Practice with Interactions among Continuous Predictors in General Linear Models (as estimated using restricted maximum likelihood in MIXED)

The models for this example come from Hoffman (2014) chapter 2. We will be examining the extent to which cognition (as measured by an information test outcome) can be predicted from age (centered at 85 years) grip strength (centered at 9 pounds), sex (with men as the reference group) and dementia status (none, future, current, with none as the reference) in a sample of 550 older adults. SPSS syntax and output as well as SAS syntax are given below; STATA syntax and output is available online. In example 1 we examined main effects only; now we examine interactions involving age, grip strength, and sex (a binary predictor we will treat as continuous in the models that follow).

SPSS Syntax for Data Manipulation:

```
* Define location of files used in code below -- change this to your directory.
FILE HANDLE filesave /NAME = "C:\Dropbox\PilesOfVariance\Chapter2\SPSS".
* Import chapter 2 example data.
GET FILE = "filesave/SPSS_Chapter2.sav".
DATASET NAME Chapter2 WINDOW=FRONT.

* Center continuous predictors.
COMPUTE age85 = age - 85.
COMPUTE grip9 = grip - 9.
* Creating contrasts for dementia groups.
DO IF (demgroup=1).
COMPUTE demNF=0.
COMPUTE demNC=0.
END IF.
DO IF (demgroup=2).
COMPUTE demNF=1.
COMPUTE demNC=0.
END IF.
DO IF (demgroup=3).
COMPUTE demNF=0.
COMPUTE demNC=1.
END IF.
* Labeling new variables.
VARIABLE LABELS
age85  "age85: Age in Years (0=85)"
grip9  "grip9: Grip Strength in Pounds (0=9)"
demNF  "demNF: Dementia Contrast for None=0 vs Future=1"
demNC  "demNC: Dementia Contrast for None=0 vs Current=1".
EXECUTE.
```

SAS Syntax for Data Manipulation:

```
* Defining global variable for file location to be replaced in code below;
%LET filesave= C:\Dropbox\PilesOfVariance\Chapter2\SAS;
* Location for SAS files for these models (uses macro variable filesave);
LIBNAME filesave "&filesave.";

* Import chapter 2 example data into work library;
DATA work.Chapter2; SET filesave.SAS_Chapter2;
* Center continuous predictors;
age85 = age - 85;
grip9 = grip - 9;
* Creating all possible contrasts for dementia groups;
     IF demgroup=1 THEN DO; demNF=0; demNC=0; END;
ELSE IF demgroup=2 THEN DO; demNF=1; demNC=0; END;
ELSE IF demgroup=3 THEN DO; demNF=0; demNC=1; END;
```

```
* Labeling new variables;
LABEL
age85=  "age85: Age in Years (0=85)"
grip9=  "grip9: Grip Strength in Pounds (0=9)"
demNF=  "demNF: Dementia Contrast for None=0 vs Future=1"
demNC=  "demNC: Dementia Contrast for None=0 vs Current=1";
RUN;
```

STATA Syntax and Data Manipulation:

```
* Defining global variable for file location to be replaced in code below
global filesave "C:\Dropbox\PilesOfVariance\Chapter2\STATA"

* Import chapter 2 data into temporary file
use "$filesave\STATA_Chapter2.dta", clear
* Centering continuous predictors
gen age85 = age - 85
gen grip9 = grip - 9
* Creating contrasts for dementia groups
gen demNF=0
gen demNC=0
* Demgroup = none
replace demNF=0 if (demgroup==1)
replace demNC=0 if (demgroup==1)
* Demgroup = future
replace demNF=1 if (demgroup==2)
replace demNC=0 if (demgroup==2)
* Demgroup = current
replace demNF=0 if (demgroup==3)
replace demNC=1 if (demgroup==3)
* Labeling new variables
label variable age85  "age85: Age in Years (0=85)"
label variable grip9  "grip9: Grip Strength in Pounds (0=9)"
label variable demNF  "demNF: Dementia Contrast for None=0 vs Future=1"
label variable demNC  "demNC: Dementia Contrast for None=0 vs Current=1"
```

Repeated from the end of Example 1:

MIXED Syntax and SPSS/SAS Output for Dementia Model in Equation 2.8

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

We can use the model equation to calculate the **dementia group means** for predicted cognition:

Cognition for None =	β_0
Cognition for Future =	$\beta_0 + \beta_4$
Cognition for Current =	$\beta_0 + \beta_5$

We can determine the **differences between the dementia group means** as follows:

None vs. Future =	Future – None = $(\beta_0 + \beta_4) - (\beta_0) = \beta_4$
None vs. Current =	Current – None = $(\beta_0 + \beta_5) - (\beta_0) = \beta_5$
Future vs. Current =	Current – Future = $(\beta_0 + \beta_5) - (\beta_0 + \beta_4) = \beta_5 - \beta_4 = -\beta_4 + \beta_5$

These values are then requested via the SPSS TEST and SAS ESTIMATE statements below…

SPSS Syntax:

MIXED dv BY categorical predictors
WITH continuous predictors
/METHOD = REML or ML
/PRINT = regression solution
/FIXED = predictors for means model

```
DATASET ACTIVATE Chapter2 WINDOW=FRONT.
ECHO 'Eq 2.8: Adding Dementia Group'
      + ', Using Manual Group Contrasts so Reference=None'.
MIXED cognition WITH age85 grip9 sexMW demNF demNC
     /METHOD   = REML
     /PRINT    = SOLUTION TESTCOV
     /FIXED    = age85 grip9 sexMW demNF demNC
     /TEST     = "Model R2 F-Test" age85 1; grip9 1; sexMW 1; demNF 1; demNC 1
     /TEST     = "Omnibus F-Test for Dementia Group" demNF 1; demNC 1
     /TEST     = "Intercept for None Group"      intercept 1 demNF 0 demNC 0
     /TEST     = "Intercept for Future Group"    intercept 1 demNF 1 demNC 0
     /TEST     = "Intercept for Current Group"   intercept 1 demNF 0 demNC 1
     /TEST     = "None   vs Future  Group"       demNF  1 demNC 0
     /TEST     = "None   vs Current Group"       demNF  0 demNC 1
     /TEST     = "Future vs Current Group"       demNF -1 demNC 1.
```

SAS Syntax:

METHOD = ML or REML (default)
CLASS = categorical predictors
MODEL dv = fixed effects

```
TITLE1 'Eq 2.8: Adding Dementia Group';
TITLE2 'Using Manual Group Contrasts so Reference=None';
PROC MIXED DATA=work.Chapter2 COVTEST NOCLPRINT NAMELEN=100 IC METHOD=REML;
     MODEL cognition = age85 grip9 sexMW demNF demNC / CHISQ SOLUTION CL DDFM=BW;
     ODS OUTPUT CovParms=CovDem;
     CONTRAST "Model R2 F-Test" age85 1, grip9 1, sexmw 1, demNF 1, demNC 1 / CHISQ;
     CONTRAST "Omnibus F-Test for Dementia Group" demNF 1, demNC 1 / CHISQ;
     * Request group means (hold age=85, grip=9, men);
     ESTIMATE "Intercept for None Group"    intercept 1 demNF 0 demNC 0 / CL;
     ESTIMATE "Intercept for Future Group"  intercept 1 demNF 1 demNC 0 / CL;
     ESTIMATE "Intercept for Current Group" intercept 1 demNF 0 demNC 1 / CL;
     * Request group differences;
     ESTIMATE "None   vs. Future  Group"  demNF  1 demNC 0 / CL;
     ESTIMATE "None   vs. Current Group"  demNF  0 demNC 1 / CL;
     ESTIMATE "Future vs. Current Group"  demNF -1 demNC 1 / CL;
RUN; TITLE1; TITLE2;
     * Call macro to calculate R2 for overall model;
       %ModelR2(CovBase=CovEmpty, CovFewer=CovSex, CovMore=CovDem);
```

STATA Syntax:

