Methods for Dealing with Clustered Data

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  - How does it happen?
  - What’s the problem?
- Robust estimators
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- Longitudinal multilevel models

Clustered data

- What is it?
- How does it happen?
- What’s the problem?

What is Clustered Data?

- Where cases are related
  - Lots of names
    - Non-independence
    - Dependency
    - Autocorrelation
    - Clustered
    - Multilevel
- All statistical tests assume independence
  - If I know something about person 1
    - That should not tell me anything about person 2

- Children in classrooms
  - Always used as an example
  - Where the issue was first identified
- The assumption:
  - If I know Child 1’s test score
  - I should not be able to predict child 2’s test score any better than child 102’s test score
- But I can
  - Two children in the same classroom
    - More similar than two children in different classrooms

Class 1	Score	Class 2	Score
Alice	10	Fred	2
Bob	9	George	4
Carol	8	Harriet	5
David	9	Ian	4
Ethel	8	James	?

- I can make a guess about James’s score
  - This is bad
  - Independence has been violated

Why is Violation of Independence Bad?

- Your standard errors are wrong

$$se = \frac{\sigma}{\sqrt{n}}$$

- N – sample size
  - It’s about the amount of *information* that we have
  - Not the number of measures
  - We can usually use N to represent the amount of information
    - Unless we’ve violated independence

- 100 classrooms
  - 1 child sampled from each classroom
  - N = 100
- Sample a second child from classroom 1
  - There is non-independence
  - Child 2 from classroom 1 does not provide as much information as Child 1 from classroom 101
- Child 3 from classroom 1 provides less information
  - Child 101 from classroom 1 – even less
  - Child 1002 from classroom 1 – even less

The Intra Class Correlation

- Intraclass correlation (ICC)
  - Same thing, used in lots of places
  - Confusing
  - In SPSS: Analyze, Scale, Reliability, Statistics,
    - ICC is an option
    - These are not the ICCs we are looking for
    - We’ll come to calculation of ICC later

- Formula for intra-class correlation

$$ICC = \frac{M}{M-1} \times \frac{SSW}{SST}$$

- Where
  - M is the mean number of individuals per cluster
  - SSW – Sum of squares within groups (from anova)
  - SST – total sum of squares (from anova)
- (Very easy to calculate in Stata)
- (Assumes equal sized groups, but it’s close enough)

Adult Literacy: A Real Example

- Trial of incentives for adults attended literacy classes
  - Brooks, G., Burton, M., Cole, P., Miles, J., Torgerson, C., Torgerson, D. (2008). Randomised controlled trial of incentives to improve attendance at adult literacy classes. *Oxford Review of Education,* 34, 5, 493-504.
- Some classes were incentivized to attend
  - Given £5 M&S Vouchers for each class
  - £20 M&S Vouchers for taking final exam

- Adults were in randomized by classroom
  - We can’t randomize individually
    - (which would remove the problem)
- Data are in ‘adult literacy.sav’
  - Variables:
  - Group: Group assigned to (not given to analyst – i.e. me)
  - Classid: Class
  - Sessions: Number of sessions attended (outcome)
  - Postscore: Final score (outcome)

Analysis

- Analyze data, see if group difference occurs for
  - Hours
  - Postscore
- What do you find?

- Do we trust this result?
- Why not?

Violation of Independence

- It’s likely that we’ve violated independence
  - Calculate the ICC
  - …

Violation of Independence

- ANOVA method:
  - 0.376
  - “Proper” method 1 (least squares):
    - 0.388
  - “Proper” method 2 (restricted maximum likelihood)
    - 0.399
  - “Proper” method 2 (maximum likelihood)
    - 0.387

- All pretty close

Violation of Independence

- ICC is 0.388
  - How big is that?

- ICC of 0.02 can cause BIG problems

Design Effect / VIF

- To find the effect of the ICC
  - – Calculate **design effect / variance inflation factor**
  - – Same thing, different names

$$VIF = (m-1)ICC$$

  - – ICC: ICC
  - – M – mean number of individuals per cluster
    - Assumed to be equal, if not equal, it’s close enough

- Tells you:
  - How much you have overestimated your sample size by
- Calculate for our data:

$$VIF = 1 + (m - 1)ICC$$

$$VIF = 1 + (152 / 28 - 1) \times 0.38$$

$$VIF = 3.06$$

- Our sample size was 152
  - Our effective sample size was 152/3.06 = 49.7

Small VIF, Big Problems

- Cluster randomized trial: Project CHOICE
  - Drug alcohol use in teens
- Sample size
  - 8000 children in 16 schools
    - Pretty big
- Randomized trial of a school intervention
  - ICC 0.02
    - Pretty small
- VIF = 500*0.02 = 10
- Effective sample size = 8000/10 = 800
- 10% drank alcohol = 80 ☹

Back to Our Data

- (Optional bit coming up)
- Standard error was 0.504
  - Calculated with naïve sample size
- Standard deviation of parameter
  - SD = SE * sqrt(N)
  - SD = 0.504*sqrt(152) = 6.21
  - Corrected SE = 6.21 / sqrt(49.7) = 0.88
  - *t* = est / se = 1.405 / 0.88 = 1.59
    - NOT SIGNIFICANT

- (Optional bit over)
- Square root of VIF
  - Multiplier for standard error
  - SE = sqrt(3.06) * 0.504 = 0.72
  - *t* = est / se = 1.405 / 0.72 = 1.59
    - NOT SIGNIFICANT

(Spoiler: Real *t* is ~1.67)

Other Solutions

- Randomly select one person from each cluster
  - Assumes ICC = 1
  - Often used with household surveys
- Find average score
  - Use aggregate
  - What do we find?
  - Also assumes ICC = 1
  - Is used with very large samples
    - Answers converge

An Aside on Psychometrics

- We give people psychometric tests
- We take many measures from one individual
  - That’s just like taking lots of children from each classroom
- We add up the score (equivalent of taking the average)
  - Analyze each person with one score
- We calculate Cronbach’s alpha
  - This is an ICC

- We use the Spearman Brown Prophecy formula
  - Longer questionnaires are more reliable
  - But twice as many questions is not twice as good

$$\rho* = \frac{N\rho}{1+(N-1)\rho}$$

  - We don’t need to average, we can use items
    - We call this factor analysis / structural equation modeling

Clusters Everywhere

- People in families
- Patients in hospitals
- Patients treated by doctors
- People in counties / cities / countries
- Articles in journals
- Teeth in mouths
- Hooves on cows
- Pigs in litters
- Workers in companies
- Fights in deer
- Experiments within papers
- Teachers in schools
- Schools in districts
- Falls in patients

Conclusion

- Clustered data are common
- Clustered data are problematic

Number of people

>

Effect Sample Size

>

Number of clusters

- Failing to take clustering into account
  - Dramatic increases in Type I error rate
    - Even small ICCs can increase Type I error rate from 0.05 to 0.50
  - This is bad
  - We need to deal with it

2. Dealing with Clusters 1: “Robust” Estimation

Robust Estimation

- Horrible name
  - Robust means many different things
- Many different names given
  - Huber-White estimates (Stata)
  - Empirical standard errors (SAS)
  - Sandwich estimators (Lots of places. But sandwich estimators do other things)
  - Survey estimates
  - Taylor series linear approximations (What??)

