**Assignment 1**

**a.**

We load the data, compute the covariance matrix, and we fit a CFA model with three correlated factors (one for each attitude concept), and assuming each item only has a loading on the concept it aims to measure. We print fit measures, the standardized solution and we compute, for each latent variable, the composite reliability, the average variance extracted and the maximum shared variance with other latent variables.

load("ess.Rdata")

ess <- ess[-1]

names(ess)[1:13]<-c("sotru1","sotru2","sotru3","truin1","truin2","truin3","truin4",

"webe1","webe2","webe3","webe4","webe5","webe6")

covmat<-cov(ess)

##specify model with 3 correlated factors

cfa1<-'sotru =~NA\*+sotru1+sotru2+sotru3

truin =~NA\*truin1+truin2+truin3+truin4

webe =~NA\*webe1+webe2+webe3+webe4+webe5+webe6

sotru ~~1\*sotru

truin ~~1\*truin

webe ~~1\*webe'

#fit model on covariance matrix

fitcfa1<-cfa(cfa1,sample.cov=covmat,sample.nobs=4046)

#print fit measures

> fitmeasures(fitcfa1,c("chisq","df","pvalue","cfi","tli","rmsea","srmr"))

chisq df pvalue cfi tli rmsea srmr

1526.049 62.000 0.000 0.912 0.889 0.076 0.040

> #standardized solution

> d<-standardizedSolution(fitcfa1)

> d

lhs op rhs est.std se z pvalue ci.lower ci.upper

1 sotru =~ sotru1 0.684 0.013 52.036 0 0.658 0.709

2 sotru =~ sotru2 0.648 0.013 48.322 0 0.622 0.674

3 sotru =~ sotru3 0.626 0.014 46.031 0 0.600 0.653

4 truin =~ truin1 0.789 0.008 93.956 0 0.773 0.805

5 truin =~ truin2 0.718 0.010 74.774 0 0.699 0.737

6 truin =~ truin3 0.581 0.012 48.194 0 0.557 0.605

7 truin =~ truin4 0.802 0.008 97.758 0 0.786 0.818

8 webe =~ webe1 0.661 0.011 60.710 0 0.640 0.683

9 webe =~ webe2 0.670 0.011 62.343 0 0.649 0.691

10 webe =~ webe3 0.589 0.012 48.379 0 0.565 0.612

11 webe =~ webe4 0.718 0.010 72.725 0 0.699 0.738

12 webe =~ webe5 0.677 0.011 63.729 0 0.656 0.698

13 webe =~ webe6 0.595 0.012 49.291 0 0.571 0.618

14 sotru ~~ sotru 1.000 0.000 NA NA 1.000 1.000

15 truin ~~ truin 1.000 0.000 NA NA 1.000 1.000

16 webe ~~ webe 1.000 0.000 NA NA 1.000 1.000

17 sotru1 ~~ sotru1 0.533 0.018 29.674 0 0.498 0.568

18 sotru2 ~~ sotru2 0.580 0.017 33.355 0 0.546 0.614

19 sotru3 ~~ sotru3 0.608 0.017 35.629 0 0.574 0.641

20 truin1 ~~ truin1 0.377 0.013 28.488 0 0.352 0.403

21 truin2 ~~ truin2 0.485 0.014 35.192 0 0.458 0.512

22 truin3 ~~ truin3 0.662 0.014 47.280 0 0.635 0.690

23 truin4 ~~ truin4 0.357 0.013 27.162 0 0.331 0.383

24 webe1 ~~ webe1 0.562 0.014 39.020 0 0.534 0.591

25 webe2 ~~ webe2 0.551 0.014 38.292 0 0.523 0.579

26 webe3 ~~ webe3 0.654 0.014 45.641 0 0.626 0.682

27 webe4 ~~ webe4 0.484 0.014 34.112 0 0.456 0.512

28 webe5 ~~ webe5 0.542 0.014 37.693 0 0.514 0.570

29 webe6 ~~ webe6 0.646 0.014 45.059 0 0.618 0.675

30 sotru ~~ truin 0.555 0.016 34.183 0 0.524 0.587

31 sotru ~~ webe 0.287 0.020 14.604 0 0.248 0.326

32 truin ~~ webe 0.185 0.018 10.022 0 0.149 0.221

> factorscore<-c("sotru","truin","webe")

> #composite reliability

> reliability<-round(c(compositerel(d[1:3,4]),compositerel(d[4:6,4]),compositerel(d[7:9,4])),3)

