Applied Analysis of Variance and Experimental Design

401–0625–00G

Marianne Müller

mlm@ethz.ch

Introduction

- Content
- Learning Material
- Exercises
- Organisation

Consumer research: New type of beer

Has it potential?

- Business survey on sales figures
- Consumer survey on attitudes, preferences among beer drinkers
- Controlled Experiment: subjects test the new beer. Comparison with other beers.

Reliability analysis: Ball Bearing

Two production methods: standard, new
Two measuring devices: M1, M2
Experiment on two days: standard product on day 1, new product on day 2

Response: survival times in minutes

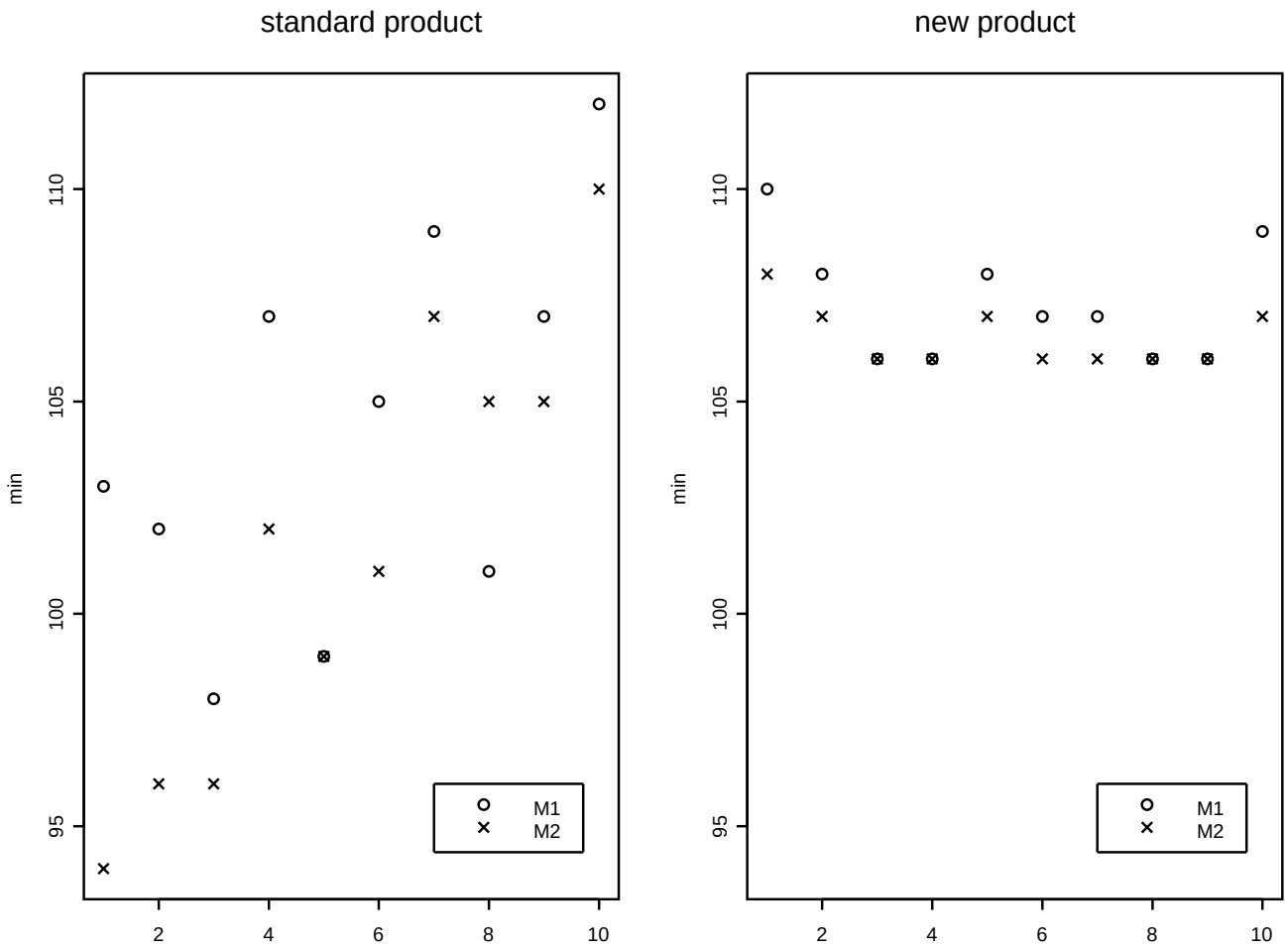
standard product:

