

Example 1: Reviewing General Linear Models and Interaction Terms (complete syntax, data, and output available for STATA, R, and SAS electronically)

These example data come from Hoffman (2015) chapter 2, which examined prediction of a **cognition outcome** from **age** (centered at 85 years), **grip strength** (centered at 9 pounds), **sex** (with men as the reference group) and subsequent **dementia status** (none = 1, future = 2, and current = 3, with none as the reference) in a sample of 550 older adults. This example first uses a main-effects only model to demonstrate two ways of generating predicted outcomes (via individual-specific estimates or using fake people). It then illustrates how to include and interpret different kinds of interactions: first for age by grip strength, and then adding sex by dementia status.

STATA Syntax for Importing and Preparing Data for Analysis:

```
// Defining global variable for file location to be replaced in code below
// \\Client\ precedes path in Virtual Desktop outside H drive
global filesave "C:\Dropbox\23_PSQF6270\PSQF6270_Example1"

// Open chapter 2 STATA dataset and clear away any existing data
use "$filesave\STATA_Chapter2.dta", clear // Has converted all variables to lower-case

// Center quantitative predictors
gen age85 = age-85
gen grip9 = grip-9
// Create dummy-coded binary indicator predictors for dementia groups
gen demnf=. // Create two new empty variables
gen demnc=.
// Recode if demgroup = none
replace demnf=0 if demgroup==1 → refered and paid
replace demnc=0 if demgroup==1
// Recode if demgroup = future
replace demnf=1 if demgroup==2
replace demnc=0 if demgroup==2
// Recode if demgroup = current
replace demnf=0 if demgroup==3
replace demnc=1 if demgroup==3
// Label all variables
label variable age85 "age85: Age in Years (0=85)"
label variable grip9 "grip9: Grip Strength in Pounds (0=9)"
label variable sexmw "sexmw: Sex (0=Men, 1=Women)"
label variable demnf "demnf: Dementia Predictor for None=0 vs Future=1"
label variable demnc "demnc: Dementia Predictor for None=0 vs Current=1"
label variable cognition "cognition: Cognition Outcome"
label variable demgroup "demgroup: Dementia Group 1N 2F 3C"

// Filter to only cases complete on all variables to be used below
egen nmiss=rowmiss(cognition age grip sexmw demgroup)
drop if nmiss>0 → This is important for consistency across models
```

R Syntax for Importing and Preparing Data for Analysis (after loading packages readxl, expss, TeachingDemos, psych, multcomp, prediction, reghelper, and interactions as shown online):

```
# Define variables for working directory and data name
filesave = "C:\\Dropbox\\23_PSQF6270\\PSQF6270_Example1\\"
filename = "Excel_Chapter2.xlsx"
setwd(dir=filesave)

# Import chapter 2 Excel data as Example1
Example1 = read_excel(path=paste0(filesave,filename))
# Convert to data frame to use for analysis
Example1 = as.data.frame(Example1)
# Sort data by PersonID
Example1 = sort_asc(data=Example1, PersonID)
```

```

# Center quantitative predictors
Example1$age85 = Example1$age-85
Example1$grip9 = Example1$grip-9
# Create dummy-coded binary indicator predictors for dementia groups
Example1$demNF = NA; Example1$demNC = NA # Create two new empty variables
# Recode if demgroup=none
Example1$demNF[which(Example1$demgroup==1)]=0
Example1$demNC[which(Example1$demgroup==1)]=0
# Recode if demgroup=future
Example1$demNF[which(Example1$demgroup==2)]=1
Example1$demNC[which(Example1$demgroup==2)]=0
# Recode if demgroup=current
Example1$demNF[which(Example1$demgroup==3)]=0
Example1$demNC[which(Example1$demgroup==3)]=1
# Labels for all variables given as comments only (not actually added to data)
# Filter to only cases complete on all variables to be used below
Example1 = Example1[complete.cases(Example1[, 1:6]),]

```

STATA Syntax and Output for Descriptive Statistics

```

display "STATA Descriptive Statistics"
format cognition age grip sexmw demnf demnc %4.3f // to control precision
summarize cognition age grip sexmw demnf demnc, format // for quantitative variables
summarize cognition age grip sexmw demnf demnc, detail // detail to get variance
tabulate sexmw demgroup // for categorical variables

```

Variable	Obs	Mean	Std. Dev.	Min	Max
cognition	550	24.822	10.989	0.000	44.000
age	550	84.927	3.430	80.016	96.967
grip	550	9.113	2.983	0.000	19.000
sexmw	550	0.587	0.493	0.000	1.000
demnf	550	0.198	0.399	0.000	1.000
demnc	550	0.076	0.266	0.000	1.000

sexmw: Sex	demgroup: Dementia Group 1N 2F 3C			
(0=Men,				
1=Women)	1	2	3	Total
0.000	168	40	19	227
1.000	231	69	23	323
Total	399	109	42	550

cells size can affect power to detect significant difference between groups.

R Syntax and Output for Descriptive Statistics

```

print("R Descriptive Statistics")
describe(x=Example1[, c("cognition","age","grip","sexMW")]) # for quantitative variables
table(x=Example1$sexMW, Example1$demgroup, useNA="ifany") # for categorical variables

```

```

> describe(x = Example1[, c("cognition", "age", "grip", "sexMW")])
      vars   n mean   sd median trimmed   mad   min   max range  skew kurtosis   se
cognition  1 550 24.82 10.99  25.00  25.18 11.86   0.00 44.00 44.00 -0.26   -0.62 0.47
age         2 550 84.93  3.43  84.33  84.49  2.88 80.02 96.97 16.95  1.10    0.72 0.15
grip        3 550  9.11  2.98   9.00   9.11  2.97  0.00 19.00 19.00 -0.01   -0.17 0.13
sexMW       4 550  0.59  0.49   1.00   0.61  0.00  0.00  1.00  1.00 -0.35   -1.88 0.02

```

```

> table(x = Example1$sexMW, Example1$demgroup, useNA = "ifany")
x      1      2      3
0    168     40     19
1    231     69     23

```

STATA Syntax and Output for Eq 2.8: Main-Effects-Only GLM Predicting Cognition

$$\text{Cognition}_i = \beta_0 + \beta_1(\text{Age}_i - 85) + \beta_2(\text{Grip}_i - 9) + \beta_3(\text{SexMW}_i) + \beta_4(\text{DemNF}_i) + \beta_5(\text{DemNC}_i) + e_i$$

Linear combination for difference of future vs current dementia:

$$(\beta_0 + \beta_5) - (\beta_0 + \beta_4) = \beta_5 - \beta_4$$

display "STATA Eq 2.8: Main-Effects-Only GLM Predicting Cognition"
regress cognition c.age85 c.grip9 c.sexmw c.demnf c.demnc, level(95)

monotonic predictor
Model Summary and Model-Estimated Fixed Effects

Source	SS	df	MS	Number of obs	=	550
Model	18385.9793	5	3677.19586	F(5, 544)	=	41.75
Residual	47910.5589	544	88.0708803	Prob > F	=	0.0000
Total	66296.5382	549	120.758722	R-squared	=	0.2773
				Adj R-squared	=	0.2707
				Root MSE	=	9.3846

cognition	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]		
age85	-.405734	.1188972	-3.41	0.001	-.6392878	-.1721802	Beta1
grip9	.6042256	.1497757	4.03	0.000	.310016	.8984351	Beta2
sexmw	-3.657374	.8914326	-4.10	0.000	-5.408446	-1.906303	Beta3
demnf	-5.721971	1.019078	-5.61	0.000	-7.723782	-3.72016	Beta4
demnc	-16.47981	1.522754	-10.82	0.000	-19.47101	-13.48862	Beta5
_cons	29.26433	.6985079	41.90	0.000	27.89222	30.63643	Beta0 =LAST!

