Psychometrics Using Stata

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Humor involves two risks

- May not be funny
- May offend

Disclaimer

The use of clinical depression and its diagnosis in this talk is not meant to make light of this very serious condition. The examples use a depression index and the examples are silly (and fictitious!). This is not meant to imply that depression is silly.

- Given the current state of the world economy, the staff at StataCorp began to worry about the emotional well-being of our users.
- In early 2010, the marketing department hired a consultant to design a depression index to assess our users.
- The index was pilot-tested on StataCorp employees to determine its psychometric properties.
- The index was then sent to 1000 randomly selected Stata users.
- **(All data are simulated and this is completely fictitious!)**

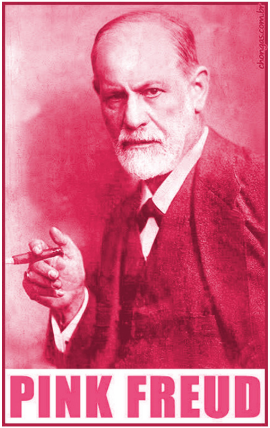
An Inventory for Measuring Depression

A. T. BECK, M.D.
C. H. WARD, M.D.
M. MENDELSON, M.D.
J. MOCK, M.D.
AND
J. ERBAUGH, M.D.
PHILADELPHIA

The symptom-attitude categories are as follows:

a. Mood
b. Pessimism
c. Sense of Failure
d. Lack of Satis-faction
e. Guilty Feeling
f. Sense of Punish-ment
g. Self-Hate
h. Self Accusations
i. Self Punitive Wishes
j. Crying Spells
k. Irritability
l. Social Withdrawal
m. Indecisiveness
n. Body Image
o. Work Inhibition
p. Sleep Disturbance
q. Fatigability
r. Loss of Appetite
s. Weight Loss
t. Somatic Pre-occupation
u. Loss of Libido

My statistical software makes me...



Q1 ...feel sad
Q2 ...feel pessimistic about the future
Q3 ...feel like a failure
Q4 ...feel dissatisfied
Q5 ...feel guilty or unworthy
Q6 ...feel that I am being punished
Q7 ...feel disappointed in myself
Q8 ...feel am very critical of myself
Q9 ...feel like harming myself
Q10 ...feel like crying more than usual
Q11 ...become annoyed or irritated easily
Q12 ...lose interest in other people
Q13 ...have trouble making decisions
Q14 ...feel unattractive
Q15 ...feel like not working
Q16 ...have trouble sleeping
Q17 ...feel tired or fatigued
Q18 ...makes my appetite lower than usual
Q19 ...concerned about my health
Q20 ...experience decreased libido

My statistical software makes me….

Question 1: …feel sad.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

- Administered to all StataCorp employees
- Explore the psychometric properties of the index
  - Descriptive Statistics
  - Item Response Characteristics
  - Reliability
  - Validity
  - Dimensionality and Exploratory Factor Analysis

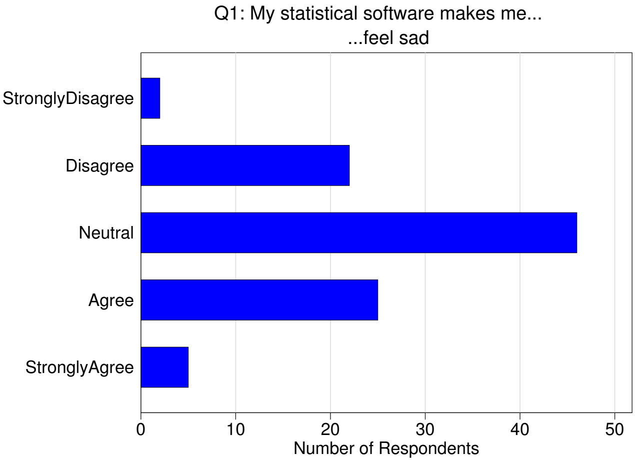
```
. describe id qu1_t1-qu20_t1

              storage  display     value
variable name   type   format      label      variable label
-------------------------------------------------------------------------------
id              byte   %9.0g                  Identification Number
qu1_t1          byte   %16.0g      qu1_t1     ...feel sad
qu2_t1          byte   %16.0g      qu2_t1     ...feel pessimistic about the future
qu3_t1          byte   %16.0g      qu3_t1     ...feel like a failure
qu4_t1          byte   %16.0g      qu4_t1     ...feel dissatisfied
qu5_t1          byte   %16.0g      qu5_t1     ...feel guilty or unworthy
qu6_t1          byte   %16.0g      qu6_t1     ...feel that I am being punished
qu7_t1          byte   %16.0g      qu7_t1     ...feel disappointed in myself
qu8_t1          byte   %16.0g      qu8_t1     ...feel am very critical of myself
qu9_t1          byte   %16.0g      qu9_t1     ...feel like harming myself
qu10_t1         byte   %16.0g      qu10_t1    ...feel like crying more than usual
qu11_t1         byte   %16.0g      qu11_t1    ...become annoyed or irritated easily
qu12_t1         byte   %16.0g      qu12_t1    ...have lost interest in other people
qu13_t1         byte   %16.0g      qu13_t1    ...have trouble making decisions
qu14_t1         byte   %16.0g      qu14_t1    ...feel unattractive
qu15_t1         byte   %16.0g      qu15_t1    ...feel like not working
qu16_t1         byte   %16.0g      qu16_t1    ...have trouble sleeping
qu17_t1         byte   %16.0g      qu17_t1    ...feel tired or fatigued
qu18_t1         byte   %16.0g      qu18_t1    ...makes my appetite lower than usual
qu19_t1         byte   %16.0g      qu19_t1    ...concerned about my health
qu20_t1         byte   %16.0g      qu20_t1    ...experience decreased libido
```

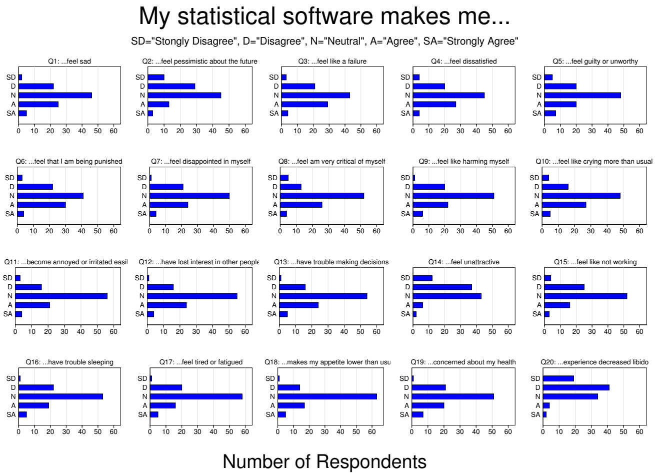
```
. summ qu1_t1-qu20_t1
```

Variable	Obs	Mean	Std. Dev.	Min	Max
qu1_t1	100	3.09	.8656754	1	5
qu2_t1	100	2.7	.9265991	1	5
qu3_t1	100	3.1	.8819171	1	5
qu4_t1	100	3.07	.8905225	1	5
qu5_t1	100	3.04	.9419516	1	5
qu6_t1	100	3.1	.8932971	1	5
qu7_t1	100	3.09	.8052229	1	5
qu8_t1	100	3.11	.8633386	1	5
qu9_t1	100	3.12	.832181	1	5
qu10_t1	100	3.13	.8836906	1	5
qu11_t1	100	3.07	.8072275	1	5
qu12_t1	100	3.14	.7656779	1	5
qu13_t1	100	3.16	.7877855	1	5
qu14_t1	100	2.49	.8586459	1	5
qu15_t1	100	2.89	.8274947	1	5
qu16_t1	100	3.05	.8087276	1	5
qu17_t1	100	3.04	.7774603	1	5
qu18_t1	100	3.11	.7371115	1	5
qu19_t1	100	3.11	.8515583	1	5
qu20_t1	100	2.29	.8909761	1	5

```
. tab qu1_t1
```

...feel sad	Freq.	Percent	Cum.
StronglyDisagree	2	2.00	2.00
Disagree	22	22.00	24.00
Neutral	46	46.00	70.00
Agree	25	25.00	95.00
StronglyAgree	5	5.00	100.00
Total	100	100.00	


Q1: My statistical software makes me...
...feel sad
StronglyDisagree
Disagree
Neutral
Agree
StronglyAgree
0
10
20
30
40
50
Number of Respondents


My statistical software makes me...
SD="Stongly Disagree", D="Disagree", N="Neutral", A="Agree", SA="Strongly Agree"
Q1: ...feel sad
Q2: ...feel pessimistic about the future
Q3: ...feel like a failure
Q4: ...feel dissatisfied
Q5: ...feel guilty or unworthy
Q6: ...feel that I am being punished
Q7: ...feel disappointed in myself
Q8: ...feel am very critical of myself
Q9: ...feel like harming myself
Q10: ...feel like crying more than usual
Q11: ...become annoyed or irritated easil
Q12: ...have lost interest in other people
Q13: ...have trouble making decisions
Q14: ...feel unattractive
Q15: ...feel like not working
Q16: ...have trouble sleeping
Q17: ...feel tired or fatigued
Q18: ...makes my appetite lower than usu
Q19: ...concerned about my health
Q20: ...experience decreased libido
SD
D
N
A
SA
0 10 20 30 40 50 60
Number of Respondents

...how did I make that graph?!?

```
// CREATE A TEMPORARY VARIABLE CALLED "one" FOR USE IN THE GRAPHS BELOW
gen one = 1

// GRAPH EACH OF QUESTIONS 1-20 FOR THE COMBO GRAPH
forvalues i = 1(1)20 {
local GraphTitle : variable label qu`i'_t1
graph hbar (count) one, over(qu`i'_t1, relabel(1 SD 2 D 3 N 4 A 5 SA)) ///
bar(1, fcolor(blue) lcolor(black)) ///
title("Q`i': `GraphTitle'", size(medsmall) color(black)) ///
ytitle(" ") ylabel(0(10)60) ymtick(0(10)60) ///
scheme(s1color) ///
name(qu`i'_t1, replace)
}

// COMBINE THE GRAPHS OF EACH QUESTION INTO A SINGLE GRAPH
graph combine qu1_t1 qu2_t1 qu3_t1 qu4_t1 qu5_t1 qu6_t1 qu7_t1 qu8_t1 qu9_t1 qu10_t1 ///
qu11_t1 qu12_t1 qu13_t1 qu14_t1 qu15_t1 qu16_t1 qu17_t1 qu18_t1 qu19_t1 qu20_t1, ///
rows(4) cols(5) ///
title("My statistical software makes me...") ///
subtitle(`"SD="Stongly Disagree", D="Disagree", N="Neutral", A="Agree", SA="Strongly Agree""', ///
size(vsmall) color(black)) ///
b1title(Number of Respondents) ///
scheme(s1color)
graph export .\graphs\Figure1.png, as(png) replace
graph export .\graphs\Figure1.ps, as(ps) mag(160) logo(off) orientation(landscape) replace

// REMOVE THE "one" VARIABLE
drop one
```

The Pilot Study

- Descriptive Statistics
- **Item Response Characteristics**
- Reliability
- Validity
- Dimensionality and Exploratory Factor Analysis

Item Response Theory

- What are the characteristics of each item?
- How do they relate to the overall test score?
- Are some items more predictive than others?

The Latent Trait: Depression

- The Idea
  - We **observe** the responses to the 20 questions
  - We would like to use these responses to **infer** something about a **latent trait** which we will call depression.
- The Mechanics
  - Dichotomize each question as Yes/No based on their ordinal response
  - Sum the dichotomized responses to create a total score
  - The total score is our **latent variable** (theta)

My statistical software makes me….

Question 1: …feel sad.

These responses suggest no depression and are coded as 0 (No)

- [x] Strongly Disagree
- [ ] Disagree
- [ ] Neutral

These responses suggest the presence of depression and are coded as 1 (Yes)

- [ ] Agree
- [ ] Strongly Agree

Create A Dichotomous Variable For Each Question

```
// CREATE A DICHOTOMOUS VARIABLE FOR EACH QUESTION (1,2,3 = 0 & 4,5 = 1)
forvalues i = 1(1)20 {
recode qu`i'_t1 (1/3=0 "No") (4/5=1 "Yes"), gen(qu`i'_t1_bin)
local TempLabel : variable label qu`i'_t1
label var qu`i'_t1_bin "`TempLabel' (binary)"
}
```

```
. tab qu1_t1 qu1_t1_bin
```

...feel sad	...feel sad (binary) No	Yes	Total
StronglyDisagree	2	0	2
Disagree	22	0	22
Neutral	46	0	46
Agree	0	25	25
StronglyAgree	0	5	5
Total	70	30	100

Create The Latent Variable (theta)

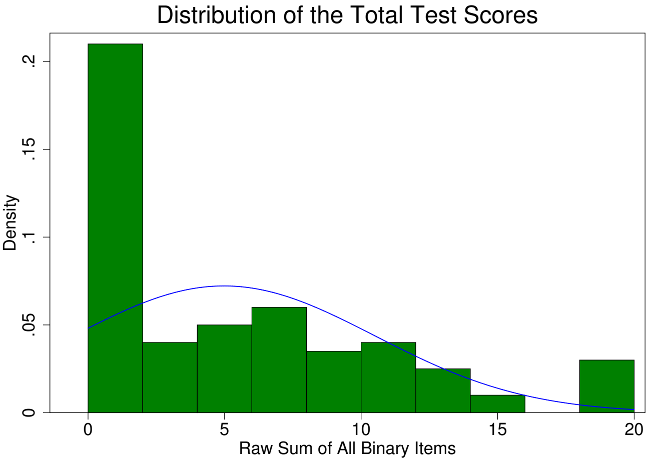
```
// SUM THE 20 BINARY QUESTIONS
egen TotalBinary = rowtotal(qu1_t1_bin - qu20_t1_bin)
label var TotalBinary "Sum of all 20 binary question scores"
```

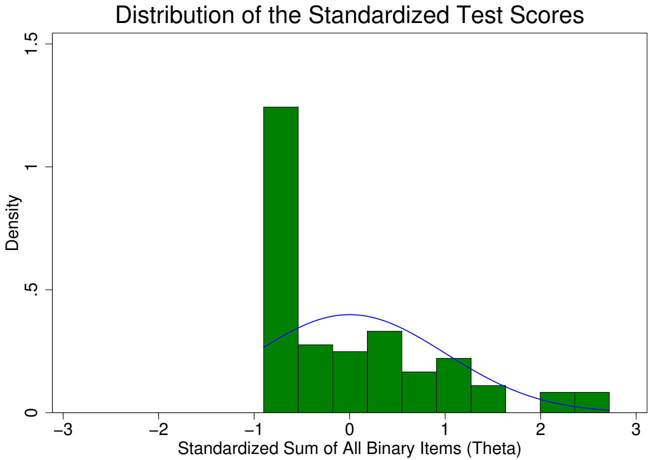
```
Responses for Participant #1
-------------------------------------------------------
...feel sad (binary) =                                0
...feel pessimistic about the future (binary) =       0
...feel like a failure (binary) =                     0
...feel dissatisfied (binary) =                       0
...feel guilty or unworthy (binary) =                 0
...feel that I am being punished (binary) =           0
...feel disappointed in myself (binary) =             0
...feel am very critical of myself (binary) =         0
...feel like harming myself (binary) =                0
...feel like crying more than usual (binary) =        0
...become annoyed or irritated easily (binary) =      0
...have lost interest in other people (binary) =      0
...have trouble making decisions (binary) =           1
...feel unattractive (binary) =                       0
...feel like not working (binary) =                   0
...have trouble sleeping (binary) =                   1
...feel tired or fatigued (binary) =                  0
...makes my appetite lower than usual (binary) =      0
...concerned about my health (binary) =               1
...experience decreased libido (binary) =             0
-------------------------------------------------------
Sum of all 20 binary question scores =                3
```

