Example 5: General Linear Models with Single-DF and Multiple-DF Interactions
(complete syntax, data, and output available for STATA, R, and SAS electronically)

The data for this example come from Hoffman (2015) chapter 2. Using this sample of 550 older adults (which was simulated based on real data), we examine the extent to which cognition (as measured by the *information test*, a measure of crystallized general intelligence) can be predicted from quantitative age (centered at 85 years), quantitative grip strength (centered at 9 pounds per square inch), binary sex (with men as the reference), and subsequent three-category dementia diagnosis (none = 1, future = 2, and current = 3, with the none as the reference). Starting with the combined final main-effects-only model of Example 4b, this example illustrates how to include and interpret interactions: first examining sex by age and sex by grip strength, then examining age by grip strength, and then examining sex by dementia status. The syntax for creating predictors is below for reference (but it's the same as was used in Example 4b).

STATA Syntax for Importing and Preparing Data for Analysis:

```
// Paste in the folder address where "Example5_Data.xlsx" is saved between " "
cd "C:\Dropbox\24_PSQF6243\PSQF6243_Example5"
// Using UIowa virtual desktop instead
//cd "\\Client\C:\Dropbox\24_PSQF6243\PSQF6243_Example5"

// Import Example5.xlsx data from working directory using exact file name
// To change all variable names to lowercase, remove "case(preserve")
clear // Clear before means close any open data
import excel "Example5_Data.xlsx", case(preserve) firstrow sheet("Example5") clear
// Clear after means re-import if it already exists (if need to start over)

// 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 all 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 (after loading packages *readxl*, *supernova*, *multcomp*, *lmhelpers*, *reghelper*, *interactions*, and *TeachingDemos*):

```
# Set working directory (to import and export files to)
# Paste in the folder address where "Example5_Data.xlsx" is saved in quotes
setwd("C:/Dropbox/24_PSQF6243/PSQF6243_Example5")
```

```
# Import Example5_Data.xlsx data from working directory -- path = file name
Example5 = read_excel(path="Example5_Data.xlsx", sheet="Example5")
# 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

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

Note: I also wrote five custom functions to automate calculations of effect sizes from lm or glht output—please see code online for these (as used in this example).

Main-Effects-Only Model (Equation 2.8) Predicting Cognition

RQ: How do age in years, grip strength in pounds per square inch, binary sex, and three-group dementia status each uniquely predict cognition?

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

Linear combination for difference of future vs current dementia:

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

```
display "STATA: Main Effects Only Predicting Cognition (Equation 2.8)"
regress cognition c.age85 c.grip9 c.sexMW c.demNF c.demNC, level(95)
estimates store ModelMain      // Save all model results for R2 in effect sizes below
ereturn list                   // See what has been stored automatically
global SSmain = e(mss)         // Save main-effects model SS model for effect sizes below
```

```
      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
------------------------------------------------------------------------------
```

```
lincom c.demNF*-1 + c.demNC*1 // Mean Diff: Future vs. Current = beta5-beta4
------------------------------------------------------------------------------
   cognition |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         (1) |  -10.75784   1.707957    -6.30   0.000     -14.11284   -7.402844
------------------------------------------------------------------------------
```

```
print("R Main-Effects-Only Model Predicting Cognition (Equation 2.8)")
ModelMain = lm(data=Example5, formula=cognition~1+age85+grip9+sexMW+demNF+demNC)
supernova(ModelMain)           # supernova prints sums of squares and residual variance

                                   SS   df         MS        F   PRE      p
 ----- --------------- | ---------- --- ---------- -------- ----- -----
 Model (error reduced) | 18385.979   5   3677.196   41.753 .2773 .0000
 age85                 |  1025.586   1   1025.586   11.645 .0210 .0007
 grip9                 |  1433.336   1   1433.336   16.275 .0290 .0001
 sexMW                 |  1482.498   1   1482.498   16.833 .0300 .0000
 demNF                 |  2776.568   1   2776.568   31.527 .0548 .0000
 demNC                 | 10315.200   1 10315.200  117.124 .1772 .0000
 Error (from model)    | 47910.559 544     88.071
 ----- --------------- | ---------- --- ---------- -------- ----- -----
 Total (empty model)   | 66296.538 549    120.759

SummaryCI(ModelMain, level=.95) # custom function to add CIs to fixed effects table

            Estimate Std.Err t.value p.value Lower.CI Upper.CI
(Intercept)  29.2643  0.6985  41.895 <0.0001  27.8922  30.6364  beta0
age85        -0.4057  0.1189  -3.412  0.0007  -0.6393  -0.1722  beta1
grip9         0.6042  0.1498   4.034  0.0001   0.3100   0.8984  beta2
sexMW        -3.6574  0.8914  -4.103 <0.0001  -5.4084  -1.9063  beta3
demNF        -5.7220  1.0191  -5.615 <0.0001  -7.7238  -3.7202  beta4
demNC       -16.4798  1.5228 -10.822 <0.0001 -19.4710 -13.4886  beta5

print("R Ask for missing model-implied group difference as beta5-beta4")
glhtModelMain = glht(model=ModelMain, linfct=rbind("Future vs Current" = c(0,0,0,0,-1,1)))
glhtSummaryCI(glhtModelMain, level=.95)  # custom function to add CIs to glht output table

                  Estimate Std.Err p.value Lower.CI Upper.CI
Future vs Current   -10.76   1.708 <0.0001   -14.11   -7.403
```

FOR HW06 → Model Adding Two Interactions: Sex by Age and Sex by Grip

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

RQ: Do the effects of age and grip strength differ between men and women?

STATA Syntax and Output:

```
display "STATA Add 2 Interactions -- Sex by Age, 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)

      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
          grip9 |   .6968828   .2387998     2.92   0.004     .2277964    1.165969
          sexMW |  -3.626534   .9111454    -3.98   0.000    -5.416343   -1.836725
          demNF |  -5.748826   1.020154    -5.64   0.000    -7.752765   -3.744887
          demNC |  -16.49476   1.523337   -10.83   0.000    -19.48713   -13.50239
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
------------------------------------------------------------------------------
```

Do the two new interaction terms improve the model prediction?

```
test (c.sexMW#c.age85=0)(c.sexMW#c.grip9=0) // DFnum=2 F-test for two new interactions

       F(  2,   542) =    0.81
            Prob > F =    0.4438

global  SSint2 = e(mss) - $SSmain                  // Save addition to main-effect model SS
display "Partial R2 = "      $SSint2/($SSint2+e(rss)) // Uses SS residual from this model
display "Semi-Partial R2 = " $SSint2/(e(mss)+e(rss))  // Uses SS model+res from this model
Partial R2 = .00299345
Semi-Partial R2 = .00216328
```

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

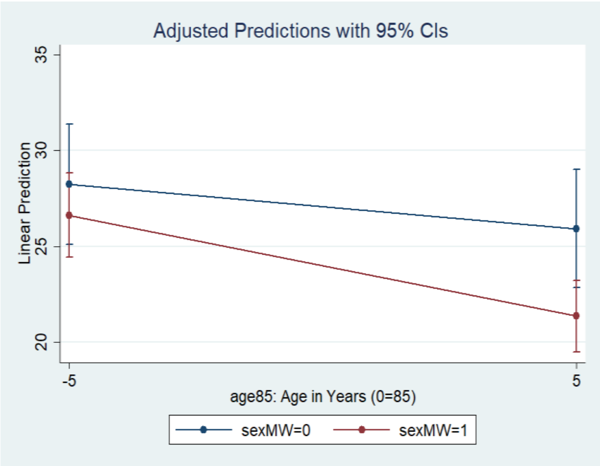
Simple Age Slope = $\boldsymbol{\beta_1}(\boldsymbol{Age_i}-\mathbf{85})+\boldsymbol{\beta_6}(\boldsymbol{SexMW_i})(\boldsymbol{Age_i}-\mathbf{85})$

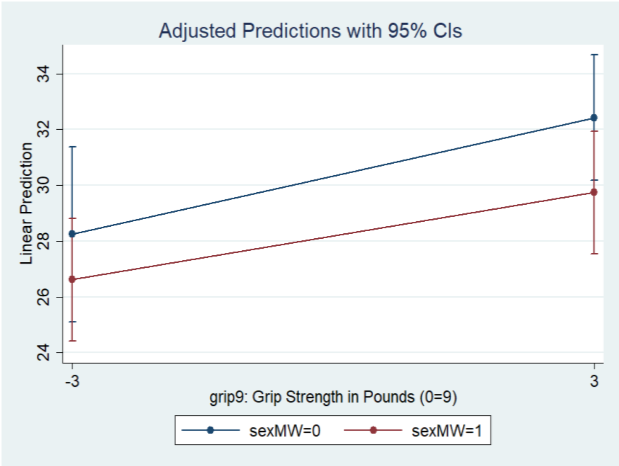
= $[\boldsymbol{\beta_1}+\boldsymbol{\beta_6}(\boldsymbol{SexMW_i})]$ that multiplies $(\boldsymbol{Age_i}-\mathbf{85})$

