# ANCOVA

**Description:**

ANCOVA is a type of analysis of variance that allows you to first control for variable(s) that change the relationship of the independent variable with the dependent variable.

IV

DV

CV

Usually the section marked with an arrow would be considered error. But since we used the control variable (covariate, see below), it’s now accounted for, which means there is less error in the DV (always a good thing).

**Definitions/Abbreviations:**

* CV – covariate. This variable changes with the dependent variable and is used to adjust the dependent variable to create equal groups or eliminate nuisance information. CVs can be either a continuous variable (such as age) or a categorical variable (such as gender). CVs are used to adjust the values of the dependent variables, usually to create larger group differences on your independent variables. This variable, if actually related to the DV, helps control for error variance.
* IV – independent variable. This variable *has* to be a categorical variable. You can put people into groups based on any category (gender, handedness) or your experimental manipulation (instructions versus no instructions).
* DV – dependent variable. The dependent variable *needs* to be a continuous variable or another type of analysis might work better (see log regression). Your dependent variable should be the measurement you took in your study or what information you are expecting to see changed over groups.

**Relation to other designs:**

* ANCOVA is a type of ANOVA with control/covariates. However, ANOVA is mathematically related to regression – so it’s fair to say that ANCOVA is half-way between a traditional regression and ANOVA.
* First, the variance between the DV and CV is analyzed, looking at the overlap in the two (or more) variables. Then, the DV is adjusted to not include the CV variance (i.e. that variance is taken out). This step is very similar to regression, especially if the CV is continuous.
* Second, a regular ANOVA is analyzed on the adjusted means.
* **Therefore:** 
  + Between subjects designs:
    - Still get and interpret Levene’s test for homogeneity
    - Post hoc test: Independent t or BN ANCOVA on adjusted means
    - Post hoc correction: Tukey
  + Repeated measures designs
    - Still get and interpret Mauchly’s test for Sphericity
    - Post hoc test: Dependent t or RM ANCOVA on adjusted means
    - Post hoc correction: Tukey
  + Mixed designs
    - Get both Levene’s and Mauchly’s test
    - Post hoc test: depends on which IV you choose to split/analyze

Chart of ANCOVA Analysis:

|  |  |  |  |
| --- | --- | --- | --- |
|  | ANCOVA | | |
|  | Main Effect Between | Main Effect Repeated Measures | Interaction |
| If levels > 2  And significant | Independent t-test  Tukey correction | Dependent t-test  Tukey correction | SPLIT one IV column  Independent t-test OR  Dependent t-test  Tukey correction |
| If levels = 2 | Interpret means | Interpret means |

If the interaction is significant, often people ignore any analyses with the main effects:

* This procedure reduces Type 1 error because you are running less post hoc tests.
* You are interested in the interaction anyway, so why only interpret one variable at a time?
* Also, be sure to follow up with the correct test type – do not do dependent t on the between subjects factor.

**New to this section:**

* We will have to get the *adjusted means* to calculate effect size and for the post hoc tests.

**Notes on Assumptions:**

* Accuracy: same as regular ANOVA.
* Missing: same as regular ANOVA – mostly you cannot fill in because the percent of missing data would be too high.
* Outliers:
  + With ANCOVA, we have at least two columns – one for the DV and one for the CV. Therefore, you would be making sure that people do not have a strange combination of answers on the CV and DV.
* Additivity:
  + If you have ONE CV: not necessary.
  + If you have TWO OR MORE CVs: You want to check your CVs by using a correlation to make sure they do not overlap too much. If they overlap a great deal, then you want to use only one of them or combine them. Look for variables with *r* > .70. Highly correlated CVs cause you to lose power in this type of analysis.
* Linearity:
  + Linearity between the CV and DV is a very important issue. If you are using a regression to adjust the values of the DV with the CV, then there needs to be a linear relationship. You can check for this value using our fake regression procedure and looking at the PP Plot.
* Normality:
  + You also want the CV and DV combination to be normally distributed. You can check for multivariate normality by running a fake regression and looking at the histogram of the residuals.
* Homogeneity:
  + The variance of the groups from your IV need to be equal across both the DV and CV. You can check this information with a residual plot from your fake regression (you do not want raining or an unequal spread of the dots around 0). You can also use Levene’s test of homogeneity – you *do not* want p < .001.
  + You will also check for Sphericity for repeated measures designs – you *do not* want p < .001.
* Homoscedasticity:
  + The spread of the scores on the CV need to be equal around all the values of the DV. You have to check this assumption by looking at a residual plot from a fake regression. You do not want a megaphone shape.

