Lab Assignment No. 5: Answer Key

1) What are the appropriate univariate measures of central tendency and bivariate correlations for your data (including age)? Interpret the means and correlations.

Table 1. Variable correlations

	Anxiety	Independence	Teamwork	age
Anxiety	1.00			
Independence	0.51	1.00		
	<.0001			
Teamwork	0.51	0.39	1.00	
	<.0001	<.0001		
age	0.10	0.07	0.01	1.00
	0.11	0.27	0.85	

Table 2. Specific group means

Group	Variable	Mean	*SD*	*SE*	Min	Max
Male None	Anxiety	63.93	9.36	1.03	33.00	86.00
	Independence	56.82	10.24	1.12	31.00	75.00
	Teamwork	62.31	11.42	1.25	27.00	89.00
Male Some	Anxiety	62.98	9.87	1.44	41.00	83.00
	Independence	61.19	9.97	1.45	37.00	87.00
	Teamwork	55.66	10.84	1.58	34.00	76.00
Female None	Anxiety	67.67	10.46	1.28	46.00	90.00
	Independence	57.09	10.03	1.23	33.00	77.00
	Teamwork	61.28	11.69	1.43	33.00	87.00
Female Some	Anxiety	69.13	10.22	1.40	41.00	93.00
	Independence	56.02	11.52	1.58	33.00	83.00
	Teamwork	56.68	10.31	1.42	28.00	77.00

From the above two tables it follows that the youths' ages were not correlated with any one of the three investigate measures. This is of importance when considering a range of ages across a given population. A correlation between the outcome measures and age would be not desirable since it would suggest a specific age effect that is not being modeled/investigated here.

As per the means it would appear that means are relatively close to one another. The female group with some prior convictions stands out with a high mean on the anxiety measure, but with comparatively low scores on *Teamwork* and *Independence.* Since low scores on *Teamwork* and *Independence* suggest an inability to comply with the ramifications of those specific working environments we would certainly keep an eye on the male group with some priors since they scored lowest on *Teamwork*. However, further investigation is needed to make any substantive conclusions.

2) Assess whether your data is multivariate normally distributed and meets basic assumptions (leverage values, Mardia's coefficients, Henze-Zirkler T, and Bartlett's test).

Reviewing the group specific leverage values only the *Male None* and *Male Some* groups exceeded the expected criterion (Crit 3, Table 3). Table 3 shows the critical leverage values and the corresponding maximum observed leverage values for each group.

Table 3. Critical and maximum observed leverage values

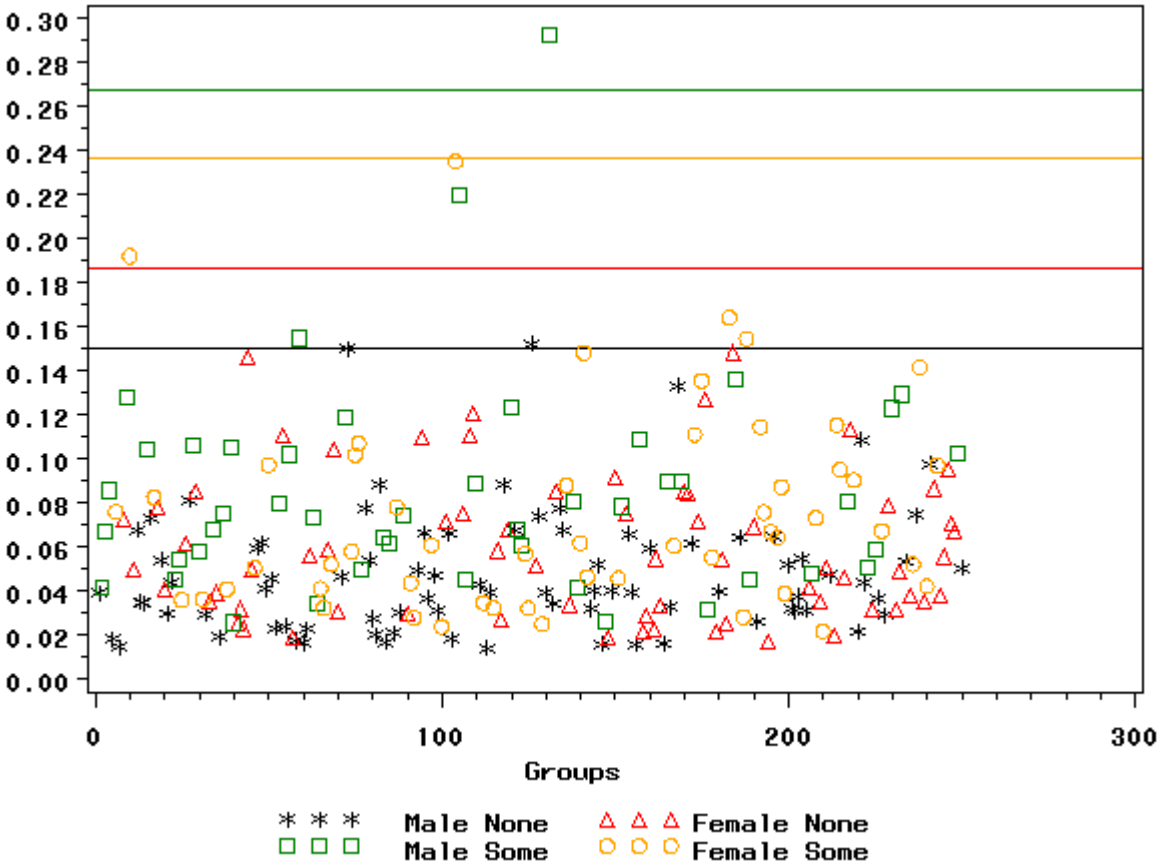
Group	Crit 1	Crit 2	Crit 3	Max
Male None	0.0723	0.0964	0.1504	0.1523
Female None	0.0896	0.1194	0.1868	0.1485
Male Some	0.1277	0.1702	0.2679	0.2930
Female Some	0.1132	0.1509	0.2370	0.2352