Interpret these fixed effects:

Intercept β_0 =

Slope for Age β_1 =

Slope for Grip Strength β_2 =

Slope for sexMW β_3 =

Slope for demNF β_4 =

Slope for demNC β_5 =

Requested LINCOM linear combinations of model-estimated fixed effects and TEST F-tests

// LINCOM creates a single linear combination of fixed effects
lincom c.demnf*-1 + c.demnc*1 // Mean Diff: Future vs. Current = B5-B4

cognition	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]	
(1)	-10.75784	1.707957	-6.30	0.000	-14.11284	-7.402844

// TEST lumps together fixed effects for joint tests -- indicate DFnun by ()
test (c.age85=0) (c.grip9=0) (c.sexmw=0) (c.demnf=0) (c.demnc=0) // DFnun=5 F-test for Model R2
 F(5, 544) = **41.75** → Same as given by default for model above
 Prob > F = 0.0000

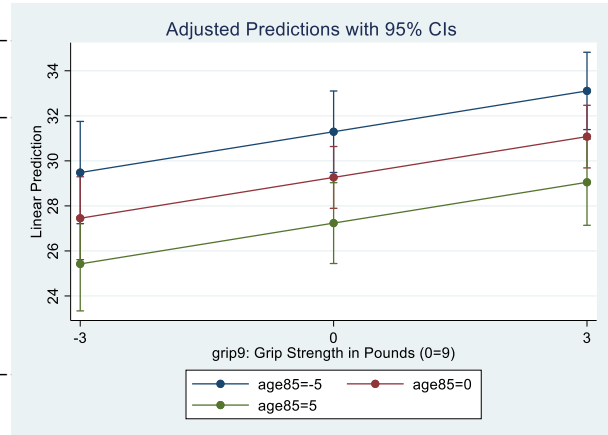
test (c.demnf=0) (c.demnc=0) // DFnun=2 Omnibus F-test for Demgroup
 F(2, 544) = **67.06** → Is new information (not given by default)
 Prob > F = 0.0000

Requested MARGINS for predicted outcomes

```
// Pred cognition outcomes holding sexmw=men, demnf=none, and demnc=none
// predictor=(from(by)to), c.=quantitative predictor, vsquish compresses output empty lines
margins, at(c.age85=(-5(5)5) c.grip9=(-3(3)3) c.sexmw=0 c.demnf=0 c.demnc=0) vsquish
// Get and save plot of predicted outcomes
marginsplot, xdimension(grip9) name(predicted means, replace)
graph export "$filesave\STATA plots\STATA Main-Effect-Only GLM Plot.png", replace
```

Although annoying that they are not labeled here, a long table preceded this MARGINS result that says what the predictor values are for each of these 9 predicted outcomes.

		Delta-method			
		Margin	Std. Err.	t	P> t
_at	1	29.48032	1.155906	25.50	0.000
	2	31.293	.9209086	33.98	0.000
	3	33.10567	.8739657	37.88	0.000
	4	27.45165	.9373122	29.29	0.000
	5	29.26433	.6985079	41.90	0.000
	6	31.077	.7078574	43.90	0.000
	7	25.42298	1.061987	23.94	0.000
	8	27.23566	.913554	29.81	0.000
	9	29.04833	.9721806	29.88	0.000

**R Syntax and Output for Eq 2.8: Main-Effects Only GLM Predicting Cognition:**

$$\text{Cognition}_i = \beta_0 + \beta_1(\text{Age}_i - 85) + \beta_2(\text{Grip}_i - 9) + \beta_3(\text{SexMW}_i) + \beta_4(\text{DemNF}_i) + \beta_5(\text{DemNC}_i) + e_i$$

Linear combination for difference of future vs current dementia:

$$(\beta_0 + \beta_5) - (\beta_0 + \beta_4) = \beta_5 - \beta_4$$

```
print("R Eq 2.8: Main-Effects-Only GLM Predicting Cognition")
ModelMain = lm(data=Example1, formula=cognition~1+age85+grip9+sexMW+demNF+demNC)
summary(ModelMain); anova(ModelMain) # anova to get residual variance
```

Model-Estimated Fixed Effects

```
Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept)  29.26433    0.69851  41.8955 < 0.00000000000000022
age85        -0.40573    0.11890  -3.4125    0.0006917
grip9         0.60423    0.14978   4.0342    0.0000626304
sexMW        -3.65737    0.89143  -4.1028    0.0000470693
demNF        -5.72197    1.01908  -5.6148    0.0000000314
demNC       -16.47981    1.52275 -10.8224 < 0.00000000000000022
---
```

```
Residual standard error: 9.3846 on 544 degrees of freedom
Multiple R-squared:  0.27733,    Adjusted R-squared:  0.27069
F-statistic: 41.753 on 5 and 544 DF,  p-value: < 2.22e-16
```

ANOVA Table—Printed *Just* to Get the Residual Variance (= Mean Square Error or Residual)

Analysis of Variance Table → Type I sequential SS below, which are not helpful here!

```
      Df Sum Sq Mean Sq F value Pr(>F)
age85  1  1926.2  1926.18  21.8708  0.0000036833209
grip9   1  3039.2  3039.17  34.5082  0.0000000073976
sexMW   1  1609.3  1609.32  18.2731  0.0000226023607
demNF   1  1496.1  1496.10  16.9875  0.0000434979953
demNC   1 10315.2 10315.20 117.1239 < 0.00000000000000022
Residuals 544 47910.6    88.07 → This is residual variance (all we need)
```

Requested GLHT linear combinations of model-estimated fixed effects and F-tests

```
print("Get missing demgroup difference: Future vs Current = Beta5-Beta4")
summary(glht(model=ModelMain, linfct=rbind(c(0,0,0,0,-1,1))), test=adjusted("none"))
```

Linear Hypotheses:

	Estimate	Std. Error	t value	Pr(> t)
1 == 0	-10.758	1.708	-6.2987	0.0000000006198

```
print("Get DFnun=5 F-test of Model R2 only for demonstration purposes")
```

```
MainFR2 = glht(model=ModelMain, linfct=c("age85=0", "grip9=0", "sexMW=0", "demNF=0", "demNC=0"))
summary(MainFR2, test=Ftest()) # ask for joint hypothesis test instead of separate
```

Linear Hypotheses:

	Estimate
age85 == 0	-0.40573
grip9 == 0	0.60423
sexMW == 0	-3.65737
demNF == 0	-5.72197
demNC == 0	-16.47981

Global Test:

	F	DF1	DF2	Pr(>F)
1	41.753	5	544	2.1562e-36

```
print("Get DFnun=2 F-test for demgroup") # Omnibus group main effect
```

```
mainFdem = glht(model=ModelMain, linfct=c("demNF=0", "demNC=0"))
summary(mainFdem, test=Ftest()) # ask for joint hypothesis test instead of separate
```

Linear Hypotheses:

	Estimate
demNF == 0	-5.722
demNC == 0	-16.480

Global Test:

	F	DF1	DF2	Pr(>F)
1	67.056	2	544	9.3117e-27

```
print("Pred cognition outcomes holding sexMW=men, demNF=none, and demNC=none")
```

```
print("Provides predicted outcomes from min,max,by=increment of predictors")
```

```
PredMain = summary(prediction(model=ModelMain, type="response",
  at=list(sexMW=0, demNF=0, demNC=0, age85=seq(-5,5,by=5), grip9=seq(-3,3,by=3))))
PredMain # print predicted outcomes
```

```
# Throw a warning that predictions went out of bounds!
```

```
warning messages:
```

```
1: In check_values(data, at) :
  A 'at' value for 'age85' is outside observed data range (-4.9835067729703,11.9672831683989)!
```

at (sexMW)	at (demNF)	at (demNC)	at (age85)	at (grip9)	Prediction	SE	z	p	lower	upper
0	0	0	-5	-3	29.48	1.1559	25.50	1.776e-143	27.21	31.75
0	0	0	0	-3	27.45	0.9373	29.29	1.491e-188	25.61	29.29
0	0	0	5	-3	25.42	1.0620	23.94	1.201e-126	23.34	27.50
0	0	0	-5	0	31.29	0.9209	33.98	4.315e-253	29.49	33.10
0	0	0	0	0	29.26	0.6985	41.90	0.000e+00	27.90	30.63
0	0	0	5	0	27.24	0.9136	29.81	2.662e-195	25.45	29.03
0	0	0	-5	3	33.11	0.8740	37.88	0.000e+00	31.39	34.82
0	0	0	0	3	31.08	0.7079	43.90	0.000e+00	29.69	32.46
0	0	0	5	3	29.05	0.9722	29.88	3.627e-196	27.14	30.95

```
# Create data frame with uncentered version of predictors for plotting
```

```
PredMain = data.frame(PredMain) # first remove () from variable names
```

```
PredMain = data.frame(PredMain, grip=PredMain$at.grip9.+9, age=PredMain$at.age85.+85)
```

```
PredMain = sort_asc(data=PredMain,age) # sort data by age for plot
```

```
# Save plot: open file, make plot, close file
```

