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

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

SPSS Syntax for Data Manipulation:

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

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

SAS Syntax for Data Manipulation:

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

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

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

STATA Syntax and Data Manipulation:

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

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

Repeated from the end of Example 1:

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

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

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

Cognition for None = β_0

Cognition for Future = $\beta_0 + \beta_4$

Cognition for Current = $\beta_0 + \beta_5$

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

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

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

Future vs. Current = Current – Future = $(\beta_0 + \beta_5) - (\beta_0 + \beta_4) = \beta_5 - \beta_4 = -\beta_4 + \beta_5$

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

SPSS Syntax using manual coding for DemGroup:

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

```
ECHO 'Eq 2.8: Adding Dementia Group'
      + ', Using Manual Group Contrasts so Reference=None'.
MIXED cognition WITH age85 grip9 sexMW demNF demNC
     /METHOD   = REML
     /PRINT    = SOLUTION TESTCOV
     /FIXED    = age85 grip9 sexMW demNF demNC

     /TEST     = "Model R2 F-Test" age85 1; grip9 1; sexMW 1; demNF 1; demNC 1
     /TEST     = "Omnibus F-Test for Dementia Group" demNF 1; demNC 1

     /TEST     = "Intercept for None Group"      intercept 1 demNF 0 demNC 0
     /TEST     = "Intercept for Future Group"    intercept 1 demNF 1 demNC 0
     /TEST     = "Intercept for Current Group"   intercept 1 demNF 0 demNC 1

     /TEST     = "None   vs Future  Group"       demNF  1 demNC 0
     /TEST     = "None   vs Current Group"       demNF  0 demNC 1
     /TEST     = "Future vs Current Group"       demNF -1 demNC 1.
```

SPSS Syntax treating DemGroup as "categorical":

In EMMEANS: TABLES provides means per group, COMPARE provides all pairwise contrasts, and WITH holds the covariates at specified levels

```
ECHO 'Eq 2.8: Adding Dementia Group'
      + ', Categorical Predictor for Dementia Group'.
MIXED cognition BY demgroup WITH age85 grip9 sexMW
     /METHOD   = REML
     /PRINT    = SOLUTION TESTCOV
     /FIXED    = age85 grip9 sexMW demgroup
     /EMMEANS  = TABLES (demgroup) COMPARE (demgroup)
                 WITH (age85=0 grip9=0 sexMW=0).
```

SAS Syntax using manual coding for DemGroup:

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

```
TITLE1 'Eq 2.8: Adding Dementia Group';
TITLE2 'Using Manual Group Contrasts so Reference=None';
PROC MIXED DATA=work.Chapter2 COVTEST NOCLPRINT NAMELEN=100 IC METHOD=REML;
     MODEL cognition = age85 grip9 sexMW demNF demNC / CHISQ SOLUTION CL DDFM=BW;
     ODS OUTPUT CovParms=CovDem;

     CONTRAST "Model R2 F-Test" age85 1, grip9 1, sexmw 1, demNF 1, demNC 1 / CHISQ;
     CONTRAST "Omnibus F-Test for Dementia Group" demNF 1, demNC 1 / CHISQ;
     * Request group means (hold age=85, grip=9, men);
     ESTIMATE "Intercept for None Group"    intercept 1 demNF 0 demNC 0 / CL;
     ESTIMATE "Intercept for Future Group"  intercept 1 demNF 1 demNC 0 / CL;
     ESTIMATE "Intercept for Current Group" intercept 1 demNF 0 demNC 1 / CL;
     * Request group differences;
     ESTIMATE "None   vs. Future  Group"  demNF  1 demNC 0 / CL;
     ESTIMATE "None   vs. Current Group"  demNF  0 demNC 1 / CL;
     ESTIMATE "Future vs. Current Group"  demNF -1 demNC 1 / CL;
RUN; TITLE1; TITLE2;
```

SAS Syntax treating DemGroup as "categorical":

