Practice with Fixed Effects Interactions: COMPLETED version
Example Outcome = Income (in 1000s) Predicted from Sex (MW) and Years Education (ed12)

Everything's significant in this simulated data, so no *p*-values are provided.

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************************ Model 1 ************************************;
TITLE "First Model: Fixed Quadratic Time, Time1=0 and Men=0 and Ed12=0";
PROC MIXED DATA=example COVTEST NOCLPRINT NOITPRINT METHOD=ML;
       CLASS ID;
       MODEL income = t1 t1*t1 MW ed12 MW*ed12 / SOLUTION DDFM=Satterthwaite;
       RANDOM INTERCEPT / SUBJECT=ID TYPE=UN;

* In ESTIMATE statements, first entry is the effect you are estimating
  (so first is always 1);

* Example of asking for predicted values at specific levels of predictors;
* Here, "t1" is replaced with actual time value;

ESTIMATE "Intercept at T1 for Men   Ed=12"  Int 1 t1 0 t1*t1 0  MW 0 ed12 0 MW*ed12 0;
ESTIMATE "Intercept at T1 for Men   Ed=16"  Int 1 t1 0 t1*t1 0  MW 0 ed12 4 MW*ed12 0;
ESTIMATE "Intercept at T1 for Women Ed=12"  Int 1 t1 0 t1*t1 0  MW 1 ed12 0 MW*ed12 0;
ESTIMATE "Intercept at T1 for Women Ed=16"  Int 1 t1 0 t1*t1 0  MW 1 ed12 4 MW*ed12 4;

ESTIMATE "Intercept at T6 for Men   Ed=12"  Int 1 t1 5 t1*t1 25 MW 0 ed12 0 MW*ed12 0;
ESTIMATE "Intercept at T6 for Men   Ed=16"  Int 1 t1 5 t1*t1 25 MW 0 ed12 4 MW*ed12 0;
ESTIMATE "Intercept at T6 for Women Ed=12"  Int 1 t1 5 t1*t1 25 MW 1 ed12 0 MW*ed12 0;
ESTIMATE "Intercept at T6 for Women Ed=16"  Int 1 t1 5 t1*t1 25 MW 1 ed12 4 MW*ed12 4;


* Example of asking for slopes at particular occasions;
* Here one of the "t1"=1, the other t1=actual time;

ESTIMATE "Linear Slope (for anyone) at T1"  t1 1 t1*t1 0;
ESTIMATE "Linear Slope (for anyone) at T6"  t1 1 t1*t1 10; * Remember, quad*2;


* Example of asking for simple main effects of an interaction;

ESTIMATE "Sex Diff (at any time) for Ed=12"   MW 1 MW*ed12 0;
ESTIMATE "Sex Diff (at any time) for Ed=16"   MW 1 MW*ed12 4;

ESTIMATE "Ed Slope (at any time) for Men"      ed12 1 MW*ed12 0;
ESTIMATE "Ed Slope (at any time) for Women"    ed12 1 MW*ed12 1;


run;


* Can check estimates by re-centering predictors;
TITLE "First Model: Time6=0 and Women=0 and Ed16=0 Instead";
PROC MIXED DATA=example COVTEST NOCLPRINT NOITPRINT METHOD=ML;
       CLASS ID;
       MODEL income = t6 t6*t6 WM ed16 WM*ed16 / SOLUTION DDFM=Satterthwaite;
       RANDOM INTERCEPT / SUBJECT=ID TYPE=UN;
run;
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WHAT SAS GIVES YOU BY DEFAULT IF TIME1=0, MEN=0, AND ED12=0:

Solution for Fixed Effects

Effect	Estimate	Standard Error	
Intercept	49.0432	0.07535	expected income of 49k at T1 for Man with Ed=12
t1	4.1689	0.05904	at T1, income increases 4.2k/time for all
t1*t1	-0.1929	0.01133	linear rate of change/time decreases by .4/time for all
MW	-8.4099	0.06495	if ed=12, women make 8.4k less than men
ed12	2.2751	0.02523	in men, income increases by 2.3k/year of ed
MW*ed12	-0.3983	0.03269	gender gap grows by .4/year OR ed slope is .4 smaller in women

WHAT EXTRA CONDITIONAL PREDICTIONS AND EFFECTS WE ASKED FOR:

