Answers to Exercises Basic CFA

```
library("lavaan")
```

Additional Exercise 2

a) Fit the depicted model to the data:

```
## Input covariances:
cormat <- lav_matrix_lower2full(c(
  1.000,
  0.700,  1.000,
  0.713,  0.636,  1.000,
  0.079,  0.066,  0.076,  1.000,
  0.088,  0.058,  0.070,  0.681,  1.000,
  0.084,  0.056,  0.074,  0.712,  0.633,  1.000,
  0.279,  0.248,  0.240,  0.177,  0.155,  0.170,  1.000,
  0.250,  0.214,  0.222,  0.157,  0.143,  0.152,  0.373,  1.000,
  0.280,  0.236,  0.251,  0.173,  0.178,  0.171,  0.448,  0.344,  1.000
))

## Input standard deviations:
sds = c(2.5, 2.1, 3.0, 4.1, 3.9, 4.4, 1.2, 1.0, 1.2)

## Reconstruct covariance matrix from correlations and sds:
covmat <- diag(sds) %*% cormat %*% diag(sds)

## Assign row and column names:
rownames(covmat) <- colnames(covmat) <- c("Y1", "Y2", "Y3", "Y4", "Y5", "Y6",
                                          "X1", "X2", "X3")

## Define formative model:
form.mod <- '
  SATISFACTION =~ Y1 + Y2 + Y3
  OPTIMISM =~ Y4 + Y5 + Y6
  STRESS <~ 1*X1 + X2 +X3
  SATISFACTION ~ STRESS
  OPTIMISM ~ STRESS
'

## Fit model:
form.fit <- cfa(form.mod, sample.cov=covmat, sample.nobs = 500)
summary(form.fit, standardized = TRUE, fit.measures = TRUE)
```

```
## lavaan 0.6-5 ended normally after 66 iterations
##
##   Estimator                                         ML
##   Optimization method                           NLMINB
```

```
##   Number of free parameters                         17
##
##   Number of observations                           500
##
## Model Test User Model:
##
##   Test statistic                                 2.166
##   Degrees of freedom                                22
##   P-value (Chi-square)                           1.000
##
## Model Test Baseline Model:
##
##   Test statistic                              1542.629
##   Degrees of freedom                                33
##   P-value                                        0.000
##
## User Model versus Baseline Model:
##
##   Comparative Fit Index (CFI)                    1.000
##   Tucker-Lewis Index (TLI)                       1.020
##
## Loglikelihood and Information Criteria:
##
##   Loglikelihood user model (H0)              -9192.919
##   Loglikelihood unrestricted model (H1)      -9191.836
##
##   Akaike (AIC)                               18419.837
##   Bayesian (BIC)                             18491.486
##   Sample-size adjusted Bayesian (BIC)        18437.526
##
## Root Mean Square Error of Approximation:
##
##   RMSEA                                          0.000
##   90 Percent confidence interval - lower         0.000
##   90 Percent confidence interval - upper         0.000
##   P-value RMSEA <= 0.05                          1.000
##
## Standardized Root Mean Square Residual:
##
##   SRMR                                           0.005
##
## Parameter Estimates:
##
##   Information                                 Expected
##   Information saturated (h1) model          Structured
##   Standard errors                             Standard
##
## Latent Variables:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##   SATISFACTION =~
##     Y1                1.000                               2.217    0.888
##     Y2                0.746    0.038   19.570    0.000    1.655    0.789
##     Y3                1.086    0.055   19.930    0.000    2.409    0.804
##   OPTIMISM =~
```

```
##     Y4                1.000                                3.579    0.874
##     Y5                0.848    0.045   18.733    0.000     3.035    0.779
##     Y6                1.000    0.051   19.441    0.000     3.579    0.814
##
## Composites:
##                   Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##   STRESS <~
##     X1                1.000                                0.366    0.439
##     X2                1.053    0.445    2.369    0.018     0.386    0.385
##     X3                1.073    0.434    2.469    0.014     0.393    0.471
##
## Regressions:
##                   Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##   SATISFACTION ~
##     STRESS            0.317    0.083    3.806    0.000     0.390    0.390
##   OPTIMISM ~
##     STRESS            0.338    0.101    3.358    0.001     0.258    0.258
##
## Covariances:
##                   Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##  .SATISFACTION ~~
##    .OPTIMISM          0.052    0.367    0.142    0.887     0.007    0.007
##
## Variances:
##                   Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##    .Y1                1.321    0.186    7.083    0.000     1.321    0.212
##    .Y2                1.662    0.142   11.735    0.000     1.662    0.378
##    .Y3                3.181    0.284   11.213    0.000     3.181    0.354
##    .Y4                3.964    0.528    7.509    0.000     3.964    0.236
##    .Y5                5.971    0.506   11.795    0.000     5.971    0.393
##    .Y6                6.510    0.622   10.459    0.000     6.510    0.337
##    .SATISFACTION      4.169    0.364   11.458    0.000     0.848    0.848
##    .OPTIMISM         11.960    1.064   11.238    0.000     0.933    0.933
##     STRESS            0.000                                0.000    0.000
```

