Partial and part correlations are discussed as a means of statistical control. Partial and part correlation coefficients measure relationships between two variables while controlling for the influences of one or more other variables. They are statistical methods for determining whether a true correlation exists between a dependent and an independent variable while controlling for one or more other variables. This paper discusses the use and limitations of partial correlations, and presents heuristic data illustrating that computation formulas and regression analyses with latent scores yield equivalent results. Three appendixes contain an example of Statistical Package for the Social Sciences (SPSS) partial correlation computation, SPSS commands for regression analyses, and the SPSS regression analysis printout. (Contains 3 tables, 1 figure, and 10 references.) (SLD)
Partial and Part Correlation Coefficients: Formula
and Score Regression Perspectives

Debra K. Roberts
Texas A&M University

Partial and Part Correlations

Abstract

This paper discusses partial and part correlations as means of statistical control. Partial and part correlation coefficients measure relationships between two variables while controlling for the influences of one or more other variables. The paper discusses the use and limitations of partial correlations, and presents heuristic data illustrating that computation formulae and regression analyses with latent scores both yield equivalent results.
Partial and Part Correlation Coefficients: Formula and Score Regression Perspectives

Experimental validity is an important concern for researchers (Huck & Cormier, 1996). By implementing methods of experimental and statistical control, better confidence can be placed in one’s results. These controls exist in order to reduce extraneous variability in research studies. Some common forms of experimental control include: random assignment, matching of subjects, use of experimental and control groups, and testing alternative hypotheses. While random assignment is considered one of the better variance controls, in most psychological research it is not feasible (Pedhazur, 1982). Statistical control is used as a mathematical means of comparing subjects when they can not be equivalent in fact (McBurney, 1994). Statistical methods are particularly needed when there is more than one independent variable. In these cases, the independent variables are not only related to the dependent variable, but are also related to each other. Researchers need to be able to determine the effects of some variables while controlling others. Partial and part correlations are statistical methods for determining whether a true correlation exists between a dependent and independent variable while controlling for one or more other variables (Waliczek, 1996).

Basic Ideas and Definitions

Partial and part correlation coefficients can be considered Pearson correlation coefficients and are related to multiple regression. In both partial and part correlation, two variables are correlated with the influence of one or more variables partialed out of (i.e., literally removed from) both or only one variable (Hinkle, 1998). For example, a
researcher analyzing the relationship between three variables such as height, weight, and age may want to know if a relationship exists when the age variable is removed. A partial correlation would correlate height and weight while removing the influence of age. A part correlation would correlate height and weight while the age variable is only removed from one of the variables.

In order to use partial correlation effectively, the data must be interval or ratio, comparably distributed, and a linear relationship must exist between variables (Korn, 1984; Waliczek, 1996). A partial correlation may be expressed as $r_{xy,z}$; this is interpreted as the correlation between $x$ and $y$ with $z$ removed. Often, numbers are used rather than letters, such as $r_{12,3}$. A partial correlation with one variable controlled is known as a first-order correlation. More than one variable may be controlled at a time and the coefficients from such analyses are considered second-order, third-order, and so on based on how many independent variables are removed (Pedhazur, 1982). For example, the notation, $r_{12,34}$ implies that this is a second-order correlation with variables 3 and 4 being controlled. Often, a Pearson correlation is called a zero-order correlation due to no variables being controlled since there is only one independent variable.

Examples and Cautions

Partial correlations can be extremely valuable in detecting spurious correlations. For example, this occurs when two variables, such as $x$ and $y$ are correlated due to both being affected by $z$. However, once $z$ is removed, the correlation between $x$ and $y$ disappears. According to Pedhazur (1982), one of the most common spurious correlations occurs when age is one of the variables. Researchers are not always able to test people of
the same age, therefore, partial correlation assists in determining whether age is contributing to a misleading conclusion. As Pedhazur (1982) noted,

Partial correlation is not an all-purpose method of control. Its valid application is predicated on a sound theoretical model. Controlling variables without regard to the theoretical considerations about the patterns of relations among them may amount to a distortion of reality and result in misleading or meaningless results. (p. 110)

Figure 1 provides an example of two patterns of causation that are acceptable in performing a partial correlation along with two patterns that are not acceptable. When variables exist with complex patterns of causation, partial correlation should not be used (Pedhazur, 1982; Waliczek, 1996). As stated by Franzblau (1958), partial correlation should not be considered as a substitute for careful research technique and planning.