DV = outcome, random part after || Level 2 ID is caseID, random intercept by default, so noconstant removes it, variance = Print variances instead of SD, estat ic → AIC and BIC

```
display as result "Eq 2.8: Adding Dementia Group"
display as result "Using Manual Group Contrasts so Reference=None"
mixed cognition c.age85 c.grip9 c.sexmw c.demNF c.demNC, ///
                || caseid: , noconstant variance reml,
      estat ic, n(550),
      test (c.age85=0) (c.grip9=0) (c.sexmw=0) (c.demNF=0) (c.demNC=0) // Model R2 Chi2Test
      test (c.demNF=0) (c.demNC=0) // Omnibus Chi2Test for Dementia Group
      lincom _cons*1 + c.demNF*0 + c.demNC*0 // Intercept for None Group
      lincom _cons*1 + c.demNF*1 + c.demNC*0 // Intercept for Future Group
      lincom _cons*1 + c.demNF*0 + c.demNC*1 // Intercept for Current Group
      lincom c.demNF*1  + c.demNC*0  // None   vs Future  Group
      lincom c.demNF*0  + c.demNC*1  // None   vs Current Group
      lincom c.demNF*-1 + c.demNC*1  // Future vs Current Group
```

SPSS Output:

Information Criteria[a]

-2 Restricted Log Likelihood	4016.269
Akaike's Information Criterion (AIC)	4018.269
Hurvich and Tsai's Criterion (AICC)	4018.276
Bozdogan's Criterion (CAIC)	4023.568
Schwarz's Bayesian Criterion (BIC)	4022.568

Estimates of Fixed Effects[a]

Parameter	Estimate	Std. Error	df	t	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Intercept	29.264325	.698508	544	41.895	.000	27.892222	30.636428
age85	-.405734	.118897	544	-3.412	.001	-.639288	-.172180
grip9	.604226	.149776	544.000	4.034	.000	.310016	.898435
sexMW	-3.657374	.891433	544	-4.103	.000	-5.408446	-1.906303
demNF	-5.721971	1.019078	544	-5.615	.000	-7.723782	-3.720160
demNC	-16.479813	1.522754	544	-10.822	.000	-19.471010	-13.488616

From SAS (SPSS version in all separate tables):

Estimates

Label	Estimate	Standard Error	DF	t Value	Pr > |t|	Lower	Upper
Intercept for None Group	29.2643	0.6985	544	41.90	<.0001	27.8922	30.6364
Intercept for Future Group	23.5424	1.0785	544	21.83	<.0001	21.4238	25.6609
Intercept for Current Group	12.7845	1.5302	544	8.35	<.0001	9.7787	15.7903
None vs. Future Group	-5.7220	1.0191	544	-5.61	<.0001	-7.7238	-3.7202
None vs. Current Group	-16.4798	1.5228	544	-10.82	<.0001	-19.4710	-13.4886
Future vs. Current Group	-10.7578	1.7080	544	-6.30	<.0001	-14.1128	-7.4028

R2 (% Reduction) Overall and for CovSex vs. CovDem

Name	CovParm	Estimate	StdErr	ZValue	ProbZ	R2_from_Base	R2_Increment
CovEmpty	Residual	120.76	7.2887	16.57	<.0001	-0.00000	.
CovSex	Residual	109.38	6.6200	16.52	<.0001	0.09422	.
CovDem	Residual	88.0709	5.3401	16.49	<.0001	0.27069	0.17647

Back to SPSS Output:

Estimates of Covariance Parameters[a]

Parameter	Estimate	Std. Error	Wald Z	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Residual	88.070880	5.340082	16.492	.000	78.202505	99.184546

Test of Contrasts[a]

Source	Numerator df	Denominator df	F	Sig.
Model R2 F-Test	5	544	41.753	.000

Source	Numerator df	Denominator df	F	Sig.
Omnibus F-Test for Dementia Group	2	544	67.056	.000

MIXED Syntax and Output for Equation 2.9, adding interaction of age85*grip9:

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

SPSS syntax to create and merge fake people into current data:

```
* Creating 'fake people' to show age*grip interaction.
* Each row is a fake person for which to create a predicted outcome.
DATA LIST FREE / caseID grip9 age85 sexMW demNF demNC.
BEGIN DATA.
-99  3 -5  0  0  0
-99  3  0  0  0  0
-99  3  5  0  0  0
-99  0 -5  0  0  0
-99  0  0  0  0  0
-99  0  5  0  0  0
-99 -3 -5  0  0  0
-99 -3  0  0  0  0
-99 -3  5  0  0  0
END DATA.
DATASET NAME FakeAgeGrip.

* Merge with real data.
ADD FILES FILE=Chapter2 /FILE=FakeAgeGrip.
DATASET NAME PlotAgeGrip.
SORT CASES BY caseID.
DATASET CLOSE FakeAgeGrip.
```

Note that the variables that are not part of the age*grip interaction are held constant at 0, but they must be included for predicted outcomes to be created.

The dataset "PlotAgeGrip" will be used in estimating this model instead of the original Chapter2 dataset.

SAS syntax to create and merge fake people into current data:

```
* Creating 'fake people' to show age*grip interaction;
* Each row is a fake person for which to create a predicted outcome;
DATA work.FakeAgeGrip; INPUT caseID grip9 age85 sexMW demNF demNC;
DATALINES;
-99  3 -5  0  0  0
-99  3  0  0  0  0
-99  3  5  0  0  0
-99  0 -5  0  0  0
-99  0  0  0  0  0
-99  0  5  0  0  0
-99 -3 -5  0  0  0
-99 -3  0  0  0  0
-99 -3  5  0  0  0
; RUN;

* Merge with real data;
DATA work.PlotAgeGrip; MERGE work.Chapter2 work.FakeAgeGrip; BY caseID; RUN;
```

Note that the variables that are not part of the age*grip interaction are held constant at 0, but they must be included for predicted outcomes to be created.

The dataset "PlotAgeGrip" will be used in estimating this model instead of the original Chapter2 dataset.

Given the easiness of the MARGINS option in STATA, we don't need to create fake people.

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

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

Simple Effect of Age = $\beta_1(\text{Age}_i - 85) + \beta_6(\text{Age}_i - 85)(\text{Grip}_i - 9) \rightarrow (\text{Age}_i - 85)[\beta_1 + \beta_6(\text{Grip}_i - 9)]$

Likewise, we can use the model equation to calculate the **simple effect of grip strength** at any level of *age* (grip strength as the effect, age as the moderator):

Simple Effect of Grip = $\beta_2(\text{Grip}_i - 9) + \beta_6(\text{Age}_i - 85)(\text{Grip}_i - 9) \rightarrow (\text{Grip}_i - 9)[\beta_2 + \beta_6(\text{Age}_i - 85)]$

Manual calculations for predicted values for "fake people" to plot interaction:

$\text{Predicted Cognition}_i = \beta_0 + \beta_1(\text{Age}_i - 85) + \beta_2(\text{Grip}_i - 9) + \beta_6(\text{Age}_i - 85)(\text{Grip}_i - 9)$

$\text{Grip Strength} = 12,\ \text{Age} = 80: \quad 29.41 - 0.33(-5) + 0.62(3) + 0.12(-5)(3) = 31.12$

$\text{Grip Strength} = 12,\ \text{Age} = 85: \quad 29.41 - 0.33(0) + 0.62(3) + 0.12(0)(3) = 31.27$

$\text{Grip Strength} = 12,\ \text{Age} = 90: \quad 29.41 - 0.33(5) + 0.62(3) + 0.12(5)(3) = 31.42$

$\text{Grip Strength} = 9,\ \text{Age} = 80: \quad 29.41 - 0.33(-5) + 0.62(0) + 0.12(-5)(0) = 31.06$

$\text{Grip Strength} = 9,\ \text{Age} = 85: \quad 29.41 - 0.33(0) + 0.62(0) + 0.12(0)(0) = 29.41$

$\text{Grip Strength} = 9,\ \text{Age} = 90: \quad 29.41 - 0.33(5) + 0.62(0) + 0.12(5)(0) = 27.76$

$\text{Grip Strength} = 6,\ \text{Age} = 80: \quad 29.41 - 0.33(-5) + 0.62(-3) + 0.12(-5)(-3) = 31.00$

$\text{Grip Strength} = 6,\ \text{Age} = 85: \quad 29.41 - 0.33(0) + 0.62(-3) + 0.12(0)(-3) = 27.55$

$\text{Grip Strength} = 6,\ \text{Age} = 90: \quad 29.41 - 0.33(5) + 0.62(-3) + 0.12(5)(-3) = 24.10$