Estimates

Label	Estimate	Standard Error
Intercept at T1 for Men Ed=12	49.0432	0.07535
Intercept at T1 for Men Ed=16	58.1438	0.1241
Intercept at T1 for Women Ed=12	40.6333	0.06944
Intercept at T1 for Women Ed=16	48.1407	0.1092
Intercept at T6 for Men Ed=12	65.0664	0.07535
Intercept at T6 for Men Ed=16	74.1670	0.1241
Intercept at T6 for Women Ed=12	56.6565	0.06944
Intercept at T6 for Women Ed=16	64.1639	0.1092
Linear Slope (for anyone) at T1	4.1689	0.05904
Linear Slope (for anyone) at T6	2.2403	0.05904
Sex Diff (at any time) if Ed=12	-8.4099	0.06495
Sex Diff (at any time) if Ed=16	-10.0031	0.1451
Ed Slope (at any time) for Men	2.2751	0.02523
Ed Slope (at any time) for Women	1.8768	0.02078

WHAT YOU GET IF YOU RE-CENTER AT TIME6=0, WOMEN=0, AND ED16=0 INSTEAD:

Solution for Fixed Effects

Effect	Estimate	Standard Error	
Intercept	64.1639	0.1092	expected income of 64k at T6 for women with ed=16
t6	2.2403	0.05904	at T6, income increases by 2.2k/time for all
t6*t6	-0.1929	0.01133	linear rate of change/time decreases by .4/time for all
WM	10.0031	0.1451	if ed=16, men make 10k more than women
ed16	1.8768	0.02078	in women, income increases by 1.9k/year of ed
WM*ed16	0.3983	0.03269	gender gap grows by .4/year or ed slope is .4 bigger in men

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************************ Model 2 ************************************;
TITLE "Second Model: Fixed Quadratic Time, Time1=0 and Men=0 and Ed12=0";
PROC MIXED DATA=example COVTEST NOCLPRINT NOITPRINT METHOD=ML;
       CLASS ID;
       MODEL income = t1 t1*t1 MW ed12 MW*ed12
                      MW*t1 MW*t1*t1 ed12*t1 / SOLUTION DDFM=Satterthwaite;
       RANDOM INTERCEPT / SUBJECT=ID TYPE=UN;

* Example of asking for slopes at particular occasions for particular people;
* Here one of the "t1" = 1, the other t1=actual time;

ESTIMATE "Linear at T1 for Men   Ed=12" t1 1 t1*t1 0  MW*t1 0 MW*t1*t1 0  ed12*t1 0;
ESTIMATE "Linear at T1 for Men   Ed=16" t1 1 t1*t1 0  MW*t1 0 MW*t1*t1 0  ed12*t1 4;
ESTIMATE "Linear at T1 for Women Ed=12" t1 1 t1*t1 0  MW*t1 1 MW*t1*t1 0  ed12*t1 0;
ESTIMATE "Linear at T1 for Women Ed=16" t1 1 t1*t1 0  MW*t1 1 MW*t1*t1 0  ed12*t1 4;

ESTIMATE "Linear at T6 for Men   Ed=12" t1 1 t1*t1 10 MW*t1 0 MW*t1*t1 0  ed12*t1 0;
ESTIMATE "Linear at T6 for Men   Ed=16" t1 1 t1*t1 10 MW*t1 0 MW*t1*t1 0  ed12*t1 4;
ESTIMATE "Linear at T6 for Women Ed=12" t1 1 t1*t1 10 MW*t1 1 MW*t1*t1 10 ed12*t1 0;
ESTIMATE "Linear at T6 for Women Ed=16" t1 1 t1*t1 10 MW*t1 1 MW*t1*t1 10 ed12*t1 4;


* Example of asking for simple main effects of an interaction;
* Here, "t1" is actual time always;

ESTIMATE "Sex Diff at T1 if Ed=12"      MW 1 MW*t1 0 MW*t1*t1 0  MW*ed12 0;
ESTIMATE "Sex Diff at T1 if Ed=16"      MW 1 MW*t1 0 MW*t1*t1 0  MW*ed12 4;

ESTIMATE "Sex Diff at T6 if Ed=12"      MW 1 MW*t1 5 MW*t1*t1 25 MW*ed12 0;
ESTIMATE "Sex Diff at T6 if Ed=16"      MW 1 MW*t1 5 MW*t1*t1 25 MW*ed12 4;


ESTIMATE "Ed Slope at T1 for Men"       ed12 1 ed12*t1 0 MW*ed12 0;
ESTIMATE "Ed Slope at T1 for Women"     ed12 1 ed12*t1 0 MW*ed12 1;

ESTIMATE "Ed Slope at T6 for Men"       ed12 1 ed12*t1 5 MW*ed12 0;
ESTIMATE "Ed Slope at T6 for Women"     ed12 1 ed12*t1 5 MW*ed12 1;