> #average variance extracted

> average\_var\_extracted<-round(c(mean(d[1:3,4]^2),mean(d[4:6,4]^2),mean(d[7:9,4]^2)),3)

> #maximum shared variance

> max\_shared\_var<-round(c(max(d[c(22,23),4]^2),max(d[c(22,24),4]^2),max(d[c(23,24),4]^2)),3)

> data.frame(factorscore,reliability,average\_var\_extracted,max\_shared\_var)

factorscore reliability average\_var\_extracted max\_shared\_var

1 sotru 0.690 0.427 0.439

2 truin 0.741 0.492 0.439

3 webe 0.756 0.510 0.316

The **fit measures** indicate that the model is rejected by an absolute goodness of fit test, i.e. the fit of the model is significantly lower than for a perfectly fitting model (chisquare= 1526.049, df=62, p<.001). Furthermore, descriptive fit measures also indicate that the model cannot reproduce the observed covariance matrix well: CFI (.912) and TLI (.889) both are lower than 0.95 and hence do not meet the cutoff of good fit. RMSEA (.076) indicates poor fit as it is below 0.08. Given these results, it is clear that further modifications to the model are needed.

As can be seen in the standardized solution, not all variables have significant? and positive standardized loadings that exceed 0.7. Hence, the individual variables have sufficient reliability and **convergent validity** is satisfied for the measurement model. Furthermore, **divergent validity** is satisfied as all latent variables have moderate correlations

that are significantly smaller than 1 (.555, .287, .185). Divergent validity is also confirmed using the criterion of Fornell and Lanker as we see that for, each latent variable, the average variance extracted in the observed indicator variables is larger than the maximum variance that is shared with other latent variables.

Finally, we see that composite reliability of the factor scores is not good as for all latent variables **composite reliabilities** are between 0.6 and 0.8.

**b.**

We compute modification indices that indicate how much the model chi-square will be improved if imposed constraints are relaxed. Cut off: hundres (idk, seems right given chi2 1526)

> modificationIndices(fitcfa1)