M1	103	102	98	107	99	105	109	101	107	112
M2	94	96	96	102	99	101	107	105	105	110

new product:

M1	110	108	106	106	108	107	107	106	106	109
M2	108	107	106	106	107	106	106	106	106	107

Graphical display



Planning of Experiments I

1. Statement of problem, empirically testable hypotheses
2. Collecting information
3. Choice of variables:
   - outcome, response variable
   - Influencing factors: factors are categorical, explanatory variables. The values of a factor are called levels.
4. Choice of measurement methods
5. Choice of design
6. Conducting the experiment

Planning of Experiments II

7. Data scrutiny, plausibility tests
8. Data analysis: exploratory, graphically, model fitting and checking
9. Interpretation

Important principles of experimental design

- Replication
- Randomisation
- Blocking

Confounding

A confounding variable is correlated with both the outcome and an explanatory variable. Effects cannot be distinguished.

Example: Coronary Drug Project (1980)

	Medication	Placebo
5 Year Mortality	20%	21%

Experimental group:

	Compliance	
	high	low
5 Year Mortality	15%	25%

Same effect in Placebo group

	Compliance	
	high	low
5 Year Mortality	15%!	28%

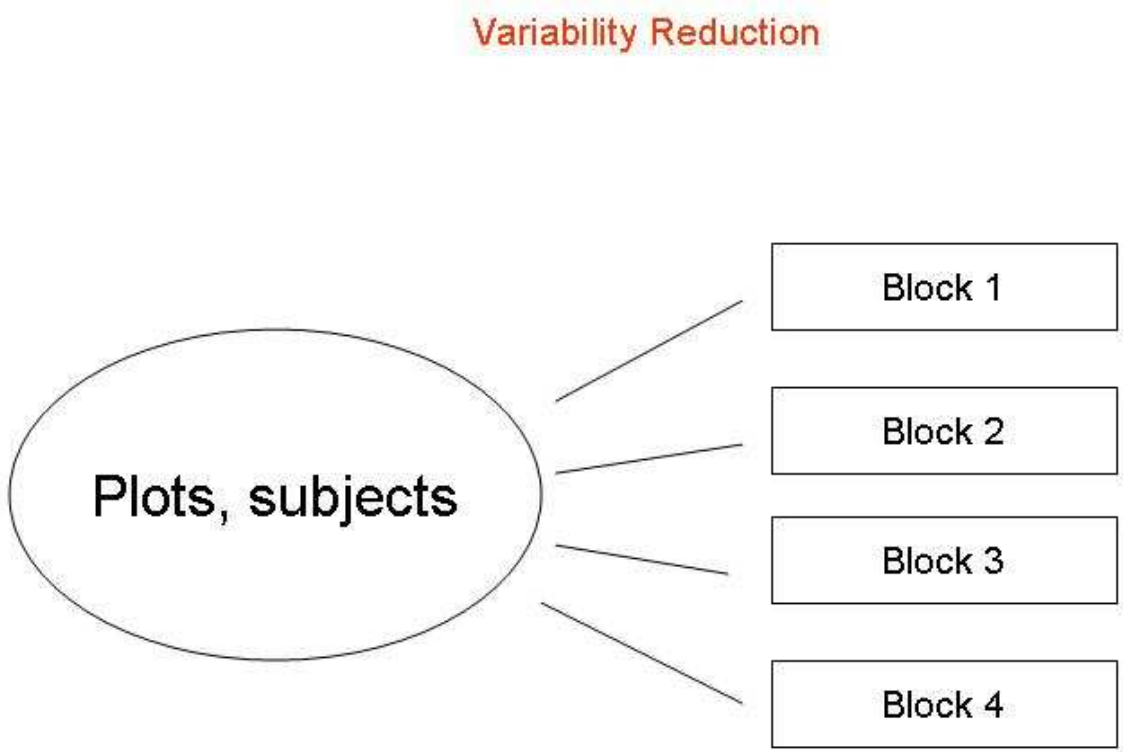
Randomisation

Random allocation of plots or subjects to experimental conditions to avoid selection bias