* Example of asking for simple two-way interactions of a three-way interaction;

ESTIMATE "Quadratic for Men"     t1*t1 1 MW*t1*t1 0;
ESTIMATE "Quadratic for Women"   t1*t1 1 MW*t1*t1 1;


ESTIMATE "Sex by Time at T1"     MW*t1 1 MW*t1*t1 0;
ESTIMATE "Sex by Time at T6"     MW*t1 1 MW*t1*t1 10;

run;

* Can check estimates by re-centering predictors;
TITLE "Second Model: Time6=0 and Women=0 and Ed16=0 Instead";
PROC MIXED DATA=example COVTEST NOCLPRINT NOITPRINT METHOD=ML;
       CLASS ID;
       MODEL income = t6 t6*t6 WM ed16 WM*ed16
                      WM*t6 WM*t6*t6 ed16*t6 / SOLUTION DDFM=Satterthwaite;
       RANDOM INTERCEPT / SUBJECT=ID TYPE=UN;
run;
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WHAT SAS GIVES YOU BY DEFAULT IF TIME1=0, MEN=0, AND ED12=0 (same or different interpretation?):

Solution for Fixed Effects

Effect	Estimate	Standard Error	
Intercept	49.9467	0.05817	(same as before)
t1	4.0427	0.03066	at T1, income increases 4k/time for men with ed=12
t1*t1	-0.2570	0.005886	linear rate of change in income decreases by .5/time in men
MW	-9.9066	0.07503	if ed=12, women make 9.9k less than men at T1
ed12	0.9451	0.02614	in men, income increases by .9/year of ed at T1
MW*ed12	-0.3983	0.03269	(same as before)
t1*MW	0.2074	0.03955	gender gap reduced by .2/time at T1 (for all ed)
t1*t1*MW	0.1067	0.007592	quadratic change is .1 less negative in women
t1*ed12	0.5320	0.002741	ed slope is more positive by .5/time (for both sexes)

WHAT EXTRA CONDITIONAL PREDICTIONS AND EFFECTS WE ASKED FOR:

Estimates

Label		Estimate	Standard Error
Linear at T1 for Men	Ed=12	4.0427	0.03066
Linear at T1 for Men	Ed=16	6.1709	0.03248
Linear at T1 for Women	Ed=12	4.2501	0.02498
Linear at T1 for Women	Ed=16	6.3782	0.02734
Linear at T6 for Men	Ed=12	1.4727	0.03066
Linear at T6 for Men	Ed=16	3.6008	0.03248
Linear at T6 for Women	Ed=12	2.7473	0.02498
Linear at T6 for Women	Ed=16	4.8754	0.02734
Sex Diff at T1 if Ed=12		-9.9066	0.07503
Sex Diff at T1 if Ed=16		-11.4998	0.1498
Sex Diff at T6 if Ed=12		-6.2016	0.07503
Sex Diff at T6 if Ed=16		-7.7948	0.1498
Ed Slope at T1 for Men		0.9451	0.02614
Ed Slope at T1 for Women		0.5468	0.02188
Ed Slope at T6 for Men		3.6052	0.02614
Ed Slope at T6 for Women		3.2069	0.02188
Quadratic for Men		-0.2570	0.005886
Quadratic for Women		-0.1503	0.004796
Sex by Time at T1		0.2074	0.03955
Sex by Time at T6		1.2747	0.03955

WHAT YOU GET IF YOU RE-CENTER AT TIME6=0, WOMEN=0, AND ED16=0 INSTEAD:

Solution for Fixed Effects

Effect	Estimate	Standard Error	
Intercept	70.3613	0.1006	(same as before)
t6	4.8754	0.02734	at T6, income increases by 4.8k/time for women with ed=16
t6*t6	-0.1503	0.004796	linear rate of change in income decreases by .3/time in women
WM	7.7948	0.1498	if ed=16, men make 7.8k more than women at T6
ed16	3.2069	0.02188	in women, income increases by 3.2k/year of ed at T6
WM*ed16	0.3983	0.03269	(same as before)
t6*WM	-1.2747	0.03955	gender gap reduced by 1.3k/time at T6 (for all ed)
t6*t6*WM	-0.1067	0.007592	quadratic change is .1 more negative in men
t6*ed16	0.5320	0.002741	ed slope is more positive by .5/time (for both sexes)