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

// Simple slopes of grip by sex
   lincom c.grip9*1 + c.sexMW#c.grip9*0  // Grip Slope for Men
------------------------------------------------------------------------------
   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
------------------------------------------------------------------------------
   cognition |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         (1) |   .5201555   .1930589     2.69   0.007     .1409201    .8993908
------------------------------------------------------------------------------

// Get predicted outcomes for each combination of (from(by)to)
display "Predicted Outcomes by Age and Sex for Grip=6"
margins, at(c.demNF=0 c.demNC=0 c.age85=(-5(10)5) c.grip9=-3 c.sexMW=(0(1)1)) vsquish
marginsplot, xdimension(age85) // Plot pred outcomes by age
graph export "STATA plots\STATA Sex by Age=x GLM Plot.png", replace

display "Predicted Outcomes by Grip and Sex for Age=80"
margins, at(c.demNF=0 c.demNC=0 c.age85=-5 c.grip9=(-3(6)3) c.sexMW=(0(1)1)) vsquish
marginsplot, xdimension(grip9) // Plot pred outcomes by grip
graph export "STATA plots\STATA Sex by Grip=x GLM Plot.png", replace
```





R Syntax and Output:

```
print("R Add 2 Interactions -- Sex by Age, Sex by Grip")
ModelInt2 = lm(data=Example5, formula=cognition~1+age85+grip9+sexMW+demNF+demNC
                                                 +age85:sexMW +grip9:sexMW)
supernova(ModelInt2)             # supernova prints sums of squares and residual variance

                                      SS  df        MS       F   PRE     p
 ----------- --------------- | --------- --- --------- ------- ----- -----
       Model (error reduced) | 18529.397   7  2647.057  30.035 .2795 .0000
       age85                 |   132.531   1   132.531   1.504 .0028 .2206
       grip9                 |   750.553   1   750.553   8.516 .0155 .0037
       sexMW                 |  1396.169   1  1396.169  15.842 .0284 .0001
       demNF                 |  2798.705   1  2798.705  31.756 .0553 .0000
       demNC                 | 10333.082   1 10333.082 117.247 .1778 .0000
 age85:sexMW                 |   128.691   1   128.691   1.460 .0027 .2274
 grip9:sexMW                 |    29.276   1    29.276   0.332 .0006 .5646
       Error (from model)    | 47767.141 542    88.131
 ----------- --------------- | --------- --- --------- ------- ----- -----
       Total (empty model)   | 66296.538 549   120.759

SummaryCI(ModelInt2, level=.95) # custom function to add CIs to fixed effects table

            Estimate Std.Err  t.value p.value Lower.CI Upper.CI
(Intercept)  29.1721  0.7584  38.4675 <0.0001  27.6824  30.6618
age85        -0.2322  0.1894  -1.2263  0.2206  -0.6043   0.1398
grip9         0.6969  0.2388   2.9183  0.0037   0.2278   1.1660
sexMW        -3.6265  0.9111  -3.9802  0.0001  -5.4163  -1.8367
demNF        -5.7488  1.0202  -5.6353 <0.0001  -7.7528  -3.7449
demNC       -16.4948  1.5233 -10.8280 <0.0001 -19.4871 -13.5024
age85:sexMW  -0.2948  0.2439  -1.2084  0.2274  -0.7740   0.1844  beta6
grip9:sexMW  -0.1767  0.3066  -0.5764  0.5646  -0.7791   0.4256  beta7
```

Do the two new interaction terms improve the model prediction?

```
# Get F-test and effect sizes for fixed slopes of interest using custom function
R2changeF(ReducedModel=ModelMain, FullModel=ModelInt2, PredName="Two New Interactions")

F-Test and R2 Change for Two New Interactions Slopes
  R2.Total R2.Change DF.num DF.den F.value p.value Partial.R2 SemiPartial.R2
2   0.2795  0.002163      2    542  0.8137  0.4438   0.002993       0.002163
```

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

We can use the model equation to calculate the **simple age and grip slopes** 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 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 $(\boldsymbol{Grip_i} - \mathbf{9})$

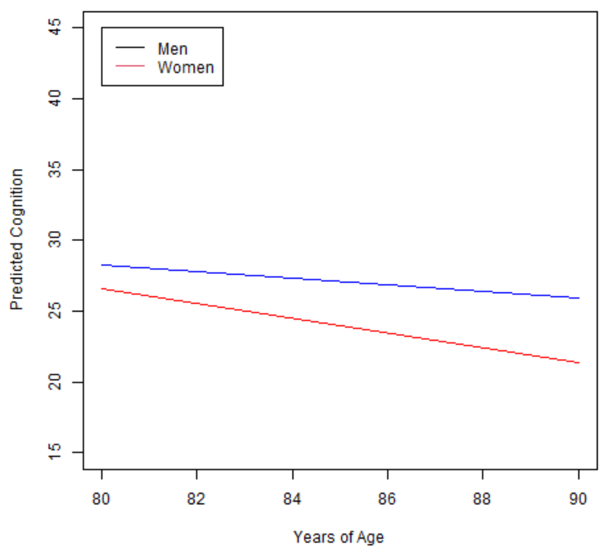
```
print("Simple slopes of age by sex, simple slopes of sex by age")
glhtSlopesInt2 = glht(model=ModelInt2, linfct=rbind(
  "Age Slope for Men"      = c(0,1,0,0,0,0,0,0,0),  # Multipliers in order of fixed effects
  "Age Slope for Women"    = c(0,1,0,0,0,0,1,0),

  "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)))
glhtSummaryCI(glhtSlopesInt2, level=.95)  # custom function to add CIs to glht output table
```

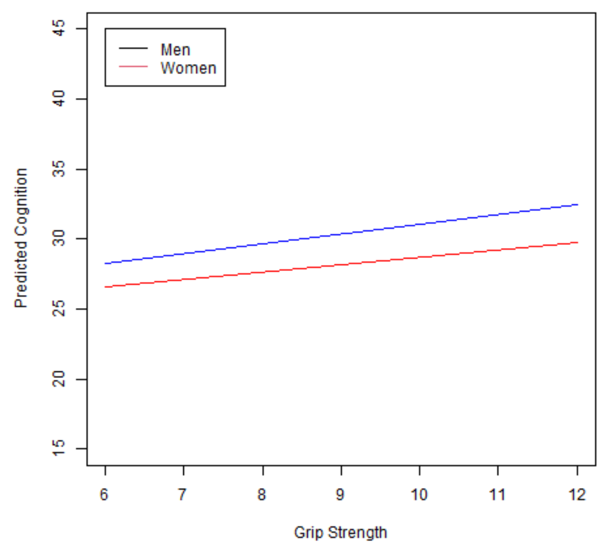
```
                     Estimate Std.Err p.value Lower.CI Upper.CI
Age Slope for Men     -0.2322  0.1894  0.2206  -0.6043   0.1398
Age Slope for Women   -0.5270  0.1538  0.0007  -0.8291  -0.2250

Grip Slope for Men     0.6969  0.2388  0.0037   0.2278   1.1660
Grip Slope for Women   0.5202  0.1931  0.0073   0.1409   0.8994
```

```
print("Pred cognition outcomes holding demNF=none, and demNC=none")
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); print(PlotInt2, digits=6) # Save predictions for plotting
```

```
at(demNF) at(demNC) at(grip9) at(age85) at(sexMW) Prediction       SE       z            p   lower   upper
        0         0        -3        -5         0    28.2427 1.594901 17.7081  3.63113e-70 25.1167 31.3686
        0         0         3        -5         0    32.4240 1.145406 28.3078 2.76774e-176 30.1790 34.6689
        0         0        -3         5         0    25.9202 1.566544 16.5461  1.70845e-61 22.8498 28.9906
        0         0         3         5         0    30.1015 1.276913 23.5736 7.18750e-123 27.5988 32.6042
        0         0        -3        -5         1    26.6202 1.118191 23.8065 2.85875e-125 24.4286 28.8119
        0         0         3        -5         1    29.7412 1.115829 26.6539 1.61295e-156 27.5542 31.9282
        0         0        -3         5         1    21.3499 0.957061 22.3078 3.10557e-110 19.4741 23.2257
        0         0         3         5         1    24.4708 1.337982 18.2894  1.00594e-74 21.8484 27.0932
```

See code given online for making the plots below in R





Example Results Section for 2 Sex Interactions Model (as Equation 1, adding on from the end of Example 4b):

We then estimated a new model (as shown in Equation 1) to examine the extent to which the slopes of age and grip strength differed between men and women. Although the augmented 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 with sex were removed from the model.

NONE OF WHAT FOLLOWS IS NEEDED FOR HW06, but this model provides an example of a quantitative*quantitative predictor interaction…

Remove 2 Sex Interactions; Add Interaction of Age by Grip Strength (Equation 2.9)

$$\begin{aligned} Cognition_i = &\ \beta_0 + \beta_1(Age_i - 85) + \beta_2(Grip_i - 9) + \beta_3(SexMW_i) \\ &+ \beta_4(DemNF_i) + \beta_5(DemNC_i) \\ &+ \beta_6(Age_i - 85)(Grip_i - 9) + e_i \end{aligned}$$

RQ: Does the effect of age vary by grip strength (or does the effect of grip strength vary by age)?

STATA Syntax and Output:

```
display "STATA Remove 2 Sex Interactions, Add Age by Grip Interaction (Equation 2.9)"
regress cognition c.age85 c.grip9 c.sexMW c.demNF c.demNC c.age85#c.grip9, level(95)

      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
          grip9 |   .6194186   .1487424     4.16   0.000     .3272376    .9115996
          sexMW |  -3.455637   .8872749    -3.89   0.000    -5.198549   -1.712726
          demNF |  -5.922543   1.013632    -5.84   0.000    -7.913663   -3.931424
          demNC |   -16.3004   1.512547   -10.78   0.000    -19.27157   -13.32924
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
------------------------------------------------------------------------------

global  SSagegrip = e(mss) - $SSmain                   // Save addition to main-effect model SS
display "Partial R2 = "      $SSagegrip/($SSagegrip+e(rss)) // Uses SS residual from this model
display "Semi-Partial R2 = " $SSagegrip/(e(mss)+e(rss))     // Uses SS model+res from this model
Partial R2 = .0166782
Semi-Partial R2 = .01205284
```

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

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

```
// 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 (repeated below)
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
```

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

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

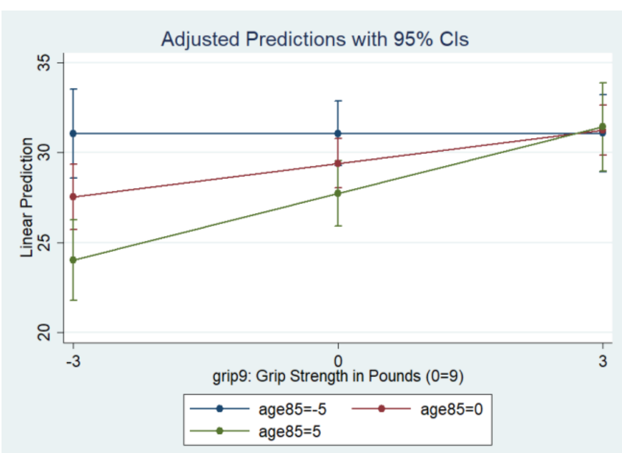
Simple Grip Slope = $\boldsymbol{\beta_2(Grip_i - 9) + \beta_6(Age_i - 85)(Grip_i - 9)}$

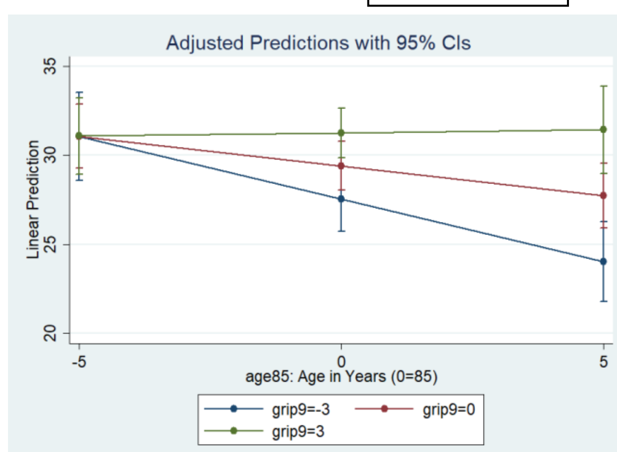
= $[\boldsymbol{\beta_2 + \beta_6(Age_i - 85)}]$ that multiplies $(\boldsymbol{Grip_i - 9})$

```
// 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 (repeated below)
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
------------------------------------------------------------------------------
             |      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
------------------------------------------------------------------------------
```

```
display "STATA Pred cognition outcomes holding sexMW=0, demNF=none, and demNC=none"
// predictor=(from(by)to), c.=quantitative predictor
margins, at(c.sexMW=0 c.demNF=0 c.demNC=0 c.age85=(-5(5)5) c.grip9=(-3(3)3)) vsquish
marginsplot, xdimension(grip9)    // Plot pred outcomes by grip
graph export "STATA plots\STATA Age by Grip=x GLM Plot.png", replace
marginsplot, xdimension(age85)    // Plot pred outcomes by age
graph export "STATA plots\STATA Grip by Age=x GLM Plot.png", replace
```

Figures 2.1 and 2.2






```
estat vce  // Asymptotic covariance matrix of fixed effects for regions of significance
             |                                                         c.age85#
        e(V) |      age85       grip9       sexMW       demNF       demNC     c.grip9       _cons
-------------+-------------------------------------------------------------------------------------
       age85 |   .0144857
       grip9 |  .00331698    .0221243
       sexMW |    .005024   .05374269   .78725672
       demNF | -.00413095  -.01338766  -.07101552    1.027449
       demNC | -.00115115  -.00030106   .02370811   .21291169   2.2877993
     c.age85#|
     c.grip9 |   .0009587   .00020294   .00269465  -.00267909    .0023964   .00164319
       _cons |  .00045357  -.03075328  -.45067156  -.18202858  -.22634698   .00191647   .48289456
```

```
// Simple slope boundaries for age and grip given by regions of significance in R
lincom c.age85*1 + c.age85#c.grip9*0.665    // Age Slope at Grip =  9.665
lincom c.age85*1 + c.age85#c.grip9*9.521    // Age Slope at Grip = 18.521
lincom c.grip9*1 + c.age85#c.grip9*-14.873  // Grip Slope at Age = 70.127
lincom c.grip9*1 + c.age85#c.grip9*-2.281   // Grip Slope at Age = 82.719
```

R Syntax and Output:

```
print("R: Remove 2 Sex Interactions, Add Age by Grip Interaction (Equation 2.9)")
ModelAgeGrip = lm(data=Example5, formula=cognition~1+age85+grip9+sexMW+demNF+demNC
                                                   +age85:grip9)
supernova(ModelAgeGrip)          # supernova prints sums of squares and residual variance

                                      SS  df        MS       F   PRE     p
 ----------- --------------- | --------- --- --------- -------- ----- -----
       Model (error reduced) | 19185.041   6  3197.507  36.854 .2894 .0000
       age85                 |   668.002   1   668.002   7.699 .0140 .0057
       grip9                 |  1504.617   1  1504.617  17.342 .0309 .0000
       sexMW                 |  1316.034   1  1316.034  15.168 .0272 .0001
       demNF                 |  2961.988   1  2961.988  34.139 .0592 .0000
       demNC                 | 10076.412   1 10076.412 116.139 .1762 .0000
 age85:grip9                 |   799.062   1   799.062   9.210 .0167 .0025
       Error (from model)    | 47111.497 543    86.762
 ----------- --------------- | --------- --- --------- -------- ----- -----
       Total (empty model)   | 66296.538 549   120.759

SummaryCI(ModelAgeGrip, level=.95) # custom function to add CIs to fixed effects table

            Estimate Std.Err t.value p.value  Lower.CI  Upper.CI
(Intercept)  29.4078 0.69491  42.319 <0.0001  28.04277  30.77284
age85        -0.3340 0.12036  -2.775  0.0057  -0.57038  -0.09754
grip9         0.6194 0.14874   4.164 <0.0001   0.32724   0.91160
sexMW        -3.4556 0.88727  -3.895  0.0001  -5.19855  -1.71273
demNF        -5.9225 1.01363  -5.843 <0.0001  -7.91366  -3.93142
demNC       -16.3004 1.51255 -10.777 <0.0001 -19.27157 -13.32924
age85:grip9   0.1230 0.04054   3.035  0.0025   0.04339   0.20265  beta6

# Get F-test and effect sizes for fixed slopes of interest using custom function
R2changeF(ReducedModel=ModelMain, FullModel=ModelAgeGrip, PredName="Age by Grip")