What do they do?

- Correct for *i.i.d.* assumption
  - Independent and identically distributed

- Correct standard errors for clustering
- Correct for heteroscedasticity

When are robust methods appropriate?

- When the clustering variable is an irritant
  - Not something you are interested in
- When you’re not interested in modeling the clustering
- Cluster randomized trials

Robust Methods in SPSS

- Added to handle survey methods
- Not especially user friendly
  - If you have a choice,
    - Stata is very good at this
    - SAS is OK (but SAS is horrible)
    - R is not great

Robust Methods 1: Heteroscedasticity

- We worry about heteroscedasticity in t-tests and regression
  - Second i of i.i.d
  - Only a problem if the sample sizes are different in groups (for t-tests)
  - Equivalent to skewed predictor variable in regression
    - (Dumville, J.C., Hahn, S., Miles, J.N.V., Torgerson, D.J. (2006). The use of unequal allocation ratios in clinical trials: a review. *Contemporary Clinical Trials 27,* 1, 1 - 12.)
  - We worry about heteroscedasticity a bit
    - It’s a really easy assumption to discard
    - (Although sometimes it’s interesting)

Correcting in T-Test

- In the t-test corrections are done automatically
    - Use hours as outcome, group as predictor
    - Adjusts df
        - Equivalent to reducing effective sample size
- Two corrections
    - Browne-Forsythe or Welch

Results

- Differences are small (here)
  - Uncorrected: p = 0.148
  - Corrected: p = 0.150
- That’s a t-test
  - How do we do it for regression?

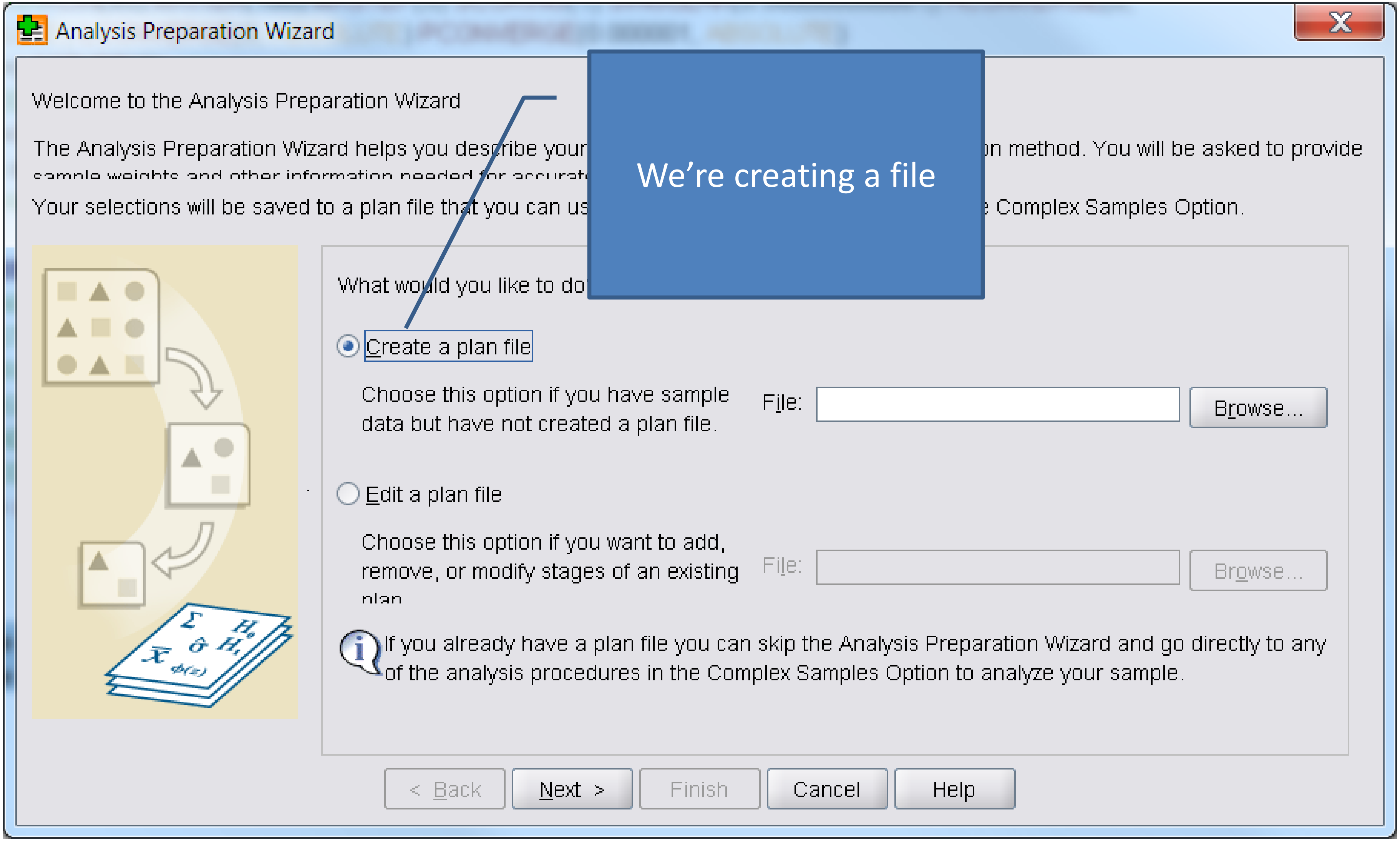
Complex Samples

- We use what SPSS calls complex samples
- Fiddly to set up
- Need two new variables
  - Constant, equals 1
  - Unique ID

```
Compute constant = 1.
Compute id  = $casenum.
```

Complex Samples

- First, create plan file
  - Analyze; Complex Samples; Prepare for Analysis



Analysis Preparation Wizard

Welcome to the Analysis Preparation Wizard

The Analysis Preparation Wizard helps you describe your on method. You will be asked to provide sample weights and other information needed for accurat

Your selections will be saved to a plan file that you can us e Complex Samples Option.

What would you like to do

● Create a plan file

Choose this option if you have sample data but have not created a plan file.

File:

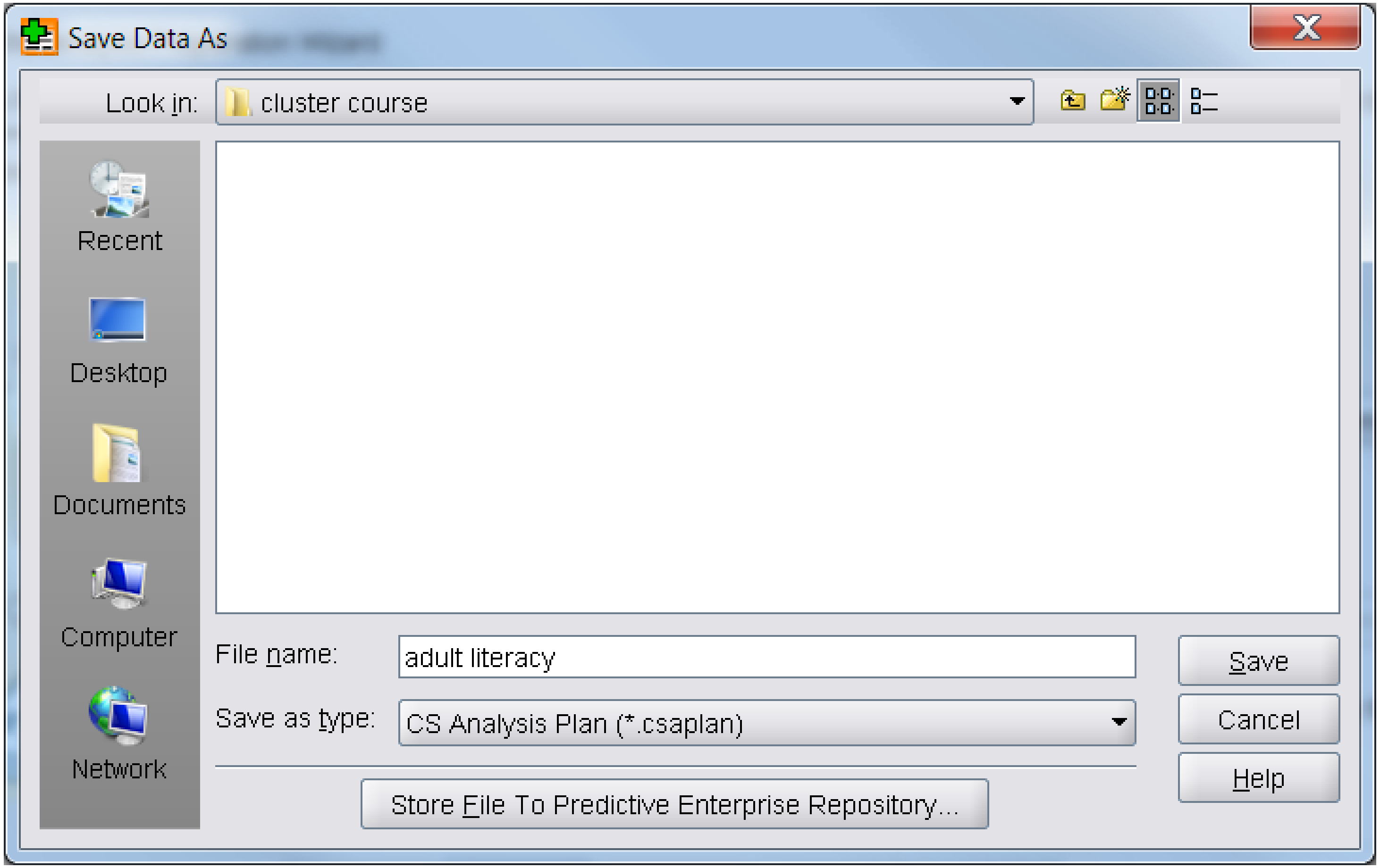
○ Edit a plan file

Choose this option if you want to add, remove, or modify stages of an existing plan

File:

If you already have a plan file you can skip the Analysis Preparation Wizard and go directly to any of the analysis procedures in the Complex Samples Option to analyze your sample.

We’re creating a file

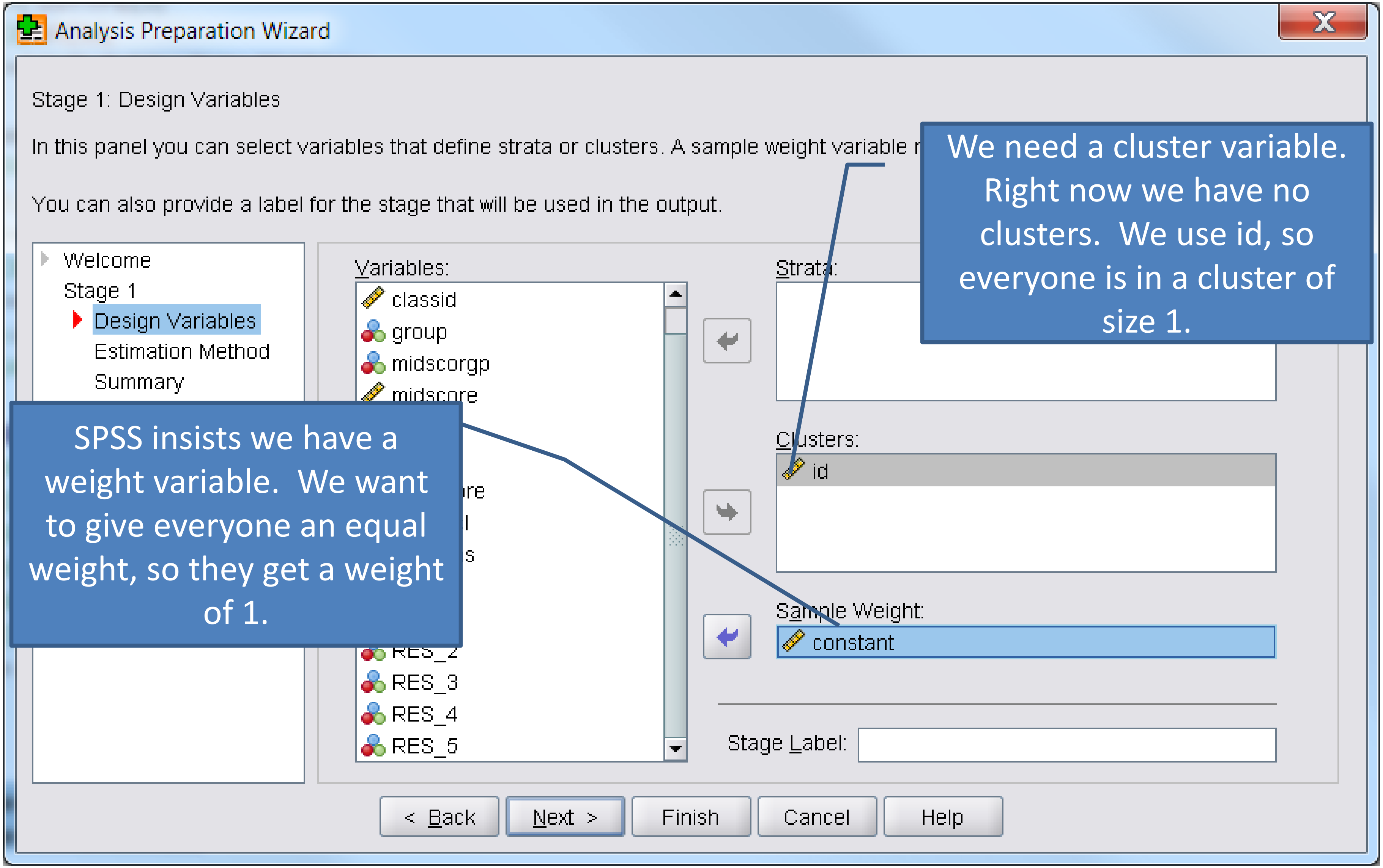


Save Data As

Look in: cluster course

File name: adult literacy

Save as type: CS Analysis Plan (*.csaplan)