Create The Latent Variable (theta)

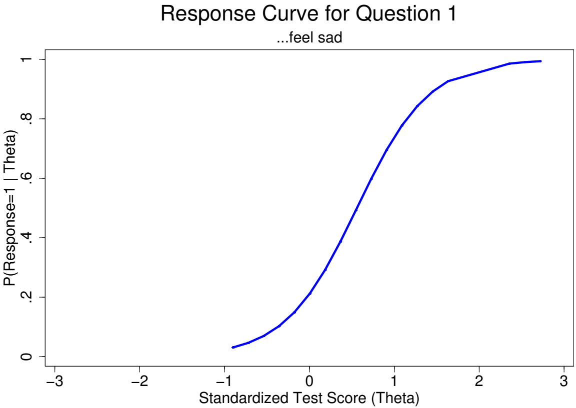
```
// SUM THE 20 BINARY QUESTIONS
egen TotalBinary = rowtotal(qu1_t1_bin - qu20_t1_bin)
label var TotalBinary "Sum of all 20 binary question scores"
```

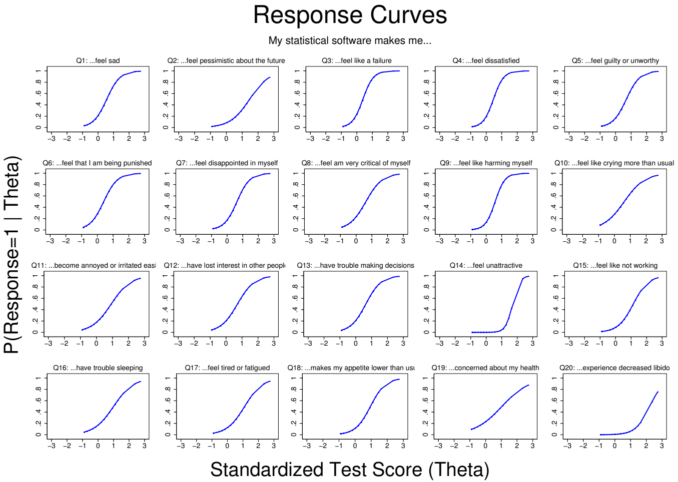
```
Responses for Participant #1
----------------------------------------------------------
...feel sad (binary) =                                   0
...feel pessimistic about the future (binary) =          0
...feel like a failure (binary) =                        0
...feel dissatisfied (binary) =                          0
...feel guilty or unworthy (binary) =                    0
...feel that I am being punished (binary) =              0
...feel disappointed in myself (binary) =                0
...feel am very critical of myself (binary) =            0
...feel like harming myself (binary) =                   0
...feel like crying more than usual (binary) =           0
...become annoyed or irritated easily (binary) =         0
...have lost interest in other people (binary) =         0
...have trouble making decisions (binary) =              1
...feel unattractive (binary) =                          0
...feel like not working (binary) =                      0
...have trouble sleeping (binary) =                      1
...feel tired or fatigued (binary) =                     0
...makes my appetite lower than usual (binary) =         0
...concerned about my health (binary) =                  1
...experience decreased libido (binary) =                0
----------------------------------------------------------
Sum of all 20 binary question scores =                   3
```


Distribution of the Total Test Scores
Density
0
.05
.1
.15
.2
0
5
10
15
20
Raw Sum of All Binary Items


Distribution of the Standardized Test Scores
Density
0
.5
1
1.5
−3
−2
−1
0
1
2
3
Standardized Sum of All Binary Items (Theta)

We can then fit a logistic regression model for each binary outcome using the latent variable (standardized test score) as a continuous predictor variable:




Response Curves
My statistical software makes me...
Q1: ...feel sad
Q2: ...feel pessimistic about the future
Q3: ...feel like a failure
Q4: ...feel dissatisfied
Q5: ...feel guilty or unworthy
Q6: ...feel that I am being punished
Q7: ...feel disappointed in myself
Q8: ...feel am very critical of myself
Q9: ...feel like harming myself
Q10: ...feel like crying more than usual
Q11: ...become annoyed or irritated easi
Q12: ...have lost interest in other peopl
Q13: ...have trouble making decisions
Q14: ...feel unattractive
Q15: ...feel like not working
Q16: ...have trouble sleeping
Q17: ...feel tired or fatigued
Q18: ...makes my appetite lower than usi
Q19: ...concerned about my health
Q20: ...experience decreased libido
P(Response=1 | Theta)
Standardized Test Score (Theta)

The Rasch Model

- Since each individual responds to all 20 questions, we could conceptualize this as a multilevel model.
- Could fit a mixed-effects logistic regression model with a coefficient for each question.
- The simplest form of this kind of model is known as The Rasch Model.

Reshape the Data From Wide to Long Format

```
list id qu1_t1_bin-qu10_t1_bin if id==1, nolabel
```

	id	qu1_t1~n	qu2_t1~n	qu3_t1~n	qu4_t1~n	qu5_t1~n	qu6_t1~n	qu7_t1~n	qu8_t1~n	qu9_t1~n	qu10_t~n
1.	1	0	0	0	0	0	0	0	0	0	0

```
. reshape long qu@_t1_bin, i(id) j(question)
. list id question qu_t1_bin if id==1, nolab
```

	id	question	qu_t1_~n
1.	1	1	0
2.	1	2	0
3.	1	3	0
4.	1	4	0
5.	1	5	0
6.	1	6	0
7.	1	7	0
8.	1	8	0
9.	1	9	0
10.	1	10	0
11.	1	11	0
12.	1	12	0
13.	1	13	1
14.	1	14	0
15.	1	15	0
16.	1	16	1
17.	1	17	0
18.	1	18	0
19.	1	19	1
20.	1	20	0

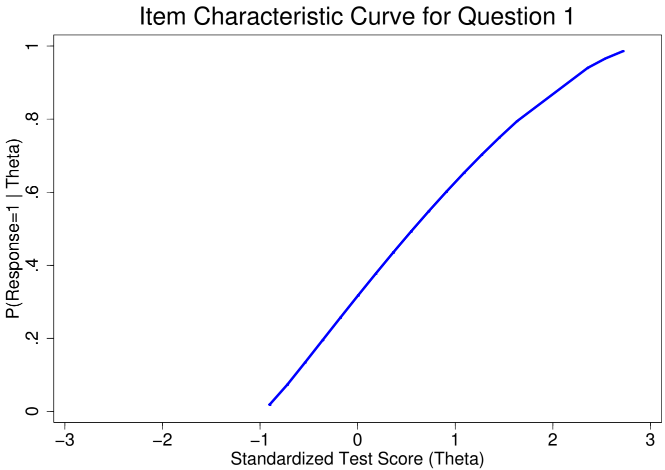
Create Indicator Variables for Each Question

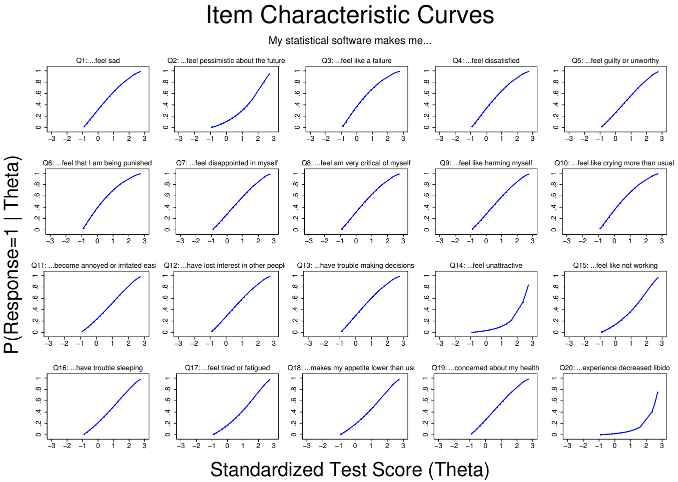
```
forvalues num =1/20{
      gen Delta`num' = -(question==`num')
}

. list id qu_t1_bin question Delta1-Delta10 if id==1, nodisplay noobs nolabel
```

id	qu_t1_~n	question	Delta1	Delta2	Delta3	Delta4	Delta5	Delta6	Delta7	Delta8	Delta9	Delta10
1	0	1	-1	0	0	0	0	0	0	0	0	0
1	0	2	0	-1	0	0	0	0	0	0	0	0
1	0	3	0	0	-1	0	0	0	0	0	0	0
1	0	4	0	0	0	-1	0	0	0	0	0	0
1	0	5	0	0	0	0	-1	0	0	0	0	0
1	0	6	0	0	0	0	0	-1	0	0	0	0
1	0	7	0	0	0	0	0	0	-1	0	0	0
1	0	8	0	0	0	0	0	0	0	-1	0	0
1	0	9	0	0	0	0	0	0	0	0	-1	0
1	0	10	0	0	0	0	0	0	0	0	0	-1
1	0	11	0	0	0	0	0	0	0	0	0	0
1	0	12	0	0	0	0	0	0	0	0	0	0
1	1	13	0	0	0	0	0	0	0	0	0	0
1	0	14	0	0	0	0	0	0	0	0	0	0
1	0	15	0	0	0	0	0	0	0	0	0	0
1	1	16	0	0	0	0	0	0	0	0	0	0
1	0	17	0	0	0	0	0	0	0	0	0	0
1	0	18	0	0	0	0	0	0	0	0	0	0
1	1	19	0	0	0	0	0	0	0	0	0	0
1	0	20	0	0	0	0	0	0	0	0	0	0

Fit the Rasch Model with -xtmelogit-

```
xtmelogit qu_t1_bin Delta1-Delta20, noconstant || id:, covariance(identity) nolog

Mixed-effects logistic regression               Number of obs      =      2000
Group variable: id                              Number of groups   =       100
                                                Obs per group: min =        20
                                                               avg =      20.0
                                                               max =        20
Integration points =   7                        Wald chi2(20)      =    117.44
Log likelihood = -765.69974                     Prob > chi2        =    0.0000

   qu_t1_bin |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      Delta1 |   1.805149   .4280238     4.22   0.000     .9662381    2.644061
      Delta2 |   3.171066   .4758495     6.66   0.000     2.238418    4.103714
      Delta3 |   1.555716   .4238328     3.67   0.000     .7250189    2.386413
      Delta4 |    1.72126   .4264998     4.04   0.000      .885336    2.557185
      Delta5 |   2.062939   .4335186     4.76   0.000     1.213258     2.91262
      Delta6 |    1.47382   .4226682     3.49   0.000     .6454058    2.302235
      Delta7 |   1.975836   .4315174     4.58   0.000     1.130078    2.821595
      Delta8 |   1.805149   .4280238     4.22   0.000     .9662382    2.644061
      Delta9 |   1.975836   .4315174     4.58   0.000     1.130077    2.821595
     Delta10 |   1.638157   .4251067     3.85   0.000     .8049635    2.471351
     Delta11 |   2.241544   .4381266     5.12   0.000     1.382832    3.100256
     Delta12 |   1.975836   .4315174     4.58   0.000     1.130077    2.821595
     Delta13 |   1.889959   .4296914     4.40   0.000      1.04778    2.732139
     Delta14 |   4.444528   .5805036     7.66   0.000     3.306762    5.582295
     Delta15 |   2.829789   .4589574     6.17   0.000     1.930249    3.729329
     Delta16 |   2.333454   .4407813     5.29   0.000     1.469538    3.197369
     Delta17 |   2.622612   .4505291     5.82   0.000     1.739592    3.505633
     Delta18 |   2.523699   .4469441     5.65   0.000     1.647705    3.399694
     Delta19 |   2.062939   .4335186     4.76   0.000     1.213258     2.91262
     Delta20 |   4.946324   .6431941     7.69   0.000     3.685686    6.206961
------------------------------------------------------------------------------

------------------------------------------------------------------------------
  Random-effects Parameters  |   Estimate   Std. Err.     [95% Conf. Interval]
-----------------------------+------------------------------------------------
id: Identity                 |
                   sd(_cons) |   2.777908   .3097652      2.232545    3.456492
------------------------------------------------------------------------------
LR test vs. logistic regression: chibar2(01) =   643.87 Prob>=chibar2 = 0.0000
```


Item Characteristic Curve for Question 1
P(Response=1 | Theta)
0
.2
.4
.6
.8
1
−3
−2
−1
0
1
2
3
Standardized Test Score (Theta)


Item Characteristic Curves
My statistical software makes me...
Q1: ...feel sad
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Q12: ...have lost interest in other peopl
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Q19: ...concerned about my health
Q20: ...experience decreased libido
P(Response=1 | Theta)
Standardized Test Score (Theta)

Extensions of the Rasch Model

- The Rasch Model
  - One parameter logistic or 1PL model
  - Parameter quantifies the difficulty of the item
- Two parameter logistic (2PL) model
  - A second parameter accounts for guessing
- Three parameter logistic (3PL) model
  - A third parameter accounts for the ability of the question to discriminate between people with high and low values of the latent trait

User Written IRT Commands

- -raschtest- by Jean-Benoit Hardouin
  - Fixed and random effects Rasch Models
  - Stata Journal (2007) Volume 7, Number 1, pp. 22-44
- Nonparametric IRT models by Jean-Benoit Hardouin, Angèlique Bonnaud-Antignac and Vèronique Sèbille
  - Trace lines, Mokken scales, Loevinger coefficients, Guttman errors
  - Stata Journal (2011) Volume 11, Number 1, pp. 30-51
- -openirt- by Tristan Zajonc
  - Fits 1PL, 2PL and 3PL models
  - Maximum Likelihood (ML)
  - Bayesian Expected a Posterior (EAP)
  - Plausible Values (Multiple Imputation)

The Pilot Study

- Descriptive Statistics
- Item Response Characteristics
- **Reliability**
- Validity
- Dimensionality and Exploratory Factor Analysis

Reliability

We would like for our depression index to be **reliable** in the sense that repeated administration of the instrument would yield similar results.