Further, an investigation of the plot in Figure 1 depicting the above leverage values shows that there are only two observations that fall outside of the corresponding criteria. Considering that these points are still relatively close to the criterion cut-off value they were not removed until the multivariate distribution was investigated.

All of the four groups were multivariate normally distributed with corresponding Mardia's skewness and kurtosis as well as Henze-Zirkler tests all non-significant. This further supported the retention of the two observations that fell outside the cutt-off values for the leverage values seen earlier.

Last but not least the assumption of equal variance/covariance matrices was investigated using a Bartlett's test. The groups were found not to differ on their variance/covariances, χ^2 (df=18) = 9.45, p = .95. This finding further supports the use of a factorial (multi-way) MANOVA. Since all of the assumptions were met we proceeded with the analysis.

Figure 1. Group leverage values and critical value cut-offs



3) Run a 2x2 factorial MANOVA. Report, discuss and interpret the produced Wilk's Lambdas.

Since there are three effects we are investigating there will be three corresponding Wilk's Lambdas, one for *gender*, one for *prior* and one for the interaction between the two. Ideally we would like to see only one (especially the interaction term) to produce a significant multivariate test. However, several significant tests could potentially suggests specific impacts at specific levels/variables.

The three observed lambdas were all significant, $\Lambda_{gende} = .86,\ F(3,\ 244) = 13.49,\ p < .01$, $\Lambda_{prior} = .90,\ F(3,\ 244) = 9.25,\ p < .01$, and $\Lambda_{gender*prior} = .96,\ F(3,\ 244) = 3.60,\ p = .01$. This suggests that for any one of the three factors there is at least one mean vector difference significantly different from zero. However, in order to teas apart the exact effects these factors have on the three measures we must consult the corresponding univariate ANOVAs and subsequent *t*-tests in order to investigate where the significant differences lie.

4) Report, discuss and interpret the produced univariate ANOVA's.

It would appear that each factor that was modeled has a specific impact on one of the variables analyzed. Table 4 shows that for *gender* there was only a significant difference in *Anxiety* scores. For prior convictions it would appear that the youth in the study varied significantly on their *Teamwork* scores and the interaction was marginally significant for the *Independence* measure.

Table 4. ANOVA follow-up tests

Factor	Variable	*F*-test	*p*
Gender	Anxiety	14.76	< .001
	Independence	3.30	.07
	Teamwork	.00	.98
Prior	Anxiety	.04	.84
	Independence	1.50	.22
	Teamwork	15.16	< .001
Gender*Prior	Anxiety	.87	.35
	Independence	4.06	.04
	Teamwork	.50	.48

These findings are very interesting because they suggest that within any one of the three variables the observed effects can be almost exclusively attributed to only one of the three factors. Here we observed that gender was able to distinguish between higher and lower scores of anxiety. Prior convictions on the other hand distinguished between people who did and did not work well in groups. This would seem intuitive since individuals who have been previously charged with misconduct seem to be less inclined to work well in groups. The interaction term, however, did not produce as clear results as anticipated. Whilst significant there appears to be only on group that stood out in its mean score on *Independence,* males with priors.

5) Report, discuss and interpret ***only*** the appropriate and significant *t*-tests with their corresponding simultaneous confidence intervals.

Since only three of the nine ANOVAs were significant we ought to interpret only those simultaneous confidence intervals for mean differences that are associated with those ANOVA findings. This is the case because much like with the progression from multivariate to univariate we use significant results as a decision criterion on which subsequent multiple comparisons we should consider.