The formula to compute a first-order partial correlation is:

\[ r_{xy \cdot z} = \frac{r_{xy} - r_{xz}r_{yz}}{\sqrt{1 - r_{xz}^2} \sqrt{1 - r_{yz}^2}} \]

Note that the partial correlation coefficient can be calculated directly from the three correlation coefficients: \( r_{xy} \), \( r_{xz} \), and \( r_{yz} \). The same is true for a first-order part correlation. The formula for a first-order part correlation is:

\[ r_{x(y \cdot z)} = \frac{r_{xy} - r_{xz}r_{yz}}{\sqrt{1 - r_{yz}^2}} \]

Tables 1 and 2 show the formula calculations for a partial correlation using a
computer spreadsheet program. Table 1 illustrates an extreme case in which the partialed variable z causes the correlation coefficient between variables x and y to increase. Table 2 illustrates another extreme case where the effect is the opposite.

In cases where more than one independent variable is partialed out, the same formulas for partial and part correlations are utilized. For example, if a second-order partial correlation is hand-calculated, one must first calculate three first-order partials to plug into the formula. The formula would appear as:

\[ r_{12.34} = \frac{r_{12.3} - r_{14.3} r_{24.3}}{\sqrt{1 - r_{14.3}^2} \sqrt{1 - r_{24.3}^2}} \]

Another simple approach to computing partial correlation coefficients is by using a computer statistical software program. The Statistical Package for Social Sciences (SPSS) is able to quickly calculate partial correlations. Table 3 contains a small data set and the results from SPSS analysis of these data are illustrated in Appendix A.

As stated earlier, partial and part correlations are related to regression.

In simplest terms, the partial correlation \( r_{12.3} \) is merely the correlation between the residual from predicting \( X_1 \) from \( X_3 \) and the residual from predicting \( X_2 \) from \( X_3 \). (Hays, 1994, p. 675)

In regression, the correlation between an independent variable (predictor) and residuals of another variable is always zero. In other words, error scores are always uncorrelated with yhat scores. In a first-order partial correlation with \( X, Y, \) and \( Z \) variables, two regression equations would be obtained. In partialing out \( Z \), we would have one equation for predicting \( X \) from \( Z \) and one for \( Y \) from \( Z \). The partial correlation is simply the
correlation of the residuals or error scores of $X$ and $Y$. An SPSS example is presented here to show that computation formulae and regression analyses with $\hat{y}$ and “e” scores both yield equivalent results.

Using the small data set from Table 3, two regression analyses were performed. Appendix B contains the SPSS commands used in this example. Data for $b$ weights and $y$-intercepts were obtained and entered into prediction equations. This resulted in a final computer printout, Appendix C, that contains the correlation coefficient between the $X$ “e” scores and the $Y$ “e” scores. By comparing the score regression analyses to the formula computation in Appendix A, we find that the values are identical.

Summary

Partial and part correlations can be usefully applied in many research situations. In fact, statistically controlling for an extraneous variable may even result in a part or partial correlation that is closer to +1 or to −1 (i.e., further from zero) than the original $r$, if “suppressor effects” are involved (see Henard, 1998).

However, statistical control mechanisms such as these must be used thoughtfully (Franzblau, 1958). A particular problem that can occur, particularly if the control involves quite a few orders (e.g., second-order, third-order, fourth-order) is that it may no longer be clear what is being correlated, after removing so much variance from the two measured variables of primary interest (Thompson, 1995).
References


Table 1: Partial Correlation Computation

<table>
<thead>
<tr>
<th></th>
<th>$r_{xy}$</th>
<th>$r_{xz}$</th>
<th>$r_{yz}$</th>
<th>$r_{xz}^2$</th>
<th>$r_{yz}^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.6</td>
<td>0.8</td>
<td>0.1</td>
<td>0.64</td>
<td>0.01</td>
</tr>
</tbody>
</table>

