Psychology 405: Psychometric Theory
More on Correlations

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Outline

Applied Problems
  Partial Correlation

Multiple Correlation
  Unit Weighted correlations

Other correlations

Correlations, regressions, and categorical variables
Predicting scores: Question 1

1. If a person has a GRE verbal score of 680, then what would you expect his/her GRE quantitative score to be?

2. Mean GRE V = 600 SD = 80 r = .72

3. Mean GRE Q = 650 SD = 100

4. Observe GRE V = 680

5. Predicted GRE Q = ?
Predicting scores: Answer 1

1. If a person has a GRE verbal score of 680, then what would you expect his/her GRE quantitative score to be?

2. Mean GRE V = 600 SD = 80 r = .72

3. Mean GRE Q = 650 SD = 100

4. Observe GRE V = 680

5. \( z \text{ GRE V} = (680 - 600)/80 = 1.0 \)

6. predicted \( z \text{ GRE Q} = r_{xy} z_{x} = .72 * (1) = .72 \)

7. predicted GRE Q = \( .72 * 100 + 650 = 722 \)
Predicting scores: Question 2

1. If a person has a GRE Quant score of 722, then what would you expect his/her GRE Verbal score to be?
2. Mean GRE V = 600 SD = 80 r = .72
3. Mean GRE Q = 650 SD = 100
4. Observe GRE Q = 722
5. Predicted GRE V = ?
Predicting scores: Answer 2

1. If a person has a GRE Quant score of 722, then what would you expect his/her GRE Verbal score to be?
2. Mean GRE V = 600 SD = 80 r = .72
3. Mean GRE Q = 650 SD = 100
4. Observe GRE Q = 722
5. Predicted GRE V = ?
6. \( z_{GRE\ Q} = \frac{722 - 650}{100} = .72 \)
7. predicted \( z_{GRE\ V} = r_{xy} z_{x} = .72 \times (.72) = .52 \)
8. predicted GRE Q = .52 * 100 + 600 = 652
1. For a person with an anxiety score of 16, what is the expected GPA?

2. Anxiety Mean = 12 sd = 4 r = -.39

3. GPA Mean = 3.0 sd = .5
Predicting Scores: Answer 3

1. For a person with an anxiety score of 16, what is the expected GPA?

2. Anxiety Mean = 12  sd = 4  r = -.39

3. GPA Mean = 3.0  sd = .5

4. \[ z_{anx} = \frac{(16 - 12)}{4} = 1.0 \]

5. predicted \( z_{gpa} = r_{xy} \cdot z_x = -.39 \cdot (1) = -.39 \)

6. predicted \( gpa = -.39 \cdot .5 + 3 = 2.805 \)
Partial Correlations: Question

1. Assuming the classical model of partial correlations, what is the correlation between GRE Quantitative and GPA with GRE Verbal held constant?

2. $r_{GREQ,GPA} = .34$

3. $r_{GREQ,V} = .72$ $r_{GREV,GPA} = .38$

4. We want to find the covariance of Q and GPA without V.

5. All correlations are $\frac{C_{xy}}{\sqrt{V_x V_y}}$. So we just need to find the Covariances and Variances.
Partial Correlations: Answer

1. Assuming the classical model of partial correlations, what is the correlation between GRE Quantitative and GPA with GRE Verbal held constant?

2. \( r_{GREQ,GPA} = .34 \)

3. \( r_{GREQ,V} = .72 \) \( r_{GREV,GPA} = .38 \)