In LSMEANS: list effect to get means per group, DIFF=ALL provides all pairwise contrasts, and AT holds the covariates at specified levels

```
TITLE1 'Eq 2.8: Adding Dementia Group';
TITLE2 'Categorical Predictor for Dementia Group';
PROC MIXED DATA=work.Chapter2 COVTEST NOCLPRINT NAMELEN=100 IC METHOD=REML;
     CLASS demgroup;
     MODEL cognition = age85 grip9 sexMW demgroup / SOLUTION CL DDFM=BW;
     LSMEANS demgroup / DIFF=ALL CL AT(age85 grip9 sexMW) = (0 0 0);
RUN; TITLE1; TITLE2;
```

STATA Syntax using manual coding for DemGroup:

```
display as result "Eq 2.8: Adding Dementia Group"
display as result "Using Manual Group Contrasts so Reference=None"
mixed cognition c.age85 c.grip9 c.sexmw c.demNF c.demNC, ///
                || caseid: , noconstant variance reml,

      test (c.age85=0) (c.grip9=0) (c.sexmw=0) (c.demNF=0) (c.demNC=0) // Model R2 Chi2Test
      test (c.demNF=0) (c.demNC=0) // Omnibus Chi2Test for Dementia Group

      lincom _cons*1 + c.demNF*0 + c.demNC*0 // Intercept for None Group
      lincom _cons*1 + c.demNF*1 + c.demNC*0 // Intercept for Future Group
      lincom _cons*1 + c.demNF*0 + c.demNC*1 // Intercept for Current Group

      lincom c.demNF*1  + c.demNC*0  // None   vs Future  Group
      lincom c.demNF*0  + c.demNC*1  // None   vs Current Group
      lincom c.demNF*-1 + c.demNC*1  // Future vs Current Group
```

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

STATA Syntax treating DemGroup as "categorical":

```
display as result "Eq 2.8: Adding Dementia Group"
display as result "Categorical Predictor for Dementia Group"
mixed cognition c.age85 c.grip9 c.sexmw i.demgroup, ///
        || caseid: , noconstant variance reml,
      contrast i.demgroup, // Omnibus Chi2Test for Dementia Group
      margins  i.demgroup, at(c.age85=0 c.grip9=0 c.sexmw=0) // Get means per group
      margins  i.demgroup, pwcompare(pveffects), // Pairwise group comparisons
```

SPSS Output (−2LL and other fit statistics, residual variance, and R^2 are same across models):

Information Criteria[a]

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

Estimates of Covariance Parameters[a]

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

From SAS:

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

Name	CovParm	Estimate	StdErr	ZValue	ProbZ	R2_from_Base
CovEmpty	Residual	120.76	7.2887	16.57	<.0001	-0.00000
CovDem	Residual	88.0709	5.3401	16.49	<.0001	0.27069

From SPSS using Manual Coding:

Estimates of Fixed Effects from manual coding of demgroup

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

Interpret β_4 for demNF:

Interpret β_5 for demNC:

From SAS using Manual Coding (SPSS version is in all separate tables):
Terms NOT given by the model are in BOLD

Estimates

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

Test of Contrasts[a]

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

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

From SPSS, now treating DemGroup as "categorical":

Type III Tests of Fixed Effects[a]

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	544	754.313	.000
age85	1	544	11.645	.001
grip9	1	544	16.275	.000
sexMW	1	544	16.833	.000
demgroup	2	544	67.056	.000

The multivariate Wald test (df=2) for whether **β_4 for demNF=0 and β_5 for demNC=0** requested in the manual group contrasts model above is given by default below by treating demgroup as "categorical"

Note the change below in who is the dementia reference group once demgroup is "categorical":

Estimates of Fixed Effects[a] for "categorical" demgroup

Parameter	Estimate	Std. Error	df	t	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Intercept	12.784512	1.530193	544.000	8.355	.000	9.778701	15.790323
age85	-.405734	.118897	544	-3.412	.001	-.639288	-.172180
grip9	.604226	.149776	544	4.034	.000	.310016	.898435
sexMW	-3.657374	.891433	544	-4.103	.000	-5.408446	-1.906303
[demgroup=1]	16.479813	1.522754	544.000	10.822	.000	13.488616	19.471010
[demgroup=2]	10.757842	1.707957	544	6.299	.000	7.402844	14.112841
[demgroup=3]	0[b]	0	.	.	.	.	.

b. This parameter is set to zero because it is redundant.