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************************ Model 3 ************************************;
TITLE "Third Model: Fixed Quadratic Time, Time1=0 and Men=0 and Ed12=0";
PROC MIXED DATA=example COVTEST NOCLPRINT NOITPRINT METHOD=ML;
      CLASS ID;
      MODEL income = t1 t1*t1 MW ed12 MW*ed12 MW*t1 MW*t1*t1 ed12*t1
                     MW*ed12*t1 / SOLUTION DDFM=Satterthwaite;
      RANDOM INTERCEPT / SUBJECT=ID TYPE=UN;

* Example of asking for slopes at particular occasions for particular people;
* Here one of the "t1"=1, the other t1=actual time;
ESTIMATE "Linear T1 M Ed=12"     t1 1 t1*t1 0  MW*t1 0 MW*t1*t1 0  ed12*t1 0 MW*ed12*t1 0;
ESTIMATE "Linear T1 M Ed=16"     t1 1 t1*t1 0  MW*t1 0 MW*t1*t1 0  ed12*t1 4 MW*ed12*t1 0;
ESTIMATE "Linear T1 W Ed=12"     t1 1 t1*t1 0  MW*t1 1 MW*t1*t1 0  ed12*t1 0 MW*ed12*t1 0;
ESTIMATE "Linear T1 W Ed=16"     t1 1 t1*t1 0  MW*t1 1 MW*t1*t1 0  ed12*t1 4 MW*ed12*t1 4;

ESTIMATE "Linear T6 M Ed=12"     t1 1 t1*t1 10 MW*t1 0 MW*t1*t1 0  ed12*t1 0 MW*ed12*t1 0;
ESTIMATE "Linear T6 M Ed=16"     t1 1 t1*t1 10 MW*t1 0 MW*t1*t1 0  ed12*t1 4 MW*ed12*t1 0;
ESTIMATE "Linear T6 W Ed=12"     t1 1 t1*t1 10 MW*t1 1 MW*t1*t1 10 ed12*t1 0 MW*ed12*t1 0;
ESTIMATE "Linear T6 W Ed=16"     t1 1 t1*t1 10 MW*t1 1 MW*t1*t1 10 ed12*t1 4 MW*ed12*t1 4;

* Example of asking for simple main effects of an interaction;
* Here, "t1" is actual time always;
ESTIMATE "Sex Diff at T1 if Ed=12"      MW 1 MW*ed12 0 MW*t1 0 MW*t1*t1 0  MW*ed12*t1 0;
ESTIMATE "Sex Diff at T1 if Ed=16"      MW 1 MW*ed12 4 MW*t1 0 MW*t1*t1 0  MW*ed12*t1 0;

ESTIMATE "Sex Diff at T6 if Ed=12"      MW 1 MW*ed12 0 MW*t1 5 MW*t1*t1 25 MW*ed12*t1 0;
ESTIMATE "Sex Diff at T6 if Ed=16"      MW 1 MW*ed12 4 MW*t1 5 MW*t1*t1 25 MW*ed12*t1 20;

ESTIMATE "Ed Slope at T1 for Men"       ed12 1 MW*ed12 0 ed12*t1 0  MW*ed12*t1 0;
ESTIMATE "Ed Slope at T1 for Women"     ed12 1 MW*ed12 1 ed12*t1 0  MW*ed12*t1 0;

ESTIMATE "Ed Slope at T6 for Men"       ed12 1 MW*ed12 0 ed12*t1 5  MW*ed12*t1 0;
ESTIMATE "Ed Slope at T6 for Women"     ed12 1 MW*ed12 1 ed12*t1 5  MW*ed12*t1 5;

* Example of asking for simple two-way interactions of a three-way interaction;
ESTIMATE "Quadratic for Men"           t1*t1 1 MW*t1*t1 0;
ESTIMATE "Quadratic for Women"         t1*t1 1 MW*t1*t1 1;

ESTIMATE "Sex by Ed at T1"             MW*ed12 1 MW*ed12*t1 0;
ESTIMATE "Sex by Ed at T6"             MW*ed12 1 MW*ed12*t1 5;

ESTIMATE "Ed by Time for Men"          ed12*t1 1 MW*ed12*t1 0;
ESTIMATE "Ed by Time for Women"        ed12*t1 1 MW*ed12*t1 1;

ESTIMATE "Sex by Time (at T1) for Ed=12"      MW*t1  1 MW*ed12*t1 0 MW*t1*t1 0;
ESTIMATE "Sex by Time (at T1) for Ed=16"      MW*t1  1 MW*ed12*t1 4 MW*t1*t1 0;
ESTIMATE "Sex by Time (at T6) for Ed=12"      MW*t1  1 MW*ed12*t1 0 MW*t1*t1 10;
ESTIMATE "Sex by Time (at T6) for Ed=16"      MW*t1  1 MW*ed12*t1 4 MW*t1*t1 10;

run;