- Test-Retest Reliability
  - Could be quantified using canonical correlation
  - Quantified by the intraclass correlation coefficient (ICC)
- Split-half reliability
  - Quantified by the Spearman-Brown prophesy formula
- Internal Consistency
  - Quantified by Cronbach's alpha

Test-Retest Reliability

- Perhaps the most obvious way to assess the reliability of a psychometric instrument is to administer it twice to the same group of people and examine the degree of agreement
- Could quantify reliability as the canonical correlation between the two sets of repeated questions
- Could consider repeated responses within a participant as longitudinal data and compute the intraclass correlation coefficient (ICC) based on a mixed-effects linear model

Canonical Correlation

- Each participant was given the Stata Depression Index twice with a 6-month interval between tests.
- The canonical correlation between the two sets of questions was then estimated:

```
canon (qu1_t1-qu20_t1) (qu1_t2-qu20_t2), lc(1)

Canonical correlations:
  0.9907  0.7895  0.7468  0.6918  0.6207  0.5908  0.5407  0.4998  0.4755  0.4131

Tests of significance of all canonical correlations
                         Statistic      df1      df2            F     Prob>F
         Wilks' lambda  .000128345      400  914.629       2.0138     0.0000 a
        Pillai's trace    4.82041       400     1580       1.2544     0.0016 a
Lawley-Hotelling trace    60.0375       400     1162       8.7204     0.0000 a
    Roy's largest root    53.2379        20       79     210.2896     0.0000 u

                            e = exact, a = approximate, u = upper bound on F
```

Intraclass Correlation Coefficient (ICC)

- We could manually compute the intraclass correlation coefficient for Question 1 using Stata's -xtmixed- command:

```
. xtmixed qu1_t, || id:, covariance(identity) variance nolog

Mixed-effects ML regression                     Number of obs      =       200
Group variable: id                              Number of groups   =       100
                                                Obs per group: min =         2
                                                               avg =       2.0
                                                               max =         2
                                                Wald chi2(0)       =         .
Log likelihood = -244.98455                     Prob > chi2        =         .
------------------------------------------------------------------------------
       qu1_t |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       _cons |      3.055   .0744631    41.03   0.000     2.909055    3.200945
------------------------------------------------------------------------------
------------------------------------------------------------------------------
  Random-effects Parameters  |   Estimate   Std. Err.     [95% Conf. Interval]
-----------------------------+------------------------------------------------
id: Identity                 |
                   var(_cons) |    .346975   .0837256      .216223    .5567938
-----------------------------+------------------------------------------------
               var(Residual) |       .415   .0586899     .3145358     .547553
------------------------------------------------------------------------------
LR test vs. linear regression: chibar2(01) =    23.24 Prob >= chibar2 = 0.0000
. estat icc
Intraclass correlation
------------------------------------------------------------------------------
                       Level |        ICC   Std. Err.     [95% Conf. Interval]
-----------------------------+------------------------------------------------
                          id |   .4553627   .0792645      .308863    .6100182
------------------------------------------------------------------------------
```

Intraclass Correlation Coefficient (ICC)

- But it would be more convenient to simply use Stata's built-in -icc- command:

```
. icc qu1_t id time

Intraclass correlations
Two-way random-effects model
Absolute agreement

Random effects: id                Number of targets =       100
Random effects: time              Number of raters  =         2

------------------------------------------------------------
               qu1_t |        ICC       [95% Conf. Interval]
---------------------+--------------------------------------
          Individual |   .4587313       .2890881    .6004393
             Average |   .6289456       .4485157    .7503431
------------------------------------------------------------
F test that ICC=0.00: F(99.0, 99.0) = 2.69        Prob > F = 0.000

Note: ICCs estimate correlations between individual measurements
      and between average measurements made on the same target.
```

Intraclass Correlation Coefficient (ICC)

- We could even loop through all 20 questions quickly:

```
forvalues i = 1(1)20 {
    quietly icc qu`i'_t id time
    disp as text "The ICC for Question `i' = " _col(30) as result %5.4f r(icc_i)
}

The ICC for Question 1 =     0.4587
The ICC for Question 2 =     0.4367
The ICC for Question 3 =     0.5210
The ICC for Question 4 =     0.5450
The ICC for Question 5 =     0.5847
The ICC for Question 6 =     0.5299
The ICC for Question 7 =     0.4914
The ICC for Question 8 =     0.4329
The ICC for Question 9 =     0.5044
The ICC for Question 10 =    0.4634
The ICC for Question 11 =    0.4848
The ICC for Question 12 =    0.3827
The ICC for Question 13 =    0.4706
The ICC for Question 14 =    0.3806
The ICC for Question 15 =    0.3376
The ICC for Question 16 =    0.4766
The ICC for Question 17 =    0.4859
The ICC for Question 18 =    0.3879
The ICC for Question 19 =    0.4704
The ICC for Question 20 =    0.2491
```

Split-Half Reliability

- If we could assume that we have two equivalent forms of the instrument, we could simply calculate the correlation between those two "halves" of the test.
- For example, we could examine the correlation between the **even numbered questions** and the **odd numbered questions**.

```
egen TotalEven = rowtotal(qu2_t1 qu4_t1 qu6_t1 qu8_t1 qu10_t1 qu12_t1 qu14_t1 qu16_t1 qu18_t1 qu20_t1)

egen TotalOdd = rowtotal(qu1_t1 qu3_t1 qu5_t1 qu7_t1 qu9_t1 qu11_t1 qu13_t1 q u15_t1 qu17_t1 qu19_t1)


corr TotalEven TotalOdd
(obs=100)

             | TotalE~n TotalOdd
-------------+------------------
   TotalEven |   1.0000
    TotalOdd |   0.9586   1.0000
```

Split-Half Reliability

Because we have correlated half of our test with the other half, it is common to use the Spearman-Brown Prophesy Formula to assess split-half reliability:

$$R_{sb} = \frac{2r_{sh}}{(1 + r_{sh})}$$

```
local sbpf = 2*r(rho) / (1+r(rho))
disp "The Spearman-Brown Prophesy Reliability Estimate = " as result \%5.4f `sbpf'
The Spearman-Brown Prophesy Reliability Estimate = 0.9788
```

Split-Half Reliability

- Unfortunately, there is nothing sacred about odd and even numbered questions.
- If the questions were numbered differently, the estimate of the Spearman-Brown Prophesy Formula would change.
- It would be nice to get the same estimate regardless of the way the questions are numbered.

Cronbach's Alpha

Cronbach's Alpha is a function of the average covariance (or correlation) among all possible combinations of the variables.

```
alpha qu1_t1-qu20_t1


Test scale = mean(unstandardized items)

Average interitem covariance:     .3402467
Number of items in the scale:           20
Scale reliability coefficient:      0.9476
```

The Pilot Study

- Descriptive Statistics
- Item Response Characteristics
- Reliability
- **Validity**
- Dimensionality and Exploratory Factor Analysis

Validity

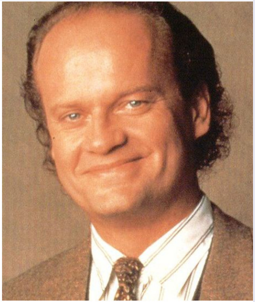
- While there are different kinds of validity, essentially we would like to be able to say that our instrument measures what we think we are measuring.
- One way to assess the validity of our instrument is to examine the correlation between our index and other known indices.
- For example, we might compare the results of the Stata Depression Index with the ratings of trained psychiatric professionals.

Validity

- To assess the validity of the Stata Depression Index, we wanted to compare our results to the rating of a psychiatrist.
- However, since psychiatrists are much like economists (no explanation necessary), we decided to hire two psychiatrists and compare their inter-rater reliability before comparing their ratings to our instrument.

Inter-Rater Reliability

Dr. Hannibal Lector and Dr. Frasier Crane were hired to interview each employee at StataCorp and rate them in terms of none, mild, moderate or severe depression.



Cohen's Kappa Statistic

We can tabulate the diagnoses of Dr Lector and Dr Crane and the first thing we notice is that their diagnoses tend to fall on the main diagonal of the table.

```
. tab DrLector DrCrane

          Dr |
    Lector's |             Dr Crane's Diagnosis
   Diagnosis |      None       Mild   Moderate     Severe |     Total
-------------+--------------------------------------------+----------
        None |         2          5          0          0 |         7
        Mild |        20         45          0          0 |        65
    Moderate |         0          8         14          0 |        22
      Severe |         0          0          3          2 |         5
-------------+--------------------------------------------+----------
       Total |        22         58         17          2 |        99
```

The second thing we notice is that our sample size dropped from n=100 to n=99.

Cohen's Kappa Statistic

It appears that one of Dr. Lector's ratings is missing. This matter is still under investigation.

```
. tab DrLector DrCrane, missing
```

Dr Lector's Diagnosis	Dr Crane's Diagnosis None	Mild	Moderate	Severe	Total
None	2	5	0	0	7
Mild	20	45	0	0	65
Moderate	0	8	14	0	22
Severe	0	0	3	2	5
.	1	0	0	0	1
Total	23	58	17	2	100

Cohen's Kappa Statistic

Because two raters can agree with each simply due to chance, we compute Cohen's Kappa statistic to assess the chance-corrected measure of inter-rater agreement:

```
. kap DrLector DrCrane
```

Agreement	Expected Agreement	Kappa	Std. Err.	Z	Prob>Z
63.64%	43.95%	0.3512	0.0659	5.33	0.0000

A Kappa of 0.3512 is generally considered poor agreement among raters. We are disappointed but not surprised.

Cohen's Kappa Statistic

However, we notice that very few ratings fall on the off-diagonals of the table. So we down-weight those cells in the table and compute a weighted kappa statistic:

```
. kapwgt MyWeight 1 \ .8 1 \ 0 0 1 \ 0 0 .8 1          //   (define matrix)

. kapwgt MyWeight

 1.0000
 0.8000 1.0000
 0.0000 0.0000 1.0000
 0.0000 0.0000 0.8000 1.0000

. kap DrLector DrCrane, wgt(MyWeight)

Ratings weighted by:
   1.0000    0.8000    0.0000    0.0000
   0.8000    1.0000    0.0000    0.0000
   0.0000    0.0000    1.0000    0.8000
   0.0000    0.0000    0.8000    1.0000

                 Expected
Agreement       Agreement      Kappa    Std. Err.         Z      Prob>Z
-----------------------------------------------------------------------
  86.26%          59.99%      0.6566      0.0842        7.80      0.0000
```

Combine ratings into a "Diagnosis" variable

We elected to combine the ratings of Dr Lector and Dr Crane by creating new variable called "diagnosis":

```
. tab DrLector DrCrane

         Dr |
   Lector's |               Dr Crane's Diagnosis
  Diagnosis |      None       Mild   Moderate     Severe |     Total
------------+--------------------------------------------+----------
       None |         2          5          0          0 |         7 
       Mild |        20         45          0          0 |        65 
   Moderate |         0          8         14          0 |        22 
     Severe |         0          0          3          2 |         5 
------------+--------------------------------------------+----------
      Total |        22         58         17          2 |        99 

. gen diagnosis = 0

. replace diagnosis = 1 if DrLector>=3 | DrCrane>=3
(28 real changes made)
```

Association Between Our Index and Diagnosis

Next we wanted to examine the association between the Stata Depression Index and the diagnosis based on Drs. Lector and Crane.

```
. tab qu1_t1 diagnosis, all exact

                 |  Diagnosis based on
                 | Drs Lector and Crane
       ...feel sad | NotDepres  Depressed |     Total
-----------------+----------------------+----------
StronglyDisagree |         2          0 |         2
        Disagree |        22          0 |        22
         Neutral |        37          9 |        46
           Agree |        11         14 |        25
   StronglyAgree |         0          5 |         5
-----------------+----------------------+----------
           Total |        72         28 |       100

          Pearson chi2(4) =  33.5361   Pr = 0.000
 likelihood-ratio chi2(4) =  38.8171   Pr = 0.000
               Cramer's V =   0.5791
                    gamma =   0.8705  ASE = 0.057
          Kendall's tau-b =   0.5104  ASE = 0.060
           Fisher's exact =                 0.000
```

Point-Biserial Correlation

- When one variable is continuous and the other is binary, a popular measure of association frequently used in psychometrics is the point-biserial correlation coefficient.
- This is easily calculated in one of two ways:
  - Student's t-test
  - Linear Regression

Point-Biserial Correlation Using Student's t-test

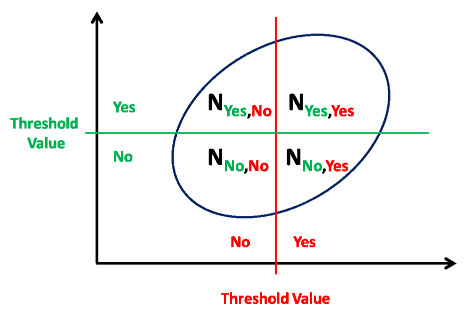
```
. ttest qu1_t1, by(diagnosis)

Two-sample t test with equal variances

   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
NotDepre |      72    2.791667    .0860758    .7303771    2.620036    2.963297
Depresse |      28    3.857143    .1332766    .7052336    3.583682    4.130604
---------+--------------------------------------------------------------------
combined |     100        3.09    .0865675    .8656754    2.918231    3.261769
---------+--------------------------------------------------------------------
    diff |           -1.065476    .1611445               -1.385262   -.7456902
------------------------------------------------------------------------------
    diff = mean(NotDepre) - mean(Depresse)                        t =  -6.6119
Ho: diff = 0                                     degrees of freedom =       98

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 1.0000

. local rsquared = (r(t)^2) / ((r(t)^2)+r(df_t))

. disp as text "The Point-Biserial Correlation based on the t-test = " as result %5.4f sqrt(`rsquared')

The Point-Biserial Correlation based on the t-test = 0.5554
```

Point-Biserial Correlation Using Linear Regression

```
. regress qu1_t1 diagnosis

      Source |       SS       df       MS              Number of obs =     100
-------------+------------------------------           F(  1,    98) =   43.72
       Model |  22.8864286     1  22.8864286           Prob > F      =  0.0000
    Residual |  51.3035714    98  .523505831           R-squared     =  0.3085
-------------+------------------------------           Adj R-squared =  0.3014
       Total |       74.19    99  .749393939           Root MSE      =  .72354

------------------------------------------------------------------------------
      qu1_t1 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
   diagnosis |   1.065476   .1611445     6.61   0.000     .7456902    1.385262
       _cons |   2.791667   .0852697    32.74   0.000     2.622452    2.960882
------------------------------------------------------------------------------

. local pointbs = sqrt(e(r2))

. disp as text "The Point-Biserial Correlation coefficient = " as result %5.4f `pointbs'

The Point-Biserial Correlation coefficient = 0.5554
```

Tetrachoric Correlation

When two dichotomous variables are conceptualized as having an underlying bivariate normal distribution, the association between them can be estimated using the tetrachoric correlation coefficient.



First, Dichotomize the Questions

My statistical software makes me….

Question 1: …feel sad.