From EMMEANS:

Estimates[a]

demgroup: Dementia Diagnosis (1=None, 2=Future, 3=Current)	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
1	29.264[b]	.699	544.000	27.892	30.636
2	23.542[b]	1.079	544	21.424	25.661
3	12.785[b]	1.530	544.000	9.779	15.790

b. Covariates appearing in the model are evaluated at the following values: age85: Age in Years (0=85) = .00, grip9: Grip Strength in Pounds (0=9) = .00, sexMW: Sex (0=Men, 1=Women) = 0.

Pairwise Comparisons[a]

(I) demgroup: Dementia Diagnosis (1=None, 2=Future, 3=Current)	(J) demgroup: Dementia Diagnosis (1=None, 2=Future, 3=Current)	Mean Difference (I-J)	Std. Error	df	Sig.[c]	95% Confidence Interval for Difference[c]	
						Lower Bound	Upper Bound
1	2	5.722*	1.019	544	.000	3.720	7.724
	3	16.480*	1.523	544.000	.000	13.489	19.471
2	1	-5.722*	1.019	544	.000	-7.724	-3.720
	3	10.758*	1.708	544	.000	7.403	14.113
3	1	-16.480*	1.523	544.000	.000	-19.471	-13.489
	2	-10.758*	1.708	544	.000	-14.113	-7.403

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

c. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Renouncing ANOVA dogma: You can ask the programs to apply Type I error correction to pairwise follow-ups if desired, although I personally don't believe they should have any special status relative to any other default-provided *p*-values because all group comparisons are already provided by the model.

In addition, it is possible to have significant pairwise group comparisons even if the "omnibus" test is not significant because it is evaluated per df. So if one group is very different than all the others, then the average effect per df may not be different than 0 (but you'd be missing the real story by only examining the "omnibus" result). So I do not think the omnibus F-test should be the gate-keeper to examining group comparisons. But just remember, for every 20 *p*-values, one is significant by chance!

MIXED Syntax and Output for Equation 2.16, adding interactions of age85*grip9 and sex by dementia group, in which sex and dementia group are both "categorical":

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

SPSS Output:

Information Criteria[a]

-2 Restricted Log Likelihood	3997.408
Akaike's Information Criterion (AIC)	3999.408
Hurvich and Tsai's Criterion (AICC)	3999.415
Bozdogan's Criterion (CAIC)	4004.701
Schwarz's Bayesian Criterion (BIC)	4003.701

The first and second EMMEANS request marginal means and main effects comparisons (what above output refers to). The third and fourth EMMEANS request cell means and simple effects (more useful).

Estimates of Covariance Parameters[a]

					95% Confidence Interval	
Parameter	**Estimate**	**Std. Error**	**Wald Z**	**Sig.**	**Lower Bound**	**Upper Bound**
Residual	85.972415	5.227277	16.447	.000	76.314059	96.853140

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	

We will use this table of estimated cell and marginal means to understand what the ANOVA F-tests provided by default tell us (and why they are basically useless given a significant interaction).

Default Output (printed from SAS):

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	Chi-Square	F Value	Pr > ChiSq	Pr > F	
age85	1	541	7.80	7.80	0.0052	0.0054	is simple: just Wald t^2
grip9	1	541	17.41	17.41	<.0001	<.0001	is simple: just Wald t^2
sexMW	**1**	**541**	**19.45**	**19.45**	**<.0001**	**<.0001**	**is marginal: 23.03=17.62?**
demgroup	**2**	**541**	**129.24**	**64.62**	**<.0001**	**<.0001**	**is marginal: 27.63=21.66=11.72?**
age85*grip9	1	541	9.16	9.16	0.0025	0.0026	is just Wald t^2
sexMW*demgroup	**2**	**541**	**6.98**	**3.49**	**0.0304**	**0.0311**	**is difference of differences=0?**

So what we know so far is that the effect of sex differs somehow by dementia group (but not whether there is an effect of sex within each dementia group) OR that the effect of dementia differs somehow by sex (but not whether there is an effect of dementia per sex). Super helpful, huh?