Examples of each of these are requested via TEST/ESTIMATE/LINCOM statements below…

SPSS Syntax:

```
* Estimate model on data with fake people to make predictions.
DATASET ACTIVATE PlotAgeGrip WINDOW=FRONT.
ECHO 'Eq 2.9: Adding Age by Grip Interaction'
      + ', Age 0=85 Grip 0=9'.
MIXED cognition WITH age85 grip9 sexMW demNF demNC
     /METHOD   = REML
     /PRINT    = SOLUTION TESTCOV COVB
     /FIXED    = age85 grip9 sexMW demNF demNC
                 age85*grip9
     /SAVE     = FIXPRED (PredAgeGrip)
/TEST  = 'Age Slope at Grip Strength =  6'    age85 1 age85*grip9 -3
/TEST  = 'Age Slope at Grip Strength =  9'    age85 1 age85*grip9  0
/TEST  = 'Age Slope at Grip Strength = 12'    age85 1 age85*grip9  3
/TEST  = 'Grip Strength Slope at Age = 80'    grip9 1 age85*grip9 -5
/TEST  = 'Grip Strength Slope at Age = 85'    grip9 1 age85*grip9  0
/TEST  = 'Grip Strength Slope at Age = 90'    grip9 1 age85*grip9  5
```

On PRINT: COVB adds the asymptotic covariance matrix for regions of significance; SAVE = FIXPRED saves predicted outcomes as new named variable

If you are not using fake people, you have to write these extra statements to create predicted outcomes

```
/TEST = 'Cognition at Grip = 12 Age = 80'    intercept 1 age85 -5 grip9  3 age85*grip9 -15
/TEST = 'Cognition at Grip = 12 Age = 85'    intercept 1 age85  0 grip9  3 age85*grip9   0
/TEST = 'Cognition at Grip = 12 Age = 90'    intercept 1 age85  5 grip9  3 age85*grip9  15
/TEST = 'Cognition at Grip =  9 Age = 80'    intercept 1 age85 -5 grip9  0 age85*grip9   0
/TEST = 'Cognition at Grip =  9 Age = 85'    intercept 1 age85  0 grip9  0 age85*grip9   0
/TEST = 'Cognition at Grip =  9 Age = 90'    intercept 1 age85  5 grip9  0 age85*grip9   0
/TEST = 'Cognition at Grip =  6 Age = 80'    intercept 1 age85 -5 grip9 -3 age85*grip9  15
/TEST = 'Cognition at Grip =  6 Age = 85'    intercept 1 age85  0 grip9 -3 age85*grip9   0
/TEST = 'Cognition at Grip =  6 Age = 90'    intercept 1 age85  5 grip9 -3 age85*grip9 -15.
```

```
* Subset predicted outcomes data to fake people.
DATASET ACTIVATE PlotAgeGrip.
SELECT IF (caseID=-99).
EXECUTE.
ECHO 'Predicted Outcomes for Fake People in PlotAgeGrip Data'.
PRINT TABLE / age85 grip9 sexMW demNF demNC PredAgeGrip.
EXECUTE.
```

SAS Syntax:

On MODEL after /: COVB adds the asymptotic covariance matrix for regions of significance; OUTPM = saves predicted outcomes in new named dataset

```
TITLE1 'Eq 2.9: Adding Age by Grip Interaction';
TITLE2 'Age 0=85 Grip 0=9';
* Estimate model on data with fake people to make predictions;
PROC MIXED DATA=work.PlotAgeGrip COVTEST NOCLPRINT NAMELEN=100 IC METHOD=REML;
MODEL cognition = age85 grip9 sexMW demNF demNC age85*grip9
                      / CHISQ SOLUTION CL DDFM=BW COVB OUTPM=PredAgeGrip;
ODS OUTPUT CovParms=CovAgeGrip SolutionF=FixAgeGrip COVB=CovBAgeGrip;
ESTIMATE 'Age Slope at Grip Strength =  6' age85 1 age85*grip9 -3 / CL;
ESTIMATE 'Age Slope at Grip Strength =  9' age85 1 age85*grip9  0 / CL;
ESTIMATE 'Age Slope at Grip Strength = 12' age85 1 age85*grip9  3 / CL;
ESTIMATE 'Grip Strength Slope at Age = 80' grip9 1 age85*grip9 -5 / CL;
ESTIMATE 'Grip Strength Slope at Age = 85' grip9 1 age85*grip9  0 / CL;
ESTIMATE 'Grip Strength Slope at Age = 90' grip9 1 age85*grip9  5 / CL;
* If you are not using fake people, you have to write these to create predicted outcomes;
ESTIMATE 'Cognition at Grip = 12 Age = 80' intercept 1 age85 -5 grip9  3 age85*grip9 -15;
ESTIMATE 'Cognition at Grip = 12 Age = 85' intercept 1 age85  0 grip9  3 age85*grip9   0;
ESTIMATE 'Cognition at Grip = 12 Age = 90' intercept 1 age85  5 grip9  3 age85*grip9  15;
ESTIMATE 'Cognition at Grip =  9 Age = 80' intercept 1 age85 -5 grip9  0 age85*grip9   0;
ESTIMATE 'Cognition at Grip =  9 Age = 85' intercept 1 age85  0 grip9  0 age85*grip9   0;
ESTIMATE 'Cognition at Grip =  9 Age = 90' intercept 1 age85  5 grip9  0 age85*grip9   0;
ESTIMATE 'Cognition at Grip =  6 Age = 80' intercept 1 age85 -5 grip9 -3 age85*grip9  15;
ESTIMATE 'Cognition at Grip =  6 Age = 85' intercept 1 age85  0 grip9 -3 age85*grip9   0;
ESTIMATE 'Cognition at Grip =  6 Age = 90' intercept 1 age85  5 grip9 -3 age85*grip9 -15;
RUN; TITLE1; TITLE2;
* Call macro for regions of significance for main effects of interaction;
%Regions(FixData=FixAgeGrip, CovBData=CovBAgeGrip, Pred=grip9, Mod=age85,
         ModCenter=85, Interact=age85*grip9, Order=6);
%Regions(FixData=FixAgeGrip, CovBData=CovBAgeGrip, Pred=age85, Mod=grip9,
         ModCenter=9, Interact=age85*grip9, Order=6)
* Call macro to calculate R2 for overall model;
%ModelR2(CovBase=CovEmpty, CovFewer=CovDem, CovMore=CovAgeGrip);
* Subset predicted outcomes data to fake people;
DATA PredAgeGrip; SET PredAgeGrip; WHERE caseID=-99; RUN;
TITLE9 'Predicted Outcomes for Fake People';
PROC PRINT NOOBS DATA=PredAgeGrip; VAR age85 grip9 sexMW demNF demNC pred; RUN;
```

STATA Syntax:

```
display as result "Eq 2.9: Adding Age by Grip Interaction"
display as result "Age 0=85 Grip 0=9"
mixed cognition c.age85 c.grip9 c.sexmw c.demNF c.demNC c.age85#c.grip9, ///
                || caseid: , noconstant variance reml,
      estat ic, n(550),
      estat vce,
      lincom c.age85*1 + c.age85#c.grip9*-3 // Age Slope at Grip Strength =  6
      lincom c.age85*1 + c.age85#c.grip9*0  // Age Slope at Grip Strength =  9
      lincom c.age85*1 + c.age85#c.grip9*3  // Age Slope at Grip Strength = 12
      lincom c.grip9*1 + c.age85#c.grip9*-5 // Grip Strength Slope at Age = 80
      lincom c.grip9*1 + c.age85#c.grip9*0  // Grip Strength Slope at Age = 85
      lincom c.grip9*1 + c.age85#c.grip9*5  // Grip Strength Slope at Age = 90
      margins, at (c.age85=(-5(5)5) c.grip9=(-3(3)3)) vsquish,
```

vce = COVB asymptotic cov matrix

The MARGINS option replaces the fake people and the separate prediction statements. Format: predictor=(start(interval)end)

SPSS Output (unless otherwise noted, and re-ordered for convenience):

Information Criteria[a]