F-Test and R2 Change for Age by Grip
  R2.Total R2.Change DF.num DF.den F.value p.value Partial.R2 SemiPartial.R2
2   0.2894   0.01205      1    543    9.21  0.0025    0.01668        0.01205
```

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

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

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

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

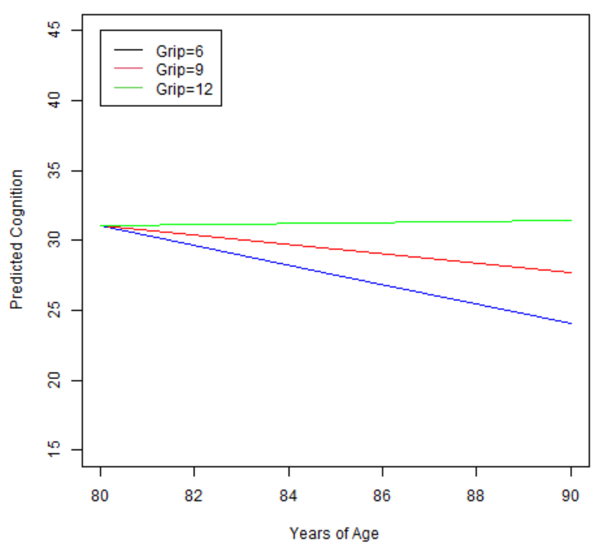
Simple Grip Slope = $\boldsymbol{\beta_2}(\boldsymbol{Grip_i}-\mathbf{9})+\boldsymbol{\beta_6}(\boldsymbol{Age_i}-\mathbf{85})(\boldsymbol{Grip_i}-\mathbf{9})$

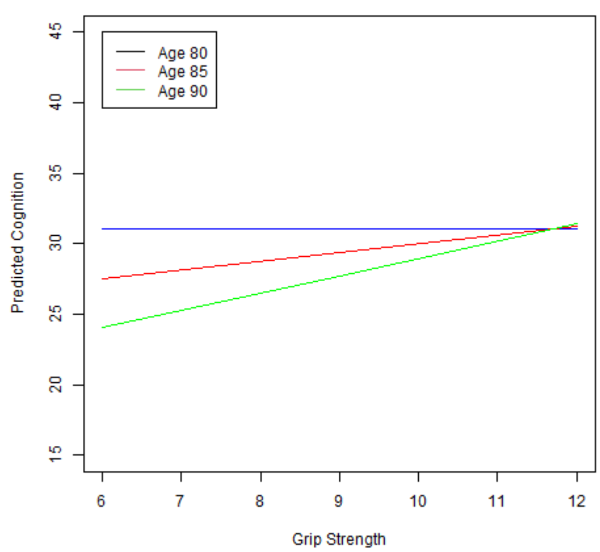
= $[\boldsymbol{\beta_2}+\boldsymbol{\beta_6}(\boldsymbol{Age_i}-\mathbf{85})]$ that multiplies $(\boldsymbol{Grip_i}-\mathbf{9})$

```
glhtSlopesAgeGrip = glht(model=ModelAgeGrip, linfct=rbind(
  "Age Slope at Grip = 6"  = c(0,1,0,0,0,0,-3),  # Multipliers 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)))
```

```
glhtSummaryCI(glhtSlopesAgeGrip, level=.95)  # custom function to add CIs to glht output

                        Estimate Std.Err p.value Lower.CI Upper.CI
Age Slope at Grip = 6  -0.703016  0.1534 <0.0001  -1.0043 -0.40175
Age Slope at Grip = 9  -0.333961  0.1204  0.0057  -0.5704 -0.09754
Age Slope at Grip = 12  0.035095  0.1872  0.8513  -0.3325  0.40273

Grip Slope at Age = 80  0.004326  0.2473  0.9861  -0.4815  0.49018
Grip Slope at Age = 85  0.619419  0.1487 <0.0001   0.3272  0.91160
Grip Slope at Age = 90  1.234511  0.2554 <0.0001   0.7328  1.73622

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

   age85  grip9 Test Estimate Std. Error t value  df    Pr(>|t|)
1 sstest     -3        -0.703      0.153  -4.584 543 0.00000567
2 sstest      0        -0.334      0.120  -2.775 543    0.00571
3 sstest      3         0.035      0.187   0.188 543    0.85132

4     -5 sstest         0.004      0.247   0.017 543    0.98605
5      0 sstest         0.619      0.149   4.164 543 0.00003631
6      5 sstest         1.235      0.255   4.833 543 0.00000175

print("Pred cognition outcomes holding sexMW=0, demNF=none, and demNC=none")
print("Provides predicted outcomes from min,max,by=increment of predictors")
PredAgeGrip = prediction(model=ModelAgeGrip, type="response", at=list(sexMW=0, demNF=0,
                         demNC=0, grip9=seq(-3,3,by=3), age85=seq(-5,5,by=5)))
PlotAgeGrip = summary(PredAgeGrip); print(PlotAgeGrip, digits=6) # Save pred for plot

# Threw a warning that predictions went out of bounds!
Warning messages:
1: In check_values(data, at) :
  A 'at' value for 'age85' is outside observed data range (-4.9835067729703,11.9672831683989)!

at(sexMW) at(demNF) at(demNC) at(grip9) at(age85) Prediction       SE       z           p   lower   upper
        0         0         0        -3        -5    31.0646 1.260473 24.6452 4.14143e-134 28.5941 33.5351
        0         0         0         0        -5    31.0776 0.916789 33.8983 7.04923e-252 29.2807 32.8745
        0         0         0         3        -5    31.0906 1.092408 28.4606 3.60205e-178 28.9495 33.2317
        0         0         0        -3         0    27.5495 0.930878 29.5952 1.72045e-192 25.7251 29.3740
        0         0         0         0         0    29.4078 0.694906 42.3191  0.00000e+00 28.0458 30.7698
        0         0         0         3         0    31.2661 0.705332 44.3281  0.00000e+00 29.8836 32.6485
        0         0         0        -3         5    24.0345 1.149080 20.9163  3.80801e-97 21.7823 26.2866
        0         0         0         0         5    27.7380 0.921723 30.0936 5.86735e-199 25.9315 29.5445
        0         0         0         3         5    31.4415 1.246179 25.2304 1.86086e-140 28.9991 33.8840
```

See code given online for making the plots below in R (as Figures 1 and 2 in the results)





```
print("Regions of significance using interactions package") # plots broke my computer
vcov(ModelAgeGrip) # Asymptotic covariance matrix of fixed effects for regions
```

```
              (Intercept)      age85      grip9     sexMW     demNF      demNC age85:grip9
(Intercept)     0.4828946  0.0004536 -0.0307533 -0.450672 -0.182029 -0.2263470   0.0019165
age85           0.0004536  0.0144857  0.0033170  0.005024 -0.004131 -0.0011511   0.0009587
grip9          -0.0307533  0.0033170  0.0221243  0.053743 -0.013388 -0.0003011   0.0002029
sexMW          -0.4506716  0.0050240  0.0537427  0.787257 -0.071016  0.0237081   0.0026947
demNF          -0.1820286 -0.0041309 -0.0133877 -0.071016  1.027449  0.2129117  -0.0026791
demNC          -0.2263470 -0.0011511 -0.0003011  0.023708  0.212912  2.2877993   0.0023964
age85:grip9     0.0019165  0.0009587  0.0002029  0.002695 -0.002679  0.0023964   0.0016432
```

In the above "asymptotic covariance matrix of the fixed effects" the diagonal is the SE^2 (sampling variance) for each slope, and the off-diagonals hold the covariances among the slope SE values. Bold values are needed to compute regions of significance for the age and grip strength slopes, shown next.

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

JOHNSON-NEYMAN INTERVAL → **[9.665, 18.521] pounds in original metric**

```
When grip9 is OUTSIDE the interval [0.665, 9.521], the slope of age85 is p < .05.
Note: The range of observed values of grip9 is [-9.000, 10.000]
```

This result indicates that the age slope will be significantly negative below grip = 9.665 pounds, nonsignificant between grip = 9.665 and 18.521 pounds, and significantly positive after grip = 18.521 pounds.

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

JOHNSON-NEYMAN INTERVAL → **[70.127, 82.719] years in original metric**

```
When age85 is OUTSIDE the interval [-14.873, -2.281], the slope of grip9 is p < .05.
Note: The range of observed values of age85 is [-4.984, 11.967]
```

This result indicates that the grip strength slope will be significantly negative below age = 70.127 years, nonsignificant between age = 70.127 and 82.719 years, and significantly positive after age = 82.719 years.

