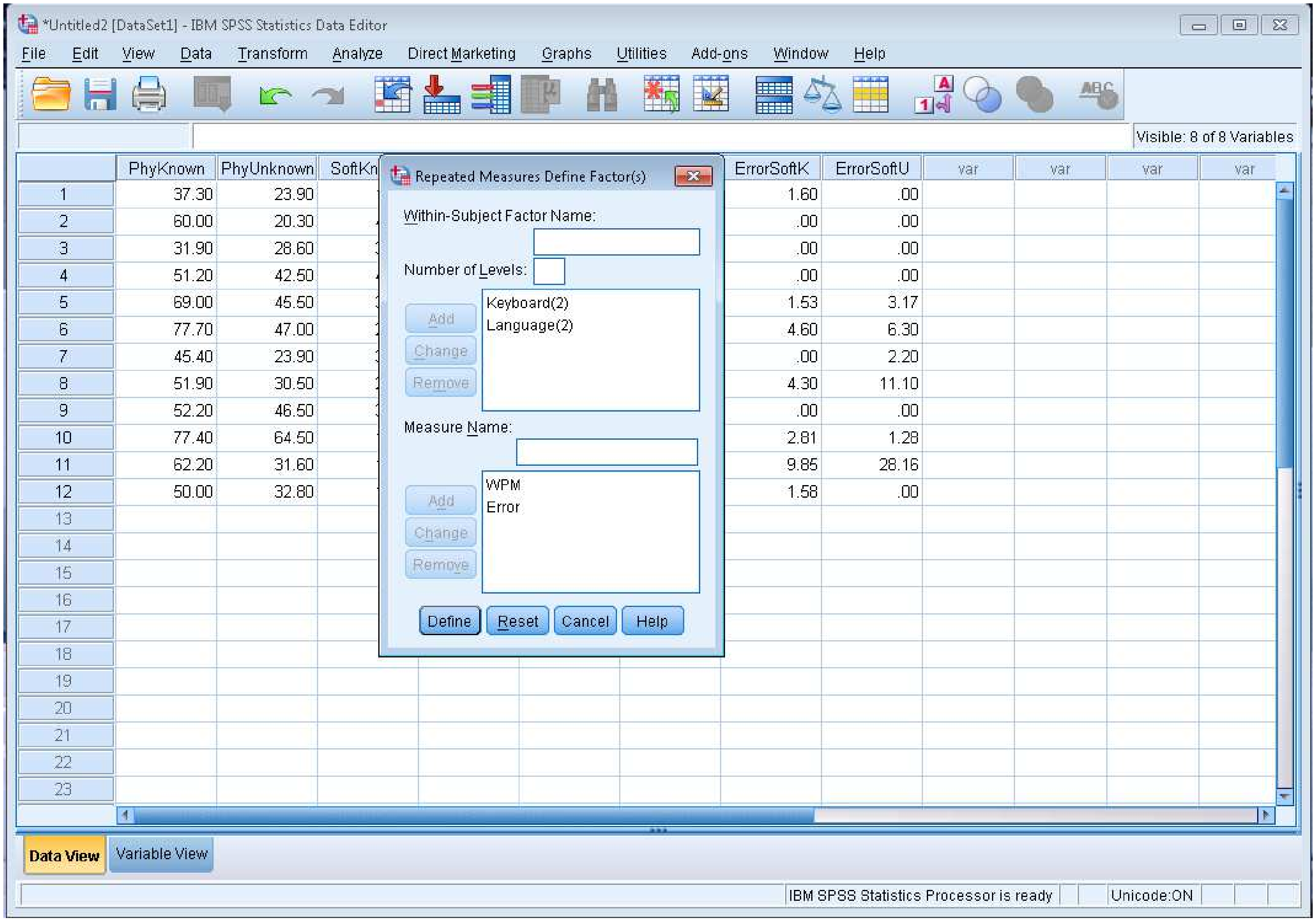
Analyzing Quantitative Data

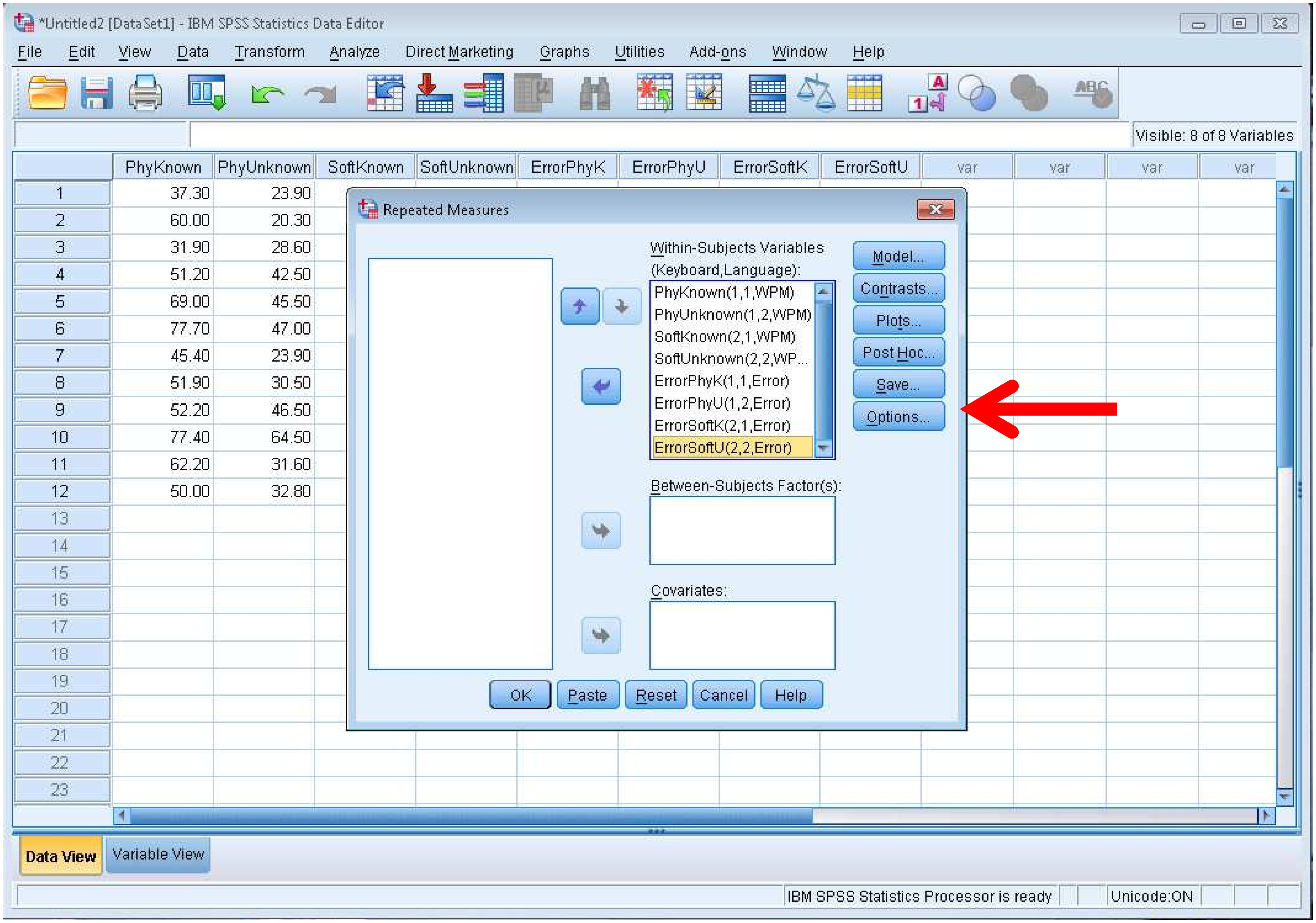
Analysis is about **QUESTIONS**

- Does physical vs soft keyboard, known vs unknown language affect typing speed or error rate?
- Hypotheses?