Analysis Preparation Wizard

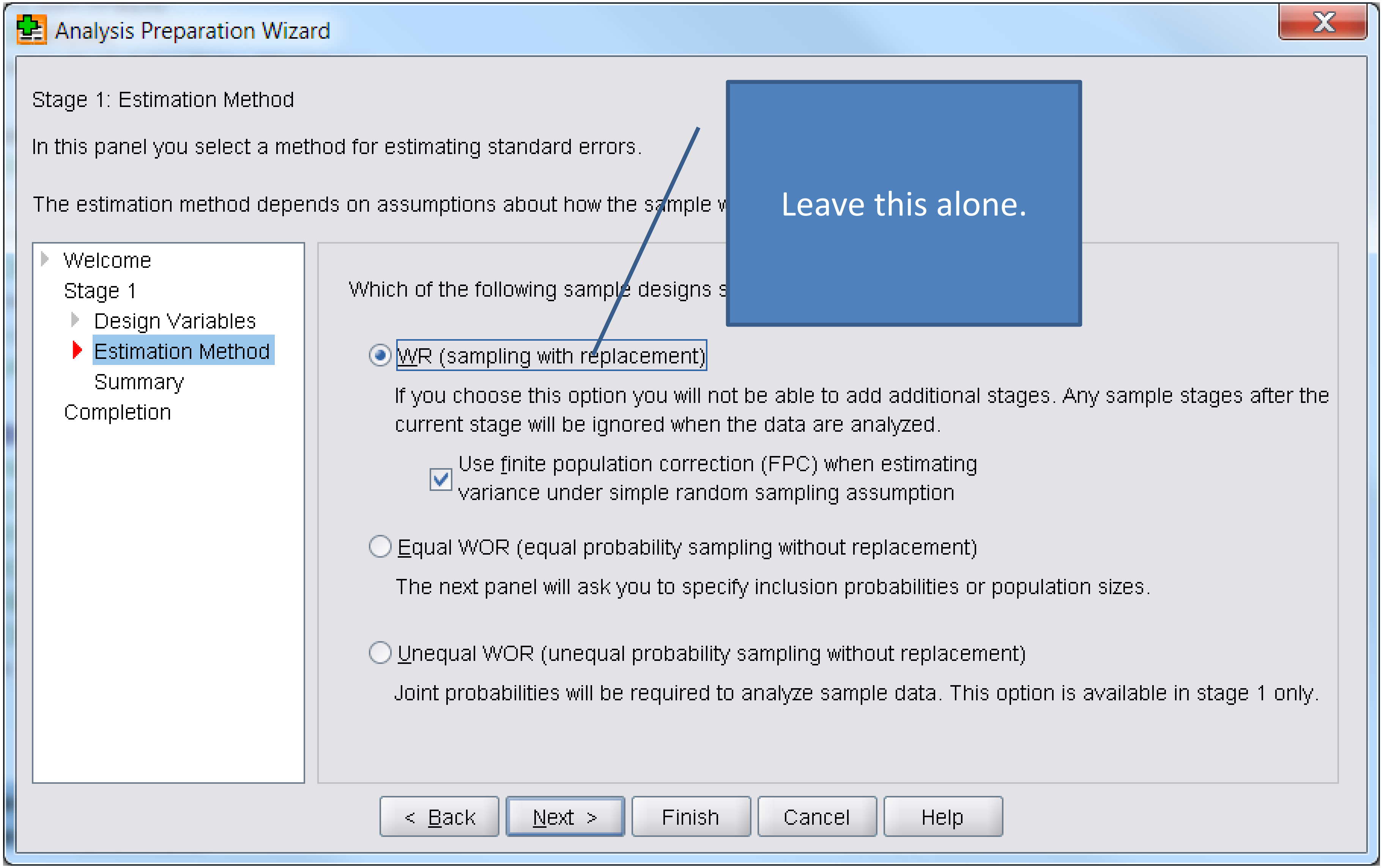
Stage 1: Design Variables

In this panel you can select variables that define strata or clusters. A sample weight variable r

You can also provide a label for the stage that will be used in the output.

We need a cluster variable. Right now we have no clusters. We use id, so everyone is in a cluster of size 1.

SPSS insists we have a weight variable. We want to give everyone an equal weight, so they get a weight of 1.



Stage 1: Estimation Method

In this panel you select a method for estimating standard errors.

The estimation method depends on assumptions about how the sample w

Which of the following sample designs s

● WR (sampling with replacement)

If you choose this option you will not be able to add additional stages. Any sample stages after the current stage will be ignored when the data are analyzed.

☑ Use finite population correction (FPC) when estimating variance under simple random sampling assumption

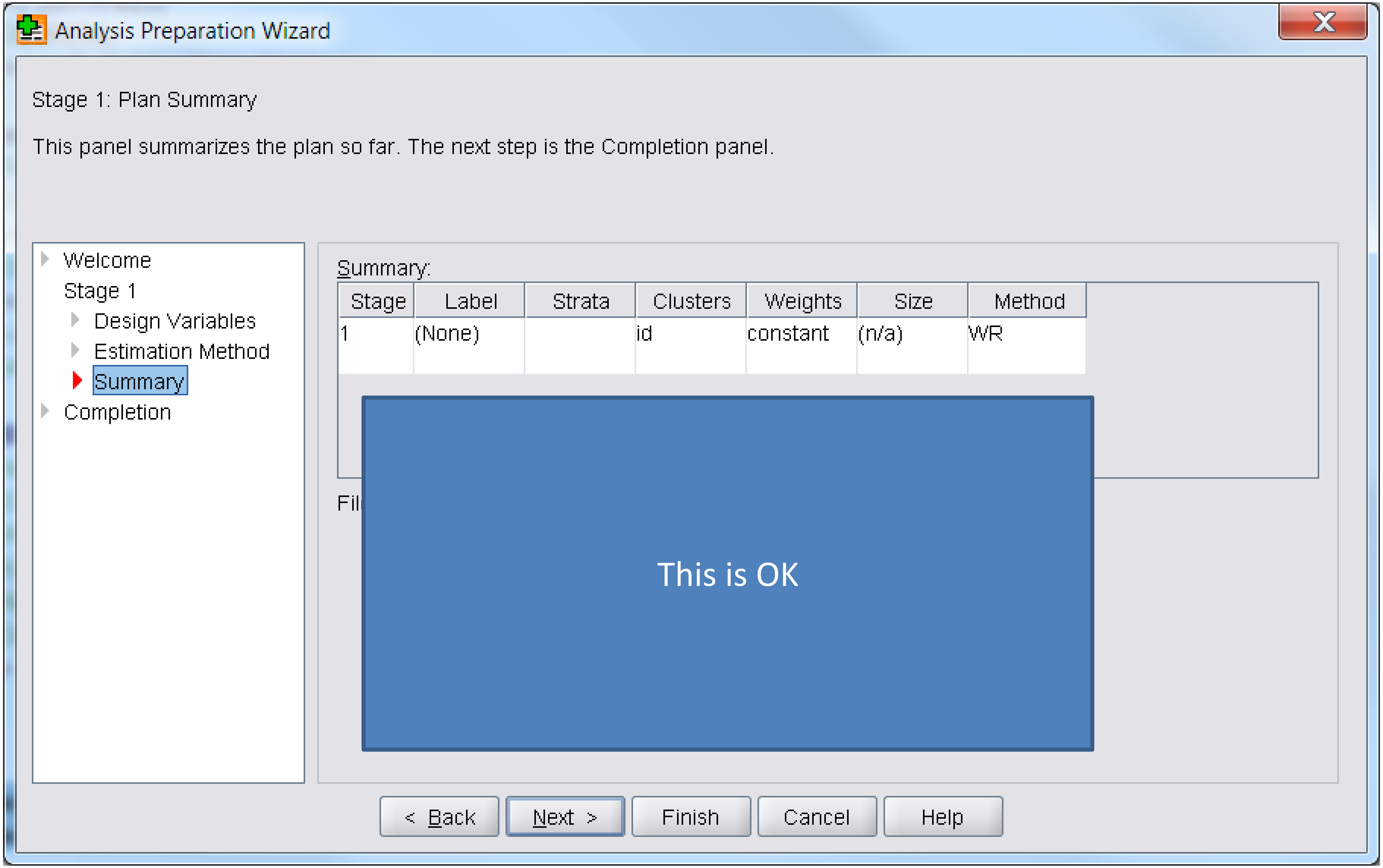
○ Equal WOR (equal probability sampling without replacement)

The next panel will ask you to specify inclusion probabilities or population sizes.