Example: Planting of varities A and B

poor design: A A A A A B B B B B
better design: A A B A B A B B B A

Block design



Crossover design

Subject = Block

subject 1	Treatment 1	Treatment 2	Treatment 3
subject 2	Treatment 1	Treatment 2	Treatment 3
subject 3	Treatment 1	Treatment 2	Treatment 3
subject n	Treatment 1	Treatment 2	Treatment 3

Complex Effects

- Effect of coffee and whisky on reaction time in car driving, experiment in simulator
- Results:
  without coffee/with one glas of whisky: +0.45 sec
  without alcohol/with one cup of coffee: – 0.2 sec
- What happens after several cups of coffee and glasses of whisky? Are the effects linear and additive?
  linear: 4 cups of coffee: -0.8
  additive: 1 whisky and 1 coffee: +0.25
  linear and additive: 10 whisky and 23 coffee: -0.1

Full Example: Sewage treatment

- Procedure:
  - Mechanical process, grit chamber and bar screen, to remove large objects
  - biological process, bacteria, to remove organic contaminants
  - chemical process, microfiltration and disinfection, to remove sulphate and nitrate.
- New development: resin treatment, relatively cheap.

Can sulphate levels be reduced?

- Experiment: compare samples from treated water with average level of untreated water
- Analysis: one-sample t test
- Result: statistically significant reduction, but still too high levels.

Is a more intensive treatment helpful?

- Experiment: comparison of two groups of samples with normal and intensive treatment.
- Analysis: two-sample t test
- Result: no significant difference.

Comparison with standard

- Experiment: comparison with five commercially available treatments.
- Analysis: one-way analysis of variance
- Result: resin treatment is at least as good.

Are there other important factors?

- Experiment: treatment under various controlled conditions of amount of water, flow speed, tank size
- Design and Analysis: factorial design
- Result: there is a combination which produces acceptable water quality

Is the resin treatment successful under realistic conditions?

- Experiment: Treatment under a very large number of conditions.
- Design and Analysis: Fractional factorial design
- Result: Treatment is successful under most common conditions

Further steps

How can quality be optimized at minimal cost?

- Design and Analysis: Response surface design

Quality management

- Method: Quality control charts and variance components analysis

Application of experimental design

- agriculture and biology
- medicine
- engineering and industry
- market research
- psychology

Participants

- Electronic registration: 86
- Study programmes: Envir 9, Earth 3, Food 31, Bio 14, Math. 19, Engin 5, Agric 2, Human Mov 1
- Degree: BSc 20, MSc 55, Dr 5, Mobil 5, Auditor 1
- Language: German 65, English 1, Chinese 4, Spanish 2, Italian 3, French 1, others 10
- Previous statistical education: ?????

Material

- Program, literature, organisational details

`stat.ethz.ch/education/semesters/as2010/anova`

- Recommended textbook: Montgomery, D.C (2001). *Design and Analysis of Experiments*, Wiley, New York.
- Exercises, datasets, solutions see website above.
- Slides and any additional material on `eva-elba.unibas.ch`

ETH D-MATH

– Müller Marianne

– anova

Organisation of Exercises

- Assistants:
  Philipp Rütimann, HG G11
  Patric Müller, HG G14.2
- Introduction into R on 11/10/10 13 - 15 pm in HG E 19 and HG E 26.1.
- Afterwards every two weeks according to program in HG D1.2.
- External auditors who need an account send an email to an assistant.

Exam

- No confirmation required, keine Testatbedingung
- Session examination:
  - written exam
  - duration 120 minutes
  - 4 credits