-2 Restricted Log Likelihood	4011.694
Akaike's Information Criterion (AIC)	4013.694
Hurvich and Tsai's Criterion (AICC)	4013.701
Bozdogan's Criterion (CAIC)	4018.991
Schwarz's Bayesian Criterion (BIC)	4017.991

Estimates of Covariance Parameters[a]

					95% Confidence Interval	
Parameter	**Estimate**	**Std. Error**	**Wald Z**	**Sig.**	**Lower Bound**	**Upper Bound**
Residual	86.761505	5.265531	16.477	.000	77.031419	97.720629

From SAS Output for ModelR2 Macro:

R2 (% Reduction) Overall and for CovDem vs. CovAgeGrip

Name	CovParm	Estimate	StdErr	ZValue	ProbZ	R2_from_Base	R2_Increment
CovEmpty	Residual	120.76	7.2887	16.57	<.0001	-0.00000	.
CovDem	Residual	88.0709	5.3401	16.49	<.0001	0.27069	.
CovAgeGrip	Residual	86.7615	5.2655	16.48	<.0001	0.28153	0.010843

Estimates of Fixed Effects[a]

						95% Confidence Interval	
Parameter	**Estimate**	**Std. Error**	**df**	**t**	**Sig.**	**Lower Bound**	**Upper Bound**
Intercept	29.407803	.694906	543.000	42.319	.000	28.042770	30.772837
age85	-.333961	.120357	543	-2.775	.006	-.570382	-.097539
grip9	.619419	.148742	543	4.164	.000	.327238	.911600
sexMW	-3.455637	.887275	543	-3.895	.000	-5.198549	-1.712726
demNF	-5.922543	1.013632	543	-5.843	.000	-7.913663	-3.931424
demNC	-16.300405	1.512547	543	-10.777	.000	-19.271566	-13.329244
age85 * grip9	.123018	.040536	543	3.035	.003	.043391	.202646

Interpret these fixed effects:

Intercept β_0 =

Simple main effect of Age β_1 =

Simple main effect of Grip Strength β_2 =

Interpret Age by Grip Strength β_6 → Age as Simple Effect, Grip as Moderator:

Interpret Age by Grip Strength β_6 → Grip as Simple Effect, Age as Moderator:

From SAS Output for ESTIMATE (or TEST in SPSS in separate tables):

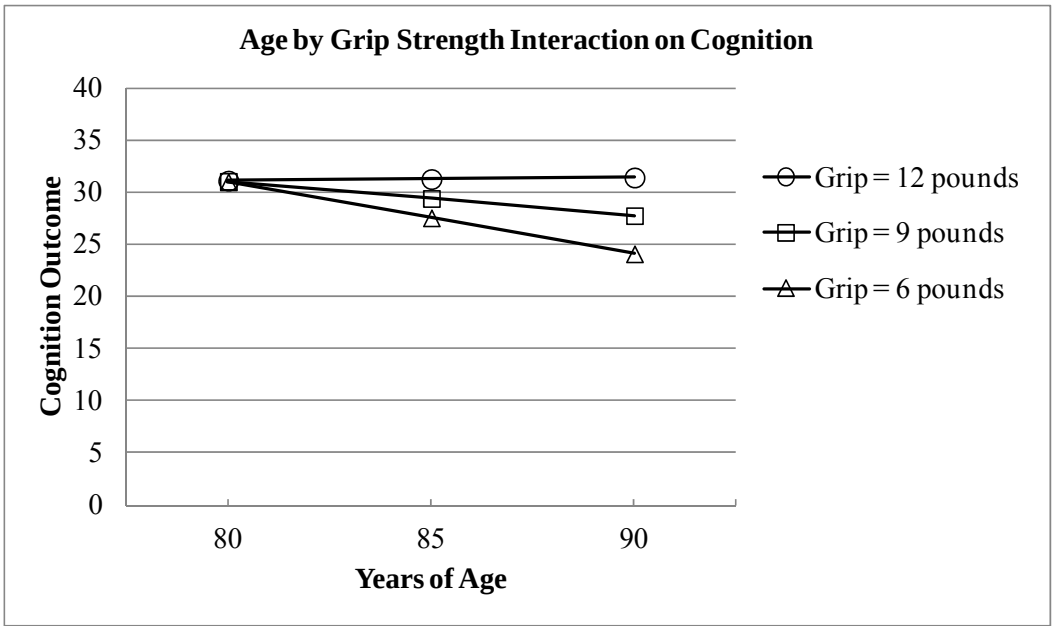
Label	Estimate	Standard Error	DF	t Value	Pr > |t|	Lower	Upper
Age Slope at Grip Strength = 6	-0.7030	0.1534	543	-4.58	<.0001	-1.0043	-0.4017
Age Slope at Grip Strength = 9	-0.3340	0.1204	543	-2.77	0.0057	-0.5704	-0.09754
Age Slope at Grip Strength = 12	0.03509	0.1872	543	0.19	0.8513	-0.3325	0.4027
Grip Strength Slope at Age = 80	0.004326	0.2473	543	0.02	0.9861	-0.4815	0.4902
Grip Strength Slope at Age = 85	0.6194	0.1487	543	4.16	<.0001	0.3272	0.9116
Grip Strength Slope at Age = 90	1.2345	0.2554	543	4.83	<.0001	0.7328	1.7362
Cognition at Grip = 12 Age = 80	31.0906	1.0924	543	28.46	<.0001	28.9447	33.2364
Cognition at Grip = 12 Age = 85	31.2661	0.7053	543	44.33	<.0001	29.8805	32.6516
Cognition at Grip = 12 Age = 90	31.4415	1.2462	543	25.23	<.0001	28.9936	33.8895
Cognition at Grip = 9 Age = 80	31.0776	0.9168	543	33.90	<.0001	29.2767	32.8785
Cognition at Grip = 9 Age = 85	29.4078	0.6949	543	42.32	<.0001	28.0428	30.7728
Cognition at Grip = 9 Age = 90	27.7380	0.9217	543	30.09	<.0001	25.9274	29.5486
Cognition at Grip = 6 Age = 80	31.0646	1.2605	543	24.65	<.0001	28.5886	33.5406
Cognition at Grip = 6 Age = 85	27.5495	0.9309	543	29.60	<.0001	25.7210	29.3781
Cognition at Grip = 6 Age = 90	24.0345	1.1491	543	20.92	<.0001	21.7773	26.2917

Predicted Outcomes for Fake People

age85	grip9	sexmw	dem NF	dem NC	Pred
-5	3	0	0	0	31.0906
0	3	0	0	0	31.2661
5	3	0	0	0	31.4415
-5	0	0	0	0	31.0776
0	0	0	0	0	29.4078
5	0	0	0	0	27.7380
-5	-3	0	0	0	31.0646
0	-3	0	0	0	27.5495
5	-3	0	0	0	24.0345

This printout of the fake cases only is from the "PlotAgeGrip" dataset in SPSS (in which the "pred" column is named as given in the FIXPRED option) or the "PredAgeGrip" dataset in SAS (as given by the OUTPM= option).

From plotting predicted outcomes in excel:



Repeated from above (values needed for regions of significance in bold):

Estimates of Fixed Effects[a]

Parameter	Estimate	Std. Error	df	t	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Intercept	29.407803	.694906	543.000	42.319	.000	28.042770	30.772837
age85	**-.333961**	.120357	543	-2.775	.006	-.570382	-.097539
grip9	**.619419**	.148742	543	4.164	.000	.327238	.911600
sexMW	-3.455637	.887275	543	-3.895	.000	-5.198549	-1.712726
demNF	-5.922543	1.013632	543	-5.843	.000	-7.913663	-3.931424
demNC	-16.300405	1.512547	543	-10.777	.000	-19.271566	-13.329244
age85 * grip9	**.123018**	.040536	543	3.035	.003	.043391	.202646

From adding COVB in SPSS or SAS, or estat vce in STATA (bolded values needed for regions):

Covariance Matrix for Estimates of Fixed Effects[a]

