

## Split-plot ANOVA

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## Research paper

- Effects of alcohol and caffeine on driving ability
- 4 conditions:
  - No alcohol; no caffeine
  - alcohol; no caffeine
  - No alcohol; caffeine
  - Alcohol; caffeine
- Driving in simulator
- Error rate
- Split-plot design

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## Split-plot design

- Alcohol as between-participants factor
- Caffeine as within-participants factor
- Meaning:
  - 12 participants in the no alcohol condition
  - 12 participants in the alcohol condition
  - But all of them in the caffeine/no caffeine conditions

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## Split-plot design

| No Alcohol  |             |          | Alcohol     |             |          |
|-------------|-------------|----------|-------------|-------------|----------|
| Participant | No caffeine | Caffeine | Participant | No caffeine | Caffeine |
| 1           |             |          | 10          |             |          |
| 2           |             |          | 11          |             |          |
| 3           |             |          | 12          |             |          |
| 4           |             |          | 13          |             |          |
| 5           |             |          | 14          |             |          |
| 6           |             |          | 15          |             |          |
| 7           |             |          | 16          |             |          |
| 8           |             |          | 17          |             |          |
| 9           |             |          | 18          |             |          |

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## SPSS output: "between effects"

### Main effect of alcohol

Measure: MEASURE\_1  
Transformed Variable: Average

| Source    | Type III Sum of Squares | df | Mean Square | F        | Sig. |
|-----------|-------------------------|----|-------------|----------|------|
| Intercept | 5250.083                | 1  | 5250.083    | 1394.388 | .000 |
| ALCGROUP  | 1474.083                | 1  | 1474.083    | 391.507  | .000 |
| Error     | 82.833                  | 22 | 3.765       |          |      |

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## SPSS output: "within effects"

### Main effect of caffeine

Measure: MEASURE\_1

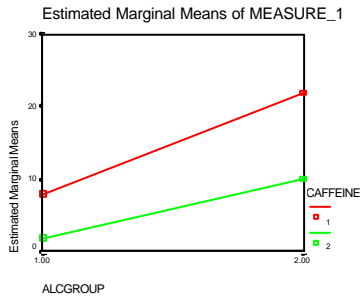
| Source              | Type III Sum of Squares | df      | Mean Square | F       | Sig.    |      |
|---------------------|-------------------------|---------|-------------|---------|---------|------|
| CAFFEINE            | Sphericity Assumed      | 972.000 | 1           | 972.000 | 497.302 | .000 |
|                     | Greenhouse-Geisser      | 972.000 | 1.000       | 972.000 | 497.302 | .000 |
|                     | Huynh-Feldt             | 972.000 | 1.000       | 972.000 | 497.302 | .000 |
|                     | Lower-bound             | 972.000 | 1.000       | 972.000 | 497.302 | .000 |
| CAFFEINE * ALCGROUP | Sphericity Assumed      | 108.000 | 1           | 108.000 | 55.256  | .000 |
|                     | Greenhouse-Geisser      | 108.000 | 1.000       | 108.000 | 55.256  | .000 |
|                     | Huynh-Feldt             | 108.000 | 1.000       | 108.000 | 55.256  | .000 |
|                     | Lower-bound             | 108.000 | 1.000       | 108.000 | 55.256  | .000 |
| Error(CAFFEINE)     | Sphericity Assumed      | 43.000  | 22          | 1.955   |         |      |
|                     | Greenhouse-Geisser      | 43.000  | 22.000      | 1.955   |         |      |
|                     | Huynh-Feldt             | 43.000  | 22.000      | 1.955   |         |      |
|                     | Lower-bound             | 43.000  | 22.000      | 1.955   |         |      |

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### Interaction between caffeine and alcohol

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## SPSS output: cell plot



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## Research paper

### • Results:

The number of driving errors was analyzed with a split-plot ANOVA with alcohol as the between-participants factor and caffeine as the within-participants factor. The test indicated a main effect of alcohol ( $F(1, 22) = 382.28, p < 0.001$ ) and of caffeine ( $F(1, 22) = 521.56, p < 0.001$ ). The interaction between alcohol and caffeine was significant as well ( $F(1, 22) = 57.95, p < 0.001$ ).

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## Comparison

### • Between-participants design:

- Alcohol: ( $F(1, 44) = 339.8, p < 0.001$ )
- Caffeine: ( $F(1, 44) = 515.4, p < 0.001$ )
- Alcohol x caffeine:  $F(1, 44) = 37.8, p < 0.001$ .

### • Within-participants design:

- Alcohol ( $F(1, 11) = 577.9, p < 0.001$ )
- Caffeine ( $F(1, 11) = 692.5, p < 0.001$ ).
- Alcohol x Caffeine: ( $F(1, 11) = 52.8, p < 0.001$ ).