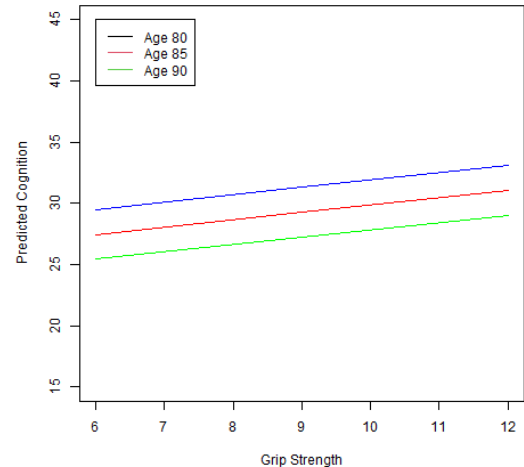
```
png(file = "R Main-Effects-Only GLM Plot.png")
```

```
plot(y= PredMain$Prediction, x=PredMain$grip, type="n", ylim=c(15,45), xlim=c(6,12),
```

```

xlab="Grip Strength",ylab="Predicted Cognition")
lines(x=PredMain$grip[1:3],
      y=PredMain$Prediction[1:3], type="l", col="blue1")
lines(x=PredMain$grip[4:6],
      y=PredMain$Prediction[4:6], type="l", col="red1")
lines(x=PredMain$grip[7:9],
      y=PredMain$Prediction[7:9], type="l", col="green1")
legend(x=6, y=45,
       legend=c("Age 80","Age 85","Age 90"),
       col=1:3, lty=1) #lty=linetype
dev.off() # close file

```



STATA Syntax and Output for Eq 2.9: GLM Adding Age by Grip Strength Interaction

$$\text{Cognition}_i = \beta_0 + \beta_1(\text{Age}_i - 85) + \beta_2(\text{Grip}_i - 9) + \beta_3(\text{SexMW}_i) + \beta_4(\text{DemNF}_i) + \beta_5(\text{DemNC}_i) + \beta_6(\text{Age}_i - 85)(\text{Grip}_i - 9) + e_i$$

```

display "STATA Eq 2.9: GLM Adding Age by Grip Strength Interaction"
regress cognition c.age85 c.grip9 c.sexmw c.demnf c.demnc c.age85#c.grip9, level(95)

```

Model Summary and Model-Estimated Fixed Effects

Source	SS	df	MS	Number of obs	=	550
Model	19185.0411	6	3197.50684	F(6, 543)	=	36.85
Residual	47111.4971	543	86.7615048	Prob > F	=	0.0000
				R-squared	=	0.2894
				Adj R-squared	=	0.2815
Total	66296.5382	549	120.758722	Root MSE	=	9.3146

cognition	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]	
age85	-.3339606	.1203566	-2.77	0.006	-.5703821	-.0975391 Beta1
grip9	.6194186	.1487424	4.16	0.000	.3272376	.9115996 Beta2
sexmw	-3.455637	.8872749	-3.89	0.000	-5.198549	-1.712726 Beta3
demnf	-5.922543	1.013632	-5.84	0.000	-7.913663	-3.931424 Beta4
demnc	-16.3004	1.512547	-10.78	0.000	-19.27157	-13.32924 Beta5
c.age85#c.grip9	.1230185	.0405363	3.03	0.003	.0433914	.2026456 Beta6
_cons	29.4078	.6949062	42.32	0.000	28.04277	30.77284 Beta0

Requested LINCOM linear combinations of model-estimated fixed effects and TEST F-tests

```
lincom c.demnf*-1 + c.demnc*1 // Mean Diff: Future vs. Current = Beta5-Beta4
```

cognition	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]	
(1)	-10.37786	1.699831	-6.11	0.000	-13.71691	-7.038812

```

test (c.demnf=0) (c.demnc=0) // DFnum=2 Omnibus F-test for main effect of demgroup
F( 2, 543) = 67.70
Prob > F = 0.0000

```

```

test (c.age85=0) (c.grip9=0) (c.age85#c.grip9=0) // DFnum=3 F-test for age, grip, age*grip
F( 3, 543) = 14.60
Prob > F = 0.0000

```

We can use the model equation to calculate the **simple age slope** at any *grip strength* (as the moderator):

$$\begin{aligned}\text{Simple Age Slope} &= \beta_1(\text{Age}_i - 85) + \beta_6(\text{Age}_i - 85)(\text{Grip}_i - 9) \\ &= [\beta_1 + \beta_6(\text{Grip}_i - 9)] \text{ that multiplies } (\text{Age}_i - 85)\end{aligned}$$

```
lincom c.age85*1 + c.age85#c.grip9*-3 // Age Slope at Grip = 6
lincom c.age85*1 + c.age85#c.grip9*0 // Age Slope at Grip = 9
lincom c.age85*1 + c.age85#c.grip9*3 // Age Slope at Grip = 12
```

```
// dydx in margins provides simple slopes for that variable by (from(by)to) moderator
margins, at(c.grip9=(-3(3)3)) dydx(c.age85) vsquish // Age Slope per Grip
```

		Delta-method					
		dy/dx	Std. Err.	t	P> t	[95% Conf. Interval]	
age85	_at						
	1	-.703016	.1533696	-4.58	0.000	-1.004286	-.4017456
	2	-.3339606	.1203566	-2.77	0.006	-.5703821	-.0975391
	3	.0350949	.1871539	0.19	0.851	-.3325394	.4027291

We can also use the model equation to calculate the **simple grip strength slope** at any *age* (as the moderator):

$$\begin{aligned}\text{Simple Grip Slope} &= \beta_2(\text{Grip}_i - 9) + \beta_6(\text{Age}_i - 85)(\text{Grip}_i - 9) \\ &= [\beta_2 + \beta_6(\text{Age}_i - 85)] \text{ that multiplies } (\text{Grip}_i - 9)\end{aligned}$$

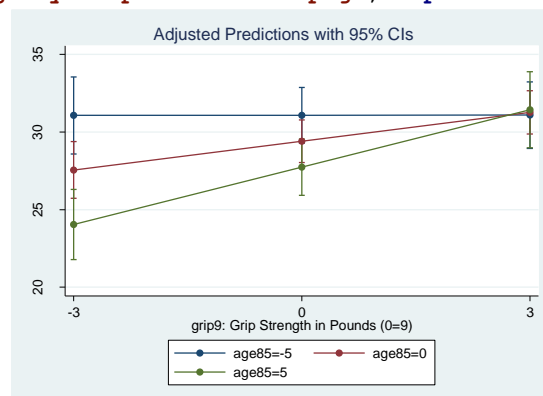
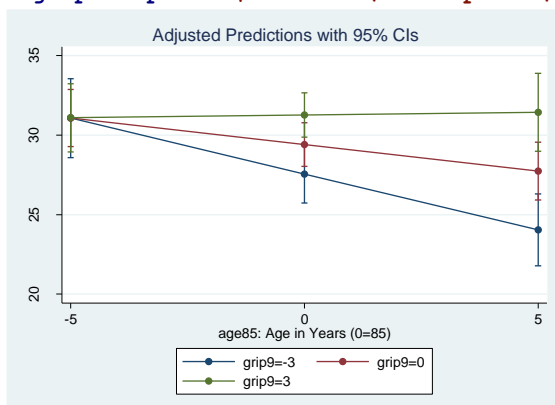
```
lincom c.grip9*1 + c.age85#c.grip9*-5 // Grip Slope at Age = 80
lincom c.grip9*1 + c.age85#c.grip9*0 // Grip Slope at Age = 85
lincom c.grip9*1 + c.age85#c.grip9*5 // Grip Slope at Age = 90
```

```
// dydx in margins provides simple slopes for that variable by (from(by)to) moderator
margins, at(c.age85=(-5(5)5)) dydx(c.grip9) vsquish // Grip per Age
```

		Delta-method					
		dy/dx	Std. Err.	t	P> t	[95% Conf. Interval]	
grip9	_at						
	1	.0043262	.2473351	0.02	0.986	-.4815246	.490177
	2	.6194186	.1487424	4.16	0.000	.3272376	.9115996
	3	1.234511	.2554083	4.83	0.000	.7328017	1.73622

Requested MARGINS for predicted outcomes

```
// predictor=(from(by)to), c.=quantitative predictor, vsquish compresses output empty lines
margins, at(c.age85=(-5(5)5) c.grip9=(-3(3)3) c.sexmw=0 c.demnf=0 c.demnc=0) vsquish
marginsplot, xdimension(age85) // Get and save plot for pred outcomes by age
graph export "$filesave\STATA plots\STATA Grip by Age=x GLM Plot.png", replace
marginsplot, xdimension(grip9) // Get and save plot for pred outcomes by grip
graph export "$filesave\STATA plots\STATA Age by Grip=x GLM Plot.png", replace
```



Bonus: How to the Asymptotic Covariance Matrix for Regions of Significance for the Age*Grip Interaction
BOLD values below get used to compute regions (diagonal = SE², off-diagonals = SE covariances); see excel file!

```
display "STATA Eq 2.9: GLM with Age by Grip Interaction adding VCE for regions"
regress cognition c.age85 c.grip9 c.sexmw c.demnf c.demnc c.age85#c.grip9, level(95)
estat vce // Asymptotic covariance matrix of fixed effects for regions
```

