Example 5: General Linear Models with Single-Slope Interactions of Quantitative and Binary Predictors *(complete syntax, data, and output available for SAS, STATA, and R electronically)*

The data for this example come from Hoffman (2015) chapter 2, which examined prediction of cognition (as measured by an information test 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. Building on the combined final main-effects-only model of Example 4b, this example begins by showing two ways of generating predicted outcomes using a main-effects-only model within each program. It then illustrates how to include and interpret interactions: first with sex by age and sex by grip strength, and then with age by grip strength. Syntax for creating predictors is below (same as Example 4b).

Note that there is extra syntax online for generating effect sizes (semipartial squared correlations for amount of the model R^2 attributable to each conceptual predictor; partial *r* and *d* effect sizes per slope) that is omitted here for brevity, but these effect sizes would still be relevant for a complete reporting of a moderation analysis!

<u>SAS</u> 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;
  %LET filesave= C:\Dropbox\21SP_PSQF6242\PSQF6242_Example5;
* Location for SAS files for these models (uses macro variable filesave);
  LIBNAME filesave "&filesave.";

* Import chapter 2 example data into work library as Example5;
DATA work.Example5; SET filesave.SAS_Chapter2;
* Center quantitative predictors near their means;
  age85 = age - 85;
  grip9 = grip - 9;
* Create 2 indicator-dummy-coded binary predictors for 3 dementia groups;
  demNF=.; demNC=.; * Create two new empty variables;
  IF demgroup=1 THEN DO; demNF=0; demNC=0; END; * Replace each for none group;
  IF demgroup=2 THEN DO; demNF=1; demNC=0; END; * Replace each for future group;
  IF demgroup=3 THEN DO; demNF=0; demNC=1; END; * Replace each for current group;
* Label new variables - note semi-colon is only at the end of ALL labels;
  LABEL
  age85=     "age85: Age in Years (0=85)"
  grip9=     "grip9: Grip Strength in Pounds (0=9)"
  sexMW=     "sexMW: Sex (0=M, 1=W)"
  demNF=     "demNF: Dementia Contrast for None=0 vs Future=1"
  demNC=     "demNC: Dementia Contrast for None=0 vs Current=1"
  cognition= "cognition: Cognition Outcome"
  demgroup=  "demgroup: Dementia Group 1N 2F 3C";
* Select cases complete on variables to be used;
  IF NMISS(cognition,age,grip,sexmw,demgroup)>0 THEN DELETE;
RUN;
```

<u>STATA</u> 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
   cd "C:\Dropbox\22SP_PSQF6243\PSQF6243_Example5"

// Import chapter 2 data in STATA format
   use "STATA_Chapter2.dta", clear // Has converted all variables to lower-case

// Center quantitative predictors near their means
   gen age85 = age - 85
   gen grip9 = grip - 9
```

```
// Create 2 indicator-dummy-coded binary predictors for 3 dementia groups
   gen demnf=.  // Create 2 new empty variables
   gen demnc=.
// Replace for demgroup = none
   replace demnf=0 if demgroup==1
   replace demnc=0 if demgroup==1
// Replace for demgroup = future
   replace demnf=1 if demgroup==2
   replace demnc=0 if demgroup==2
// Replace for 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 Contrast for None=0 vs Future=1"
   label variable demnc     "demnc: Dementia Contrast for None=0 vs Current=1"
   label variable cognition "cognition: Cognition Outcome"
   label variable demgroup  "demgroup: Dementia Group 1N 2F 3C"
// Select cases complete on variables to be used
   egen nmiss=rowmiss(cognition age grip sexmw demgroup)
   drop if nmiss>0
```

R Syntax for Importing and Preparing Data for Analysis:

```
# Set working directory (to import and export files to)
# Paste in the folder address where "SAS_Chapter2.sas7bdat" is saved in quotes
setwd("C:/Dropbox/22SP_PSQF6243/PSQF6243_Example5")

# Import chapter 2 SAS data using haven package
Example5 = read_sas(data_file="SAS_Chapter2.sas7bdat")
# Convert to data frame to use for analysis
Example5 = as.data.frame(Example5)

# Center quantitative predictors near their means
Example5$age85=Example5$age-85
Example5$grip9=Example5$grip-9

# Create 2 indicator-dummy-coded binary predictors for 3 dementia groups
Example5$demNF=NA; Example5$demNC=NA  # Create 2 new empty variables
Example5$demNF[which(Example5$demgroup==1)]=0  # Replace each for none group
Example5$demNC[which(Example5$demgroup==1)]=0
Example5$demNF[which(Example5$demgroup==2)]=1  # Replace each for future group
Example5$demNC[which(Example5$demgroup==2)]=0
Example5$demNF[which(Example5$demgroup==3)]=0  # Replace each for current group
Example5$demNC[which(Example5$demgroup==3)]=1
# demNF: None=0 vs Future=1
# demNC: None=0 vs Current=1

# Label all variables as comments only (not actually added to data)
#age85=     "age85: Age in Years (0=85)"
#grip9=     "grip9: Grip Strength in Pounds (0=9)"
#sexMW=     "sexMW: Sex (0=M, 1=W)"
#demNF=     "demNF: Dementia Predictor for None=0 vs Future=1"
#demNC=     "demNC: Dementia Predictor for None=0 vs Current=1"
#cognition= "cognition: Cognition Outcome"
#demgroup=  "demgroup: Dementia Group 1N 2F 3C"

# Select cases complete on all variables to be used
Example5 = Example5[complete.cases(Example5[ ,
            c("cognition","age","grip","sexMW","demgroup")]),]
```

SAS Syntax and Output with Main Effects Only of All Predictors of Cognition:
Demonstrating how to get predicted outcomes using ESTIMATE statements and plot them

$$Cognition_i = \beta_0 + \beta_1(Age_i - 85) + \beta_2(Grip_i - 9) + \beta_3(SexMW_i) + \beta_4(DemNF_i) + \beta_5(DemNC_i) + e_i$$

Linear combination for difference of future vs current dementia:

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

```
TITLE1 "SAS Combined Main-Effects-Only Model Predicting Cognition";
TITLE2 "Demonstrating how to get predicted outcomes using ESTIMATE statements";
PROC GLM DATA=work.Example5 NAMELEN=100;
MODEL cognition = age85 grip9 sexMW demNF demNC / SOLUTION ALPHA=.05 CLPARM SS3 EFFECTSIZE;
* CONTRAST lumps together fixed effects for joint tests -- indicate DFnum by commas;
CONTRAST "DFnum=2 F-test for Demgroup"   demNF 1, demNC 1; * Omnibus group main effect;
* ESTIMATE creates a single linear combination of fixed effects;
ESTIMATE "Future vs Current Diff"  demNF -1 demNC 1; * Beta5-Beta4;

* Pred cognition outcomes holding sexMW=men, demNF=none, and demNC=none;
ESTIMATE "Yhat for Age=80 Grip=6"  intercept 1 age85 -5 grip9 -3 sexMW 0 demNF 0 demNC 0;
ESTIMATE "Yhat for Age=80 Grip=9"  intercept 1 age85 -5 grip9  0 sexMW 0 demNF 0 demNC 0;
ESTIMATE "Yhat for Age=80 Grip=12" intercept 1 age85 -5 grip9  3 sexMW 0 demNF 0 demNC 0;
ESTIMATE "Yhat for Age=85 Grip=6"  intercept 1 age85  0 grip9 -3 sexMW 0 demNF 0 demNC 0;
ESTIMATE "Yhat for Age=85 Grip=9"  intercept 1 age85  0 grip9  0 sexMW 0 demNF 0 demNC 0;
ESTIMATE "Yhat for Age=85 Grip=12" intercept 1 age85  0 grip9  3 sexMW 0 demNF 0 demNC 0;
ESTIMATE "Yhat for Age=90 Grip=6"  intercept 1 age85  5 grip9 -3 sexMW 0 demNF 0 demNC 0;
ESTIMATE "Yhat for Age=90 Grip=9"  intercept 1 age85  5 grip9  0 sexMW 0 demNF 0 demNC 0;
ESTIMATE "Yhat for Age=90 Grip=12" intercept 1 age85  5 grip9  3 sexMW 0 demNF 0 demNC 0;
ODS OUTPUT Estimates=work.EstMainEffects; * Save ESTIMATEs to dataset for plotting;
RUN; QUIT; TITLE1; TITLE2;

* Labeling saved ESTIMATES to plot -- INDEX finds value in parentheses for that column;
DATA work.EstMainEffects; SET work.EstMainEffects;
     IF INDEX(Parameter,"Age=80")>0  THEN age=80;
     IF INDEX(Parameter,"Age=85")>0  THEN age=85;
     IF INDEX(Parameter,"Age=90")>0  THEN age=90;
     IF INDEX(Parameter,"Grip=6")>0  THEN grip=6;
     IF INDEX(Parameter,"Grip=9")>0  THEN grip=9;
     IF INDEX(Parameter,"Grip=12")>0 THEN grip=12; RUN;

* Plot ESTIMATES -- grip as X by age;
PROC SGPLOT DATA=work.EstMainEffects;
     SERIES x=grip y=Estimate / GROUP=age;
     XAXIS GRID LABEL="Grip Strength" VALUES=(6 TO 12 BY 3);
     YAXIS GRID LABEL="Predicted Cognition" VALUES=(15 TO 45 BY 5); RUN; QUIT;
```

SAS Combined Main Effects Only Model Predicting Cognition

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	**5**	18385.97930	3677.19586	**41.75**	<.0001
Error	**544**	47910.55888	**88.07088**		
Corrected Total	549	66296.53818			

R-Square	Coeff Var	Root MSE	cognition Mean
0.277329	37.80790	9.384609	24.82182

Requested CONTRAST F-test

Contrast	DF	Contrast SS	Mean Square	F Value	Pr > F
DFnum=2 F-test for Demgroup	2	11811.30155	5905.65077	**67.06**	<.0001

Table of Model-Estimated Fixed Effects (normally is last)

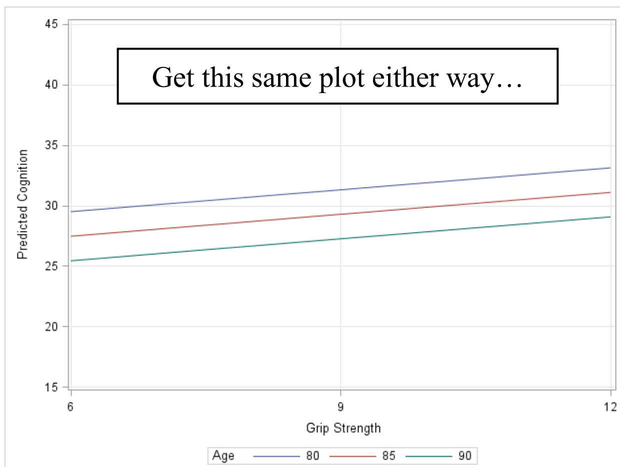
Parameter	Estimate	Standard Error	t Value	Pr > |t|	95% Confidence Limits		
Intercept	29.26432541	0.69850792	41.90	<.0001	27.89222232	30.63642850	**Beta0**
age85	-0.40573396	0.11889717	-3.41	0.0007	-0.63928775	-0.17218017	**Beta1**
grip9	0.60422556	0.14977568	4.03	<.0001	0.31001605	0.89843507	**Beta2**
sexMW	-3.65737421	0.89143262	-4.10	<.0001	-5.40844590	-1.90630252	**Beta3**
demNF	-5.72197100	1.01907848	-5.61	<.0001	-7.72378184	-3.72016016	**Beta4**
demNC	-16.47981327	1.52275357	-10.82	<.0001	-19.47101037	-13.48861616	**Beta5**