To find out the differences within condition (simple effects), some people may turn to separate models (e.g., select only men, then examine the effect of dementia group). However, that model will have a different residual variance, and thus the test may not be the same as it would be when done correctly in a full model. So let's see how to ask for all the relevant simple effects instead…

SPSS Syntax treating SexMW and DemGroup as "categorical":

```
ECHO 'Eq 2.16: Adding Sex by Dementia Interaction'
      + ', Categorical Sex and Dementia'.
MIXED cognition BY sexMW demgroup WITH age85 grip9
     /METHOD    = REML
     /PRINT     = SOLUTION TESTCOV
     /FIXED     = age85 grip9 sexMW demgroup age85*grip9 sexMW*demgroup
```

These EMMEANS request marginal means and main effects comparisons (what above F-tests refer to).

```
/EMMEANS = TABLES (sexMW)    COMPARE (sexMW)    WITH (age85=0 grip9=0)
/EMMEANS = TABLES (demgroup) COMPARE (demgroup) WITH (age85=0 grip9=0)
```

These EMMEANS request cell means and simple effects thereof (more useful).

```
/EMMEANS = TABLES (sexMW*demgroup) COMPARE (demgroup) WITH (age85=0 grip9=0)
/EMMEANS = TABLES (sexMW*demgroup) COMPARE (sexMW)    WITH (age85=0 grip9=0)
```

These TESTS request contrasts of simple effects (to say where the interaction actually is.
The order of the values corresponds to the order on the BY statement: **MN MF MC WN WF WC**

The TESTS within each pair are equivalent (two interpretations of same two-way interaction of 4 cells).
Note that in each, the direction of the contract across cells is flipped in one group relative to the other.

```
/TEST= "A: Sex Effect differ btw None and Future?"    sexMW*demgroup -1  1  0  1 -1  0
/TEST= "A: None-Future Effect differ by Sex?"         sexMW*demgroup -1  1  0  1 -1  0

/TEST= "B: Sex Effect differ btw None and Current?"   sexMW*demgroup -1  0  1  1  0 -1
/TEST= "B: None-Current Effect differ by Sex?"        sexMW*demgroup -1  0  1  1  0 -1

/TEST= "C: Sex Effect differ btw Future and Current?" sexMW*demgroup  0 -1  1  0  1 -1
/TEST= "C: Future-Current Effect differ by Sex?"      sexMW*demgroup  0 -1  1  0  1 -1.
```

DemGroup	Men	Women	Sex Difference
None	(1) 29.07	(4) 26.20	2.87
Future	(2) 23.01	(5) 20.30	2.71
Current	(3) 17.10	(6) 6.35	10.75

			Difference of Difference	TEST
None-Future Diff	6.06	5.90	0.16	A
None-Current Diff	11.97	19.85	-7.88	B
Future-Current Diff	5.91	13.95	-8.04	C

SAS Syntax treating SexMW and DemGroup as "categorical":

```
TITLE1 'Eq 2.16: Adding Sex by Dementia Interaction';
TITLE2 'Categorical Sex and Dementia';
PROC MIXED DATA=work.Chapter2 COVTEST NOCLPRINT NAMELEN=100 IC METHOD=REML;
     CLASS sexMW demgroup;
     MODEL cognition = age85 grip9 sexMW demgroup age85*grip9 sexMW*demgroup
                       / CHISQ SOLUTION CL DDFM=BW;
```