### • Mixed design:

- Alcohol ( $F(1, 22) = 382.28, p < 0.001$ )
- Caffeine ( $F(1, 22) = 521.56, p < 0.001$ ).
- Alcohol x Caffeine: ( $F(1, 22) = 55.25, p < 0.001$ ).

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## 1. Example

- Do boys and girls differ in the ability to perceive colours?
- The study assumed that girls will be better than boys at perceiving differences in colours from a very early age. They therefore tested two different age groups (5-year-olds and 11-year-olds) on a standard colour perception test and compared the performance (marked out of 10) of boys and girls.

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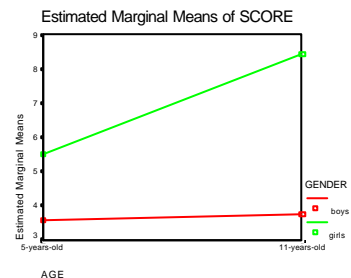
## Performance

| 5-year-olds |       | 11-year-olds |       |
|-------------|-------|--------------|-------|
| boys        | girls | boys         | girls |
| 4           | 6     | 4            | 8     |
| 3           | 5     | 2            | 9     |
| 4           | 6     | 3            | 9     |
| 5           | 4     | 4            | 8     |
| 9           | 6     | 7            | 7     |
| 1           | 7     | 5            | 10    |
| 0           | 8     | 4            | 9     |
| 2           | 6     | 3            | 10    |
| 3           | 5     | 2            | 8     |
| 3           | 4     | 2            | 6     |
| 4           | 6     | 4            | 9     |
| 5           | 3     | 5            | 8     |

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## Cell plot



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## Results

- Age:  $F(1,44) = 10.72$ ;  $p = 0.002$
- Gender:  $F(1,44) = 48.862$ ;  $p < 0.001$
- Age x Gender:  $F(1,44) = 22.69$ ;  $p = 0.006$

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## 2. Example

- Has the academic ability fallen in the last 20 years?
- The study compared the A-level performance of a sample of students who the exams in 1977 and a sample who took them in 1997. Each had taken an examination in both English and Mathematics. In order to ensure that the exams are marked to the same criteria the samples are re-marked by examiners.

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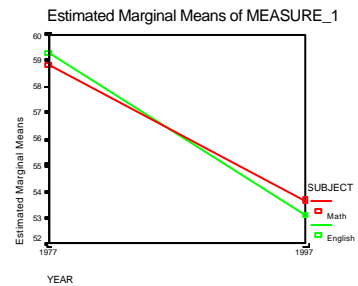
## New marks

| Students from 1977 |         | Students from 1997 |         |
|--------------------|---------|--------------------|---------|
| Mathematics        | English | Mathematics        | English |
| 67                 | 62      | 67                 | 63      |
| 52                 | 73      | 49                 | 67      |
| 45                 | 41      | 48                 | 42      |
| 58                 | 51      | 61                 | 52      |
| 59                 | 62      | 54                 | 51      |
| 81                 | 59      | 55                 | 54      |
| 61                 | 65      | 51                 | 55      |
| 55                 | 57      | 49                 | 52      |
| 60                 | 58      | 53                 | 51      |
| 57                 | 60      | 56                 | 48      |
| 51                 | 63      | 51                 | 50      |
| 60                 | 61      | 50                 | 52      |

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## Cell plot



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## Results

- Subject:  $F(1,22) = 0.001$ ;  $p = 0.982$
- Year:  $F(1,22) = 5.828$ ;  $p = 0.025$
- Subject x Year:  $F(1,22) = 0.088$ ;  $p = 0.982$

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## More independent variables

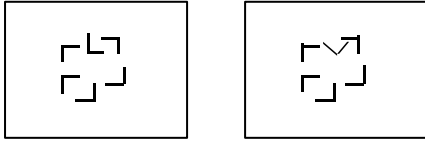
- So far:
  - 2 x 2 factorial design
  - 3 x 3 factorial design
- Possible: arbitrary number of independent variables and levels
- Examples:
  - 3 x 4 x 5 factorial design (Three-way ANOVA)
  - 4 x 4 x 2 x 2 x 2 x 5 x 6 factorial design
- However, more than 3 independent variables does not make sense!

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## Example for 3x2x2 design

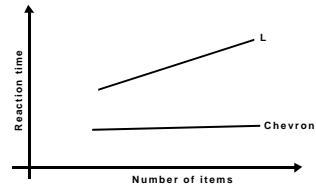
- Does advance information help in visual search?