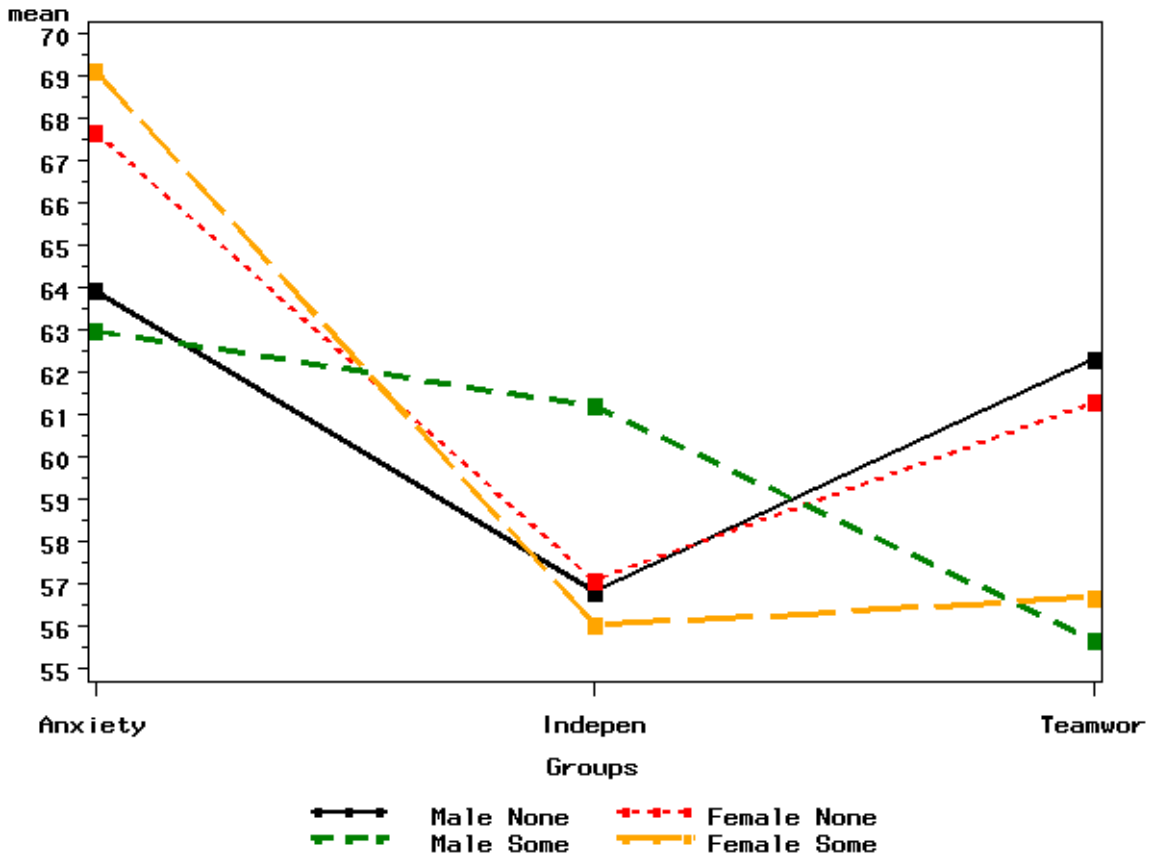
Males and females varied significantly on their *Anxiety* scores. On average, females experienced higher anxiety, regardless of their prior convictions (68.40). The mean difference between males and females on this measure was statistically significant (4.95, $p < .001$), with a 95% simultaneous confidence interval from 2.41 to 7.48.

As for the *Independence* measure the interaction term appeared to be the only significant differentiator. Consulting the mean differences however it appears that none of the mean difference scores on *Independence* are significant. This can be largely attributed to the Bonferroni correction applied. The largest mean difference was between *Female Some* and *Male Some* groups, with a mean difference of -5.17, $p = .08$, and a 95% simultaneous confidence interval from -10.73 to .38.

Known if the youth had prior convictions was a significant factor in the ability to distinguish between individuals in the *Teamwork* variable. The significant mean difference, 5.63, $p < .001$, was in favor of those with no prior convictions denoting those individuals to work better in teamwork/group environments. The corresponding 95% simultaneous confidence interval for the mean difference ranged from 2.78 to 8.48.

6) Provide a means plot for the observed four groups (gender by prior). What can you deduce from this plot? How does this plot relate to your findings?

Figure 2. Comparative means plot



The plot graphically depicts the interaction term relationships for *gender*prior*. However, given that the interaction term is a composite of the two variables, variable specific effects too can be inferred. For instance, even though we have seen that gender and prior are effective singular factors in the mean comparisons for *Anxiety* and *Teamwork* we can use the plot to verify these relationships. The plotted means for *Anxiety* very clearly differ between males and females in that the means for both the female groups are much greater than those for either of the comparative male groups. Similar, means for prior groups (pooled across genders) are higher on *Teamwork* as opposed to those without priors.