These responses suggest no depression and are coded as 0 (No)

- [x] Strongly Disagree
- [ ] Disagree
- [ ] Neutral

These responses suggest the presence of depression and are coded as 1 (Yes)

- [ ] Agree
- [ ] Strongly Agree

Tetrachoric Correlation Using -tetrachoric-

```
. tab qu1_t1_bin diagnosis

 Question 1, |  Diagnosis based on
Time 1 Coded | Drs Lector and Crane
   as Binary | NotDepres  Depressed |     Total
-------------+----------------------+----------
NotDepressed |        61          9 |        70
   Depressed |        11         19 |        30
-------------+----------------------+----------
       Total |        72         28 |       100


. tetrachoric qu1_t1_bin diagnosis

   Number of obs =       100
 Tetrachoric rho =       0.7415
       Std error =       0.0971

Test of Ho: qu1_t1_bin and diagnosis are independent
 2-sided exact P =       0.0000
```

Tetrachoric Correlation Using -biprobit-

```
. biprobit qu1_t1_bin diagnosis

Bivariate probit regression                       Number of obs   =        100
                                                  Wald chi2(0)    =          .
Log likelihood =  -107.6575                       Prob > chi2     =          .

------------------------------------------------------------------------------
             |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
qu1_t1_bin   |
       _cons |  -.5244005   .1317996    -3.98   0.000     -.782723    -.266078
-------------+----------------------------------------------------------------
diagnosis    |
       _cons |  -.5828415   .1333832    -4.37   0.000    -.8442677   -.3214153
-------------+----------------------------------------------------------------
     /athrho |   .9538723   .2157823     4.42   0.000     .5309467    1.376798
-------------+----------------------------------------------------------------
         rho |   .7415311   .0971304                      .4861044    .8802322
------------------------------------------------------------------------------
Likelihood-ratio test of rho=0:     chi2(1) =  25.4485    Prob > chi2 = 0.0000
```

Correlation Between Each Item and Diagnosis

Question	Pearson	Biserial	Tetrachoric
Question 1	0.5554	0.5554	0.7415
Question 2	0.5894	0.5894	0.8568
Question 3	0.5635	0.5635	0.8286
Question 4	0.6043	0.6043	0.8936
Question 5	0.5912	0.5912	0.8009
Question 6	0.5563	0.5563	0.7684
Question 7	0.5971	0.5971	0.8260
Question 8	0.4905	0.4905	0.7415
Question 9	0.5552	0.5552	0.8260
Question 10	0.4904	0.4904	0.7029
Question 11	0.4448	0.4448	0.6910
Question 12	0.4993	0.4993	0.7310
Question 13	0.5262	0.5262	0.7611
Question 14	0.5287	0.5287	1.0000
Question 15	0.5161	0.5161	0.7451
Question 16	0.4871	0.4871	0.5935
Question 17	0.4860	0.4860	0.6809
Question 18	0.4834	0.4834	0.7128
Question 19	0.4710	0.4710	0.5133
Question 20	0.5497	0.5497	1.0000

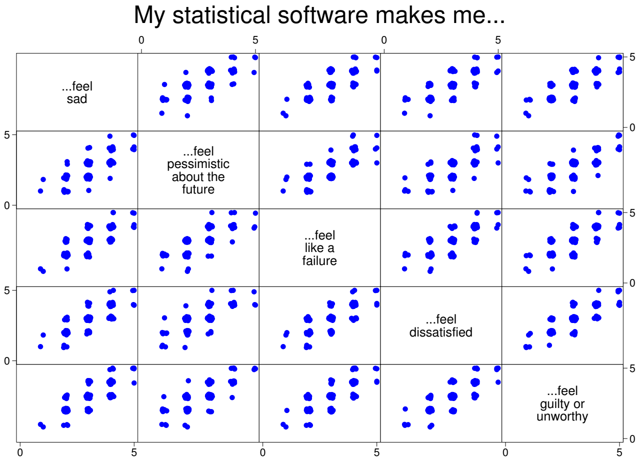
The Pilot Study

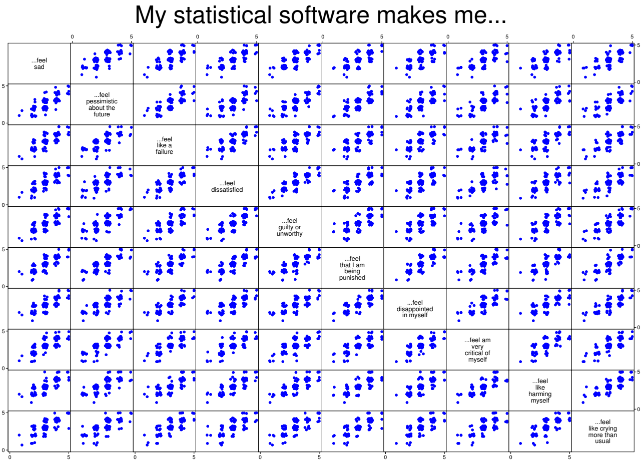
- Descriptive Statistics
- Item Response Characteristics
- Reliability
- Validity
- **Dimensionality and Exploratory Factor Analysis**

Dimensionality and Exploratory Factor Analysis

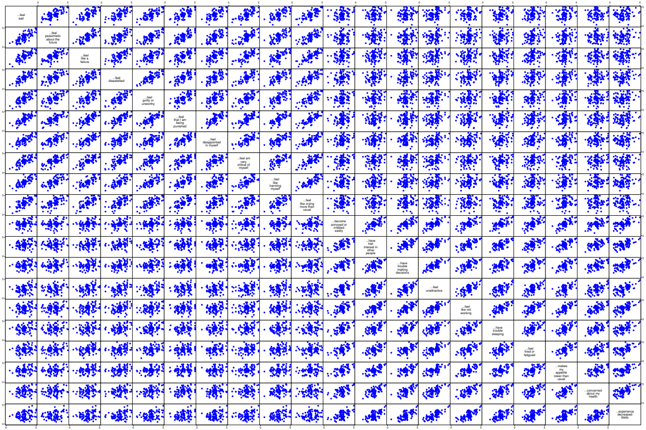
- The Cronbach's Alpha estimated earlier suggests a high degree of correlation among the questions
- It might be useful to look for patterns among these correlations
- There might be groups of questions that measure some underlying latent attribute
- We could treat the questions as ordinal or as continuous variables

Since all correlation coefficients measure the degree of linear relationship between variables, it might be wise to visually inspect scatterplots of the variables before calculating various correlation matrices...


My statistical software makes me...
...feel sad
...feel pessimistic about the future
...feel like a failure
...feel dissatisfied
...feel guilty or unworthy
0
5


My statistical software makes me...
...feel sad
...feel pessimistic about the future
...feel like a failure
...feel dissatisfied
...feel guilty or unworthy
...feel that I am being punished
...feel disappointed in myself
...feel am very critical of myself
...feel like harming myself
...feel like crying more than usual
0
5

My statistical software makes me...



Spearman Rank Correlation Matrix

```
. quietly spearman qu1_t1-qu20_t1

. matrix list r(Rho), format(%4.2f) nonames noheader

  1.00
  0.75  1.00
  0.74  0.78  1.00
  0.76  0.75  0.78  1.00
  0.75  0.76  0.71  0.76  1.00
  0.76  0.78  0.79  0.81  0.77  1.00
  0.73  0.71  0.76  0.72  0.66  0.78  1.00
  0.73  0.74  0.78  0.76  0.69  0.77  0.71  1.00
  0.78  0.73  0.77  0.76  0.75  0.79  0.74  0.77  1.00
  0.75  0.74  0.75  0.74  0.77  0.80  0.71  0.76  0.78  1.00
  0.25  0.20  0.29  0.34  0.30  0.23  0.26  0.20  0.28  0.18  1.00
  0.19  0.09  0.28  0.33  0.30  0.15  0.28  0.22  0.30  0.12  0.71  1.00
  0.21  0.18  0.27  0.38  0.30  0.20  0.25  0.24  0.30  0.14  0.77  0.72  1.00
  0.29  0.17  0.30  0.39  0.32  0.28  0.29  0.28  0.33  0.22  0.72  0.69  0.74 1.00
  0.21  0.12  0.25  0.34  0.25  0.20  0.28  0.20  0.28  0.15  0.72  0.77  0.75 0.76  1.00
  0.26  0.19  0.27  0.30  0.38  0.26  0.32  0.25  0.29  0.20  0.68  0.69  0.66 0.62  0.75  1.00
  0.19  0.19  0.34  0.32  0.30  0.20  0.28  0.24  0.25  0.15  0.68  0.66  0.71 0.71  0.69  0.63  1.00
  0.23  0.15  0.25  0.34  0.32  0.14  0.25  0.21  0.26  0.14  0.69  0.71  0.70 0.66  0.74  0.68  0.69  1.00
  0.12  0.06  0.19  0.25  0.24  0.22  0.25  0.15  0.20  0.08  0.64  0.64  0.70 0.62  0.73  0.66  0.64  0.67  1.00
  0.19  0.14  0.21  0.30  0.25  0.23  0.24  0.24  0.33  0.14  0.66  0.65  0.73 0.74  0.73  0.67  0.63  0.66  0.69  1.00
```

Kendall's Tau-a Rank Correlation Matrix

```
. quietly ktau qu1_t1-qu20_t1, stats(taua)

. matrix list r(Tau_a), format(%4.2f) nonames noheader

  0.68
  0.47  0.69
  0.47  0.49  0.69
  0.49  0.48  0.50  0.69
  0.48  0.48  0.45  0.49  0.69
  0.48  0.50  0.51  0.52  0.49  0.70
  0.45  0.44  0.48  0.44  0.41  0.49  0.65
  0.45  0.46  0.48  0.48  0.43  0.48  0.43  0.65
  0.49  0.45  0.48  0.47  0.47  0.49  0.45  0.46  0.65
  0.48  0.46  0.47  0.46  0.49  0.51  0.43  0.47  0.48  0.67
  0.15  0.11  0.17  0.20  0.17  0.13  0.14  0.12  0.16  0.10  0.62
  0.11  0.05  0.16  0.19  0.17  0.08  0.16  0.13  0.17  0.07  0.41  0.62
  0.12  0.10  0.16  0.22  0.17  0.11  0.14  0.13  0.16  0.08  0.46  0.42  0.63
  0.17  0.10  0.17  0.23  0.19  0.17  0.17  0.17  0.19  0.12  0.43  0.42  0.45 0.67
  0.12  0.07  0.15  0.20  0.15  0.12  0.16  0.11  0.16  0.09  0.43  0.46  0.45 0.46  0.65
  0.15  0.11  0.16  0.17  0.22  0.15  0.19  0.14  0.17  0.11  0.40  0.41  0.39 0.37  0.45  0.64
  0.11  0.11  0.20  0.18  0.17  0.11  0.16  0.13  0.14  0.08  0.38  0.37  0.41 0.42  0.41  0.36  0.60
  0.13  0.08  0.14  0.19  0.17  0.08  0.13  0.12  0.14  0.07  0.38  0.40  0.39 0.37  0.42  0.38  0.37  0.56
  0.07  0.03  0.11  0.15  0.14  0.13  0.14  0.08  0.12  0.05  0.37  0.37  0.42 0.38  0.44  0.40  0.37  0.38  0.66
  0.11  0.08  0.12  0.18  0.15  0.14  0.14  0.14  0.19  0.08  0.39  0.39  0.45 0.46  0.45  0.41  0.37  0.37  0.42  0.69
```

Kendall's Tau-b Rank Correlation Matrix

```
. quietly ktau qu1_t1-qu20_t1, stats(taub)

. matrix list r(Tau_b), format(%4.2f) nonames noheader

  1.00
  0.69  1.00
  0.68  0.71  1.00
  0.71  0.69  0.73  1.00
  0.70  0.70  0.65  0.70  1.00
  0.70  0.72  0.73  0.75  0.70  1.00
  0.67  0.66  0.71  0.66  0.60  0.73  1.00
  0.67  0.68  0.72  0.71  0.64  0.72  0.66  1.00
  0.73  0.67  0.71  0.71  0.70  0.73  0.68  0.71  1.00
  0.70  0.67  0.69  0.68  0.71  0.74  0.65  0.71  0.73  1.00
  0.22  0.17  0.25  0.30  0.26  0.20  0.23  0.18  0.24  0.16  1.00
  0.17  0.08  0.24  0.29  0.26  0.13  0.25  0.20  0.26  0.11  0.67  1.00
  0.18  0.15  0.24  0.34  0.26  0.17  0.22  0.21  0.26  0.13  0.73  0.68  1.00
  0.25  0.14  0.26  0.34  0.27  0.24  0.26  0.25  0.29  0.19  0.67  0.65  0.70  1.00
  0.18  0.11  0.22  0.30  0.22  0.17  0.24  0.18  0.25  0.13  0.67  0.73  0.71  0.71  1.00
  0.23  0.17  0.24  0.26  0.33  0.23  0.29  0.22  0.26  0.17  0.64  0.65  0.62  0.57  0.70  1.00
  0.16  0.17  0.30  0.28  0.26  0.18  0.25  0.21  0.22  0.13  0.63  0.61  0.66  0.67  0.65  0.58  1.00
  0.21  0.13  0.22  0.30  0.28  0.12  0.22  0.19  0.23  0.12  0.65  0.67  0.66  0.61  0.70  0.64  0.64  1.00
  0.11  0.05  0.16  0.22  0.20  0.20  0.22  0.13  0.18  0.07  0.59  0.58  0.65  0.57  0.68  0.62  0.59  0.62  1.00
  0.16  0.12  0.18  0.26  0.22  0.20  0.21  0.21  0.28  0.12  0.60  0.60  0.68  0.68  0.68  0.62  0.58  0.60  0.63  1.00
```

Simple Covariance Matrix

```
. quietly corr qu1_t1-qu20_t1, cov means

. matrix list r(C), format(%4.2f) nonames noheader

  0.75
  0.60  0.86
  0.58  0.62  0.78
  0.59  0.62  0.61  0.79
  0.63  0.68  0.60  0.65  0.89
  0.59  0.65  0.61  0.62  0.62  0.80
  0.51  0.54  0.54  0.51  0.52  0.56  0.65
  0.54  0.60  0.57  0.59  0.58  0.58  0.51  0.75
  0.54  0.55  0.54  0.56  0.59  0.55  0.48  0.53  0.69
  0.58  0.59  0.59  0.58  0.65  0.61  0.51  0.58  0.56  0.78
  0.16  0.15  0.19  0.24  0.23  0.16  0.17  0.16  0.18  0.11  0.65
  0.13  0.08  0.18  0.22  0.23  0.08  0.17  0.16  0.19  0.07  0.45  0.59
  0.14  0.14  0.18  0.26  0.22  0.14  0.17  0.15  0.18  0.09  0.49  0.45  0.62
  0.22  0.16  0.22  0.28  0.28  0.21  0.22  0.22  0.23  0.16  0.51  0.49  0.53  0.74
  0.14  0.12  0.18  0.24  0.23  0.12  0.18  0.15  0.19  0.12  0.49  0.50  0.50  0.55  0.68
  0.18  0.16  0.19  0.23  0.29  0.18  0.22  0.20  0.19  0.13  0.46  0.46  0.45  0.47  0.52  0.65
  0.14  0.18  0.22  0.22  0.24  0.14  0.19  0.18  0.17  0.10  0.43  0.41  0.44  0.50  0.47  0.41  0.60
  0.15  0.13  0.15  0.22  0.24  0.09  0.15  0.15  0.15  0.09  0.42  0.42  0.43  0.43  0.48  0.43  0.41  0.54
  0.11  0.08  0.14  0.20  0.21  0.16  0.17  0.14  0.14  0.07  0.47  0.45  0.49  0.49  0.53  0.50  0.44  0.44  0.73
  0.16  0.15  0.16  0.23  0.23  0.18  0.20  0.19  0.24  0.09  0.47  0.46  0.52  0.57  0.56  0.50  0.46  0.45  0.54  0.79
```

