Trends Analysis
PSY710

3 Initialize R

Before starting this lab, please initialize R by entering the following commands at the prompt:

```r
options(contrasts = c("contr.sum", "contr.poly"), digits = 6, width = 70)
load(url("http://www.psychology.mcmaster.ca/bennett/psy710/datasets/tracklearn.Rdata"))
```

3.1 Sensorimotor learning task

An experiment was conducted to evaluate the effects of the duration of the inter-trial interval on learning/performance in a sensorimotor task. On each trial, a spot moved along a random, curvilinear path on a computer screen, and the subject’s task was to use a computer mouse to keep a cursor on the dot. To increase task difficulty, the relation between the mouse’s horizontal motion and the cursor’s horizontal motion was reversed: leftward mouse movement produced rightward cursor movement and vice versa. There were 10 trials and each trial lasted one minute. The dependent variable was the duration (in seconds) in which the cursor was located on the target spot. The independent variable was the duration of the inter-trial interval, which was 0, 20, 40, or 60 seconds. (N.B. In the 0 second condition, trial N+1 started immediately following trial N). The duration of the inter-trial duration was a between-subject variable: each subject was assigned randomly to one condition with the constraint that there were 5 subjects per group. The data are stored in the data frame `tracklearn`: the dependent variable is `y` and the independent variable is the factor `itd` (inter-trial duration). The group means are plotted in Figure 1.

1. Calculate the mean and standard deviation of `y` for each `itd`.

```r
(group.mean <- with(tracklearn, tapply(y, itd, mean)))
## d0  d20  d40  d60
##  8.0 14.0 19.2 18.0

(group.sd <- with(tracklearn, tapply(y, itd, sd)))
## d0  d20  d40  d60
## 2.91548 2.64575 3.42053 4.00000
```

2. Confirm that `itd` is an ordered factor and ist the contrasts that are linked with `itd`.

```r
class(tracklearn$itd)
## [1] "ordered" "factor"

# each column contains weights for one contrast
# .L == linear; .Q == quadratic; .C == cubic
contrasts(tracklearn$itd)
```
3. Verify that the contrasts for `itd` are orthogonal.

```r
lin.weights <- contrasts(tracklearn$itd)[,1]
quad.weights <- contrasts(tracklearn$itd)[,2]
cubic.weights <- contrasts(tracklearn$itd)[,3]
# following assumes equal n per group:
sum(lin.weights*quad.weights) # should be zero
## [1] 0
sum(lin.weights*cubic.weights) # should be zero
## [1] 2.77556e-17
sum(quad.weights*cubic.weights) # should be zero
## [1] 9.71445e-17
```

4. Use `aov` to perform an ANOVA to evaluate the null hypothesis that performance is the same in all groups.

```r
# use aov command:
track.aov.01 <- aov(y~itd, data=tracklearn)
anova(track.aov.01)
## Analysis of Variance Table
## Response: y
## Df  Sum Sq Mean Sq F value Pr(>F)
## itd   3   382.4   127.5 11.80 0.00025 ***
## Residuals 16   172.8   10.8
## ---
## Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

# summary(track.aov.01) # same result
```

5. Take the result of your `aov` command and then split the between-groups sum-of-squares to evaluate the linear, quadratic, and cubic trends. What null hypotheses are being evaluated by the $F$ tests?

```r
# summary of aov object yields F tests:
summary(track.aov.01, split=list(itd=list(linear=1, quad=2, cubic=3)))
## Df  Sum Sq Mean Sq F value Pr(>F)
## itd   3   382.4   127.5 11.80 0.00025 ***
```
Answer: Each $F$ test is a two-tailed test that evaluates the null hypothesis that the trend (linear, quadratic, or cubic) is zero.

6. Use `lm` to perform an ANOVA to evaluate the null hypothesis that performance is the same in all groups.

```r
track.lm.01 <- lm(y~itd, data=tracklearn)
anova(track.lm.01) # the anova is the same as the one obtained with aov
```

### Analysis of Variance Table

<table>
<thead>
<tr>
<th>Df</th>
<th>Sum Sq</th>
<th>Mean Sq</th>
<th>F value</th>
<th>Pr(&gt;F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>itd</td>
<td>3</td>
<td>382.4</td>
<td>127.5</td>
<td>11.8</td>
</tr>
<tr>
<td>Residuals</td>
<td>16</td>
<td>172.8</td>
<td>10.8</td>
<td></td>
</tr>
</tbody>
</table>

### Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

7. Take the result of your `lm` command and evaluate the linear, quadratic, and cubic trends using $t$ tests. What null hypotheses are being evaluated by the $t$ tests?

```r
# summary of lm object yields t test
summary(track.lm.01)
```

### Call:
`lm(formula = y ~ itd, data = tracklearn)`

### Residuals:

<table>
<thead>
<tr>
<th>Min</th>
<th>1Q</th>
<th>Median</th>
<th>3Q</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>-5.00</td>
<td>-2.25</td>
<td>-0.60</td>
<td>2.25</td>
<td>5.00</td>
</tr>
</tbody>
</table>

### Coefficients:

| (Intercept) | 14.800 | 0.735 | 20.14 | 8.6e-13 *** |
| itd.L | 7.871 | 1.470 | 5.36 | 6.4e-05 *** |
| itd.Q | -3.600 | 1.470 | -2.45 | 0.026 * |
| itd.C | -1.252 | 1.470 | -0.85 | 0.407 |

### Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

### Residual standard error: 3.29 on 16 degrees of freedom
### Multiple R-squared: 0.689, Adjusted R-squared: 0.63
### F-statistic: 11.8 on 3 and 16 DF, p-value: 0.00025
**Answer:** The hypotheses are the same as those being evaluated in question 5. Each $t$ test is a two-tailed test that evaluates the null hypothesis that the trend (linear, quadratic, or cubic) is zero.

8. How are the $F$ and $t$ values in 5 and 7 related?

**Answer:** $F = t^2$

9. Why is the $t$ value for the quadratic trend in 7 less than zero?

**Answer:** If you plot the weights for the quadratic trend you will see that they are a U-function of itd (see Figure 2). The reason $t$ is negative is because the quadratic trend of $y$ across itd is an inverted-u function of itd (Figure 1), so the trend of the means is *negatively* correlated with the weights, and hence $t < 0$.

```r
# first plot group means:
xvals <- c(0,20,40,60)
group.means <- with(tracklearn,tapply(y,itd,mean))
dev.new(height=4,width=4)
plot(xvals,group.means,"b",xlab="ITD",ylab="Tracking (s)",main="Group Means")
# then plot weights for each trend:
dev.new(height=3,width=9)
par(mfrow=c(1,3))
plot(xvals,lin.weights,"b",xlab="ITD",ylab="weight",main="Linear Trend")
plot(xvals,quad.weights,"b",xlab="ITD",ylab="weight",main="Quadratic Trend")
plot(xvals,cubic.weights,"b",xlab="ITD",ylab="weight",main="Cubic Trend")
```

10. What happens to our trend analyses if our weights are multiplied by a constant (e.g., 3)?

```r
(old.contrasts <- contrasts(tracklearn$itd) )

# # .L .Q .C
# [1,] -0.670820 0.5 -0.223607
# [2,] -0.223607 -0.5 0.670820
# [3,] 0.223607 -0.5 -0.670820
# [4,] 0.670820 0.5 0.223607

new.contrasts <- 3*old.contrasts # calculate new weights
contrasts(tracklearn$itd) <- new.contrasts # assign them to factor
contrasts(tracklearn$itd) # check to see if they're different

# # .L .Q .C
# d0  -2.01246 1.5 -0.67082
# d20 -0.67082 -1.5 2.01246
# d40  0.67082 -1.5 -2.01246
# d60  2.01246 1.5  0.67082

track.aov.02 <- aov(y~itd,tracklearn)
summary(track.aov.02,split=list(itd=list(lin=1,quad=2,cubic=3)))
```
# Trend Analysis Exercises

## Df Sum Sq Mean Sq F value Pr(>F)
## itd 3 382 127.5 11.80 0.00025 ***
## itd: lin 1 310 309.8 28.68 6.4e-05 ***
## itd: quad 1 65 64.8 6.00 0.02620 *
## itd: cubic 1 8 7.8 0.73 0.40678
## Residuals 16 173 10.8
## ---
## Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

# compare to previous results:
summary(track.aov.01,split=list(itd=list(lin=1,quad=2,cubic=3)))

## Df Sum Sq Mean Sq F value Pr(>F)
## itd 3 382 127.5 11.80 0.00025 ***
## itd: lin 1 310 309.8 28.68 6.4e-05 ***
## itd: quad 1 65 64.8 6.00 0.02620 *
## itd: cubic 1 8 7.8 0.73 0.40678
## Residuals 16 173 10.8
## ---
## Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

# SS-contrast, MS-contrast, F, and p-values are unchanged

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Figure 1: Group means.
Figure 2: Weights for linear, quadratic, and cubic trends.