Analysis

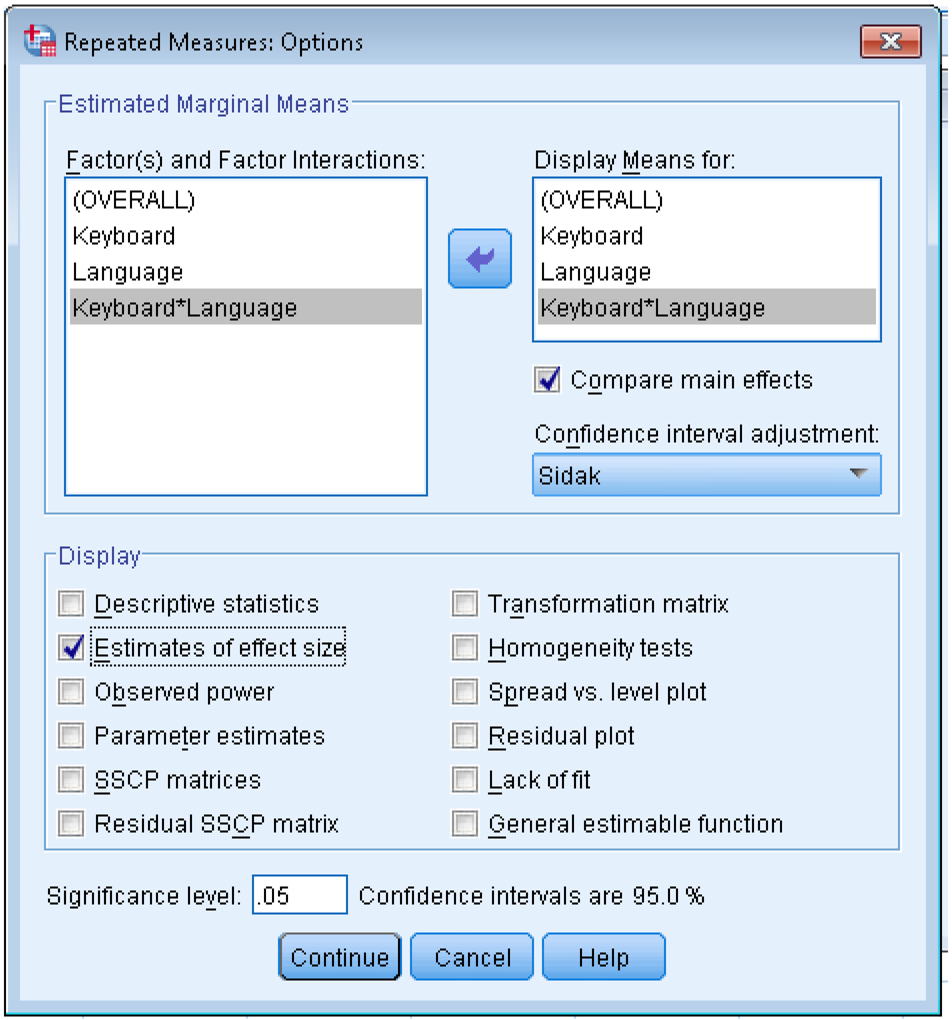

*Untitled2 [DataSet1] - IBM SPSS Statistics Data Editor
File Edit View Data Transform Analyze Direct Marketing Graphs Utilities Add-ons Window Help
Visible: 8 of 8 Variables
PhyKnown PhyUnknown SoftKn ErrorSoftK ErrorSoftU var var var var
Repeated Measures Define Factor(s)
Within-Subject Factor Name:
Number of Levels:
Add
Change
Remove
Keyboard(2)
Language(2)
Measure Name:
WPM
Error
Define Reset Cancel Help
Data View
Variable View
IBM SPSS Statistics Processor is ready
Unicode:ON

Analysis (2)

