The General Linear Model - ANOVA Part 1 (Video 3)

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Repeated Measures ANOVA

- Let’s imagine we have an experiment where we asked 32 participants to learn how to pronounce words of differing levels of complexity - Very Easy, Easy, Hard, and Very Hard.
- They were presented with these words in an initial exposure phase. After a 30 minute break we tested participants by asking them to say the words out loud when they appeared on a computer screen.
- We want to know whether there is a difference in their response times as a function of each level of word complexity.

Repeated Measures ANOVA

```
rm_data <-
read_csv("https://raw.githubusercontent.com/ajstewartlang/11_glm_anova_pt1/master/data/rm_data.csv")
head(rm_data)

# A tibble: 6 x 3
  Participant Condition    RT
        <dbl> <chr>     <dbl>
1           1 Very Easy  1.25
2           2 Very Easy  1.16
3           3 Very Easy  1.12
4           4 Very Easy  1.33
5           5 Very Easy  1.16
6           6 Very Easy  1.15
```

Repeated Measures ANOVA

```
rm_data_tidied <- rm_data %>%
  mutate(Condition = factor(Condition))
head(rm_data_tidied)

# A tibble: 6 x 3
  Participant Condition    RT
        <dbl> <fct>     <dbl>
1           1 Very Easy  1.25
2           2 Very Easy  1.16
3           3 Very Easy  1.12
4           4 Very Easy  1.33
5           5 Very Easy  1.16
6           6 Very Easy  1.15
```

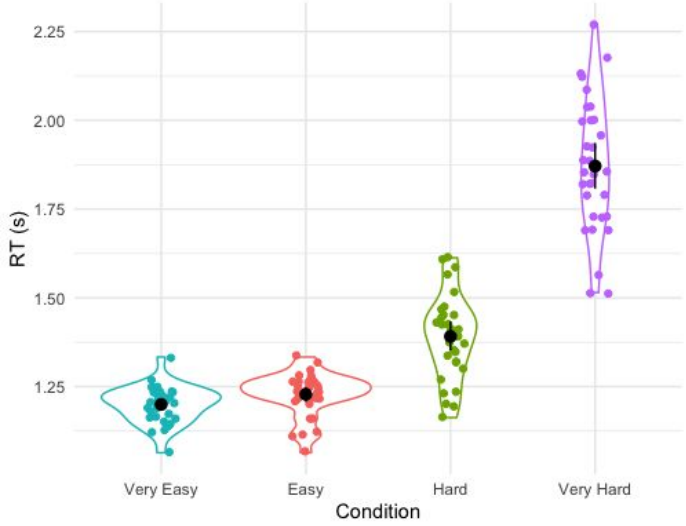
Summarising our Data

```
rm_data_tidied %>%
  group_by(Condition) %>%
  summarise(mean = mean(RT), sd = sd (RT))

# A tibble: 4 x 3
  Condition  mean     sd
  <fct>     <dbl>  <dbl>
1 Easy       1.23 0.0610
2 Hard       1.39 0.118
3 Very Easy  1.20 0.0511
4 Very Hard  1.87 0.187
```

Visualising our Data

```
rm_data_tidied %>%
  ggplot(aes(x = fct_reorder(Condition, RT), y = RT, colour = Condition)) +
  geom_violin() +
  geom_jitter(width = .1) +
  guides(colour = FALSE) +
  stat_summary(fun.data = "mean_cl_boot", colour = "black") +
  theme(text = element_text(size = 13)) +
  theme_minimal() +
  labs(x = "Condition", y = "RT (s)")
```



Modelling our Data

```
> rm_model <- aov_4(RT ~ Condition + (1 + Condition | Participant), data = rm_data_tidied)
> summary(rm_model)
Univariate Type III Repeated-Measures ANOVA Assuming Sphericity

            Sum Sq num Df Error SS den Df  F value    Pr(>F)
(Intercept) 259.07      1  0.50313     31 15962.33 < 2.2e-16 ***
Condition     9.27      3  1.20624     93   238.23 < 2.2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Mauchly Tests for Sphericity

          Test statistic    p-value
Condition        0.38404 3.0211e-05

Greenhouse-Geisser and Huynh-Feldt Corrections
 for Departure from Sphericity
           GG eps Pr(>F[GG])
Condition 0.65596  < 2.2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

             HF eps   Pr(>F[HF])
Condition 0.7000534 3.359493e-31
```

Our Effect Size Measure

```
> anova(rm_model)
Anova Table (Type 3 tests)

Response: RT
          num Df den Df      MSE      F     ges    Pr(>F)
Condition 1.9679 61.004 0.019773 238.23 0.84431 < 2.2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

The effect size is measured by ges and is the recommended effect size measure for repeated measures designs (Bakeman, 2005). Note the dfs in this output are always corrected as if there is a violation of sphericity (violated when the variances of the differences between all possible pairs of within-subject conditions (i.e., levels of the independent variable) are **not** equal) - to be conservative (and to avoid Type I errors) we might be better off to always choose these corrected dfs.

Interpreting our Model

To determine what's driving the effect we can use `emmeans::emmeans()` to run pairwise comparisons (note, default is Tukey correction and we have explicitly asked for Bonferroni below).

```
> emmeans(rm_model, pairwise ~ Condition, adjust = "Bonferroni")
$emmeans
 Condition emmean     SE  df lower.CL upper.CL
 Easy        1.23 0.0208 123     1.18     1.28
 Hard        1.39 0.0208 123     1.34     1.44
 Very.Easy   1.20 0.0208 123     1.15     1.25
 Very.Hard   1.87 0.0208 123     1.82     1.92

Warning: EMMs are biased unless design is perfectly balanced
Confidence level used: 0.95
Conf-level adjustment: bonferroni method for 4 estimates

$contrasts
 contrast              estimate     SE df t.ratio p.value
 Easy - Hard            -0.1633 0.0285 93  -5.735 <.0001
 Easy - Very.Easy        0.0285 0.0285 93   1.000 1.0000
 Easy - Very.Hard       -0.6430 0.0285 93 -22.584 <.0001
 Hard - Very.Easy        0.1917 0.0285 93   6.734 <.0001
 Hard - Very.Hard       -0.4797 0.0285 93 -16.849 <.0001
 Very.Easy - Very.Hard  -0.6715 0.0285 93 -23.584 <.0001

P value adjustment: bonferroni method for 6 tests
```