OHSU OGI ECE-580-DOE:

Design and Analysis of Engineering Experiments

using

Text: **Design and Analysis of Experiments, 5th Edition**
Author Douglas C.Montgomery, John Wiley & Sons: ISBN 0-471-31649-0; 5th ed. 2001

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Design of Engineering Experiments Introduction Chapter 1, Text

- **Why** is this trip necessary? Goals of the course
- An abbreviated **history** of DOE or DOX
- Some basic **principles** and terminology
- The **strategy** of experimentation
- **Guidelines** for planning, conducting and analyzing experiments

Introduction to DOX

- An **experiment** is a test or a series of tests
- Experiments are used widely in the engineering world
  - Process characterization & optimization
  - Evaluation of material properties
  - Product design & development
  - Component & system tolerance determination
- ***"All experiments are designed experiments, some are poorly designed, some are well-designed"***

Engineering Experiments

- Reduce **time** to design/develop new products & processes
- Improve **performance** of existing processes
- Improve **reliability** and performance of products
- Achieve product & process **robustness**
- **Evaluation** of materials, design alternatives, **setting** component & system tolerances, etc.

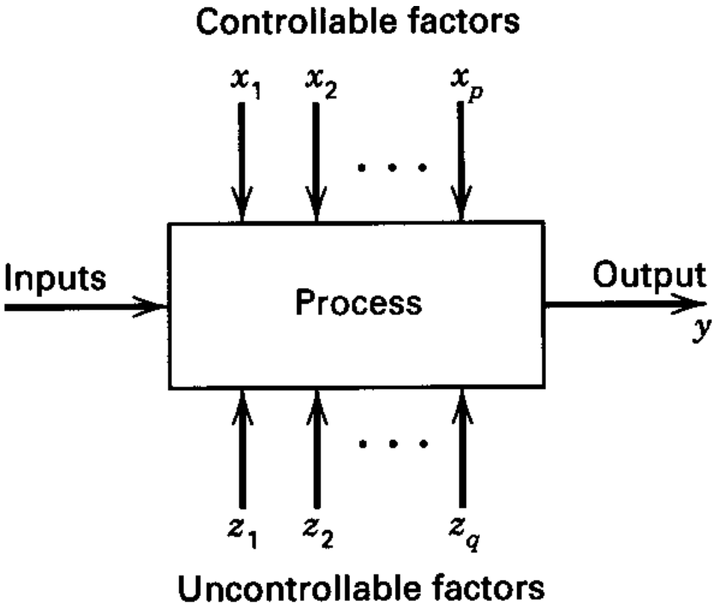


Figure 1-1 General model of a process or system.

Four Eras in the History of DOX

- The **agricultural** origins, 1918 – 1940s
  - R. A. Fisher & his co-workers
  - Profound impact on agricultural science
  - Factorial designs, ANOVA
- The **first industrial** era, 1951 – late 1970s (not used extensively in the USA due to poor training)
  - Box & Wilson, response surfaces
  - Applications in the chemical & process industries
- The **second industrial** era, late 1970s – 1990
  - Quality improvement initiatives in many companies
  - Taguchi and robust parameter design, process robustness
- The **modern** era, beginning circa 1990

The 3 Basic Principles of DOX

- **Randomization**
  - Running the trials in an experiment in random order
  - Notion of balancing out effects of “lurking” variables
- **Replication**
  - Sample size (improving precision of effect estimation, estimation of error or background noise)
  - Replication versus repeat measurements?
- **Blocking**
  - Dealing with nuisance factors

Strategy of Experimentation

All experiments are designed.

It's just that some are not designed well.

Hopefully in this class you will learn how to design a good efficient and effective experiment!

- **"Best-guess" experiments**
  - Used a lot
  - More successful than you might suspect, but there are disadvantages…
- **One-factor-at-a-time (OFAT) experiments**
  - Sometimes associated with the "scientific" or "engineering" method
  - Devastated by interaction, also very inefficient
- **Statistically designed experiments**
  - Based on Fisher's factorial concept

Factorial Designs

- In a factorial experiment, **all possible combinations** of factor levels are tested
- The golf experiment:
  - Type of driver
  - Type of ball
  - Walking vs. riding
  - Type of beverage
  - Time of round
  - Weather
  - Type of golf spike
  - Etc, etc, etc…

