We will use a data set called hsb2.sas7bdat (https://stats.idre.ucla.edu/wp-content/uploads/2016/02/hsb2-1.sas7bdat) to demonstrate.

Example 1: One-way ANOVA

The dependent variable is **write** and the factor variable is **ses** which has three levels.

```
proc glm data= hsb2;
   class ses;
   model write = ses /solution;
run;
quit;
```

Parameter		Estimate		Standard Error	t Value	Pr > |t|
Intercept		55.91379310	B	1.22049134	45.81	<.0001
SES	1	-5.29677183	B	1.82423349	-2.90	0.0041
SES	2	-3.98747731	B	1.54888301	-2.57	0.0108
SES	3	0.00000000	B	.	.	.

An **estimate** statement corresponds to an L-matrix, which corresponds to a linear combination of the parameter estimates. With this simple model, we have three parameters, the intercept and two parameters for ses =1 and ses =2. Group of ses =3 is the reference group. The regression equation is the following, where ses1 is the dummy variable for ses =1 and ses2 is the dummy variable for ses =2.

write = intercept + b_1*ses1 + b_2*ses2.

The parameter for the intercept is the expected cell mean for ses =3 since it is the comparison group. The parameter for ses1 is the difference of the mean for cell ses =1 and the cell ses =3. To get the expected mean for ses = 1, we will add the coefficient for ses1 to the intercept. Similarly, we will get the expected mean for ses = 2 by adding the intercept to the coefficient for ses = 2. The difference between the mean of cell ses = 1 and cell ses = 2 will be the difference of b_1 and b_2.

Beside using the **solution** option to get the parameter estimates, we can also use the option "**e**" following the **estimate** statement to get the L matrix.

```
proc glm data= hsb2;
   class ses;
   model write = ses /solution;
   estimate 'ses 1' intercept 1 ses 1 0 0 /e;  /*cell mean for ses = 1*/
```

```
   estimate 'ses 1' intercept 1 ses 1 0 0 /e;  /*cell mean for ses = 1*/
   estimate 'ses 2' intercept 1 ses 0 1 0;      /*cell mean for ses = 2*/
   estimate 'ses 3' intercept 1 ses 0 0 1;      /*cell mean for ses = 3*/
   estimate 'ses 1 vs 2' ses 1 -1 0;
   estimate 'ses 1 vs 3' ses 1 0 -1;
   estimate 'ses 2 vs 3' ses 0 1 -1;
   estimate 'ses 1 and 2 vs 3' ses .5 .5 -1;
run;
quit;
```

```
Coefficients for Estimate ses 1

                     Row 1

Intercept                1

SES       1              1
SES       2              0
SES       3              0
                                      Standard
Parameter                  Estimate           Error    t Value    Pr > |t|

ses 1                    50.6170213      1.35581293      37.33      <.0001
ses 2                    51.9263158      0.95364536      54.45      <.0001
ses 3                    55.9137931      1.22049134      45.81      <.0001
ses 1 vs 2               -1.3092945      1.65760917      -0.79      0.4306
ses 1 vs 3               -5.2967718      1.82423349      -2.90      0.0041
ses 2 vs 3               -3.9874773      1.54888301      -2.57      0.0108
ses 1 and 2 vs 3         -4.6421246      1.47530206      -3.15      0.0019


                                    Standard
Parameter           Estimate            Error    t Value    Pr > |t|

Intercept        55.91379310 B      1.22049134      45.81      <.0001
SES       1      -5.29677183 B      1.82423349      -2.90      0.0041
SES       2      -3.98747731 B      1.54888301      -2.57      0.0108
SES       3       0.00000000 B       .                .         .
```

