Statistics One

Lecture 18
Repeated measures ANOVA

1

Two segments

- Repeated measures: Pros & Cons
- Repeated measures: Example

2

Lecture 18 ~ Segment 1

Repeated measures
Pros & Cons

3

Repeated measures: Pros & cons

- Pros
  - Less cost (fewer subjects required)
  - More statistical power
    - This is the important new concept

Repeated measures: Pros & cons

- Working memory training example
- Four independent groups (8, 12, 17, 19)
  - There were 20 subjects per group
  - Total N = 80

5

Repeated measures: Pros & cons

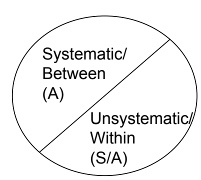
- Working memory training example
- Repeated measures design
  - N = 20

6

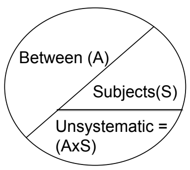
Repeated measures: Pros & cons

- More statistical power
  - Variance across subjects may be systematic
  - If so, it will not contribute to the error term

Between groups design (SS)



Repeated measures design (SS)



Error in a repeated measures design is the inconsistency of subjects from one condition to another

Therefore:

$F_A = MS_A / MS_{AxS}$

MS and F

- $MS_A = SS_A / df_A$
- $MS_{AxS} = SS_{AxS} / df_{AxS}$

- $F = MS_A / MS_{AxS}$

Repeated measures: Pros & cons

- Cons
  - Order effects
  - Counterbalancing
  - Missing data
  - Extra assumption

Counterbalancing

- Consider a simple design with just two conditions, A1 and A2
- One approach is a Blocked Design
  - Subjects are randomly assigned to one of two “order” conditions
    - A1, A2
    - A2, A1

Counterbalancing

- Another approach is a Randomized Design
  - Conditions are presented randomly in a mixed fashion
    - A2, A1, A1, A2, A2, A1, A2…..

Counterbalancing

- Now suppose a = 3 and a blocked design
- There are 6 possible orders (3!)
  - A1, A2, A3
  - A1, A3, A2
  - A2, A1, A3
  - A2, A3, A1
  - A3, A1, A2
  - A3, A2, A1

Counterbalancing

- To completely counterbalance, subjects would be randomly assigned to one of 6 order conditions
- The number of conditions needed to completely counterbalance becomes large with more conditions
  - 4! = 24
  - 5! = 120

Counterbalancing

- With many levels of the IV a better approach is to use a "Latin Squares" design
- Latin Squares designs aren't completely counterbalanced but every condition appears at every position at least once

Counterbalancing

- For example, if a = 3, then
  - A1, A2, A3
  - A2, A3, A1
  - A3, A1, A2

Missing data

- Two issues to consider
  - *Relative amount* of missing data
  - *Pattern* of missing data

Missing data ~ Relative amount

- How much is a lot?
  - No hard and fast rules
  - A rule of thumb is
    - Less than 10% on any one variable, OK
    - Greater than 10%, not OK

Missing data ~ Pattern?

- Is the pattern random or lawful?
  - This can easily be detected
  - For any variable of interest (X) create a new variable (XM)
    - XM = 0 if X is missing
    - XM = 1 if X is not missing
  - Conduct a t-test with XM as the IV
  - If significant then pattern of missing data *may be* lawful

Missing data ~ Remedies

- Drop all cases without a perfect profile
  - Drastic
  - Use only if you can afford it
- Keep all cases and estimate the values of the missing data points
  - There are several options for how to estimate values

Sphericity assumption

- Homogeneity of variance
- Homogeneity of covariance

Sphericity assumption

- How to test?
  - Mauchly's test
  - If significant then report an adjusted p-value
    - Greenhouse-Geisser
    - Huyn-Feldt

Segment summary

- Pros
  - Less cost (fewer subjects required)
  - More statistical power
    - This is the important new concept

24

Segment summary

- Cons
  - Order effects
  - Counterbalancing
  - Missing data
  - Extra assumption

25

END SEGMENT

26

Lecture 18 ~ Segment 2

Repeated measures ANOVA
Example

27

Repeated measures: Pros & cons

- Working memory training example
- Four independent groups (8, 12, 17, 19)
  - There were 20 subjects per group
  - Total N = 80

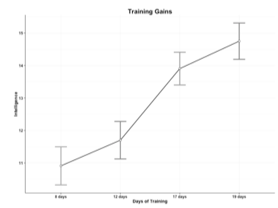
28

Repeated measures: Pros & cons

- Working memory training example
- Repeated measures design
  - N = 20

29

Working memory training



30

Common dataframe

subject	A1 (8)	A2 (12)	A3 (17)	A4 (19)
1				
2				
3				
4				
5				
6				
…				

31

R dataframe

subject	condition	IQ
1	A1 (8)	
1	A2 (12)	
1	A3 (17)	
1	A4 (19)	
2	A1 (8)	
2	A2 (12)	
…		

32

Results: ANOVA

```
> summary(anova <- aov(WM$IQ ~ WM$condition +
Error(factor(WM$subject)/WM$condition)))

Error: factor(WM$subject)
          Df Sum Sq Mean Sq F value Pr(>F)
Residuals 19  175.6   9.242

Error: factor(WM$subject):WM$condition
             Df Sum Sq Mean Sq F value   Pr(>F)
WM$condition  3  196.1   65.36   12.51 2.16e-06 ***
Residuals    57  297.8    5.22
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

33

Results: Post-hoc tests (Holm)

```
> with(WM, pairwise.t.test(IQ, condition, paired=T)) #all comp.

 Pairwise comparisons using paired t tests

data:  IQ and condition

        12 days 17 days 19 days
17 days 0.01924 -       -
19 days 0.00269 0.39572 -
8 days  0.39572 0.00237 0.00055

P value adjustment method: holm
```

34

Results: Post-hoc tests (Bonferroni)

```
> with(WM, pairwise.t.test(IQ, condition, paired=T, p.adjust.method="bonferroni")) #all comp.

 Pairwise comparisons using paired t tests

data:  IQ and condition

        12 days 17 days 19 days
17 days 0.03910 -       -
19 days 0.00405 1.00000 -
8 days  1.00000 0.00293 0.00054

P value adjustment method: bonferroni
```

35

Results: Paired t-test 12 vs. 17

```
> t.test(Days12, Days17, paired=T)

 Paired t-test

data:  Days12 and Days17
t = -3.0549, df = 19, p-value = 0.006517
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -3.7157116 -0.6942884
sample estimates:
mean of the differences
                 -2.205

> cohensD(Days12, Days17)
[1] 0.9087788
```

36

Comparison of procedures

Procedure	p-value for 12 vs. 17
Paired t-test	0.0065
Holm	0.0192
Bonferroni	0.0391

37

Repeated measures ANOVA

- Appropriate when comparing group means
  - Three or more group means
  - Same subjects tested in each condition

  - F-test
  - Post-hoc testss

38

END SEGMENT

39

END LECTURE 18

40