

## Example 5: General Linear Models with Single-DF and Multiple-DF Interactions (complete data, syntax, and output in R available online)

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 from the [Octogenarian Twin Study of Aging](#)), 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). After starting with a main-effects-only model, 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. This example will continue to estimate general linear models using the base R `lm` function. It will demonstrate how to create predicted outcomes using the `prediction` R package, how to estimate simple (conditional) slopes using the `glht` function from the `multcomp` R package and the `simple_slopes` function from the `reghelper` R package, and how to obtain regions of significance from the `interactions` R package.

**Syntax for importing and preparing data for analysis (after loading packages `TeachingDemos`, `readxl`, `multcomp`, `supernova`, `prediction`, `lmhelpers`, `reghelper`, and `interactions`):**

```
# Set working directory (to import and export files to)
# Paste in the folder address where your data file is saved in quotes
# Note the slashes are backwards relative to Windows file paths
setwd("C:/Dropbox/26_EDF9770/Example5/")

# Import Example5_Data.xlsx data from working directory -- path = file name
Example5 = read_excel(path="Example5_Data.xlsx", sheet="Data")
# Convert to data frame to use for analysis
Example5 = as.data.frame(Example5)

# Load R functions for this class from R file in working directory
source("EDF9770_Functions.R")
```

**Descriptive statistics and creating new predictor variables:**

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

print("R Descriptive Statistics for Quantitative Variables")
psych::describe(x=Example5[ , c("cognition", "age", "grip", "sexMW")])
```

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

```
# Center quantitative predictors near their means
Example5$age85=Example5$age-85 # age85: Age in Years (0=85)
Example5$grip9=Example5$grip-9 # grip9: Grip Strength in Pounds (0=9)
```

```
print("R Descriptive Statistics for Categorical Variables")
prop.table(table(x=Example5$sexMW, useNA="ifany")) # 0=Men, 1=Women
```

```
      0      1
0.4127 0.5873
```

```
prop.table(table(x=Example5$demgroup,useNA="ifany")) # 1=None, 2=Future, 3=Current
```

```
      1      2      3
0.72545 0.19818 0.07636
```

```
# Create 2 indicator-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 # 1=None
Example5$demNC[which(Example5$demgroup==1)]=0
Example5$demNF[which(Example5$demgroup==2)]=1 # 2=Future
Example5$demNC[which(Example5$demgroup==2)]=0
Example5$demNF[which(Example5$demgroup==3)]=0 # 3=Current
Example5$demNC[which(Example5$demgroup==3)]=1
# demNF: None=0 vs Future=1, demNC: None=0 vs Current=1
```

demgroup	demNF	demNC
1 = None	0	0
2 = Future	1	0
3 = Current	0	1

**Bivariate relations—first, let's check age and grip strength for nonlinear relations:**

$$\text{Cognition}_i = \beta_0 + \beta_1(\text{Age}_i - 85) + \beta_2(\text{Age}_i - 85)^2 + e_i$$

```
print("Quadratic Age?")
ModelQuadAge = lm(data=Example5, formula=cognition~1+age85+I(age85^2))
obj=LMSummary(ModelQuadAge) # Custom output
```

```
Fixed Effects Table
      Est      SE      t      p      LCI      UCI
Intercept 24.571 0.601 40.912 <0.001 23.392 25.751
age85     -0.609 0.178 -3.433 <0.001 -0.958 -0.261
I(age85^2) 0.018 0.032 0.549 0.583 -0.045 0.080
```

$$\text{Cognition}_i = \beta_0 + \beta_1(\text{Grip}_i - 9) + \beta_2(\text{Grip}_i - 9)^2 + e_i$$

```
print("Quadratic Grip?")
ModelQuadGrip = lm(data=Example5, formula=cognition~1+grip9+I(grip9^2))
obj=LMSummary(ModelQuadGrip) # Custom output
```

```
Fixed Effects Table
      Est      SE      t      p      LCI      UCI
Intercept 24.579 0.566 43.420 <0.001 23.467 25.691
grip9      0.888 0.153 5.801 <0.001 0.587 1.188
I(grip9^2) 0.016 0.038 0.424 0.671 -0.058 0.090
```

**Now that we have evidence that a linear trend for both age and grip is sufficient, let's examine their linear relations with cognition (and with binary sex, in which 0 = men and 1=women):**

```
print("Pearson Correlation Matrix with p-values -- Must convert data frame to matrix")
Corrs=Hmisc::rcorr(x=as.matrix(Example5
      [,c("cognition","age","grip","sexMW")]), type="pearson"); Corrs
```

```
      cognition age grip sexMW
cognition 1.00 -0.17 0.24 -0.24
age        -0.17 1.00 -0.18 0.05
grip        0.24 -0.18 1.00 -0.40
sexMW       -0.24 0.05 -0.40 1.00
```

```
n= 550
```

```
P
      cognition age grip sexMW
cognition 0.0000 0.0000 0.0000
age        0.0000 0.0000 0.2858
grip        0.0000 0.0000 0.0000
sexMW       0.0000 0.2858 0.0000
```

**What can we conclude about the linear relationships between each pair of variables?****Cognition and age:** neg sig**Cognition and grip:** pos sig**Cognition and sex:** neg sig**Age and grip:** neg sig**Age and sex:** pos pos nonsig**Grip and sex:** neg sig

Our fourth predictor is three-category dementia group—we do not yet know if there is a significant bivariate relation of dementia group with cognition. A Pearson correlation would not have provided the desired interpretation of each binary predictor (i.e., it would have lumped together both groups coded 0 within each binary predictor). Instead, we can examine their bivariate relation by predicting cognition with dementia group in a GLM:

demgroup	demNF	demNC
1 = None	0	0
2 = Future	1	0
3 = Current	0	1

$$\text{Cognition}_i = \beta_0 + \beta_1(\text{DemNF}_i) + \beta_2(\text{DemNC}_i) + e_i$$

Linear combination for difference of future vs current dementia:

$$(\beta_0 + \beta_2) - (\beta_0 + \beta_1) = \beta_2 - \beta_1$$

```
print("Demgroup")
ModelDem = lm(data=Example5, formula=cognition~1+demNF+demNC)
obj=lmsummary(ModelDem) # Custom output
```

```
Sums of Squares Table
      SS  DF  MS  F  p  R2
Model 11685.511  2 5842.755 58.523 <0.001 0.176
Error 54611.027 547  99.837
Total 66296.538 549 120.759
```

```
Fixed Effects Table
      Est  SE  t  p  LCI  UCI
Intercept 27.198 0.500 54.372 <0.001 26.215 28.181
demNF -5.675 1.080 -5.255 <0.001 -7.796 -3.554
demNC -16.388 1.621 -10.111 <0.001 -19.572 -13.205
```

```
print("R Ask for missing model-implied group difference as beta3-beta2")
glhtDem = multcomp::glht(model=ModelDem, linfct=rbind("Future vs Current"=c(0,-1,1)))
obj=glhtSummary(glhtObject=glhtDem) # Custom output
```

```
Linear Combinations Table
      Est  SE  t  p  LCI  UCI
Future vs Current -10.713 1.815 -5.904 <0.001 -14.278 -7.149
```

```
R2=Corrs[["r"]]2; R2 # Print R2 values
      cognition  age  grip  sexMW
cognition  1.00000 0.029054 0.05848 0.055830
age         0.02905 1.000000 0.03391 0.002079
grip       0.05848 0.033906 1.00000 0.162605
sexMW      0.05583 0.002079 0.16260 1.000000
```

Given that bivariate relations can be expressed using  $R^2$  more generally, here is the squared version of the  $r$  matrix for the other single-slope predictors

**Model 1 with main effects only (Equation 2.8 in chapter 2):** How do age in years, grip strength in pounds per square inch, binary sex, and dementia diagnosis each uniquely predict cognition?

$$\text{Equation 1: } \text{Cognition}_i = \beta_0 + \beta_1(\text{Age}_i - 85) + \beta_2(\text{Grip}_i - 9) + \beta_3(\text{SexMW}_i) + \beta_4(\text{DemNF}_i) + \beta_5(\text{DemNC}_i) + e_i$$

Linear combination for difference of future vs current dementia:

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