7) How would you answer the center's original hypotheses/questions? As someone who works at the center, what recommendations would you make regarding the approach to the youth mandated to enroll at the center?

The center's original hypothesis was supported by our investigation. Males with prior convictions were found indeed to score highest on the *Independence* measure and lowest of all four groups on *Teamwork.* Moreover, males with prior convictions also scored lower on the *Anxiety* measure as opposed to their female counterparts with prior convictions (who scored highest of all four groups on *Anxiety*).

As a member of staff my recommendation would be to address the specific behavioral patterns of each of the four groups. If anxiety was the main focus to be addressed it is clear that an intervention or focus program should take the gender differences into account above and beyond knowledge of prior convictions. Similar with *Teamwork.* The program ought to focus on addressing those characteristic components associated with having had prior convictions when addressing the lack of teamwork skills rather than gender differences. It is a bit more difficult to interpret the *Independence* measure. Since we desire youth to score highly on both *Independence* and *Teamwork* the center's staff could perhaps utilize the knowledge from the male group with some prior convictions to instill greater independence in the other three groups. Furthermore, this could perhaps be useful in a didactic framework whereby males with prior convictions could perhaps aid in the structuring and execution of tasks aimed at encouraging independent work.

8) The center's director is a strong advocate that anxiety, independent and teamwork oriented working are all greatly influenced by both gender and prior convictions. What would you say to the director and what evidence would you site/present?

It is evident that while all three factors, gender, prior and their interaction, do indeed provide some information regarding the differentiation between group specific means on *Anxiety, Independence* and *Teamwork,* the interaction performed poorest. As can be seen from the means plot the gender differentiation in *Anxiety* and the prior differentiation in *Teamwork* are much more prevalent and clearer than that given by the interaction for *Independent.*

9) Look at the multivariate distribution of residuals (by group). Discuss their corresponding distributions. What direct bearing do these residuals have on your analysis?

Residuals should be investigated in order to evaluate the models adequacy and fit to the data analyzed. Since SAS produces (via the procedures used in lab) unstandardized residuals their magnitude cannot be informative as is usually practice in regression. This is also not so much the point when assessing model fit in the multivariate environment. Instead, much more informative is the assessment of univariate and multivariate distribution of those errors.