○ Unequal WOR (unequal probability sampling without replacement)

Joint probabilities will be required to analyze sample data. This option is available in stage 1 only.

Leave this alone.



Stage 1: Plan Summary

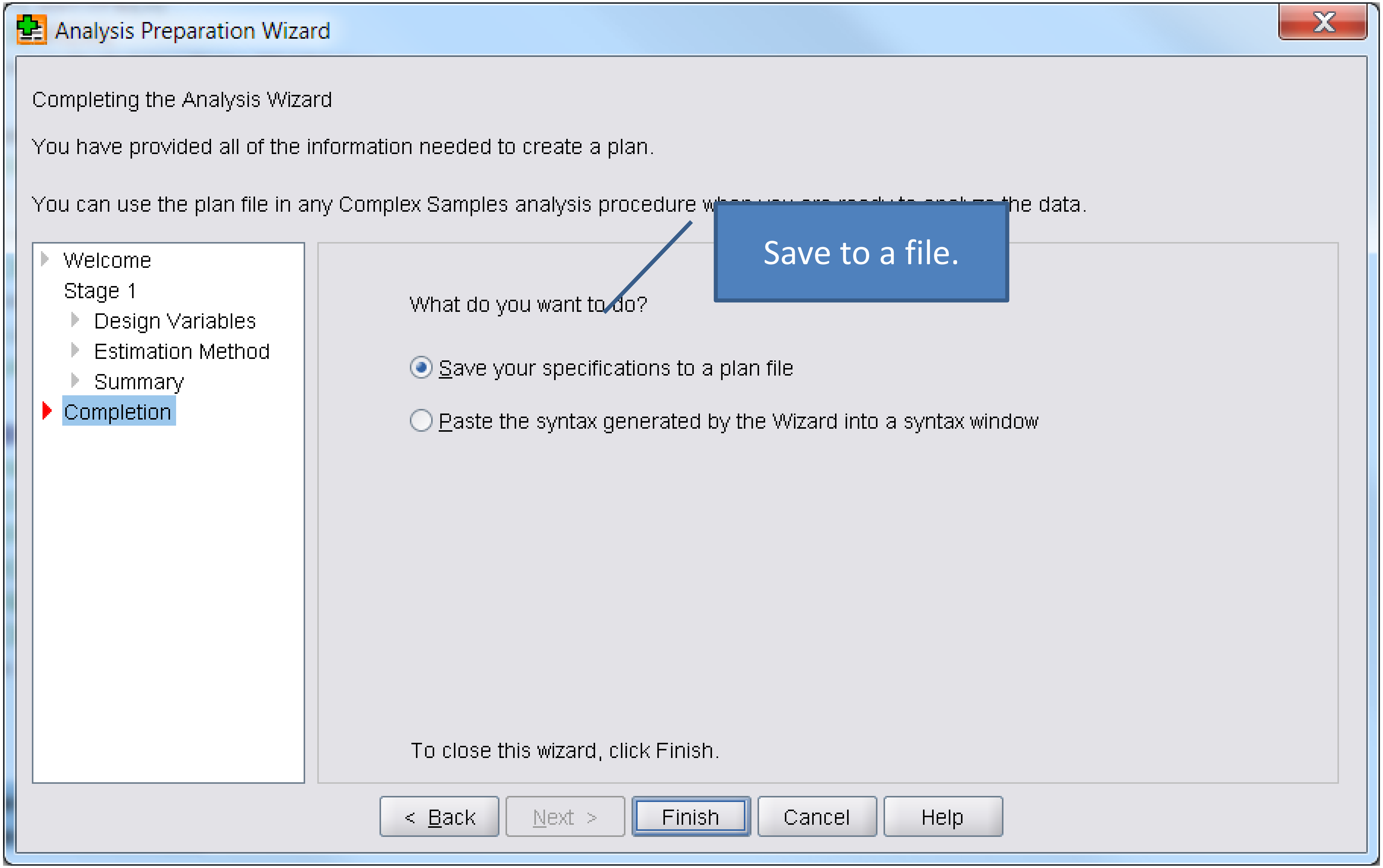
This panel summarizes the plan so far. The next step is the Completion panel.

Summary:

Stage	Label	Strata	Clusters	Weights	Size	Method
1	(None)		id	constant	(n/a)	WR

Fil

This is OK



Completing the Analysis Wizard

You have provided all of the information needed to create a plan.

You can use the plan file in any Complex Samples analysis procedure when you are ready to analyze the data.

What do you want to do?