```
print("Simple slopes at boundaries given by regions of significance")
glhtSlopesAgeGrip = glht(model=ModelAgeGrip, linfct=rbind(
  "Age Slope at Grip =  9.665"  = c(0,1,0,0,0,0, 0.665),  # Multipliers in order of fixed effects
  "Age Slope at Grip = 18.521"  = c(0,1,0,0,0,0, 9.521),
  "Grip Slope at Age = 70.127"  = c(0,0,1,0,0,0,-14.873),
  "Grip Slope at Age = 82.719"  = c(0,0,1,0,0,0, -2.281)))
glhtSummaryCI(glhtSlopesAgeGrip, level=.95)  # custom function to add CIs to glht output table
```

```
                           Estimate Std.Err p.value    Lower.CI    Upper.CI
Age Slope at Grip =  9.665  -0.2522  0.1284  0.0501 -0.50438147  0.00007489
Age Slope at Grip = 18.521   0.8373  0.4263  0.0500 -0.00001698  1.67461368
Grip Slope at Age = 70.127  -1.2102  0.6161  0.0500 -2.42045365 -0.00001674
Grip Slope at Age = 82.719   0.3388  0.1725  0.0500  0.00001168  0.67761527
```

<u>Example Results Section for Age*Grip Model as Equation 2 (building on the main-effects-only model)</u>

We then estimated a new model (as shown in Equation 2) adding an interaction between age and grip strength to examine the extent to which the slope of age varied by grip strength (and also how the slope of grip strength varied by age). The augmented model accounted for a significant amount of variance in cognition, $F(6, 543) = 36.85$, MSE = 86.67, $p < .0001$, $R^2 = .289$. The age by grip strength interaction was significant and added .012 to the R^2 relative to the main-effects-only model. The pattern of the age by grip strength interaction is described below.

The simple main effect of age $\beta_1 = 0.33$ indicated that cognition is predicted to be significantly lower by 0.33 for every additional year of age (in persons with a grip strength of 9 pounds per square inch). The simple main effect of grip strength $\beta_2 = 0.62$ indicated that cognition is predicted to be significantly greater by 0.62 for every additional pound of grip strength (in persons who are age 85). As shown in Figure 1, the age by grip strength interaction $\beta_6 = 0.12$ indicated the age slope predicting cognition became significantly less negative by 0.12 for each additional pound of grip strength (as shown by the differences in the 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 in Figure 1, or the differences in the slopes of the lines in Figure 2).

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 asymptotic covariance matrix (see Hoffman, 2015). For the effect of age, the threshold values of grip strength were 9.67 and 18.52 pounds. Given the range of grip strength of 0–19 pounds in the current sample (M ≈ 9 pounds), the effect of age is expected to be negative for about half 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 threshold values of age were 70.13 and 82.72 years. Given the range of age of 80–97 years in the sample (M ≈ 85 years), 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).

NONE OF WHAT FOLLOWS IS NEEDED FOR HW06, but this model provides an example of a categorical*binary (or quantitative) predictor interaction…

Add sex*dementia interaction (Equation 2.13):

$$\begin{aligned}Cognition_i &= \beta_0 + \beta_1(Age_i - 85) + \beta_2(Grip_i - 9)\\ &+\beta_3(SexMW_i) + \beta_4(DemNF_i) + \beta_5(DemNC_i)\\ &+\beta_6(Age_i - 85)(Grip_i - 9)\\ &+\beta_7(SexMW_i)(DemNF_i)\\ &+\beta_8(SexMW_i)(DemNC_i) + e_i\end{aligned}$$

RQs: Does the effect of sex on cognition vary by dementia group (or does the effect of dementia group on cognition vary by sex)?

Adjusted means holding age=85 and grip=9:

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

STATA Syntax and Output:

```
display "STATA Add Sex by Dementia Group Interaction (Equation 2.13)"
display "Binary-Coded Predictors for Sex (0=Men) and Demgroup (0=None)"
regress cognition c.age85 c.grip9 c.sexMW c.demNF c.demNC c.age85#c.grip9   ///
                 c.sexMW#c.demNF c.sexMW#c.demNC, level(95)
estimates store DemOnly   // Save all model results for effect sizes below

      Source |       SS           df       MS      Number of obs   =       550
-------------+----------------------------------   F(8, 541)       =     28.77
       Model |  19785.4615         8  2473.18268   Prob > F        =    0.0000
    Residual |  46511.0767       541  85.9724154   R-squared       =    0.2984
-------------+----------------------------------   Adj R-squared   =    0.2881
       Total |  66296.5382       549  120.758722   Root MSE        =    9.2721

------------------------------------------------------------------------------
      cognition |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
----------------+-------------------------------------------------------------
          age85 |  -.3347988   .1198875    -2.79   0.005    -.5703009   -.0992966
          grip9 |   .6178929   .1480794     4.17   0.000     .3270117     .908774
          sexMW |  -2.875594   1.011237    -2.84   0.005    -4.862027   -.8891616
          demNF |  -6.055901   1.635126    -3.70   0.000    -9.267875   -2.843927
          demNC |  -11.97073   2.244954    -5.33   0.000    -16.38062   -7.560836
c.age85#c.grip9 |   .1221516   .0403529     3.03   0.003     .0428841    .2014191
c.sexMW#c.demNF |     .16427   2.070475     0.08   0.937    -3.902886    4.231426  beta7
c.sexMW#c.demNC |    -7.8751   3.024536    -2.60   0.009    -13.81637   -1.933825  beta8
          _cons |   29.07015   .7484992    38.84   0.000     27.59983    30.54047
------------------------------------------------------------------------------
```

Do the two new interaction terms improve the model prediction?

```
// Omnibus DF=2 F-Test for Dementia*Sex Interaction
test (c.sexMW#c.demNF=0) (c.sexMW#c.demNC=0)

       F(  2,   541) =    3.49
            Prob > F =    0.0311

global  SSsexdem = e(mss) - ($SSagegrip+$SSmain)       // Save addition to agegrip model SS
display "Partial R2 = "    $SSsexdem/($SSsexdem+e(rss)) // Uses SS residual from this model
display "Semi-Partial R2 = " $SSsexdem/(e(mss)+e(rss)) // Uses SS model+res from this model
Partial R2 = .01274467
Semi-Partial R2 = .00905659

// In TESTs below, linear combinations are created within parentheses (still 1 DF each)
// Omnibus DF=2 F-test for Dementia Simple Main Effect for Men
test (c.demNF*1 + c.sexMW#c.demNF*0 =0)(c.demNC*1 + c.sexMW#c.demNC*0 =0)

       F(  2,   541) =   18.69
            Prob > F =    0.0000

// Omnibus DF=2 F-test for Dementia Simple Main Effect for Men
test (c.demNF*1 + c.sexMW#c.demNF*1 =0)(c.demNC*1 + c.sexMW#c.demNC*1 =0)

       F(  2,   541) =   53.16
            Prob > F =    0.0000
```

STATA syntax for cell means and simple slopes (output provided online only)

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

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

Simple Sex Slope = $\boldsymbol{\beta_3}(\boldsymbol{SexMW_i}) + \boldsymbol{\beta_7}(\boldsymbol{SexMW_i})(\boldsymbol{DemNF_i}) + \boldsymbol{\beta_8}(\boldsymbol{SexMW_i})(\boldsymbol{DemNC_i})$

= $[\boldsymbol{\beta_3} + \boldsymbol{\beta_7}(\boldsymbol{DemNF_i}) + \boldsymbol{\beta_8}(\boldsymbol{DemNC_i})]$ that multiplies $(\boldsymbol{SexMW_i})$