Table of Extra Requested Linear Combinations of Model-Estimated Fixed Effects

Parameter	Estimate	Standard Error	t Value	Pr > |t|	95% Confidence Limits	
Future vs Current Diff	**-10.7578423**	1.70795708	-6.30	<.0001	-14.1128410	-7.4028435
Yhat for Age=80 Grip=6	29.4803185	1.15590606	25.50	<.0001	27.2097326	31.7509045
Yhat for Age=80 Grip=9	31.2929952	0.92090860	33.98	<.0001	29.4840228	33.1019676
Yhat for Age=80 Grip=12	33.1056719	0.87396571	37.88	<.0001	31.3889110	34.8224327
Yhat for Age=85 Grip=6	27.4516487	0.93731216	29.29	<.0001	25.6104543	29.2928432
Yhat for Age=85 Grip=9	29.2643254	0.69850792	41.90	<.0001	27.8922223	30.6364285
Yhat for Age=85 Grip=12	31.0770021	0.70785742	43.90	<.0001	29.6865335	32.4674707
Yhat for Age=90 Grip=6	25.4229789	1.06198691	23.94	<.0001	23.3368816	27.5090763
Yhat for Age=90 Grip=9	27.2356556	0.91355395	29.81	<.0001	25.4411302	29.0301810
Yhat for Age=90 Grip=12	29.0483323	0.97218055	29.88	<.0001	27.1386447	30.9580199

Demonstrating how to get predicted outcomes in SAS using "fake people" and plot them

```
* Demonstrating how to get predicted outcomes using "fake people";
* Each row is a fake person for which to create a predicted outcome;
DATA work.FakePeople; * List variables;
INPUT PersonID age grip sexMW demNF demNC;
* Center predictors;
  age85=age-85; grip9=grip-9;
* Enter new data;
  DATALINES;
-99 80  6  0  0  0
-99 80  9  0  0  0
-99 80 12  0  0  0
-99 85  6  0  0  0
-99 85  9  0  0  0
-99 85 12  0  0  0
-99 90  6  0  0  0
-99 90  9  0  0  0
-99 90 12  0  0  0
; RUN;
* Merge with real data;
DATA work.Example5;
SET work.FakePeople work.Example5; RUN;
```




```
TITLE1 "SAS Combined Main-Effects-Only Model Predicting Cognition";
TITLE2 "Using dataset with fake people to get predicted outcomes as saved variable";
PROC GLM DATA=work.Example5 NAMELEN=100;
MODEL cognition = age85 grip9 sexMW demNF demNC / SOLUTION ALPHA=.05 CLPARM SS3 EFFECTSIZE;
* We are ignoring the extra effects we would normally request for dementia for now;
* Request columns of predicted outcome and SE for all cases;
  OUTPUT OUT=work.PredMainOutcomes PREDICTED=Yhat STDP=SEyhat; RUN; QUIT; TITLE1; TITLE2;

* Plot saved predicted values for fake people -- grip as X by age;
PROC SGPLOT DATA=work.PredMainOutcomes; WHERE PersonID=-99; * Only for fake people;
     SERIES x=grip y=Yhat / GROUP=age;
     XAXIS GRID LABEL="Grip Strength" VALUES=(6 TO 12 BY 3);
     YAXIS GRID LABEL="Predicted Cognition" VALUES=(15 TO 45 BY 5); RUN; QUIT;
```

STATA Syntax and Output for Main-Effects-Only Model of All Predictors of Cognition:
Demonstrating how to get predicted outcomes using MARGINS statement and plot them

$$Cognition_i = \beta_0 + \beta_1(Age_i - 85) + \beta_2(Grip_i - 9) + \beta_3(SexMW_i) + \beta_4(DemNF_i) + \beta_5(DemNC_i) + e_i$$

Linear combination for difference of future vs current dementia:

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

```
display "STATA Combined Main-Effects-Only Model Predicting Cognition"
regress cognition c.age85 c.grip9 c.sexmw c.demnf c.demnc, level(95)
// TEST lumps together fixed effects for joint tests -- indicate DFnum by ()
test (c.demnf=0)(c.demnc=0)   // DFnum=2 Omnibus F-test for Demgroup
// LINCOM creates a single linear combination of fixed effects
lincom c.demnf*-1 + c.demnc*1 // Future vs. Current Diff = B5-B4

// Pred cognition outcomes holding sexMW=men, demNF=none, and demNC=none
// The LONGER WAY -- writing out separate LINCOM statements per prediction
lincom _cons*1 + c.age85*-5 + c.grip9*-3 + c.sexmw*0 + c.demnf*0 + c.demnc*0 // yhat for Age=80 Grip=6
lincom _cons*1 + c.age85*-5 + c.grip9*0  + c.sexmw*0 + c.demnf*0 + c.demnc*0 // yhat for Age=80 Grip=9
lincom _cons*1 + c.age85*-5 + c.grip9*3  + c.sexmw*0 + c.demnf*0 + c.demnc*0 // yhat for Age=80 Grip=12
lincom _cons*1 + c.age85*0  + c.grip9*-3 + c.sexmw*0 + c.demnf*0 + c.demnc*0 // yhat for Age=85 Grip=6
lincom _cons*1 + c.age85*0  + c.grip9*0  + c.sexmw*0 + c.demnf*0 + c.demnc*0 // yhat for Age=85 Grip=9
lincom _cons*1 + c.age85*0  + c.grip9*3  + c.sexmw*0 + c.demnf*0 + c.demnc*0 // yhat for Age=85 Grip=12
lincom _cons*1 + c.age85*5  + c.grip9*-3 + c.sexmw*0 + c.demnf*0 + c.demnc*0 // yhat for Age=90 Grip=6
lincom _cons*1 + c.age85*5  + c.grip9*0  + c.sexmw*0 + c.demnf*0 + c.demnc*0 // yhat for Age=90 Grip=9
lincom _cons*1 + c.age85*5  + c.grip9*3  + c.sexmw*0 + c.demnf*0 + c.demnc*0 // yhat for Age=90 Grip=12
```

STATA Combined Main-Effects-Only Model Predicting Cognition

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

Results of TEST for custom F-test:

```
.    test (c.demnf=0)(c.demnc=0)    // DFnum=2 F-test for Demgroup
 ( 1)  demnf = 0
 ( 2)  demnc = 0
       F(  2,   544) =   67.06
            Prob > F =    0.0000
```

Results of lincom for missing group difference:

```
.    lincom c.demnf*-1 + c.demnc*1 // Future vs. Current Diff = B5-B4
 ( 1)  - demnf + demnc = 0
------------------------------------------------------------------------------
   cognition |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         (1) |  -10.75784   1.707957    -6.30   0.000    -14.11284   -7.402844
------------------------------------------------------------------------------
```

Results of Individual LINCOMs for Predicted Outcomes (3 of 9 printed):

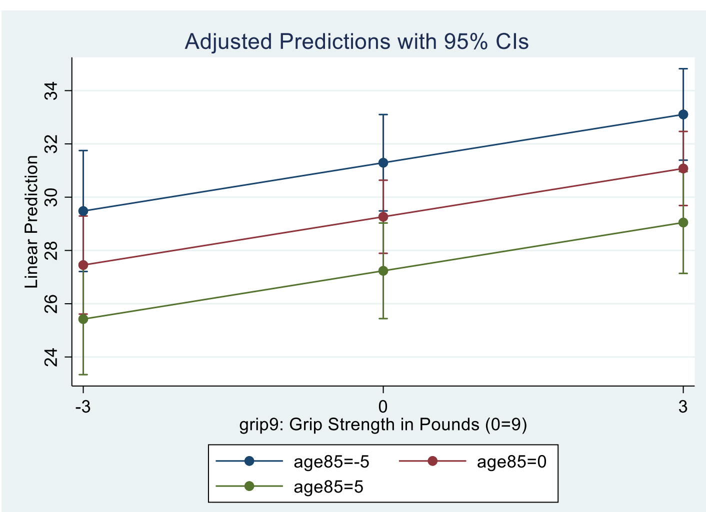
```
.
 lincom _cons*1 + c.age85*-5 + c.grip9*-3 + c.sexmw*0 + c.demnf*0 + c.demnc*0 // yhat Age=80 Grip=6
 ( 1)  - 5*age85 - 3*grip9 + _cons = 0
------------------------------------------------------------------------------
   cognition |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         (1) |   29.48032   1.155906    25.50   0.000     27.20973     31.7509
------------------------------------------------------------------------------

. lincom _cons*1 + c.age85*-5 + c.grip9*0  + c.sexmw*0 + c.demnf*0 + c.demnc*0 // yhat Age=80 Grip=9
 ( 1)  - 5*age85 + _cons = 0
------------------------------------------------------------------------------
   cognition |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         (1) |     31.293   .9209086    33.98   0.000     29.48402    33.10197
------------------------------------------------------------------------------

. lincom _cons*1 + c.age85*-5 + c.grip9*3  + c.sexmw*0 + c.demnf*0 + c.demnc*0 // yhat Age=80 Grip=12
 ( 1)  - 5*age85 + 3*grip9 + _cons = 0
------------------------------------------------------------------------------
   cognition |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         (1) |   33.10567   .8739657    37.88   0.000     31.38891    34.82243
------------------------------------------------------------------------------
```

```
// The SHORTER WAY -- one margins replaces 9 SAS ESTIMATEs (or STATA LINCOMs or R GLHTs)
// 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 and save
marginsplot, xdimension(grip9) name(predicted_means, replace)
graph export "STATA Main-Effect-Only GLM Plot.png", replace
```

Results of MARGINS to generate all 9 predicted outcomes:

```
------------------------------------------------------------------------------
             |            Delta-method
             |     Margin   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         _at |
          1  |   29.48032   1.155906    25.50   0.000     27.20973     31.7509
          2  |     31.293   .9209086    33.98   0.000     29.48402    33.10197
          3  |   33.10567   .8739657    37.88   0.000     31.38891    34.82243
          4  |   27.45165   .9373122    29.29   0.000     25.61045    29.29284
          5  |   29.26433   .6985079    41.90   0.000     27.89222    30.63643
          6  |     31.077   .7078574    43.90   0.000     29.68653    32.46747
          7  |   25.42298   1.061987    23.94   0.000     23.33688    27.50908
          8  |   27.23566    .913554    29.81   0.000     25.44113    29.03018
          9  |   29.04833   .9721806    29.88   0.000     27.13864    30.95802
------------------------------------------------------------------------------
```

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.