Parameter	Intercept	age85	grip9	sexmw	demNF	demNC	age85 * grip9
Intercept	.482895	.000454	-.030753	-.450672	-.182029	-.226347	.001916
age85	.000454	**.014486**	.003317	.005024	-.004131	-.001151	**.000959**
grip9	-.030753	.003317	**.022124**	.053743	-.013388	-.000301	**.000203**
sexMW	-.450672	.005024	.053743	.787257	-.071016	.023708	.002695
demNF	-.182029	-.004131	-.013388	-.071016	1.027449	.212912	-.002679
demNC	-.226347	-.001151	-.000301	.023708	.212912	2.287799	.002396
age85 * grip9	.001916	.000959	.000203	.002695	-.002679	.002396	**.001643**

See excel sheet for calculations, as provided by the SAS macro %Regions below:

```
Regions of significance for age85*grip9 interaction:

The effect of grip9 will be significant at centered values of age85 BELOW the lower bound
and ABOVE the upper bound, which translate to these uncentered lower and upper bounds.

Centered    Centered    Uncentered    Uncentered
  Lower       Upper       Lower         Upper
-14.8174    -2.28519      70.1826       82.7148
```

So the effect of grip strength will be significantly negative below age = 70.19 years, nonsignificant between age = 70.19 and 82.71 years, and significantly positive after age = 82.71 years.

```
Regions of significance for age85*grip9 interaction:

The effect of age85 will be significant at centered values of grip9 BELOW the lower bound
and ABOVE the upper bound, which translate to these uncentered lower and upper bounds.

Centered    Centered    Uncentered    Uncentered
  Lower       Upper       Lower         Upper
 0.66541     9.52041      9.66541       18.5204
```

Similarly, the effect of age will be significantly negative below grip strength = 9.66 pounds, nonsignificant between 9.66 and 18.48 pounds, and significantly positive after 18.48 pounds.

MIXED Syntax and Output for Equation 2.18, adding sexMW*demNC, sexMW*demNF, age85*sexMW, grip9*sexMW, age85*grip9*sexMW:

Syntax for creating fake people to show three-way interaction in SPSS and SAS:

```
* Creating 'fake people' to show age*grip*sex interaction.
* Each row is a fake person for which to create a predicted outcome.
DATA LIST FREE / caseID grip9 age85 sexMW demNF demNC.
BEGIN DATA.
-99   3  -5  0  0  0
-99   3   0  0  0  0
-99   3   5  0  0  0
-99   0  -5  0  0  0
-99   0   0  0  0  0
-99   0   5  0  0  0
-99  -3  -5  0  0  0
-99  -3   0  0  0  0
-99  -3   5  0  0  0
-99   3  -5  1  0  0
-99   3   0  1  0  0
-99   3   5  1  0  0
-99   0  -5  1  0  0
-99   0   0  1  0  0
-99   0   5  1  0  0
-99  -3  -5  1  0  0
-99  -3   0  1  0  0
-99  -3   5  1  0  0
END DATA.
DATASET NAME FakeAgeGripSex.

* Merge with real data.
ADD FILES FILE=Chapter2 /FILE=FakeAgeGripSex.
DATASET NAME PlotAgeGripSex.
SORT CASES BY caseID.
DATASET CLOSE FakeAgeGripSex.


* Creating 'fake people' to show age*grip*sex interaction;
* Each row is a fake person for which to create a predicted outcome;
DATA work.FakeAgeGripSex; INPUT caseID grip9 age85 sexMW demNF demNC;
DATALINES;
-99   3  -5  0  0  0
-99   3   0  0  0  0
-99   3   5  0  0  0
-99   0  -5  0  0  0
-99   0   0  0  0  0
-99   0   5  0  0  0
-99  -3  -5  0  0  0
-99  -3   0  0  0  0
-99  -3   5  0  0  0
-99   3  -5  1  0  0
-99   3   0  1  0  0
-99   3   5  1  0  0
-99   0  -5  1  0  0
-99   0   0  1  0  0
-99   0   5  1  0  0
-99  -3  -5  1  0  0
-99  -3   0  1  0  0
-99  -3   5  1  0  0
; RUN;

* Merge with real data;
DATA work.PlotAgeGripSex; MERGE work.Chapter2 work.FakeAgeGripSex; BY caseID; RUN;
```

Note that the variables that are not part of the age*grip*sex interaction are held constant at 0, but they must be included for predicted outcomes to be created.

The dataset "PlotAgeGripSex" will be used in estimating this model instead of the original Chapter2 dataset.

SPSS Syntax (separated by function here, but must be in contiguous lines to run in SPSS):

```
* Estimate model on data with fake people to make predictions.
DATASET ACTIVATE PlotAgeGripSex WINDOW=FRONT.
ECHO 'Eq 2.18: Adding Sex by Age by Grip Three-Way Interaction'
      + ', Age 0=85 Grip 0=9 Sex 0=Men Dementia 0=None'.
MIXED cognition WITH age85 grip9 sexMW demNF demNC
     /METHOD   = REML
     /PRINT    = SOLUTION TESTCOV
     /FIXED    = age85 grip9 sexmw demNF demNC age85*grip9 sexMW*demNF sexMW*demNC
                 age85*sexMW grip9*sexMW age85*grip9*sexMW
     /SAVE     = FIXPRED (Pred3AgeSexGrip)
```

$$\begin{aligned}\text{Cognition}_i = {} & \beta_0 + \beta_1(\text{Age}_i - 85) + \beta_2(\text{Grip}_i - 9) + \beta_3(\text{SexMW}_i) + \beta_4(\text{DemNF}_i) + \beta_5(\text{DemNC}_i) \\ & + \beta_6(\text{Age}_i - 85)(\text{Grip}_i - 9) + \underline{\beta_7(\text{SexMW}_i)(\text{DemNF}_i)} + \underline{\beta_8(\text{SexMW}_i)(\text{DemNC}_i)} \\ & + \underline{\beta_9(\text{Age}_i - 85)(\text{SexMW}_i) + \beta_{10}(\text{Grip}_i - 9)(\text{SexMW}_i)} \\ & + \underline{\beta_{11}(\text{Age}_i - 85)(\text{Grip}_i - 9)(\text{SexMW}_i)} + e_i\end{aligned}$$

Simple main effects come from:
what it is (main effect)
+ what modifies it (2-ways + 3-ways)

Simple main effect of age:

$\beta_1(\text{Age}_i-85) + \beta_6(\text{Age}_i-85)(\text{Grip}_i-9) + \beta_9(\text{Age}_i-85)(\text{SexMW}_i) + \beta_{11}(\text{Age}_i-85)(\text{Grip}_i-9)(\text{SexMW}_i)$
$= (\text{Age}_i-85)*[\underline{\beta_1 + \beta_6(\text{Grip}_i-9) + \beta_9(\text{SexMW}_i) + \beta_{11}(\text{Grip}_i-9)(\text{SexMW}_i)}]$

```
/TEST =  "Age for Grip=6,  Men"   age85 1 age85*grip9 -3 age85*sexMW  0 age85*grip9*sexMW  0
/TEST =  "Age for Grip=9,  Men"   age85 1 age85*grip9  0 age85*sexMW  0 age85*grip9*sexMW  0
/TEST =  "Age for Grip=12, Men"   age85 1 age85*grip9  3 age85*sexMW  0 age85*grip9*sexMW  0
/TEST =  "Age for Grip=6,  Women" age85 1 age85*grip9 -3 age85*sexMW  1 age85*grip9*sexMW -3
/TEST =  "Age for Grip=9,  Women" age85 1 age85*grip9  0 age85*sexMW  1 age85*grip9*sexMW  0
/TEST =  "Age for Grip=12, Women" age85 1 age85*grip9  3 age85*sexMW  1 age85*grip9*sexMW  3
```

Simple main effect of grip strength:

$\beta_2(\text{Grip}_i-9) + \beta_6(\text{Age}_i-85)(\text{Grip}_i-9) + \beta_{10}(\text{Grip}_i-9)(\text{SexMW}_i) + \beta_{11}(\text{Age}_i-85)(\text{Grip}_i-9)(\text{SexMW}_i)$
$= (\text{Grip}_i-9)*[\underline{\beta_2 + \beta_6(\text{Age}_i-85) + \beta_{10}(\text{SexMW}_i) + \beta_{11}(\text{Age}_i-85)(\text{SexMW}_i)}]$

```
/TEST =  "Grip for Age=80, Men"   grip9 1 age85*grip9 -5 grip9*sexMW  0 age85*grip9*sexMW  0
/TEST =  "Grip for Age=85, Men"   grip9 1 age85*grip9  0 grip9*sexMW  0 age85*grip9*sexMW  0
/TEST =  "Grip for Age=90, Men"   grip9 1 age85*grip9  5 grip9*sexMW  0 age85*grip9*sexMW  0
/TEST =  "Grip for Age=80, Women" grip9 1 age85*grip9 -5 grip9*sexMW  1 age85*grip9*sexMW -5
/TEST =  "Grip for Age=85, Women" grip9 1 age85*grip9  0 grip9*sexMW  1 age85*grip9*sexMW  0
/TEST =  "Grip for Age=90, Women" grip9 1 age85*grip9  5 grip9*sexMW  1 age85*grip9*sexMW  5
```