$\text{Partial1} = \frac{r_{xy} - r_{xz}r_{yz}}{\sqrt{(1-r_{xz}^2)(1-r_{yz}^2)}}$

$= 0.6 - 0.8 (0.1)$
$= 0.6 - 0.8 \sqrt{0.36}(0.99)$
$= 0.52$
$0.596992$
$= 0.871033$

Table 2: Partial Correlation Computation

<table>
<thead>
<tr>
<th></th>
<th>$r_{xy}$</th>
<th>$r_{xz}$</th>
<th>$r_{yz}$</th>
<th>$r_{xz}^2$</th>
<th>$r_{yz}^2$</th>
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</thead>
<tbody>
<tr>
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<td>0.75</td>
<td>0.8</td>
<td>0.9</td>
<td>0.64</td>
<td>0.81</td>
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</table>

$\text{Partial2} = \frac{r_{xy} - r_{xz}r_{yz}}{\sqrt{(1-r_{xz}^2)(1-r_{yz}^2)}}$

$= 0.75 - 0.8 (0.9)$
$= 0.75 - 0.8 \sqrt{0.36}(0.19)$
$= 0.03$
$0.261534$
$= 0.114708$
Table 3: Example Data Set

<table>
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<tr>
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<th>X</th>
<th>Y</th>
<th>Z</th>
</tr>
</thead>
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<td>48</td>
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<td>2</td>
<td>20</td>
<td>68</td>
<td>34</td>
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<tr>
<td>3</td>
<td>25</td>
<td>36</td>
<td>39</td>
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<td>4</td>
<td>30</td>
<td>42</td>
<td>46</td>
</tr>
<tr>
<td>5</td>
<td>35</td>
<td>14</td>
<td>17</td>
</tr>
<tr>
<td>6</td>
<td>40</td>
<td>60</td>
<td>22</td>
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<tr>
<td>7</td>
<td>45</td>
<td>47</td>
<td>56</td>
</tr>
<tr>
<td>8</td>
<td>50</td>
<td>72</td>
<td>60</td>
</tr>
<tr>
<td>9</td>
<td>55</td>
<td>80</td>
<td>65</td>
</tr>
<tr>
<td>10</td>
<td>60</td>
<td>91</td>
<td>59</td>
</tr>
</tbody>
</table>
Figure 1: Models of Causation
Appendix A

Example SPSS Partial Correlation Computation

PARTIAL CORR
/VARIABLES= var00001 var00002 BY var00003
/SIGNIFICANCE=TWOTAIL
/MISSING=LISTWISE.

--PARTIAL CORRELATION COEFFICIENTS--

Controlling for.. VAR Z

<table>
<thead>
<tr>
<th></th>
<th>VAR X</th>
<th>VAR Y</th>
</tr>
</thead>
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<tr>
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<td>( 7)</td>
</tr>
<tr>
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<td>P=.</td>
<td>P=.559</td>
</tr>
<tr>
<td>VAR Y</td>
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</tr>
<tr>
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<td>( 7)</td>
<td>( 0)</td>
</tr>
<tr>
<td></td>
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<td>P=.</td>
</tr>
</tbody>
</table>