```
print("R Main-Effects-Only Model Predicting Cognition (Equation 2.8)")
Modell1 = lm(data=Example5, formula=cognition~1+age85+grip9+sexMW+demNF+demNC)
obj=LMSummary(Modell1, explain=TRUE, effectsizes=TRUE) # Custom output
```

Sums of Squares Table

	SS	DF	MS	F	p	R2
Model	18385.979	5	3677.196	41.753	<0.001	0.277
Error	47910.559	544	88.071			
Total	66296.538	549	120.759			

Fixed Effects Table

	Est	SE	t	p	LCI	UCI	
Intercept	29.264	0.699	41.895	<0.001	27.892	30.636	beta0
age85	-0.406	0.119	-3.412	<0.001	-0.639	-0.172	beta1
grip9	0.604	0.150	4.034	<0.001	0.310	0.898	beta2
sexMW	-3.657	0.891	-4.103	<0.001	-5.408	-1.906	beta3
demNF	-5.722	1.019	-5.615	<0.001	-7.724	-3.720	beta4
demNC	-16.480	1.523	-10.822	<0.001	-19.471	-13.489	beta5

Effect Sizes for Fixed Effects Table

	Est	SE	p	d	pr	sR2
age85	-0.406	0.119	<0.001	-0.293	-0.145	0.015
grip9	0.604	0.150	<0.001	0.346	0.170	0.022
sexMW	-3.657	0.891	<0.001	-0.352	-0.173	0.022
demNF	-5.722	1.019	<0.001	-0.481	-0.234	0.042
demNC	-16.480	1.523	<0.001	-0.928	-0.421	0.156

```
print("R Ask for missing model-implied group difference as beta5-beta4")
```

```
SlopesModell1 = multcomp::glht(model=Modell1,
                               linfct=rbind("Future vs Current"=c(0,0,0,0,-1,1)))
obj=glhtSummary(glhtObject=SlopesModell1, effectsizes=TRUE) # Custom output
```

Linear Combinations Table

	Est	SE	t	p	LCI	UCI	
Future vs Current	-10.758	1.708	-6.299	<0.001	-14.113	-7.403	beta5-beta4

Effect Sizes for Linear Combinations Table

	Est	SE	p	d	pr	sR2
Future vs Current	-10.758	1.708	<0.001	-0.540	-0.261	0.053

```
# Get F-test and effect sizes for change in R2 from full model for demgroup
```

```
Modell1NoDem = lm(data=Example5, formula=cognition~1+age85+grip9+sexMW)
obj=R2compare(ReducedModel=Modell1NoDem, FullModel=Modell1, PredName="Demgroup")
```

F-Test and R2 Change for Demgroup Slopes

R2reduced	R2full	R2diff	DFnum	DFden	F	p	pR2	sR2
0.099	0.277	0.178	2	544	67.056	<0.001	0.198	0.178

Let's compare effect sizes from the bivariate to unique versions of the same relations:

	Bivariate R2	Unique sR2
age85	0.029	0.015
grip9	0.058	0.022
sexMW	0.056	0.022
demgroup	0.176	0.178

## Example Results Section Part 1

### Analytic Strategy

The extent to which cognition (as measured by the information test) could be predicted from age in years, grip strength in pounds per square inch, binary sex, and dementia group was examined in a series of general linear models. All analyses were conducted using the `lm` function in R v. 4.5.2. Predicted outcomes and linear combinations of the fixed effects were generated using the `glht` function within the `multcomp` package v. 1.4-29. To provide a meaningful intercept in the models that follow, we centered age such that 0 = 85 years and grip strength such that 0 = 9 pounds per square inch (i.e., near their sample means). Sex was coded such that 0 = men and 1 = women. Dementia group was represented by two binary contrasts to distinguish the three types, in which no diagnosis served as the reference to be compared to future diagnosis and current diagnosis.

### Bivariate Relations

The predictors were first examined in separate models to obtain their bivariate relations (i.e., before controlling for the other predictors). Cognition was significantly higher in persons who were younger ( $R^2 = .029$ ), with greater grip strength ( $R^2 = .058$ ), and who were men ( $R^2 = .056$ ). Although we examined the potential for quadratic effects of age and grip strength, neither quadratic slope was significant, indicating that linear slopes for age and grip strength were likely to be sufficient. In a separate analysis of variance, we examined the bivariate effect of dementia group and found significant mean differences in cognition across the three groups,  $F(2, 547) = 58.52$ ,  $MSE = 99.84$ ,  $p < .001$ ,  $R^2 = .176$ . Relative to the reference group of persons with no diagnosis, cognition was significantly lower in both the future and current diagnosis groups; cognition was also significantly lower in the current than future diagnosis group.

### Main Effects Model

The results from a combined model (as shown in Equation 1) with main effects for all four predictors are shown in Table 1. In addition to the partial  $r$  and Cohen's  $d$  effect sizes given in Table 1, semi-partial squared correlation ( $sR^2$ ) effect sizes were also obtained to describe the amount of variance in cognition explained by each predictor variable. The model accounted for a significant amount of variance in cognition,  $F(5, 544) = 41.75$ ,  $MSE = 88.07$ ,  $p < .0001$ ,  $R^2 = .277$ . The unique contribution of each predictor remained significant in the same direction as their bivariate effects. Cognition was predicted to be significantly lower by 0.41 per year of age ( $sR^2 = .015$ ), significantly higher by 0.60 per pound per square inch of grip strength ( $sR^2 = .022$ ), and significantly lower by 3.66 in women ( $sR^2 = .022$ ). The overall effect of dementia group remained significant,  $F(2, 544) = 67.06$ ,  $p < .001$ ,  $sR^2 = .178$ . Relative to the reference group of persons with no diagnosis, cognition was significantly lower by 5.72 in the future diagnosis group, significantly lower by 16.48 in the current diagnosis group, and cognition was significantly lower by 10.76 in the future than current diagnosis group.

**Table 1**  
Results from Main Effects Model in Equation 1

Fixed Effect	Est	SE	$p <$	Cohen's $d$	Partial $r$
$\beta_0$ Intercept	29.264	0.699			
$\beta_1$ Age (0=85 years)	-0.406	0.119	.001	-0.293	-0.145
$\beta_2$ Grip (0=9 pounds)	0.604	0.150	.001	0.346	0.170
$\beta_3$ Sex (0=Men)	-3.657	0.891	.001	-0.352	-0.173
$\beta_4$ None vs Future Dementia	-5.722	1.019	.001	-0.481	-0.234
$\beta_5$ None vs Current Dementia	-16.480	1.523	.001	-0.928	-0.421
$\beta_5 - \beta_4$ Future vs Current Dementia	-10.758	1.708	.001	-0.540	-0.261

Note: Est = estimate, SE = standard error. Cohen's  $d$  and partial  $r$  effect sizes were computed from the slope of each  $t$  test-statistic as follows:  $d = \frac{2t}{\sqrt{DF_{den}}}$ ;  $r = \frac{t}{\sqrt{t^2 + DF_{den}}}$ .

**FOR HW5 → Model 2 adding sex by age and sex by grip: Do the effects of age and grip strength differ between men and women?**

$$\text{Equation 2: } \text{Cognition}_i = \beta_0 + \beta_1(\text{Age}_i - 85) + \beta_2(\text{Grip}_i - 9) + \beta_3(\text{SexMW}_i) + \beta_4(\text{DemNF}_i) + \beta_5(\text{DemNC}_i) + \beta_6(\text{SexMW}_i)(\text{Age}_i - 85) + \beta_7(\text{SexMW}_i)(\text{Grip}_i - 9) + e_i$$

```
print("Model 2: Add 2 Interactions -- Sex by Age, Sex by Grip")
Model2 = lm(data=Example5, formula=cognition~1+age85+grip9+sexMW+demNF+demNC
           +age85:sexMW +grip9:sexMW)

# Get F-test and effect sizes for change in R2 from full model for program
obj=R2compare(ReducedModel=Model1, FullModel=Model2, PredName="Sex*Age and Sex*Grip")
```

```
F-Test and R2 Change for Sex*Age and Sex*Grip Slopes
R2reduced R2full R2diff DFnum DFden F p pR2 sR2
0.277 0.279 0.002 2 542 0.814 0.444 0.003 0.002
```