● Save your specifications to a plan file

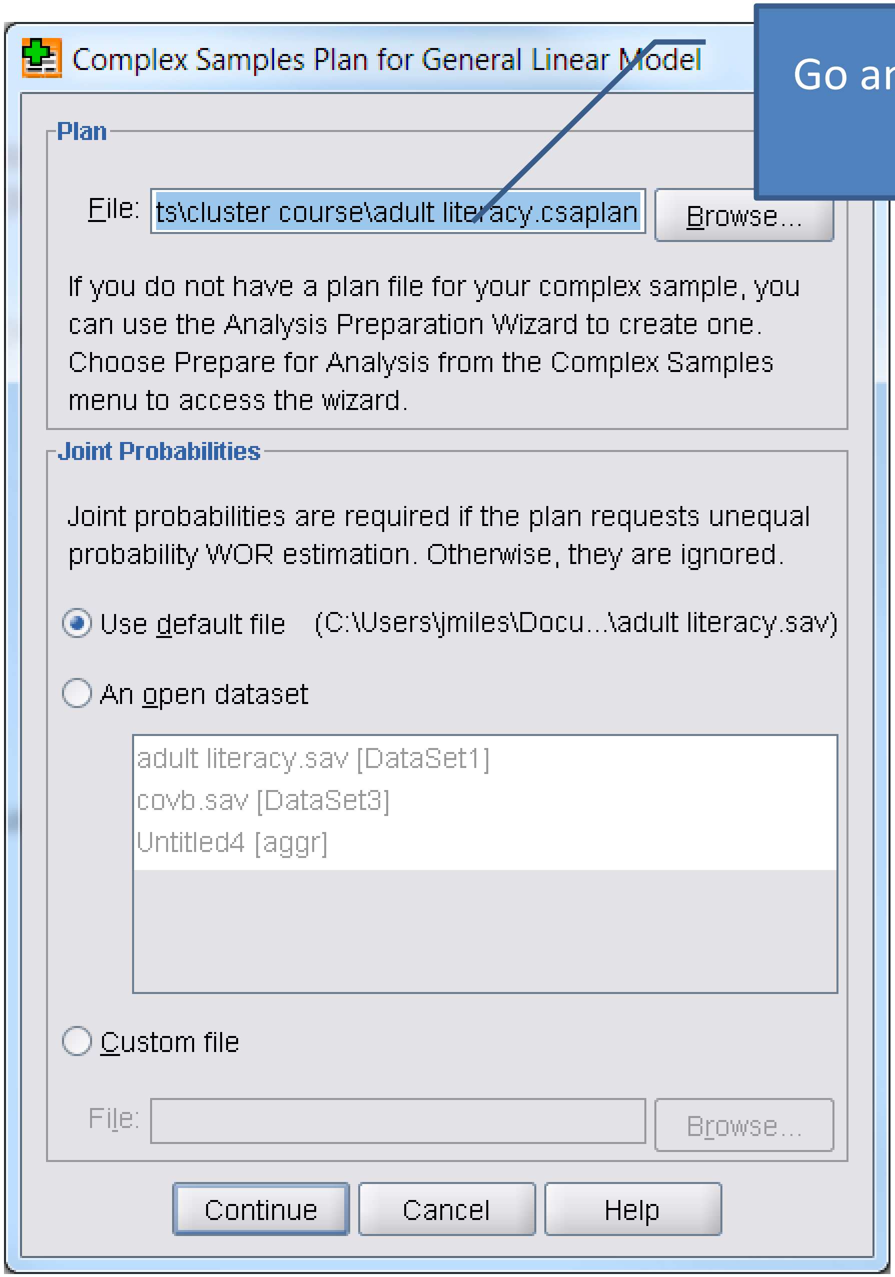
○ Paste the syntax generated by the Wizard into a syntax window

To close this wizard, click Finish.

Save to a file.

Running Complex Samples

- Analyze; Complex Samples; General Linear Model



Complex Samples Plan for General Linear Model

Plan

File: ts\cluster course\adult literacy.csaplan Browse...

If you do not have a plan file for your complex sample, you can use the Analysis Preparation Wizard to create one. Choose Prepare for Analysis from the Complex Samples menu to access the wizard.

Joint Probabilities

Joint probabilities are required if the plan requests unequal probability WOR estimation. Otherwise, they are ignored.

● Use default file (C:\Users\jmiles\Docu...\adult literacy.sav)

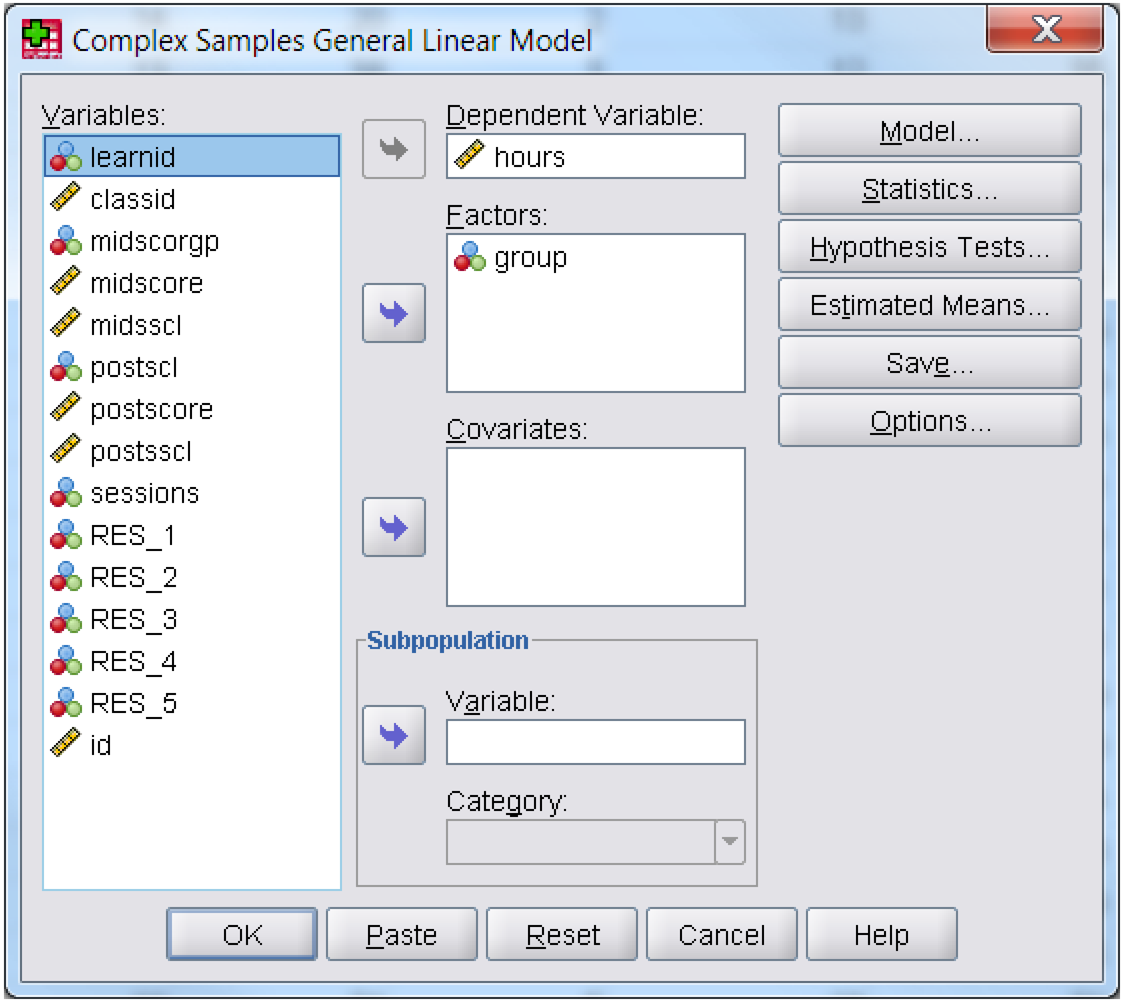
○ An open dataset

adult literacy.sav [DataSet1]
covb.sav [DataSet3]
Untitled4 [aggr]

○ Custom file

File: Browse...

Go and find the file that we just created.