4. All correlations are \( \frac{C_{xy}}{\sqrt{V_x V_y}} \). So we just need to find the Covariances and Variances.

5. Partial \( r_{xy,z} = \frac{r_{xy} - r_{xz}r_{yx}}{\sqrt{(1 - r^2_{xz})(1 - r^2_{yx})}} \)

6. \( r_{gpa,v} = \frac{(.34 - .72*.38)}{\sqrt{(.482*.856)}} = .103 \) partial

7. Part \( r = \frac{r_{xy} - r_{xz}r_{yx}}{\sqrt{1 - r^2_{xz}}} = .096 \) part
Multiple Correlation: Question

1. What is the multiple correlation of GRE V and GRE Q with rated quality of the MA?

2. $r_{GRE \ V, \ MA} = .32 \ r_{GRE \ Q, \ MA} = .29 \ r_{GRE \ V,Q} = .72$

3. $\beta_{y.x} = \frac{r_{xy} - r_{xz} \cdot r_{yz}}{1 - r_{xz}^2}$

4. $R^2 = \sum \beta_i r_{x_i y}$
Multiple Correlation: Answer

1. What is the multiple correlation of GRE V and GRE Q with rated quality of the MA?
2. \( r \text{ GRE V, MA} = .32 \) \( r \text{ GRE Q, MA} = .29 \) \( r \text{ GRE V,Q} = .72 \)
3. \( \beta_{y,x} = \frac{r_{xy} - r_{xz} \cdot r_{yz}}{1 - r_{xz}^2} \)
4. \( \beta \text{ GRE V, MA} = (0.32 - 0.72 \cdot 0.29)/(1 - 0.72^2) = 0.231 \)
5. \( \beta \text{ GRE Q, MA} = (0.29 - 0.72 \cdot 0.32)/(1 - 0.72^2) = 0.124 \)
6. \( R^2 = \beta_{y,x} \cdot r_{xy} + \beta_{y,z} \cdot r_{yz} \ldots \)
7. \( R^2 = \beta \text{ GRE Q, MA} \cdot r \text{ GRE Q, MA} + \beta \text{ GRE V, MA} \cdot r \text{ GRE V, MA} = \)
8. \( R^2 = 0.124 \cdot 0.29 + 0.231 \cdot 0.32 = 0.108 \)
9. \( R = 0.329 \)
1. What is the unit weighted correlation of GREV and GRE Q with MA?

<table>
<thead>
<tr>
<th>Variable</th>
<th>GREV</th>
<th>GREQ</th>
<th>MA</th>
</tr>
</thead>
<tbody>
<tr>
<td>GREV</td>
<td>1.00</td>
<td>0.72</td>
<td>0.32</td>
</tr>
<tr>
<td>GREQ</td>
<td>0.72</td>
<td>1.00</td>
<td>0.29</td>
</tr>
<tr>
<td>MA</td>
<td>0.32</td>
<td>0.29</td>
<td>1.00</td>
</tr>
</tbody>
</table>

2. All correlations are \( \frac{C_{xy}}{\sqrt{V_x V_y}} \). So we just need to find the Covariances and Variances.
Unit Weighted Multiple R

1. Weight the two predictors equally

<table>
<thead>
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<tbody>
<tr>
<td>GREV</td>
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<td>0.72</td>
<td>0.32</td>
</tr>
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<td>GREQ</td>
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<td>1.00</td>
<td>0.29</td>
</tr>
<tr>
<td>MA</td>
<td>0.32</td>
<td>0.29</td>
<td>1.00</td>
</tr>
</tbody>
</table>

2. All correlations are $r = \frac{C_{xy}}{\sqrt{V_x V_y}}$. So we just need to find the Covariances and Variances.

4. $C_{v+q,MA} = .32 + .29 = .61$

5. $V_{v+q} = 1.00 + .72 + .72 + 1.00 = 3.44$

6. $r_{v+q,MA} = \frac{.61}{\sqrt{3.44*1}} = .329$
Correlating two composites – unit weights

Table: Ability and Performance

<table>
<thead>
<tr>
<th>Variable</th>
<th>GREV</th>
<th>GREQ</th>
<th>GREA</th>
<th>GPA</th>
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1. What is the unit weighted correlation between the ability measures and the performance measures?

2. All correlations are $C_{xy} = \frac{C_{xy}}{\sqrt{V_X V_Y}}$. So we just need to find the Covariances and Variances.
Correlating two composites – unit weights

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set

1. $V_{ability} = 1.0 + .72 + .54 + .72 + 1.0 + .48 + .54 + .48 + 1 = 3 \times 1 + 2 \times (.72 + .54 + .48) = 6.48$
2. $V_{performance} = 3 \times 1 + 2 \times (.42 + .35 + .30) = 5.14$
3. $C_{ability,performance} = .38 + .34 + .55 + .32 + .29 + .47 + .27 + .24 + .39 = 3.25$
4. $R_{ability,performance} = \frac{3.25}{\sqrt{6.48 \times 5.14}} = .563$
R code

```r
R <- structure(list(GREV = c(1, 0.72, 0.54, 0.38, 0.32, 0.27),
                     GREQ = c(0.72, 1, 0.48, 0.34, 0.29, 0.24),
                     GREA = c(0.54, 0.48, 1, 0.55, 0.47, 0.39),
                     GPA = c(0.38, 0.34, 0.55, 1, 0.42, 0.35),
                     Pre = c(0.32, 0.29, 0.47, 0.42, 1, 0.3),
                     MA = c(0.27, 0.24, 0.39, 0.35, 0.3, 1)), row.names = c("GREV", "GREQ", "GREA", "GPA", "Pre", "MA"),
                     class = "data.frame")
Rx <- R[1:3,1:3]
Ry <- R[4:6,4:6]
Rxy <- R[1:3,4:6]
sum(Rx); sum(Ry); sum(Rxy)
  sum(Rxy)/sqrt(sum(Rx)* sum(Ry))
```