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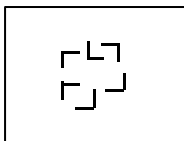
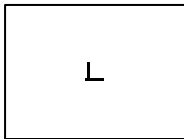
## Typical Visual Search results



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## Experimental procedure



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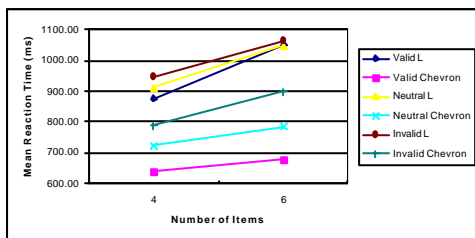
## Design

- Target: L, Chevron, absent (catch-trials)
- Advance Information (prime): Valid, Invalid, Neutral
- Number of items: 4, 6
- 2x3x2 ANOVA repeated-measures

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## Results



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## Results

- Validity:  $F(2,34)=10.624, p < 0.001$
- Target:  $F(1,17)=47.477, p < 0.001$
- Items:  $F(1,17)=60.306, p < 0.001$
- Validity x target:  $F(2, 34) = 19.515, p < 0.001$
- Validity x items:  $F(2, 34) = 0.371, p=0.693$
- Target x items:  $F(1,17) = 12.205, p=0.003$
- Validity x target x items:  $F(2,34)=6.116, p=0.005$

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## Results: Simple effect

- Target Chrevon:
  - Validity :  $F(2,34)=17.885, p < 0.001$
  - Item:  $F(1,17)=23.638, p < 0.001$
  - Validity x items:  $F(2,34)=4.629, p = 0.017$
- Target L:
  - Validity:  $F(2,34)=1.752, p=0.189$
  - Item:  $F(1,17)=54.152, p < 0.000$
  - Validity x items:  $F(2,34)=2.427, p = 0.103$

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## Power of test

- Probability of correctly rejecting a false  $H_0$
- Or not making Type II error

| Decision             | State of the world:<br>$H_0$ true | State of the world:<br>$H_0$ false |
|----------------------|-----------------------------------|------------------------------------|
|                      | Reject $H_0$                      | Type I error                       |
| Fail to reject $H_0$ | Correct decision                  | Type II error                      |

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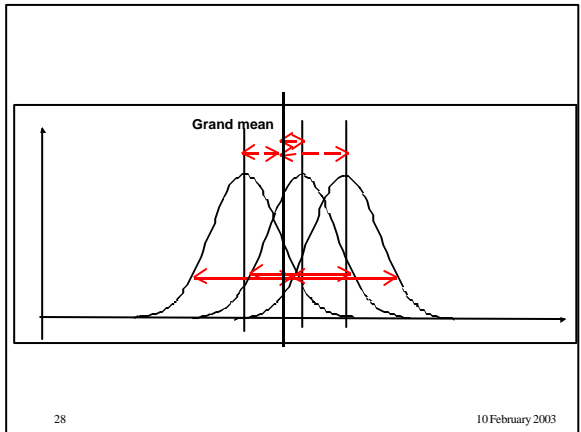
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## Influences on power of test

- $\alpha$ -level (Probability of Type I error)
- True difference between the null hypothesis and the alternative hypothesis
- Sample size
- Variance
- Properties of the test employed

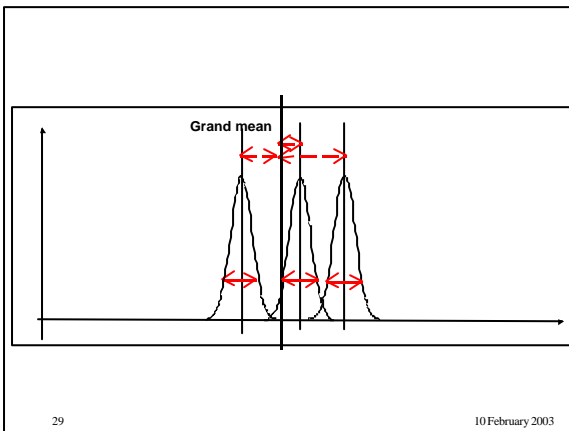
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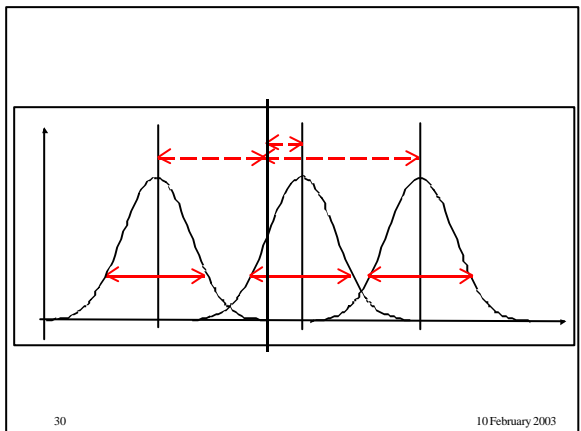
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