```
obj=LMsummary(Model2, effectsizes=TRUE) # Custom output
```

```
Sums of Squares Table
      SS DF      MS      F      p      R2
Model 18529.397  7 2647.057 30.035 <0.001 0.279
Error 47767.141 542  88.131
Total 66296.538 549 120.759
```

```
Fixed Effects Table
      Est SE      t      p      LCI      UCI
Intercept 29.172 0.758 38.467 <0.001 27.682 30.662 beta0
age85 -0.232 0.189 -1.226 0.221 -0.604 0.140 beta1
grip9 0.697 0.239 2.918 0.004 0.228 1.166 beta2
sexMW -3.627 0.911 -3.980 <0.001 -5.416 -1.837 beta3
demNF -5.749 1.020 -5.635 <0.001 -7.753 -3.745 beta4
demNC -16.495 1.523 -10.828 <0.001 -19.487 -13.502 beta5
age85:sexMW -0.295 0.244 -1.208 0.227 -0.774 0.184 beta6
grip9:sexMW -0.177 0.307 -0.576 0.565 -0.779 0.426 beta7
```

Effect Sizes for Fixed Effects Table						
	Est	SE	p	d	pr	sR2
age85	-0.232	0.189	0.221	-0.105	-0.053	0.002
grip9	0.697	0.239	0.004	0.251	0.124	0.011
sexMW	-3.627	0.911	<0.001	-0.342	-0.169	0.021
demNF	-5.749	1.020	<0.001	-0.484	-0.235	0.042
demNC	-16.495	1.523	<0.001	-0.930	-0.422	0.156
age85:sexMW	-0.295	0.244	0.227	-0.104	-0.052	0.002
grip9:sexMW	-0.177	0.307	0.565	-0.050	-0.025	0.000

**Interpret  $\beta_1$  for age85:** cog is lower by .232 per year of age *in men*

**Interpret  $\beta_6$  for age85\*sexMW with sex as moderator:** age slope is more neg in women by .295

**Interpret  $\beta_2$  for grip9:** cog is higher by .700 per pound of grip *in men*

**Interpret  $\beta_7$  for grip9\*sexMW with sex as moderator:** grip slope is less pos in women by .177

**Interpret  $\beta_3$  for sexMW:** women are lower than men by 3.627 for age=85 and grip=9

**Interpret  $\beta_6$  for age85\*sexMW with age85 as moderator:** sex diff larger by 0.295 per year of age

**Interpret  $\beta_7$  for grip9\*sexMW with grip9 as moderator:** sex diff larger by 0.177 per pound of grip

**Computing "simple" (conditional) age and grip strength slopes for men and women:**

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

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

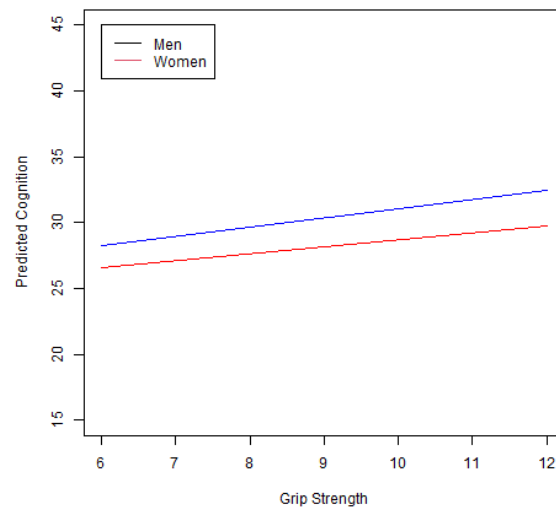
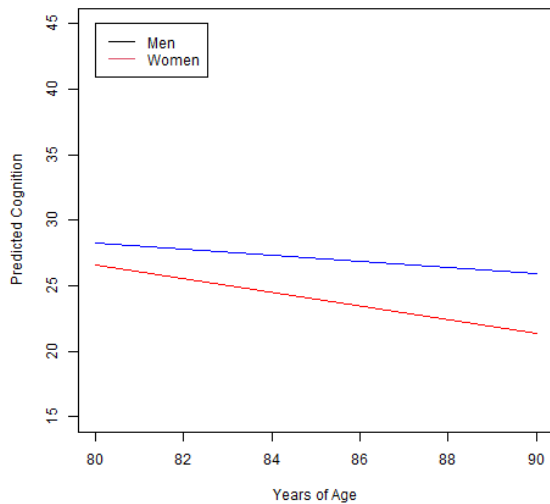
$$\begin{aligned} \text{Simple Age Slope} = & \beta_1(Age_i - 85) + \beta_6(SexMW_i)(Age_i - 85) \\ = & [\beta_1 + \beta_6(SexMW_i)] \text{ that multiplies } (Age_i - 85) \end{aligned}$$

$$\begin{aligned} \text{Simple Grip Slope} = & \beta_2(Grip_i - 9) + \beta_7(SexMW_i)(Grip_i - 9) \\ = & [\beta_2 + \beta_7(SexMW_i)] \text{ that multiplies } (Grip_i - 9) \end{aligned}$$

```
print("Simple slopes of age by sex, simple slopes of sex by age")
SlopesModel2 = multcomp::glht(model=Model2, linfct=rbind(
  "Age Slope for Men"      = c(0,1,0,0,0,0,0,0), # 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)))
obj=glhtSummary(glhtObject=SlopesModel2, effectsizes=TRUE) # Custom output
```

Linear Combinations Table						
	Est	SE	t	p	LCI	UCI
Age Slope for Men	-0.232	0.189	-1.226	0.221	-0.604	0.140
Age Slope for Women	-0.527	0.154	-3.428	<0.001	-0.829	-0.225
Grip Slope for Men	0.697	0.239	2.918	0.004	0.228	1.166
Grip Slope for Women	0.520	0.193	2.694	0.007	0.141	0.899

Effect Sizes for Linear Combinations Table						
	Est	SE	p	d	pr	sR2
Age Slope for Men	-0.232	0.189	0.221	-0.105	-0.053	0.002
Age Slope for Women	-0.527	0.154	<0.001	-0.294	-0.146	0.016
Grip Slope for Men	0.697	0.239	0.004	0.251	0.124	0.011
Grip Slope for Women	0.520	0.193	0.007	0.231	0.115	0.010



```
print("Pred cognition outcomes holding demNF=none, and demNC=none")
print("Provides predicted outcomes from min,max,by=increment of predictors")
PredModel2 = prediction::prediction(model=Model2, type="response",
  at=list(demNF=0, demNC=0, grip9=seq(-3,3,by=6), age85=seq(-5,5,by=10), sexMW=0:1))
PlotModel2 = summary(PredModel2); print(PlotModel2, digits=6) # Save and print predictions for plotting
```

at (demNF)	at (demNC)	at (grip9)	at (age85)	at (sexMW)	Prediction	SE	z	p	lower	upper
0	0	-3	-5	0	28.24	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

```
# Make and save plots of Predicted Outcomes
png(file = "Sex by Grip=x GLM Plot.png") # open file
PlotModel2age80 = PlotModel2[which(PlotModel2$`at (age85)`== -5),] # Subset to age=80
plot(y=PlotModel2age80$Prediction, x=(PlotModel2age80$`at (grip9)`+9), type="n", # n= no dots
  ylim=c(15,45), xlim=c(6,12), xlab="Grip Strength", ylab="Predicted Cognition")
lines(x=(PlotModel2age80$`at (grip9)`+9)[1:2], y=PlotModel2age80$Prediction[1:2], type="l", col="blue1")
lines(x=(PlotModel2age80$`at (grip9)`+9)[3:4], y=PlotModel2age80$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 = "Sex by Age=x GLM Plot.png") # open file
PlotModel2grip6 = PlotModel2[which(PlotModel2$`at (grip9)`== -3),] # Subset to grip=6
plot(y=PlotModel2grip6$Prediction, x=(PlotModel2grip6$`at (grip9)`+9), type="n", # n= no dots
  ylim=c(15,45), xlim=c(80,90), xlab="Years of Age", ylab="Predicted Cognition")
lines(x=(PlotModel2grip6$`at (age85)`+85)[1:2], y=PlotModel2grip6$Prediction[1:2], type="l",
  col="blue1")
lines(x=(PlotModel2grip6$`at (age85)`+85)[3:4], y=PlotModel2grip6$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
```

## Example Results Section Part 2

### Interactions of Sex with Age and Grip Strength

We then estimated a new model (as shown in Equation 2) 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.

**NONE OF WHAT FOLLOWS IS NEEDED FOR HW05,  
but this model provides an example of a quantitative\*quantitative predictor interaction...**

**Model 3 removing 2 sex interactions; add interaction of age by grip (Equation 2.9 in chapter 2):**

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

$$\text{Model 3: } \text{Cognition}_i = \beta_0 + \beta_1(\text{Age}_i - 85) + \beta_2(\text{Grip}_i - 9) + \beta_3(\text{SexMW}_i) + \beta_4(\text{DemNF}_i) + \beta_5(\text{DemNC}_i) + \beta_6(\text{Age}_i - 85)(\text{Grip}_i - 9) + e_i$$