lhs op rhs mi epc sepc.lv sepc.all sepc.nox

33 sotru =~ truin1 15.852 -0.181 -0.181 -0.077 -0.077

34 sotru =~ truin2 11.370 0.157 0.157 0.067 0.067

35 sotru =~ truin3 35.878 0.288 0.288 0.129 0.129

36 sotru =~ truin4 8.738 -0.125 -0.125 -0.057 -0.057

37 sotru =~ webe1 1.248 0.013 0.013 0.018 0.018

38 sotru =~ webe2 0.967 -0.011 -0.011 -0.016 -0.016

39 sotru =~ webe3 5.258 0.030 0.030 0.039 0.039

40 sotru =~ webe4 2.192 -0.019 -0.019 -0.023 -0.023

41 sotru =~ webe5 0.033 -0.002 -0.002 -0.003 -0.003

42 sotru =~ webe6 0.065 -0.004 -0.004 -0.004 -0.004

43 truin =~ sotru1 20.844 0.242 0.242 0.112 0.112

44 truin =~ sotru2 19.103 -0.206 -0.206 -0.104 -0.104

45 truin =~ sotru3 0.078 -0.014 -0.014 -0.007 -0.007

46 truin =~ webe1 1.275 0.012 0.012 0.016 0.016

47 truin =~ webe2 0.666 0.008 0.008 0.012 0.012

48 truin =~ webe3 1.761 0.015 0.015 0.020 0.020

49 truin =~ webe4 8.275 -0.032 -0.032 -0.040 -0.040

50 truin =~ webe5 0.185 -0.005 -0.005 -0.006 -0.006

51 truin =~ webe6 0.461 0.009 0.009 0.010 0.010

52 webe =~ sotru1 3.265 -0.069 -0.069 -0.032 -0.032

53 webe =~ sotru2 12.584 0.123 0.123 0.062 0.062

54 webe =~ sotru3 2.954 -0.063 -0.063 -0.030 -0.030

55 webe =~ truin1 0.131 -0.011 -0.011 -0.005 -0.005

56 webe =~ truin2 7.008 0.086 0.086 0.037 0.037

57 webe =~ truin3 11.255 0.115 0.115 0.051 0.051

58 webe =~ truin4 16.240 -0.117 -0.117 -0.054 -0.054

59 sotru1 ~~ sotru2 1.114 -0.088 -0.088 -0.037 -0.037

60 sotru1 ~~ sotru3 6.018 -0.207 -0.207 -0.080 -0.080

61 sotru1 ~~ truin1 0.838 0.045 0.045 0.020 0.020

62 sotru1 ~~ truin2 2.162 0.076 0.076 0.030 0.030

63 sotru1 ~~ truin3 0.404 -0.035 -0.035 -0.012 -0.012

64 sotru1 ~~ truin4 2.323 0.069 0.069 0.033 0.033

65 sotru1 ~~ webe1 0.167 0.007 0.007 0.008 0.008

66 sotru1 ~~ webe2 0.559 0.012 0.012 0.015 0.015

67 sotru1 ~~ webe3 9.170 0.056 0.056 0.058 0.058

68 sotru1 ~~ webe4 6.366 -0.044 -0.044 -0.051 -0.051

69 sotru1 ~~ webe5 7.718 -0.051 -0.051 -0.055 -0.055

70 sotru1 ~~ webe6 0.008 0.002 0.002 0.002 0.002

71 sotru2 ~~ sotru3 11.982 0.252 0.252 0.102 0.102

72 sotru2 ~~ truin1 3.196 -0.081 -0.081 -0.037 -0.037

73 sotru2 ~~ truin2 1.005 0.048 0.048 0.020 0.020

74 sotru2 ~~ truin3 3.177 0.090 0.090 0.033 0.033

75 sotru2 ~~ truin4 12.337 -0.147 -0.147 -0.075 -0.075

76 sotru2 ~~ webe1 0.000 0.000 0.000 0.000 0.000

77 sotru2 ~~ webe2 3.723 -0.028 -0.028 -0.037 -0.037

78 sotru2 ~~ webe3 13.839 -0.064 -0.064 -0.069 -0.069

79 sotru2 ~~ webe4 8.465 0.048 0.048 0.057 0.057

80 sotru2 ~~ webe5 29.089 0.093 0.093 0.103 0.103

81 sotru2 ~~ webe6 0.001 -0.001 -0.001 -0.001 -0.001

82 sotru3 ~~ truin1 15.508 -0.190 -0.190 -0.081 -0.081

83 sotru3 ~~ truin2 0.487 0.036 0.036 0.013 0.013

84 sotru3 ~~ truin3 30.187 0.297 0.297 0.100 0.100

85 sotru3 ~~ truin4 0.077 -0.012 -0.012 -0.006 -0.006

86 sotru3 ~~ webe1 0.075 0.004 0.004 0.005 0.005

87 sotru3 ~~ webe2 1.452 -0.019 -0.019 -0.023 -0.023

88 sotru3 ~~ webe3 8.985 0.055 0.055 0.055 0.055

89 sotru3 ~~ webe4 0.012 0.002 0.002 0.002 0.002

90 sotru3 ~~ webe5 5.836 -0.044 -0.044 -0.046 -0.046

91 sotru3 ~~ webe6 1.311 -0.024 -0.024 -0.021 -0.021

92 truin1 ~~ truin2 52.242 -0.492 -0.492 -0.210 -0.210

93 truin1 ~~ truin3 211.717 -0.854 -0.854 -0.326 -0.326

94 truin1 ~~ truin4 559.300 1.707 1.707 0.914 0.914

95 truin1 ~~ webe1 0.319 0.008 0.008 0.011 0.011

96 truin1 ~~ webe2 2.238 0.021 0.021 0.030 0.030

97 truin1 ~~ webe3 2.379 -0.026 -0.026 -0.030 -0.030