The first two LSMEANS request marginal means and main effects comparisons (what above F-tests refer to). The third LSMEANS gives cell means and simple effects thereof (where SLICE = "per")

```
LSMEANS sexMW    / DIFF=ALL CL AT(age85 grip9) = (0 0);
LSMEANS demgroup / DIFF=ALL CL AT(age85 grip9) = (0 0);
LSMEANS sexMW*demgroup / SLICE=demgroup SLICE=sexMW DIFF=ALL CL AT(age85 grip9) = (0 0);
* Order by CLASS statement: MN MF MC WN WF WC -- use /E to check;
CONTRAST "A: Sex Effect differ btw None and Future?"      sexMW*demgroup -1  1  0  1 -1  0;
CONTRAST "A: None-Future Effect differ by Sex?"           sexMW*demgroup -1  1  0  1 -1  0;
CONTRAST "B: Sex Effect differ btw None and Current?"     sexMW*demgroup -1  0  1  1  0 -1;
CONTRAST "B: None-Current Effect differ by Sex?"          sexMW*demgroup -1  0  1  1  0 -1;
CONTRAST "C: Sex Effect differ btw Future and Current?"   sexMW*demgroup  0 -1  1  0  1 -1;
CONTRAST "C: Future-Current Effect differ by Sex?"        sexMW*demgroup  0 -1  1  0  1 -1;
RUN; TITLE1; TITLE2;
```

STATA Syntax treating SexMW and DemGroup as "categorical":

```
display as result "Eq 2.16: Adding Sex by Dementia Interaction"
display as result "Categorical Sex and Dementia"
mixed cognition c.age85 c.grip9 i.sexmw i.demgroup ///
               c.age85#c.grip9 i.sexmw#i.demgroup, ///
               || caseid: , noconstant variance reml,
contrast i.sexmw#i.demgroup // Omnibus interaction Chi2Test
margins  i.sexmw#i.demgroup, at(c.age85=0 c.grip9=0) // cell means
margins  i.sexmw#i.demgroup, pwcompare(pveffects), // all cell comparisons
margins  i.sexmw@i.demgroup, at(c.age85=0 c.grip9=0) // sex per demgroup
margins  i.demgroup@i.sexmw, at(c.age85=0 c.grip9=0) // demgroup per sex
contrast {i.sexmw#i.demgroup -1  1  0  1 -1  0} // A: Sex Effect differ btw None, Future?
contrast {i.sexmw#i.demgroup -1  1  0  1 -1  0} // A: None-Future Effect differ by Sex?
contrast {i.sexmw#i.demgroup -1  0  1  1  0 -1} // B: Sex Effect differ btw None, Current?
contrast {i.sexmw#i.demgroup -1  0  1  1  0 -1} // B: None-Current Effect differ by Sex?
contrast {i.sexmw#i.demgroup  0 -1  1  0  1 -1} // C: Sex Effect differ btw Future,Current?
contrast {i.sexmw#i.demgroup  0 -1  1  0  1 -1} // C: Future-Current Effect differ by Sex?
```

SPSS Output for fixed effect estimates (where demgroup=current is reference):

Estimates of Fixed Effects[a]

Parameter	Estimate	Std. Error	df	t	Sig.	95% CI	
						Lower	Upper
Intercept	6.348722	1.947880	541.000	3.259	.001	2.522386	10.175058
age85	-.334799	.119888	541	-2.793	.005	-.570301	-.099297
grip9	.617893	.148079	541	4.173	.000	.327012	.908774
[sexMW=0]	10.750694	2.899323	541	3.708	.000	5.055383	16.446004
[sexMW=1]	0[b]	0	.	.	.	.	.
[demgroup=1]	19.845830	2.028583	541.000	9.783	.000	15.860965	23.830695
[demgroup=2]	13.954199	2.238917	541	6.233	.000	9.556162	18.352235
[demgroup=3]	0[b]	0	.	.	.	.	.
age85 * grip9	.122152	.040353	541	3.027	.003	.042884	.201419
[sexMW=0] * [demgroup=1]	-7.875100	3.024536	541	-2.604	.009	-13.816374	-1.933825
[sexMW=0] * [demgroup=2]	-8.039370	3.415165	541	-2.354	.019	-14.747978	-1.330761
[sexMW=0] * [demgroup=3]	0[b]	0	.	.	.	.	.
[sexMW=1] * [demgroup=1]	0[b]	0	.	.	.	.	.
[sexMW=1] * [demgroup=2]	0[b]	0	.	.	.	.	.
[sexMW=1] * [demgroup=3]	0[b]	0	.	.	.	.	.

b. This parameter is set to zero because it is redundant.