```
// DF=1 simple slopes for sex per demgroup
lincom c.sexMW*1 + c.sexMW#c.demNF*0 + c.sexMW#demNC*0  // Sex Diff for No Dementia
lincom c.sexMW*1 + c.sexMW#c.demNF*1 + c.sexMW#demNC*0  // Sex Diff for Future Dementia
lincom c.sexMW*1 + c.sexMW#c.demNF*0 + c.sexMW#demNC*1  // Sex Diff for Current Dementia
```

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

Simple None vs. Future Slope = $\boldsymbol{\beta_4}(\boldsymbol{DemNF_i}) + \boldsymbol{\beta_7}(\boldsymbol{SexMW_i})(\boldsymbol{DemNF_i})$

= $[\boldsymbol{\beta_4} + \boldsymbol{\beta_7}(\boldsymbol{SexMW_i})]$ that multiplies $(\boldsymbol{DemNF_i})$

Simple None vs. Current Slope = $\boldsymbol{\beta_5}(\boldsymbol{DemNC_i}) + \boldsymbol{\beta_8}(\boldsymbol{SexMW_i})(\boldsymbol{DemNC_i})$

= $[\boldsymbol{\beta_5} + \boldsymbol{\beta_8}(\boldsymbol{SexMW_i})]$ that multiplies $(\boldsymbol{DemNC_i})$

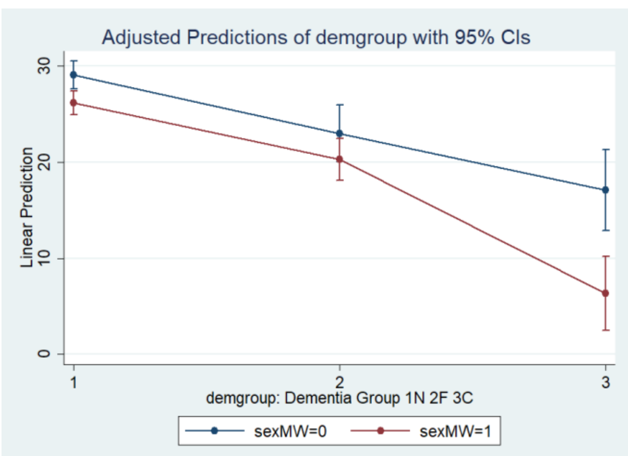
Simple Future vs. Current Slope = $[\boldsymbol{\beta_5} + \boldsymbol{\beta_8}(\boldsymbol{SexMW_i})] - [\boldsymbol{\beta_4} + \boldsymbol{\beta_7}(\boldsymbol{SexMW_i})]$

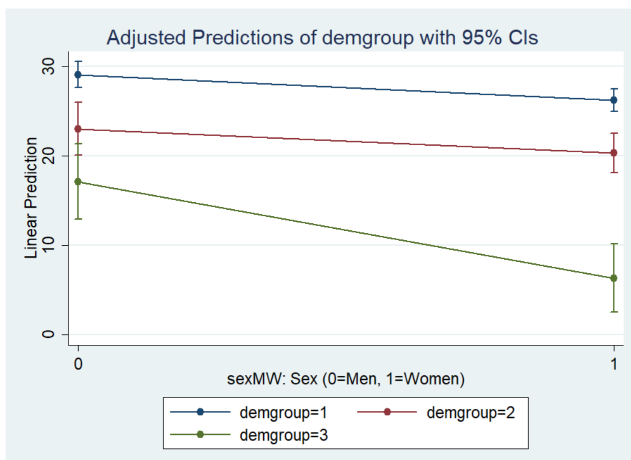
```
// DF=1 simple slopes for demgroup per sex
lincom c.demNF*1  + c.demNC*0 + c.sexMW#c.demNF*0  + c.sexMW#c.demNC*0 // None-Future Diff for Men
lincom c.demNF*1  + c.demNC*0 + c.sexMW#c.demNF*1  + c.sexMW#c.demNC*0 // None-Future Diff for Women

lincom c.demNF*0  + c.demNC*1 + c.sexMW#c.demNF*0  + c.sexMW#c.demNC*0 // None-Current Diff for Men
lincom c.demNF*0  + c.demNC*1 + c.sexMW#c.demNF*0  + c.sexMW#c.demNC*1 // None-Current Diff for Women

lincom c.demNF*-1 + c.demNC*1 + c.sexMW#c.demNF*0  + c.sexMW#c.demNC*0 // Future-Current Diff for Men
lincom c.demNF*-1 + c.demNC*1 + c.sexMW#c.demNF*-1 + c.sexMW#c.demNC*1 // Future-Current Diff for Women
```

```
// DF=1 differences in simple slopes = interactions
lincom c.sexMW#c.demNF*1  + c.sexMW#c.demNC*0  // A: Sex Effect differ btw None and Future?
lincom c.sexMW#c.demNF*1  + c.sexMW#c.demNC*0  // A: None-Future Effect differ btw Men and Women?

lincom c.sexMW#c.demNF*0  + c.sexMW#c.demNC*1  // B: Sex Effect differ btw None and Current?
lincom c.sexMW#c.demNF*0  + c.sexMW#c.demNC*1  // B: None-Current Effect differ btw Men and Women?

lincom c.sexMW#c.demNF*-1 + c.sexMW#c.demNC*1  // C: Sex Effect differ btw Future and Current?
lincom c.sexMW#c.demNF*-1 + c.sexMW#c.demNC*1  // C: Future-Current Effect differ btw Men and Women?
```

STATA code for effect sizes of linear combinations and model fixed slopes (output not shown)

```
display "Repeating lincoms needed for effect sizes for linear combinations of fixed effects"
lincom c.sexMW*1 + c.sexMW#c.demNF*0 + c.sexMW#demNC*1  // Sex Diff for Current Dementia
   display "Partial d = "  (2*(r(estimate)/r(se)))/sqrt(r(df))
   display "Partial r = "     (r(estimate)/r(se))/ sqrt((r(estimate)/r(se))^2+r(df))
lincom c.demNF*-1 + c.demNC*1 + c.sexMW#c.demNF*0  + c.sexMW#c.demNC*0 // Future-Current Diff for Men
   display "Partial d = "  (2*(r(estimate)/r(se)))/sqrt(r(df))
   display "Partial r = "     (r(estimate)/r(se))/ sqrt((r(estimate)/r(se))^2+r(df))
lincom c.demNF*-1 + c.demNC*1 + c.sexMW#c.demNF*-1 + c.sexMW#c.demNC*1 // Future-Current Diff for Women
   display "Partial d = "  (2*(r(estimate)/r(se)))/sqrt(r(df))
   display "Partial r = "     (r(estimate)/r(se))/ sqrt((r(estimate)/r(se))^2+r(df))
lincom c.sexMW#c.demNF*-1 + c.sexMW#c.demNC*1  // C: Sex Effect differ btw Future and Current?
   display "Partial d = "  (2*(r(estimate)/r(se)))/sqrt(r(df))
   display "Partial r = "     (r(estimate)/r(se))/ sqrt((r(estimate)/r(se))^2+r(df))

// Create observed interaction variables to use to get effect sizes
gen age85grip9 = age85*grip9
gen sexNF = sexMW*demNF
gen sexNC = sexMW*demNC
display "STATA semipartial and partial effect sizes per slope"
pcorr cognition age85 grip9 sexMW demNF demNC age85grip9 sexNF sexNC

// To make pictures, need to represent demgroup as program-categorical predictor instead
display "Program-Categorical Predictor for Demgroup Instead"
regress cognition c.age85 c.grip9 c.sexMW i.demgroup c.age85#c.grip9 c.sexMW#i.demgroup, level(95)
// Get predicted cognition outcomes --adjusted cell means-- holding age=85 and grip=9
margins i.demgroup, at(c.age85=0 c.grip9=0 c.sexMW=(0(1)1))
marginsplot, xdimension(demgroup)  // Get and save plot for pred outcomes by demgroup
graph export "STATA plots\STATA Sex by Demgroup=x GLM Plot.png", replace
marginsplot, xdimension(sexMW)  // Get and save plot for pred outcomes by sexMW
graph export "STATA plots\STATA Demgroup by Sex=x GLM Plot.png", replace
```






```
estat vce  // Asymptotic covariance matrix of fixed effects for regions of significance
// Simple slope boundaries for age and grip given by regions of significance in R
lincom c.age85*1 + c.age85#c.grip9*0.680    // Age Slope at Grip =  9.680
lincom c.age85*1 + c.age85#c.grip9*9.638    // Age Slope at Grip = 18.638
lincom c.grip9*1 + c.age85#c.grip9*-15.003  // Grip Slope at Age = 69.997
lincom c.grip9*1 + c.age85#c.grip9*-2.293   // Grip Slope at Age = 82.707
```

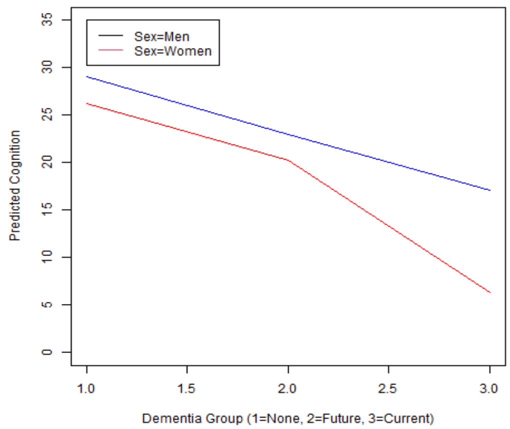
R Syntax and Output:

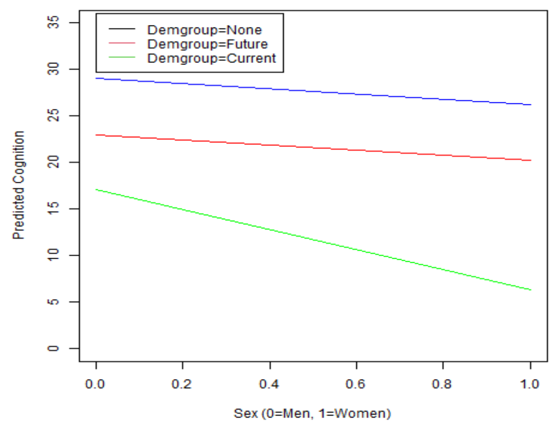
```
print("R: Keep Age by Grip Interaction, Add Sex by Dementia Group Interaction")
print("Binary-Coded Predictors for Sex (0=Men) and Demgroup (0=None)")
ModelSexDem = lm(data=Example5, formula=cognition~1+age85+grip9+sexMW+demNF+demNC
                                    +age85:grip9 +sexMW:demNF +sexMW:demNC)
supernova(ModelSexDem)            # supernova prints sums of squares and residual variance