Figure 3. Boxplot by group for *Anxiety Residuals*

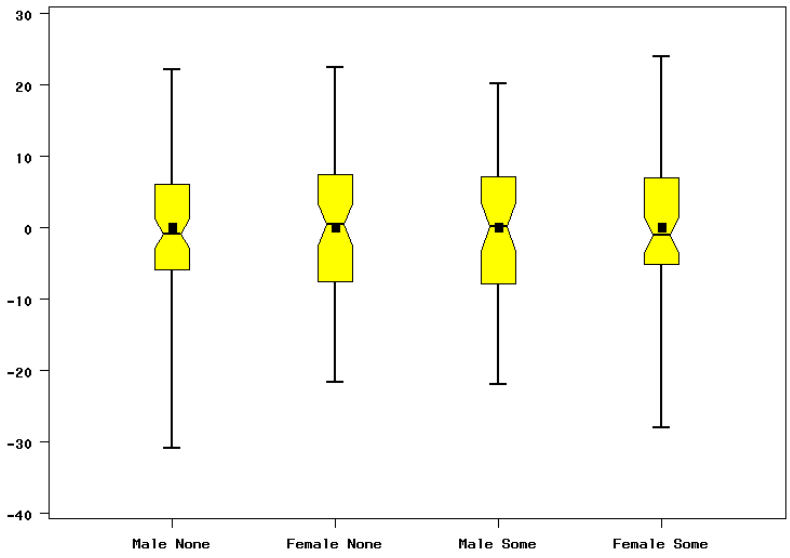


Figure 4. Boxplot by group for *Independence Residuals*

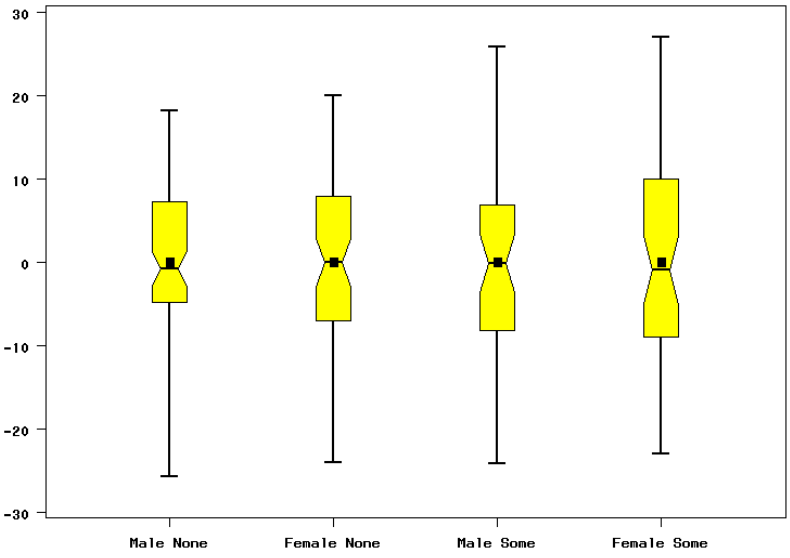
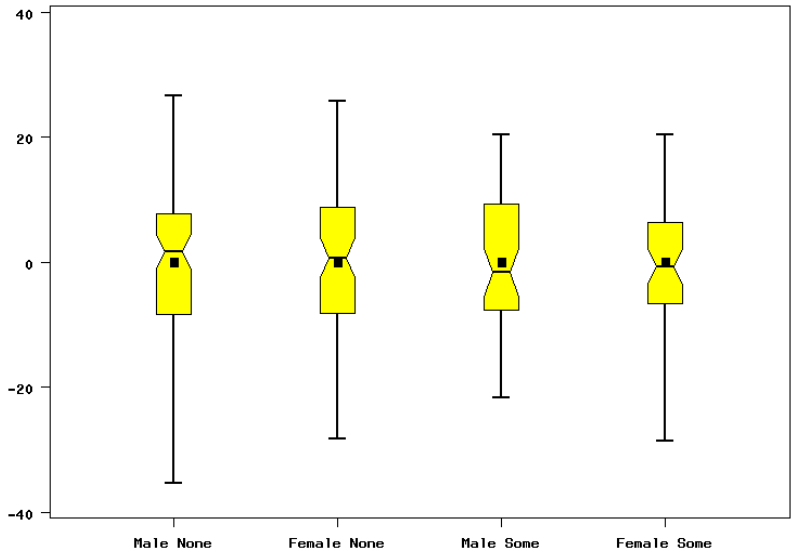


Figure 5. Boxplot by group for *Teamwork Residuals*



Again, evaluated individually we would look for potential outliers. Of the three variable residuals (by the four groups) only *Male None* and *Female Some* for the residuals of *Anxiety* and *Teamwork* produced residuals which could be considered outliers. However, a multivariate investigation using the Mardia's coefficients and the Henze-Zirkler test revealed that none of the residuals multivariate distributions were non-normal.

10) What potential limitations could this analysis have? Also, as a program evaluator what further recommendations (for research and analysis) would you make based on these analyses and results alone?

All results usually need to be verified. This means a retest of the center's hypotheses would be recommended given that the center seeks to structure its treatment plan based on these analyses. Moreover, no comparative sample was presented. The center should consider evaluating these four groups as compared against some control that was not mandated to be enrolled in the center's program. Also, it was reported that the mean score on all of these measures is around 50 points. This would suggest that all four of these groups are already above average on all three of these measures, with the *Female Some* score on *Independence* closest to the hypothesized mean (yet still 6 points above it). Given the relatively high scores on *Anxiety*, and taking into consideration the situation these youth have found themselves in, the analyst may want to consider to apply some sore of centering technique that would allow for a subgroup specific analysis.

Extra Credit: Produce at least one additional plot / graph that could be helpful to the staff at the center. Why did you choose this plot / graph and how is it useful?