b) Fit a model with stress as a reflective LV:

```
refl.mod <- '
  SATISFACTION =~ Y1 + Y2 + Y3
  OPTIMISM =~ Y4 + Y5 + Y6
  STRESS =~ 1*X1 + X2 +X3
  SATISFACTION ~ STRESS
  OPTIMISM ~ STRESS
'
refl.fit <- cfa(refl.mod, sample.cov = covmat, sample.nobs = 500)
summary(refl.fit, standardized = TRUE, fit.measures = TRUE)
```

```
## lavaan 0.6-5 ended normally after 65 iterations
##
##   Estimator                                         ML
##   Optimization method                           NLMINB
##   Number of free parameters                         21
##
##   Number of observations                           500
##
```

```
## Model Test User Model:
##
##   Test statistic                                3.010
##   Degrees of freedom                               24
##   P-value (Chi-square)                          1.000
##
## Model Test Baseline Model:
##
##   Test statistic                             1752.818
##   Degrees of freedom                               36
##   P-value                                       0.000
##
## User Model versus Baseline Model:
##
##   Comparative Fit Index (CFI)                   1.000
##   Tucker-Lewis Index (TLI)                      1.018
##
## Loglikelihood and Information Criteria:
##
##   Loglikelihood user model (H0)             -9193.341
##   Loglikelihood unrestricted model (H1)     -9191.836
##
##   Akaike (AIC)                              18428.681
##   Bayesian (BIC)                            18517.188
##   Sample-size adjusted Bayesian (BIC)       18450.533
##
## Root Mean Square Error of Approximation:
##
##   RMSEA                                         0.000
##   90 Percent confidence interval - lower        0.000
##   90 Percent confidence interval - upper        0.000
##   P-value RMSEA <= 0.05                         1.000
##
## Standardized Root Mean Square Residual:
##
##   SRMR                                          0.008
##
## Parameter Estimates:
##
##   Information                                 Expected
##   Information saturated (h1) model          Structured
##   Standard errors                             Standard
##
## Latent Variables:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##   SATISFACTION =~
##     Y1                1.000                               2.217    0.888
##     Y2                0.747    0.038   19.570    0.000    1.655    0.789
##     Y3                1.086    0.055   19.926    0.000    2.408    0.804
##   OPTIMISM =~
##     Y4                1.000                               3.580    0.874
##     Y5                0.848    0.045   18.731    0.000    3.034    0.779
##     Y6                1.000    0.051   19.440    0.000    3.579    0.814
##   STRESS =~
```

```
##     X1                1.000                               0.812    0.677
##     X2                0.675    0.078    8.696    0.000    0.548    0.548
##     X3                0.962    0.103    9.314    0.000    0.781    0.652
##
## Regressions:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##   SATISFACTION ~
##     STRESS            1.299    0.177    7.345    0.000    0.476    0.476
##   OPTIMISM ~
##     STRESS            1.388    0.272    5.110    0.000    0.315    0.315
##
## Covariances:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##  .SATISFACTION ~~
##    .OPTIMISM         -0.337    0.378   -0.892    0.372   -0.051   -0.051
##
## Variances:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##    .Y1                1.321    0.187    7.082    0.000    1.321    0.212
##    .Y2                1.661    0.142   11.731    0.000    1.661    0.377
##    .Y3                3.182    0.284   11.214    0.000    3.182    0.354
##    .Y4                3.963    0.528    7.506    0.000    3.963    0.236
##    .Y5                5.972    0.506   11.796    0.000    5.972    0.393
##    .Y6                6.510    0.622   10.459    0.000    6.510    0.337
##    .X1                0.778    0.080    9.758    0.000    0.778    0.542
##    .X2                0.698    0.054   12.810    0.000    0.698    0.700
##    .X3                0.827    0.079   10.497    0.000    0.827    0.576
##    .SATISFACTION      3.804    0.367   10.353    0.000    0.774    0.774
##    .OPTIMISM         11.545    1.065   10.837    0.000    0.901    0.901
##     STRESS            0.659    0.099    6.662    0.000    1.000    1.000
```

c) For both models, fit indices indicate excellent model fit. The formative model fits slightly better than the reflective model according to the SRMR, but the difference is very small.