```
print("Model 3: Remove 2 Sex Interactions, Add Age by Grip Interaction (Equation 2.9)")
Model3 = lm(data=Example5, formula=cognition~1+age85+grip9+sexMW+demNF+demNC+age85:grip9)
obj=lmsummary(Model3, effectsizes=TRUE) # Custom output
```

```
Sums of Squares Table
      SS DF      MS      F      p      R2
Model 19185.041  6 3197.507 36.854 <0.001 0.289
Error  47111.497 543  86.762
Total  66296.538 549  120.759
```

```
Fixed Effects Table
      Est SE      t      p      LCI      UCI
Intercept 29.408 0.695 42.319 <0.001 28.043 30.773
age85     -0.334 0.120 -2.775 0.006 -0.570 -0.098
grip9      0.619 0.149  4.164 <0.001  0.327  0.912
sexMW     -3.456 0.887 -3.895 <0.001 -5.199 -1.713
demNF     -5.923 1.014 -5.843 <0.001 -7.914 -3.931
demNC    -16.300 1.513 -10.777 <0.001 -19.272 -13.329
age85:grip9 0.123 0.041  3.035 0.003  0.043  0.203
```

```
Effect Sizes for Fixed Effects Table
      Est SE      p      d      pr      sR2
age85     -0.334 0.120 0.006 -0.238 -0.118 0.010 beta0
grip9      0.619 0.149 <0.001  0.357  0.176 0.023 beta1
sexMW     -3.456 0.887 <0.001 -0.334 -0.165 0.020 beta2
demNF     -5.923 1.014 <0.001 -0.501 -0.243 0.045 beta3
demNC    -16.300 1.513 <0.001 -0.925 -0.420 0.152 beta4
age85:grip9 0.123 0.041 0.003  0.260  0.129 0.012 beta5
```

**Interpret  $\beta_1$  for age85:** cog is lower by 0.334 per year for grip=9

**Interpret  $\beta_6$  for age85\*grip9 with grip9 as moderator:** negative age slope becomes weaker by 0.123 per pound of grip

**Interpret  $\beta_2$  for grip9:** cog is higher by 0.619 per pound of grip for age=85

**Interpret  $\beta_6$  for age85\*grip9 with age85 as moderator:** positive grip strength slope becomes stronger by 0.123 per year of age

```
# Get F-test and effect sizes for change in R2 from full model for demgroup
Model3NoDem = lm(data=Example5, formula=cognition~1+age85+grip9+sexMW+age85:grip9)

obj=R2compare(ReducedModel=Model3NoDem, FullModel=Model3, PredName="Demgroup")
```

```
F-Test and R2 Change for Demgroup Slopes
R2reduced R2full R2diff DFnum DFden      F      p      pR2      sR2
  0.112  0.289  0.177    2    543 67.701 <0.001 0.200 0.177
```

```
print("R Ask for missing model-implied group difference as beta5-beta4")
SlopesModel3 = multcomp::glht(model=Model3,
                             linfct=rbind("Future vs Current"=c(0,0,0,0,-1,1,0)))
obj=glhtSummary(glhtObject=SlopesModel3, effectsizes=TRUE) # Custom output
```

Linear Combinations Table

	Est	SE	t	p	LCI	UCI
Future vs Current	-10.378	1.700	-6.105	<0.001	-13.717	-7.039

Effect Sizes for Linear Combinations Table

	Est	SE	p	d	pr	sR2
Future vs Current	-10.378	1.700	<0.001	-0.524	-0.253	0.049

### Computing simple (conditional) age and grip strength slopes at quantitative moderator values:

$$\widehat{Cognition}_i = \beta_0 + \beta_1(Age_i - 85) + \beta_2(Grip_i - 9) + \beta_3(SexMW_i) + \beta_4(DemNF_i) + \beta_5(DemNC_i) + \beta_6(Age_i - 85)(Grip_i - 9)$$

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

$$\text{Simple Age Slope} = \beta_1(Age_i - 85) + \beta_6(Age_i - 85)(Grip_i - 9) = [\beta_1 + \beta_6(Grip_i - 9)](Age_i - 85)$$

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

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

```
SlopesModel3 = multcomp::glht(model=Model3, 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)))
obj=glhtSummary(glhtObject=SlopesModel3, effectsizes=TRUE) # Custom output
```

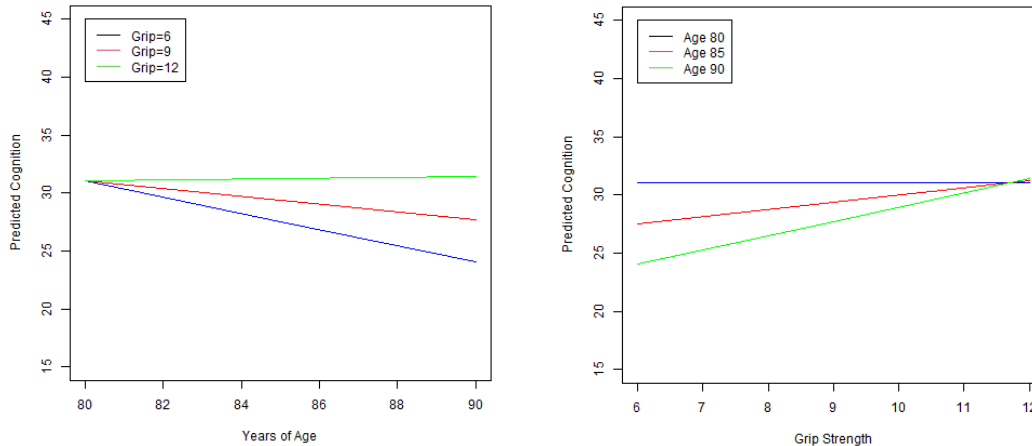
Linear Combinations Table

	Est	SE	t	p	LCI	UCI
Age Slope at Grip = 6	-0.703	0.153	-4.584	<0.001	-1.004	-0.402
Age Slope at Grip = 9	-0.334	0.120	-2.775	0.006	-0.570	-0.098
Age Slope at Grip = 12	0.035	0.187	0.188	0.851	-0.333	0.403
Grip Slope at Age = 80	0.004	0.247	0.017	0.986	-0.482	0.490
Grip Slope at Age = 85	0.619	0.149	4.164	<0.001	0.327	0.912
Grip Slope at Age = 90	1.235	0.255	4.833	<0.001	0.733	1.736

Effect Sizes for Linear Combinations Table

	Est	SE	p	d	pr	sR2
Age Slope at Grip = 6	-0.703	0.153	<0.001	-0.393	-0.193	0.027
Age Slope at Grip = 9	-0.334	0.120	0.006	-0.238	-0.118	0.010
Age Slope at Grip = 12	0.035	0.187	0.851	0.016	0.008	0.000
Grip Slope at Age = 80	0.004	0.247	0.986	0.002	0.001	0.000
Grip Slope at Age = 85	0.619	0.149	<0.001	0.357	0.176	0.023
Grip Slope at Age = 90	1.235	0.255	<0.001	0.415	0.203	0.031

(Figure 1 and 2 for the results)



```
print("Simple slopes over range of moderator values using reghelper package instead")
reghelper::simple_slopes(model=Model3,
  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