                                      SS  df       MS      F   PRE     p
 ----------- --------------- | --------- --- -------- ------ ----- -----
       Model (error reduced) | 19785.461   8 2473.183 28.767 .2984 .0000
       age85                 |   670.469   1  670.469  7.799 .0142 .0054
       grip9                 |  1496.911   1 1496.911 17.412 .0312 .0000
       sexMW                 |   695.198   1  695.198  8.086 .0147 .0046
       demNF                 |  1179.273   1 1179.273 13.717 .0247 .0002
       demNC                 |  2444.475   1 2444.475 28.433 .0499 .0000
 age85:grip9                 |   787.787   1  787.787  9.163 .0167 .0026
 sexMW:demNF                 |     0.541   1    0.541  0.006 .0000 .9368
 sexMW:demNC                 |   582.846   1  582.846  6.779 .0124 .0095
       Error (from model)    | 46511.077 541   85.972
 ----------- --------------- | --------- --- -------- ------ ----- -----
       Total (empty model)   | 66296.538 549  120.759

SummaryCI(ModelSexDem, level=.95) # custom function to add CIs to fixed effects table

             Estimate Std.Err  t.value p.value  Lower.CI Upper.CI
(Intercept)  29.0701 0.74850 38.83791 <0.0001  27.59983  30.5405
age85        -0.3348 0.11989 -2.79261  0.0054  -0.57030  -0.0993
grip9         0.6179 0.14808  4.17271 <0.0001   0.32701   0.9088
sexMW        -2.8756 1.01124 -2.84364  0.0046  -4.86203  -0.8892
demNF        -6.0559 1.63513 -3.70363  0.0002  -9.26788  -2.8439
demNC       -11.9707 2.24495 -5.33228 <0.0001 -16.38062  -7.5608
age85:grip9   0.1222 0.04035  3.02709  0.0026   0.04288   0.2014
sexMW:demNF   0.1643 2.07048  0.07934  0.9368  -3.90289   4.2314  beta7
sexMW:demNC  -7.8751 3.02454 -2.60374  0.0095 -13.81637  -1.9338  beta8

# Get F-test and effect sizes for new interactions using custom function
R2changeF(ReducedModel=ModelAgeGrip, FullModel=ModelSexDem, PredName="Sex by Dementia Int")

F-Test and R2 Change for Sex by Dementia Int
  R2.Total R2.Change DF.num DF.den F.value p.value Partial.R2 SemiPartial.R2
2   0.2984  0.009057      2    541   3.492  0.0311    0.01274       0.009057

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

Global Test:
     F DF1 DF2        Pr(>F)
1 18.7   2 541 0.0000000142

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

Global Test:
     F DF1 DF2   Pr(>F)
1 53.2   2 541 8.38e-22

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

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

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

See code given online for making the plots below in R (as Figures 3 and 4 in the results)





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

Simple Sex Slope = $\beta_3(SexMW_i) + \beta_7(SexMW_i)(DemNF_i) + \beta_8(SexMW_i)(DemNC_i)$

= $[\beta_3 + \beta_7(DemNF_i) + \beta_8(DemNC_i)]$ that multiplies $(SexMW_i)$

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

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

Simple None vs. Future Slope = $\beta_4(DemNF_i) + \beta_7(SexMW_i)(DemNF_i)$

= $[\beta_4 + \beta_7(SexMW_i)]$ that multiplies $(DemNF_i)$

Simple None vs. Current Slope = $\beta_5(DemNC_i) + \beta_8(SexMW_i)(DemNC_i)$

= $[\beta_5 + \beta_8(SexMW_i)]$ that multiplies $(DemNC_i)$

Simple Future vs. Current Slope = $[\beta_5 + \beta_8(SexMW_i)] - [\beta_4 + \beta_7(SexMW_i)]$

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

```
  "A: Sex effect differ btw None and Future?"          = c(0,0,0,0,0,0,0, 1,0),
  "A: None-Future effect differ btw Men and Women?"    = c(0,0,0,0,0,0,0, 1,0),

  "B: Sex effect differ btw None and Current?"         = c(0,0,0,0,0,0,0, 0,1),
  "B: None-Current effect differ btw Men and Women?"   = c(0,0,0,0,0,0,0, 0,1),

  "C: Sex effect differ btw Future and Current?"       = c(0,0,0,0,0,0,0,-1,1),
  "C: Future-Current effect differ btw Men and Women?" = c(0,0,0,0,0,0,0,-1,1)))

glhtSummaryCI(glhtModelSexDem, level=.95)  # custom function to add CIs to glht output
```

```
                                                    Estimate Std.Err p.value Lower.CI Upper.CI
Sex Diff for No Dementia                             -2.8756   1.011  0.0046   -4.862  -0.8892
Sex Diff for Future Dementia                         -2.7113   1.874  0.1485   -6.393   0.9700
Sex Diff for Current Dementia                       -10.7507   2.899  0.0002  -16.446  -5.0554

None-Future Diff for Men                             -6.0559   1.635  0.0002   -9.268  -2.8439
None-Future Diff for Women                           -5.8916   1.278 <0.0001   -8.402  -3.3817
None-Current Diff for Men                           -11.9707   2.245 <0.0001  -16.381  -7.5608
None-Current Diff for Women                         -19.8458   2.029 <0.0001  -23.831 -15.8610
Future-Current Diff for Men                          -5.9148   2.587  0.0226  -10.996  -0.8335
Future-Current Diff for Women                       -13.9542   2.239 <0.0001  -18.352  -9.5562

A: Sex effect differ btw None and Future?             0.1643   2.070  0.9368   -3.903   4.2314
A: None-Future effect differ btw Men and Women?       0.1643   2.070  0.9368   -3.903   4.2314
B: Sex effect differ btw None and Current?           -7.8751   3.025  0.0095  -13.816  -1.9338
B: None-Current effect differ btw Men and Women?     -7.8751   3.025  0.0095  -13.816  -1.9338
C: Sex effect differ btw Future and Current?         -8.0394   3.415  0.0189  -14.748  -1.3308
C: Future-Current effect differ btw Men and Women?   -8.0394   3.415  0.0189  -14.748  -1.3308
```

```
glhtEffectSizes(glhtObject=glhtModelSexDem, modelObject=ModelSexDem, level=.95)
# custom function to compute glht effect sizes (R2 versions not shown below
```

```
                                                  Estimate p.value Partial.d Partial.r SemiPartial.r
Sex Diff for No Dementia                           -2.8756  0.0046 -0.244515 -0.121354     -0.102402
Sex Diff for Future Dementia                       -2.7113  0.1485 -0.124402 -0.062081     -0.052099
Sex Diff for Current Dementia                     -10.7507  0.0002 -0.318839 -0.157431     -0.133529

None-Future Diff for Men                           -6.0559  0.0002 -0.318463 -0.157250     -0.133371
None-Future Diff for Women                         -5.8916 <0.0001 -0.396476 -0.194454     -0.166043
None-Current Diff for Men                         -11.9707 <0.0001 -0.458506 -0.223456     -0.192020
None-Current Diff for Women                       -19.8458 <0.0001 -0.841217 -0.387709     -0.352298
Future-Current Diff for Men                        -5.9148  0.0226 -0.196615 -0.097836     -0.082342
Future-Current Diff for Women                     -13.9542 <0.0001 -0.535918 -0.258828     -0.224440

A: Sex effect differ btw None and Future?           0.1643  0.9368  0.006822  0.003411      0.002857
A: None-Future effect differ btw Men and Women?     0.1643  0.9368  0.006822  0.003411      0.002857
B: Sex effect differ btw None and Current?         -7.8751  0.0095 -0.223887 -0.111249     -0.093763
B: None-Current effect differ btw Men and Women?   -7.8751  0.0095 -0.223887 -0.111249     -0.093763
C: Sex effect differ btw Future and Current?       -8.0394  0.0189 -0.202415 -0.100693     -0.084770
C: Future-Current effect differ btw Men and Women? -8.0394  0.0189 -0.202415 -0.100693     -0.084770
```

```
FixedEffectSizes(ModelSexDem)     # custom function to add effect sizes for fixed slopes
```

```
            Estimate p.value Partial.d Partial.r SemiPartial.r Partial.R2 SemiPartial.R2
(Intercept)  29.0701 <0.0001  3.339545  0.857915      1.398589 0.73601817    1.956050362
age85        -0.3348  0.0054 -0.240127 -0.119207     -0.100564 0.01421041    0.010113182
grip9         0.6179 <0.0001  0.358798  0.176580      0.150263 0.03118046    0.022579023
sexMW        -2.8756  0.0046 -0.244515 -0.121354     -0.102402 0.01472680    0.010486181
demNF        -6.0559  0.0002 -0.318463 -0.157250     -0.133371 0.02472770    0.017787847
demNC       -11.9707 <0.0001 -0.458506 -0.223456     -0.192020 0.04993255    0.036871840
age85:grip9   0.1222  0.0026  0.260289  0.129056      0.109008 0.01665551    0.011882774
sexMW:demNF   0.1643  0.9368  0.006822  0.003411      0.002857 0.00001164    0.000008163
sexMW:demNC  -7.8751  0.0095 -0.223887 -0.111249     -0.093763 0.01237624    0.008791495
```