98 truin1 ~~ webe4 2.427 -0.025 -0.025 -0.032 -0.032

99 truin1 ~~ webe5 1.698 0.022 0.022 0.026 0.026

100 truin1 ~~ webe6 0.003 0.001 0.001 0.001 0.001

101 truin2 ~~ truin3 478.146 1.275 1.275 0.430 0.430

102 truin2 ~~ truin4 168.787 -0.834 -0.834 -0.395 -0.395

103 truin2 ~~ webe1 0.000 0.000 0.000 0.000 0.000

104 truin2 ~~ webe2 0.671 0.013 0.013 0.015 0.015

105 truin2 ~~ webe3 1.245 0.020 0.020 0.020 0.020

106 truin2 ~~ webe4 0.004 0.001 0.001 0.001 0.001

107 truin2 ~~ webe5 0.006 0.001 0.001 0.001 0.001

108 truin2 ~~ webe6 0.196 0.009 0.009 0.008 0.008

109 truin3 ~~ truin4 73.909 -0.471 -0.471 -0.199 -0.199

110 truin3 ~~ webe1 2.761 -0.028 -0.028 -0.029 -0.029

111 truin3 ~~ webe2 0.001 0.000 0.000 0.000 0.000

112 truin3 ~~ webe3 1.206 0.021 0.021 0.019 0.019

113 truin3 ~~ webe4 3.041 0.032 0.032 0.032 0.032

114 truin3 ~~ webe5 0.204 0.009 0.009 0.008 0.008

115 truin3 ~~ webe6 0.967 0.021 0.021 0.017 0.017

116 truin4 ~~ webe1 1.231 0.015 0.015 0.022 0.022

117 truin4 ~~ webe2 0.493 -0.009 -0.009 -0.014 -0.014

118 truin4 ~~ webe3 0.022 0.002 0.002 0.003 0.003

119 truin4 ~~ webe4 3.942 -0.030 -0.030 -0.041 -0.041

120 truin4 ~~ webe5 3.947 -0.031 -0.031 -0.040 -0.040

121 truin4 ~~ webe6 0.012 -0.002 -0.002 -0.002 -0.002

122 webe1 ~~ webe2 153.517 0.068 0.068 0.255 0.255

123 webe1 ~~ webe3 50.754 0.045 0.045 0.137 0.137

124 webe1 ~~ webe4 62.404 -0.051 -0.051 -0.173 -0.173

125 webe1 ~~ webe5 68.018 -0.054 -0.054 -0.171 -0.171

126 webe1 ~~ webe6 5.876 -0.017 -0.017 -0.047 -0.047

127 webe2 ~~ webe3 128.133 0.068 0.068 0.219 0.219

128 webe2 ~~ webe4 57.439 -0.047 -0.047 -0.168 -0.168

129 webe2 ~~ webe5 86.209 -0.058 -0.058 -0.194 -0.194

130 webe2 ~~ webe6 23.523 -0.033 -0.033 -0.094 -0.094

131 webe3 ~~ webe4 114.875 -0.075 -0.075 -0.219 -0.219

132 webe3 ~~ webe5 150.356 -0.088 -0.088 -0.239 -0.239

133 webe3 ~~ webe6 33.002 0.045 0.045 0.105 0.105

134 webe4 ~~ webe5 612.318 0.182 0.182 0.553 0.553

135 webe4 ~~ webe6 0.199 0.004 0.004 0.009 0.009

136 webe5 ~~ webe6 3.493 0.015 0.015 0.037 0.037

The results suggest that some other common factors can explain (pairs with red). We fit a new model with correlated error terms for these pairs of items.

> cfa2<-'sotru =~NA\*+sotru1+sotru2+sotru3

+ truin =~NA\*truin1+truin2+truin3+truin4

+ webe =~NA\*webe1+webe2+webe3+webe4+webe5+webe6

+ sotru ~~1\*sotru

+ truin ~~1\*truin

+ webe ~~1\*webe

+ truin1 ~~ truin3

+ truin1 ~~ truin4

+ truin2 ~~ truin3

+ truin2 ~~ truin4

+ webe1 ~~ webe2

+ webe2 ~~ webe3

+ webe3 ~~ webe4

+ webe3 ~~ webe5

+ webe4 ~~ webe5'

>

> #fit model on covariance matrix

> fitcfa2<-cfa(cfa2,sample.cov=covmat,sample.nobs=4046)

> #summary(fitcfa1,fit.measures=TRUE,std=TRUE)

>

> #fit measures

> fitmeasures(fitcfa2,c("chisq","df","pvalue","cfi","tli","rmsea","srmr"))

chisq df pvalue cfi tli rmsea srmr

169.929 53.000 0.000 0.993 0.990 0.023 0.017

The **fit measures** indicate that the model is still rejected by an absolute goodness of fit test, i.e. the fit of the model is significantly lower than for a perfectly fitting model (chisquare=169.929, df=53, p<.001). However, descriptive fit measures indicate that the model can reproduce the observed covariance matrix well: CFI (.993) and TLI (.99) both are lower than 0.95 and hence meet the cutoff of good fit. RMSEA (.023) indicates good fit as it is far below 0.08. SRMR indicates . Given these results, it is clear that modifications to the model were effective.

**c.**