R Syntax and Output for Main-Effects-Only Model of All Predictors of Cognition:
Demonstrating how to get predicted outcomes using MARGINS statement and plot them

$$Cognition_i = \beta_0 + \beta_1(Age_i - 85) + \beta_2(Grip_i - 9) + \beta_3(SexMW_i) + \beta_4(DemNF_i) + \beta_5(DemNC_i) + e_i$$

Linear combination for difference of future vs current dementia:

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

```
print("R Combined Main-Effects-Only Model Predicting Cognition")
ModelMain = lm(data=Example5, formula=cognition~1+age85+grip9+sexMW+demNF+demNC)
anova(ModelMain)    # anova to get residual variance
summary(ModelMain) # print fixed effects solution
confint(ModelMain, level=.95) # confint for level% CI for fixed effects

print("Get DFnum=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

print("Get missing demgroup difference: Future vs Current")
DemMain = summary(glht(model=ModelMain, linfct=rbind(c(0,0,0,0,-1,1))),
                      test=adjusted("none")) # Beta5-Beta4
print(DemMain); confint(DemMain, level=.95, calpha=univariate_calpha())

print("Pred cognition outcomes holding sexMW=men, demNF=none, and demNC=none")
print("The LONGER WAY -- writing out separate glht statement per prediction")
PredMain = glht(model=ModelMain, linfct=rbind(
            "Yhat for Age=80 Grip=6"  = c(1,-5,-3, 0,0,0),  # in order of fixed effects
            "Yhat for Age=80 Grip=9"  = c(1,-5, 0, 0,0,0),
            "Yhat for Age=80 Grip=12" = c(1,-5, 3, 0,0,0),
            "Yhat for Age=85 Grip=6"  = c(1, 0,-3, 0,0,0),
            "Yhat for Age=85 Grip=9"  = c(1, 0, 0, 0,0,0),
            "Yhat for Age=85 Grip=12" = c(1, 0, 3, 0,0,0),
            "Yhat for Age=90 Grip=6"  = c(1, 5,-3, 0,0,0),
            "Yhat for Age=90 Grip=9"  = c(1, 5, 0, 0,0,0),
            "Yhat for Age=90 Grip=12" = c(1, 5, 3, 0,0,0)))
summary(PredMain, test=adjusted("none"))
confint(PredMain, level=.95, calpha=univariate_calpha()) # unadjusted CIs
```

Model Summary and Model-Estimated Fixed Effects

```
Analysis of Variance Table
Response: cognition
           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       < 2.22e-16
Residuals 544 47910.6    88.07 → Residual variance
```

> Remember that this anova table provides sequential Type I sums of squares, which we do not want! We are only printing this to get the residual variance.

```
Coefficients:
             Estimate Std. Error  t value     Pr(>|t|)
(Intercept)  29.26433    0.69851  41.8955     < 2.2e-16  Beta0
age85        -0.40573    0.11890  -3.4125     0.0006917  Beta1
grip9         0.60423    0.14978   4.0342 0.0000626304  Beta2
sexMW        -3.65737    0.89143  -4.1028 0.0000470693  Beta3
demNF        -5.72197    1.01908  -5.6148 0.0000000314  Beta4
demNC       -16.47981    1.52275 -10.8224     < 2.2e-16  Beta5

Residual standard error: 9.3846 on 544 degrees of freedom → Btw, =SQRT(residual variance)
Multiple R-squared:  0.27733,     Adjusted R-squared:  0.27069
F-statistic: 41.753 on 5 and 544 DF,  p-value: < 2.22e-16
```

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

```
         General Linear Hypotheses
Linear Hypotheses:
           Estimate
demNF == 0   -5.722
demNC == 0  -16.480
Global Test: of Omnibus effect of demgroup
       F DF1  DF2      Pr(>F)
1 67.056   2 544 9.3117e-27

Linear Hypotheses:
Estimate Std. Error t value        Pr(>|t|)
1 == 0   -10.758      1.708 -6.2987 0.0000000006198 → Future vs. Current: Beta5 - Beta4
(Adjusted p values reported -- none method)

Linear Hypotheses:
                             Estimate Std. Error t value  Pr(>|t|)
Yhat for Age=80 Grip=6 == 0  29.48032    1.15591  25.504 < 2.2e-16
Yhat for Age=80 Grip=9 == 0  31.29300    0.92091  33.981 < 2.2e-16
Yhat for Age=80 Grip=12 == 0 33.10567    0.87397  37.880 < 2.2e-16
Yhat for Age=85 Grip=6 == 0  27.45165    0.93731  29.288 < 2.2e-16
Yhat for Age=85 Grip=9 == 0  29.26433    0.69851  41.895 < 2.2e-16
Yhat for Age=85 Grip=12 == 0 31.07700    0.70786  43.903 < 2.2e-16
Yhat for Age=90 Grip=6 == 0  25.42298    1.06199  23.939 < 2.2e-16
Yhat for Age=90 Grip=9 == 0  27.23566    0.91355  29.813 < 2.2e-16
Yhat for Age=90 Grip=12 == 0 29.04833    0.97218  29.880 < 2.2e-16
(Adjusted p values reported -- none method)
```

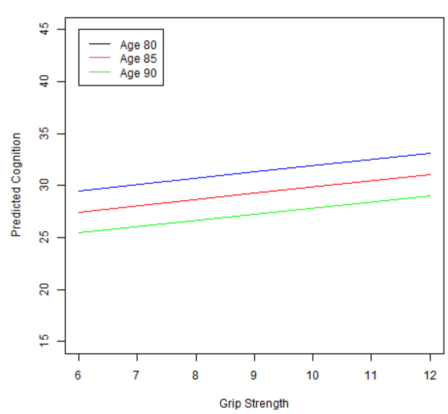
Using prediction to replace separate GLHTs per predicted outcome:

```
print("The SHORTER WAY -- one prediction replaces 9 glht statements")
print("Provides predicted outcomes from min,max,by=increment of predictors")
PredMainP = prediction(model=ModelMain, type="response", at=list(
              sexMW=0, demNF=0, demNC=0, grip9=seq(-3,3,by=3), age85=seq(-5,5,by=5)))
PlotMain = summary(PredMainP); PlotMain # Save predictions for plotting
```

Btw, R generates a warning that the predictor values requested are (just) outside the range of the observed data for the combination of age-80 and grip=12…

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

```
png(file = "R Main-Effects-Only GLM Plot.png") # open file
plot(y=PlotMain$Prediction, x=(PlotMain$`at(grip9)`+9),
     type="n", ylim=c(15,45), xlim=c(6,12),
     xlab="Grip Strength",ylab="Predicted Cognition")
lines(x=(PlotMain$`at(grip9)`+9)[1:3],
      y=PlotMain$Prediction[1:3], type="l", col="blue1")
lines(x=(PlotMain$`at(grip9)`+9)[4:6],
      y=PlotMain$Prediction[4:6], type="l", col="red1")
lines(x=(PlotMain$`at(grip9)`+9)[7:9],
      y=PlotMain$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
```



<u>FOR HW6</u> → SAS Syntax adding Two Interactions: Sex by Age and Sex by Grip Strength

$$Cognition_i = \beta_0 + \beta_1(Age_i - 85) + \beta_2(Grip_i - 9) + \beta_3(SexMW_i) + \beta_4(DemNF_i) + \beta_5(DemNC_i) + \beta_6(SexMW_i)(Age_i - 85) + \beta_7(SexMW_i)(Grip_i - 9) + e_i$$

```
TITLE1 "SAS GLM adding 2 Interactions -- Sex by Age, Sex by Grip";
PROC GLM DATA=work.Example5 NAMELEN=100;
MODEL cognition = age85 grip9 sexMW demNF demNC
                  sexMW*age85 sexMW*grip9 / SOLUTION ALPHA=.05 CLPARM SS3 EFFECTSIZE;
ESTIMATE "Future vs. Current Diff"      demNF -1 demNC 1; * B5-B4;
CONTRAST "DFnum=2 F-test for Demgroup"  demNF 1, demNC 1;
CONTRAST "DFnum=2 F-test for new interactions"  sexMW*age85 1, sexMW*grip9 1;
```

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

Simple Age Slope = $\beta_1(Age_i - 85) + \beta_6(SexMW_i)(Age_i - 85)$

= $[\beta_1 + \beta_6(SexMW_i)]$ that multiplies $(Age_i - 85)$

```
* Simple slopes of age by sex;
ESTIMATE "Age Slope for Men"    age85 1 sexMW*age85 0;
ESTIMATE "Age Slope for Women"  age85 1 sexMW*age85 1;
```

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

Simple Grip Slope = $\beta_2(Grip_i - 9) + \beta_7(SexMW_i)(Grip_i - 9)$

= $[\beta_2 + \beta_7(SexMW_i)]$ that multiplies $(Grip_i - 9)$

```
* Simple slopes of grip by sex;
ESTIMATE "Grip Slope for Men"   grip9 1 sexMW*grip9 0;
ESTIMATE "Grip Slope for Women" grip9 1 sexMW*grip9 1;

* If you are NOT using fake people, you have to write these to create predicted outcomes;
* Pred cognition outcomes holding demNF=none and demNC=none;
ESTIMATE "Yhat Men Age=80 Grip=6"    intercept 1 sexMW 0 age85 -5 grip9 -3 sexMW*age85  0 sexMW*grip9  0;
ESTIMATE "Yhat Men Age=80 Grip=12"   intercept 1 sexMW 0 age85 -5 grip9  3 sexMW*age85  0 sexMW*grip9  0;
ESTIMATE "Yhat Men Age=90 Grip=6"    intercept 1 sexMW 0 age85  5 grip9 -3 sexMW*age85  0 sexMW*grip9  0;
ESTIMATE "Yhat Men Age=90 Grip=12"   intercept 1 sexMW 0 age85  5 grip9  3 sexMW*age85  0 sexMW*grip9  0;
ESTIMATE "Yhat Women Age=80 Grip=6"  intercept 1 sexMW 1 age85 -5 grip9 -3 sexMW*age85 -5 sexMW*grip9 -3;
ESTIMATE "Yhat Women Age=80 Grip=12" intercept 1 sexMW 1 age85 -5 grip9  3 sexMW*age85 -5 sexMW*grip9  3;
ESTIMATE "Yhat Women Age=90 Grip=6"  intercept 1 sexMW 1 age85  5 grip9 -3 sexMW*age85  5 sexMW*grip9 -3;
ESTIMATE "Yhat Women Age=90 Grip=12" intercept 1 sexMW 1 age85  5 grip9  3 sexMW*age85  5 sexMW*grip9  3;
ODS OUTPUT Estimates=work.EstSexInteract; * Save estimates to dataset;
RUN; QUIT; TITLE1; TITLE2;

* Labeling saved ESTIMATES for use in plot;
* INDEX finds value in parentheses for that column;
DATA work.EstSexInteract; LENGTH sex $6; SET work.EstSexInteract;
     IF INDEX(Parameter,"Men")>0     THEN sex="Men";
     IF INDEX(Parameter,"Women")>0   THEN sex="Women";
     IF INDEX(Parameter,"Age=80")>0  THEN age=80;
     IF INDEX(Parameter,"Age=90")>0  THEN age=90;
     IF INDEX(Parameter,"Grip=6")>0  THEN grip=6;
     IF INDEX(Parameter,"Grip=12")>0 THEN grip=12;
RUN;

* Plot ESTIMATES -- grip as X by sex holding age=80;
PROC SGPLOT DATA=work.EstSexInteract; WHERE age=80;
     SERIES x=grip y=Estimate / GROUP=sex;
     XAXIS GRID LABEL="Grip Strength" VALUES=(6 TO 12 BY 3);
     YAXIS GRID LABEL="Predicted Cognition" VALUES=(15 TO 45 BY 5);
RUN; QUIT;

* Plot ESTIMATES -- age as X by sex holding grip=6;
PROC SGPLOT DATA=work.EstSexInteract; WHERE grip=6;
     SERIES x=age y=Estimate / GROUP=sex;
     XAXIS GRID LABEL="Years of Age" VALUES=(80 TO 90 BY 5);
     YAXIS GRID LABEL="Predicted Cognition" VALUES=(15 TO 45 BY 5);
RUN; QUIT;
```