R

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</table>

sum(Rx)
[1] 6.48
> sum(Ry)
[1] 5.14
> sum(Rxy)
[1] 3.25
sum(Rxy)/sqrt(sum(Rx)* sum(Ry)) = 0.56
Instability of beta weights

An example from Niels Waller

R code

```
Y  X1  X2  X3  C
Y 1.000 0.561 0.568 0.520 0.35
X1 0.561 1.000 0.720 0.526 0.40
X2 0.568 0.720 1.000 0.554 -0.25
X3 0.520 0.526 0.554 1.000 0.30
C 0.350 0.400 -0.250 0.300 1.00

setCor(Y ~ X1 + X2 + X3, data=R)
```

```
setCor(Y ~ X1 + X2 + X3, data=R)
Call: setCor(y = Y ~ X1 + X2 + X3, data = R)
Multiple Regression from matrix input

DV = Y
  slope  VIF  Vy.x
X1  0.25 2.18 0.14
X2  0.25 2.28 0.14
X3  0.25 1.52 0.13

Multiple Regression
  R  R2  Ruw  R2uw
Y 0.64 0.41 0.64 0.41
```

```
setCor(Y ~ X1 + X2 + X3 + C, data=R)
Call: setCor(y = Y ~ X1 + X2 + X3 + C, data = R)
Multiple Regression from matrix input

DV = Y
  slope  VIF  Vy.x
X1  -1.99 12.47 -1.12
X2  2.87 16.34 1.63
X3  -0.64 3.14 -0.33
C  2.06 8.66 0.72

Multiple Regression
  R  R2  Ruw  R2uw
Y 0.95 0.9 0.69 0.47
```
Cohen’s Set correlation versus unit weighted correlations

1. What is the relationship between two sets of variables? Two alternative answers.

2. Set correlation: 1 - the ratio of determinants
   \[ R = 1 - \frac{||R_{xy}||}{||R_x||\cdot||R_y||} \]

3. Unit weighted correlation
   \[ R_{uw} = \frac{1R_{yx}1'}{(1R_{yy}1')^{.5}(1R_{xx}1')^{.5}} \]

4. Both are found using the `set_cor` function
**set.cor to find multiple correlations from correlation matrices**

```r
set.cor(4:6,1:3,R)
```

<table>
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<td>0.30</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Call: set.cor(y = 4:6, x = 1:3, data = m1)

Multiple Regression from matrix input

**Beta weights**

<table>
<thead>
<tr>
<th></th>
<th>GPA</th>
<th>Pre</th>
<th>MA</th>
</tr>
</thead>
<tbody>
<tr>
<td>GREV</td>
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<td>0.06</td>
<td>0.06</td>
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<tr>
<td>GREQ</td>
<td>0.05</td>
<td>0.05</td>
<td>0.03</td>
</tr>
<tr>
<td>GREA</td>
<td>0.48</td>
<td>0.41</td>
<td>0.34</td>
</tr>
</tbody>
</table>

**Unweighted multiple R**

<table>
<thead>
<tr>
<th></th>
<th>GPA</th>
<th>Pre</th>
<th>MA</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPA</td>
<td>0.50</td>
<td>0.42</td>
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</tbody>
</table>

**Unweighted multiple R2**

<table>
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<th>GPA</th>
<th>Pre</th>
<th>MA</th>
</tr>
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<tbody>
<tr>
<td>GPA</td>
<td>0.25</td>
<td>0.18</td>
<td>0.13</td>
</tr>
</tbody>
</table>

**Various estimates of between set correlations**

Squared Canonical Correlations

```
[1] 4.1e-01 6.0e-05 1.6e-06
```

Average squared canonical correlation = 0.14

Cohen's Set Correlation R2 = 0.41

Unweighted correlation between the two sets = 0.56
Just use Verbal and Quant

> ml
> set.cor(4:6,1:2,m1)