### Computing and plotting predicted outcomes:

```
print("Pred cognition outcomes holding sexMW=0, demNF=none, and demNC=none")
print("Provides predicted outcomes from min,max,by=increment of predictors")
PredModel3 = prediction(model=Model3, type="response",
  at=list(sexMW=0, demNF=0, demNC=0, grip9=seq(-3,3,by=3), age85=seq(-5,5,by=5)))
PlotModel3 = summary(PredModel3); print(PlotModel3, digits=4) # Save and print predictions for plotting
```

at (sexMW)	at (demNF)	at (demNC)	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

```
# Make and save plots
```

```
png(file = "Age by Grip=x GLM Plot.png") # open file
PlotModel3 = PlotModel3[order(PlotModel3$`at(age85)`), ] # 3 rows per age
plot(y=PlotModel3$Prediction, x=(PlotModel3$`at(grip9)`+9), type="n", # n= no points
  ylim=c(15,45), xlim=c(6,12), xlab="Grip Strength", ylab="Predicted Cognition")
lines(x=(PlotModel3$`at(grip9)`+9)[1:3], y=PlotModel3$Prediction[1:3], type="l", col="blue1")
lines(x=(PlotModel3$`at(grip9)`+9)[4:6], y=PlotModel3$Prediction[4:6], type="l", col="red1")
lines(x=(PlotModel3$`at(grip9)`+9)[7:9], y=PlotModel3$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 = "Grip by Age=x GLM Plot.png") # open file
PlotModel3 = PlotModel3[order(PlotModel3$`at(grip9)`), ] # 3 rows per grip
plot(y=PlotModel3$Prediction, x=(PlotModel3$`at(age85)`+85), type="n", # n= no points
  ylim=c(15,45), xlim=c(80,90), xlab="Years of Age", ylab="Predicted Cognition")
lines(x=(PlotModel3$`at(age85)`+85)[1:3], y=PlotModel3$Prediction[1:3], type="l", col="blue1")
lines(x=(PlotModel3$`at(age85)`+85)[4:6], y=PlotModel3$Prediction[4:6], type="l", col="red1")
lines(x=(PlotModel3$`at(age85)`+85)[7:9], y=PlotModel3$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
```

## Computing and plotting regions of significance for age and grip strength slopes:

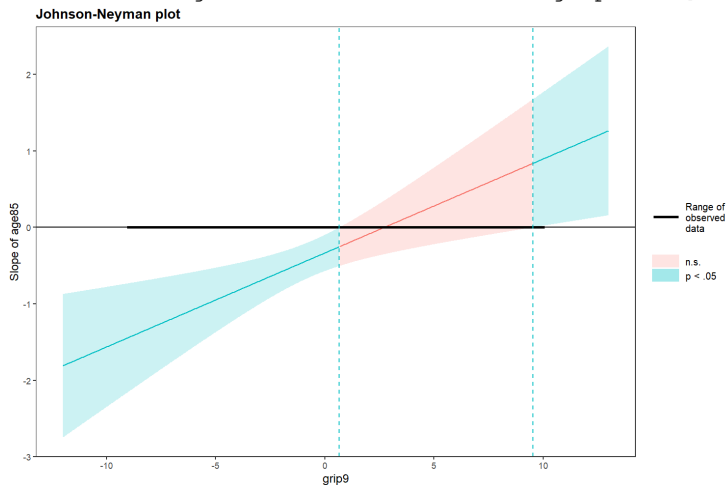
```
print("Values for regions of significance")
vcov(Model3) # Asymptotic covariance matrix of fixed effects for regions
      (Intercept)      age85      grip9      sexMW      demNF      demNC      age85:grip9
(Intercept)  0.4828946  0.0004536 -0.0307533 -0.450672 -0.182029 -0.2263470  0.0019165
age85        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 (or see excel spreadsheet).

```
print(Model3[["coefficients"]], digits=8) # Get fixed effects with more precision
(Intercept)      age85      grip9      sexMW      demNF      demNC      age85:grip9
29.40780315 -0.33396058  0.61941863 -3.45563720 -5.92254309 -16.30040485  0.12301848
interactions::johnson_neyman(model=Model3, pred="age85", modx="grip9", digits=3, plot=TRUE)
```

### JOHNSON-NEYMAN INTERVAL → [9.665, 18.521] pounds per square 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]

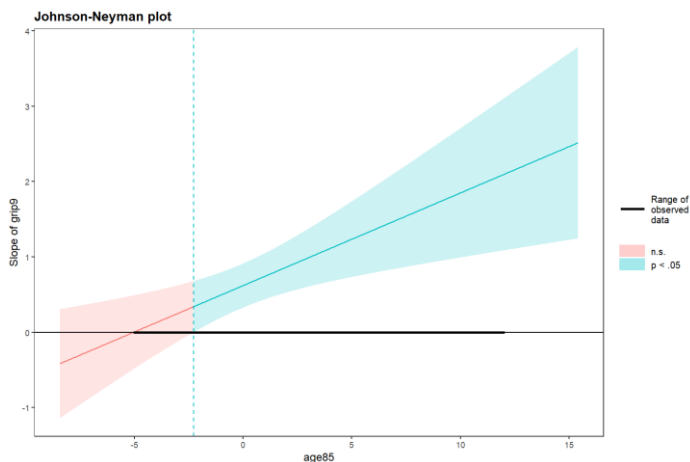


This result indicates that the age slope will be significantly negative below grip = 9.665 pounds, nonsignificant between grip = 9.665 and 18.521 pounds, and significantly positive after grip = 18.521 pounds.

```
interactions::johnson_neyman(model=Model3, pred="grip9", modx="age85", digits=3, plot=TRUE)
```

### 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 slope boundaries for age and grip given by regions of significance")
RegionSlopesModel3 = multcomp::glht(model=Model3, 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)))
obj=glhtSummary(glhtObject=RegionSlopesModel3, effectsizes=TRUE) # Custom output
```

Linear Combinations Table

	Est	SE	t	p	LCI	UCI
Age Slope at Grip = 9.665	-0.252	0.128	-1.964	0.050	-0.504	0.000
Age Slope at Grip = 18.521	0.837	0.426	1.964	0.050	-0.000	1.675
Grip Slope at Age = 70.127	-1.210	0.616	-1.964	0.050	-2.420	-0.000
Grip Slope at Age = 82.719	0.339	0.172	1.964	0.050	0.000	0.678

Effect Sizes for Linear Combinations Table

	Est	SE	p	d	pr	sR2
Age Slope at Grip = 9.665	-0.252	0.128	0.050	-0.169	-0.084	0.005
Age Slope at Grip = 18.521	0.837	0.426	0.050	0.169	0.084	0.005
Grip Slope at Age = 70.127	-1.210	0.616	0.050	-0.169	-0.084	0.005
Grip Slope at Age = 82.719	0.339	0.172	0.050	0.169	0.084	0.005

### Example Results Section Part 3

#### Age by Grip Strength Interaction

We then estimated a new model (as shown in Equation 3) adding an interaction between age and grip strength to examine the extent to which the slope of age varied by grip strength (or equivalently, how the slope of grip strength varied by age). The augmented model accounted for a significant amount of variance in cognition,  $F(6, 543) = 36.85$ ,  $MSE = 86.67$ ,  $p < .0001$ ,  $R^2 = .289$ . Cognition was predicted to be significantly lower by 3.46 in women ( $sR^2 = .020$ ). The overall effect of dementia group remained significant,  $F(2, 543) = 67.70$ ,  $p < .001$ ,  $sR^2 = .177$ . Relative to the reference group of persons with no diagnosis, cognition was significantly lower by 5.92 in the future diagnosis group, significantly lower by 16.30 in the current diagnosis group, and cognition was significantly lower by 10.38 in the future than current diagnosis group. The age by grip strength interaction was significant and added .012 to the  $R^2$  relative to the main-effects-only Model 1. The pattern of the age by grip strength interaction is described below.

The simple slope of age given directly by the model indicated that cognition was predicted to be significantly lower by 0.33 per additional year of age (in persons with a grip strength of 9 pounds per square inch). The simple slope of grip strength given directly by the model indicated that cognition was predicted to be significantly greater by 0.62 per additional pound of grip strength (in persons who are age 85). As shown in Figure 1, the age by grip strength interaction indicated the age slope predicting cognition became significantly less negative by 0.12 per additional pound per square inch 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 per 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 per square inch. Given the range of grip strength of 0–19 pounds per square inch in the current sample ( $M \approx 9$  pounds per square inch), the slope of age is expected to be negative for about half the sample ( $< 9.67$  pounds per square inch), to be nonsignificant for the other half (9.67–18.52 pounds per square inch), and to be positive for almost no one ( $> 18.52$  pounds per square inch). 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 ( $M \approx 85$  years), the slope of grip strength is expected to be negative for no one ( $< 70.13$  years), to be nonsignificant for a small part of the sample (70.13–82.71 years), and to be positive for the majority of the sample ( $> 82.71$  years).