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

JOHNSON-NEYMAN INTERVAL → **[9.680, 18.638] pounds in original metric**

```
When grip9 is OUTSIDE the interval [0.680, 9.521], the slope of age85 is p < .05.
Note: The range of observed values of grip9 is [-9.000, 10.000]
```

This result indicates that the age slope will be significantly negative below grip = 9.680 pounds, nonsignificant between grip = 9.680 and 18.638 pounds, and significantly positive after grip = 18.638 pounds.

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

JOHNSON-NEYMAN INTERVAL → **[69.997, 82.707] years in original metric**

```
When age85 is OUTSIDE the interval [-15.003, -2.293], the slope of grip9 is p < .05.
Note: The range of observed values of age85 is [-4.984, 11.967]
```

This result indicates that the grip strength slope will be significantly negative below age = 69.997 years, nonsignificant between age = 69.997 and 82.707 years, and significantly positive after age = 82.707 years.

```
print("Simple slope boundaries for age and grip given by regions of significance")
glhtSlopesSexDem = glht(model=ModelSexDem, linfct=rbind(
  "Age Slope at Grip =  9.680"  = c(0,1,0,0,0,0,  0.680, 0,0),  # Multipliers in order
  "Age Slope at Grip = 18.638"  = c(0,1,0,0,0,0,  9.638, 0,0),
  "Grip Slope at Age = 69.997"  = c(0,0,1,0,0,0,-15.003, 0,0),
  "Grip Slope at Age = 82.707"  = c(0,0,1,0,0,0, -2.293, 0,0)))
glhtSummaryCI(glhtSlopesSexDem, level=.95)  # custom function to add CIs to glht output
```

```
                           Estimate Std.Err p.value      Lower.CI      Upper.CI
Age Slope at Grip =  9.680  -0.2517  0.1281  0.0500 -0.503437057 -0.000034322
Age Slope at Grip = 18.638   0.8425  0.4289  0.0500 -0.000003324  1.684999895
Grip Slope at Age = 69.997  -1.2147  0.6184  0.0500 -2.429504034  0.000009034
Grip Slope at Age = 82.707   0.3378  0.1719  0.0500  0.000029501  0.675569008
```

Example Results Section for Sex*Dementia Group Model as Equation 3 [notes about what could be included]:

We estimated a new model (as shown in Equation 3) adding an interaction between sex and dementia group to examine the extent to which the dementia slopes differed between men and women (and how the sex difference differed across dementia groups). The augmented model accounted for a significant amount of variance in cognition, $F(8, 541) = 28.77$, MSE = 85.97, $p < .0001$, $R^2 = .298$. The omnibus sex by dementia group interaction was significant, $F(2, 541) = 3.49$, $p = .031$, and added .009 to the model R^2 relative to the previous model. Table 1 provides the model results, including the fixed effects estimated directly in the model, as well as their linear combinations that provide simple slopes by which to describe the sex by dementia group interaction. Effect sizes in Cohen's *d* (standardized mean difference) and partial *r* (correlation metric) are also provided in Table 1.

Results from this model can be interpreted as follows. The intercept $\beta_0 = 29.07$ is the expected cognition outcome for an 85-year-old man with 9 pounds of grip strength who will not be diagnosed with dementia later in the study. The simple main effect of age $\beta_1 = -0.33$ indicated that cognition is predicted to be significantly lower by 0.33 for every additional year of age (in persons with grip strength of 9 pounds). The simple main effect of grip strength $\beta_2 = 0.62$ indicated that cognition is predicted to be significantly greater by 0.62 for every additional pound of grip strength (in persons who are age 85). As shown in [figure generated from this model], the age by grip strength interaction $\beta_6 = 0.12$ indicated that the age slope predicting cognition became significantly less negative by 0.12 for each additional pound of grip strength (as shown by the difference in slope across 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 difference in the vertical distance between the lines). 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 asymptotic covariance matrix (see Hoffman, 2015). For the effect of age, the threshold values of grip strength were 9.68 and 18.64 pounds. Given the range of grip strength of 0–19 pounds in the current sample (M ≈ 9 pounds), the effect of age is expected to be negative for about half the sample (below 9.68 pounds), the effect of age is expected to be nonsignificant for the other half (between 9.68 and 18.64 pounds), and the effect of age is expected to be positive for almost no one (above 18.64 pounds). Similarly, for the effect of grip strength, the threshold values of age were 70.00 and 82.71 years. Given the range of age of 80–97 years in the sample (M ≈ 85 years), the effect of grip strength is expected to be negative for no one (below 70.00 years), the effect of grip strength is expected to be nonsignificant for a small part of the sample (between 70.00 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).

The main and interactive effects of sex by dementia group are presented next, as illustrated in Figure 3, in which the sex differences are shown by the vertical distance between the lines, and the dementia group differences are shown by the difference within the lines. [Figure 4 could also be used instead.] Given the significant sex by dementia group interaction, $F(2, 541) = 3.49$, $p = .031$, simple slopes and their differences (i.e., interaction contrasts) for both sex and dementia group are reported next.

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

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

Table 1: Results for Final Model

	Model Parameter	Est	SE	$p <$	d	r
β_0	Intercept	**29.07**	0.75	.001		
β_1	Age Slope	**−0.33**	0.12	.005	−.240	−.119
β_2	Grip Strength Slope	**0.62**	0.15	.001	.359	.177
β_6	Age by Grip Interaction	**0.12**	0.04	.003	.260	.129
	Sex (0 = Men, 1 = Women) Differences:					
β_3	No Diagnosis	**−2.88**	1.01	.005	−.245	−.121
$\beta_3 + \beta_7$	Future Diagnosis	−2.71	1.87	.149	−.124	−.062
$\beta_3 + \beta_8$	Current Diagnosis	**−10.75**	2.90	.001	−.319	−.157
	Dementia Group Differences:					
	None vs. Future Diagnosis					
β_4	Men	**−6.06**	1.64	.001	−.318	−.157
$\beta_4 + \beta_7$	Women	**−5.89**	1.28	.001	−.396	−.194
β_7	Sex by None vs. Future	0.16	2.07	.937	.007	.003
	None vs. Current Diagnosis					
β_5	Men	**−11.97**	2.25	.001	−.459	−.223
$\beta_5 + \beta_8$	Women	**−19.85**	2.03	.001	−.841	−.388
β_8	Sex by None vs. Current	**−7.88**	3.03	.010	−.224	−.111
	Future vs. Current Diagnosis					
$\beta_5 - \beta_4$	Men	**−5.91**	2.59	.023	−.197	−.098
$\beta_5 - \beta_4 + \beta_8 - \beta_7$	Women	**−13.95**	2.24	.001	−.536	−.259
$\beta_8 - \beta_7$	Sex by Future vs. Current	**−8.04**	3.42	.019	−.202	−.101
Model for the Variance						
σ_e^2	Residual Variance	85.97				
	R^2 relative to Empty Model	.30				

Note: d and r partial effect sizes were computed from the slope t test-statistics as follows: $d = \frac{2t}{\sqrt{DF_{den}}}$; $r = \frac{t}{\sqrt{t^2 + DF_{den}}}$. Bold estimates indicate $p < .05$.