FOR HW6 → STATA Syntax adding Two Interactions: Sex by Age and Sex by Grip Strength

```
display "STATA GLM adding 2 Interactions (Sex by Age and Sex by Grip"
regress cognition c.age85 c.grip9 c.sexmw c.demnf c.demnc    /// line continuer
                  c.sexmw#c.age85 c.sexmw#c.grip9, level(95)
  lincom c.demnf*-1 + c.demnc*1 // Future vs. Current Diff = B5-B4
  test (c.demnf=0)(c.demnc=0)   // DFnum=2 F-test for Demgroup
  test (c.sexmw#c.age85=0)(c.sexmw#c.grip9=0) // DFnum=2 F-test for two new interactions
```

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

Simple Age Slope = $\boldsymbol{\beta_1}(\boldsymbol{Age_i}-\mathbf{85})+\boldsymbol{\beta_6}(\boldsymbol{SexMW_i})(\boldsymbol{Age_i}-\mathbf{85})$

= $[\boldsymbol{\beta_1}+\boldsymbol{\beta_6}(\boldsymbol{SexMW_i})]$ that multiplies $(\boldsymbol{Age_i}-\mathbf{85})$

```
// Simple slopes of age by sex
   lincom c.age85*1 + c.sexmw#c.age85*0  // Age Slope for Men
   lincom c.age85*1 + c.sexmw#c.age85*1  // Age Slope for Women
```

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

Simple Grip Slope = $\boldsymbol{\beta_2}(\boldsymbol{Grip_i}-\mathbf{9})+\boldsymbol{\beta_7}(\boldsymbol{SexMW_i})(\boldsymbol{Grip_i}-\mathbf{9})$

= $[\boldsymbol{\beta_2}+\boldsymbol{\beta_7}(\boldsymbol{SexMW_i})]$ that multiplies $(\boldsymbol{Grip_i}-\mathbf{9})$

```
// Simple slopes of grip by sex
   lincom c.grip9*1 + c.sexmw#c.grip9*0  // Grip Slope for Men
   lincom c.grip9*1 + c.sexmw#c.grip9*1  // Grip Slope for Women

// one margins replaces 8 separate LINCOMs; vsquish compresses output empty lines
// Get predicted outcomes for each combination of (from(by)to)
margins, at(c.age85=(-5(10)5) c.grip9=(-3(6)3) c.sexmw=(0(1)1) c.demnf=0 c.demnc=0) vsquish
marginsplot, xdimension(grip9) bydimension(age85)  // Plot pred outcomes by grip
graph export "STATA Sex by Grip=x GLM Plot.png", replace
marginsplot, xdimension(age85) bydimension(grip9)  // Plot pred outcomes by age
graph export "STATA Sex by Age=x GLM Plot.png", replace
```

FOR HW6 → R Syntax adding Two Interactions: Sex by Age and Sex by Grip Strength

```
print("R GLM Adding 2 Interactions -- Sex by Age, Sex by Grip")
ModelInt2 = lm(data=Example5, formula=cognition~1+age85+grip9+sexMW+demNF+demNC
                                                 +age85:sexMW +grip9:sexMW)
anova(ModelInt2)     # anova to print residual variance
summary(ModelInt2)   # print fixed effects solution
confint(ModelInt2, level=.95) # confint for level% CI
```

Note that R insists interactions be listed in order of predictor entry into model

```
print("Get DFnum=2 F-test for demgroup") # Omnibus group main effect
Int2Fdem = glht(model=ModelInt2,linfct=c("demNF=0","demNC=0"))
summary(Int2Fdem, test=Ftest()) # ask for joint hypothesis test instead of separate

print("Get DFnum=2 F-test for new interactions")
Int2FInt = glht(model=ModelInt2, linfct=c("age85:sexMW=0","grip9:sexMW=0"))
summary(Int2FInt, test=Ftest()) # ask for joint hypothesis test instead of separate

print("Missing dem diff; Simple slopes of age by sex, simple slopes of sex by age")
SlopesInt2 = glht(model=ModelInt2, linfct=rbind(
  "Future vs Current Diff" = c(0,0,0,0,-1,1,0,0),  # Beta5 - Beta4
  "Age Slope for Men"      = c(0,1,0,0, 0,0,0,0),  # in order of fixed effects
  "Age Slope for Women"    = c(0,1,0,0, 0,0,1,0),
  "Grip Slope for Men"     = c(0,0,1,0, 0,0,0,0),
  "Grip Slope for Women"   = c(0,0,1,0, 0,0,0,1)))
summary(SlopesInt2, test=adjusted("none"))
confint(SlopesInt2, level=.95, calpha=univariate_calpha()) # unadjusted CIs

print("Pred cognition outcomes holding demNF=none, and demNC=none")
print("The SHORTER WAY -- one prediction replaces 8 separate glht statements")
print("Provides predicted outcomes from min,max,by=increment of predictors")
```

```
PredInt2 = prediction(model=ModelInt2, type="response", at=list(
                 demNF=0, demNC=0, grip9=seq(-3,3,by=6), age85=seq(-5,5,by=10), sexMW=0:1))
PlotInt2 = summary(PredInt2); PlotMain # Save predictions for plotting

# Make and save plots of Predicted Outcomes -- now working correctly
png(file = "R Sex by Grip=x GLM Plot.png")  # open file
PlotInt2age80=PlotInt2[which(PlotInt2$`at(age85)`==-5),] # Subset to age=80
plot(y=PlotInt2age80$Prediction, x=(PlotInt2age80$`at(grip9)`+9), type="n",  # n= no dots
     ylim=c(15,45), xlim=c(6,12), xlab="Grip Strength",ylab="Predicted Cognition")
lines(x=(PlotInt2age80$`at(grip9)`+9)[1:2], y=PlotInt2age80$Prediction[1:2], type="l", col="blue1")
lines(x=(PlotInt2age80$`at(grip9)`+9)[3:4], y=PlotInt2age80$Prediction[3:4], type="l", col="red1")
legend(x=6, y=45, legend=c("Men","Women"), col=1:2, lty=1) # lty=linetype
dev.off()  # close file
png(file = "R Sex by Age=x GLM Plot.png")  # open file
PlotInt2grip6=PlotInt2[which(PlotInt2$`at(grip9)`==-3),] # Subset to grip=6
plot(y=PlotInt2grip6$Prediction, x=(PlotInt2grip6$`at(grip9)`+9), type="n",  # n= no dots
     ylim=c(15,45), xlim=c(80,90), xlab="Years of Age",ylab="Predicted Cognition")
lines(x=(PlotInt2grip6$`at(age85)`+85)[1:2], y=PlotInt2grip6$Prediction[1:2], type="l", col="blue1")
lines(x=(PlotInt2grip6$`at(age85)`+85)[3:4], y=PlotInt2grip6$Prediction[3:4], type="l", col="red1")
legend(x=80, y=45, legend=c("Men","Women"), col=1:2, lty=1) # lty=linetype
dev.off()  # close file
```

SAS Output:

SAS GLM with 2 Interactions (Sex by Age, Sex by Grip)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	**7**	18529.39696	2647.05671	**30.04**	<.0001
Error	**542**	47767.14122	**88.13126**		
Corrected Total	549	66296.53818			

R-Square	Coeff Var	Root MSE	cognition Mean
0.279493	37.82086	9.387825	24.82182

Change in R^2 = .2795−.2773 = .0022, as given by semipartial eta-square for 2 new interaction terms below (from CONTRAST)

Source	Total Variation Accounted For: Semipartial Eta-Square	Total Variation Accounted For: Semipartial Omega-Square	Partial Variation Accounted For: Partial Eta-Square	Partial Variation Accounted For: Partial Omega-Square	
age85	0.0020	0.0007	0.0028	0.0009	ok, but conditional
grip9	0.0113	0.0100	0.0155	0.0135	ok, but conditional
sexMW	0.0211	0.0197	0.0284	0.0263	ok, but conditional
demNF	0.0422	0.0408	0.0553	0.0530	**sr2 needs combined**
demNC	0.1559	0.1543	0.1778	0.1745	**sr2 needs combined**
age85*sexMW	0.0019	0.0006	0.0027	0.0008	ok, unconditional
grip9*sexMW	0.0004	-0.0009	0.0006	-0.0012	ok, unconditional
DFnum=2 F-test Demgroup	0.1786	0.1757	0.1231	0.2330	ok, from CONTRAST
DFnum=2 F-test interactions	**0.0022**	-0.0005	0.0000	0.0136	ok, from CONTRAST

Contrast	DF	Contrast SS	Mean Square	F Value	Pr > F
DFnum=2 F-test for Demgroup	2	11843.12235	5921.56117	67.19	<.0001
DFnum=2 F-test for new interactions	2	143.41767	71.70883	**0.81**	0.4438

Table of Model-Estimated Fixed Effects (normally is last)

Parameter	Estimate	Standard Error	t Value	Pr > |t|	95% Confidence Limits		
Intercept	29.17207481	0.75835647	38.47	<.0001	27.68239690	30.66175272	**Beta0**
age85	-0.23224895	0.18939121	-1.23	0.2206	-0.60427967	0.13978178	**Beta1**
grip9	0.69688281	0.23879978	2.92	0.0037	0.22779635	1.16596927	**Beta2**
sexMW	-3.62653419	0.91114541	-3.98	<.0001	-5.41634312	-1.83672526	**Beta3**
demNF	-5.74882607	1.02015364	-5.64	<.0001	-7.75276537	-3.74488677	**Beta4**
demNC	-16.49475985	1.52333719	-10.83	<.0001	-19.48712801	-13.50239170	**Beta5**
age85*sexMW	-0.29478557	0.24394817	-1.21	0.2274	-0.77398527	0.18441413	**Beta6**
grip9*sexMW	-0.17672735	0.30663085	-0.58	0.5646	-0.77905782	0.42560311	**Beta7**

Interpret these fixed effects:

Simple main effect of Age β_1 =

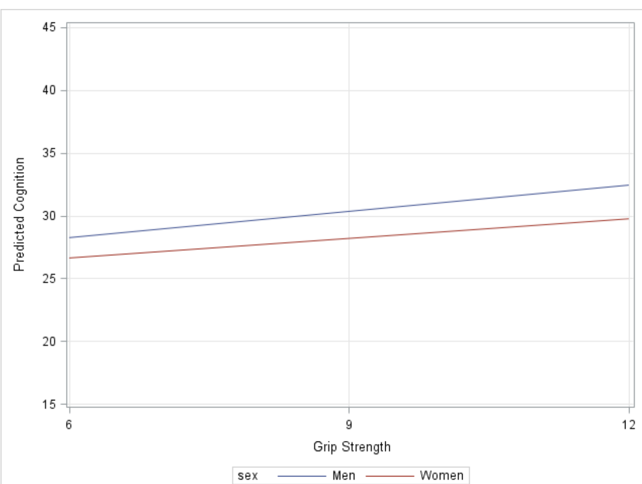
Simple main effect of Grip Strength β_2 =