**Table 2**

Results from Age\*Grip Strength Model in Equation 3

Fixed Effect	Est	SE	$p <$	Cohen's $d$	Partial $r$
$\beta_0$ Intercept	29.408	0.695			
$\beta_1$ Age (0=85 years)	-0.334	0.120	.006	-0.238	-0.118
$\beta_2$ Grip (0=9 pounds)	0.619	0.149	.001	0.357	0.176
$\beta_6$ Age * Grip	0.123	0.041	.003	0.260	0.129
$\beta_3$ Sex (0=Men)	-3.456	0.887	.001	-0.334	-0.165
$\beta_4$ None vs Future Dementia	-5.923	1.014	.001	-0.501	-0.243
$\beta_5$ None vs Current Dementia	-16.300	1.513	.001	-0.925	-0.420
$\beta_5 - \beta_4$ Future vs Current Dementia	-10.378	1.700	.001	-0.524	-0.253

Note: Est = estimate, SE = standard error. Cohen's  $d$  and partial  $r$  effect sizes were computed from the slope of each  $t$  test-statistic as follows:  $d = \frac{2t}{\sqrt{DF_{den}}}$ ;  $r = \frac{t}{\sqrt{t^2 + DF_{den}}}$ .

**NONE OF WHAT FOLLOWS IS NEEDED FOR HW05, but this model provides an example of a categorical\*binary (or quantitative) predictor interaction...**

#### Model 4 adding interaction of sex by demgroup

(Equation 2.13 in chapter 2): Does the effect of sex on cognition vary by dementia group (or does the effect of dementia on cognition vary by sex)?

**Equation 4:**  $Cognition_i = \beta_0 + \beta_1(Age_i - 85)$

+  $\beta_2(Grip_i - 9) + \beta_3(SexMW_i)$

+  $\beta_4(DemNF_i) + \beta_5(DemNC_i)$

+  $\beta_6(Age_i - 85)(Grip_i - 9)$

+  $\beta_7(SexMW_i)(DemNF_i)$

+  $\beta_8(SexMW_i)(DemNC_i) + e_i$

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	

```
print("Model 4: Add Sex by Dementia Group Interaction (Equation 2.13)")
print("Binary Predictors for Sex (0=Men) and Demgroup (0=None)")
Model4 = lm(data=Example5, formula=cognition~1+age85+grip9+sexMW+demNF+demNC +age85:grip9
            +sexMW:demNF +sexMW:demNC)
```

```
# Get F-test and effect sizes for change in R2 for two new interactions
obj=R2compare(ReducedModel=Model3, FullModel=Model4, PredName="Sex*Demgroup")
```

```
F-Test and R2 Change for Sex*Demgroup Slopes
R2reduced R2full R2diff DFnum DFden F p pR2 sR2
0.289 0.298 0.009 2 541 3.492 0.031 0.013 0.009
```

```
# Get F-test and effect sizes for change in R2 for age, grip, and age*grip
Model4NoAgeGrip = lm(data=Example5, formula=cognition~1+sexMW+sexMW:demNF +sexMW:demNC)
obj=R2compare(ReducedModel=Model4NoAgeGrip, FullModel=Model4,
              PredName="Age, Grip, and Age*Grip")
```

```
F-Test and R2 Change for Age, Grip, and Age*Grip Slopes
R2reduced R2full R2diff DFnum DFden F p pR2 sR2
0.193 0.298 0.106 5 541 16.329 <0.001 0.131 0.106
```

```
obj=LMSummary(Model4, effectsizes=TRUE) # Custom output
```

## Sums of Squares Table

	SS	DF	MS	F	p	R2
Model	19785.461	8	2473.183	28.767	<0.001	0.298
Error	46511.077	541	85.972			
Total	66296.538	549	120.759			

## Fixed Effects Table

	Est	SE	t	p	LCI	UCI	
Intercept	29.070	0.748	38.838	<0.001	27.600	30.540	beta0
age85	-0.335	0.120	-2.793	0.005	-0.570	-0.099	beta1
grip9	0.618	0.148	4.173	<0.001	0.327	0.909	beta2
sexMW	-2.876	1.011	-2.844	0.005	-4.862	-0.889	beta3
demNF	-6.056	1.635	-3.704	<0.001	-9.268	-2.844	beta4
demNC	-11.971	2.245	-5.332	<0.001	-16.381	-7.561	beta5
age85:grip9	0.122	0.040	3.027	0.003	0.043	0.201	beta6
sexMW:demNF	0.164	2.070	0.079	0.937	-3.903	4.231	beta7
sexMW:demNC	-7.875	3.025	-2.604	0.009	-13.816	-1.934	beta8

## Effect Sizes for Fixed Effects Table

	Est	SE	p	d	pr	sR2
age85	-0.335	0.120	0.005	-0.240	-0.119	0.010
grip9	0.618	0.148	<0.001	0.359	0.177	0.023
sexMW	-2.876	1.011	0.005	-0.245	-0.121	0.010
demNF	-6.056	1.635	<0.001	-0.318	-0.157	0.018
demNC	-11.971	2.245	<0.001	-0.459	-0.223	0.037
age85:grip9	0.122	0.040	0.003	0.260	0.129	0.012
sexMW:demNF	0.164	2.070	0.937	0.007	0.003	0.000
sexMW:demNC	-7.875	3.025	0.009	-0.224	-0.111	0.000

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	

**Interpret  $\beta_3$  for sexMW:** in the none group, cognition is lower by 2.876 in women than men

**Interpret  $\beta_7$  for sexMW\*demNF with demNF as moderator:** the gender gap in cognition (favoring men) is smaller by 0.164 in the future group relative to the none group

**Interpret  $\beta_8$  for sexMW\*demNF with demNC as moderator:** the gender gap in cognition (favoring men) is larger by 7.875 in the current group relative to the none group

**Interpret  $\beta_4$  for demNF:** in men, the future group is lower in cognition by 6.056 than the none group

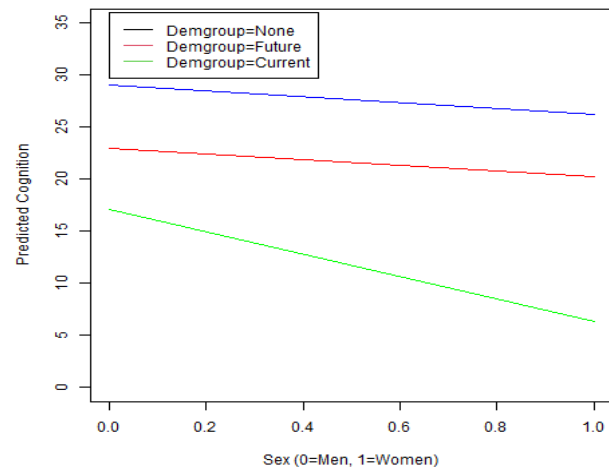
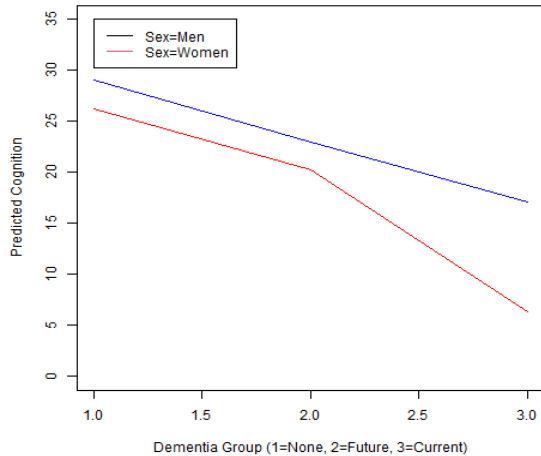
**Interpret  $\beta_7$  for sexMW\*demNF with sexMW as moderator:** the effect of none vs future dementia is smaller by 0.164 in women than in men