* Can check estimates by re-centering predictors;
TITLE "Third Model: Time6=0 and Women=0 and Ed16=0 Instead";
PROC MIXED DATA=example COVTEST NOCLPRINT NOITPRINT METHOD=ML;
      CLASS ID;
      MODEL income = t6 t6*t6 WM ed16 WM*ed16 WM*t6 WM*t6*t6 ed16*t6
                     WM*ed16*t6 / SOLUTION DDFM=Satterthwaite;
      RANDOM INTERCEPT / SUBJECT=ID TYPE=UN;
run;
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WHAT SAS GIVES YOU BY DEFAULT IF TIME1=0, MEN=0, AND ED12=0 (same or different interpretation?):

Solution for Fixed Effects

Effect	Estimate	Standard Error	
Intercept	49.9393	0.05803	(same as before)
t1	4.0457	0.03036	(same as before)
t1*t1	-0.2570	0.005828	(same as before)
MW	-9.9023	0.07484	(same as before)
ed12	1.0275	0.02739	(same as before)
MW*ed12	-0.5367	0.03549	gender gap grows by .5/year of ed at T1 OR ed slope is .5 less in W atT1
t1*MW	0.2056	0.03916	gender gap reduced by .2/time at T1 for ed=12
t1*t1*MW	0.1067	0.007517	(same as before)
t1*ed12	0.4991	0.004268	ed slope is more positive by .5/time linearly for men
t1*MW*ed12	0.05536	0.005529	reduction of gender gap of .2/time grows .05/year of ed OR increase in ed slope over time is .05/time larger in women OR bigger gender gap per year of ed lessens by .05/time

WHAT EXTRA CONDITIONAL PREDICTIONS AND EFFECTS WE ASKED FOR:

Estimates

Label	Estimate	Standard Error
Linear at T1 for Men Ed=12	4.0457	0.03036
Linear at T1 for Men Ed=16	6.0419	0.03464
Linear at T1 for Women Ed=12	4.2513	0.02473
Linear at T1 for Women Ed=16	6.4689	0.02855
Linear at T6 for Men Ed=12	1.4756	0.03036
Linear at T6 for Men Ed=16	3.4718	0.03464
Linear at T6 for Women Ed=12	2.7485	0.02473
Linear at T6 for Women Ed=16	4.9662	0.02855
Sex Diff at T1 if Ed=12	-9.9023	0.07484
Sex Diff at T1 if Ed=16	-12.0490	0.1595
Sex Diff at T6 if Ed=12	-6.2060	0.07484
Sex Diff at T6 if Ed=16	-7.2456	0.1595
Ed Slope at T1 for Men	1.0275	0.02739
Ed Slope at T1 for Women	0.4908	0.02256
Ed Slope at T6 for Men	3.5228	0.02739
Ed Slope at T6 for Women	3.2629	0.02256
Quadratic for Men	-0.2570	0.005828
Quadratic for Women	-0.1503	0.004748
Sex by Ed at T1	-0.5367	0.03549
Sex by Ed at T6	-0.2599	0.03549
Ed by Time for Men	0.4991	0.004268
Ed by Time for Women	0.5544	0.003515
Sex by Time (at T1) for Ed=12	0.2056	0.03916
Sex by Time (at T1) for Ed=16	0.4270	0.04489
Sex by Time (at T6) for Ed=12	1.2729	0.03916
Sex by Time (at T6) for Ed=16	1.4943	0.04489

WHAT YOU GET IF YOU RE-CENTER AT TIME6=0, WOMEN=0, AND ED16=0 INSTEAD:

Solution for Fixed Effects

Effect	Estimate	Standard Error	
Intercept	70.5881	0.1030	(same as before)
t6	4.9662	0.02855	(same as before)
t6*t6	-0.1503	0.004748	(same as before)
WM	7.2456	0.1595	(same as before)
ed16	3.2629	0.02256	(same as before)
WM*ed16	0.2599	0.03549	gender gap grows by .26/year of ed at T6 OR ed slope is .26 more in M atT6
t6*WM	-1.4943	0.04489	gender gap reduced by 1.5/time at T6 for ed=16
t6*t6*WM	-0.1067	0.007517	(same as before)
t6*ed16	0.5544	0.003515	ed slope is more positive by .55/time linearly for women
t6*WM*ed16	-0.05536	0.005529	