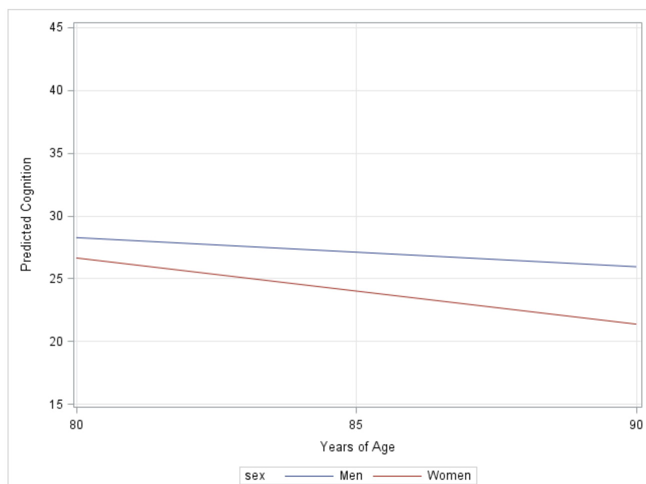
Interpret Sex by Age β_6 → Age as Simple Slope, Sex as Moderator:

Interpret Sex by Grip Strength β_7 → Grip as Simple Slope, Sex as Moderator:

Table of Extra Requested Linear Combinations of Model-Estimated Fixed Effects

Parameter	Estimate	Standard Error	t Value	Pr > |t|	95% Confidence Limits	
Future vs. Current Diff	-10.7459338	1.70875193	-6.29	<.0001	-14.1025215	-7.3893461
Age Slope for Men	-0.2322489	0.18939121	-1.23	0.2206	-0.6042797	0.1397818
Age Slope for Women	-0.5270345	0.15376644	-3.43	0.0007	-0.8290857	-0.2249833
Grip Slope for Men	0.6968828	0.23879978	2.92	0.0037	0.2277964	1.1659693
Grip Slope for Women	0.5201555	0.19305890	2.69	0.0073	0.1409201	0.8993908
Yhat: Men Age=80 Grip=6	28.2426711	1.59490110	17.71	<.0001	25.1097264	31.3756159
Yhat: Men Age=80 Grip=12	32.4239680	1.14540612	28.31	<.0001	30.1739889	34.6739471
Yhat: Men Age=90 Grip=6	25.9201816	1.56654423	16.55	<.0001	22.8429397	28.9974236
Yhat: Men Age=90 Grip=12	30.1014785	1.27691341	23.57	<.0001	27.5931730	32.6097840
Yhat: Women Age=80 Grip=6	26.6202468	1.11819135	23.81	<.0001	24.4237271	28.8167666
Yhat: Women Age=80 Grip=12	29.7411796	1.11582861	26.65	<.0001	27.5493011	31.9330581
Yhat: Women Age=90 Grip=6	21.3499017	0.95706096	22.31	<.0001	19.4698985	23.2299048
Yhat: Women Age=90 Grip=12	24.4708344	1.33798219	18.29	<.0001	21.8425684	27.0991004





STATA Output—see code online for how to get semipartial eta-squares (→ SAS CONTRAST):

```
      Source |       SS           df       MS      Number of obs   =       550
-------------+----------------------------------   F(7, 542)       =     30.04
       Model |   18529.397         7  2647.05671   Prob > F        =    0.0000
    Residual |  47767.1412       542  88.1312568   R-squared       =    0.2795
-------------+----------------------------------   Adj R-squared   =    0.2702
       Total |  66296.5382       549  120.758722   Root MSE        =    9.3878

------------------------------------------------------------------------------
   cognition |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       age85 |  -.2322489   .1893912    -1.23   0.221    -.6042797    .1397818  Beta1
       grip9 |   .6968828   .2387998     2.92   0.004     .2277964    1.165969  Beta2
      sexmw  |  -3.626534   .9111454    -3.98   0.000    -5.416343   -1.836725  Beta3
```

Change in R^2 = .2795−.2773 = .0022
(as also given by semipartial eta-square for 2 new interaction terms (see code online)

```
         demnf |  -5.748826   1.020154    -5.64   0.000    -7.752765   -3.744887  Beta4
         demnc |  -16.49476   1.523337   -10.83   0.000    -19.48713   -13.50239  Beta5
c.sexmw#c.age85 |  -.2947856   .2439482    -1.21   0.227    -.7739853    .1844141  Beta6
c.sexmw#c.grip9 |  -.1767274   .3066309    -0.58   0.565    -.7790578    .4256031  Beta7
         _cons |   29.17207   .7583565    38.47   0.000      27.6824    30.66175  Beta0
---------------------------------------------------------------------------------

.    lincom c.demnf*-1 + c.demnc*1 // Mean Diff: Future vs. Current = B5-B4
 ( 1)  - demnf + demnc = 0
------------------------------------------------------------------------------
   cognition |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         (1) |  -10.74593   1.708752    -6.29   0.000    -14.10252   -7.389346 Beta5 – Beta4
------------------------------------------------------------------------------

.    test (c.demnf=0)(c.demnc=0)   // DFnum=2 F-test for Demgroup
 ( 1)  demnf = 0
 ( 2)  demnc = 0
       F(  2,   542) =   67.19
            Prob > F =    0.0000

.    test (c.sexmw#c.age85=0)(c.sexmw#c.grip9=0) // DFnum=2 F-test for new interactions
 ( 1)  c.sexmw#c.age85 = 0
 ( 2)  c.sexmw#c.grip9 = 0
       F(  2,   542) =    0.81
            Prob > F =    0.4438

.    lincom c.age85*1 + c.sexmw#c.age85*0  // Age Slope for Men
 ( 1)  age85 = 0
------------------------------------------------------------------------------
   cognition |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         (1) |  -.2322489   .1893912    -1.23   0.221    -.6042797    .1397818
------------------------------------------------------------------------------

.    lincom c.age85*1 + c.sexmw#c.age85*1  // Age Slope for Women
 ( 1)  age85 + c.sexmw#c.age85 = 0
------------------------------------------------------------------------------
   cognition |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         (1) |  -.5270345   .1537664    -3.43   0.001    -.8290857   -.2249833
------------------------------------------------------------------------------

.    lincom c.grip9*1 + c.sexmw#c.grip9*0  // Grip Slope for Men
 ( 1)  grip9 = 0
------------------------------------------------------------------------------
   cognition |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         (1) |   .6968828   .2387998     2.92   0.004     .2277964    1.165969
------------------------------------------------------------------------------

.    lincom c.grip9*1 + c.sexmw#c.grip9*1  // Grip Slope for Women
 ( 1)  grip9 + c.sexmw#c.grip9 = 0
------------------------------------------------------------------------------
   cognition |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         (1) |   .5201555   .1930589     2.69   0.007     .1409201    .8993908
------------------------------------------------------------------------------
```

R Output—see code online for how to get semipartial eta-squares (→ SAS CONTRAST):

```
Analysis of Variance Table
Response: cognition
             Df  Sum Sq  Mean Sq   F value           Pr(>F)
age85         1  1926.2  1926.18  21.85583 0.0000037141838
grip9         1  3039.2  3039.17  34.48461 0.0000000074973
sexMW         1  1609.3  1609.32  18.26054 0.0000227601578
demNF         1  1496.1  1496.10  16.97583 0.0000437802033
demNC         1 10315.2 10315.20 117.04361       < 2.22e-16
age85:sexMW   1   114.1   114.14   1.29514          0.25561
grip9:sexMW   1    29.3    29.28   0.33218          0.56462
Residuals   542 47767.1    88.13 → residual variance
```

Remember that this anova table provides sequential Type I sums of squares, which we do not want! We are only printing this to get the residual variance.

```
Coefficients:
              Estimate Std. Error  t value      Pr(>|t|)
(Intercept)  29.17207    0.75836  38.4675     < 2.2e-16  Beta0
age85        -0.23225    0.18939  -1.2263      0.220621  Beta1
grip9         0.69688    0.23880   2.9183      0.003666  Beta2
sexMW        -3.62653    0.91115  -3.9802 0.00007823535  Beta3
demNF        -5.74883    1.02015  -5.6353 0.00000002813  Beta4
demNC       -16.49476    1.52334 -10.8280     < 2.2e-16  Beta5
age85:sexMW  -0.29479    0.24395  -1.2084      0.227423  Beta6
grip9:sexMW  -0.17673    0.30663  -0.5764      0.564616  Beta7

Residual standard error: 9.3878 on 542 degrees of freedom
Multiple R-squared:  0.27949, Adjusted R-squared:  0.27019
F-statistic: 30.035 on 7 and 542 DF,  p-value: < 2.22e-16
[1] "Get DFnum=2 F-test for demgroup"
Linear Hypotheses:
           Estimate
demNF == 0  -5.7488
demNC == 0 -16.4948
Global Test:
      F DF1 DF2     Pr(>F)
1 67.19   2 542 8.5511e-27

[1] "Get DFnum=2 F-test for new interactions"
Linear Hypotheses:
                 Estimate
age85:sexMW == 0 -0.29479
grip9:sexMW == 0 -0.17673
Global Test:
        F DF1 DF2  Pr(>F)
1 0.81366   2 542 0.44377

Linear Hypotheses:
                             Estimate Std. Error t value        Pr(>|t|)
Future vs Current Diff == 0 -10.74593    1.70875 -6.2888 0.0000000006594
Age Slope for Men == 0       -0.23225    0.18939 -1.2263       0.2206213
Age Slope for Women == 0     -0.52703    0.15377 -3.4275       0.0006554
Grip Slope for Men == 0       0.69688    0.23880  2.9183       0.0036659
Grip Slope for Women == 0     0.52016    0.19306  2.6943       0.0072727
(Adjusted p values reported -- none method)

[1] "Pred cognition outcomes holding demNF=none, and demNC=none"
[1] "The SHORTER WAY -- one prediction replaces 9 glht statements"

at(demNF) at(demNC) at(grip9) at(age85) at(sexMW) Prediction     SE     z          p lower upper
        0         0        -3        -5         0      28.24 1.5949 17.71  3.631e-70 25.12 31.37
        0         0         3        -5         0      32.42 1.1454 28.31 2.768e-176 30.18 34.67
        0         0        -3         5         0      25.92 1.5665 16.55  1.708e-61 22.85 28.99
        0         0         3         5         0      30.10 1.2769 23.57 7.188e-123 27.60 32.60
        0         0        -3        -5         1      26.62 1.1182 23.81 2.859e-125 24.43 28.81
        0         0         3        -5         1      29.74 1.1158 26.65 1.613e-156 27.55 31.93
        0         0        -3         5         1      21.35 0.9571 22.31 3.106e-110 19.47 23.23
        0         0         3         5         1      24.47 1.3380 18.29  1.006e-74 21.85 27.09
```

Change in R^2 = .2795−.2773 = .0022, as also given by semipartial eta-square for 2 new interaction terms (see code online)

Example Results Section for Sex Interactions Model (as Equation 1, building on from Example 4b):

We then estimated a general linear model (as shown in Equation 1) to examine the extent to which cognition could be predicted from linear slopes of age (centered such that 0 = 85 years) and 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 interactions of sex with age and sex with grip strength. Although the model accounted for a significant amount of variance in cognition, $F(7, 542) = 30.04$, MSE = 88.13, $p < .0001$, $R^2 = .280$, the addition of the two interactions did not significantly improve prediction relative to the main effects model, $F(2, 542) = 0.81$, $p = .444$, change in $R^2 = .002$. Results indicated that the effects of age and grip strength did not differ significantly between men and women, and so these nonsignificant interactions were removed from the model.