(Coefficient / (D.F.) / 2-tailed Significance)
Appendix B

SPSS Commands for Regression Analyses

TITLE 'Partial correlation'.
COMMENT*************************************.
COMMENT SPSS example.
COMMENT SERA.
COMMENT*************************************.
SET BLANKS=SYSMIS UNDEFINED=WARN PRINTBACK=LISTING.
DATA LIST
   FILE='A:\partial.txt' FIXED RECORDS=1
   /ID 1-2 V1 4-5 V2 7-8 V3 10-11.
EXECUTE.
CORRELATIONS
   /VARIABLES=v1 v2 v3
   /PRINT=TWOTAIL NOSIG
   /MISSING=PAIRWISE .
REGRESSION
   /MISSING LISTWISE
   /STATISTICS COEFF OUTS R ANOVA
   /CRITERIA=PIN(.05) POUT(.10)
   /NOORIGIN
   /DEPENDENT v1
   /METHOD=ENTER v3 .
REGRESSION
   /MISSING LISTWISE
   /STATISTICS COEFF OUTS R ANOVA
   /CRITERIA=PIN(.05) POUT(.10)
   /NOORIGIN
   /DEPENDENT v2
   /METHOD=ENTER v3 .
compute yhat1=13.986+ (.576*V3) .
compute e1=V1-yhat1 .
compute yhat2=27.034+ (.705*V3) .
compute e2=V2-yhat2 .
LIST VARIABLES=YHAT1 E1/CASES=99 .
LIST VARIABLES=YHAT2 E2/CASES=99 .
correlations variables=V1 V2 V3 yhat1 yhat2 e1 e2/STATISTICS=ALL .
PARTIAL CORR VARIABLES=V1 WITH V2 BY V3 (1) .
APPENDIX C

SPSS Regression Analysis Printout

09 Nov 98 Partial correlation Page 1

-> DATA LIST
-> FILE='A: \ partial.txt' FIXED RECORDS=1
-> /ID 1-2 V1 4-5 V2 7-8 V3 10-11.
-> EXECUTE.
->
-> CORRELATIONS
-> /VARIABLES=v1 v2 v3
-> /PRINT=TWOTAIL NOSIG
-> /MISSING=PAIRWISE .

09 Nov 98 Partial correlation Page 2

- - Correlation Coefficients - -

<table>
<thead>
<tr>
<th></th>
<th>V1</th>
<th>V2</th>
<th>V3</th>
</tr>
</thead>
<tbody>
<tr>
<td>V1</td>
<td>1.0000</td>
<td>.5704</td>
<td>.7466*</td>
</tr>
<tr>
<td>V2</td>
<td>.5704</td>
<td>1.0000</td>
<td>.6037</td>
</tr>
<tr>
<td>V3</td>
<td>.7466*</td>
<td>.6037</td>
<td>1.0000</td>
</tr>
</tbody>
</table>

* - Signif. LE .05 ** - Signif. LE .01 (2-tailed)

" . " is printed if a coefficient cannot be computed

09 Nov 98 Partial correlation Page 3

-> REGRESSION
-> /MISSING LISTWISE
-> /STATISTICS COEFF OUTS R ANOVA
-> /CRITERIA=PIN(.05) POUT(.10)
-> /NOORIGIN
-> /DEPENDENT v1
-> /METHOD=ENTER v3 .

09 Nov 98 Partial correlation Page 4

* * * * MULTIPLE REGRESSION *

Listwise Deletion of Missing Data

Equation Number 1 Dependent Variable.. V1

Block Number 1. Method: Enter V3

Variable(s) Entered on Step Number 1.. V3

<table>
<thead>
<tr>
<th>Multiple R</th>
<th>.74663</th>
<th>Analysis of Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>R Square</td>
<td>.55746</td>
<td>DF</td>
</tr>
<tr>
<td>Adjusted R Square</td>
<td>.50214</td>
<td>Regression 1</td>
</tr>
<tr>
<td>Standard Error</td>
<td>10.88138</td>
<td>Residual 8</td>
</tr>
</tbody>
</table>

\[ F = 10.07753 \]

Signif F = .0131

------------------- Variables in the Equation -------------------

<table>
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<th>Variable</th>
<th>B</th>
<th>SE B</th>
<th>Beta</th>
<th>T</th>
<th>Sig T</th>
</tr>
</thead>
</table>

16
**Partial and Part 16**

Partial correlation

```
09 Nov 98 Partial correlation
-> REGRESSION
-> /MISSING LISTWISE
-> /STATISTICS COEFF OUTS R ANOVA
-> /CRITERIA=PIN(.05) POUT(.10)
-> /NOORIGIN
-> /DEPENDENT v2
-> /METHOD=ENTER v3.
```