**Interpret  $\beta_5$  for demNC:** in men, the current group is lower in cognition by 11.971 than the none group

**Interpret  $\beta_8$  for sexMW\*demNC with sexMW as moderator:** the effect of none vs current dementia is larger by 7.875 in women than in men

**What simple slopes are we missing?** all dementia group differences in women; future vs current in either sex

(Figure 3 and 4 for the results)



### Computing and plotting predicted outcomes:

```
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")
PredModel4 = summary(prediction(model=Model4, type="response", at=list(age85=0, grip9=0,
sexMW=0:1, demNF=0:1, demNC=0:1))); print(PredModel4, digits=6)
```

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")
PredModel4 = data.frame(PredModel4) # first remove () from variable names
PredModel4$sum = PredModel4$at.demNF.+PredModel4$at.demNC. # sum dummy codes
PredModel4 = subset(x=PredModel4, PredModel4$sum<2) # keep if sum<2
# Make demgroup combined variable for plot
PredModel4$demgroup=NA # Make new empty variable to be recoded
PredModel4$demgroup[which(PredModel4$at.demNF.==0 & PredModel4$at.demNC.==0)]=1
PredModel4$demgroup[which(PredModel4$at.demNF.==1 & PredModel4$at.demNC.==0)]=2
PredModel4$demgroup[which(PredModel4$at.demNF.==0 & PredModel4$at.demNC.==1)]=3
# Make and save plots
png(file = "Sex by Demgroup=x GLM Plot.png") # open file
plot(y=PredModel4$Prediction, x=PredModel4$demgroup, type="n", ylim=c(0,35), xlim=c(1,3),
xlab="Dementia Group (1=None, 2=Future, 3=Current)", ylab="Predicted Cognition")
PredModel4 = PredModel4[order(PredModel4$at.sexMW.), ] # 3 rows per sexMW now
lines(x=PredModel4$demgroup[1:3], y=PredModel4$Prediction[1:3], type="l", col="blue1")
lines(x=PredModel4$demgroup[4:6], y=PredModel4$Prediction[4:6], type="l", col="red1")
legend(x=1, y=35, legend = c("Sex=Men", "Sex=Women"), col=1:2, lty=1) #lty=linetype
dev.off() # close file

png(file = "Demgroup by Sex=x GLM Plot.png") # open file
plot(y=PredModel4$Prediction, x=PredModel4$at.sexMW., type="n", ylim=c(0,35), xlim=c(0,1),
xlab="Sex (0=Men, 1=Women)", ylab="Predicted Cognition")
PredModel4 = PredModel4[order(PredModel4$demgroup), ] # 2 rows per demgroup now
lines(x=PredModel4$at.sexMW. [1:2], y=PredModel4$Prediction[1:2], type="l", col="blue1")
lines(x=PredModel4$at.sexMW. [3:4], y=PredModel4$Prediction[3:4], type="l", col="red1")
lines(x=PredModel4$at.sexMW. [5:6], y=PredModel4$Prediction[5:6], type="l", col="green1")
legend(x=0, y=36, legend = c("Demgroup=None", "Demgroup=Future", "Demgroup=Current"),
col=1:3, lty=1) #lty=linetype
dev.off() # close file
```

**Computing predicted outcomes, all possible conditional main effect (“simple”) slopes (3 for sex, 6 for dementia), and all possible interaction slopes (3):**

$$\widehat{Cognition}_i = \beta_0 + \beta_1(Age_i - 85) + \beta_2(Grip_i - 9) + \beta_3(SexMW_i) + \beta_4(DemNF_i) + \beta_5(DemNC_i) + \beta_6(Age_i - 85)(Grip_i - 9) + \beta_7(SexMW_i)(DemNF_i) + \beta_8(SexMW_i)(DemNC_i)$$

```
# Here is another way of using GLHT create predicted outcomes
print("GLHT pred cognition outcomes --adjusted cell means-- holding age=85 and grip=9")
Pred2Model4 = multcomp::glht(model=Model4, linfct=rbind(
  "Yhat for Men None" = c(1,0,0,0,0,0,0,0,0), # in order of fixed effects
  "Yhat for Women None" = c(1,0,0,1,0,0,0,0,0),
  "Yhat for Men Future" = c(1,0,0,0,1,0,0,0,0),
  "Yhat for Women Future" = c(1,0,0,1,1,0,0,1,0),
  "Yhat for Men Current" = c(1,0,0,0,0,1,0,0,0),
  "Yhat for Women Current" = c(1,0,0,1,0,1,0,0,1)))
obj=glhtSummary(glhtObject=Pred2Model4) # Custom output
```

Linear Combinations Table

	Est	SE	t	p	LCI	UCI
Yhat for Men None	29.070	0.748	38.838	<0.001	27.600	30.540
Yhat for Women None	26.195	0.639	41.004	<0.001	24.940	27.449
Yhat for Men Future	23.014	1.493	15.417	<0.001	20.082	25.947
Yhat for Women Future	20.303	1.119	18.150	<0.001	18.106	22.500
Yhat for Men Current	17.099	2.140	7.990	<0.001	12.895	21.304
Yhat for Women Current	6.349	1.948	3.259	0.001	2.522	10.175

```
print("DF=1 simple slopes for sex per demgroup, demgroup per sex, and interactions")
SlopesModel4 = multcomp::glht(model=Model4, linfct=rbind(
```

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

$$\begin{aligned} \text{Simple Sex Slope} &= \beta_3(SexMW_i) + \beta_7(SexMW_i)(DemNF_i) + \beta_8(SexMW_i)(DemNC_i) \\ &= [\beta_3 + \beta_7(DemNF_i) + \beta_8(DemNC_i)] \text{ that multiplies } (SexMW_i) \end{aligned}$$

```
"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):

$$\begin{aligned} \text{Simple None vs. Future Slope} &= \beta_4(DemNF_i) + \beta_7(SexMW_i)(DemNF_i) \\ &= [\beta_4 + \beta_7(SexMW_i)] \text{ that multiplies } (DemNF_i) \\ \text{Simple None vs. Current Slope} &= \beta_5(DemNC_i) + \beta_8(SexMW_i)(DemNC_i) \\ &= [\beta_5 + \beta_8(SexMW_i)] \text{ that multiplies } (DemNC_i) \\ \text{Simple Future vs. Current Slope} &= [\beta_5 + \beta_8(SexMW_i)] - [\beta_4 + \beta_7(SexMW_i)] \end{aligned}$$

```
"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),
```

The interaction slopes are then computed as the difference between the relevant simple slopes—A and B are directly given as model fixed slopes, whereas C is found as a linear combination (each explained two ways):

```

"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))

```

```
obj=glhtSummary(glhtObject=SlopesModel4, effectsizes=TRUE) # Custom output
```

Linear Combinations Table

	Est	SE	t	p	LCI	UCI
Sex Diff for No Dementia	-2.876	1.011	-2.844	0.005	-4.862	-0.889
Sex Diff for Future Dementia	-2.711	1.874	-1.447	0.149	-6.393	0.970
Sex Diff for Current Dementia	-10.751	2.899	-3.708	<0.001	-16.446	-5.055
None-Future Diff for Men	-6.056	1.635	-3.704	<0.001	-9.268	-2.844
None-Future Diff for Women	-5.892	1.278	-4.611	<0.001	-8.402	-3.382
None-Current Diff for Men	-11.971	2.245	-5.332	<0.001	-16.381	-7.561
None-Current Diff for Women	-19.846	2.029	-9.783	<0.001	-23.831	-15.861
Future-Current Diff for Men	-5.915	2.587	-2.287	0.023	-10.996	-0.834
Future-Current Diff for Women	-13.954	2.239	-6.233	<0.001	-18.352	-9.556
A: Sex effect differ btw None and Future?	0.164	2.070	0.079	0.937	-3.903	4.231
A: None-Future effect differ btw Men and Women?	0.164	2.070	0.079	0.937	-3.903	4.231
B: Sex effect differ btw None and Current?	-7.875	3.025	-2.604	0.009	-13.816	-1.934
B: None-Current effect differ btw Men and Women?	-7.875	3.025	-2.604	0.009	-13.816	-1.934
C: Sex effect differ btw Future and Current?	-8.039	3.415	-2.354	0.019	-14.748	-1.331
C: Future-Current effect differ btw Men and Women?	-8.039	3.415	-2.354	0.019	-14.748	-1.331