NONE OF WHAT FOLLOWS IS NEEDED FOR HW6, but this model is included in Hoffman (2015) ch. 2 and serves as an example of a quantitative*quantitative predictor interaction…

SAS Syntax: Removing Sex Interactions; Adding Interaction of Age by Grip Strength

$$Cognition_i = \beta_0 + \beta_1(Age_i - 85) + \beta_2(Grip_i - 9) + \beta_3(SexMW_i) + \beta_4(DemNF_i) + \beta_5(DemNC_i) + \beta_6(Age_i - 85)(Grip_i - 9) + e_i$$

```
TITLE1 "SAS Eq 2.9: GLM with Age by Grip Interaction";
TITLE2 "Using dataset with fake people to get predicted outcomes as saved variable";
* Estimate model on data with fake people to make predictions;
PROC GLM DATA=work.Example5 NAMELEN=100;
MODEL cognition = age85 grip9 sexMW demNF demNC age85*grip9
                       / SOLUTION ALPHA=.05 CLPARM SS3 EFFECTSIZE;
ESTIMATE "Future vs. Current Diff"      demNF -1 demNC 1; * B5-B4;
CONTRAST "DFnum=2 F-test for Demgroup"  demNF 1, demNC 1;
CONTRAST "DFnum=3 F-test for age, grip, age*grip"  age85 1, grip9 1, age85*grip9 1;
* Request columns of predicted outcome and SE for all cases;
  OUTPUT OUT=work.PredAgeGripOutcomes PREDICTED=Yhat STDP=SEyhat;
```

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

Simple Age Slope = $\beta_1(Age_i - 85) + \beta_6(Age_i - 85)(Grip_i - 9)$

= $[\beta_1 + \beta_6(Grip_i - 9)]$ that multiplies $(Age_i - 85)$

```
ESTIMATE "Age Slope at Grip =  6" age85 1 age85*grip9 -3;
ESTIMATE "Age Slope at Grip =  9" age85 1 age85*grip9  0;
ESTIMATE "Age Slope at Grip = 12" age85 1 age85*grip9  3;
```

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

Simple Grip Slope = $\beta_2(Grip_i - 9) + \beta_6(Age_i - 85)(Grip_i - 9)$

= $[\beta_2 + \beta_6(Age_i - 85)]$ that multiplies $(Grip_i - 9)$

```
ESTIMATE "Grip Slope at Age = 80" grip9 1 age85*grip9 -5;
ESTIMATE "Grip Slope at Age = 85" grip9 1 age85*grip9  0;
ESTIMATE "Grip Slope at Age = 90" grip9 1 age85*grip9  5;
```

If you are using "fake people" then you do NOT need to write these ESTIMATE statements also.

```
* Pred cognition outcomes holding sexMW=men, demNF=none, and demNC=none;
  ESTIMATE "Yhat for Age=80 Grip=6"  intercept 1 age85 -5 grip9 -3 age85*grip9  15;
  ESTIMATE "Yhat for Age=80 Grip=9"  intercept 1 age85 -5 grip9  0 age85*grip9   0;
  ESTIMATE "Yhat for Age=80 Grip=12" intercept 1 age85 -5 grip9  3 age85*grip9 -15;
  ESTIMATE "Yhat for Age=85 Grip=6"  intercept 1 age85  0 grip9 -3 age85*grip9   0;
  ESTIMATE "Yhat for Age=85 Grip=9"  intercept 1 age85  0 grip9  0 age85*grip9   0;
  ESTIMATE "Yhat for Age=85 Grip=12" intercept 1 age85  0 grip9  3 age85*grip9   0;
  ESTIMATE "Yhat for Age=90 Grip=6"  intercept 1 age85  5 grip9 -3 age85*grip9 -15;
  ESTIMATE "Yhat for Age=90 Grip=9"  intercept 1 age85  5 grip9  0 age85*grip9   0;
  ESTIMATE "Yhat for Age=90 Grip=12" intercept 1 age85  5 grip9  3 age85*grip9  15;
* Save fixed effects and requested estimates for computing effect sizes;
  ODS OUTPUT ParameterEstimates=work.FixAgebyGrip Estimates=work.EstAgebyGrip;
RUN; TITLE1; TITLE2;

* Plot saved predicted values for fake people -- age as X;
PROC SGPLOT DATA=work.PredAgeGripOutcomes; WHERE PersonID=-99; * Only for fake people;
     SERIES x=age y=Yhat / GROUP=grip;
     XAXIS GRID LABEL="Years of Age" VALUES=(80 TO 90 BY 5);
     YAXIS GRID LABEL="Predicted Cognition" VALUES=(15 TO 45 BY 5); RUN; QUIT;

* Plot saved predicted values for fake people -- grip as X;
PROC SGPLOT DATA=work.PredAgeGripOutcomes; WHERE PersonID=-99; * Only for fake people;
     SERIES x=grip y=Yhat / GROUP=age;
     XAXIS GRID LABEL="Grip Strength" VALUES=(6 TO 12 BY 3);
     YAXIS GRID LABEL="Predicted Cognition" VALUES=(15 TO 45 BY 5); RUN; QUIT;
```

STATA Syntax: Removing Sex Interactions; Adding Interaction of Age by Grip Strength

$$Cognition_i = \beta_0 + \beta_1(Age_i - 85) + \beta_2(Grip_i - 9) + \beta_3(SexMW_i) + \beta_4(DemNF_i) + \beta_5(DemNC_i) + \beta_6(Age_i - 85)(Grip_i - 9) + e_i$$

```
display "STATA Eq 2.9: Adding Age by Grip Interaction"
regress cognition c.age85 c.grip9 c.sexmw c.demnf c.demnc c.age85#c.grip9, level(95)
  lincom c.demnf*-1 + c.demnc*1 // Future vs. Current Diff = B5-B4
  test (c.demnf=0)(c.demnc=0)    // DFnum=2 F-test for Demgroup
  test (c.age85=0)(c.grip9=0)(c.age85#c.grip9=0) // DFnum=3 F-test for age, grip, age*grip
```

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

Simple Age Slope = $\beta_1(Age_i - 85) + \beta_6(Age_i - 85)(Grip_i - 9)$

= $[\beta_1 + \beta_6(Grip_i - 9)]$ that multiplies $(Age_i - 85)$

```
// 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
   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
```

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

Simple Grip Slope = $\beta_2(Grip_i - 9) + \beta_6(Age_i - 85)(Grip_i - 9)$

= $[\beta_2 + \beta_6(Age_i - 85)]$ that multiplies $(Grip_i - 9)$

```
// 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
   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

// Get predicted outcomes for each combination of (from(by)to)
   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)   // Plot pred outcomes by age
   graph export "STATA Grip by Age=x GLM Plot.png", replace
   marginsplot, xdimension(grip9)   // Plot pred outcomes by grip
   graph export "STATA Age by Grip=x GLM Plot.png", replace
```

R Syntax: Removing Sex Interactions; Adding Interaction of Age by Grip Strength

$$Cognition_i = \beta_0 + \beta_1(Age_i - 85) + \beta_2(Grip_i - 9) + \beta_3(SexMW_i) + \beta_4(DemNF_i) + \beta_5(DemNC_i) + \beta_6(Age_i - 85)(Grip_i - 9) + e_i$$

```
print("R Eq 2.9: GLM Adding Age by Grip Strength Interaction")
ModelAgeGrip = lm(data=Example5, formula=cognition~1+age85+grip9+sexMW+demNF+demNC
                                                           +age85:grip9)
anova(ModelAgeGrip)     # anova to print residual variance
summary(ModelAgeGrip)   # print fixed effects solution
confint(ModelAgeGrip, level=.95) # confint for level% CI
```

Note that R insists interactions be referred to in order of predictor entry into the model

```
print("Get DFnum=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

print("Get DFnum=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

print("Missing dem diff; Simple slopes for age per grip, simple slopes for grip per age")
SlopesAgeGrip = glht(model=ModelAgeGrip, linfct=rbind(
  "Future vs Current Diff" = c(0,0,0,0,-1,1,0),  # Beta5 - Beta4
```

```
  "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)))
summary(SlopesAgeGrip, test=adjusted("none"))
confint(SlopesAgeGrip, level=.95, calpha=univariate_calpha()) # unadjusted CIs

print("Pred cognition outcomes holding sexMW=0, demNF=none, and demNC=none")
print("The SHORTER WAY -- one prediction replaces 9 glht statements")
print("Provides predicted outcomes from min,max,by=increment of predictors")
PredInt3 = prediction(model=ModelInt3, type="response", at=list(
              demNF=0, demNC=0, sexMW=0, grip9=seq(-3,3,by=3), age85=seq(-5,5,by=5)))
PlotInt3 = summary(PredInt3); PlotMain # Save predictions for plotting

# Make and save plots -- now working correctly
png(file = "R Age by Grip=x GLM Plot.png")  # open file
PlotInt3 = sort_asc(data=PlotInt3,`at(age85)`) # 3 rows per age
plot(y=PlotInt3$Prediction, x=(PlotInt3$`at(grip9)`+9), type="n",  # n= no points
     ylim=c(15,45), xlim=c(6,12), xlab="Grip Strength",ylab="Predicted Cognition")
lines(x=(PlotInt3$`at(grip9)`+9)[1:3], y=PlotInt3$Prediction[1:3], type="l", col="blue1")
lines(x=(PlotInt3$`at(grip9)`+9)[4:6], y=PlotInt3$Prediction[4:6], type="l", col="red1")
lines(x=(PlotInt3$`at(grip9)`+9)[7:9], y=PlotInt3$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
png(file = "R Grip by Age=x GLM Plot.png")  # open file
PlotInt3 = sort_asc(data=PlotInt3,`at(grip9)`) # 3 rows per grip
plot(y=PlotInt3$Prediction, x=(PlotInt3$`at(age85)`+85), type="n",  # n= no points
     ylim=c(15,45), xlim=c(80,90), xlab="Years of Age",ylab="Predicted Cognition")
lines(x=(PlotInt3$`at(age85)`+85)[1:3], y=PlotInt3$Prediction[1:3], type="l", col="blue1")
lines(x=(PlotInt3$`at(age85)`+85)[4:6], y=PlotInt3$Prediction[4:6], type="l", col="red1")
lines(x=(PlotInt3$`at(age85)`+85)[7:9], y=PlotInt3$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
```

SAS Model Output:

SAS Eq 2.9: GLM with Age by Grip Interaction

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	**6**	19185.04106	3197.50684	**36.85**	<.0001
Error	**543**	47111.49712	**86.76150**		
Corrected Total	549	66296.53818			

R-Square	Coeff Var	Root MSE	cognition Mean
0.289382	37.52580	9.314586	24.82182

Change in R^2 = .2894−.2773 = .0121, as also given by semipartial eta-square for 1 new interaction term below

	Total Variation Accounted For		Partial Variation Accounted For		
Source	Semipartial Eta-Square	Semipartial Omega-Square	Partial Eta-Square	Partial Omega-Square	
age85	0.0101	0.0088	0.0140	0.0120	ok but conditional
grip9	0.0227	0.0214	0.0309	0.0289	ok but conditional
sexMW	0.0199	0.0185	0.0272	0.0251	ok, unconditional
demNF	0.0447	0.0433	0.0592	0.0568	**sr2 needs combined**
demNC	0.1520	0.1505	0.1762	0.1731	**sr2 needs combined**
age85*grip9	**0.0121**	0.0107	0.0167	0.0147	ok, unconditional
DFnum=2 F-test Demgroup	0.1772	0.1744	0.1996	0.1952	ok, from CONTRAST
DFnum=3 F-test age,grip,age*grip	0.0573	0.0533	0.0746	0.0691	ok, from CONTRAST