**MULTIPLE REGRESSION**

Listwise Deletion of Missing Data

Equation Number 1  Dependent Variable..  V2

Block Number 1. Method: Enter  V3

Variable(s) Entered on Step Number 1..  V3

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<th>SE B</th>
<th>Beta</th>
<th>T</th>
<th>Sig T</th>
</tr>
</thead>
<tbody>
<tr>
<td>V3</td>
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<td>.329184</td>
<td>.603689</td>
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<td>.0646</td>
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<tr>
<td>(Constant)</td>
<td>27.033973</td>
<td>14.761264</td>
<td>1.831</td>
<td>.1044</td>
<td></td>
</tr>
</tbody>
</table>

End Block Number 1  All requested variables entered.

```
09 Nov 98 Partial correlation
-> compute e1=V1-yhat1.
-> compute yhat2=27.034+.705*V3.
-> compute e2=V2-yhat2.
-> LIST VARIABLES=YHAT1 E1/CASES=99.
```

```
YHAT1      E1
19.75      -4.75
33.57      -13.57
36.45      -11.45
40.48      -10.48
23.78      11.22
26.66      13.34
46.24      -1.24
48.55      1.45
```
Partial and Part 17

51.43 3.57
47.97 12.03

Number of cases read: 10  Number of cases listed: 10

09 Nov 98  Partial correlation
-> LIST VARIABLES=YHAT2 E2/CASES=99 .

09 Nov 98  Partial correlation
YHAT2   E2
34.08 13.92
51.00 17.00
54.53 -18.53
59.46 -17.46
39.02 -25.02
42.54 17.46
66.51 -19.51
69.33 2.67
72.86 7.14
68.63 22.37

Number of cases read: 10  Number of cases listed: 10

09 Nov 98  Partial correlation
-> correlations variables=V1 V2 V3 yhat1 yhat2 e1 e2/STATISTICS=ALL .

09 Nov 98  Partial correlation
Variable Case Mean Std Dev
V1     10  37.5000 15.1383
V2     10  55.8000 22.9046
V3     10  40.8000 19.6118
YHAT1  10  37.4868 11.2964
YHAT2  10  55.7980 13.8263
e1     10  0.0132 10.0705
e2     10  0.0020 18.2600

09 Nov 98  Partial correlation
Variables Case Cross-Prod Dev Variance-Covar
V1     V2     10  1780.0000 197.7778
V1     V3     10  1995.0000 221.6667
V1     YHAT1  10  1149.1200 127.6800
V1     YHAT2  10  1406.4750 156.2750
V1     E1     10  913.3800 101.4867
V1     E2     10  373.5250 41.5028
V2     V3     10  2440.6000 271.1778
V2     YHAT1  10  1405.7856 156.1984
V2     YHAT2  10  1720.6230 191.1803
V2     E1     10  374.2144 41.5794
V2     E2     10  3000.9770 333.4419
V3     YHAT1  10  1993.8816 221.5424
V3     YHAT2  10  2440.4280 271.1587
V3     E1     10  1.1184 1243
V3     E2     10  .1720 1.0911
YHAT1  YHAT2  10  1405.6865 156.1874
YHAT1  E1     10  .6442 0.0716
Partial and Part 18

YHAT1  E2  10  .0991  .0110
YHAT2  E1  10  .7885  .0876
YHAT2  E2  10  .1213  .0135
E1  E2  10  373.4259  41.4918

09 Nov 98  Partial correlation

- - Correlation Coefficients - -

<table>
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<tr>
<th></th>
<th>V1</th>
<th>V2</th>
<th>V3</th>
<th>YHAT1</th>
<th>YHAT2</th>
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<th>E2</th>
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<td>.531</td>
</tr>
</tbody>
</table>

(Coefficient / (Cases) / 2-tailed Significance) " . " is printed if a coefficient cannot be computed

09 Nov 98  Partial correlation

-> PARTIAL CORR VARIABLES=V1 WITH V2 BY V3 (1).

09 Nov 98  Partial correlation

--- --- --- --- PARTIAL CORRELATION COEFFICIENTS --- --- --- ---

Controlling for..  V3

V2

<table>
<thead>
<tr>
<th></th>
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<tbody>
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</tr>
<tr>
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(Coefficient / (D.F.) / 2-tailed Significance) " . " is printed if a coefficient cannot be computed

09 Nov 98  Partial correlation
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