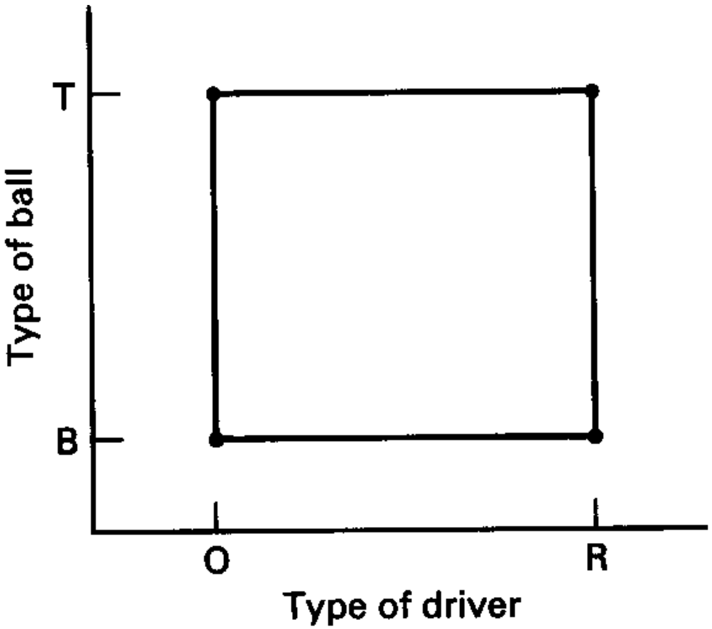
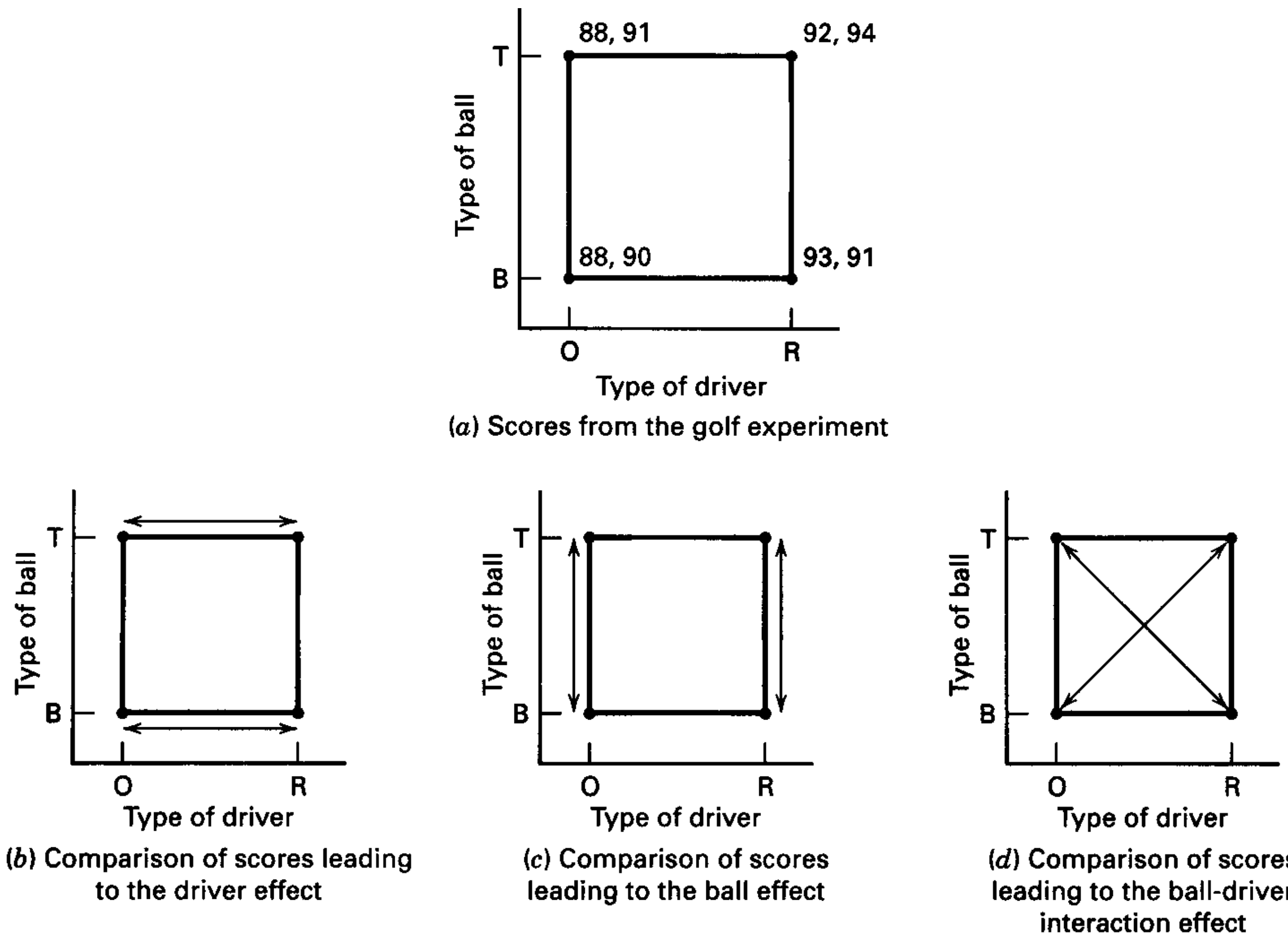


Figure 1-4 A two-factor factorial experiment involving type of driver and type of ball.

Factorial Design



(*a*) Scores from the golf experiment

(*b*) Comparison of scores leading to the driver effect

(*c*) Comparison of scores leading to the ball effect

(*d*) Comparison of scores leading to the ball-driver interaction effect

Figure 1-5 Scores from the golf experiment in Figure 1-4 and calculation of the factor effects.