EMMEANS for Demgroup (where marginal dementia group means in table came from):

Estimates[a]

demgroup: Dementia Diagnosis (1=None, 2=Future, 3=Current)	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
1	27.632[b]	.478	541	26.693	28.571
2	21.659[b]	.928	541	19.835	23.482
3	11.724[b]	1.444	541.000	8.887	14.561

b. Covariates appearing in the model are evaluated at the following values: age85: Age in Years (0=85) = .00, grip9: Grip Strength in Pounds (0=9) = .00.

Pairwise Comparisons[a]

(I) demgroup: Dementia Diagnosis (1=None, 2=Future, 3=Current)	(J) demgroup: Dementia Diagnosis (1=None, 2=Future, 3=Current)	Mean Difference (I-J)	Std. Error	df	Sig.[c]	95% Confidence Interval for Difference[c]	
						Lower Bound	Upper Bound
1	2	5.974*	1.040	541	.000	3.931	8.017
	3	15.908*	1.513	541	.000	12.935	18.881
2	1	-5.974*	1.040	541	.000	-8.017	-3.931
	3	9.935*	1.714	541	.000	6.569	13.301
3	1	-15.908*	1.513	541	.000	-18.881	-12.935
	2	-9.935*	1.714	541	.000	-13.301	-6.569

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

Univariate Tests[a]

Numerator df	Denominator df	F	Sig.
2	541.000	64.622	.000

The F tests the effect of demgroup: Dementia Diagnosis (1=None, 2=Future, 3=Current). This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

This is the omnibus F-test for the main effect of demgroup we saw earlier. The pairwise comparisons within it above tell us that, averaged across sex, each dementia group mean is significantly different from the other.

It tells us nothing about demgroup differences within men or within women (which we should care about instead given the significant sex*demgroup interaction).

EMMEANS for Sex (where marginal sex group means in table above came from):

Estimates[a]

sexMW: Sex (0=Men, 1=Women)	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
0	23.061[b]	.925	541	21.244	24.879
1	17.615[b]	.789	541	16.066	19.165

b. Covariates appearing in the model are evaluated at the following values: age85: Age in Years (0=85) = .00, grip9: Grip Strength in Pounds (0=9) = .00.

Univariate Tests[a]

Numerator df	Denominator df	F	Sig.
1	541.000	19.448	.000

The F tests the effect of sexMW: Sex (0=Men, 1=Women). This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

This is the omnibus F-test for the main effect of sex we saw earlier. Averaged across demgroups, the sex group means are significantly different from the other.

It tells us nothing about sex differences within each dementia group (which we should care about instead given the significant sex*demgroup interaction).

EMMEANS for Demgroup*Sex (where cell means in table above came from):

Estimates[a]

demgroup: Dementia Diagnosis (1=None, 2=Future, 3=Current)	sexMW: Sex (0=Men, 1=Women)	Mean	Std. Error	df	95% Confidence Interval	
					Lower Bound	Upper Bound
1	0	29.070[b]	.748	541	27.600	30.540
	1	26.195[b]	.639	541	24.940	27.449
2	0	23.014[b]	1.493	541	20.082	25.947
	1	20.303[b]	1.119	541	18.106	22.500
3	0	17.099[b]	2.140	541.000	12.895	21.304
	1	6.349[b]	1.948	541.000	2.522	10.175

b. Covariates appearing in the model are evaluated at the following values: age85: Age in Years (0=85) = .00, grip9: Grip Strength in Pounds (0=9) = .00.

