Factor analysis workflow:

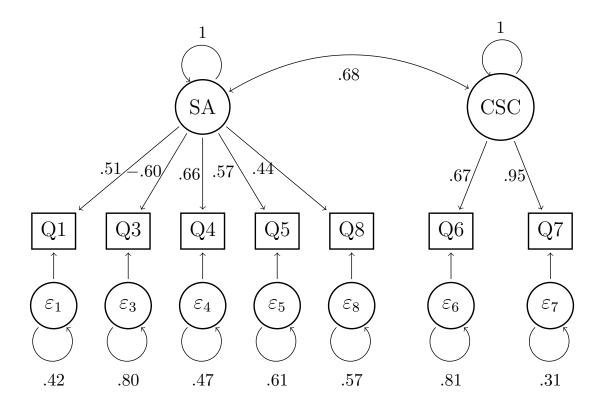
- use exploratory factor analysis to find a potential measurement model (latent factor structures) for a given set of data
 - how many factors/dimensions?
 - which items load onto the different factors?
- use *confirmatory factor analysis* to **test** this models and estimate its components
 - test of exact fit χ^2 test (\mathcal{H}_0 : model fits data exactly) compares to saturated model want p > 0.05!
 - test of absolute fit is RMSEA < 0.05?

In this lecture, we will discuss how to build and compare **competing** measurement models

- use the SEM module in JASP
- explore ways to improve model fit (compute modification indices)
- compare model fits using Bayesian information criterion (BIC)
- how to turn this into a thesis!

SAQ-8 items:

- 1. Statistics makes me cry
- 2. My friends will think I'm stupid for not being able to use statistical software
- 3. Standard deviations excite me
- 4. I dream that Pearson is attacking me with correlation coefficients
- 5. I don't understand statistics
- 6. I have little experience with computers
- 7. All computers hate me
- 8. I have never been good at mathematics



- $\chi^2(13) = 66.8$, p < 0.001 (model not a good fit, but X^2 performs badly with large N)
- RMSEA = 0.040, 95% CI = (0.031, 0.050) (model IS a good fit)

Questions for today:

- 1. Can we get a *better* model structure?
- 2. How much better?

Answers:

- 1. Can we get a *better* model structure?
 - build a "structural equation model" in JASP
 - compute "modification indices" (MIs)
 - build new model, adding components with large MI
- 2. How much better?
 - compare two models using Bayesian information criterion (BIC)
 - lower is better
 - convert difference in BIC to Bayes factor directly compare likelihood of data under the two competing models

Structural equation modeling in JASP

- uses "SEM" module
- requires lavaan syntax
 - lavaan is an R package for doing SEM

Let's demonstrate in JASP

Modification indices

- what happens to model fit when additional components are added?
- MI = change (decrease) in χ^2 statistic when adding that component

In JASP, do the following:

- select "Modification indices" from the "Statistics" menu
- choose ONE modification to make to your model (usually the one with the largest MI)
- go to "Advanced" and change model name (i.e., "Model 2")
- ullet modify the lavaan code and re-fit the model

How much better does Model 2 fit?

- use BIC smaller is better
- BIC for Model 1 = 46,711.672
- BIC for Model 2 = 46,684.084 better fit!

How much better does Model 2 fit?

- convert BIC to a *Bayes factor* (Kass & Raftery, 1995; Wagenmakers, 2007; Faulkenberry, 2018)
- Bayes factor = how much more likely is the data under Model 2 compared to Model 1?
- Computing Bayes factor:

$$BF = \exp\left(\frac{\Delta BIC}{2}\right)$$

• for our models, we have:

$$BF = \exp\left(\frac{46711.672 - 46684.084}{2}\right)$$
$$= \exp\left(\frac{27.588}{2}\right)$$
$$= \exp(13.794)$$
$$= 978719.1$$

Interpretation: our data are approximately 979,000 times more likely under Model 2 than Model 1.

Summary – how to turn this into a thesis

- construct an interpretable measurement model (exploratory factor analysis)
 - SAQ-8 seems to consist of two factors: SA and CSC
- estimate and validate the model (confirmatory factor analysis)
 - report χ^2 test and RMSEA
- use structural equation modeling (SEM) to explore potentially *better* factor structures
 - compute modification indices add some components, but remember to keep it simple
- compare model fits
 - lower BIC is better
 - how much better? Translate BIC to Bayes factor
- next step collect NEW data and confirm new model on this data (use CFA)