Figure 6. Boxplot by group for *Anxiety*

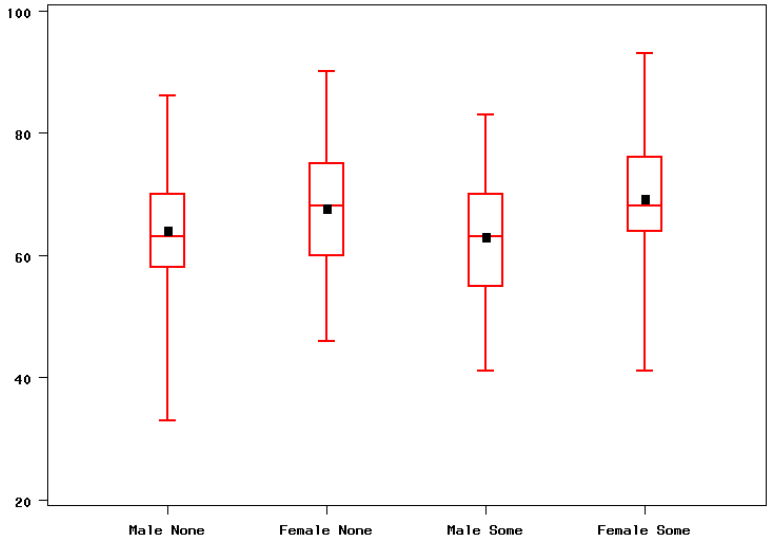


Figure 7. Boxplot by group for *Independence*

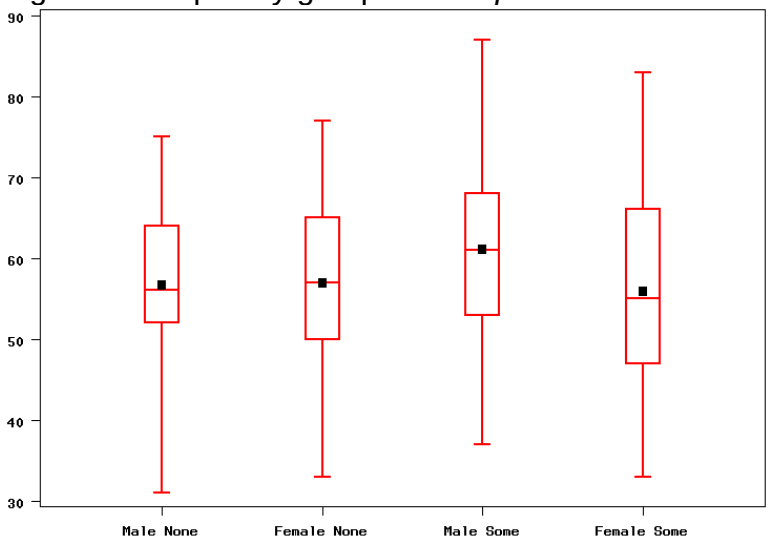
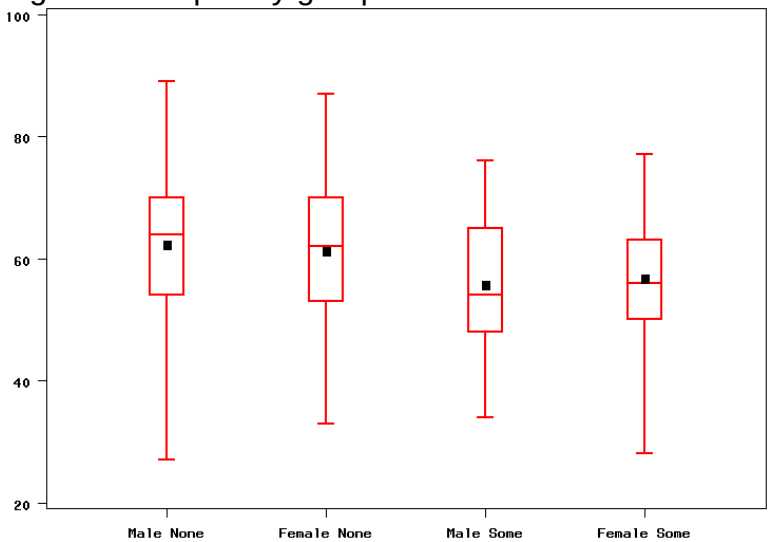
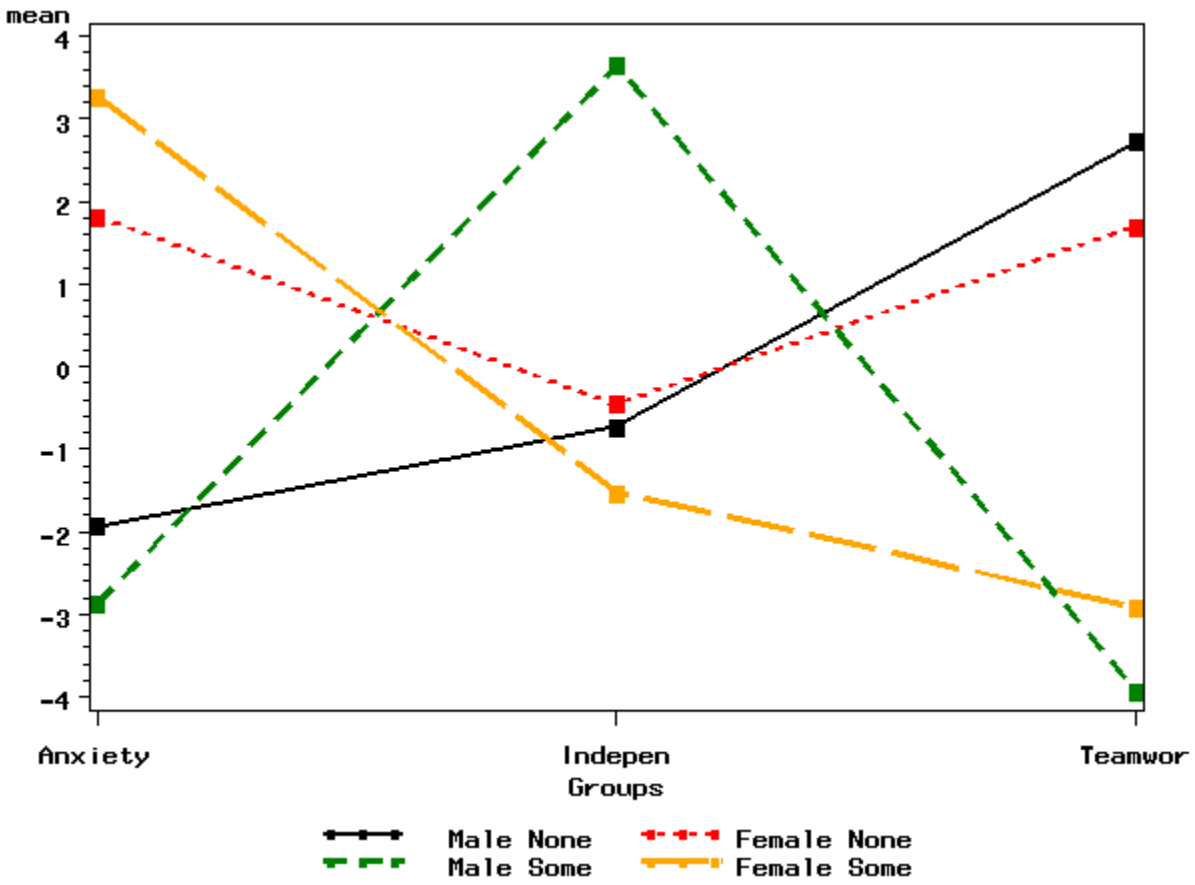