# Complete Example – All Between

The researcher has measured participant’s attitudes toward the use of drugs to see if there are group differences in attitudes. They also measured physical health symptoms to control for people who report more symptoms will have more positive attitudes towards drugs (because they are sicker). Finally, they grouped people by employment status and religion to analyze group differences and interactions on attitudes.

**Datafile:** bn ancova.csv

**IVs:**

* Employment – employed versus unemployed.
* Religion – none, Jewish, Protestant, Catholic.

**CV:**

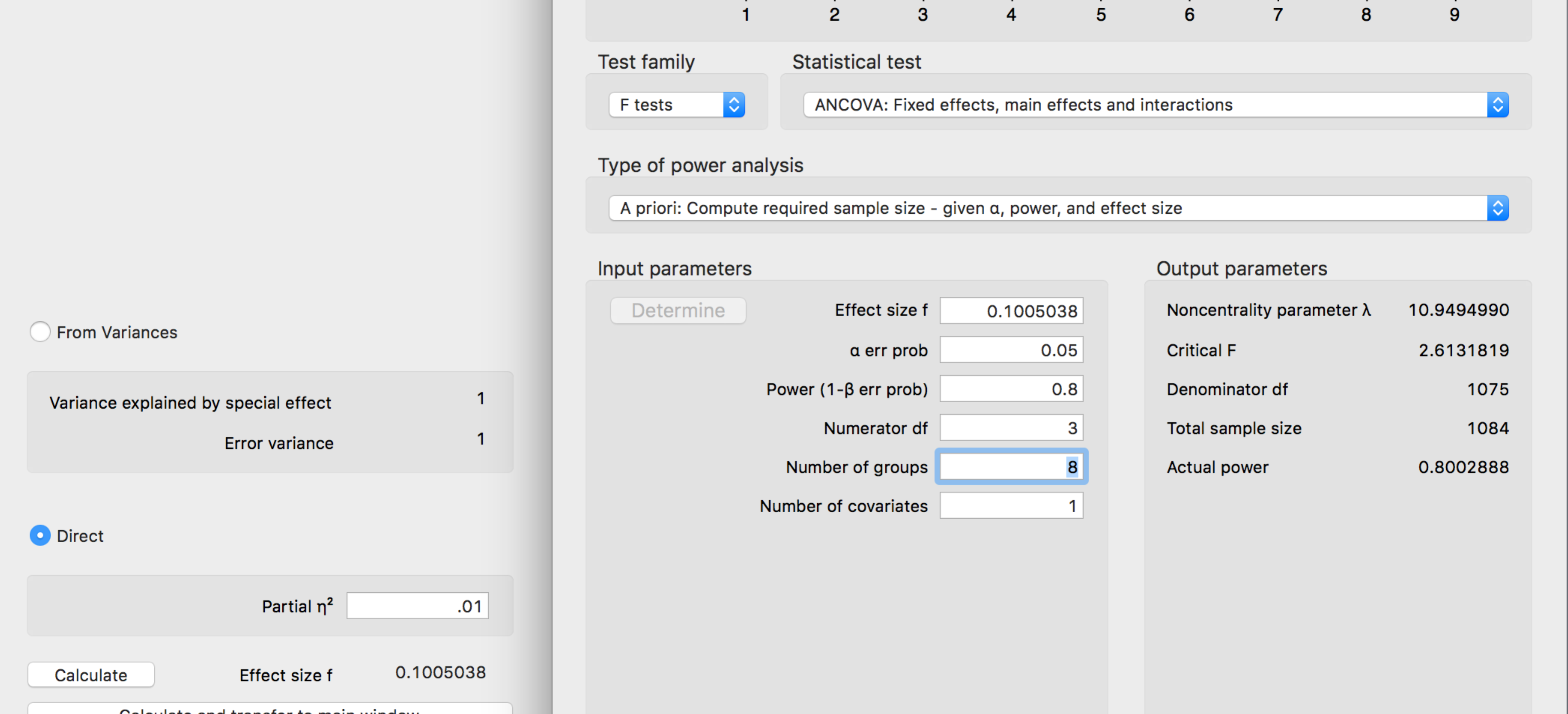
* Phyheal – physical health, higher scores indicate more health symptoms (problems).

**DV:**

* Attdrug – attitudes towards drugs, higher scores indicate more positive attitudes.