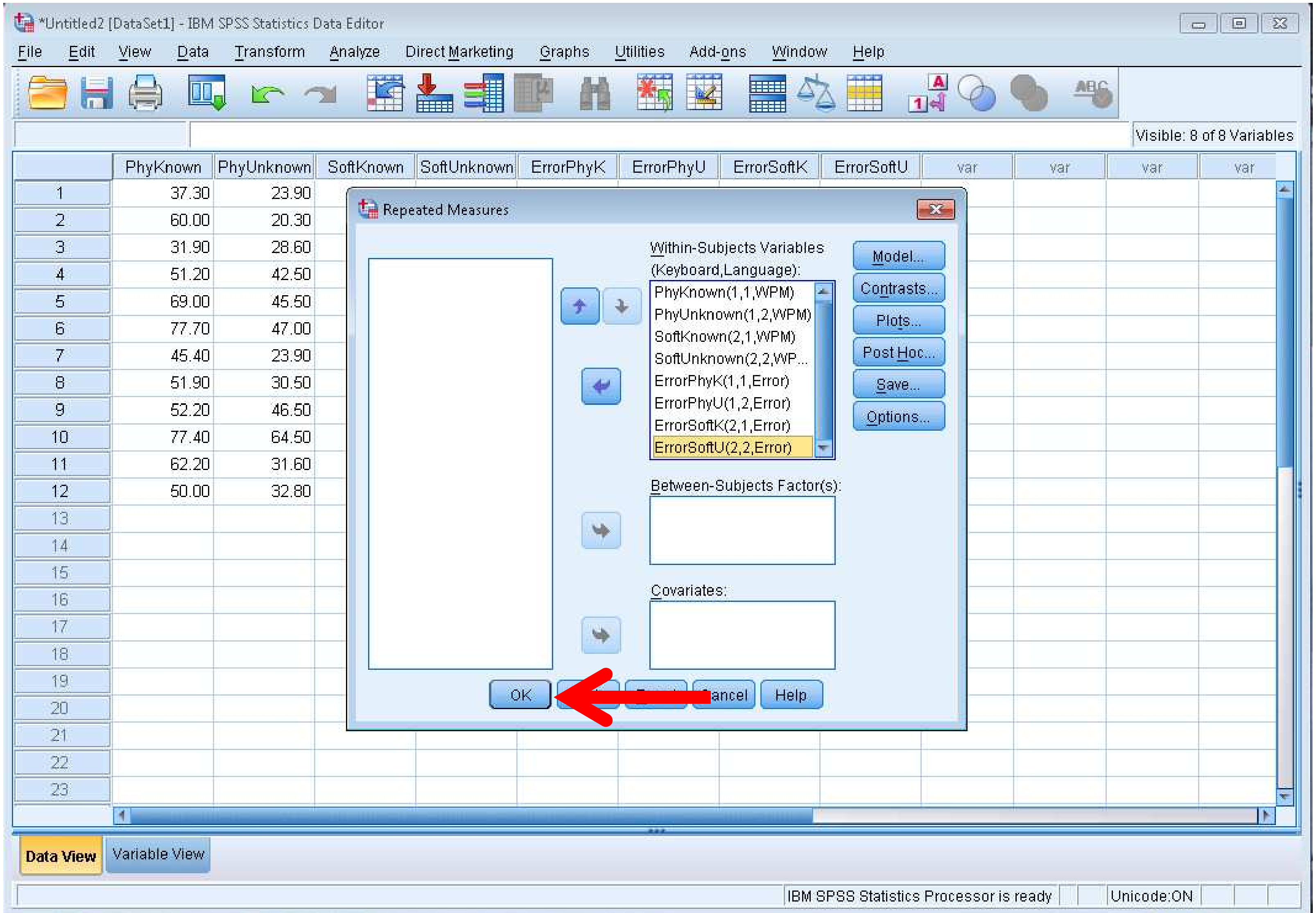


*Untitled2 [DataSet1] - IBM SPSS Statistics Data Editor
File Edit View Data Transform Analyze Direct Marketing Graphs Utilities Add-ons Window Help
Visible: 8 of 8 Variables
PhyKnown PhyUnknown SoftKnown SoftUnknown ErrorPhyK ErrorPhyU ErrorSoftK ErrorSoftU var var var var
1 37.30 23.90
2 60.00 20.30
3 31.90 28.60
4 51.20 42.50
5 69.00 45.50
6 77.70 47.00
7 45.40 23.90
8 51.90 30.50
9 52.20 46.50
10 77.40 64.50
11 62.20 31.60
12 50.00 32.80
Repeated Measures
Within-Subjects Variables (Keyboard,Language):
PhyKnown(1,1,WPM)
PhyUnknown(1,2,WPM)
SoftKnown(2,1,WPM)
SoftUnknown(2,2,WP...
ErrorPhyK(1,1,Error)
ErrorPhyU(1,2,Error)
ErrorSoftK(2,1,Error)
ErrorSoftU(2,2,Error)
Model...
Contrasts...
Plots...
Post Hoc...
Save...
Options...
Between-Subjects Factor(s):
Covariates:
OK Paste Reset Cancel Help
Data View Variable View
IBM SPSS Statistics Processor is ready
Unicode:ON

Analysis (3)


Repeated Measures: Options
Estimated Marginal Means
Factor(s) and Factor Interactions:
(OVERALL)
Keyboard
Language
Keyboard*Language
Display Means for:
(OVERALL)
Keyboard
Language
Keyboard*Language
Compare main effects
Confidence interval adjustment:
Sidak
Display
Descriptive statistics
Estimates of effect size
Observed power
Parameter estimates
SSCP matrices
Residual SSCP matrix
Transformation matrix
Homogeneity tests
Spread vs. level plot
Residual plot
Lack of fit
General estimable function
Significance level:
.05
Confidence intervals are 95.0 %
Continue
Cancel
Help

Analysis (2)



*Untitled2 [DataSet1] - IBM SPSS Statistics Data Editor
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Visible: 8 of 8 Variables
PhyKnown PhyUnknown SoftKnown SoftUnknown ErrorPhyK ErrorPhyU ErrorSoftK ErrorSoftU var var var var
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Model...
Contrasts...
Plots...
Post Hoc...
Save...
Options...
Between-Subjects Factor(s):
Covariates:
OK
Help
Data View
Variable View
IBM SPSS Statistics Processor is ready
Unicode:ON

Results

Tests of Within-Subjects Effects

Multivariate[a,b]

Within Subjects Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Keyboard	Pillai's Trace	.740	12.839[c]	2.000	9.000	.002	.740
	Wilks' Lambda	.260	12.839[c]	2.000	9.000	.002	.740
	Hotelling's Trace	2.853	12.839[c]	2.000	9.000	.002	.740
	Roy's Largest Root	2.853	12.839[c]	2.000	9.000	.002	.740
Language	Pillai's Trace	.926	56.436[c]	2.000	9.000	.000	.926