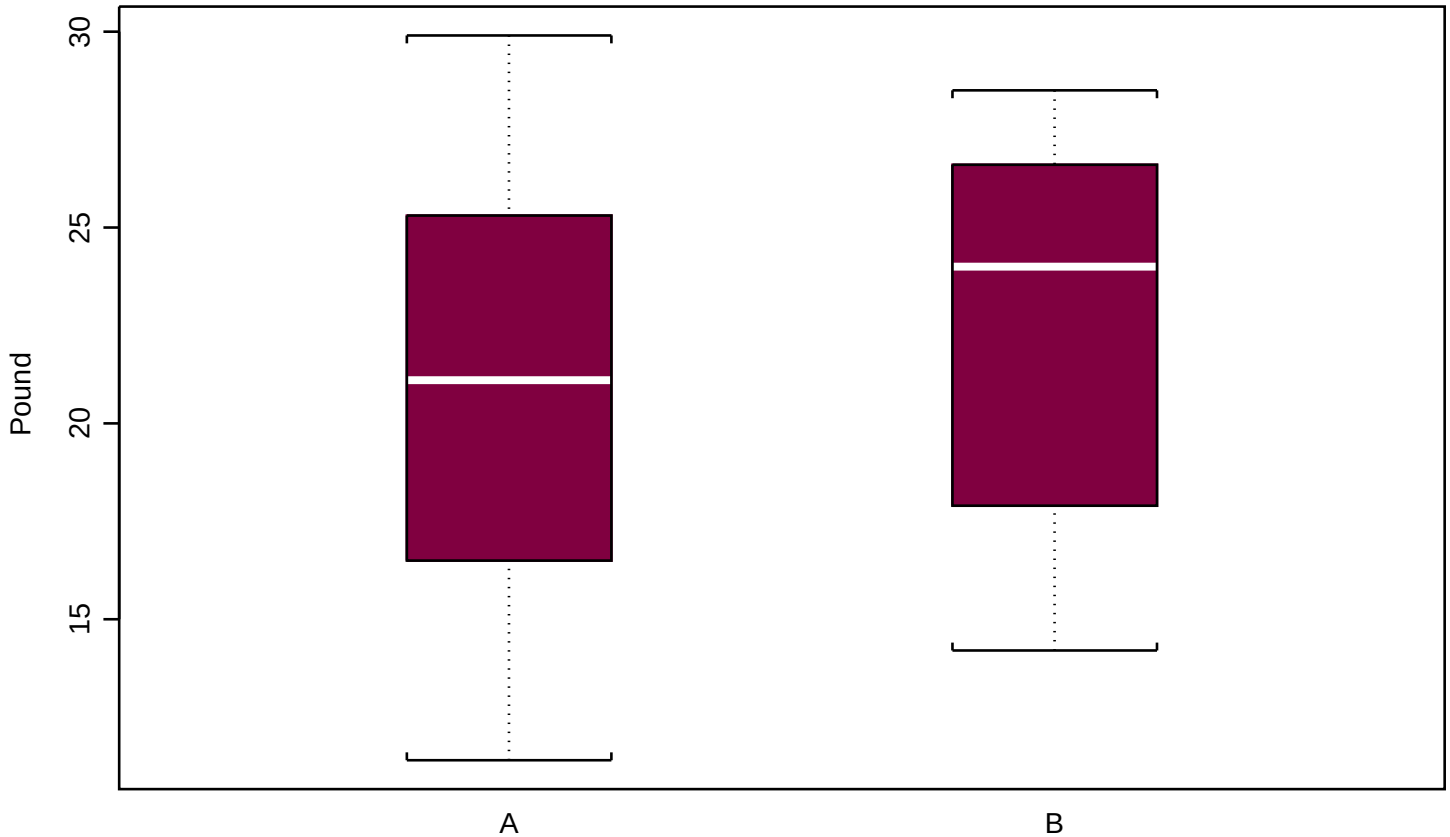
Comparison of two groups

- Effect of fertilizer mixture on yield of tomato plants. 11 plants in a single row: 5 were given standard A, 6 were given (improved?) mixture B.
- Is there a difference? How large is the difference?

A and B are randomly allocated to plants.

1	2	3	4	5	6	7	8	9	10	11
A	A	B	B	A	B	B	B	A	A	B
29.9	11.4	26.6	23.7	25.3	28.5	14.2	17.9	16.5	21.1	24.3

Boxplots



Two-sample t Test

```
> t.test(A,B)
    Standard Two-Sample t-Test

t = -0.4437, df = 9, p-value = 0.6677
alt. hypothesis: true difference in means
is not equal to 0
95 percent confidence interval:
 -10.326908   6.940241
sample estimates:
 mean of x mean of y
     20.84  22.53333
```