Pearson Correlation Matrix

```
. quietly corr qu1_t1-qu20_t1

. matrix list r(C), format(%4.2f) nonames noheader

  1.00
  0.75  1.00
  0.76  0.75  1.00
  0.76  0.75  0.78  1.00
  0.78  0.78  0.72  0.78  1.00
  0.76  0.78  0.77  0.78  0.74  1.00
  0.73  0.73  0.76  0.71  0.69  0.77  1.00
  0.72  0.75  0.75  0.77  0.71  0.76  0.73  1.00
  0.76  0.72  0.74  0.75  0.75  0.74  0.72  0.74  1.00
  0.76  0.73  0.76  0.73  0.78  0.78  0.72  0.76  0.76  1.00
  0.22  0.20  0.27  0.33  0.30  0.23  0.25  0.24  0.27  0.16  1.00
  0.19  0.12  0.26  0.33  0.31  0.11  0.27  0.24  0.29  0.11  0.74  1.00
  0.20  0.19  0.25  0.37  0.29  0.19  0.26  0.23  0.28  0.13  0.78  0.75  1.00
  0.29  0.20  0.29  0.36  0.35  0.28  0.32  0.29  0.33  0.21  0.74  0.74  0.78  1.00
  0.20  0.15  0.25  0.33  0.29  0.17  0.27  0.22  0.27  0.16  0.74  0.79  0.77  0.77  1.00
  0.25  0.21  0.26  0.32  0.38  0.24  0.33  0.28  0.28  0.19  0.71  0.74  0.70  0.68  0.78  1.00
  0.20  0.26  0.32  0.32  0.33  0.20  0.30  0.26  0.26  0.14  0.69  0.69  0.72  0.74  0.73  0.66  1.00
  0.24  0.20  0.23  0.34  0.34  0.14  0.26  0.23  0.24  0.13  0.70  0.74  0.73  0.68  0.78  0.72  0.71  1.00
  0.15  0.11  0.19  0.27  0.26  0.21  0.25  0.19  0.19  0.09  0.68  0.69  0.73  0.67  0.75  0.73  0.66  0.70  1.00
  0.20  0.18  0.21  0.29  0.27  0.23  0.27  0.25  0.32  0.12  0.66  0.68  0.74  0.75  0.76  0.69  0.67  0.69  0.72  1.00
```

Test of Univariate Normality For Each Question

```
. sktest qu1_t1-qu20_t1
```

Skewness/Kurtosis tests for Normality

Variable	Obs	Pr(Skewness)	Pr(Kurtosis)	joint adj chi2(2)	joint Prob>chi2
qu1_t1	100	0.6399	0.8266	0.27	0.8751
qu2_t1	100	0.6902	0.8652	0.19	0.9104
qu3_t1	100	0.6441	0.6682	0.40	0.8179
qu4_t1	100	0.5535	0.9643	0.36	0.8366
qu5_t1	100	0.7737	0.7742	0.16	0.9208
qu6_t1	100	0.6302	0.4610	0.79	0.6738
qu7_t1	100	0.4207	0.9779	0.66	0.7189
qu8_t1	100	0.1897	0.2654	3.04	0.2186
qu9_t1	100	0.1973	0.7911	1.77	0.4117
qu10_t1	100	0.4698	0.5995	0.81	0.6659
qu11_t1	100	0.9611	0.1937	1.73	0.4205
qu12_t1	100	0.4726	0.4254	1.18	0.5554
qu13_t1	100	0.3664	0.4896	1.32	0.5162
qu14_t1	100	0.3362	0.3805	1.74	0.4199
qu15_t1	100	0.6689	0.3861	0.95	0.6210
qu16_t1	100	0.1174	0.5234	2.94	0.2303
qu17_t1	100	0.0599	0.1748	5.27	0.0717
qu18_t1	100	0.0688	0.0573	6.47	0.0393
qu19_t1	100	0.1073	0.7823	2.74	0.2539
qu20_t1	100	0.0691	0.3650	4.24	0.1199

Tests of Multivariate Normality and Sphericity

```
. mvtest normality qu1_t1-qu20_t1, all

Test for multivariate normality

    Mardia mSkewness =   92.7382  chi2(1540) = 1596.522   Prob>chi2 =  0.1543
    Mardia mKurtosis =  437.7267     chi2(1) =    0.147   Prob>chi2 =  0.7016
    Henze-Zirkler    =  1.006083     chi2(1) =  121.119   Prob>chi2 =  0.0000
    Doornik-Hansen                  chi2(40) =   33.101   Prob>chi2 =  0.7719


. mvtest covariances qu1_t1-qu20_t1, spherical

Test that covariance matrix is spherical

 Adjusted LR chi2(209) =   2035.12
           Prob > chi2 =    0.0000
```

Pearson Correlation Matrix And Cronbach's Alpha

```
. quietly corr qu1_t1-qu20_t1
. matrix QuesCorr = r(C)
. matrix list QuesCorr, format(%4.2f) nonames noheader

  1.00
  0.75  1.00
  0.76  0.75  1.00
  0.76  0.75  0.78  1.00
  0.78  0.78  0.72  0.78  1.00
  0.76  0.78  0.77  0.78  0.74  1.00
  0.73  0.73  0.76  0.71  0.69  0.77  1.00
  0.72  0.75  0.75  0.77  0.71  0.76  0.73  1.00
  0.76  0.72  0.74  0.75  0.75  0.74  0.72  0.74  1.00
  0.76  0.73  0.76  0.73  0.78  0.78  0.72  0.76  0.76  1.00
  0.22  0.20  0.27  0.33  0.30  0.23  0.25  0.24  0.27  0.16  1.00
  0.19  0.12  0.26  0.33  0.31  0.11  0.27  0.24  0.29  0.11  0.74  1.00
  0.20  0.19  0.25  0.37  0.29  0.19  0.26  0.23  0.28  0.13  0.78  0.75  1.00
  0.29  0.20  0.29  0.36  0.35  0.28  0.32  0.29  0.33  0.21  0.74  0.74  0.78  1.00
  0.20  0.15  0.25  0.33  0.29  0.17  0.27  0.22  0.27  0.16  0.74  0.79  0.77  0.77  1.00
  0.25  0.21  0.26  0.32  0.38  0.24  0.33  0.28  0.28  0.19  0.71  0.74  0.70  0.68  0.78  1.00
  0.20  0.26  0.32  0.32  0.33  0.20  0.30  0.26  0.26  0.14  0.69  0.69  0.72  0.74  0.73  0.66  1.00
  0.24  0.20  0.23  0.34  0.34  0.14  0.26  0.23  0.24  0.13  0.70  0.74  0.73  0.68  0.78  0.72  0.71  1.00
  0.15  0.11  0.19  0.27  0.26  0.21  0.25  0.19  0.19  0.09  0.68  0.69  0.73  0.67  0.75  0.73  0.66  0.70  1.00
  0.20  0.18  0.21  0.29  0.27  0.23  0.27  0.25  0.32  0.12  0.66  0.68  0.74  0.75  0.76  0.69  0.67  0.69  0.72  1.00

. // CHECK CHRONBACH'S ALPHA FOR THE ENTIRE GROUP OF QUESTIONS
. alpha qu1_t1-qu20_t1, std

Test scale = mean(standardized items)

Average interitem correlation:      0.4759
Number of items in the scale:           20
Scale reliability coefficient:      0.9478
```

Remove Correlations <0.20

1.00																			
0.75	1.00																		
0.76	0.75	1.00																	
0.76	0.75	0.78	1.00																
0.78	0.78	0.72	0.78	1.00															
0.76	0.78	0.77	0.78	0.74	1.00														
0.73	0.73	0.76	0.71	0.69	0.77	1.00													
0.72	0.75	0.75	0.77	0.71	0.76	0.73	1.00												
0.76	0.72	0.74	0.75	0.75	0.74	0.72	0.74	1.00											
0.76	0.73	0.76	0.73	0.78	0.78	0.72	0.76	0.76	1.00										
0.22	0.20	0.27	0.33	0.30	0.23	0.25	0.24	0.27	.	1.00									
.	.	0.26	0.33	0.31	.	0.27	0.24	0.29	.	0.74	1.00								
0.20	.	0.25	0.37	0.29	.	0.26	0.23	0.28	.	0.78	0.75	1.00							
0.29	.	0.29	0.36	0.35	0.28	0.32	0.29	0.33	0.21	0.74	0.74	0.78	1.00						
.	.	0.25	0.33	0.29	.	0.27	0.22	0.27	.	0.74	0.79	0.77	0.77	1.00					
0.25	0.21	0.26	0.32	0.38	0.24	0.33	0.28	0.28	.	0.71	0.74	0.70	0.68	0.78	1.00				
0.20	0.26	0.32	0.32	0.33	.	0.30	0.26	0.26	.	0.69	0.69	0.72	0.74	0.73	0.66	1.00			
0.24	.	0.23	0.34	0.34	.	0.26	0.23	0.24	.	0.70	0.74	0.73	0.68	0.78	0.72	0.71	1.00		
.	.	.	0.27	0.26	0.21	0.25	.	.	.	0.68	0.69	0.73	0.67	0.75	0.73	0.66	0.70	1.00	
0.20	.	0.21	0.29	0.27	0.23	0.27	0.25	0.32	.	0.66	0.68	0.74	0.75	0.76	0.69	0.67	0.69	0.72	1.00

Remove Correlations <0.30

1.00																			
0.75	1.00																		
0.76	0.75	1.00																	
0.76	0.75	0.78	1.00																
0.78	0.78	0.72	0.78	1.00															
0.76	0.78	0.77	0.78	0.74	1.00														
0.73	0.73	0.76	0.71	0.69	0.77	1.00													
0.72	0.75	0.75	0.77	0.71	0.76	0.73	1.00												
0.76	0.72	0.74	0.75	0.75	0.74	0.72	0.74	1.00											
0.76	0.73	0.76	0.73	0.78	0.78	0.72	0.76	0.76	1.00										
.	.	.	0.33	0.30	.	.	.	.	.	1.00									
.	.	.	0.33	0.31	.	.	.	.	.	0.74	1.00								
.	.	.	0.37	.	.	.	.	.	.	0.78	0.75	1.00							
.	.	.	0.36	0.35	.	0.32	.	0.33	.	0.74	0.74	0.78	1.00						
.	.	.	0.33	.	.	.	.	.	.	0.74	0.79	0.77	0.77	1.00					
.	.	.	0.32	0.38	.	0.33	.	.	.	0.71	0.74	0.70	0.68	0.78	1.00				
.	.	0.32	0.32	0.33	.	0.30	.	.	.	0.69	0.69	0.72	0.74	0.73	0.66	1.00			
.	.	.	0.34	0.34	.	.	.	.	.	0.70	0.74	0.73	0.68	0.78	0.72	0.71	1.00		
.	.	.	.	.	.	.	.	.	.	0.68	0.69	0.73	0.67	0.75	0.73	0.66	0.70	1.00	
.	.	.	.	.	.	.	.	0.32	.	0.66	0.68	0.74	0.75	0.76	0.69	0.67	0.69	0.72	1.00

Remove Correlations <0.40

1.00																			
0.75	1.00																		
0.76	0.75	1.00																	
0.76	0.75	0.78	1.00																
0.78	0.78	0.72	0.78	1.00															
0.76	0.78	0.77	0.78	0.74	1.00														
0.73	0.73	0.76	0.71	0.69	0.77	1.00													
0.72	0.75	0.75	0.77	0.71	0.76	0.73	1.00												
0.76	0.72	0.74	0.75	0.75	0.74	0.72	0.74	1.00											
0.76	0.73	0.76	0.73	0.78	0.78	0.72	0.76	0.76	1.00										
.	.	.	.	.	.	.	.	.	.	1.00									
.	.	.	.	.	.	.	.	.	.	0.74	1.00								
.	.	.	.	.	.	.	.	.	.	0.78	0.75	1.00							
.	.	.	.	.	.	.	.	.	.	0.74	0.74	0.78	1.00						
.	.	.	.	.	.	.	.	.	.	0.74	0.79	0.77	0.77	1.00					
.	.	.	.	.	.	.	.	.	.	0.71	0.74	0.70	0.68	0.78	1.00				
.	.	.	.	.	.	.	.	.	.	0.69	0.69	0.72	0.74	0.73	0.66	1.00			
.	.	.	.	.	.	.	.	.	.	0.70	0.74	0.73	0.68	0.78	0.72	0.71	1.00		
.	.	.	.	.	.	.	.	.	.	0.68	0.69	0.73	0.67	0.75	0.73	0.66	0.70	1.00	
.	.	.	.	.	.	.	.	.	.	0.66	0.68	0.74	0.75	0.76	0.69	0.67	0.69	0.72	1.00

Remove Correlations <0.50

1.00																			
0.75	1.00																		
0.76	0.75	1.00																	
0.76	0.75	0.78	1.00																
0.78	0.78	0.72	0.78	1.00															
0.76	0.78	0.77	0.78	0.74	1.00														
0.73	0.73	0.76	0.71	0.69	0.77	1.00													
0.72	0.75	0.75	0.77	0.71	0.76	0.73	1.00												
0.76	0.72	0.74	0.75	0.75	0.74	0.72	0.74	1.00											
0.76	0.73	0.76	0.73	0.78	0.78	0.72	0.76	0.76	1.00										
.	.	.	.	.	.	.	.	.	.	1.00									
.	.	.	.	.	.	.	.	.	.	0.74	1.00								
.	.	.	.	.	.	.	.	.	.	0.78	0.75	1.00							
.	.	.	.	.	.	.	.	.	.	0.74	0.74	0.78	1.00						
.	.	.	.	.	.	.	.	.	.	0.74	0.79	0.77	0.77	1.00					
.	.	.	.	.	.	.	.	.	.	0.71	0.74	0.70	0.68	0.78	1.00				
.	.	.	.	.	.	.	.	.	.	0.69	0.69	0.72	0.74	0.73	0.66	1.00			
.	.	.	.	.	.	.	.	.	.	0.70	0.74	0.73	0.68	0.78	0.72	0.71	1.00		
.	.	.	.	.	.	.	.	.	.	0.68	0.69	0.73	0.67	0.75	0.73	0.66	0.70	1.00	
.	.	.	.	.	.	.	.	.	.	0.66	0.68	0.74	0.75	0.76	0.69	0.67	0.69	0.72	1.00

Two Related Groups of Questions

My statistical software makes me...