Simple main effect of sex (hold dementia group at 0=none):

$\beta_3(\text{SexMW}_i) + \beta_9(\text{Age}_i-85)(\text{SexMW}_i) + \beta_{10}(\text{Grip}_i-9)(\text{SexMW}_i) + \beta_{11}(\text{Age}_i-85)(\text{Grip}_i-9)(\text{SexMW}_i)$
$= (\text{SexMW}_i) *[\underline{\beta_3 + \beta_9(\text{Age}_i-85) + \beta_{10}(\text{Grip}_i-9) + \beta_{11}(\text{Age}_i-85)(\text{Grip}_i-9)}]$

```
/TEST =  "Sex: Age=80, Grip=6" sexMW 1 age85*sexMW-5 grip9*sexMW -3 age85*grip9*sexMW  15
/TEST =  "Sex: Age=85, Grip=6" sexMW 1 age85*sexMW 0 grip9*sexMW -3 age85*grip9*sexMW   0
/TEST =  "Sex: Age=90, Grip=6" sexMW 1 age85*sexMW 5 grip9*sexMW -3 age85*grip9*sexMW -15
/TEST =  "Sex: Age=80, Grip=9" sexMW 1 age85*sexMW-5 grip9*sexMW  0 age85*grip9*sexMW   0
/TEST =  "Sex: Age=85, Grip=9" sexMW 1 age85*sexMW 0 grip9*sexMW  0 age85*grip9*sexMW   0
/TEST =  "Sex: Age=90, Grip=9" sexMW 1 age85*sexMW 5 grip9*sexMW  0 age85*grip9*sexMW   0
/TEST =  "Sex: Age=80,Grip=12" sexMW 1 age85*sexMW-5 grip9*sexMW  3 age85*grip9*sexMW -15
/TEST =  "Sex: Age=85,Grip=12" sexMW 1 age85*sexMW 0 grip9*sexMW  3 age85*grip9*sexMW   0
/TEST =  "Sex: Age=90,Grip=12" sexMW 1 age85*sexMW 5 grip9*sexMW  3 age85*grip9*sexMW  15
```

Simple two-way interaction of age*grip: $\beta_6(Age_i-85)(Grip_i-9) + \beta_{11}(Age_i-85)(Grip_i-9)(SexMW_i)$

```
/TEST =  "Age by Grip: Men"      age85*grip9 1 age85*grip9*sexMW  0
/TEST =  "Age by Grip: Women"    age85*grip9 1 age85*grip9*sexMW  1
```

Simple two-way interaction of age*sex: $\beta_9(Age_i-85)(SexMW_i) + \beta_{11}(Age_i-85)(Grip_i-9)(SexMW_i)$

```
/TEST =  "Sex by Age:  Grip=6"   age85*sexMW1 age85*grip9*sexMW -3
/TEST =  "Sex by Age:  Grip=9"   age85*sexMW1 age85*grip9*sexMW  0
/TEST =  "Sex by Age:  Grip=12"  age85*sexMW1 age85*grip9*sexMW  3
```

Simple two-way interaction of grip*sex: $\beta_{10}(Grip_i-9)(SexMW_i) + \beta_{11}(Age_i-85)(Grip_i-9)(SexMW_i)$

```
/TEST =  "Sex by Grip: Age=80"   grip9*sexMW 1 age85*grip9*sexMW -5
/TEST =  "Sex by Grip: Age=85"   grip9*sexMW 1 age85*grip9*sexMW  0
/TEST =  "Sex by Grip: Age=90"   grip9*sexMW 1 age85*grip9*sexMW  5.

* Subset predicted outcomes data to fake people.
DATASET ACTIVATE PlotAgeGripSex.
SELECT IF (caseID=-99).
EXECUTE.
ECHO 'Predicted Outcomes for Fake People in PlotAgeGripSex Data'.
PRINT TABLE / age85 grip9 sexmw demNF demNC Pred3AgeSexGrip.
EXECUTE.
```

SAS Syntax:

```
TITLE1 'Eq 2.18: Adding Sex by Age by Grip Three-Way Interaction';
TITLE2 'Age 0=85 Grip 0=9 Sex 0=Men Dementia 0=None';
* Estimate model on data with fake people to make predictions;
PROC MIXED DATA=work.PlotAgeGripSex COVTEST NOCLPRINT NAMELEN=100 IC METHOD=REML;
     MODEL cognition = age85 grip9 sexmw demNF demNC
                       age85*grip9 sexmw*demNF sexmw*demNC
                       age85*sexMWgrip9*sexMW age85*grip9*sexMW
                         / CHISQ SOLUTION CL DDFM=BW OUTPM=Pred3AgeSexGrip;
     ODS OUTPUT CovParms=Cov3AgeSexGrip;
* Request simple effects of Age;
ESTIMATE "Age for Grip=6,  Men"   age85 1 age85*grip9 -3 age85*sexMW 0 age85*grip9*sexMW  0;
ESTIMATE "Age for Grip=9,  Men"   age85 1 age85*grip9  0 age85*sexMW 0 age85*grip9*sexMW  0;
ESTIMATE "Age for Grip=12, Men"   age85 1 age85*grip9  3 age85*sexMW 0 age85*grip9*sexMW  0;
ESTIMATE "Age for Grip=6,  Women" age85 1 age85*grip9 -3 age85*sexMW 1 age85*grip9*sexMW -3;
ESTIMATE "Age for Grip=9,  Women" age85 1 age85*grip9  0 age85*sexMW 1 age85*grip9*sexMW  0;
ESTIMATE "Age for Grip=12, Women" age85 1 age85*grip9  3 age85*sexMW 1 age85*grip9*sexMW  3;
* Request simple effects of Grip;
ESTIMATE "Grip for Age=80, Men"   grip9 1 age85*grip9 -5 grip9*sexMW 0 age85*grip9*sexMW  0;
ESTIMATE "Grip for Age=85, Men"   grip9 1 age85*grip9  0 grip9*sexMW 0 age85*grip9*sexMW  0;
ESTIMATE "Grip for Age=90, Men"   grip9 1 age85*grip9  5 grip9*sexMW 0 age85*grip9*sexMW  0;
ESTIMATE "Grip for Age=80, Women" grip9 1 age85*grip9 -5 grip9*sexMW 1 age85*grip9*sexMW -5;
ESTIMATE "Grip for Age=85, Women" grip9 1 age85*grip9  0 grip9*sexMW 1 age85*grip9*sexMW  0;
ESTIMATE "Grip for Age=90, Women" grip9 1 age85*grip9  5 grip9*sexMW 1 age85*grip9*sexMW  5;
* Request simple effects of Sex (hold demgroup 0=None);
ESTIMATE "Sex: Age=80, Grip=6" sexMW 1 age85*sexMW-5 grip9*sexMW -3 age85*grip9*sexMW  15;
ESTIMATE "Sex: Age=85, Grip=6" sexMW 1 age85*sexMW 0 grip9*sexMW -3 age85*grip9*sexMW   0;
ESTIMATE "Sex: Age=90, Grip=6" sexMW 1 age85*sexMW 5 grip9*sexMW -3 age85*grip9*sexMW -15;
ESTIMATE "Sex: Age=80, Grip=9" sexMW 1 age85*sexMW-5 grip9*sexMW  0 age85*grip9*sexMW   0;
ESTIMATE "Sex: Age=85, Grip=9" sexMW 1 age85*sexMW 0 grip9*sexMW  0 age85*grip9*sexMW   0;
ESTIMATE "Sex: Age=90, Grip=9" sexMW 1 age85*sexMW 5 grip9*sexMW  0 age85*grip9*sexMW   0;
ESTIMATE "Sex: Age=80,Grip=12" sexMW 1 age85*sexMW-5 grip9*sexMW  3 age85*grip9*sexMW -15;
ESTIMATE "Sex: Age=85,Grip=12" sexMW 1 age85*sexMW 0 grip9*sexMW  3 age85*grip9*sexMW   0;
ESTIMATE "Sex: Age=90,Grip=12" sexMW 1 age85*sexMW 5 grip9*sexMW  3 age85*grip9*sexMW  15;
* Request simple two-way interactions of age*grip;
ESTIMATE "Age by Grip: Men"      age85*grip9 1 age85*grip9*sexMW  0;
ESTIMATE "Age by Grip: Women"    age85*grip9 1 age85*grip9*sexMW  1;
```

```
* Request simple two-way interactions of age*sex;
ESTIMATE "Sex by Age:  Grip=6"    age85*sexMW 1 age85*grip9*sexMW -3;
ESTIMATE "Sex by Age:  Grip=9"    age85*sexMW 1 age85*grip9*sexMW  0;
ESTIMATE "Sex by Age:  Grip=12"   age85*sexMW 1 age85*grip9*sexMW  3;
* Request simple two-way interactions of grip*sex;
ESTIMATE "Sex by Grip: Age=80"    grip9*sexMW 1 age85*grip9*sexMW -5;
ESTIMATE "Sex by Grip: Age=85"    grip9*sexMW 1 age85*grip9*sexMW  0;
ESTIMATE "Sex by Grip: Age=90"    grip9*sexMW 1 age85*grip9*sexMW  5;
RUN; TITLE1; TITLE2;
* Call macro to calculate R2 for overall model;
%ModelR2(CovBase=CovEmpty, CovFewer=Cov2AgeSexGrip, CovMore=Cov3AgeSexGrip);
* Subset predicted outcomes data to fake people;
DATA Pred3AgeSexGrip; SET Pred3AgeSexGrip; WHERE caseID=-99; RUN;
TITLE9 'Predicted Outcomes for Fake People';
PROC PRINT NOOBS DATA=Pred3AgeSexGrip; VAR age85 grip9 sexmw demNF demNC pred; RUN;
```