	Wilks' Lambda	.074	56.436[c]	2.000	9.000	.000	.926
	Hotelling's Trace	12.541	56.436[c]	2.000	9.000	.000	.926
	Roy's Largest Root	12.541	56.436[c]	2.000	9.000	.000	.926
Keyboard * Language	Pillai's Trace	.343	2.353[c]	2.000	9.000	.151	.343
	Wilks' Lambda	.657	2.353[c]	2.000	9.000	.151	.343
	Hotelling's Trace	.523	2.353[c]	2.000	9.000	.151	.343
	Roy's Largest Root	.523	2.353[c]	2.000	9.000	.151	.343

a. Design: Intercept
Within Subjects Design: Keyboard + Language + Keyboard * Language

b. Tests are based on averaged variables.

c. Exact statistic

Univariate Tests

Univariate Tests

Source	Measure		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Keyboard	WPM	Sphericity Assumed	6046.583	1	6046.583	28.093	.000	.737
		Greenhouse-Geisser	6046.583	1.000	6046.583	28.093	.000	.737
		Huynh-Feldt	6046.583	1.000	6046.583	28.093	.000	.737
		Lower-bound	6046.583	1.000	6046.583	28.093	.000	.737
	Error	Sphericity Assumed	31.773	1	31.773	1.031	.334	.093
		Greenhouse-Geisser	31.773	1.000	31.773	1.031	.334	.093
		Huynh-Feldt	31.773	1.000	31.773	1.031	.334	.093
		Lower-bound	31.773	1.000	31.773	1.031	.334	.093
Error(Keyboard)	WPM	Sphericity Assumed	2152.357	10	215.236			
		Greenhouse-Geisser	2152.357	10.000	215.236			
		Huynh-Feldt	2152.357	10.000	215.236			
		Lower-bound	2152.357	10.000	215.236			
	Error	Sphericity Assumed	308.302	10	30.830			
		Greenhouse-Geisser	308.302	10.000	30.830			
		Huynh-Feldt	308.302	10.000	30.830			
		Lower-bound	308.302	10.000	30.830			
Language	WPM	Sphericity Assumed	1596.023	1	1596.023	108.575	.000	.916
		Greenhouse-Geisser	1596.023	1.000	1596.023	108.575	.000	.916
		Huynh-Feldt	1596.023	1.000	1596.023	108.575	.000	.916
		Lower-bound	1596.023	1.000	1596.023	108.575	.000	.916
	Error	Sphericity Assumed	36.309	1	36.309	3.538	.089	.261
		Greenhouse-Geisser	36.309	1.000	36.309	3.538	.089	.261
		Huynh-Feldt	36.309	1.000	36.309	3.538	.089	.261
		Lower-bound	36.309	1.000	36.309	3.538	.089	.261
Keyboard * Language	WPM	Sphericity Assumed	289.178	1	289.178	5.133	.047	.339
		Greenhouse-Geisser	289.178	1.000	289.178	5.133	.047	.339
		Huynh-Feldt	289.178	1.000	289.178	5.133	.047	.339
		Lower-bound	289.178	1.000	289.178	5.133	.047	.339
	Error	Sphericity Assumed	3.224	1	3.224	.350	.567	.034
		Greenhouse-Geisser	3.224	1.000	3.224	.350	.567	.034
		Huynh-Feldt	3.224	1.000	3.224	.350	.567	.034
		Lower-bound	3.224	1.000	3.224	.350	.567	.034