All possible cell mean comparisons of demgroup for each sex:

Pairwise Comparisons[a]

sexMW: Sex (0=Men, 1=Women)	(I) demgroup: Dementia Diagnosis (1=None, 2=Future, 3=Current)	(J) demgroup: Dementia Diagnosis (1=None, 2=Future, 3=Current)	Mean Difference (I-J)	Std. Error	df	Sig.[c]	95% Confidence Interval for Difference[c]	
							Lower Bound	Upper Bound
0	1	2	6.056*	1.635	541.000	.000	2.844	9.268
		3	11.971*	2.245	541	.000	7.561	16.381
	2	1	-6.056*	1.635	541.000	.000	-9.268	-2.844
		3	5.915*	2.587	541.000	.023	.834	10.996
	3	1	-11.971*	2.245	541	.000	-16.381	-7.561
		2	-5.915*	2.587	541.000	.023	-10.996	-.834
1	1	2	5.892*	1.278	541	.000	3.382	8.402
		3	19.846*	2.029	541.000	.000	15.861	23.831
	2	1	-5.892*	1.278	541	.000	-8.402	-3.382
		3	13.954*	2.239	541	.000	9.556	18.352
	3	1	-19.846*	2.029	541.000	.000	-23.831	-15.861
		2	-13.954*	2.239	541	.000	-18.352	-9.556

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

c. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Simple effects of demgroup within sex:

Univariate Tests[a]

sexMW: Sex (0=Men, 1=Women)	Numerator df	Denominator df	F	Sig.
0	2	541.000	18.688	.000
1	2	541.000	53.157	.000

Each F tests the simple effects of demgroup: Dementia Diagnosis (1=None, 2=Future, 3=Current) within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

There are significant dementia group mean differences within each sex.

But we don't know which differences differ specifically…

Table of cell mean comparisons of sex within demgroup is unnecessary…
Simple effects of sex within demgroup:

There are significant sex mean differences within each dementia group.

But we don't know which differences differ specifically…

Univariate Tests[a]

demgroup: Dementia Diagnosis (1=None, 2=Future, 3=Current)	Numerator df	Denominator df	F	Sig.
1	1	541	8.086	.005
2	1	541	2.093	.149
3	1	541	13.749	.000

Each F tests the simple effects of sexMW: Sex (0=Men, 1=Women) within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

Results (from SAS) of CONTRAST statements for differences of differences:

```
/TEST= "A: Sex Effect differ btw None and Future?"    sexMW*demgroup -1  1  0  1 -1  0
/TEST= "A: None-Future Effect differ by Sex?"         sexMW*demgroup -1  1  0  1 -1  0

/TEST= "B: Sex Effect differ btw None and Current?"   sexMW*demgroup -1  0  1  1  0 -1
/TEST= "B: None-Current Effect differ by Sex?"        sexMW*demgroup -1  0  1  1  0 -1

/TEST= "C: Sex Effect differ btw Future and Current?" sexMW*demgroup  0 -1  1  0  1 -1
/TEST= "C: Future-Current Effect differ by Sex?"      sexMW*demgroup  0 -1  1  0  1 -1.
```

Contrasts

Label	Num DF	Den DF	Chi-Square	F-Value	Pr > ChiSq	Pr > F
A: Sex Effect differ btw None and Future?	1	541	0.01	0.01	0.9368	0.9368
A: None-Future Effect differ by Sex?	1	541	0.01	0.01	0.9368	0.9368
B: Sex Effect differ btw None and Current?	1	541	6.78	6.78	0.0092	0.0095
B: None-Current Effect differ by Sex?	1	541	6.78	6.78	0.0092	0.0095
C: Sex Effect differ btw Future and Current?	1	541	5.54	5.54	0.0186	0.0189
C: Future-Current Effect differ by Sex?	1	541	5.54	5.54	0.0186	0.0189

DemGroup	Men	Women	Sex Difference	
None	(1) 29.07	(4) 26.20	2.87	
Future	(2) 23.01	(5) 20.30	2.71	
Current	(3) 17.10	(6) 6.35	10.75	
			Difference of Difference	TEST
None-Future Diff	6.06	5.90	0.16	**A n.s.**
None-Current Diff	11.97	19.85	-7.88	**B sig.**
Future-Current Diff	5.91	13.95	-8.04	**C sig.**

The numeric differences of the differences are provided in the output as well in other tables.

Now we know where the interaction is—there is a bigger effect of sex is the current dementia group than in other groups, and both current dementia effects are bigger in women than in men.