STATA Syntax:

```
display as result "Eq 2.18: Adding Sex by Age by Grip Three-Way Interaction"
display as result "Age 0=85 Grip 0=9 Sex 0=Men Dementia 0=None"
mixed cognition c.age85 c.grip9 c.sexmw c.demNF c.demNC ///
                c.age85#c.grip9 c.sexmw#c.demNF c.sexmw#c.demNC ///
                c.age85#c.sexmw c.grip9#c.sexmw c.age85#c.grip9#c.sexmw, ///
                || caseid: , noconstant variance reml,
      estat ic, n(550),
      margins, at (c.c.age85=(-5(5)5) c.c.grip9=(-3(3)3) c.c.sexmw=(0(1)1)) vsquish,
* Request simple effects of Age for grip=6,9,12 by sex=M,W
lincom c.age85*1 + c.age85#c.grip9*-3 + c.age85#c.sexmw*0 + c.age85#c.grip9#c.sexmw*0
lincom c.age85*1 + c.age85#c.grip9*0  + c.age85#c.sexmw*0 + c.age85#c.grip9#c.sexmw*0
lincom c.age85*1 + c.age85#c.grip9*3  + c.age85#c.sexmw*0 + c.age85#c.grip9#c.sexmw*0
lincom c.age85*1 + c.age85#c.grip9*-3 + c.age85#c.sexmw*1 + c.age85#c.grip9#c.sexmw*-3
lincom c.age85*1 + c.age85#c.grip9*0  + c.age85#c.sexmw*1 + c.age85#c.grip9#c.sexmw*0
lincom c.age85*1 + c.age85#c.grip9*3  + c.age85#c.sexmw*1 + c.age85#c.grip9#c.sexmw*3
* Request simple effects of Grip for age=80,85,80 by sex=M,W
lincom c.grip9*1 + c.age85#c.grip9*-5 + c.grip9#c.sexmw*0 + c.age85#c.grip9#c.sexmw*0
lincom c.grip9*1 + c.age85#c.grip9*0  + c.grip9#c.sexmw*0 + c.age85#c.grip9#c.sexmw*0
lincom c.grip9*1 + c.age85#c.grip9*5  + c.grip9#c.sexmw*0 + c.age85#c.grip9#c.sexmw*0
lincom c.grip9*1 + c.age85#c.grip9*-5 + c.grip9#c.sexmw*1 + c.age85#c.grip9#c.sexmw*-5
lincom c.grip9*1 + c.age85#c.grip9*0  + c.grip9#c.sexmw*1 + c.age85#c.grip9#c.sexmw*0
lincom c.grip9*1 + c.age85#c.grip9*5  + c.grip9#c.sexmw*1 + c.age85#c.grip9#c.sexmw*5
* Request simple effects of Sex (hold demgroup 0=None) for age=80,85,90 by grip=6,9,12
lincom c.sexmw*1 + c.age85#c.sexmw*-5 + c.grip9#c.sexmw*-3 + c.age85#c.grip9#c.sexmw*15
lincom c.sexmw*1 + c.age85#c.sexmw*0  + c.grip9#c.sexmw*-3 + c.age85#c.grip9#c.sexmw*0
lincom c.sexmw*1 + c.age85#c.sexmw*5  + c.grip9#c.sexmw*-3 + c.age85#c.grip9#c.sexmw*-15
lincom c.sexmw*1 + c.age85#c.sexmw*-5 + c.grip9#c.sexmw*0  + c.age85#c.grip9#c.sexmw*0
lincom c.sexmw*1 + c.age85#c.sexmw*0  + c.grip9#c.sexmw*0  + c.age85#c.grip9#c.sexmw*0
lincom c.sexmw*1 + c.age85#c.sexmw*5  + c.grip9#c.sexmw*0  + c.age85#c.grip9#c.sexmw*0
lincom c.sexmw*1 + c.age85#c.sexmw*-5 + c.grip9#c.sexmw*3  + c.age85#c.grip9#c.sexmw*-15
lincom c.sexmw*1 + c.age85#c.sexmw*0  + c.grip9#c.sexmw*3  + c.age85#c.grip9#c.sexmw*0
lincom c.sexmw*1 + c.age85#c.sexmw*5  + c.grip9#c.sexmw*3  + c.age85#c.grip9#c.sexmw*15
* Request simple two-way interactions of age*grip for M,W
lincom c.age85#c.grip9*1 + c.age85#c.grip9#c.sexmw*0
lincom c.age85#c.grip9*1 + c.age85#c.grip9#c.sexmw*1
* Request simple two-way interactions of age*sex for grip=6,9,12
lincom c.age85#c.sexmw*1 + c.age85#c.grip9#c.sexmw*-3
lincom c.age85#c.sexmw*1 + c.age85#c.grip9#c.sexmw*0
lincom c.age85#c.sexmw*1 + c.age85#c.grip9#c.sexmw*3
* Request simple two-way interactions of grip*sex for age=80,85,90
lincom c.grip9#c.sexmw*1 + c.age85#c.grip9#c.sexmw*-5
lincom c.grip9#c.sexmw*1 + c.age85#c.grip9#c.sexmw*0
lincom c.grip9#c.sexmw*1 + c.age85#c.grip9#c.sexmw*5
```

SPSS Output (unless otherwise noted, and re-ordered for convenience):

Information Criteria[a]

-2 Restricted Log Likelihood	3998.404
Akaike's Information Criterion (AIC)	4000.404
Hurvich and Tsai's Criterion (AICC)	4000.411
Bozdogan's Criterion (CAIC)	4005.692
Schwarz's Bayesian Criterion (BIC)	4004.692

Estimates of Covariance Parameters[a]