Figure 8. Boxplot by group for *Teamwork*



The center could probably use a series of comparative box and whisker plots depicting the three variables across the four groups. This is helpful when we are considering a subpopulation and want to know more about the specific comparisons between the groups. This is much easily seen from a graph than a table.

Figure 9. Means plot adjusted for variable means



There are several things that could be done with the means plot. Figure 9 shows a plot in which the means for each group on each of the variables has been adjusted (subtracted out) for the pooled across all factors variable mean. This allows to see a much clearer deviation of each of the groups from the overall variable mean.

```
/* ------------------------------------------------------------ */
/*           Hmw 5: Factorial MANOVA (SAS Syntax)               */
/* ------------------------------------------------------------ */

/* Format modifications */
proc format;
     value     gender    0="Male"
                         1="Female";
     value     prior     0="None"
                         1="Some";
run;

/* Getting the individual group means */
proc sort data=evaluation;
     by gender prior;
proc means mean std stderr min max;
     var Anxiety Independence Teamwork;
     by gender prior;
     format gender gender. prior prior.;
proc freq;
     table prior*gender;
     format gender gender. prior prior.;
proc corr;
     var Anxiety Independence Teamwork age;
run;

/* Multivariate Normality Assessment */

/* There are three sets of groups in a factorial design.
   Group membership can be determined by using either of the
   original categorical variables or the combination of the two
*/

data m_none;
     set evaluation;
     if gender=0 & prior=0;
data f_none;
     set evaluation;
     if gender=1 & prior=0;
data m_some;
     set evaluation;
     if gender=0 & prior=1;
data f_some;
     set evaluation;
     if gender=1 & prior=1;
run;

/* Let us investigate the leverage values for each of our
factorial groups */
proc reg data=m_none noprint;
     model age = Anxiety Independence Teamwork / influence;
```

```
     output out=m_none H=Leverage;
proc reg data=f_none noprint;
     model age = Anxiety Independence Teamwork / influence;
     output out=f_none H=Leverage;
proc reg data=m_some noprint;
     model age = Anxiety Independence Teamwork / influence;
     output out=m_some H=Leverage;
proc reg data=f_some noprint;
     model age = Anxiety Independence Teamwork / influence;
     output out=f_some H=Leverage;
run;
quit;

/* Critical leverage values we should consider */
proc iml;

     Nmnone = 83;
     Nfnone = 67;
     Nmsome = 47;
     Nfsome = 53;

     crit1_mnone = (2*3)/Nmnone;
     crit1_fnone = (2*3)/Nfnone;
     crit1_msome = (2*3)/Nmsome;
     crit1_fsome = (2*3)/Nfsome;
     crit1 =
(crit1_mnone||crit1_fnone||crit1_msome||crit1_fsome)`;

     crit2_mnone = (2*(3+1))/Nmnone;
     crit2_fnone = (2*(3+1))/Nfnone;
     crit2_msome = (2*(3+1))/Nmsome;
     crit2_fsome = (2*(3+1))/Nfsome;
     crit2 =
(crit2_mnone||crit2_fnone||crit2_msome||crit2_fsome)`;

     crit3_mnone = ((2*(gaminv(.99,1.5)))/(Nmnone-
1))+(1/Nmnone);
     crit3_fnone = ((2*(gaminv(.99,1.5)))/(Nfnone-
1))+(1/Nfnone);
     crit3_msome = ((2*(gaminv(.99,1.5)))/(Nmsome-
1))+(1/Nmsome);
     crit3_fsome = ((2*(gaminv(.99,1.5)))/(Nfsome-
1))+(1/Nfsome);
     crit3 =
(crit3_mnone||crit3_fnone||crit3_msome||crit3_fsome)`;

     Group = {'Male None','Female None','Male Some', 'Female
Some'};

     print 'Leverage cut-off values';
     print Group crit1 crit2 crit3;
```

```
quit;

/* Combining the datasets into one dataset */
data evaluation;
     set m_none f_none m_some f_some;
     if gender=0 & prior=0 then group=1;
     if gender=1 & prior=0 then group=2;
