Using R for Behavioral Data: The Fun and Frustration of Factorial and Repeated-Measures ANOVAs

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Behavioral/Psychological Data

- Often you have groups separated by differing behavioral or drug treatments
- Most common psychology statistics:
  - T-tests
  - Correlations
  - Chi-square test
  - regression
  - ANOVAs (Analysis of Variance)

One-way ANOVA

- aov()

```
> summary(aov(pf~treatment,test))
            Df Sum Sq Mean Sq F value Pr(>F)
treatment    1    909   908.7   5.695 0.0212 *
Residuals   46   7339   159.6
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Two-way or factorial ANOVAs

- Balanced data

```
> summary(aov(pf~group*treatment,test))
                Df Sum Sq Mean Sq F value Pr(>F)
group            2    555   277.7   1.747 0.1867
treatment        1    909   908.7   5.716 0.0214 *
group:treatment  2    108    53.8   0.339 0.7146
Residuals       42   6676   159.0
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
> summary(aov(pf~treatment*group,test))
                Df Sum Sq Mean Sq F value Pr(>F)
treatment        1    909   908.7   5.716 0.0214 *
group            2    555   277.7   1.747 0.1867
treatment:group  2    108    53.8   0.339 0.7146
Residuals       42   6676   159.0
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Two-way or factorial ANOVAs

- Unbalanced data

```
> summary(aov(pf~treatment*group,test))
                Df  Sum Sq Mean Sq F value   Pr(>F)
treatment        1     168     168   0.899 0.349754
group            1    3506    3506  18.790 0.000123 ***
treatment:group  1     370     370   1.982 0.168210
Residuals       34    6344     187
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
> summary(aov(pf~group*treatment,test))
                Df  Sum Sq Mean Sq F value   Pr(>F)
group            1    3294    3294  17.656 0.000181 ***
treatment        1     379     379   2.033 0.163024
group:treatment  1     370     370   1.982 0.168210
Residuals       34    6344     187
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Two-way or factorial ANOVAs

- Anova()

```
> lm1=lm(pf ~ group*treatment, data=test, contrasts=list(group=contr.sum, treatment=contr.sum))
> Anova(lm1, type=3, singular.ok=T)
Anova Table (Type III tests)

Response: pf
                Sum Sq Df F value    Pr(>F)
(Intercept)     9591.5  1 51.4039 2.727e-08 ***
group           3310.3  1 17.7408 0.0001757 ***
treatment        290.1  1  1.5550 0.2209259
group:treatment  369.9  1  1.9825 0.1682098
Residuals       6344.1 34
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
> lm1=lm(pf ~ treatment*group, data=test, contrasts=list(group=contr.sum, treatment=contr.sum))
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treatment:group  369.9  1  1.9825 0.1682098
Residuals       6344.1 34
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Repeated Measures ANOVA

- aov()

```
> aov.out = aov(pf ~ ext + Error(id/ext), data=ext)
> summary(aov.out)

Error: id
          Df Sum Sq Mean Sq F value Pr(>F)
Residuals 31  12231   394.5

Error: id:ext
           Df Sum Sq Mean Sq F value   Pr(>F)
ext         5   3196   639.2   9.779 3.87e-08 ***
Residuals 155  10132    65.4
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Repeated Measures Factorial ANOVA

- aov() for balanced data

```
> aov.out = aov(pf ~ ext * group + Error(id/ext), data=ext)
> summary(aov.out)

Error: id
          Df Sum Sq Mean Sq F value   Pr(>F)
group      1   3778    3778   13.41 0.000959 ***
Residuals 30   8453     282
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Error: id:ext
           Df Sum Sq Mean Sq F value   Pr(>F)
ext         5   3196   639.2   17.41 1.43e-13 ***
ext:group   5   4625   925.0   25.20  < 2e-16 ***
Residuals 150   5507    36.7
> aov.out = aov(pf ~ group*ext + Error(id/ext), data=ext)
> summary(aov.out)

Error: id
          Df Sum Sq Mean Sq F value   Pr(>F)
group      1   3778    3778   13.41 0.000959 ***
Residuals 30   8453     282
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Error: id:ext
           Df Sum Sq Mean Sq F value   Pr(>F)
ext         5   3196   639.2   17.41 1.43e-13 ***
group:ext   5   4625   925.0   25.20  < 2e-16 ***
Residuals 150   5507    36.7
```

Repeated Measures Factorial ANOVA

- aov() for unbalanced data

```
> aov.out = aov(pf ~ ext*treatment + Error(id/ext), data=ext)
> summary(aov.out)

Error: id
          Df Sum Sq Mean Sq
treatment  1  4.954   4.954

Error: id:ext
    Df Sum Sq Mean Sq
ext  2  18606    9303

Error: Within
              Df Sum Sq Mean Sq F value   Pr(>F)
ext            2  17089    8544  16.881 2.02e-06 ***
treatment      1    583     583   1.152    0.288
ext:treatment  2    844     422   0.834    0.440
Residuals     54  27332     506
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Repeated Measures Factorial ANOVA

- ezANOVA()

```
> ezANOVA(data= ext, dv= pf, wid= id, within= ext, between= .(treatment), type = 3)
Warning: Converting "id" to factor for ANOVA.
Warning: Data is unbalanced (unequal N per group). Make sure you specified a well-considered va
for the type argument to ezANOVA().
$ANOVA
         Effect DFn DFd           F             p p<.05         ges
2     treatment   1  19   0.6157877 4.422919e-01       0.02083945
3           ext   2  38  71.9183844 1.207636e-13     * 0.56512678
4 treatment:ext   2  38   1.5803496 2.191373e-01       0.02776314

$`Mauchly's Test for Sphericity`
         Effect         W         p p<.05
3           ext 0.9915315 0.9263146
4 treatment:ext 0.9915315 0.9263146

$`Sphericity Corrections`
         Effect       GGe        p[GG] p[GG]<.05      HFe        p[HF] p[HF]<.05
3           ext 0.9916026 1.507608e-13         * 1.106674 1.207636e-13         *
4 treatment:ext 0.9916026 2.193541e-01           1.106674 2.191373e-01
```

Repeated Measures Factorial ANOVA

- Linear mixed-effects model – lme() and Anova()

```
> am2 <- lme(pf ~ treatment*ext, random = ~1|id/ext, data=ext)
> Anova(am2, type=3, singular.ok=T)
Analysis of Deviance Table (Type III tests)

Response: pf
                Chisq Df Pr(>Chisq)
(Intercept)   90.6841  1     <2e-16 ***
treatment      0.6158  1     0.4326
ext          143.8365  2     <2e-16 ***
treatment:ext  3.1607  2     0.2059
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Thank you!

- Links:
  - https://www.r-statistics.com/2010/04/repeated-measures-anova-with-r-tutorials/
  - https://gribblelab.wordpress.com/2009/03/09/repeated-measures-anova-using-r/
  - http://coltekin.net/cagri/R/r-exercisesse5.html