GREV GREQ GREA GPA Pre MA
GREV 1.00 0.72 0.54 0.38 0.32 0.27
GREQ 0.72 1.00 0.48 0.34 0.29 0.24
GREA 0.54 0.48 1.00 0.55 0.47 0.39
GPA 0.38 0.34 0.55 1.00 0.42 0.35
Pre 0.32 0.29 0.47 0.42 1.00 0.30
MA 0.27 0.24 0.39 0.35 0.30 1.00

Multiple Regression from matrix input

Beta weights
GREV GREQ GPA Pre MA
GREV 0.28 0.23 0.20
GREQ 0.14 0.12 0.09

Multiple R
GPA Pre MA
0.39 0.33 0.28

Unweighted multiple R
GPA Pre MA
0.39 0.33 0.27

Unweighted multiple R2
GPA Pre MA
0.15 0.11 0.08

Various estimates of between set correlations
Squared Canonical Correlations
[1] 2.0e-01 4.2e-05

Average squared canonical correlation = 0.1
Cohen's Set Correlation R2 = 0.2
Unweighted correlation between the two sets = 0.44
Comorbidity

1. Symptoms are said to be comorbid if one has both symptoms.
   - This is really just one cell in a 2 x 2 table
   - We need base rates as well

2. Consider Anxiety and Depression
   - 50% of anxiety patients are also depressed
   - 67% of depressed patients are also anxious
   - base rates are 20% for anxiety, 15% for depression

\[
\text{comorbidity}(0.2, 0.15, 0.1, \text{c("Anxiety","Depression")})
\]

Call: comorbidity(d1 = 0.2, d2 = 0.15, com = 0.1, labels = c("Anxiety", "Depression"))

Comorbidity table

<table>
<thead>
<tr>
<th></th>
<th>Anxiety</th>
<th>-Anxiety</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depression</td>
<td>0.1</td>
<td>0.05</td>
</tr>
<tr>
<td>-Depression</td>
<td>0.1</td>
<td>0.75</td>
</tr>
</tbody>
</table>

implies phi = 0.49 with Yule = 0.87 and tetrachoric correlation of 0.75 and normal thresholds of 1.04 0.84
Can also treat this as an Area Under the Curve – signal detection problem

R code

```r
com <- comorbidity(.2,.15,.1,c("Anxiety","Depression")) #find the comorbidity
AUC(com$twobytwo) #convert to a Signal Detection Approach
```

AUC(com$twobytwo) #convert to a Signal Detection Approach

Decision Theory and Area under the Curve

The original data implied the following 2 x 2 table

<table>
<thead>
<tr>
<th>Predicted.Pos</th>
<th>Predicted.Neg</th>
</tr>
</thead>
<tbody>
<tr>
<td>True.Pos</td>
<td>0.1</td>
</tr>
<tr>
<td>True.Neg</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Conditional probabilities of

<table>
<thead>
<tr>
<th>Predicted.Pos</th>
<th>Predicted.Neg</th>
</tr>
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<tbody>
<tr>
<td>True.Pos</td>
<td>0.67</td>
</tr>
<tr>
<td>True.Neg</td>
<td>0.12</td>
</tr>
</tbody>
</table>

Accuracy = 0.85  Sensitivity = 0.67  Specificity = 0.88
with Area Under the Curve = 0.87
d.prime = 1.62  Criterion = 1.19  Beta = 0.13
Observed Phi correlation = 0.49
Inferred latent (tetrachoric) correlation = 0.75
Show the Signal Detection graphic

Valid Positives as function of False Positives

Decision Theory
Three ways to compare categorical means

```r
dim(spi)
t.test(wellness ~ sex, data=spi)
t.test(education ~ sex, data=spi)
```

```
t.test(wellness ~ sex, data=spi)

Welch Two Sample t-test

data:  wellness by sex
t = -6.021, df = 2872.4, p-value = 1.954e-09
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval: 
  -0.14075230 -0.07159818
sample estimates: 
mean in group 1 mean in group 2
1.479228 1.585404

> t.test(education ~ sex, data=spi)

Welch Two Sample t-test

data:  education by sex
t = 4.5873, df = 2908.4, p-value = 4.68e-06
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval: 
  0.2040981 0.5088266
sample estimates: 
mean in group 1 mean in group 2
4.314540 3.958078
```
Try regression

R code

```r
lm (wellness ~ sex, data=spi)
lm (education ~ sex, data=spi)
```

lm (wellness ~ sex, data=spi)

Call:
```
lm(formula = wellness ~ sex, data = spi)
```

Coefficients:
```
(Intercept)   sex
      1.3731 0.1062
```

> lm (education ~ sex, data=spi)