Covariance matrix of coefficients of regress model

	e (V)	age85	grip9	sexmw	demnf	demnc	c.age85#c.grip9	_cons
age85		.0144857						
grip9		.00331698	.0221243					
sexmw		.005024	.05374269	.78725672				
demnf		-.00413095	-.01338766	-.07101552	1.027449			
demnc		-.00115115	-.00030106	.02370811	.21291169	2.2877993		
c.age85#c.grip9		.0009587	.00020294	.00269465	-.00267909	.0023964	.00164319	
_cons		.00045357	-.03075328	-.45067156	-.18202858	-.22634698	.00191647	.48289456

R Syntax and Output for Eq 2.9: GLM Adding Age by Grip Strength Interaction

$$\text{Cognition}_i = \beta_0 + \beta_1(\text{Age}_i - 85) + \beta_2(\text{Grip}_i - 9) + \beta_3(\text{SexMW}_i) + \beta_4(\text{DemNF}_i) + \beta_5(\text{DemNC}_i) + \beta_6(\text{Age}_i - 85)(\text{Grip}_i - 9) + e_i$$

```
print("R Eq 2.9: GLM Adding Age by Grip Strength Interaction")
ModelAgeGrip = lm(data=Example1,
  formula=cognition~1+age85+grip9+sexMW+demNF+demNC +age85:grip9)
summary(ModelAgeGrip); anova(ModelAgeGrip) # anova to get residual variance
```

Model-Estimated Fixed Effects

Coefficients:

	Estimate	Std. Error	t value	Pr(> t)
(Intercept)	29.407803	0.694906	42.3191	< 2.2e-16
age85	-0.333961	0.120357	-2.7748	0.0057145
grip9	0.619419	0.148742	4.1644	0.00003630980
sexMW	-3.455637	0.887275	-3.8947	0.0001106
demNF	-5.922543	1.013632	-5.8429	0.00000000885
demNC	-16.300405	1.512547	-10.7768	< 2.2e-16
age85:grip9	0.123018	0.040536	3.0348	0.0025224

Residual standard error: 9.3146 on 543 degrees of freedom
Multiple R-squared: **0.28938**, Adjusted R-squared: 0.28153
F-statistic: **36.854 on 6 and 543 DF**, p-value: < 2.22e-16

ANOVA Table—Printed Just to Get the Residual Variance (= Mean Square Error or Residual)

Analysis of Variance Table → Rest of Type I sequential SS omitted!

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Residuals	543	47111.5	86.76	→ residual variance	

Interpret these fixed effects:

Simple main effect of Age $\beta_1 =$

Simple main effect of Grip Strength $\beta_2 =$

Interpret Age by Grip Strength $\beta_6 \rightarrow$ Age as Simple Slope, Grip as Moderator:

Interpret Age by Grip Strength $\beta_6 \rightarrow$ Grip as Simple Slope, Age as Moderator:

Requested GLHT linear combinations of model-estimated fixed effects and F-tests

```

print("Get missing demgroup difference: Future vs Current = Beta5-Beta4")
summary(glht(model=ModelAgeGrip, linfct=rbind(c(0,0,0,0,-1,1,0))), test=adjusted("none"))
Linear Hypotheses:
      Estimate Std. Error t value      Pr(>|t|)
1 == 0 -10.3779      1.6998 -6.1052 0.000000001956

print("Get DFnun=2 F-test for demgroup") # Omnibus group main effect
AgeGripFdem = glht(model=ModelAgeGrip, linfct=c("demNF=0", "demNC=0"))
summary(AgeGripFdem, test=Ftest()) # ask for joint hypothesis test instead of separate
Global Test:
      F DF1 DF2      Pr(>F)
1 67.701   2 543 5.6176e-27

print("Get DFnun=3 F-test for age, grip, and age*grip")
AgeGripF = glht(model=ModelAgeGrip, linfct=c("age85=0", "grip9=0", "age85:grip9=0"))
summary(AgeGripF, test=Ftest()) # ask for joint hypothesis test instead of separate
Global Test:
      F DF1 DF2      Pr(>F)
1 14.599   3 543 0.0000000037133

```

We can use the model equation to calculate the **simple age slope** at any *grip strength* (as the moderator):

$$\begin{aligned}\text{Simple Age Slope} &= \beta_1(\text{Age}_i - 85) + \beta_6(\text{Age}_i - 85)(\text{Grip}_i - 9) \\ &= [\beta_1 + \beta_6(\text{Grip}_i - 9)] \text{ that multiplies } (\text{Age}_i - 85)\end{aligned}$$

We can also use the model equation to calculate the **simple grip strength slope** at any *age* (as the moderator):

$$\begin{aligned}\text{Simple Grip Slope} &= \beta_2(\text{Grip}_i - 9) + \beta_6(\text{Age}_i - 85)(\text{Grip}_i - 9) \\ &= [\beta_2 + \beta_6(\text{Age}_i - 85)] \text{ that multiplies } (\text{Grip}_i - 9)\end{aligned}$$

```

print("Simple slopes for age per grip, grip per age")
summary(glht(model=ModelAgeGrip, linfct=rbind(
  "Age Slope at Grip = 6" = c(0,1,0,0,0,0,-3), # in order of fixed effects
  "Age Slope at Grip = 9" = c(0,1,0,0,0,0, 0),
  "Age Slope at Grip = 12" = c(0,1,0,0,0,0, 3),
  "Grip Slope at Age = 80" = c(0,0,1,0,0,0,-5),
  "Grip Slope at Age = 85" = c(0,0,1,0,0,0, 0),
  "Grip Slope at Age = 90" = c(0,0,1,0,0,0, 5))), test=adjusted("none"))

print("Simple slopes over range of moderator values using reghelper package")
simple_slopes(model=ModelAgeGrip, levels=list(age85=c(-5,0,5,'sctest'),
  grip9=c(-3,0,3,'sctest'))

```

GLHT Results:

```

Linear Hypotheses:
      Estimate Std. Error t value      Pr(>|t|)
Age Slope at Grip = 6 == 0 -0.7030160 0.1533696 -4.5838 0.000005671
Age Slope at Grip = 9 == 0 -0.3339606 0.1203566 -2.7748 0.005715
Age Slope at Grip = 12 == 0 0.0350949 0.1871539 0.1875 0.851324
Grip Slope at Age = 80 == 0 0.0043262 0.2473351 0.0175 0.986051
Grip Slope at Age = 85 == 0 0.6194186 0.1487424 4.1644 0.000036310
Grip Slope at Age = 90 == 0 1.2345110 0.2554083 4.8335 0.000001749
(Adjusted p values reported -- none method)

```

Simple_slopes Results:

	age85	grip9	Test	Estimate	Std. Error	t value	df	Pr(> t)
1	sctest	-3		-0.70302	0.15337	-4.58380	543	0.0000056714
2	sctest	0		-0.33396	0.12036	-2.77476	543	0.0057145
3	sctest	3		0.03509	0.18715	0.18752	543	0.8513240
4	-5	sctest		0.00433	0.24734	0.01749	543	0.9860510
5	0	sctest		0.61942	0.14874	4.16437	543	0.0000363098
6	5	sctest		1.23451	0.25541	4.83348	543	0.0000017488

Regions of Significance for the Age*Grip Interaction

```
print("Regions of significance using interactions package") # plots broke my computer!
johnson_neyman(model=ModelAgeGrip, pred="age85", modx="grip9", digits=3, plot=FALSE)
```

JOHNSON-NEYMAN INTERVAL → [9.665, 18.521] uncentered

When grip9 is OUTSIDE the interval [0.665, 9.521], the slope of age85 is $p < .05$.

The range of observed values of grip9 is [-9.000, 10.000] = 0 to 19 uncentered

After adding 9 to uncenter grip strength, the age slope will be significantly negative below grip = 9.665 pounds, nonsignificant between grip = 9.665 and 18.521 pounds, and significantly positive after grip = 18.521 pounds.

```
johnson_neyman(model=ModelAgeGrip, pred="grip9", modx="age85", digits=3, plot=FALSE)
```

JOHNSON-NEYMAN INTERVAL → [70.127, 82.719] uncentered

When age85 is OUTSIDE the interval [-14.873, -2.281], the slope of grip9 is $p < .05$.