Complex Samples General Linear Model

Dependent Variable: hours

Factors: group

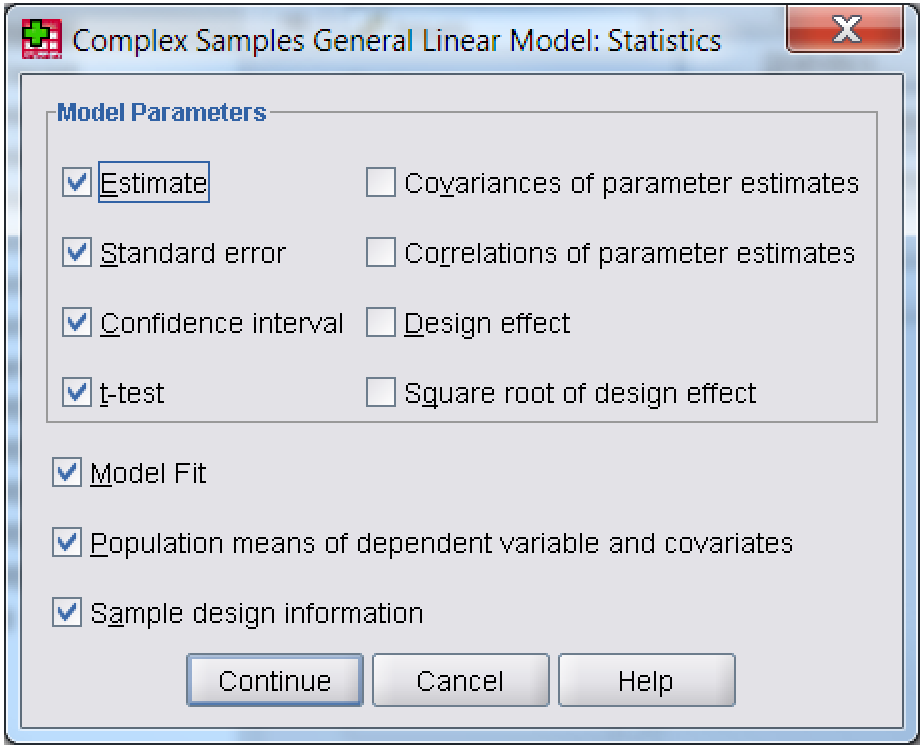
Covariates:

Subpopulation

Variable:

Category:

- Click statistics



Complex Samples General Linear Model: Statistics

Model Parameters

☑ Estimate

☑ Standard error

☑ Confidence interval

☑ t-test

☐ Covariances of parameter estimates

☐ Correlations of parameter estimates

☐ Design effect

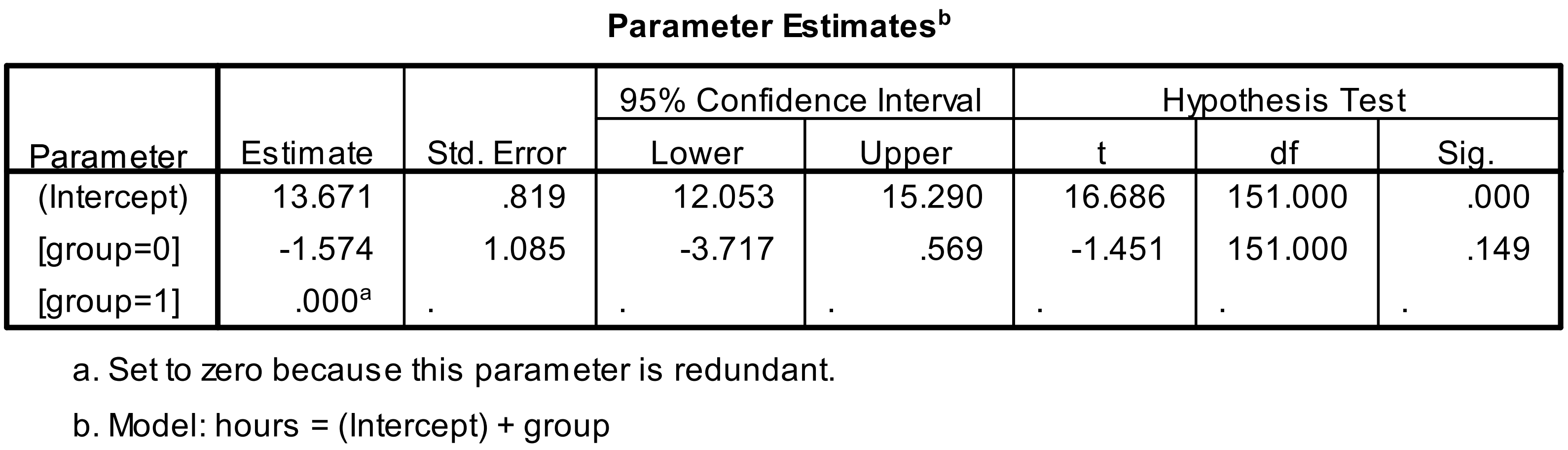
☐ Square root of design effect

☑ Model Fit

☑ Population means of dependent variable and covariates

☑ Sample design information

Results



Parameter Estimates[b]

Parameter	Estimate	Std. Error	95% Confidence Interval		Hypothesis Test		
			Lower	Upper	t	df	Sig.
(Intercept)	13.671	.819	12.053	15.290	16.686	151.000	.000
[group=0]	-1.574	1.085	-3.717	.569	-1.451	151.000	.149
[group=1]	.000[a]	.	.	.	.	.	.

a. Set to zero because this parameter is redundant.