Call:
```
lm(formula = education ~ sex, data = spi)
```

Coefficients:
```
(Intercept)   sex
     4.6710 -0.3565
```
Regression with significance tests

```r
summary(lm (wellness ~ sex, data=spi))
```

```
Call:
lm(formula = wellness ~ sex, data = spi)

Residuals:
     Min      1Q  Median      3Q     Max
-0.5854 -0.4792  0.4146  0.4146  0.5208

Coefficients:          Estimate Std. Error t value Pr(>|t|)
(Intercept) 1.37305     0.02926   46.925  < 2e-16 ***
  sex       0.10618     0.01759    6.036  1.76e-09 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.4957 on 3278 degrees of freedom
(720 observations deleted due to missingness)
Multiple R-squared:  0.01099,    Adjusted R-squared:  0.01069
F-statistic: 36.43 on 1 and 3278 DF,  p-value: 1.756e-09
```
raw units

R code

```r
spi.complete <- complete.cases(spi[c("wellness","sex")])
setCor(wellness ~ sex, data=spi[spi.complete,],std=FALSE)
Call: setCor(y = wellness ~ sex, data = spi[spi.complete, ], std = FALSE)

spi.complete <- complete.cases(spi[c("wellness","sex")])
> setCor(wellness ~ sex, data=spi[spi.complete,],std=FALSE)
Call: setCor(y = wellness ~ sex, data = spi[spi.complete, ],
  std = FALSE)

Multiple Regression from raw data

DV = wellness
  slope se t      p lower.ci upper.ci VIF
(Intercept)  1.37 0.03 46.93 0.0e+00  1.32   1.43 11.43
sex          0.11 0.02  6.04 1.8e-09  0.07   0.14 11.43

Residual Standard Error =  0.5  with  3278  degrees of freedom

Multiple Regression
  R  R2  Ruw R2uw Shrunken R2 SE of R2 overall F df1 df2  p
wellness 0.1 0.01 0.07 0.01  0.01  0  36.43  1 3278 1.76e-09
```
Do the setCor operation with default values – standardized units

R code

```r
setCor(wellness ~ sex, data=spi[spi.complete,])
```

Call: setCor(y = wellness ~ sex, data = spi[spi.complete, ])

Multiple Regression from raw data

<table>
<thead>
<tr>
<th>slope</th>
<th>se</th>
<th>t</th>
<th>p</th>
<th>lower.ci</th>
<th>upper.ci</th>
<th>VIF</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Intercept)</td>
<td>0.0</td>
<td>0.02</td>
<td>0.00</td>
<td>1.0e+00</td>
<td>-0.03</td>
<td>0.03</td>
</tr>
<tr>
<td>sex</td>
<td>0.1</td>
<td>0.02</td>
<td>6.04</td>
<td>1.8e-09</td>
<td>0.07</td>
<td>0.14</td>
</tr>
</tbody>
</table>

Residual Standard Error = 0.99 with 3278 degrees of freedom

Multiple Regression

<table>
<thead>
<tr>
<th>R</th>
<th>R2</th>
<th>Ruw</th>
<th>R2uw</th>
<th>Shrunken R2</th>
<th>SE of R2</th>
<th>overall F</th>
<th>df1</th>
<th>df2</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>wellness</td>
<td>0.1</td>
<td>0.01</td>
<td>0.1</td>
<td>0.01</td>
<td>0.01</td>
<td>36.43</td>
<td>1</td>
<td>3278</td>
<td>1.76e-09</td>
</tr>
</tbody>
</table>
Or, just show the correlations

```r
lowerCor(spi[cs(sex, wellness, education)])
corr.test(spi[cs(sex, wellness, education)])
```

```
lowerCor(spi[cs(sex, wellness, education)])
       sex  wellness  education
sex    1.00     0.10     -0.08
wellness  0.10     1.00       0.00
education -0.08     0.00     1.00

corr.test(spi[cs(sex, wellness, education)])
Call: corr.test(x = spi[cs(sex, wellness, education)])
Correlation matrix
        sex   wellness education
sex    1.00     0.10     -0.08
wellness  0.10     1.00       0.00
education -0.08     0.00     1.00
Sample Size
        sex   wellness education
sex    3946     3280     3304
wellness  3280     3311     3000
education  3304     3000     3330
Probability values (Entries above the diagonal are adjusted for multiple tests.)
        sex   wellness education
sex     0.00     0.00       0.00
wellness  0.00     0.92     0.00
education  0.92     0.00     0.00
```

To see confidence intervals of the correlations, print with the short=FALSE option