Summary Tables

Tests of Within-Subjects Contrasts

Source	Measure	Keyboard	Language	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Keyboard	WPM	Linear		6046.583	1	6046.583	28.093	.000	.737
	Error	Linear		31.773	1	31.773	1.031	.334	.093
Error(Keyboard)	WPM	Linear		2152.357	10	215.236			
	Error	Linear		308.302	10	30.830			
Language	WPM		Linear	1596.023	1	1596.023	108.575	.000	.916
	Error		Linear	36.309	1	36.309	3.538	.089	.261
Error(Language)	WPM		Linear	146.997	10	14.700			
	Error		Linear	102.635	10	10.263			
Keyboard * Language	WPM	Linear	Linear	289.178	1	289.178	5.133	.047	.339
	Error	Linear	Linear	3.224	1	3.224	.350	.567	.034
Error (Keyboard*Language)	WPM	Linear	Linear	563.322	10	56.332			
	Error	Linear	Linear	92.077	10	9.208			

So … Multivariate or Univariate

- You can look at your design from a multivariate point of view if you regard your data not as representing realisations of one DV in different conditions, but of (ultimately) different DVs which are to be analysed simultaneously.
  - http://stats.stackexchange.com/questions/4530/when-to-interpret-multivariate-tests-when-performing-repeated-measures-ancova

Also gives estimates of performance for each iv

Estimated Marginal Means

1. Grand Mean

Measure	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
WPM	34.800	2.267	29.748	39.852
Error	2.718	1.001	.486	4.949

2. Keyboard

Estimates

Measure	Keyboard	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
WPM	1	46.523	3.913	37.804	55.242
	2	23.077	2.180	18.220	27.934
Error	1	1.868	.690	.331	3.405
	2	3.567	1.712	-.247	7.382

Pairwise Comparisons

Measure	(I) Keyboard	(J) Keyboard	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
						Lower Bound	Upper Bound
WPM	1	2	23.445*	4.423	.000	13.589	33.302
	2	1	-23.445*	4.423	.000	-33.302	-13.589
Error	1	2	-1.700	1.674	.334	-5.430	2.031
	2	1	1.700	1.674	.334	-2.031	5.430

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Sidak.

Multivariate Tests

	Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Pillai's trace	.740	12.839[a]	2.000	9.000	.002	.740
Wilks' lambda	.260	12.839[a]	2.000	9.000	.002	.740
Hotelling's trace	2.853	12.839[a]	2.000	9.000	.002	.740
Roy's largest root	2.853	12.839[a]	2.000	9.000	.002	.740

Each F tests the multivariate effect of Keyboard. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Exact statistic

3. Language

Also gives estimates of performance for each iv

Estimates

Measure	Language	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
WPM	1	40.823	2.482	35.293	46.352
	2	28.777	2.189	23.900	33.654
Error	1	1.809	.634	.397	3.222
	2	3.626	1.439	.420	6.832

Pairwise Comparisons

Measure	(I) Language	(J) Language	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
						Lower Bound	Upper Bound
WPM	1	2	12.045*	1.156	.000	9.470	14.621
	2	1	-12.045*	1.156	.000	-14.621	-9.470
Error	1	2	-1.817	.966	.089	-3.969	.335
	2	1	1.817	.966	.089	-.335	3.969

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Sidak.

Multivariate Tests

	Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Pillai's trace	.926	56.436[a]	2.000	9.000	.000	.926
Wilks' lambda	.074	56.436[a]	2.000	9.000	.000	.926
Hotelling's trace	12.541	56.436[a]	2.000	9.000	.000	.926
Roy's largest root	12.541	56.436[a]	2.000	9.000	.000	.926

Each F tests the multivariate effect of Language. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Exact statistic

4. Keyboard * Language

Measure	Keyboard	Language	Mean	Std. Error	95% Confidence Interval	
					Lower Bound	Upper Bound
WPM	1	1	55.109	4.533	45.008	65.210
		2	37.936	3.744	29.594	46.279
	2	1	26.536	3.019	19.809	33.263
		2	19.618	1.703	15.824	23.412
Error	1	1	1.230	.752	-.446	2.906
		2	2.505	.787	.752	4.259
	2	1	2.388	.901	.381	4.395
		2	4.746	2.567	-.972	10.465