Effect Sizes for Linear Combinations Table

	Est	SE	p	d	pr	sR2
Sex Diff for No Dementia	-2.876	1.011	0.005	-0.245	-0.121	0.010
Sex Diff for Future Dementia	-2.711	1.874	0.149	-0.124	-0.062	0.003
Sex Diff for Current Dementia	-10.751	2.899	<0.001	-0.319	-0.157	0.018
None-Future Diff for Men	-6.056	1.635	<0.001	-0.318	-0.157	0.018
None-Future Diff for Women	-5.892	1.278	<0.001	-0.396	-0.194	0.028
None-Current Diff for Men	-11.971	2.245	<0.001	-0.459	-0.223	0.037
None-Current Diff for Women	-19.846	2.029	<0.001	-0.841	-0.388	0.124
Future-Current Diff for Men	-5.915	2.587	0.023	-0.197	-0.098	0.007
Future-Current Diff for Women	-13.954	2.239	<0.001	-0.536	-0.259	0.050
A: Sex effect differ btw None and Future?	0.164	2.070	0.937	0.007	0.003	0.000
A: None-Future effect differ btw Men and Women?	0.164	2.070	0.937	0.007	0.003	0.000
B: Sex effect differ btw None and Current?	-7.875	3.025	0.009	-0.224	-0.111	0.009
B: None-Current effect differ btw Men and Women?	-7.875	3.025	0.009	-0.224	-0.111	0.009
C: Sex effect differ btw Future and Current?	-8.039	3.415	0.019	-0.202	-0.101	0.007
C: Future-Current effect differ btw Men and Women?	-8.039	3.415	0.019	-0.202	-0.101	0.007

### Computing "omnibus" tests for the overall dementia group difference by sex:

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

```

print("Omnibus DF=2 F-test for Dementia Simple Main Effect for Men")
print("Comma separates each fixed effect to be tested jointly, already in model here")
DemforM = multcomp::glht(model=Model4,
  linfct=rbind(c(0,0,0,0,1,0,0,0,0),c(0,0,0,0,0,1,0,0,0)))
print(summary(DemforM, test=Ftest()), digits=4) # joint hypothesis test instead of separate

```

Global Test:

	F	DF1	DF2	Pr(>F)
1	18.69	2	541	0.00000001419

```
print("Omnibus DF=2 F-test for Dementia Simple Main Effect for Women")
print("Comma separates each fixed effect to be tested jointly, as a linear combination")
DemforW = multcomp::glht(model=Model4,
                        linfct=rbind(c(0,0,0,0,1,0,0,1,0),c(0,0,0,0,0,1,0,0,1)))
print(summary(DemforM, test=Ftest()), digits=4) # joint hypothesis test instead of separate
```

Global Test:

	F	DF1	DF2	Pr(>F)
1	53.16	2	541	8.378e-22

### Computing regions of significance for age and grip strength slopes from Model 4:

Fixed Effects Table

	Est	SE	t	p	LCI	UCI	
Intercept	29.070	0.748	38.838	<0.001	27.600	30.540	beta0
age85	-0.335	0.120	-2.793	0.005	-0.570	-0.099	beta1
grip9	0.618	0.148	4.173	<0.001	0.327	0.909	beta2
sexMW	-2.876	1.011	-2.844	0.005	-4.862	-0.889	beta3
demNF	-6.056	1.635	-3.704	<0.001	-9.268	-2.844	beta4
demNC	-11.971	2.245	-5.332	<0.001	-16.381	-7.561	beta5
age85:grip9	0.122	0.040	3.027	0.003	0.043	0.201	beta6
sexMW:demNF	0.164	2.070	0.079	0.937	-3.903	4.231	beta7
sexMW:demNC	-7.875	3.025	-2.604	0.009	-13.816	-1.934	beta8

```
johnson_neyman(model=Model4, pred="age85", modx="grip9", digits=3, plot=FALSE)
```

JOHNSON-NEYMAN INTERVAL → **[9.680, 18.638] pounds per square inch 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=Model4, 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.

## Example Results Section Part 4

### Sex by Dementia Diagnosis Interaction

We estimated a new model (as shown in Equation 4) adding an interaction between sex and dementia diagnosis to examine the extent to which the dementia group slopes differed between men and women (or equivalently, how the sex difference differed across dementia groups). The augmented model accounted for a significant amount of variance in cognition,  $F(8, 541) = 28.77$ ,  $MSE = 85.97$ ,  $p < .0001$ ,  $R^2 = .298$ . Table 3 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 3.

Results from Model 4 can be interpreted as follows; for clarity, model fixed effects and their linear combinations are also provided in Table 3. The intercept 29.07 is the expected cognition outcome for an 85-year-old man with 9 pounds per square inch of grip strength who will not be diagnosed with dementia later in the study. Age, grip strength, and their interaction contributed  $sR^2 = .106$  to the full model  $R^2$ . The simple slope of age given directly by the model indicated that cognition is predicted to be significantly lower by 0.33 per additional year of age (in persons with grip strength of 9 pounds per square inch). The simple slope of grip strength given directly by the model indicated that cognition is predicted to be significantly greater by 0.62 per additional pound per square inch of grip strength (in persons who are age 85). As shown in [figure generated from Model 4 specifically], the age by grip strength interaction indicated that the age slope predicting cognition became significantly less negative by 0.12 per additional pound per square inch 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 per 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 per square inch. Given the range of grip strength of 0–19 pounds per square inch in the current sample ( $M \approx 9$  pounds per square inch), the effect of age is expected to be negative for about half the sample ( $< 9.68$  pounds per square inch), the effect of age is expected to be nonsignificant for the other half (9.68–18.64 pounds per square inch), and the effect of age is expected to be positive for almost no one ( $> 18.64$  pounds per square inch). 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 ( $M \approx 85$  years), the effect of grip strength is expected to be negative for no one ( $< 70.00$  years), the effect of grip strength is expected to be nonsignificant for a small part of the sample (70.00–82.71 years), and the effect of grip strength is expected to be positive for the majority of the sample ( $> 82.71$  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,  $F(2, 541) = 3.49$ ,  $p = .031$ ,  $sR^2 = .009$ , 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 in the no dementia group, in which 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 = 0.16. However, the resulting sex difference in cognition favoring men in the future dementia group (of  $-2.88 + 0.16 = -2.71$ ) 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

= -7.88, and the resulting sex difference in the current dementia group (-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 (-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 (-6.06) and in women (-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 = 0.16. Cognition was also significantly lower in the current dementia than no dementia group, both in men (-11.97) and women (-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 = -7.88. Finally, cognition was also significantly lower in the current dementia group than future diagnosis group, both in men (-11.97 + 6.06 = -5.91) and women (-11.97 - 7.88 + 6.06 + 0.16 = -13.95). This dementia group difference was significantly larger in women, as indicated by the additional interaction contrast (-7.88 - 0.16 = -8.04).

**Table 3**

*Results from Age\*Grip Strength and Sex\*Dementia Diagnosis Model in Equation 4*

Fixed Effect	Est	SE	$p <$	Cohen's $d$	Partial $r$
$\beta_0$ Intercept	29.07	0.75	.001		
$\beta_1$ Age Slope	-0.33	0.12	.005	-.240	-.119
$\beta_2$ Grip Strength Slope	0.62	0.15	.001	.359	.177
$\beta_6$ Age by Grip Interaction	0.12	0.04	.003	.260	.129
Sex (0 = Men, 1 = Women) Differences:					
$\beta_3$ 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					
$\beta_4$ Men	-6.06	1.64	.001	-.318	-.157
$\beta_4 + \beta_7$ Women	-5.89	1.28	.001	-.396	-.194
$\beta_7$ Sex by None vs. Future	0.16	2.07	.937	.007	.003
None vs. Current Diagnosis					
$\beta_5$ Men	-11.97	2.25	.001	-.459	-.223
$\beta_5 + \beta_8$ Women	-19.85	2.03	.001	-.841	-.388
$\beta_8$ 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

Note: Est = estimate, SE = standard error. Cohen's  $d$  and partial  $r$  effect sizes were computed from the slope of

each  $t$  test-statistic as follows:  $d = \frac{2t}{\sqrt{DF_{den}}}$ ;  $r = \frac{t}{\sqrt{t^2 + DF_{den}}}$ .