Questions 1-10 appear to be highly correlated with each other

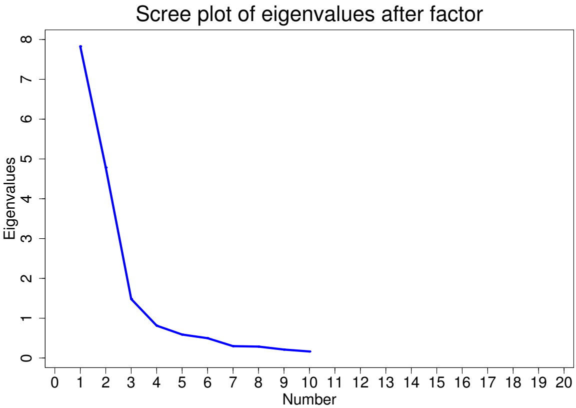
Q1 ...feel sad
Q2 ...feel pessimistic about the future
Q3 ...feel like a failure
Q4 ...feel dissatisfied
Q5 ...feel guilty or unworthy
Q6 ...feel that I am being punished
Q7 ...feel disappointed in myself
Q8 ...feel am very critical of myself
Q9 ...feel like harming myself
Q10 ...feel like crying more than usual

Questions 11-20 appear to be highly correlated with each other

Q11 ...become annoyed or irritated easily
Q12 ...lose interest in other people
Q13 ...have trouble making decisions
Q14 ...feel unattractive
Q15 ...feel like not working
Q16 ...have trouble sleeping
Q17 ...feel tired or fatigued
Q18 ...makes my appetite lower than usual
Q19 ...concerned about my health
Q20 ...experience decreased libido

Exploratory Factor Analysis Retaining The First 10 Factors

```
. factor qu1_t1-qu20_t1, factors(10) ml nolog
(obs=100)

Factor analysis/correlation                        Number of obs    =      100
    Method: maximum likelihood                     Retained factors =       10
    Rotation: (unrotated)                          Number of params =      155
                                                   Schwarz's BIC    =  732.023
    Log likelihood = -9.110648                     (Akaike's) AIC   =  328.221

    Beware: solution is a Heywood case
            (i.e., invalid or boundary values of uniqueness)

    --------------------------------------------------------------------------
         Factor  |   Eigenvalue   Difference        Proportion   Cumulative
    -------------+------------------------------------------------------------
        Factor1  |      7.82891      3.04542            0.4618       0.4618
        Factor2  |      4.78349      3.97049            0.2822       0.7439
        Factor3  |      0.81301      0.52641            0.0480       0.7919
        Factor4  |      0.28660     -1.19510            0.0169       0.8088
        Factor5  |      1.48170      0.89269            0.0874       0.8962
        Factor6  |      0.58901      0.09171            0.0347       0.9309
        Factor7  |      0.49730      0.19950            0.0293       0.9603
        Factor8  |      0.29781      0.08585            0.0176       0.9778
        Factor9  |      0.21196      0.04826            0.0125       0.9903
       Factor10  |      0.16370            .            0.0097       1.0000
    --------------------------------------------------------------------------
    LR test: independent vs. saturated: chi2(190) = 2028.01 Prob>chi2 = 0.0000
    LR test:  10 factors vs. saturated:  chi2(35) =   15.64 Prob>chi2 = 0.9981
    (tests formally not valid because a Heywood case was encountered)
```


Scree plot of eigenvalues after factor
Eigenvalues
0
1
2
3
4
5
6
7
8
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Number

Exploratory Factor Analysis Retaining Different Numbers of Factors

```
. estat factors

Factor analysis with different numbers of factors (maximum likelihood)
```

#factors	loglik	df_m	df_r	AIC	BIC
1	-522.9283	20	170	1085.857	1137.96
2	-77.7302	39	151	233.4604	335.062
3	-61.32184	57	133	236.6437	385.1384
4	-51.61906	74	116	251.2381	444.0207
5	-42.08895	90	100	264.1779	498.6432
6	-33.42972	105	85	276.8594	550.4023
7	-26.04991	119	71	290.0998	600.1151
8	-19.45802	132	58	302.916	646.7985
9	-14.17239	144	46	316.3448	691.4893
10	-9.110648	155	35	328.2213	732.0227
11	-5.691323	165	25	341.3826	771.2357
12	-3.663927	174	16	355.3279	808.6275
13	-1.444548	182	8	366.8891	841.0301
14	-.3439963	189	1	378.688	871.0652

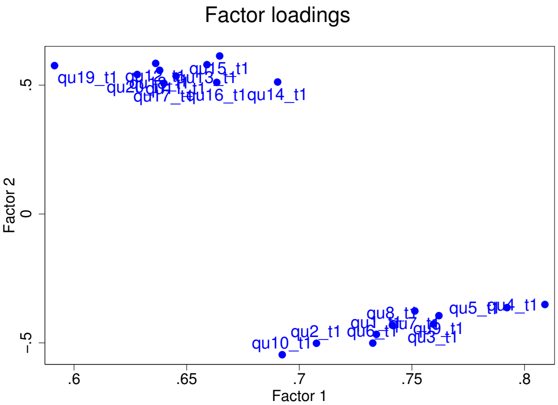
How Many Factors?

- The "Guttman" (1954) or "K1" rule that only factors with eigenvalues greater than one should be retained suggests that there are 3 factors (factors 1,2 and 5)
- The "bend in the scree plot" rule also suggests that there are three factors
- The model with the smallest AIC and BIC is the model with two factors.

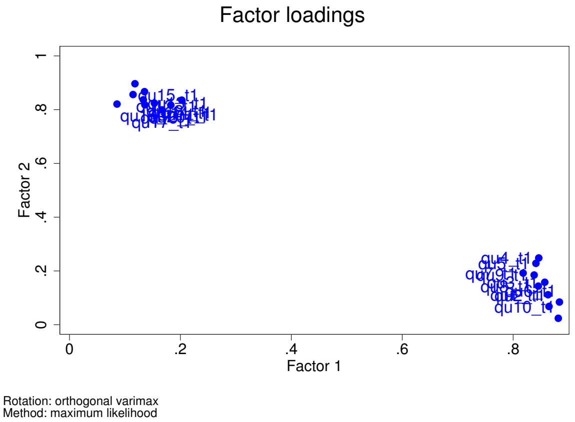
Exploratory Factor Analysis Retaining Two Factors

```
Factor analysis/correlation                        Number of obs    =      100
    Method: maximum likelihood                     Retained factors =        2
    Rotation: (unrotated)                          Number of params =       39
                                                   Schwarz's BIC    =  335.062
    Log likelihood =  -77.7302                     (Akaike's) AIC   =   233.46

    --------------------------------------------------------------------------
         Factor  |   Eigenvalue   Difference        Proportion   Cumulative
    -------------+------------------------------------------------------------
        Factor1  |      9.78438      4.79069            0.6621       0.6621
        Factor2  |      4.99369            .            0.3379       1.0000
    --------------------------------------------------------------------------
    LR test: independent vs. saturated: chi2(190) = 2028.01 Prob>chi2 = 0.0000
    LR test:    2 factors vs. saturated: chi2(151) =  141.73 Prob>chi2 = 0.6937

Factor loadings (pattern matrix) and unique variances

    -------------------------------------------------
        Variable |  Factor1   Factor2 |   Uniqueness
    -------------+--------------------+--------------
          qu1_t1 |   0.7342   -0.4668 |      0.2430
          qu2_t1 |   0.7076   -0.5015 |      0.2478
          qu3_t1 |   0.7595   -0.4273 |      0.2405
          qu4_t1 |   0.8090   -0.3510 |      0.2223
          qu5_t1 |   0.7922   -0.3631 |      0.2405
          qu6_t1 |   0.7326   -0.5008 |      0.2124
          qu7_t1 |   0.7513   -0.3762 |      0.2940
          qu8_t1 |   0.7413   -0.4310 |      0.2647
          qu9_t1 |   0.7620   -0.3944 |      0.2638
         qu10_t1 |   0.6924   -0.5459 |      0.2225
         qu11_t1 |   0.6453    0.5352 |      0.2972
         qu12_t1 |   0.6362    0.5844 |      0.2536
         qu13_t1 |   0.6590    0.5794 |      0.2300
         qu14_t1 |   0.6904    0.5122 |      0.2611
         qu15_t1 |   0.6647    0.6131 |      0.1823
         qu16_t1 |   0.6634    0.5106 |      0.2992
         qu17_t1 |   0.6399    0.5071 |      0.3334
         qu18_t1 |   0.6380    0.5576 |      0.2820
         qu19_t1 |   0.5913    0.5757 |      0.3189
         qu20_t1 |   0.6280    0.5412 |      0.3127
    -------------------------------------------------
```

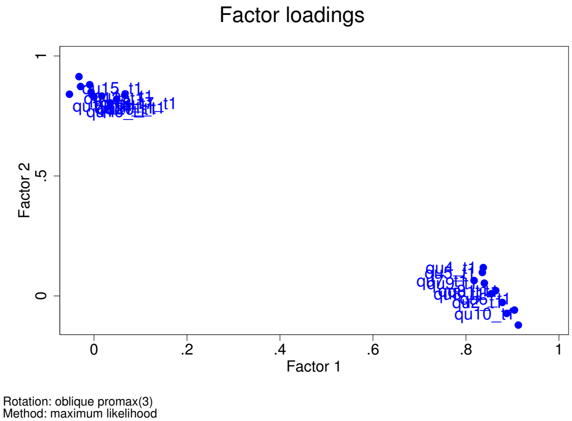
Factor Loadings (No Rotation)



Factor Loadings (VariMax Rotation)



Factor Loadings (ProMax Rotation)



Predicted Latent Variables Based On Factor Loadings

```
. predict Factor1 Factor2, regression

Scoring coefficients (method = regression; based on promax(3) rotated factors)
```

Variable	Factor1	Factor2
qu1_t1	0.11303	-0.00313
qu2_t1	0.11213	-0.00955
qu3_t1	0.11234	0.00398
qu4_t1	0.11802	0.01949
qu5_t1	0.10858	0.01504
qu6_t1	0.13304	-0.00884
qu7_t1	0.08701	0.00826
qu8_t1	0.10091	0.00189
qu9_t1	0.09957	0.00777
qu10_t1	0.12832	-0.01825
qu11_t1	0.00234	0.09845
qu12_t1	-0.00280	0.12079
qu13_t1	-0.00047	0.13446
qu14_t1	0.00861	0.11252
qu15_t1	-0.00452	0.17602
qu16_t1	0.00569	0.09628
qu17_t1	0.00385	0.08478
qu18_t1	-0.00009	0.10568
qu19_t1	-0.00460	0.09250
qu20_t1	0.00057	0.09312

```
. corr Factor1 Factor2
(obs=100)
```

	Factor1	Factor2
Factor1	1.0000	
Factor2	0.3279	1.0000

My statistical software makes me…

Latent Factor 1 (Affective)

Q1 …feel sad
Q2 ...feel pessimistic about the future
Q3 ...feel like a failure
Q4 ...feel dissatisfied
Q5 ...feel guilty or unworthy
Q6 ...feel that I am being punished
Q7 ...feel disappointed in myself
Q8 ...feel am very critical of myself
Q9 ...feel like harming myself
Q10 ...feel like crying more than usual

Latent Factor 2 (Physical)

Q11 ...become annoyed or irritated easily
Q12 ...lose interest in other people
Q13 ...have trouble making decisions
Q14 ...feel unattractive
Q15 ...feel like not working
Q16 ...have trouble sleeping
Q17 ...feel tired or fatigued
Q18 ...makes my appetite lower than usual
Q19 ...concerned about my health
Q20 ...experience decreased libido

The Pilot Study

- Descriptive Statistics
- Item Response Characteristics
- Reliability
- Validity
- Dimensionality and Exploratory Factor Analysis

The Full Study

- The Stata Depression Index was then administered to 1000 Stata users
- Analysis of the data included
    - Confirmatory Factor Analysis
    - Classical Univariate and Multivariate Models
    - Structural Equation Models

Description of the Stata User Data

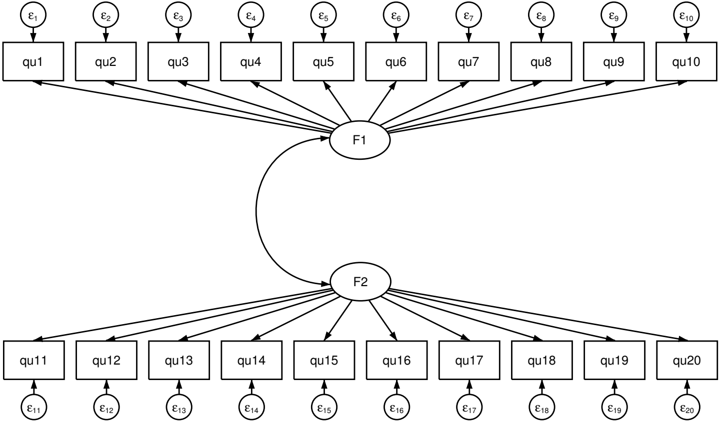
```
. describe

Contains data from BDI2_Data.dta
  obs:         1,000
 vars:            27                          11 Jul 2012 08:54
 size:        28,000
--------------------------------------------------------------------------------
              storage  display     value
variable name   type   format      label      variable label
--------------------------------------------------------------------------------
id              int    %9.0g                  Identification Number
age             byte   %9.0g                  Age (years)
sex             byte   %9.0g       sex        Sex
race            byte   %9.0g       race       Race
qu1             byte   %16.0g      qu1_t1     ...feel sad
qu2             byte   %16.0g      qu2_t1     ...feel pessimistic about the future
qu3             byte   %16.0g      qu3_t1     ...feel like a failure
qu4             byte   %16.0g      qu4_t1     ...feel dissatisfied
qu5             byte   %16.0g      qu5_t1     ...feel guilty or unworthy
qu6             byte   %16.0g      qu6_t1     ...feel that I am being punished
qu7             byte   %16.0g      qu7_t1     ...feel disappointed in myself
qu8             byte   %16.0g      qu8_t1     ...feel am very critical of myself
qu9             byte   %16.0g      qu9_t1     ...feel like harming myself
qu10            byte   %16.0g      qu10_t1    ...feel like crying more than usual
qu11            byte   %16.0g      qu11_t1    ...become annoyed or irritated easily
qu12            byte   %16.0g      qu12_t1    ...have lost interest in other people
qu13            byte   %16.0g      qu13_t1    ...have trouble making decisions
qu14            byte   %16.0g      qu14_t1    ...feel unattractive
qu15            byte   %16.0g      qu15_t1    ...feel like not working
qu16            byte   %16.0g      qu16_t1    ...have trouble sleeping
qu17            byte   %16.0g      qu17_t1    ...feel tired or fatigued
qu18            byte   %16.0g      qu18_t1    ...makes my appetite lower than usual
qu19            byte   %16.0g      qu19_t1    ...concerned about my health
qu20            byte   %16.0g      qu20_t1    ...experience decreased libido
--------------------------------------------------------------------------------
```