The range of observed values of age85 is [-4.984, 11.967] = 80.016 to 96.967 uncentered

After adding 85 to uncenter age, the grip strength slope will be significantly negative below age = 70.127 years, nonsignificant between age = 70.127 and 82.719 years, and significantly positive after age = 82.719 years.

```
print("Pred cognition outcomes holding sexMW=men, demNF=none, and demNC=none")
print("Provides predicted outcomes from min,max,by=increment of predictors")
PredAgeGrip = summary(prediction(model=ModelAgeGrip, type="response",
                                at=list(sexMW=0,demNF=0,demNC=0,age85=seq(-5,5,by=5),grip9=seq(-3,3,by=3))))
PredAgeGrip # print predicted outcomes, get warning that predictions go out of bounds
```

at (sexMW)	at (demNF)	at (demNC)	at (age85)	at (grip9)	Prediction	SE	z	p	lower	upper
0	0	0	-5	-3	31.06	1.2605	24.65	4.141e-134	28.59	33.54
0	0	0	0	-3	27.55	0.9309	29.60	1.720e-192	25.73	29.37
0	0	0	5	-3	24.03	1.1491	20.92	3.808e-97	21.78	26.29
0	0	0	-5	0	31.08	0.9168	33.90	7.049e-252	29.28	32.87
0	0	0	0	0	29.41	0.6949	42.32	0.000e+00	28.05	30.77
0	0	0	5	0	27.74	0.9217	30.09	5.867e-199	25.93	29.54
0	0	0	-5	3	31.09	1.0924	28.46	3.602e-178	28.95	33.23
0	0	0	0	3	31.27	0.7053	44.33	0.000e+00	29.88	32.65
0	0	0	5	3	31.44	1.2462	25.23	1.861e-140	29.00	33.88

```
# Create data frame with uncentered version of predictors for plotting")
```

```
PredAgeGrip = data.frame(PredAgeGrip) # first remove () from variable names
```

```
PredAgeGrip = data.frame(PredAgeGrip, grip=PredAgeGrip$at.grip9.+9,
                          age=PredAgeGrip$at.age85.+85)
```

```
# Make and save plots
```

```
png(file = "R Grip by Age=x GLM Plot.png") # open file
```

```
plot(y=PredAgeGrip$Prediction, x=PredAgeGrip$age, type="n", ylim=c(15,45), xlim=c(80,90),
     xlab="Years of Age", ylab="Predicted Cognition")
```

```
PredAgeGrip = sort_asc(data= PredAgeGrip,grip) # 3 rows per grip
```

```
lines(x=PredAgeGrip$age[1:3], y=PredAgeGrip$Prediction[1:3], type="l", col="blue1")
```

```
lines(x=PredAgeGrip$age[4:6], y=PredAgeGrip$Prediction[4:6], type="l", col="red1")
```

```
lines(x=PredAgeGrip$age[7:9], y=PredAgeGrip$Prediction[7:9], type="l", col="green1")
```

```
legend(x=80, y=45, legend = c("Grip=6", "Grip=9", "Grip=12"), col=1:3, lty=1) #lty=linetype
dev.off() # close file
```

```
png(file = "R Age by Grip=x GLM Plot.png") # open file
```

```
plot(y=PredAgeGrip$Prediction, x=PredAgeGrip$grip, type="n", ylim=c(15,45), xlim=c(6,12),
     xlab="Pounds of Grip Strength", ylab="Predicted Cognition")
```

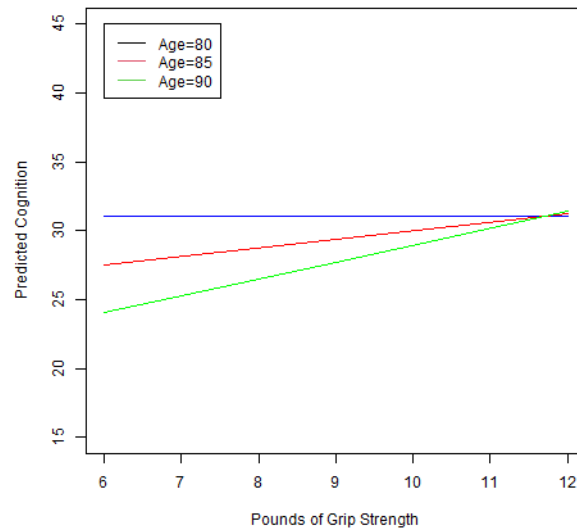
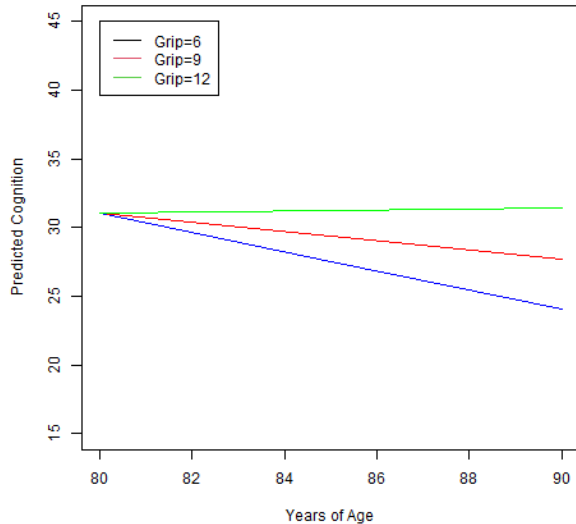
```
PredAgeGrip = sort_asc(data= PredAgeGrip,age) # 3 rows per age now
```

```
lines(x=PredAgeGrip$grip[1:3], y=PredAgeGrip$Prediction[1:3], type="l", col="blue1")
```

```
lines(x=PredAgeGrip$grip[4:6], y=PredAgeGrip$Prediction[4:6], type="l", col="red1")
```

```
lines(x=PredAgeGrip$grip[7:9], y=PredAgeGrip$Prediction[7:9], type="l", col="green1")
```

```
legend(x=6, y=45, legend = c("Age=80", "Age=85", "Age=90"), col=1:3, lty=1) #lty=linetype
dev.off() # close file
```



Equation 2.13, adding sex*dementia interaction:

$$\begin{aligned} \text{Cognition}_i = & \beta_0 + \beta_1(\text{Age}_i - 85) + \beta_2(\text{Grip}_i - 9) \\ & + \beta_3(\text{SexMW}_i) + \beta_4(\text{DemNF}_i) + \beta_5(\text{DemNC}_i) \\ & + \beta_6(\text{Age}_i - 85)(\text{Grip}_i - 9) \\ & + \beta_7(\text{SexMW}_i)(\text{DemNF}_i) \\ & + \beta_8(\text{SexMW}_i)(\text{DemNC}_i) + e_i \end{aligned}$$

Dementia Group	Men	Women	Marginal Mean
None	29.07	26.20	27.63
Future	23.01	20.30	21.66
Current	17.10	6.35	11.72
Marginal Mean	23.03	17.62	$\sigma_e^2 = 85.97$

We can use the model equation to calculate the **simple sex slope** for any *dementia group* (as the moderator):

$$\begin{aligned} \text{Simple Sex Slope} = & \beta_3(\text{SexMW}_i) + \beta_7(\text{SexMW}_i)(\text{DemNF}_i) + \beta_8(\text{SexMW}_i)(\text{DemNC}_i) \\ = & [\beta_3 + \beta_7(\text{DemNF}_i) + \beta_8(\text{DemNC}_i)] \text{ that multiplies } (\text{SexMW}_i) \end{aligned}$$

We can use the model equation to calculate the **simple dementia slope** for any *sex* (as the moderator):

$$\begin{aligned} \text{Simple None vs. Future Slope} = & \beta_4(\text{DemNF}_i) + \beta_7(\text{SexMW}_i)(\text{DemNF}_i) \\ = & [\beta_4 + \beta_7(\text{SexMW}_i)] \text{ that multiplies } (\text{DemNF}_i) \end{aligned}$$

$$\begin{aligned} \text{Simple None vs. Current Slope} = & \beta_5(\text{DemNC}_i) + \beta_8(\text{SexMW}_i)(\text{DemNC}_i) \\ = & [\beta_5 + \beta_8(\text{SexMW}_i)] \text{ that multiplies } (\text{DemNC}_i) \end{aligned}$$

$$\text{Simple Future vs. Current Slope} = [\beta_5 + \beta_8(\text{SexMW}_i)] - [\beta_4 + \beta_7(\text{SexMW}_i)]$$

R Syntax and Output for Eq 2.13: GLM Adding Sex by Dementia Group Interaction

```
print("R Eq 2.13: GLM Adding Sex by Dementia Group Interaction")
print("Dummy-Coded Predictors for Sex (0=Men) and Demgroup (0=None)")
ModelSexDem = lm(data=Example1, formula=cognition~1+age85+grip9+sexMW+demNF+demNC
                  +age85:grip9 +sexMW:demNF +sexMW:demNC)
summary(ModelSexDem) ; anova(ModelSexDem) # anova to get residual variance
```

Model-Estimated Fixed Effects

Coefficients:

	Estimate	Std. Error	t value	Pr(> t)
(Intercept)	29.070146	0.748499	38.8379	< 2.2e-16
age85	-0.334799	0.119888	-2.7926	0.0054136
grip9	0.617893	0.148079	4.1727	0.0000350646
sexMW	-2.875594	1.011237	-2.8436	0.0046288
demNF	-6.055901	1.635126	-3.7036	0.0002344
demNC	-11.970731	2.244954	-5.3323	0.0000001427
age85:grip9	0.122152	0.040353	3.0271	0.0025868
sexMW:demNF	0.164270	2.070475	0.0793	0.9367921
sexMW:demNC	-7.875100	3.024536	-2.6037	0.0094746

Residual standard error: 9.2721 on 541 degrees of freedom

Multiple R-squared: **0.29844**, Adjusted R-squared: 0.28806F-statistic: **28.767 on 8 and 541 DF**, p-value: < 2.22e-16**ANOVA Table—Printed Just to Get the Residual Variance (= Mean Square Error or Residual)**

Analysis of Variance Table → Rest of Type I sequential SS omitted!