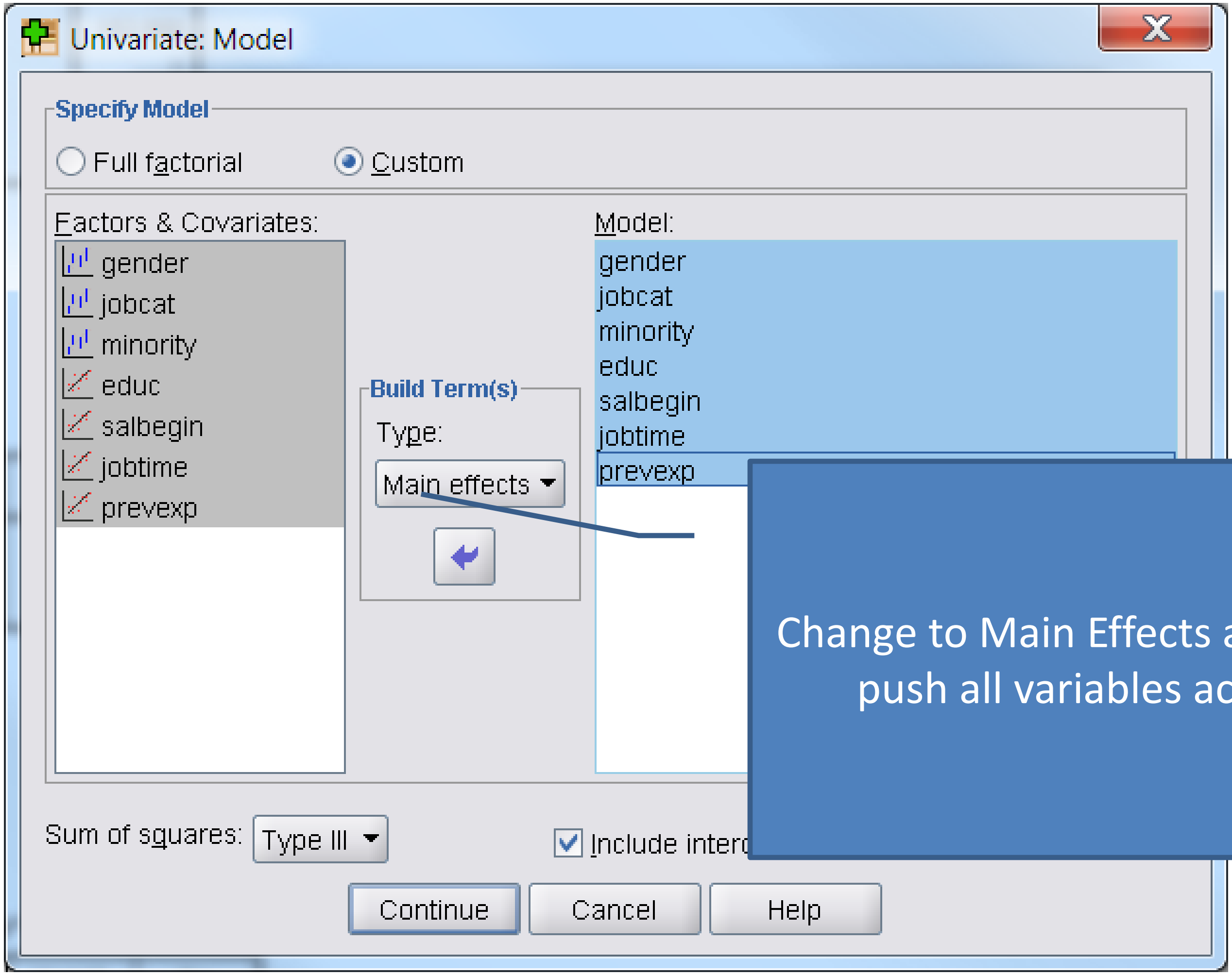
b. Model: hours = (Intercept) + group

Stata

- In Stata:
  - `reg hours group, robust`

Predicting Salary

- Use employee data.sav
- Set up complex sample as before
  - Need constant and ID
  - General Linear Model
  - Predict Salary with
    - Gender
    - Jobcat
    - Minority
    - Education
    - Salbegin
    - Jobtime
    - Prevexp



Specify Model

○ Full factorial ● Custom

Factors & Covariates:

- gender
- jobcat
- minority
- educ
- salbegin
- jobtime
- prevexp

Type: Main effects

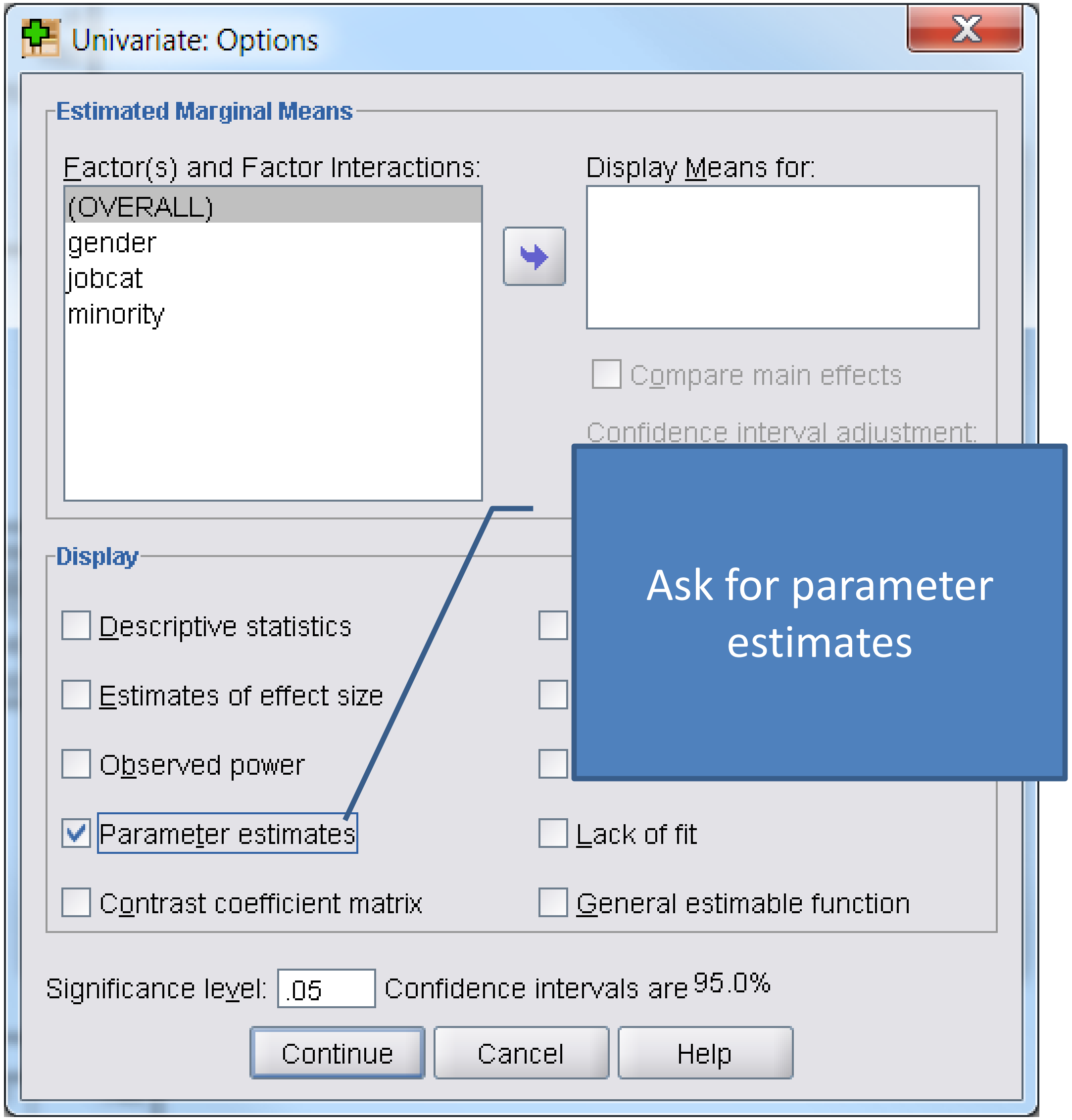
Model:

- gender
- jobcat
- minority
- educ
- salbegin
- jobtime
- prevexp

Sum of squares: Type III

☑ Include interc

Change to Main Effects and then push all variables across



Univariate: Options

Estimated Marginal Means

Factor(s) and Factor Interactions:

(OVERALL)
gender
jobcat
minority

Display Means for:

□ Compare main effects

Confidence interval adjustment:

Display

□ Descriptive statistics

□ Estimates of effect size

□ Observed power

☑ Parameter estimates

□ Contrast coefficient matrix

□ Lack of fit

□ General estimable function

Significance level: .05 Confidence intervals are 95.0%

Ask for parameter estimates

A Robust Haiku

T-stat looks too good.
Use robust standard errors.
Significance gone.

Back to Clustering

- We can correct for clusters using complex samples
- Instead of ID in the cluster variable
  - Class_id into the cluster variable

- What do you find?

People as Clusters

- People can be clusters
- Use co2.sav
    - (Wetherell, M.A., Crown, A.L., Lightman, S.L., Miles, J.N.V., Kaye, J. and Vedhara, K. (2006). The 4-dimensional Stress Test: Psychological, Sympathetic-Adrenal-Medullary, Parasympathetic and Hypothalamic-Pituitary-Adrenal Responses Following Inhalation of 35% CO2. *Psychoneuroendicronology, 31,* 6, 736-747.)

- Several measures before, during and after a stress test.
    - Heart rate
    - Blood pressure

Repeated Measures T-Test

- (Use CO2 – HR-10.0.sav)
- Two measures of heart rate
  - 10 mins before task
  - During

Adding Clusters