**Power:**

1. Open Gpower!
   1. Test family: F-test
   2. Statistical Test: ANCOVA: Fixed effects, main effects, and interactions
   3. Estimate an effect size: click determine 🡪 click direct 🡪 use eta square sizes you think might be accurate, remember small, medium, and large estimates from the notes.
   4. Alpha = .05
   5. Power (1-beta .20) = .80
   6. Numerator df:
      1. Main effects: Levels – 1
      2. Interaction: (Levels-1)\*(Levels-1)
2. Number of groups
   1. Main effects: Number of Levels
   2. Interactions: Number of Conditions
3. Number of covariates = number of CVs.
4. Let’s estimate the following:
   1. Small effect size (eta = .01)
   2. Interaction test:
      1. Numerator df = (2-1)\*(4-1) = 3
      2. Number of groups: 2\*4 = 8
   3. Number of covariates = 1
5. Let’s hope it’s not a small effect, as our power analysis says we need 1084 people!



**Results**

Participants were measured on their attitudes toward drug use and physical health symptoms to examine the interaction between employment and religion on attitudes. The data were screened for assumptions, and there were two multivariate outliers were present (using Mahalanobis distance), which were removed for the final analysis. Therefore, all participants were used for this analysis. Linearity, homogeneity (Levene’s *F*(7, 454) = 1.72, *p* = .10), homoscedasticity, and normality were all met.

A between subjects ANCOVA was used to analyze the interaction between employment and religion on attitudes towards the use of drugs after controlling for physical health symptoms. Physical health was a significant adjustor of attitudes towards the use of drugs, *F*(1, 453) = 6.65, *p* = .01, *η p*² = .01. Physical health was positively related to attitudes of the use of drugs (*r* = .13), which indicated that as more symptoms are listed more positive attitudes towards drugs exist. After controlling for physical health, the main effect of employment was not significant, *F*(1, 453) = 0.45, *p* = .50, *η p*² = .001, indicating that employed participants (*M* = 7.62, *SD* = 1.11) had the same attitudes as unemployed participants (*M* = 7.70, *SD* = 1.20). The main effect of religion was not significant, Religion, *F*(3, 453) = 2.55, *p* = .06, *η p*² = .02, with None or other groups reporting low attitudes (*M* = 7.40, *SD* = 1.13), followed by Protestant groups (*M* = 7.66, *SD* = 1.09), Jewish (*M* = 7.71, *SD* = 1.12), and finally Catholic participants (*M* = 7.86, *SD* = 1.11).

The interaction between employment and religion was significant, *F*(3, 453) = 2.86, *p* = .04, *η p*² = .02, which is shown in Figure 1. Follow up between subjects ANCOVAs were used to examine the adjusted means by employment type. Catholic participants showed equal attitudes when employed and unemployed, *F*(1, 116) = 1.41, *p* = .24, *η p*² = .03, while none or other participants showed a marginally more positive attitude when employed, *F*(1, 73) = 3.24, *p* = .08, *η p*² = .04. Jewish participants showed no difference in attitudes, *F*(1, 89) = 0.40, *p* = .53, *η p*² < .01, and Protestant participants showed marginally more positive attitudes when unemployed, *F*(1, 172) = 3.40, *p* = .07, *η p*² = .02.

# Results

## ANCOVA

| **ANCOVA - attdrug** | | | | | | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Cases** | | **Sum of Squares** | | **df** | | **Mean Square** | | **F** | | **p** | | **η²** | |
| emplmnt |  | 0.580 |  | 1 |  | 0.580 |  | 0.448 |  | 0.504 |  | 0.001 |  |
| religion |  | 9.897 |  | 3 |  | 3.299 |  | 2.550 |  | 0.055 |  | 0.016 |  |
| emplmnt ✻ religion |  | 11.106 |  | 3 |  | 3.702 |  | 2.862 |  | 0.037 |  | 0.018 |  |
| phyheal |  | 8.598 |  | 1 |  | 8.598 |  | 6.646 |  | 0.010 |  | 0.014 |  |
| Residual |  | 586.041 |  | 453 |  | 1.294 |  |  |  |  |  |  |  |
|  | | | | | | | | | | | | | |
| Note.  Type III Sum of Squares  Covariate  Physical health symptoms *F*(1, 453) = 6.65, *p* = .01, *η p*² = .01  *r* = .13  Main effects  Employment, *F*(1, 453) = 0.45, *p* = .50, *η p*² = .001 (not significant)  Religion, *F*(3, 453) = 2.55, *p* = .06, *η p*² = .02 (marginally significant)  Interaction  *F*(3, 453) = 2.86, *p* = .04, *η p*² = .02 (significant) | | | | | | | | | | | | | |