Another Interesting Effect: Tripling Data

Tests of Within-Subjects Effects

Multivariate[a,b]

Within Subjects Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Keyboard	Pillai's Trace	.740	12.839[c]	2.000	9.000	.002	.740
	Wilks' Lambda	.260	12.839[c]	2.000	9.000	.002	.740
	Hotelling's Trace	2.853	12.839[c]	2.000	9.000	.002	.740
	Roy's Largest Root	2.853	12.839[c]	2.000	9.000	.002	.740
Language	Pillai's Trace	.926	56.436[c]	2.000	9.000	.000	.926
	Wilks' Lambda	.074	56.436[c]	2.000	9.000	.000	.926
	Hotelling's Trace	12.541	56.436[c]	2.000	9.000	.000	.926
	Roy's Largest Root	12.541	56.436[c]	2.000	9.000	.000	.926
Keyboard * Language	Pillai's Trace	.343	2.353[c]	2.000	9.000	.151	.343
	Wilks' Lambda	.657	2.353[c]	2.000	9.000	.151	.343
	Hotelling's Trace	.523	2.353[c]	2.000	9.000	.151	.343
	Roy's Largest Root	.523	2.353[c]	2.000	9.000	.151	.343

a. Design: Intercept
Within Subjects Design: Keyboard + Language + Keyboard * Language

b. Tests are based on averaged variables.

c. Exact statistic

Another Interesting Effect: Tripling Data

Multivariate Tests[a]

Effect			Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Between Subjects	Intercept	Pillai's Trace	.963	403.598[b]	2.000	31.000	.000	.963
		Wilks' Lambda	.037	403.598[b]	2.000	31.000	.000	.963
		Hotelling's Trace	26.039	403.598[b]	2.000	31.000	.000	.963
		Roy's Largest Root	26.039	403.598[b]	2.000	31.000	.000	.963
Within Subjects	Keyboard	Pillai's Trace	.740	44.225[b]	2.000	31.000	.000	.740
		Wilks' Lambda	.260	44.225[b]	2.000	31.000	.000	.740
		Hotelling's Trace	2.853	44.225[b]	2.000	31.000	.000	.740
		Roy's Largest Root	2.853	44.225[b]	2.000	31.000	.000	.740
	Language	Pillai's Trace	.926	194.392[b]	2.000	31.000	.000	.926
		Wilks' Lambda	.074	194.392[b]	2.000	31.000	.000	.926
		Hotelling's Trace	12.541	194.392[b]	2.000	31.000	.000	.926
		Roy's Largest Root	12.541	194.392[b]	2.000	31.000	.000	.926
	Keyboard * Language	Pillai's Trace	.343	8.105[b]	2.000	31.000	.001	.343
		Wilks' Lambda	.657	8.105[b]	2.000	31.000	.001	.343
		Hotelling's Trace	.523	8.105[b]	2.000	31.000	.001	.343
		Roy's Largest Root	.523	8.105[b]	2.000	31.000	.001	.343

Within Subjects Design: Keyboard + Language + Keyboard * Language

b. Exact statistic

Analysis is about **QUESTIONS**

- Does physical vs soft keyboard, known vs unknown language affect typing speed or error rate?
- Hypotheses?
- OTHER QUESTIONS?

Examples of other questions

- Correlation Questions
  - Does physical keyboard speed correlate with soft keyboard typing speeds?
  - Does error rate correlate on physical vs soft keyboards?
- Likert/Preference/Rating Questions
  - Preferences for physical vs soft keyboards?
  - Perceived efficacy of soft keyboards?
  - Perceived performance of soft keyboard for known vs unknown language
- Cognitive workload questions
  - NASA TLS evaluation of soft vs physical keyboards?

Data Types

- Categorical
  - Technical discipline, Y/N
  - Gender, M/F
- Ordinal
  - Orderable but not equidistant values
  - Likert data is a good example
    - Strongly agree, agree, neutral, disagree, strongly disagree
  - Education Level (high school, some university, undergrad, grad).
- Interval
  - Equidistant values, but values are not based upon a 0.
  - Can’t really say “twice as X”.
  - Evaluate the software: Hated it = -3; Loved it = 3.
- Ratio
  - Speed: Twice as fast
  - Years of education: 2X the years of education.
  - Errors: Double the errors

Categorical (Categorical, Ordinal)

Continuous (Interval, Ratio)

Correct Test for Correct Data/Questions

		Dependent Variable	
		Categorical	*Continuous*
Independent Variable	*Categorical*	Chi Square	t-test, ANOVA
	Continuous	LDA, QDA	Regression

- Does physical vs soft keyboard, known vs unknown language affect typing speed or error rate?
- Does physical keyboard speed correlate with soft keyboard typing speeds?

A Note on Likert (and Other) Ordinal Data

- Likert Data
  - **Mann-Whitney U-Test**This test is used when we obtain ordinal data in the **independent groups** situation.
  - **Wilcoxon Signed-Ranks Test**This test is used when we obtain ordinal data in the **paired samples** situation.

Question

- Does physical vs soft correlate?

Question

- Does physical vs soft correlate?

Correlations

[DataSet2]

Correlations

		Physical	Soft
Physical	Pearson Correlation	1	.215
	Sig. (2-tailed)		.314
	N	24	24
Soft	Pearson Correlation	.215	1
	Sig. (2-tailed)	.314	
	N	24	24

Question

- Does physical vs soft correlate?

