 8.19 11.157 9.577 10.127 8.364 10.251 7.815
7.393 6.911 8.834 6.428 8.518 7.554 9.255 9.131
8.74 10.236 9.764 10.137 11.018 8.96 10.735 7.984
6.781 6.091 8.348 7.212 7.523 8.651 8.001 10.198
8.992 7.819 11.265 6.083 9.593 6.396 10.78 5.781
7.131 8.593 6.714 7.35 7.194 9.372 7.315 10.999
8.498 6.54 9.145 7.492 8.052 6.329 8.599 7.431
8.31 6.858 9.118 9.998 8.778 10.816 10.315 11.323
8.95 7.778 8.885 9.542 10.221 8.049 8.07 7.549
10.189 7.927 11.034 7.5 11.776 7.843 11.882 7.621
10.992 6.502 12.726 7.877 12.943 7.007 12.091 7.991
9.111 6.966 7.653 8.864 9.117 6.579 8.938 7.582
7.266 7.376 7.885 9.919 10.051 8.2 9.868 8.443
11.546 8.36 10.794 9.05 10.483 8.621 11.128 8.618
12.299 4.787 13.851 6.938 14.181 7.884 14.098 5.846
8.623 7.512 10.352 4.435 10.424 5.037 8.853 5.653
9.092 8.205 9.543 9.08 9.988 7.975 8.626 6.626
10.965 8.816 11.814 7.573 11.321 8.622 11.056 7.991
6.304 8.217 7.467 8.468 8.588 8.634 6.533 8.313
11.445 3.341 10.995 4.687 11.707 4.992 10.911 5.164
12.857 7.497 13.542 7.332 14.825 7.142 13.779 8.405
8.922 9.965 6.83 9.907 7.929 9.104 9.087 10.502
8.92 8.024 10.504 8.173 10.825 7.362 10.111 7.624
10.507 8.129 9.08 9.098 9.048 8.324 9.319 8.101
9.328 6.992 9.864 6.811 10.195 8.517 12.154 6.462
10.997 8.134 9.835 8.207 10.538 7.463 9.768 7.453
10.559 7.673 10.934 6.241 9.55 7.13 9.88 6.005
10.648 7.896 10.619 7.596 10.396 6.64 9.871 5.956
7.754 8.514 6.726 9.514 5.702 9.504 4.228 10.167
12.512 7.833 11.364 9.027 11.401 9.437 10.328 7.859
12.892 7.937 12.97 8.447 11.945 7.86 10.049 8.849
12.653 6.246 9.825 4.914 10.351 7.311 12.221 5.189
13.382 8.798 12.535 7.653 11.129 7.001 10.974 6.146
10.301 7.842 10.498 7.506 10.664 7.386 11.195 8.68
9.137 5.441 8.505 6.251 9.658 5.881 10.887 6.29
12.378 9.129 13.587 8.049 12.206 7.859 11.173 8.058
9.181 10.397 8.665 10.501 10.114 8.575 9.236 8.118

12.136 8.191 10.917 8.071 10.878 8.963 9.882 7.532
14.341 6.617 14.263 5.313 14.596 7.466 14.089 5.422
11.247 7.074 11.325 7.805 11.767 7.383 10.519 7.326
11.663 6.019 9.651 7.333 9.91 5.909 9.49 5.934
10.485 6.963 9.36 7.048 11.268 6.339 8.363 6.612
11.198 8.034 10.719 6.54 9.186 6.225 10.799 6.563
8.873 8.001 8.461 8.991 10.539 7.794 10.526 7.702
11.752 9.302 10.896 8.61 9.565 7.58 9.85 8.633
7.425 7.715 9.247 8.735 9.106 8.174 9.464 7.233
11.778 8.294 11.875 7.4 10.456 8.83 9.437 8.924
9.487 8.795 11.124 7.481 10.989 6.669 9.484 8.212
7.476 9.772 5.84 10.845 7.781 11.877 8.662 11.657
9.94 9.155 9.299 8.418 9.067 8.486 8.023 9.747
9.545 3.933 11.114 4.949 10.351 4.871 9.289 5.219
9.575 4.205 9.591 5.757 8.697 6.127 8.643 6.749
7.302 7.44 6.206 7.086 8.432 7.551 8.331 7.808
13.119 3.39 13.762 3.607 14.142 3.249 14.192 4.838
9.71 7.219 9.384 8.259 9.15 9.145 8.799 7.273
10.849 10.243 10.948 9.376 11.955 9.2 10.323 8.922
10.882 7.084 10.603 5.589 10.455 7.361 10.275 5.613
9.374 6.784 10.492 5.841 10.214 7.204 11.458 5.492
10.432 4.437 10.443 4.333 13.277 3.434 11.848 3.776
11.861 5.614 11.482 6.792 10.375 3.517 10.578 5.711
8.451 9.881 9.627 9.813 9.298 8.644 9.834 9.147
11.057 4.607 11.372 5.937 10.21 5.551 11.745 5.454
9.891 8.589 8.691 7.651 10.13 8.842 11.139 9.174
9.414 6.731 9.044 4.569 9.553 5.365 9.502 3.913
10.12 8.46 8.723 6.86 8.194 9.036 8.662 10.475
11.229 9.219 9.766 9.573 9.457 8.424 8.869 8.878
9.918 7.174 9.427 8.072 9.821 7.691 11.648 9.159
10.71 7.671 9.216 9.768 11.509 6.773 11.777 8.186
8.564 8.598 8.623 8.719 8.698 9.607 8.939 10.465
10.27 7.901 10.24 7.443 9.76 5.421 8.574 5.876
11.512 11.538 10.202 10.439 9.388 10.986 10.348 9.284
12.115 8.255 10.452 8.663 10.101 9.531 10.602 9.114
10.392 8.94 10.494 6.974 11.202 6.559 10.498 6.256
11.105 6.606 9.883 6.373 7.511 7.874 8.433 5.945
10.538 8.377 11.135 9.863 11.133 8.999 10.114 9.126
10.549 7.69 8.809 7.073 8.977 9.043 11.177 8.523
11.88 7.077 12.808 8.574 11.544 7.359 11.982 8.924
11.381 9.731 11.238 8.091 10.445 9.149 10.496 9.778
5.716 10.165 6.898 9.486 5.93 9.325 7.035 8.79
9.212 9.594 10.837 9.707 10.588 9.367 10.062 10.964
12.462 7.088 10.8 7.492 12.556 6.523 13.03 6.412
9.9 6.488 8.729 7.365 9.63 7.675 9.518 6.652
7.883 8.316 9.769 6.964 10.619 6.574 10.507 6.918
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