| **ANCOVA - attdrug** | | | | | | | | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Cases** | | **Sum of Squares** | | **df** | | **Mean Square** | | **F** | | **p** | | **η²** | | **η² p** | |
| emplmnt |  | 0.580 |  | 1 |  | 0.580 |  | 0.448 |  | 0.504 |  | 0.001 |  | 0.001 |  |
| religion |  | 9.897 |  | 3 |  | 3.299 |  | 2.550 |  | 0.055 |  | 0.016 |  | 0.017 |  |
| emplmnt ✻ religion |  | 11.106 |  | 3 |  | 3.702 |  | 2.862 |  | 0.037 |  | 0.018 |  | 0.019 |  |
| phyheal |  | 8.598 |  | 1 |  | 8.598 |  | 6.646 |  | 0.010 |  | 0.014 |  | 0.014 |  |
| Residual |  | 586.041 |  | 453 |  | 1.294 |  |  |  |  |  |  |  |  |  |
|  | | | | | | | | | | | | | | | |
| *Note.*  Type III Sum of Squares | | | | | | | | | | | | | | | |

### Assumption Checks

| **Test for Equality of Variances (Levene's)** | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **F** | | **df1** | | **df2** | | **p** | |
| 1.715 |  | 7 |  | 454 |  | 0.103 |  |
| *F*(7, 454) = 1.72, *p* = .10 | | | | | | | |

### Marginal Means

| **Marginal Means - emplmnt** | | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **emplmnt** | | **Marginal Mean** | | **SE** | | **Lower CI** | | **Upper CI** | |
| EMPLOYED |  | 7.620 |  | 0.076 |  | 7.470 |  | 7.769 |  |
| UNEMPLOYED |  | 7.695 |  | 0.082 |  | 7.533 |  | 7.857 |  |
|  | | | | | | | | | |

| **Marginal Means - religion** | | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **religion** | | **Marginal Mean** | | **SE** | | **Lower CI** | | **Upper CI** | |
| CATHOLIC |  | 7.863 |  | 0.105 |  | 7.657 |  | 8.068 |  |
| JEWISH |  | 7.705 |  | 0.119 |  | 7.472 |  | 7.939 |  |
| NONE OR OTHER |  | 7.397 |  | 0.134 |  | 7.134 |  | 7.659 |  |
| PROTESTANT |  | 7.664 |  | 0.086 |  | 7.494 |  | 7.833 |  |
|  | | | | | | | | | |

| **Marginal Means - emplmnt ✻ religion** | | | | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **emplmnt** | | **religion** | | **Marginal Mean** | | **SE** | | **Lower CI** | | **Upper CI** | |
| EMPLOYED |  | CATHOLIC |  | 7.688 |  | 0.144 |  | 7.406 |  | 7.970 |  |
|  |  | JEWISH |  | 7.615 |  | 0.172 |  | 7.277 |  | 7.952 |  |
|  |  | NONE OR OTHER |  | 7.669 |  | 0.168 |  | 7.340 |  | 7.999 |  |
|  |  | PROTESTANT |  | 7.507 |  | 0.119 |  | 7.274 |  | 7.740 |  |
| UNEMPLOYED |  | CATHOLIC |  | 8.038 |  | 0.152 |  | 7.739 |  | 8.337 |  |
|  |  | JEWISH |  | 7.796 |  | 0.164 |  | 7.473 |  | 8.119 |  |
|  |  | NONE OR OTHER |  | 7.124 |  | 0.208 |  | 6.716 |  | 7.533 |  |
|  |  | PROTESTANT |  | 7.821 |  | 0.125 |  | 7.575 |  | 8.067 |  |
|  | | | | | | | | | | | |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Catholic | Jewish | None | Protestant |
| Employed |  |  |  |  |
| Unemployed |  |  |  |  |

### Descriptives

| **Descriptives - attdrug** | | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **emplmnt** | | **religion** | | **Mean** | | **SD** | | **N** | |
| EMPLOYED |  | CATHOLIC |  | 7.667 |  | 0.984 |  | 63 |  |
|  |  | JEWISH |  | 7.591 |  | 1.106 |  | 44 |  |
|  |  | NONE OR OTHER |  | 7.674 |  | 1.351 |  | 46 |  |
|  |  | PROTESTANT |  | 7.511 |  | 1.084 |  | 92 |  |
| UNEMPLOYED |  | CATHOLIC |  | 8.036 |  | 1.095 |  | 56 |  |
|  |  | JEWISH |  | 7.813 |  | 1.214 |  | 48 |  |
|  |  | NONE OR OTHER |  | 7.100 |  | 1.185 |  | 30 |  |
|  |  | PROTESTANT |  | 7.843 |  | 1.194 |  | 83 |  |
|  | | | | | | | | | |