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Residuals	541	46511.1	85.97	→ residual variance	

Interpret these fixed effects:Simple main effect of Sex β_3 =Simple main effect of Dem None vs Future β_4 =Simple main effect of Dem None vs Current β_5 =Interpret Sex by DemNF β_7 → Sex as Simple Effect, DemNF as Moderator:Interpret Sex by DemNC β_8 → Sex as Simple Effect, DemNC as Moderator:Interpret Sex by DemNF β_7 → DemNF as Simple Effect, Sex as Moderator:Interpret Sex by DemNC β_8 → DemNC as Simple Effect, Sex as Moderator:**Requested GLHT F-tests and linear combinations of model-estimated fixed effects**

```
print("Omnibus DFnun=2 F-test for Sex*Demgroup Interaction")
SexDemFint = glht(model=ModelSexDem, linfct=c("sexMW:demNF=0", "sexMW:demNC=0"))
summary(SexDemFint, test=Ftest()) # ask for joint hypothesis test instead of separate
```

Linear Hypotheses:

```
Estimate
sexMW:demNF == 0  0.16427
sexMW:demNC == 0 -7.87510
```

Global Test:

```
F DF1 DF2 Pr(>F)
1 3.4919 2 541 0.03113
```

```
print("Omnibus DF=2 F-test for Dementia Simple Main Effect for Men")
DemforM = glht(model=ModelSexDem, linfct=rbind(c(0,0,0,0,1,0,0,0,0),c(0,0,0,0,0,1,0,0,0)))
summary(DemforM, test=Ftest()) # ask for joint hypothesis test instead of separate
```

Linear Hypotheses:

```
Estimate
1 == 0 -6.0559
2 == 0 -11.9707
```

Global Test:

```
      F DF1 DF2      Pr(>F)
1 18.688   2 541 0.000000014193
```

```
print("Omnibus DF=2 F-test for Dementia Simple Main Effect for Women")
```

```
DemforW = glht(model=ModelSexDem, linfct=rbind(c(0,0,0,0,1,0,0,1,0),c(0,0,0,0,0,1,0,0,1)))
summary(DemforW, test=Ftest()) # ask for joint hypothesis test instead of separate
```

Linear Hypotheses:

```
Estimate
1 == 0 -5.8916
2 == 0 -19.8458
```

Global Test:

```
      F DF1 DF2      Pr(>F)
1 53.157   2 541 8.3779e-22
```

```
print("Pred cognition outcomes --adjusted cell means-- holding age=85 and grip=9")
print("Will need to ignore impossible combinations of demNF and demNC for min:max")
PredSexDem = summary(prediction(model=ModelSexDem, type="response",
                                at=list(sexMW=0:1, demNF=0:1, demNC=0:1, age85=0, grip9=0)))
PredSexDem # print predicted outcomes
```

Adjusted cell means (for age=85 and grip=9) → red shows nonsense combinations to be removed below

at (sexMW)	at (demNF)	at (demNC)	at (age85)	at (grip9)	Prediction	SE	z	p	lower	upper
0	0	0	0	0	29.0701	0.7485	38.8379	0.000e+00	27.603	30.54
1	0	0	0	0	26.1946	0.6388	41.0037	0.000e+00	24.942	27.45
0	1	0	0	0	23.0142	1.4928	15.4172	1.253e-53	20.088	25.94
1	1	0	0	0	20.3029	1.1186	18.1498	1.290e-73	18.110	22.50
0	0	1	0	0	17.0994	2.1402	7.9896	1.354e-15	12.905	21.29
1	0	1	0	0	6.3487	1.9479	3.2593	1.117e-03	2.531	10.17
0	1	1	0	0	11.0435	2.6964	4.0956	4.211e-05	5.759	16.33
1	1	1	0	0	0.4571	2.3179	0.1972	8.437e-01	-4.086	5.00

```
print("Create data frame for plotting and remove unneeded rows")
```

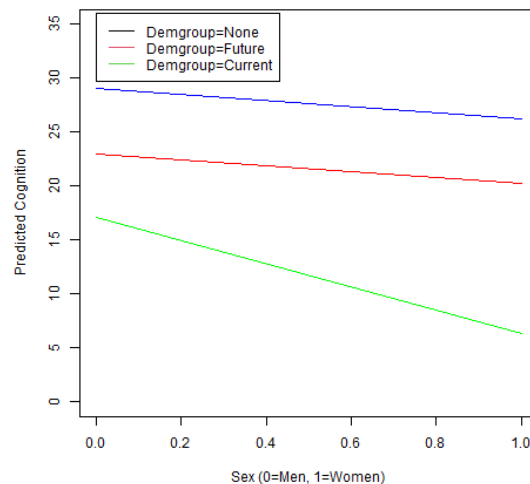
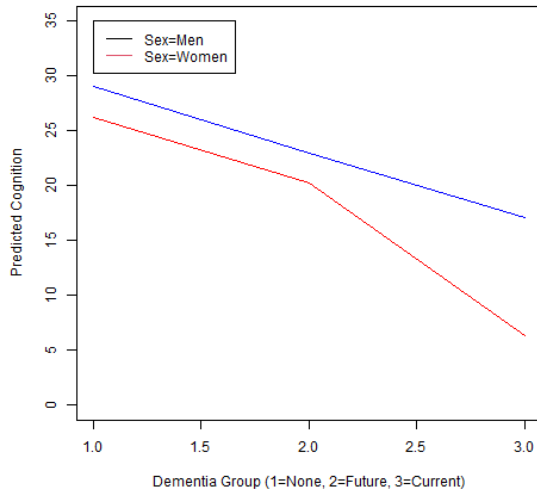
```
PredSexDem = data.frame(PredSexDem) # first remove () from variable names
PredSexDem$sum = PredSexDem$at.demNF.+PredSexDem$at.demNC. # sum dummy codes
PredSexDem = subset(x=PredSexDem, PredSexDem$sum<2) # keep if sum<2
# Make demgroup combined variable for plot
PredSexDem$demgroup=NA # Make new empty variable to be recoded
PredSexDem$demgroup[which(PredSexDem$at.demNF==0 & PredSexDem$at.demNC==0)]=1
PredSexDem$demgroup[which(PredSexDem$at.demNF==1 & PredSexDem$at.demNC==0)]=2
PredSexDem$demgroup[which(PredSexDem$at.demNF==0 & PredSexDem$at.demNC==1)]=3
```

Make and save plots

```
png(file = "R Sex by Demgroup=x GLM Plot.png") # open file
plot(y=PredSexDem$Prediction, x=PredSexDem$demgroup, type="n", ylim=c(0,35), xlim=c(1,3),
     xlab="Dementia Group (1=None, 2=Future, 3=Current)", ylab="Predicted Cognition")
PredSexDem = sort_asc(data=PredSexDem, at.sexMW.) # 3 rows per sexMW now
lines(x=PredSexDem$demgroup[1:3], y=PredSexDem$Prediction[1:3], type="l", col="blue1")
lines(x=PredSexDem$demgroup[4:6], y=PredSexDem$Prediction[4:6], type="l", col="red1")
legend(x=1, y=35, legend = c("Sex=Men", "Sex=Women"), col=1:2, lty=1) #lty=linetype
dev.off() # close file
```

```
png(file = "R Demgroup by Sex=x GLM Plot.png") # open file
plot(y=PredSexDem$Prediction, x=PredSexDem$at.sexMW., type="n", ylim=c(0,35), xlim=c(0,1),
     xlab="Sex (0=Men, 1=Women)", ylab="Predicted Cognition")
```

```
PredSexDem = sort_asc(data=PredSexDem,demgroup) # 2 rows per demgroup now
lines(x=PredSexDem$sexMW[1:2], y=PredSexDem$Prediction[1:2], type="l", col="blue1")
lines(x=PredSexDem$sexMW[3:4], y=PredSexDem$Prediction[3:4], type="l", col="red1")
lines(x=PredSexDem$sexMW[5:6], y=PredSexDem$Prediction[5:6], type="l", col="green1")
legend(x=0, y=36, legend = c("Demgroup=None", "Demgroup=Future", "Demgroup=Current"),
      col=1:3, lty=1) #lty=linetype
dev.off() # close file
```