Contrast	DF	Contrast SS	Mean Square	F Value	Pr > F
DFnum=2 F-test Demgroup	2	11747.60589	5873.80294	**67.70**	<.0001
DFnum=3 F-test age,grip,age*grip	3	3799.85696	1266.61899	**14.60**	<.0001

Table of Model-Estimated Fixed Effects (normally is last)

Parameter	Estimate	Standard Error	t Value	Pr > |t|	95% Confidence Limits		
Intercept	29.40780315	0.69490615	42.32	<.0001	28.04276953	30.77283677	**Beta0**
age85	-0.33396058	0.12035656	-2.77	0.0057	-0.57038207	-0.09753908	**Beta1**
grip9	0.61941863	0.14874241	4.16	<.0001	0.32723761	0.91159964	**Beta2**
sexMW	-3.45563720	0.88727488	-3.89	0.0001	-5.19854887	-1.71272552	**Beta3**
demNF	-5.92254309	1.01363159	-5.84	<.0001	-7.91366261	-3.93142358	**Beta4**
demNC	-16.30040485	1.51254730	-10.78	<.0001	-19.27156564	-13.32924405	**Beta5**
age85*grip9	0.12301848	0.04053626	3.03	0.0025	0.04339138	0.20264558	**Beta6**

Interpret these fixed effects:

Simple main effect of Age β_1 =

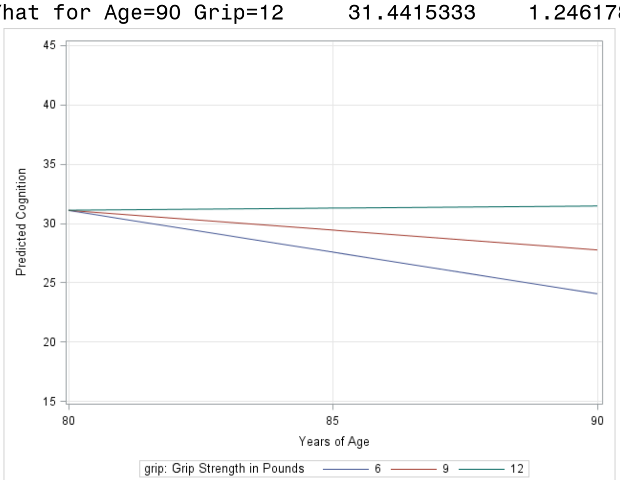
Simple main effect of Grip Strength β_2 =

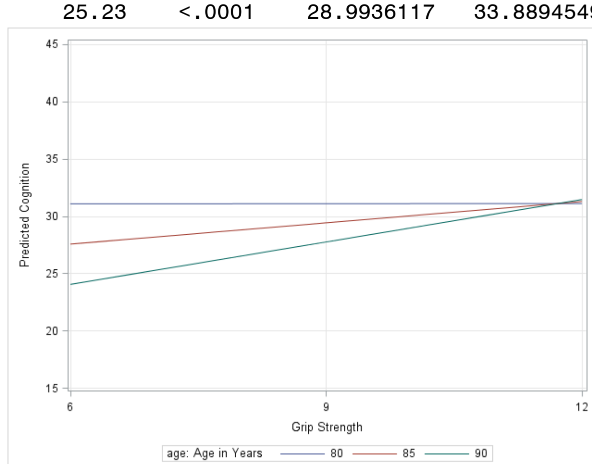
Interpret Age by Grip Strength β_6 → Age as Simple Slope, Grip as Moderator:

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

Table of Extra Requested Linear Combinations of Model-Estimated Fixed Effects

Parameter	Estimate	Standard Error	t Value	Pr > |t|	95% Confidence Limits	
Mean Diff: Fut vs. Cur	-10.3778618	1.69983087	-6.11	<.0001	-13.7169116	-7.0388119
Age Slope at Grip = 6	-0.7030160	0.15336958	-4.58	<.0001	-1.0042864	-0.4017456
Age Slope at Grip = 9	-0.3339606	0.12035656	-2.77	0.0057	-0.5703821	-0.0975391
Age Slope at Grip = 12	0.0350949	0.18715387	0.19	0.8513	-0.3325394	0.4027291
Grip Slope at Age = 80	0.0043262	0.24733508	0.02	0.9861	-0.4815246	0.4901770
Grip Slope at Age = 85	0.6194186	0.14874241	4.16	<.0001	0.3272376	0.9115996
Grip Slope at Age = 90	1.2345110	0.25540829	4.83	<.0001	0.7328017	1.7362204
Yhat for Age=80 Grip=6	31.0646273	1.26047290	24.65	<.0001	28.5886270	33.5406277
Yhat for Age=80 Grip=9	31.0776060	0.91678862	33.90	<.0001	29.2767193	32.8784928
Yhat for Age=80 Grip=12	31.0905847	1.09240761	28.46	<.0001	28.9447221	33.2364473
Yhat for Age=85 Grip=6	27.5495473	0.93087754	29.60	<.0001	25.7209850	29.3781095
Yhat for Age=85 Grip=9	29.4078031	0.69490615	42.32	<.0001	28.0427695	30.7728368
Yhat for Age=85 Grip=12	31.2660590	0.70533225	44.33	<.0001	29.8805450	32.6515731
Yhat for Age=90 Grip=6	24.0344672	1.14908030	20.92	<.0001	21.7772801	26.2916544
Yhat for Age=90 Grip=9	27.7380003	0.92172276	30.09	<.0001	25.9274212	29.5485794
Yhat for Age=90 Grip=12	31.4415333	1.24617867	25.23	<.0001	28.9936117	33.8894549



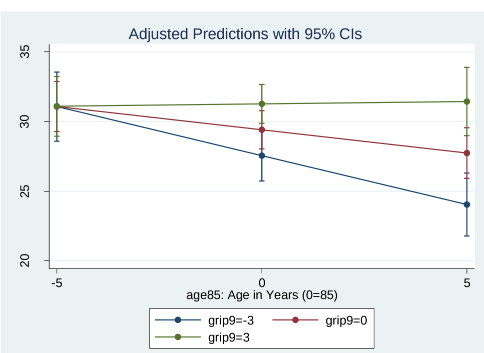


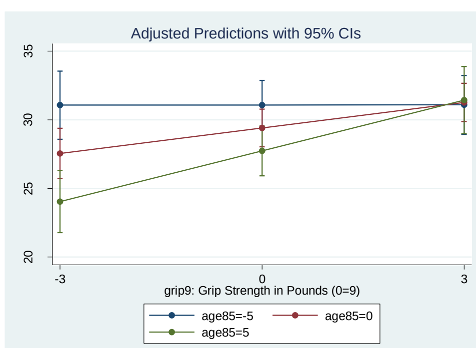
STATA Output—see code online for how to get semipartial eta-squares (→ SAS CONTRAST):

```
      Source |       SS           df       MS      Number of obs   =       550
-------------+----------------------------------   F(6, 543)       =     36.85
       Model |  19185.0411         6  3197.50684   Prob > F        =    0.0000
    Residual |  47111.4971       543  86.7615048   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
--------------------------------------------------------------------------------

.   lincom c.demnf*-1 + c.demnc*1 // Future vs. Current Diff = B5-B4
 ( 1)  - demnf + demnc = 0
------------------------------------------------------------------------------
   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 F-test for Demgroup
 ( 1)  demnf = 0
 ( 2)  demnc = 0
       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
 ( 1)  age85 = 0
 ( 2)  grip9 = 0
 ( 3)  c.age85#c.grip9 = 0
       F(  3,   543) =   14.60
            Prob > F =    0.0000

. // 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
Expression   : Linear prediction, predict()
dy/dx w.r.t. : age85
1._at        : grip9           =          -3
2._at        : grip9           =           0
3._at        : grip9           =           3
------------------------------------------------------------------------------
             |            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
------------------------------------------------------------------------------
.    lincom c.age85*1 + c.age85#c.grip9*-3  // Age Slope at Grip =  6
 ( 1)  age85 - 3*c.age85#c.grip9 = 0
------------------------------------------------------------------------------
   cognition |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         (1) |   -.703016   .1533696    -4.58   0.000    -1.004286   -.4017456
------------------------------------------------------------------------------
.    lincom c.age85*1 + c.age85#c.grip9*0   // Age Slope at Grip =  9
 ( 1)  age85 = 0
------------------------------------------------------------------------------
   cognition |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         (1) |  -.3339606   .1203566    -2.77   0.006    -.5703821   -.0975391
------------------------------------------------------------------------------
```

```
.    lincom c.age85*1 + c.age85#c.grip9*3   // Age Slope at Grip = 12
 ( 1)  age85 + 3*c.age85#c.grip9 = 0
------------------------------------------------------------------------------
   cognition |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         (1) |   .0350949   .1871539     0.19   0.851    -.3325394    .4027291
------------------------------------------------------------------------------
. // 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 Slope per Age
Expression   : Linear prediction, predict()
dy/dx w.r.t. : grip9
1._at        : age85           =          -5
2._at        : age85           =           0
3._at        : age85           =           5
------------------------------------------------------------------------------
             |            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
------------------------------------------------------------------------------
.    lincom c.grip9*1 + c.age85#c.grip9*-5  // Grip Slope at Age = 80
 ( 1)  grip9 - 5*c.age85#c.grip9 = 0
------------------------------------------------------------------------------
   cognition |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         (1) |   .0043262   .2473351     0.02   0.986    -.4815246     .490177
------------------------------------------------------------------------------
.    lincom c.grip9*1 + c.age85#c.grip9*0   // Grip Slope at Age = 85
 ( 1)  grip9 = 0
------------------------------------------------------------------------------
   cognition |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         (1) |   .6194186   .1487424     4.16   0.000     .3272376    .9115996
------------------------------------------------------------------------------
.    lincom c.grip9*1 + c.age85#c.grip9*5   // Grip Slope at Age = 90
 ( 1)  grip9 + 5*c.age85#c.grip9 = 0
------------------------------------------------------------------------------
   cognition |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         (1) |   1.234511   .2554083     4.83   0.000     .7328017     1.73622
------------------------------------------------------------------------------
------------------------------------------------------------------------------
             |            Delta-method
             |     Margin   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         _at |
          1  |   31.06463   1.260473    24.65   0.000     28.58863    33.54063
          2  |   31.07761   .9167886    33.90   0.000     29.27672    32.87849
          3  |   31.09058   1.092408    28.46   0.000     28.94472    33.23645
          4  |   27.54955   .9308775    29.60   0.000     25.72099    29.37811
          5  |    29.4078   .6949062    42.32   0.000     28.04277    30.77284
          6  |   31.26606   .7053323    44.33   0.000     29.88054    32.65157
          7  |   24.03447    1.14908    20.92   0.000     21.77728    26.29165
          8  |     27.738   .9217228    30.09   0.000     25.92742    29.54858
          9  |   31.44153   1.246179    25.23   0.000     28.99361    33.88945
------------------------------------------------------------------------------
```

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.