Summary of the Stata User Data

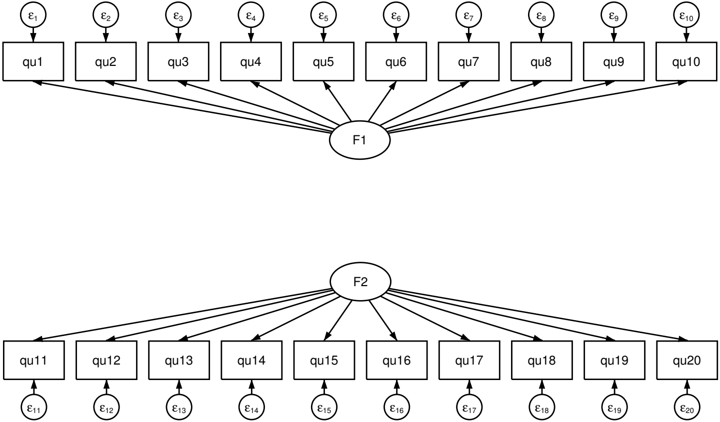
```
. summ
```

Variable	Obs	Mean	Std. Dev.	Min	Max
id	1000	500.5	288.8194	1	1000
age	1000	36.542	9.48009	22	60
sex	1000	.288	.4530577	0	1
race	1000	2.38	.7085916	1	3
qu1	1000	2.986	.859385	1	5
qu2	1000	2.637	.8461365	1	5
qu3	1000	2.978	.856884	1	5
qu4	1000	2.955	.8292543	1	5
qu5	1000	2.944	.8506395	1	5
qu6	1000	2.955	.8693277	1	5
qu7	1000	2.96	.8503665	1	5
qu8	1000	2.955	.8553986	1	5
qu9	1000	2.964	.8481883	1	5
qu10	1000	2.954	.85476	1	5
qu11	1000	2.999	.8060078	1	5
qu12	1000	2.984	.7977345	1	5
qu13	1000	2.985	.8008848	1	5
qu14	1000	2.421	.8200192	1	5
qu15	1000	2.793	.8466805	1	5
qu16	1000	3	.7953821	1	5
qu17	1000	2.988	.7965491	1	5
qu18	1000	2.969	.8116019	1	5
qu19	1000	3.002	.8041409	1	5
qu20	1000	1.982	.8308829	1	4

Confirmatory Factor Analysis



Confirmatory Factor Analysis



Likelihood Ratio Test For the Constrained vs Unconstrained Covariance Between Latent Factors

```
// STRUCTURAL EQUATION MODEL WITH UNCONSTRAINTED COVARIANCE BETWEEN LATENT FACTORS
sem (F1 -> qu1-qu10) ///
    (F2 -> qu11-qu20), stand
est store full

// STRUCTURAL EQUATION MODEL WITH COVARIANCE BETWEEN LATENT FACTORS CONSTRAINED TO ZERO
sem (F1 -> qu1-qu10) ///
    (F2 -> qu11-qu20), ///
    cov(F1*F2@0) stand
est store reduced
lrtest full reduced
```

```
. lrtest full reduced

Likelihood-ratio test                                 LR chi2(1)  =    153.33
(Assumption: reduced nested in full)                  Prob > chi2 =    0.0000
```

Score Test For the Constrained vs Unconstrained Covariance Between Latent Factors

```
// STRUCTURAL EQUATION MODEL WITH COVARIANCE BETWEEN FACTORS CONSTRAINED TO ZERO
sem (F1 -> qu1-qu10) ///
    (F2 -> qu11-qu20), ///
    cov(Affective*Physical@0) stand
```

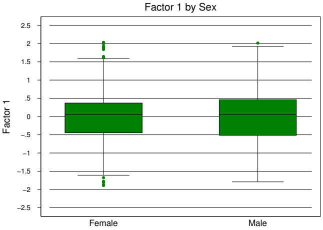
```
. estat scoretests

Score tests for linear constraints

  (3)   [cov(F1,F2)]_cons = 0
```

	chi2	df	P>chi2
(3)	142.127	1	0.00

Create Predicted Variables from the Latent Variables

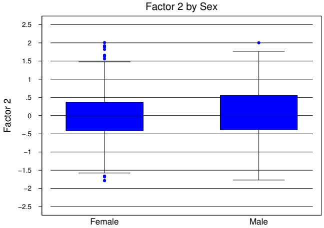
```
sem (F1 -> qu1-qu10) ///
    (F2 -> qu11-qu20), stand


// CREATE PREDICTED VARIABLES FOR THE LATENT VARIABLES
predict F1 F2, latent(Affective Physical)
label var F1 "Factor 1 (Affective)"
label var F2 "Factor 2 (Physical)"
```

Student's t-test for Latent Variable F1 by Sex



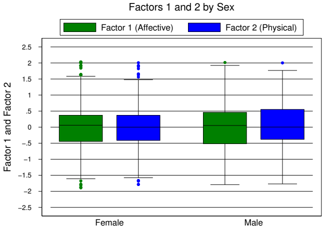

```
. ttest F1, by(sex)

Two-sample t test with equal variances
------------------------------------------------------------------------------
   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
  Female |     712    .0018819    .0271581    .7246673   -.0514377    .0552014
    Male |     288   -.0046524      .04334    .7355044    -.089957    .0806522
---------+--------------------------------------------------------------------
combined |    1000   -1.44e-10    .0230037     .727442   -.0451412    .0451412
---------+--------------------------------------------------------------------
    diff |            .0065343    .0508248               -.0932016    .1062701
------------------------------------------------------------------------------
    diff = mean(Female) - mean(Male)                              t =   0.1286
Ho: diff = 0                                     degrees of freedom =      998

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.5511         Pr(|T| > |t|) = 0.8977          Pr(T > t) = 0.4489
```

Student's t-test for Latent Variable F2 by Sex



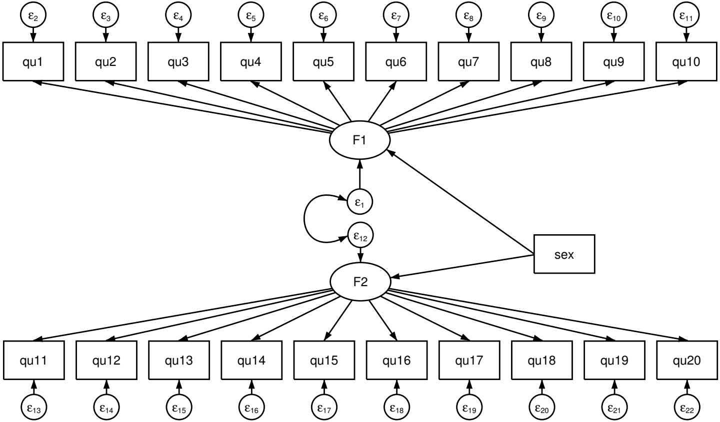

```
. ttest F2, by(sex)

Two-sample t test with equal variances
------------------------------------------------------------------------------
   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
  Female |     712   -.0187195    .0247589    .6606498   -.0673288    .0298897
    Male |     288    .0462789    .0407991    .6923839   -.0340246    .1265823
---------+--------------------------------------------------------------------
combined |    1000   -6.30e-10    .0211949    .6702416   -.0415916    .0415916
---------+--------------------------------------------------------------------
    diff |           -.0649984    .0467835               -.1568038     .026807
------------------------------------------------------------------------------
    diff = mean(Female) - mean(Male)                              t =  -1.3893
Ho: diff = 0                                     degrees of freedom =      998

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.0825         Pr(|T| > |t|) = 0.1650          Pr(T > t) = 0.9175
```

Hotelling's T-Squared for Latent Variables F1 and F2 by Sex

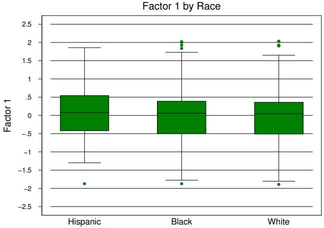



```
. hotelling F1 F2, by(sex)

-> sex = Female
    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+---------------------------------------------------------
          F1 |       712    .0018819    .7246673  -1.891131   2.031987
          F2 |       712   -.0187195    .6606498   -1.78537    2.00687

-> sex = Male
    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+---------------------------------------------------------
          F1 |       288   -.0046524    .7355044  -1.790884   2.014114
          F2 |       288    .0462789    .6923839    -1.7694   2.002456
2-group Hotelling's T-squared = 2.5043409
F test statistic: ((1000-2-1)/(1000-2)(2)) x 2.5043409 = 1.2509158
H0: Vectors of means are equal for the two groups
              F(2,997) =     1.2509
       Prob > F(2,997) =     0.2867
```

Structural Equation Model Including Sex

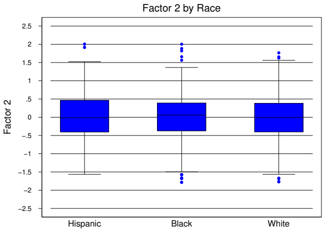


Oneway ANOVA for Latent Variable F1 by Race



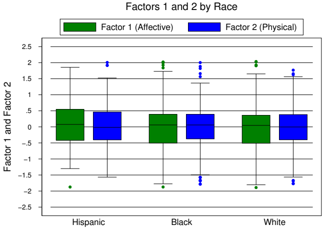

```
. anova F1 race

                           Number of obs =     1000     R-squared     =  0.0012
                           Root MSE      =  .727742     Adj R-squared = -0.0008

                  Source |  Partial SS    df       MS           F     Prob > F
              -----------+----------------------------------------------------
                   Model |  .622465698     2  .311232849       0.59     0.5558
                         |
                    race |  .622465698     2  .311232849       0.59     0.5558
                         |
                Residual |  528.020207   997  .529609034
              -----------+----------------------------------------------------
                   Total |  528.642673   999  .529171845
```

Oneway ANOVA for Latent Variable F2 by Race



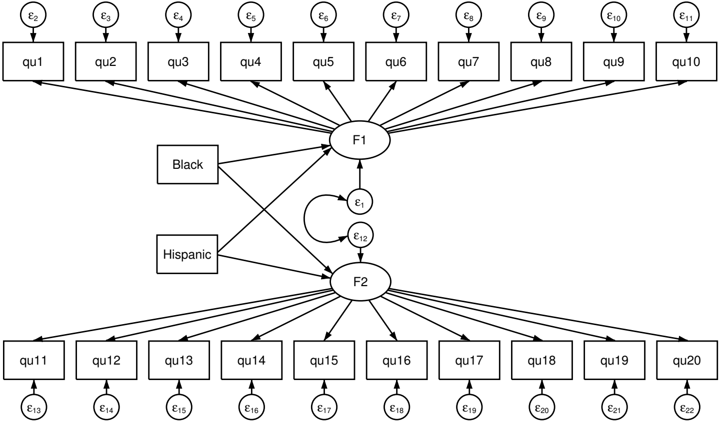

```
. anova F2 race

                         Number of obs =     1000     R-squared     =  0.0005
                         Root MSE      = .670744      Adj R-squared = -0.0015

                  Source |  Partial SS    df       MS           F     Prob > F
              -----------+----------------------------------------------------
                   Model |   .2265257      2   .11326285       0.25     0.7775
                         |
                    race |   .2265257      2   .11326285       0.25     0.7775
                         |
                Residual |  448.548027   997  .449897721
              -----------+----------------------------------------------------
                   Total |  448.774553   999  .449223777
```

Multivariate ANOVA for Latent Variables F1 and F2 by Race




```
. manova F1 F2 = race

                           Number of obs =     1000

                           W = Wilks' lambda      L = Lawley-Hotelling trace
                           P = Pillai's trace     R = Roy's largest root

                  Source |  Statistic      df   F(df1,    df2) =   F   Prob>F
              -----------+----------------------------------------------------
                    race | W   0.9986       2     4.0  1992.0     0.36 0.8406 e
                         | P   0.0014             4.0  1994.0     0.36 0.8404 a
                         | L   0.0014             4.0  1990.0     0.35 0.8408 a
                         | R   0.0012             2.0   997.0     0.60 0.5501 u
                         |----------------------------------------------------
                Residual |                997
              -----------+----------------------------------------------------
                   Total |                999
              ----------------------------------------------------------------
                           e = exact, a = approximate, u = upper bound on F
```

Structural Equation Model Including Race



Reference Level Contrasts for Race

```
// r. differences from a reference (base) level; the default
. contrast r.race

Contrasts of marginal linear predictions

Margins      : asbalanced
```

	df	F	P>F
F1			
race			
(2 vs 1)	1	0.67	0.4133
(3 vs 1)	1	1.18	0.2786
Joint	2	0.59	0.5558
Residual	997		

	Contrast	Std. Err.	[95% Conf.	Interval]
F1				
race				
(2 vs 1)	-.0605743	.0740141	-.2058157	.0846671
(3 vs 1)	-.0767675	.0708124	-.215726	.062191

```
// THIS IS EQUIVALENT TO:
contrast {race -1 1 0} ///
         {race -1 0 1}, equation(F1)
```

Adjacent Categories Contrasts for Race

```
// a. differences from the next level (adjacent contrasts)
. contrast a.race

Contrasts of marginal linear predictions

Margins      : asbalanced

------------------------------------------------
             |         df           F        P>F
-------------+----------------------------------
F1           |
        race |
    (1 vs 2) |          1        0.67     0.4133
    (2 vs 3) |          1        0.10     0.7475
       Joint |          2        0.59     0.5558
             |
    Residual |        997
------------------------------------------------

--------------------------------------------------------------
             |   Contrast   Std. Err.     [95% Conf. Interval]
-------------+------------------------------------------------
F1           |
        race |
    (1 vs 2) |   .0605743   .0740141     -.0846671    .2058157
    (2 vs 3) |   .0161932   .0502837     -.0824807    .1148672
--------------------------------------------------------------


// THIS IS EQUIVALENT TO:
contrast {race 1 -1  0} ///
         {race 0  1 -1}, equation(F1)
```

Grand Means Contrasts for Race

```
// g. differences from the balanced grand mean
. contrast g.race

Contrasts of marginal linear predictions

Margins      : asbalanced
```

	df	F	P>F
F1			
race			
(1 vs mean)	1	1.02	0.3123
(2 vs mean)	1	0.18	0.6723
(3 vs mean)	1	0.90	0.3432
Joint	2	0.59	0.5558
Residual	997		

	Contrast	Std. Err.	[95% Conf.	Interval]
F1				
race				
(1 vs mean)	.0457806	.0452849	-.0430841	.1346453
(2 vs mean)	-.0147937	.0349582	-.0833938	.0538064
(3 vs mean)	-.0309869	.0326728	-.0951022	.0331284

```
// THIS IS EQUIVALENT TO:
contrast {race -0.6666 0.3333 0.3333} ///
         {race 0.3333 -0.6666 0.3333} ///
         {race 0.3333 0.3333 -0.6666}, equation(F1)
```

Pairwise Comparisons for Race Using The Tukey Adjustment

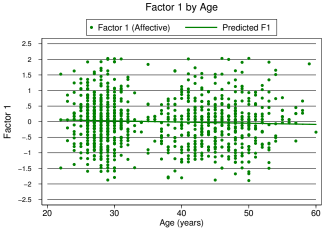
```
. pwcompare race, equation(F1) effects mcompare(tukey)

Pairwise comparisons of marginal linear predictions
Margins      : asbalanced

---------------------------
             |    Number of
             |  Comparisons
-------------+-------------
F1           |
        race |            3
---------------------------

-------------------------------------------------------------------------------
             |                              Tukey                Tukey
             |   Contrast   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+-----------------------------------------------------------------
F1           |
        race |
     2 vs 1  |  -.0605743   .0740141    -0.82   0.692    -.2343012    .1131526
     3 vs 1  |  -.0767675   .0708124    -1.08   0.524    -.2429793    .0894443
     3 vs 2  |  -.0161932   .0502837    -0.32   0.944    -.1342197    .1018332
-------------------------------------------------------------------------------
Note: The tukey method requires balanced data for proper level coverage. A
      factor was found to be unbalanced.
```