Correlations

[DataSet2]

Correlations

		Physical	Soft
Physical	Pearson Correlation	1	.215
	Sig. (2-tailed)		.314
	N	24	24
Soft	Pearson Correlation	.215	1
	Sig. (2-tailed)	.314	
	N	24	24

Correlations

Correlations

		Physical	Soft
Physical	Pearson Correlation	1	-.112
	Sig. (2-tailed)		[illegible]
	N	12	[illegible]
Soft	Pearson Correlation	-.112	1
	Sig. (2-tailed)	.728	
	N	12	12

Double-click
activate

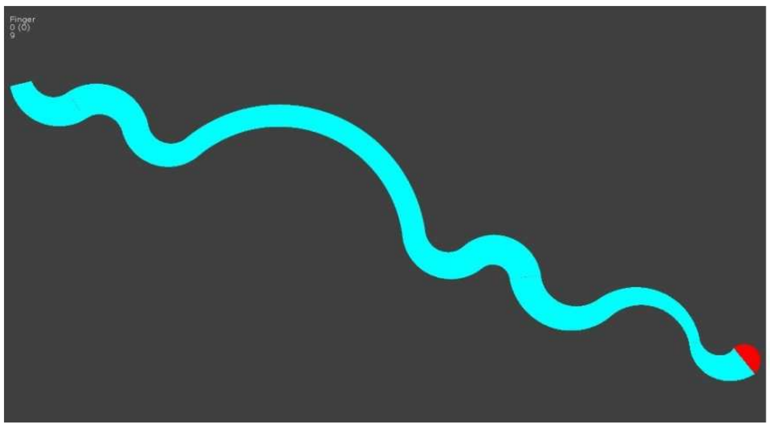
Correlations

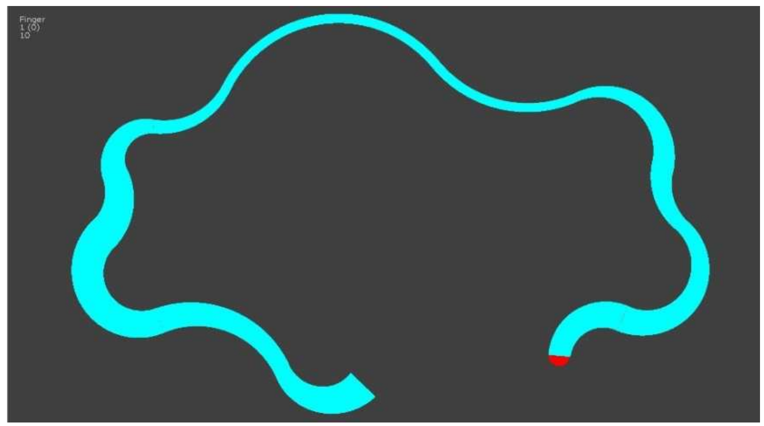
Correlations

		Anxiety	Sleep
Anxiety	Pearson Correlation	1	-.365*
	Sig. (2-tailed)		.036
	N	33	33
Sleep	Pearson Correlation	-.365*	1
	Sig. (2-tailed)	.036	
	N	33	33

*. Correlation is significant at the 0.05 level (2-tailed).