**ANCOVA catholic**

| **ANCOVA - attdrug** | | | | | | | | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Cases** | | **Sum of Squares** | | **df** | | **Mean Square** | | **F** | | **p** | | **η²** | | **η² p** | |
| emplmnt |  | 3.679 |  | 1 |  | 3.679 |  | 3.430 |  | 0.067 |  | 0.028 |  | 0.029 |  |
| phyheal |  | 1.513 |  | 1 |  | 1.513 |  | 1.410 |  | 0.237 |  | 0.012 |  | 0.012 |  |
| Residual |  | 124.416 |  | 116 |  | 1.073 |  |  |  |  |  |  |  |  |  |
|  | | | | | | | | | | | | | | | |
| *Note.*  Type III Sum of Squares | | | | | | | | | | | | | | | |

**ANCOVA jewish**

| **ANCOVA - attdrug** | | | | | | | | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Cases** | | **Sum of Squares** | | **df** | | **Mean Square** | | **F** | | **p** | | **η²** | | **η² p** | |
| emplmnt |  | 0.531 |  | 1 |  | 0.531 |  | 0.403 |  | 0.527 |  | 0.004 |  | 0.005 |  |
| phyheal |  | 4.696 |  | 1 |  | 4.696 |  | 3.565 |  | 0.062 |  | 0.038 |  | 0.039 |  |
| Residual |  | 117.252 |  | 89 |  | 1.317 |  |  |  |  |  |  |  |  |  |
|  | | | | | | | | | | | | | | | |
| *Note.*  Type III Sum of Squares | | | | | | | | | | | | | | | |

## ANCOVA None

| **ANCOVA - attdrug** | | | | | | | | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Cases** | | **Sum of Squares** | | **df** | | **Mean Square** | | **F** | | **p** | | **η²** | | **η² p** | |
| emplmnt |  | 5.419 |  | 1 |  | 5.419 |  | 3.235 |  | 0.076 |  | 0.042 |  | 0.042 |  |
| phyheal |  | 0.513 |  | 1 |  | 0.513 |  | 0.306 |  | 0.582 |  | 0.004 |  | 0.004 |  |
| Residual |  | 122.296 |  | 73 |  | 1.675 |  |  |  |  |  |  |  |  |  |
|  | | | | | | | | | | | | | | | |
| Note.  Type III Sum of Squares | | | | | | | | | | | | | | | |

## ANCOVA Protestant

| **ANCOVA - attdrug** | | | | | | | | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Cases** | | **Sum of Squares** | | **df** | | **Mean Square** | | **F** | | **p** | | **η²** | | **η² p** | |
| emplmnt |  | 4.369 |  | 1 |  | 4.369 |  | 3.399 |  | 0.067 |  | 0.019 |  | 0.019 |  |
| phyheal |  | 2.827 |  | 1 |  | 2.827 |  | 2.199 |  | 0.140 |  | 0.012 |  | 0.013 |  |
| Residual |  | 221.126 |  | 172 |  | 1.286 |  |  |  |  |  |  |  |  |  |
|  | | | | | | | | | | | | | | | |
| Note.  Type III Sum of Squares | | | | | | | | | | | | | | | |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Mean 1 | Mean 2 | Post hoc test | Effect Size | Explain |
| CATHOLIC  UN  M = 8.04  SD = 1.10  N = 56 | CATHOLIC  EMP  M = 7.67  SD = 0.98  N = 63 | *F*(1, 116) = 1.41, *p* = .24 | *η p*² = .03 | Not significant |
| JEWISH  UN  M = 7.81  SD = 1.21  N = 48 | JEWISH  EMP  M = 7.60  SD = 1.11  N = 44 | *F*(1, 89) = 0.40, *p* = .53 | *η p*² < .01 | Not significant |
| PROTESTANT  UN  M = 7.84  SD = 1.19  N = 83 | PROTESTANT  EMP  M = 7.51  SD = 1.08  N = 92 | *F*(1, 172) = 3.40, *p* = .07 | *η p*² = .02 | Marginal  Un > emp |
| NONE  UN  M = 7.10  SD = 1.19  N = 30 | NONE  EMP  M = 7.67  SD = 1.35  N = 46 | *F*(1, 73) = 3.24, *p* = .08 | *η p*² = .04 | Marginal  Emp > Un |