Example 2: Two-way ANOVA, main effects only

```
proc glm data= hsb2;
   class ses female ;
   model write = ses female /solution;
   estimate 'ses 1 and female 0' intercept 1 ses 1 0 0 female 1 0 /e;
```

```
   estimate 'ses 1 and female 0' intercept 1 ses 1 0 0 female 1 0 /e;
   estimate 'ses 2 and female 0' intercept 1 ses 0 1 0 female 1 0;
   estimate 'ses 3 and female 0' intercept 1 ses 0 0 1 female 1 0;
   estimate 'ses 1 and female 1' intercept 1 ses 1 0 0 female 0 1;
   estimate 'ses 2 and female 1' intercept 1 ses 0 1 0 female 0 1;
   estimate 'ses 3 and female 1' intercept 1 ses 0 0 1 female 0 1;
   estimate 'ses 1 vs 2' ses 1 -1 0;
   estimate 'ses 1 vs 3' ses 1 0 -1;
   estimate 'ses 2 vs 3' ses 0 1 -1;
   estimate 'averaging across level of female at ses = 1' intercept 1 ses 1 0 0 /e;
run;
quit;
```

```
Coefficients for Estimate ses 1 and female 0

                     Row 1

Intercept                1

SES       1              1
SES       2              0
SES       3              0

FEMALE    0              1
FEMALE    1              0
```

```
Coefficients for Estimate averaging across level of female at ses = 1

                     Row 1

Intercept                1

SES       1              1
SES       2              0
SES       3              0

FEMALE    0            0.5
FEMALE    1            0.5
```

```
                                                        Standard
Parameter                                 Estimate          Error   t Value   Pr > |t|

ses 1 and female 0                      46.9599907     1.56788763     29.95     <.0001
```

```
ses 2 and female 0                          49.2124141     1.12199872     43.86     <.0001
ses 3 and female 0                          53.2281612     1.33618828     39.84     <.0001
ses 1 and female 1                          52.3312544     1.36505131     38.34     <.0001
ses 2 and female 1                          54.5836778     1.11425673     48.99     <.0001
ses 3 and female 1                          58.5994250     1.33618828     43.86     <.0001
ses 1 vs 2                                  -2.2524235     1.60796178     -1.40     0.1629
ses 1 vs 3                                  -6.2681706     1.76744072     -3.55     0.0005
ses 2 vs 3                                  -4.0157471     1.48770056     -2.70     0.0076
averaging across level of female at ses = 1 49.6456225     1.32273692     37.53     <.0001


                                  Standard
Parameter           Estimate         Error    t Value    Pr > |t|

Intercept        58.59942496 B      1.33618828      43.86      <.0001
SES       1      -6.26817058 B      1.76744072      -3.55      0.0005
SES       2      -4.01574712 B      1.48770056      -2.70      0.0076
SES       3       0.00000000 B       .                .          .
FEMALE    0      -5.37126371 B      1.28247478      -4.19      <.0001
FEMALE    1       0.00000000 B       .                .          .
```

Example 3: Two-way ANOVA with interaction

```
proc glm data= hsb2;
   class ses female ;
   model write = ses|female /solution;
   estimate 'ses 1 and female 1' intercept 1 ses 1 0 0 female 0 1
```

```
   estimate 'ses 1 and female 1' intercept 1 ses 1 0 0 female 0 1
                                 ses*female 0 1 0 0 0 0;
   estimate 'ses 2 and female 1' intercept 1 ses 0 1 0 female 0 1
                                 ses*female 0 0 0 1 0 0;
   estimate 'ses 3 and female 1' intercept 1 ses 0 0 1 female 0 1
                                 ses*female 0 0 0 0 0 1;
   estimate 'ses 1 and female 0' intercept 1 ses 1 0 0 female 1 0
                                 ses*female 1 0 0 0 0 0;
   estimate 'ses 2 and female 0' intercept 1 ses 0 1 0 female 1 0
                                 ses*female 0 0 1 0 0 0;
   estimate 'ses 3 and female 0' intercept 1 ses 0 0 1 female 1 0
                                 ses*female 0 0 0 0 1 0;
```

```
   estimate 'ses 1 vs 2 at female = 0' ses 1 -1 0
                                       ses*female 1 0 -1 0  0 0;
   estimate 'ses 1 vs 3 at female = 0' ses 1 0 -1
                                       ses*female 1 0 0 0 -1 0;
   estimate 'ses 2 vs 3 at female = 0' ses 0 1 -1
                                       ses*female 0 0 1 0 -1 0;
```

```
   estimate 'ses 1 vs 2 at female = 1' ses 1 -1 0;
   estimate 'ses 1 vs 3 at female = 1' ses 1 0 -1;
   estimate 'ses 2 vs 3 at female = 1' ses 0 1 -1;
```

```
   estimate 'female 0 vs 1 at ses = 1' female 1 -1  ses*female 1 -1 0 0 0 0;
   estimate 'female 0 vs 1 at ses = 2' female 1 -1  ses*female 0 0 1 -1 0 0;
   estimate 'female 0 vs 1 at ses = 3' female 1 -1  ses*female 0 0 0 0 1 -1;
run;
quit;
```

Example 4: Three-way ANOVA with main effects only

```
proc glm data= hsb2;
   class ses female prog;
   model write = ses female prog /solution;
   estimate 'ses 1, female 0 and prog 1' intercept 1 ses 1 0 0 female 1 0 prog 1 0 0/e;
```

```
   estimate 'ses 1, female 0 and prog 1' intercept 1 ses 1 0 0 female 1 0 prog 1 0 0/e;
   estimate 'ses 2, female 0 and prog 2' intercept 1 ses 0 1 0 female 1 0 prog 0 1 0;
   estimate 'ses 3, female 1 and prog 1' intercept 1 ses 0 0 1 female 0 1 prog 1 0 0;

   estimate 'ses 1 and female 0' intercept 1 ses 1 0 0 female 1 0 /e; /*averaging across all levels of prog*/
   estimate 'ses 2 and female 0' intercept 1 ses 0 1 0 female 1 0 ;
   estimate 'ses 3 and female 0' intercept 1 ses 0 0 1 female 1 0;

   estimate 'ses 1 vs 2' ses 1 -1 0 /e; /*the difference is the same across any levels of female or prog
                                        since this is a marginal effect model.*/
   estimate 'ses 1 vs 3' ses 1 0 -1;
   estimate 'ses 2 vs 3' ses 0 1 -1;
run;
quit;
```

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