     if gender=0 & prior=1 then group=3;
     if gender=1 & prior=1 then group=4;
run;

/* Comparing highest leverages */
proc sort data=evaluation;
     by gender prior;
proc means data=evaluation max;
     var Leverage;
     by gender prior;
     title 'Leverage Values';
     format gender gender. prior prior.;
run;

/* Plotting leverage values */
goptions reset=symbol;
legend1 label=(height=1 position=top justify=center 'Groups')
          value=('Male None' 'Female None' 'Male Some' 'Female
Some') across=2 down=2;
proc gplot data=evaluation;
  title 'Leverage Values';
  axis1 length=4.5 in;
  axis2 length=7.5 in;
  plot Leverage*id=group / vaxis=axis1 haxis=axis2
legend=legend1
  vref=(.1504 .1868 .2679 .2370) cvref=('black' 'red' 'green'
'orange');
  symbol1 v=star i=none color=black;
  symbol2 v=star i=none color=red;
  symbol3 v=star i=none color=green;
  symbol4 v=star i=none color=orange;
run;
quit;

/* RUN THE MULTNORM2 MACRO */

/* Let's assess multivariate normality */
%multnormplt (data=m_none,
     var= Anxiety Independence Teamwork,
     title='Male None');
%multnormplt (data=f_none,
     var= Anxiety Independence Teamwork,
     title='Female None');
```

```
%multnormplt (data=m_some,
     var= Anxiety Independence Teamwork,
     title='Male Some');
%multnormplt (data=f_some,
     var= Anxiety Independence Teamwork,
     title='Female Some');
quit;

/* Bartlett's Test */
proc discrim data=evaluation pool=test;
  class group;
  var Anxiety Independence Teamwork;
run;

/* Running the MANOVA and saving out residuals */
proc glm data=evaluation;
  class gender prior;
  model Anxiety Independence Teamwork = gender prior
gender*prior;
  lsmeans gender prior gender*prior / stderr cl pdiff
adjust=Bon;
  manova h=gender prior gender*prior/ printe printh;
  output out=resids r=ranx rind rtea;
  format gender gender. prior prior.;
run;
quit;

/* Let us create the corresponding profile plot */
title "Profile Plot for Evaluation Data";
data evalflat;
  set evaluation;
  admin='Anxiety'; score=Anxiety; output;
  admin='Independence'; score=Independence; output;
  admin="Teamwork"; score=Teamwork; output;
  keep group admin score;
run;

proc sort data=evalflat;
  by group admin;
proc means noprint;
  by group admin;
  var score;
  output out=evalmeans mean=mean;
run;

proc gplot data=evalmeans;
  axis1 length=4.5 in;
  axis2 length=7.5 in;
  plot mean*admin=group / vaxis=axis1 haxis=axis2
legend=legend1;
  symbol1 v=K f=special w=2 h=2 l=1 i=join color=black;
```

```
  symbol2 v=K f=special w=2 h=2 l=1 i=join color=red;
  symbol3 v=K f=special w=2 h=2 l=1 i=join color=green;
  symbol4 v=K f=special w=2 h=2 l=1 i=join color=orange;
run;
quit;

/* Investigating residuals */
proc sort data=resids;
     by group;
proc univariate plot;
     by group;
     var ranx rind rtea;
run;
quit;

/* Run the multnorm2 SAS macro */
data m_none_res;
     set resids;
     if gender=0 & prior=0;
data f_none_res;
     set resids;
     if gender=1 & prior=0;
data m_some_res;
     set resids;
     if gender=0 & prior=1;
data f_some_res;
     set resids;
     if gender=1 & prior=1;
run;

%multnormplt (data=m_none_res,
     var= ranx rind rtea,
     title='Male None');
%multnormplt (data=f_none_res,
     var= ranx rind rtea,
     title='Female None');
%multnormplt (data=m_some_res,
     var= ranx rind rtea,
     title='Male Some');
%multnormplt (data=f_some_res,
     var= ranx rind rtea,
     title='Female Some');
quit;

proc format;
     value     group     1="Male None"
                         2="Female None"
                         3="Male Some"
                         4="Female Some";
proc boxplot data=resids;
     plot (ranx rind rtea)*group /cboxes=black notches
```

```
                                        cboxfill=yellow;
     title 'Residual Boxplots';
     format group group.;
run;
```