$$v(s) = \frac{1}{b'} w(s) \cdot r(s)^{1/3}$$

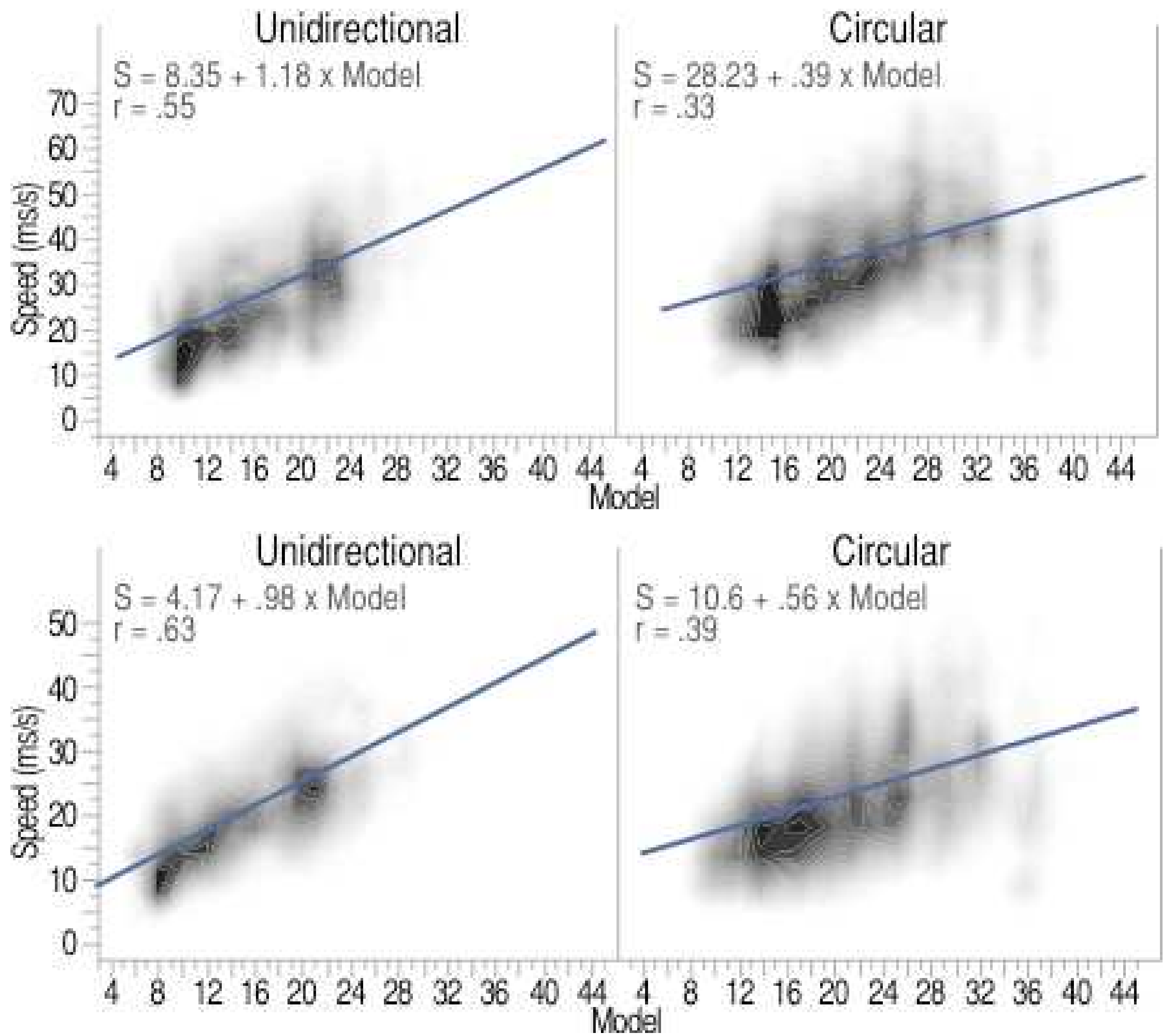




Models and Correlation

Touch

Mouse



Analysis?

	Paths	r	p	Intercept	Slope
Unidir	All	.55	<.0001	8.35	1.18
	Last	.56	<.0001	7.73	1.18
Circular	All	.37	<.0001	28.23	.39
	Last	.33	<.0001	27.11	.40

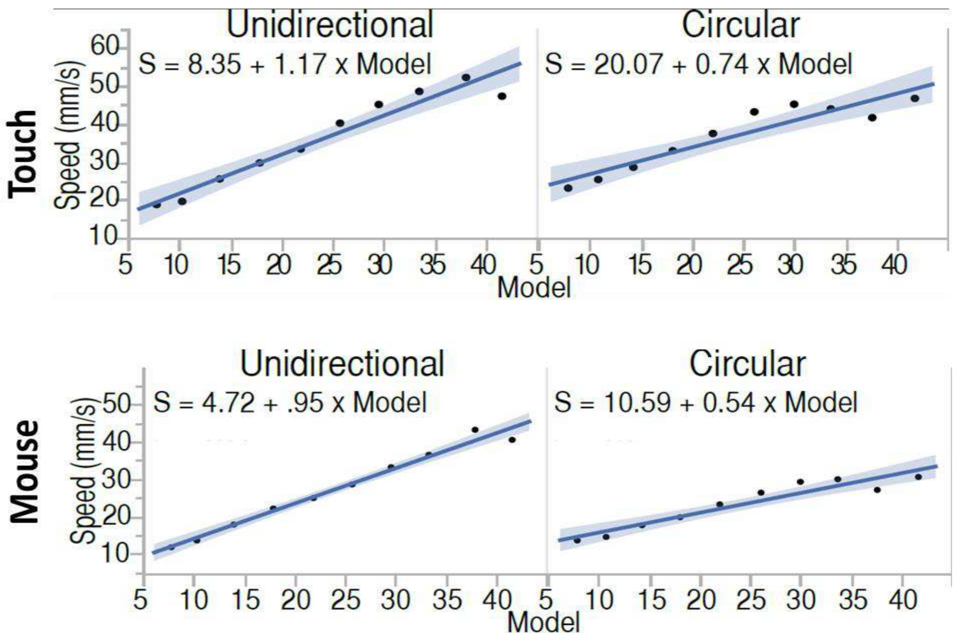
	Paths	r	p	Intercept	Slope
Unidir	All	.63	<.0001	4.17	.98
	Last	.64	<.0001	4.53	.95
Circular	All	.39	<.0001	10.6	.56
	Last	.41	<.0001	10.3	.57

What about nice Fitts's Law correlation?

Averaging

- Averaging serves a highly valuable purpose; when curves are averaged, factors including naturally occurring neurophysiological noise, errors (overshoot, undershoot and target misses), and cognitive variations such as response bias [14] that are present in any one sample are eliminated. What remains is the expected performance value for a task, i.e. the average cost given a large number of iterations. The higher the correlation coefficient for average input time, the more *encompassing* the model.

Analysis



	Filter	Touch		Mouse	
		r^2	p	r^2	p
Unidir	All	.94	<.0001	.98	<.0001
	Last	.93	<.0001	.97	<.0001
Circular	All	.87	<.001	.90	<.0001
	Last	.89	<.001	.92	<.0001