Pairwise Comparisons for Race Using The Bonferroni Adjustment

```
. pwcompare race, equation(F1) effects mcompare(bonf)

Pairwise comparisons of marginal linear predictions
Margins      : asbalanced

---------------------------
             |    Number of
             |  Comparisons
-------------+-------------
F1           |
        race |            3
---------------------------

-----------------------------------------------------------------------------
             |                            Bonferroni           Bonferroni
             |   Contrast   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+---------------------------------------------------------------
F1           |
        race |
     2 vs 1  |  -.0605743   .0740141    -0.82   1.000    -.2380622    .1169136
     3 vs 1  |  -.0767675   .0708124    -1.08   0.836    -.2465776    .0930426
     3 vs 2  |  -.0161932   .0502837    -0.32   1.000    -.1367748    .1043884
-----------------------------------------------------------------------------
```

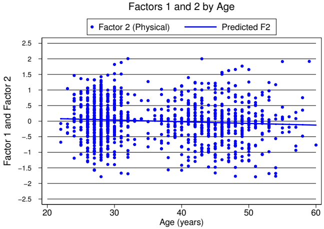
- Built-In Contrasts (as-balanced and as-observed
  - Reference Level Contrasts
  - Adjacent Levels Contrasts
  - Differences From The Grand Mean
  - Orthogonal Polynomials
  - Helmert and Reverse-Helmert
- Pairwise Comparison Adjustments
  - Bonferroni
  - Tukey
  - Scheffe
  - Duncan
  - Dunnett
  - Student-Newman-Keuls

Linear Regression for Latent Variable F1 by Age



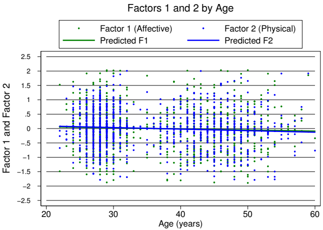

```
. regress F1 age

      Source |       SS       df       MS              Number of obs =    1000
-------------+------------------------------           F(  1,   998) =    2.41
       Model |  1.27353577     1  1.27353577           Prob > F      =  0.1209
    Residual |  527.369137   998  .528425989           R-squared     =  0.0024
-------------+------------------------------           Adj R-squared =  0.0014
       Total |  528.642673   999  .529171845           Root MSE      =  .72693

------------------------------------------------------------------------------
          F1 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         age |  -.0037663    .002426    -1.55   0.121     -.008527    .0009945
       _cons |   .1376267    .091584     1.50   0.133    -.0420926     .317346
------------------------------------------------------------------------------
```

Linear Regression for Latent Variable F2 by Age



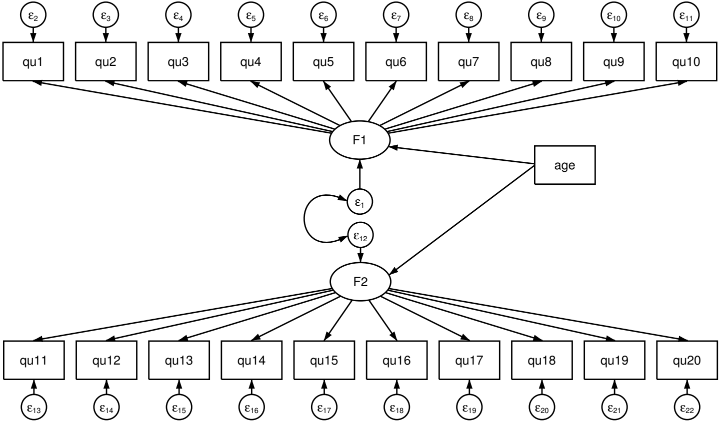

```
. regress F2 age

      Source |       SS       df       MS              Number of obs =    1000
-------------+------------------------------           F(  1,   998) =    5.86
       Model |  2.62133472     1  2.62133472           Prob > F      =  0.0156
    Residual |  446.153218   998  .447047313           R-squared     =  0.0058
-------------+------------------------------           Adj R-squared =  0.0048
       Total |  448.774553   999  .449223777           Root MSE      =  .66862

------------------------------------------------------------------------------
          F2 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         age |  -.0054034   .0022314    -2.42   0.016    -.0097822   -.0010246
       _cons |   .1974505   .0842373     2.34   0.019     .0321481     .362753
------------------------------------------------------------------------------
```

Multivariate Regression for Latent Variables F1 and F2 by Age




```
. mvreg F1 F2 = age

Equation             Obs  Parms        RMSE    "R-sq"          F        P
F1                  1000      2    .7269291    0.0024   2.410055   0.1209
F2                  1000      2     .668616    0.0058   5.863663   0.0156

              |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
F1            |
          age |  -.0037663     .002426    -1.55   0.121     -.008527    .0009945
        _cons |   .1376267     .091584     1.50   0.133    -.0420926     .317346
F2            |
          age |  -.0054034    .0022314    -2.42   0.016    -.0097822   -.0010246
        _cons |   .1974505    .0842373     2.34   0.019     .0321481     .362753
```

Structural Equation Model Including Age



Multivariate Regression Model Including Sex, Race and Age

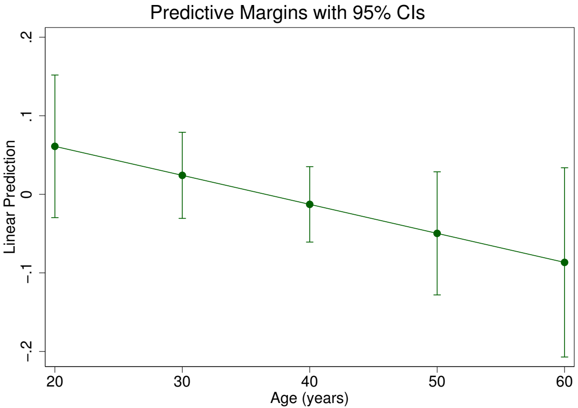
```
. mvreg F1 F2 = age i.sex##i.race

Equation          Obs  Parms        RMSE    "R-sq"          F        P
----------------------------------------------------------------------
F1               1000      7      .72724    0.0066   1.092484   0.3648
F2               1000      7    .6687077    0.0106   1.764698   0.1032

------------------------------------------------------------------------------
             |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
F1           |
         age |  -.0036923    .002429    -1.52   0.129    -.0084588    .0010743
       1.sex |   .1130077   .1333148     0.85   0.397    -.1486033    .3746188
             |
        race |
          2  |   -.040209   .0897508    -0.45   0.654     -.216332    .1359139
          3  |  -.0114758   .0863719    -0.13   0.894    -.1809682    .1580165
             |
    sex#race |
        1 2  |  -.0427163   .1593227    -0.27   0.789    -.3553641    .2699314
        1 3  |  -.2035214   .1509514    -1.35   0.178    -.4997418    .0926989
             |
       _cons |    .156677   .1166336     1.34   0.179    -.0721996    .3855537
-------------+----------------------------------------------------------------
F2           |
         age |  -.0055679   .0022335    -2.49   0.013    -.0099509    -.001185
       1.sex |   .2013137   .1225849     1.64   0.101    -.0392415    .4418689
             |
        race |
          2  |    .062532   .0825271     0.76   0.449    -.0994155    .2244796
          3  |   .0100582   .0794202     0.13   0.899    -.1457925    .1659089
             |
    sex#race |
        1 2  |   -.208859   .1464995    -1.43   0.154    -.4963432    .0786251
        1 3  |  -.1206021    .138802    -0.87   0.385     -.392981    .1517767
             |
       _cons |   .1558802   .1072463     1.45   0.146    -.0545752    .3663356
------------------------------------------------------------------------------
```

Linear Predictions of F1 at Ages 20,30,40,50 and 60

```
. margins , at(age=(20(10)60)) predict(equation(F1)) vsquish
Predictive margins                                Number of obs   =       1000

Expression   : Linear prediction, predict(equation(F1))
1._at        : age             =          20
2._at        : age             =          30
3._at        : age             =          40
4._at        : age             =          50
5._at        : age             =          60

------------------------------------------------------------------------------
             |            Delta-method
             |     Margin   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         _at |
          1  |   .0610775   .0462963     1.32   0.187    -.0296615    .1518166
          2  |   .0241548   .0279533     0.86   0.388    -.0306326    .0789423
          3  |  -.0127679   .0244832    -0.52   0.602    -.0607541    .0352184
          4  |  -.0496906   .0399684    -1.24   0.214    -.1280273    .0286461
          5  |  -.0866133   .0614453    -1.41   0.159    -.2070439    .0338174
------------------------------------------------------------------------------
```

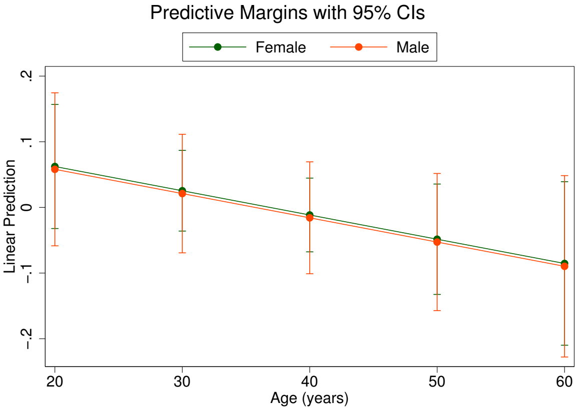
Margins Plot of Latent Variable F1 at Ages 20,30,40,50 and 60

```
margins , at(age=(20(10)60)) predict(equation(F1)) vsquish
marginsplot, scheme(s1color)
```



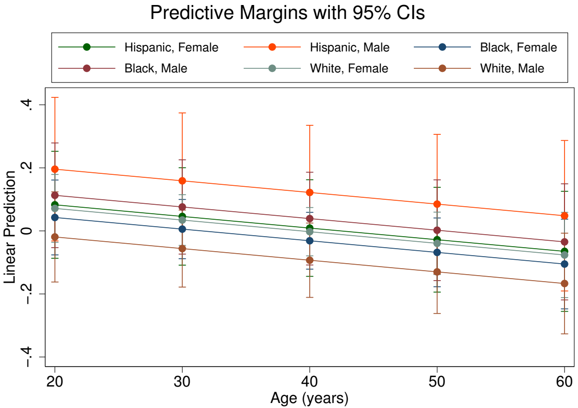
Margins Plot of Latent Variable F1 at By Sex at Ages 20-60

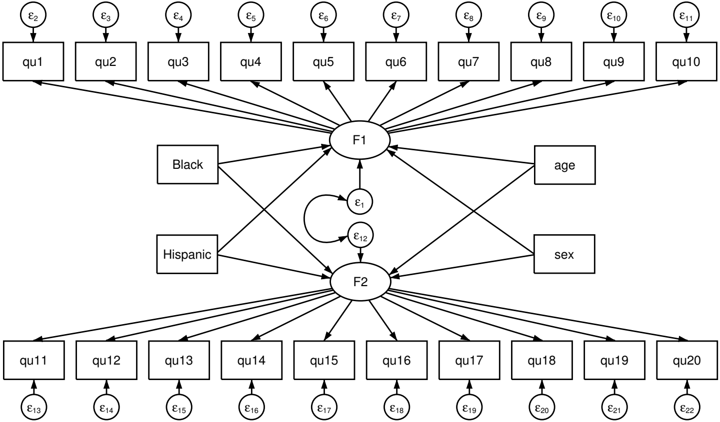
```
margins , over(sex) at(age=(20(10)60)) predict(equation(F1))
marginsplot, scheme(s1color)
```

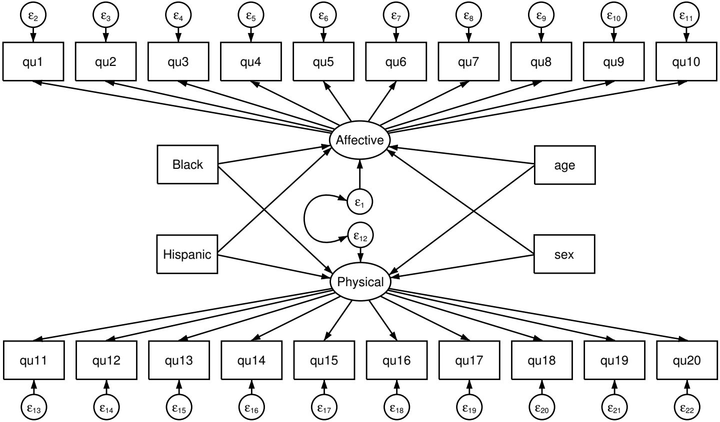


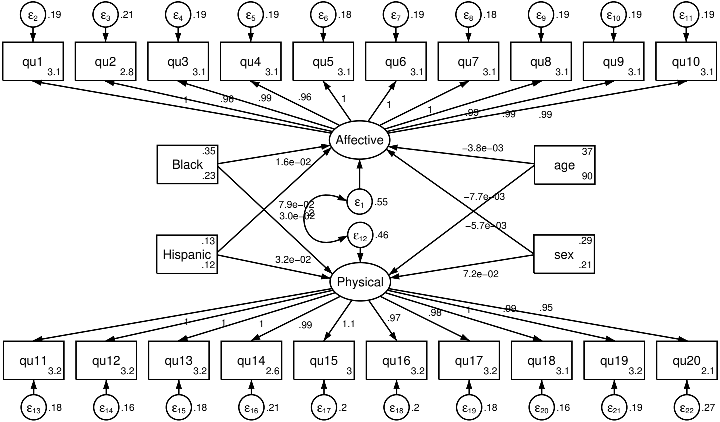
Margins Plot of F1 at By Sex and Race at Ages 20-60

```
margins , over(race sex) at(age=(20(10)60)) predict(equation(F1))
marginsplot, scheme(s1color)
```




ε2
ε3
ε4
ε5
ε6
ε7
ε8
ε9
ε10
ε11
qu1
qu2
qu3
qu4
qu5
qu6
qu7
qu8
qu9
qu10
F1
Black
age
ε1
ε12
Hispanic
sex
F2
qu11
qu12
qu13
qu14
qu15
qu16
qu17
qu18
qu19
qu20
ε13
ε14
ε15
ε16
ε17
ε18
ε19
ε20
ε21
ε22


ε2
ε3
ε4
ε5
ε6
ε7
ε8
ε9
ε10
ε11
qu1
qu2
qu3
qu4
qu5
qu6
qu7
qu8
qu9
qu10
Affective
Black
age
ε1
ε12
Hispanic
sex
Physical
qu11
qu12
qu13
qu14
qu15
qu16
qu17
qu18
qu19
qu20
ε13
ε14
ε15
ε16
ε17
ε18
ε19
ε20
ε21
ε22


qu1 3.1
qu2 2.8
qu3 3.1
qu4 3.1
qu5 3.1
qu6 3.1
qu7 3.1
qu8 3.1
qu9 3.1
qu10 3.1
Affective
Black .35 .23
Hispanic .13 .12
age 37 90
sex .29 .21
1.6e−02
−3.8e−03
7.9e−02
3.0e−02
−7.7e−03
−5.7e−03
3.2e−02
7.2e−02
.55
.46
Physical
qu11 3.2
qu12 3.2
qu13 3.2
qu14 2.6
qu15 3
qu16 3.2
qu17 3.2
qu18 3.1
qu19 3.2
qu20 2.1

Conclusions

- For privacy reasons, we cannot reveal all the details of our analysis
- We are happy to report that Stata users are doing just fine
- Stata is very well equipped for both Classical and Modern psychometric analyses
- There were too many slides in this presentation!!!

References

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