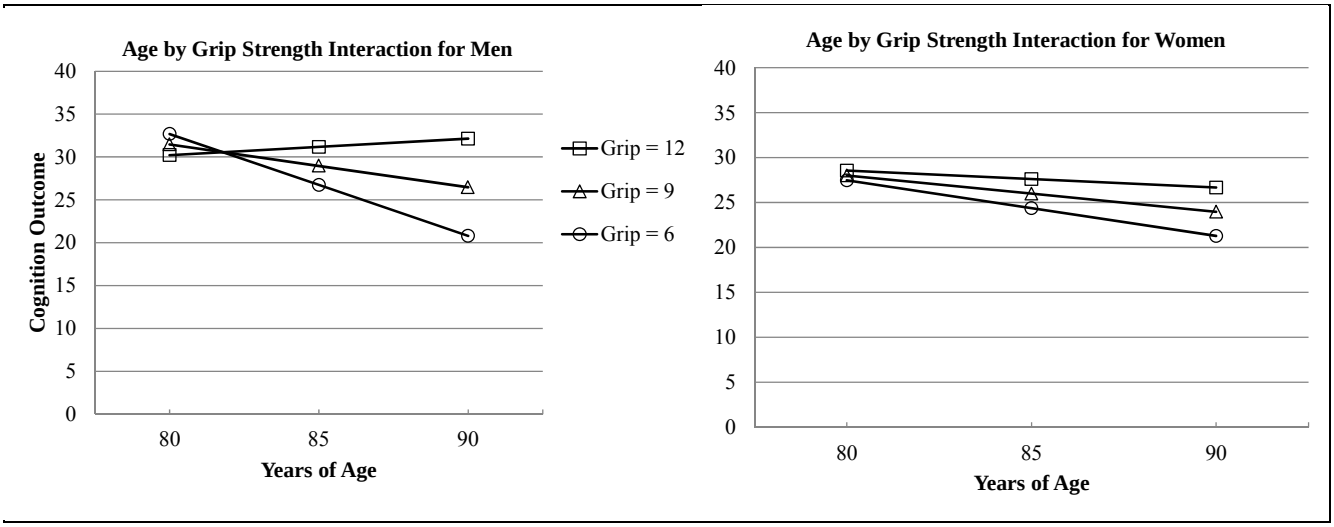
Parameter	Estimate	Std. Error	Wald Z	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Residual	85.943306	5.240056	16.401	.000	76.262912	96.852477

Predicted Outcomes for Fake People

age85	grip9	sexmw	dem NF	dem NC	Pred
-5	3	0	0	0	30.2157
0	3	0	0	0	31.1737
5	3	0	0	0	32.1316
-5	0	0	0	0	31.4473
0	0	0	0	0	28.9558
5	0	0	0	0	26.4644
-5	-3	0	0	0	32.6788
0	-3	0	0	0	26.7380
5	-3	0	0	0	20.7972
-5	3	1	0	0	28.5407
0	3	1	0	0	27.6000
5	3	1	0	0	26.6592
-5	0	1	0	0	27.9984
0	0	1	0	0	25.9824
5	0	1	0	0	23.9663
-5	-3	1	0	0	27.4561
0	-3	1	0	0	24.3648
5	-3	1	0	0	21.2734

This printout of the fake cases only is from the "PlotAgeGripSex" dataset in SPSS (in which the "pred" column is named as given in the FIXPRED option) or the "PredAgeGripSex" dataset in SAS (as given by the OUTPM= option).

From plotting predicted outcomes in excel:



Estimates of Fixed Effects[a]

Parameter	Estimate	Std. Error	df	t	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Intercept	28.955843	.797243	538	36.320	.000	27.389752	30.521934
age85	-.498287	.206250	538.000	-2.416	.016	-.903442	-.093132
grip9	.739275	.236418	538	3.127	.002	.274859	1.203691
sexMW	-2.973490	1.036365	538	-2.869	.004	-5.009308	-.937671
demNF	-6.165427	1.637934	538	-3.764	.000	-9.382957	-2.947898
demNC	-11.783713	2.247900	538	-5.242	.000	-16.199450	-7.367977
age85 * grip9	.229958	.075949	538	3.028	.003	.080765	.379150
sexMW * demNF	.396883	2.079577	538	.191	.849	-3.688203	4.481970
sexMW * demNC	-8.145702	3.028321	538	-2.690	.007	-14.094485	-2.196919
age85 * sexMW	.095072	.274158	538	.347	.729	-.443479	.633624
grip9 * sexMW	-.200074	.304567	538	-.657	.512	-.798361	.398213
age85 * grip9 * sexMW	-.158270	.095325	538	-1.660	.097	-.345525	.028984

From SAS Output for ESTIMATE (or TEST in SPSS in separate tables):

Label	Estimate	Standard Error	DF	t Value	Pr > |t|	Lower	Upper
Age for Grip=6, Men	-1.1882	0.3659	538	-3.25	0.0012	-1.9068	-0.4695
Age for Grip=9, Men	-0.4983	0.2063	538	-2.42	0.0160	-0.9034	-0.09313
Age for Grip=12, Men	0.1916	0.2346	538	0.82	0.4146	-0.2693	0.6525
Age for Grip=6, Women	-0.6183	0.1694	538	-3.65	0.0003	-0.9510	-0.2856
Age for Grip=9, Women	-0.4032	0.1806	538	-2.23	0.0260	-0.7580	-0.04841
Age for Grip=12, Women	-0.1882	0.3103	538	-0.61	0.5446	-0.7977	0.4214
Grip for Age=80, Men	-0.4105	0.4368	538	-0.94	0.3478	-1.2686	0.4476
Grip for Age=85, Men	0.7393	0.2364	538	3.13	0.0019	0.2749	1.2037
Grip for Age=90, Men	1.8891	0.4576	538	4.13	<.0001	0.9902	2.7879
Grip for Age=80, Women	0.1808	0.3294	538	0.55	0.5834	-0.4663	0.8278
Grip for Age=85, Women	0.5392	0.1920	538	2.81	0.0052	0.1620	0.9164
Grip for Age=90, Women	0.8976	0.3622	538	2.48	0.0135	0.1862	1.6091
Sex: Age=80, Grip=6	-5.2227	2.5462	538	-2.05	0.0407	-10.2244	-0.2210
Sex: Age=85, Grip=6	-2.3733	1.4657	538	-1.62	0.1060	-5.2525	0.5059
Sex: Age=90, Grip=6	0.4761	2.4373	538	0.20	0.8452	-4.3116	5.2639
Sex: Age=80, Grip=9	-3.4489	1.6404	538	-2.10	0.0360	-6.6713	-0.2264
Sex: Age=85, Grip=9	-2.9735	1.0364	538	-2.87	0.0043	-5.0093	-0.9377
Sex: Age=90, Grip=9	-2.4981	1.7931	538	-1.39	0.1641	-6.0205	1.0242
Sex: Age=80,Grip=12	-1.6750	2.0704	538	-0.81	0.4188	-5.7420	2.3919
Sex: Age=85,Grip=12	-3.5737	1.2921	538	-2.77	0.0059	-6.1119	-1.0355
Sex: Age=90,Grip=12	-5.4724	2.5730	538	-2.13	0.0339	-10.5267	-0.4181
Age by Grip: Men	0.2300	0.07595	538	3.03	0.0026	0.08077	0.3791
Age by Grip: Women	0.07169	0.05761	538	1.24	0.2139	-0.04148	0.1849
Age by Sex: Grip=6	0.5699	0.4032	538	1.41	0.1581	-0.2221	1.3618
Age by Sex: Grip=9	0.09507	0.2742	538	0.35	0.7289	-0.4435	0.6336
Age by Sex: Grip=12	-0.3797	0.3890	538	-0.98	0.3295	-1.1440	0.3845
Grip by Sex: Age=80	0.5913	0.5471	538	1.08	0.2803	-0.4834	1.6660
Grip by Sex: Age=85	-0.2001	0.3046	538	-0.66	0.5115	-0.7984	0.3982
Grip by Sex: Age=90	-0.9914	0.5836	538	-1.70	0.0899	-2.1378	0.1549

From SAS Output for ModelR2 Macro:

R2 (% Reduction) Overall and for Cov2AgeSexGrip vs. Cov3AgeSexGrip

Name	CovParm	Estimate	StdErr	ZValue	ProbZ	R2_from_Base	R2_Increment
CovEmpty	Residual	120.76	7.2887	16.57	<.0001	-0.00000	.
Cov3AgeSexGrip	Residual	85.9433	5.2401	16.40	<.0001	0.28831	.