Model syntax repeated to be able to understand the GLHT statements below:

```
ModelSexDem = lm(data=Example1, formula=cognition~1+age85+grip9+sexMW+demNF+demNC
               +age85:grip9 +sexMW:demNF +sexMW:demNC)
```

```
print("DF=1 simple slopes for sex per demgroup, demgroup per sex, and interactions")
summary(glht(model=ModelSexDem, linfct=rbind(
  "Sex Diff for No Dementia"      = c(0,0,0,1, 0,0,0, 0,0), # in order of fixed effects
  "Sex Diff for Future Dementia"  = c(0,0,0,1, 0,0,0, 1,0),
  "Sex Diff for Current Dementia" = c(0,0,0,1, 0,0,0, 0,1),

  "None-Future Diff for Men"      = c(0,0,0,0, 1,0,0, 0,0),
  "None-Future Diff for Women"    = c(0,0,0,0, 1,0,0, 1,0),
  "None-Current Diff for Men"     = c(0,0,0,0, 0,1,0, 0,0),
  "None-Current Diff for Women"   = c(0,0,0,0, 0,1,0, 0,1),
  "Future-Current Diff for Men"   = c(0,0,0,0,-1,1,0, 0,0),
  "Future-Current Diff for Women" = c(0,0,0,0,-1,1,0,-1,1),

  "A: Sex effect differ btw None and Future?"      = c(0,0,0,0,0,0,0, 1,0),
  "A: None-Future effect differ btw Men and Women?" = c(0,0,0,0,0,0,0, 1,0),
  "B: Sex effect differ btw None and Current?"      = c(0,0,0,0,0,0,0, 0,1),
  "B: None-Current effect differ btw Men and Women?" = c(0,0,0,0,0,0,0, 0,1),
  "C: Sex effect differ btw Future and Current?"     = c(0,0,0,0,0,0,0,-1,1),
  "C: Future-Current effect differ btw Men and Women?" = c(0,0,0,0,0,0,0,-1,1))),
      test=adjusted("none"))
```

DF=1 simple effects of sex per dementia group

	Estimate	Std. Error	t value	Pr(> t)
Sex Diff for No Dementia == 0	-2.87559	1.01124	-2.8436	0.0046288
Sex Diff for Future Dementia == 0	-2.71132	1.87407	-1.4468	0.1485438
Sex Diff for Current Dementia == 0	-10.75069	2.89932	-3.7080	0.0002304

DF=1 simple effects of dementia group per sex

	Estimate	Std. Error	t value	Pr(> t)
None-Future Diff for Men == 0	-6.05590	1.63513	-3.7036	0.0002344
None-Future Diff for Women == 0	-5.89163	1.27776	-4.6109	0.0000050083059
None-Current Diff for Men == 0	-11.97073	2.24495	-5.3323	0.0000001427086
None-Current Diff for Women == 0	-19.84583	2.02858	-9.7831	< 2.2e-16
Future-Current Diff for Men == 0	-5.91483	2.58676	-2.2866	0.0226061
Future-Current Diff for Women == 0	-13.95420	2.23892	-6.2326	0.0000000009239

DF=1 differences in simple effects = interactions

A: Sex effect differ btw None and Future? == 0	0.16427	2.07048	0.0793	0.9367921
A: None-Future effect differ btw Men and Women? == 0	0.16427	2.07048	0.0793	0.9367921
B: Sex effect differ btw None and Current? == 0	-7.87510	3.02454	-2.6037	0.0094746
B: None-Current effect differ btw Men and Women? == 0	-7.87510	3.02454	-2.6037	0.0094746
C: Sex effect differ btw Future and Current? == 0	-8.03937	3.41516	-2.3540	0.0189282
C: Future-Current effect differ btw Men and Women? == 0	-8.03937	3.41516	-2.3540	0.0189282

Values in gray italics would be typical marginal ANOVA results (that are useless)...

Dementia Group	Men	Women	MARGINAL	Sex Difference
Adjusted Means	Mean	Mean	MEAN	
None Mean	29.07	26.20	<i>27.63</i>	-2.87 (p=.0046)
Future Mean	23.01	20.30	<i>21.66</i>	-2.71 (p=.1485)
Current Mean	<u>17.10</u>	<u>6.35</u>	<i>11.72</i>	-10.75 (p=.0002)
MARGINAL	23.03	17.62		<i>-5.45 (p<.0001)</i>

Dementia Group	Men	Women	MARGINAL	Simple Effect
Differences	Diff	Diff	DIFF	Difference
None-Future Diff	-6.06 (p=.0002)	-5.90 (p<.0001)	<i>-5.97 (p<.0001)</i>	A = 0.16 (p=.9368)
None-Current Diff	-11.97 (p<.0001)	-19.85 (p<.0001)	<i>-15.91 (p<.0001)</i>	B = -7.88 (p=.0095)
Future-Current Diff	-5.91 (p=.0226)	-13.95 (p<.0001)	<i>-9.93 (p<.0001)</i>	C = -8.04 (p=.0189)

STATA Syntax: GLM Adding Sex by Dementia Group Interaction (output is online only)

```

display "STATA Eq 2.13: GLM Adding Sex by Dementia Group Interaction"
display "Dummy-Coded Predictors for Sex (0=Men) and Demgroup (0=None)"
regress cognition c.age85 c.grip9 c.sexmw c.demnf c.demnc c.age85#c.grip9 ///
           c.sexmw#c.demnf c.sexmw#c.demnc, level(95)

// Omnibus DF=2 F-test for Sex*Demgroup Interaction
test (c.sexmw#c.demnf=0) (c.sexmw#c.demnc=0)
// In TESTs below, linear combinations are created within parentheses (still 1 DF each)
// Omnibus DF=2 F-test for Dementia Simple Main Effect for Men
test (c.demnf*1 + c.sexmw#c.demnf*0 = 0) (c.demnc*1 + c.sexmw#c.demnc*0 = 0)
// Omnibus DF=2 F-Test for Dementia Simple Main Effect for Women
test (c.demnf*1 + c.sexmw#c.demnf*1 = 0) (c.demnc*1 + c.sexmw#c.demnc*1 = 0)

// Predicted cognition outcomes --adjusted cell means-- holding age=85 and grip=9
margins, at(c.age85=0 c.grip9=0 c.sexmw=(0(1)1) c.demnf=0 c.demnc=0) // yhats for None
margins, at(c.age85=0 c.grip9=0 c.sexmw=(0(1)1) c.demnf=1 c.demnc=0) // yhats for Future
margins, at(c.age85=0 c.grip9=0 c.sexmw=(0(1)1) c.demnf=0 c.demnc=1) // yhats for Current

// DF=1 simple slopes for sex per demgroup
lincom c.sexmw*1 + c.sexmw#c.demnf*0 + c.sexmw#demnc*0 // Sex Diff for No Dementia
lincom c.sexmw*1 + c.sexmw#c.demnf*1 + c.sexmw#demnc*0 // Sex Diff for Future Dementia
lincom c.sexmw*1 + c.sexmw#c.demnf*0 + c.sexmw#demnc*1 // Sex Diff for Current Dementia

// DF=1 simple slopes for demgroup per sex
lincom c.demnf*1 + c.demnc*0 + c.sexmw#c.demnf*0 + c.sexmw#c.demnc*0 // None-Future Diff for Men
lincom c.demnf*1 + c.demnc*0 + c.sexmw#c.demnf*1 + c.sexmw#c.demnc*0 // None-Future Diff for Women
lincom c.demnf*0 + c.demnc*1 + c.sexmw#c.demnf*0 + c.sexmw#c.demnc*0 // None-Current Diff for Men
lincom c.demnf*0 + c.demnc*1 + c.sexmw#c.demnf*0 + c.sexmw#c.demnc*1 // None-Current Diff for Women
lincom c.demnf*-1 + c.demnc*1 + c.sexmw#c.demnf*0 + c.sexmw#c.demnc*0 // Future-Current Diff for Men
lincom c.demnf*-1 + c.demnc*1 + c.sexmw#c.demnf*-1 + c.sexmw#c.demnc*1 // Future-Current Diff for Women

// DF=1 differences in simple slopes = interactions
lincom c.sexmw#c.demnf*1 + c.sexmw#c.demnc*0 // A: Sex Effect differ btw None and Future?
lincom c.sexmw#c.demnf*1 + c.sexmw#c.demnc*0 // A: None-Future Effect differ btw Men and Women?
lincom c.sexmw#c.demnf*0 + c.sexmw#c.demnc*1 // B: Sex Effect differ btw None and Current?
lincom c.sexmw#c.demnf*0 + c.sexmw#c.demnc*1 // B: None-Current Effect differ btw Men and Women?
lincom c.sexmw#c.demnf*-1 + c.sexmw#c.demnc*1 // C: Sex Effect differ btw Future and Current?
lincom c.sexmw#c.demnf*-1 + c.sexmw#c.demnc*1 // C: Future-Current Effect differ btw Men and Women?