R Output—see code online for how to get semipartial eta-squares (→ SAS CONTRAST):

```
Analysis of Variance Table
Response: cognition
             Df  Sum Sq  Mean Sq   F value           Pr(>F)
age85         1  1926.2  1926.18  22.20088 0.0000031236433
grip9         1  3039.2  3039.17  35.02904 0.0000000057589
sexMW         1  1609.3  1609.32  18.54883 0.0000196562944
demNF         1  1496.1  1496.10  17.24384 0.0000381734048
demNC         1 10315.2 10315.20 118.89144      < 2.22e-16
age85:grip9   1   799.1   799.06   9.20987       0.0025224
Residuals   543 47111.5    86.76 → residual variance
```

Remember that this anova table provides sequential Type I sums of squares, which we do not want! We are only printing this to get the residual variance.

```
Coefficients:
              Estimate Std. Error  t value      Pr(>|t|)
(Intercept)  29.407803   0.694906  42.3191     < 2.2e-16  Beta0
age85        -0.333961   0.120357  -2.7748     0.0057145  Beta1
grip9         0.619419   0.148742   4.1644 0.00003630980  Beta2
sexMW        -3.455637   0.887275  -3.8947     0.0001106  Beta3
demNF        -5.922543   1.013632  -5.8429 0.00000000885  Beta4
demNC       -16.300405   1.512547 -10.7768     < 2.2e-16  Beta5
age85:grip9   0.123018   0.040536   3.0348     0.0025224  Beta6

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
```

Change in R^2 = .2894−.2773 = .0121, as also given by semipartial eta-square for 1 new interaction term (see code online)

```
[1] "Get DFnum=2 F-test for demgroup"
Linear Hypotheses:
           Estimate
demNF == 0  -5.9225
demNC == 0 -16.3004
Global Test:
       F DF1 DF2     Pr(>F)
1 67.701   2 543 5.6176e-27

[1] "Get DFnum=3 F-test for age, grip, and age*grip"
Linear Hypotheses:
                 Estimate
age85 == 0       -0.33396
grip9 == 0        0.61942
age85:grip9 == 0  0.12302
Global Test:
       F DF1 DF2          Pr(>F)
1 14.599   3 543 0.0000000037133

Linear Hypotheses:
                              Estimate  Std. Error t value       Pr(>|t|)
Future vs Current Diff == 0 -10.3778618   1.6998309 -6.1052 0.000000001956
Age Slope at Grip = 6 == 0   -0.7030160   0.1533696 -4.5838 0.000005671395
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 0.000036309797
Grip Slope at Age = 90 == 0   1.2345110   0.2554083  4.8335 0.000001748820
(Adjusted p values reported -- none method)

[1] "Pred cognition outcomes holding sexMW=0, demNF=none, and demNC=none"
[1] "The SHORTER WAY -- one prediction replaces 9 glht statements"

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

Syntax and SAS Output for Regions of Significance:

To get all the necessary info to calculate regions of significance for the age*grip interaction, we need to change to SAS PROC MIXED, which does GLMs but has many other options, including COVB for the asymptotic covariance matrix of the fixed effects, in which the diagonal is their squared standard errors, and the off-diagonals give the covariances among their SEs. COVB is provided in STATA as "estat vce" after estimating a model with fixed effects (as given in the STATA syntax below), as well as by vcov () after R LM (see below).

```
TITLE1 "SAS Eq 2.9: MIXED with Age by Grip Interaction to Get COVB";
TITLE2 "Using dataset with fake people to get predicted outcomes as saved variable";
* Estimate model on data with fake people to make predictions;
PROC MIXED DATA=work.Example5 COVTEST NOCLPRINT NAMELEN=100 METHOD=REML;
     MODEL cognition = age85 grip9 sexMW demNF demNC age85*grip9
                       / SOLUTION DDFM=BW COVB; * COVB needed for regions;
     * Saving info for regions to datasets: fixed effects and COVB;
     ODS OUTPUT SolutionF=FixAgeGrip COVB=CovBAgeGrip;
     RUN; TITLE1; TITLE2;

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

print("Regions of significance using interactions package") # plots broke my computer
ModelAgeGrip = lm(data=Example5, formula=cognition~1+age85+grip9+sexMW+demNF+demNC
                                                   +age85:grip9)
vcov(ModelAgeGrip) # Asymptotic covariance matrix of fixed effects for regions
johnson_neyman(model=ModelAgeGrip, pred="age85", modx="grip9", digits=3, plot=FALSE)
johnson_neyman(model=ModelAgeGrip, pred="grip9", modx="age85", digits=3, plot=FALSE)
```

From COVB using SAS MIXED instead of GLM (bolded values needed for %*regions* macro):

Covariance Matrix for Fixed Effects

Row	Effect	Col1	Col2	Col3	Col4	Col5	Col6	Col7
1	Intercept	0.4829	0.000454	-0.03075	-0.4507	-0.1820	-0.2263	0.001916
2	age85	0.000454	**0.01449**	0.003317	0.005024	-0.00413	-0.00115	0.000959
3	grip9	-0.03075	0.003317	**0.02212**	0.05374	-0.01339	-0.00030	0.000203
4	sexMW	-0.4507	0.005024	0.05374	0.7873	-0.07102	0.02371	0.002695
5	demNF	-0.1820	-0.00413	-0.01339	-0.07102	1.0274	0.2129	-0.00268
6	demNC	-0.2263	-0.00115	-0.00030	0.02371	0.2129	2.2878	0.002396
7	age85*grip9	0.001916	0.000959	0.000203	0.002695	-0.00268	0.002396	**0.001643**

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

```
* Call SAS 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 of significance for age85*grip9 interaction:

The grip9 slope 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 Lower	Centered Upper	Uncentered Lower	Uncentered Upper
-14.8174	-2.28519	70.1826	82.7148

So the grip strength slope 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.

```
* Call SAS macro for regions of significance for main effects of interaction;
%Regions(FixData=FixAgeGrip, CovBData=CovBAgeGrip, Pred=age85, Mod=grip9,
         ModCenter=9, Interact=age85*grip9, Order=6)
```

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

The age85 slope 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
```

So the age slope will be significantly negative below grip = 9.67 pounds, nonsignificant between grip = 9.67 and 18.52 pounds, and significantly positive after grip = 18.52 pounds.

Example Results Section for Age*Grip Model Using SAS Output [notes about what also to include]:

We estimated a general linear model (as shown in Equation 2) to examine the extent to which cognition could be predicted from linear slopes of age (centered such that 0 = 85 years), grip strength (centered such that 0 = 9 pounds per square inch), and their interaction, as well as sex (0 = men, 1= women), and dementia status (none vs. future; none vs. current). The model accounted for a significant amount of variance in cognition, $F(6, 543) = 36.85$, MSE = 86.67, $p < .0001$, $R^2 = .289$. Table 2 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 age by grip strength interaction. Effect sizes are given below using semipartial eta-squared (η^2) values, the contribution of each slope (or combinations of slopes) to the total model R^2.

Equation 2:

$$Cognition_i = \beta_0 + \beta_1(Age_i - 85) + \beta_2(Grip_i - 9) + \beta_3(SexMW_i) + \beta_4(DemNF_i) + \beta_5(DemNC_i) + \beta_6(Age_i - 85)(Grip_i - 9) + e_i$$

Table 1: Model Results (bold values indicate *p* < .0001)

	Model Parameter	Est	SE	*p* <	η^2
β_0	Intercept	**29.41**	0.69	.001	
	Age Slope				
	Grip Strength (0 = 6 lbs)	**−0.70**	0.15	.001	
β_1	Grip Strength (0 = 9 lbs)	**−0.33**	0.12	.006	.010
	Grip Strength (0 = 12 lbs)	0.04	0.19	.851	
	Grip Strength Slope				
	Age (0 = 80 years)	0.00	0.25	.986	
β_2	Age (0 = 85 years)	**0.62**	0.15	.001	.023
	Age (0 = 90 years)	**1.23**	0.26	.001	
β_3	Sex (0 = Men, 1 = Women)	**−3.46**	0.89	.001	.020
	Dementia Group:				
β_4	None vs. Future	**−5.92**	1.01	.001	
β_5	None vs. Current	**−16.30**	1.51	.001	
$\beta_5 - \beta_4$	Future vs. Current	**−10.38**	1.70	.001	
β_6	Age by Grip Interaction	**0.12**	0.04	.003	.012

Note: η^2 = semipartial eta-squared for amount of model R^2 due to that predictor.

The intercept β_0 = 29.41 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. Women were predicted to have significantly lower cognition by the main effect of sex, $\beta_3 = -3.46$. Likewise, relative to the no dementia group, cognition was predicted to be significantly lower in the future group by $\beta_4 = -5.92$ and in the current group by $\beta_5 = -16.30$. The future and current groups also differed significantly by $\beta_5 - \beta_4 = -10.38$ and the omnibus effect for differences across the three groups was significant as well, $F(2, 543) = 67.70$, $p < .0001$, $\eta^2 = .177$.

The simple main effect of age β_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 β_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 2.1, the age by grip strength interaction β_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). The combination of the linear slopes for age, grip strength, and their interaction accounted for significant variance, $F(3, 543) = 14.60$, $p < .0001$, $\eta^2 = .057$.

Simple slopes for age and grip at other levels of the interacting predictor are also given in Table 1. To further describe the age by grip strength interaction, the regions along each moderator through which the other main effect is expected to be significant were then calculated using the fixed effect estimates and their associated covariance matrix, as described in Hoffman (2015). For the effect of age, the obtained threshold values of grip strength were 9.67 and 18.52 pounds. Given the range of grip strength of 0 to 19 pounds in the current sample (M ≈ 9), the effect of age is expected to be negative for about half of the sample (below 9.67 pounds), the effect of age is expected to be nonsignificant for the other half (between 9.67 and 18.52 pounds), and the effect of age is expected to be positive for almost no one (above 18.52 pounds). Similarly, for the effect of grip strength, the obtained threshold values of age were 70.18 and 82.71 years. Given the range of age of 80 to 97 years in the sample (M ≈ 85), the effect of grip strength is expected to be negative for no one (below 70.18 years), the effect of grip strength is expected to be nonsignificant for a small part of the sample (between 70.18 and 82.71 years), and the effect of grip strength is expected to be positive for the majority of the sample (above 82.71 years).

Additional per-slope partial effect sizes could be reported as needed (see code and output online):

Per-Slope Effect Sizes for Age by Grip Model

Parameter	Estimate	StdErr	Probt	PartialD	PartialR
Intercept	29.40780315	0.69490615	<.0001	3.62883	0.87579
age85	-0.33396058	0.12035656	0.0057	-0.23793	-0.11813
grip9	0.61941863	0.14874241	<.0001	0.35709	0.17577
sexMW	-3.45563720	0.88727488	0.0001	-0.33396	-0.16470
demNF	-5.92254309	1.01363159	<.0001	-0.50102	-0.24300
demNC	-16.30040485	1.51254730	<.0001	-0.92410	-0.41944
age85*grip9	0.12301848	0.04053626	0.0025	0.26023	0.12903
Future vs. Current Diff	-10.37786175	1.69983087	<.0001	-0.52352	-0.25323
Age Slope at Grip = 6	-0.70301601	0.15336958	<.0001	-0.39306	-0.19284
Age Slope at Grip = 9	-0.33396058	0.12035656	0.0057	-0.23793	-0.11813
Age Slope at Grip = 12	0.03509486	0.18715387	0.8513	0.01608	0.00804
Grip Slope at Age = 80	0.00432624	0.24733508	0.9861	0.00150	0.00075
Grip Slope at Age = 85	0.61941863	0.14874241	<.0001	0.35709	0.17577
Grip Slope at Age = 90	1.23451102	0.25540829	<.0001	0.41447	0.20292