```



```
// To make pictures, need to represent demgroup as program-categorical predictor instead
display "STATA Eq 2.13: Adding Sex by Dementia Group Interaction"
display "Program-Categorical Predictor for Demgroup Instead"
regress cognition c.age85 c.grip9 c.sexmw i.demgroup c.age85#c.grip9 c.sexmw#i.demgroup, level(95)

// Get predicted cognition outcomes --adjusted cell means-- holding age=85 and grip=9
margins i.demgroup, at(c.age85=0 c.grip9=0 c.sexmw=(0(1)1))
marginsplot, xdimension(demgroup) // Get and save plot for pred outcomes by demgroup
graph export "$filesave\STATA plots\STATA Sex by Demgroup=x GLM Plot.png", replace
marginsplot, xdimension(sexmw) // Get and save plot for pred outcomes by sexmw
graph export "$filesave\STATA plots\STATA Demgroup by Sex=x GLM Plot.png", replace
```

Example Results Section for Final Model [notes about what also to include]:

Note: The description of how the betas were used to create the simple effects is not typically included in a results section, but I included it here for pedagogical reasons.

We estimated a general linear model (as shown in Equation 1) to examine the extent to which cognition could be predicted from main effects of age (centered such that 0 = 85 years), grip strength (centered such that 0 = 9 pounds per square inch), sex (0 = men, 1 = women), and dementia status (none vs. future; none vs. current), as well as an interaction between age and grip strength, and an interaction between sex and dementia status. The model accounted for a significant amount of variance in cognition, $F(8, 541) = 28.77$, $MSE = 85.97$, $p < .0001$, $R^2 = .298$. Table 1 provides the model results, including the fixed effects estimated directly in the model, as well as their linear combinations in order to provide simple slopes by which to describe the sex by dementia group interaction. [Effect sizes should also be reported, but they are not our focus today.]

Equation 1 for final model:

$$\text{Cognition}_i = \beta_0 + \beta_1(\text{Age}_i - 85) + \beta_2(\text{Grip}_i - 9) + \beta_3(\text{SexMW}_i) + \beta_4(\text{DemNF}_i) + \beta_5(\text{DemNC}_i) \\ + \beta_6(\text{Age}_i - 85)(\text{Grip}_i - 9) + \beta_7(\text{SexMW}_i)(\text{DemNF}_i) + \beta_8(\text{SexMW}_i)(\text{DemNC}_i) + e_i$$

Results from this model can be interpreted as follows. The intercept $\beta_0 = 29.07$ is the expected cognition outcome for an 85-year-old man with 9 pounds of grip strength who will not be diagnosed with dementia later in the study.

The simple main effect of age $\beta_1 = 0.33$ indicated that cognition is predicted to be significantly lower by 0.33 for every additional year of age (in persons with grip strength of 9 pounds). The simple main effect of grip strength $\beta_2 = 0.62$ indicated that cognition is predicted to be significantly greater by 0.62 for every additional pound of grip strength (in persons who are age 85). As shown in [figure], the age by grip strength interaction $\beta_6 = 0.12$ indicated the age slope predicting cognition became significantly less negative by 0.12 for each additional pound of grip strength (as shown by the differences in slopes of the lines). Equivalently, the grip strength slope predicting cognition became significantly more positive by 0.12 for each additional year of age (as shown by the differences in the vertical distance between the lines). [Regions of significance and simple slopes could also be reported here, as described at the end of in chapter 2.]

The main and interactive effects of sex by dementia group are presented next, as illustrated in [figure], in which the sex differences are shown by the vertical distances between the lines, and the dementia group differences are shown by the differences within the lines. Given the significant sex by dementia group interaction, $F(2, 541) = 3.49$, $MSE = 85.97$, $p = .031$, simple slopes and their differences (i.e., interaction contrasts) for both sex and dementia group are reported next.

First, there was a significant simple main effect of sex ($\beta_3 = -2.88$) such that in the no dementia group, cognition was significantly lower by 2.88 in women than in men. The sex difference in cognition was equivalent in no dementia and future dementia groups, as shown by the nonsignificant sex by no dementia vs. future dementia interaction ($\beta_7 = 0.16$). However, the resulting sex difference in cognition favoring men in the future dementia group (of $\beta_3 + \beta_7 = -2.88 + 0.16 = -2.71$) was not significant, likely a result of the small number of persons with future dementia (only 20% of the sample). In addition, the sex difference in cognition was significantly larger in the current dementia group than in the no dementia group, as shown by the significant sex by no dementia vs. current dementia interaction ($\beta_8 = -7.88$), and the resulting sex difference in the current dementia group (of $\beta_3 + \beta_8 = 2.88 - 7.88 = -10.75$) was also significant. The sex difference in cognition was also significantly larger in the current dementia group than in the future dementia group (as found by $\beta_8 - \beta_7 = -7.88 - 0.16 = -8.04$).

Second, with respect to differences among dementia groups, a significant omnibus group difference was found both in men, $F(2, 541) = 18.69$, $MSE = 85.97$, $p < .001$, and in women, $F(2, 541) = 53.16$, $MSE = 85.97$, $p < .001$. More specifically, cognition was significantly lower in the future dementia than no dementia group, both in men ($\beta_4 = -6.06$) and women ($\beta_4 + \beta_7 = -6.06 + 0.16 = -5.89$). This group difference was equivalent across sexes, as indicated by the nonsignificant sex by no dementia vs. future dementia interaction ($\beta_4 = 0.16$). Cognition was also significantly lower in the current dementia than no dementia group, both in men ($\beta_5 = -11.97$) and women ($\beta_5 + \beta_8 = -11.97 - 7.88 = -19.85$). This group difference was significantly larger in women, as indicated by the sex by no dementia vs. current dementia interaction ($\beta_8 = -7.88$). Finally, cognition was also significantly lower in the current dementia group than future diagnosis group, both in men ($\beta_5 - \beta_4 = -11.97 + 6.06 = -5.91$) and women ($\beta_5 + \beta_8 - \beta_4 - \beta_7 = -11.97 - 7.88 + 6.06 + 0.16 = -13.95$). This group difference was significantly larger in women, as indicated by the additional interaction contrast (of $\beta_8 - \beta_7 = -7.88 - 0.16 = -8.04$).

Table 1: Model Results (bold values indicate $p < .05$)

Model Fixed Effects		Est	SE	$p <$
<u>Model for the Means</u>				
β_0	Intercept	29.07	0.75	.001
β_1	Age Slope (0 = 85 years)	-0.33	0.12	.005
β_2	Grip Strength Slope (0 = 9 lbs)	0.62	0.15	.001
β_6	Age by Grip Interaction	0.12	0.04	.003
Sex (0 = Men, 1 = Women) Differences:				
β_3	No Diagnosis	-2.88	1.01	.005
$\beta_3 + \beta_7$	Future Diagnosis	-2.71	1.87	.149
$\beta_3 + \beta_8$	Current Diagnosis	-10.75	2.90	.001
Dementia Group Differences:				
None vs. Future Diagnosis				
β_4	Men	-6.06	1.64	.001
$\beta_4 + \beta_7$	Women	-5.89	1.28	.001
β_7	Sex by None vs. Future	0.16	2.07	.937
None vs. Current Diagnosis				
β_5	Men	-11.97	2.25	.001
$\beta_5 + \beta_8$	Women	-19.85	2.02	.001
β_8	Sex by None vs. Current	-7.88	3.02	.010
Future vs. Current Diagnosis				
$-\beta_4 + \beta_5$	Men	-5.91	2.59	.023
$-\beta_4 + \beta_5 - \beta_7 + \beta_8$	Women	-13.95	2.24	.001
$-\beta_7 + \beta_8$	Sex by Future vs. Current	-8.04	3.42	.019