Factorial Designs with Several Factors

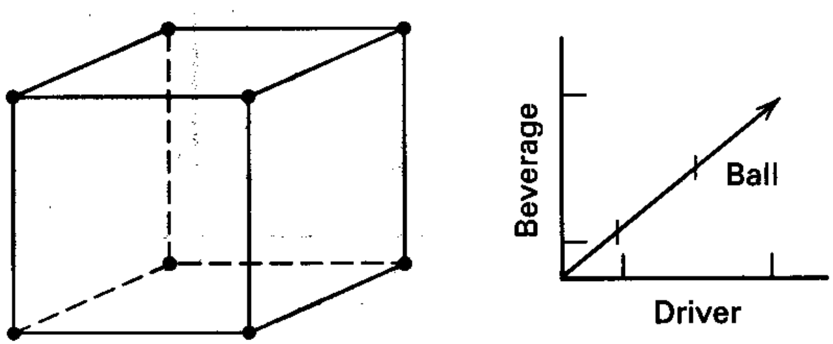


Figure 1-6 A three-factor factorial experiment involving type of driver, type of ball, and type of beverage.

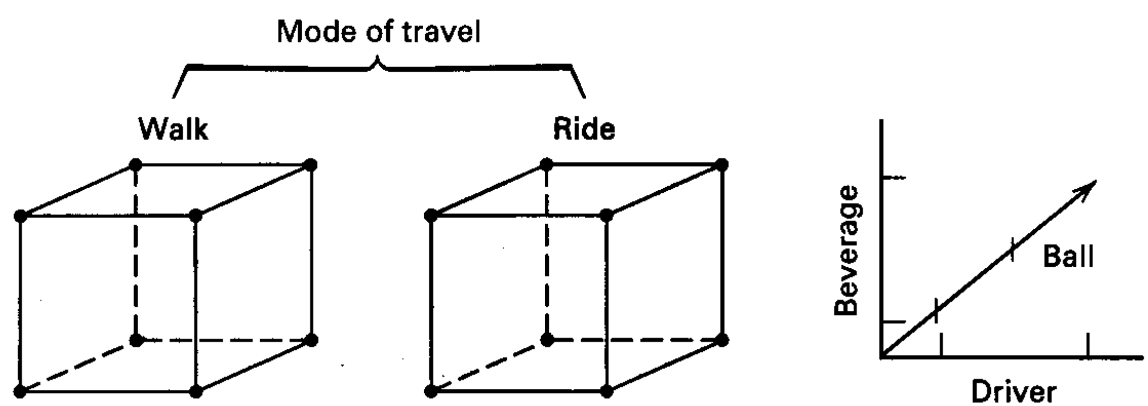


Figure 1-7 A four-factor factorial experiment involving type of driver, type of ball, type of beverage, and mode of travel.

Factorial Designs with Several Factors
A Fractional Factorial

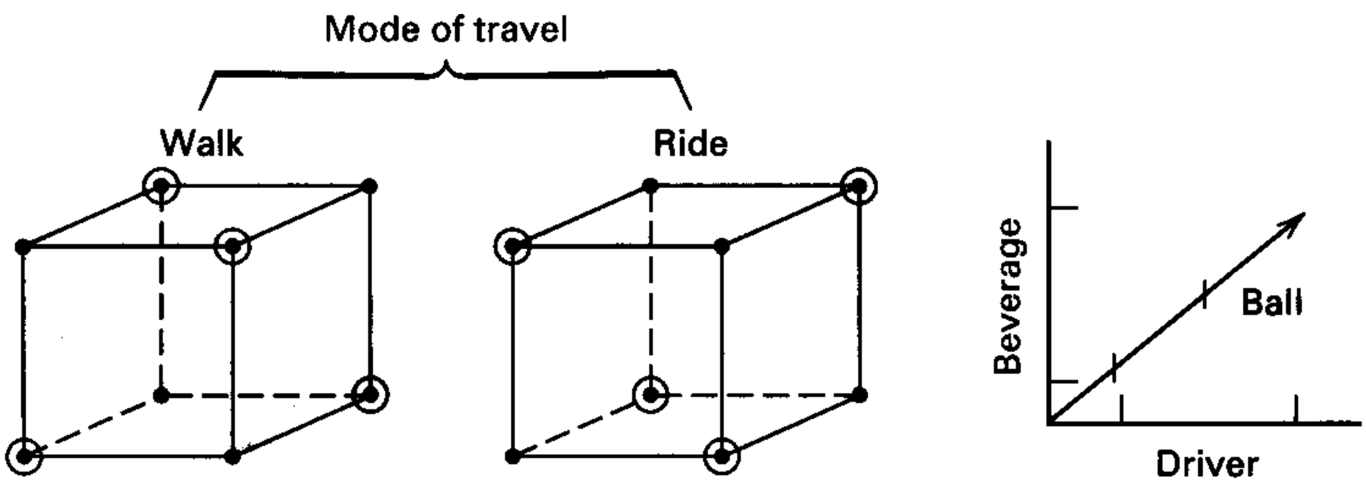


Figure 1-8 A four-factor fractional factorial experiment involving type of driver, type of ball, type of beverage, and mode of travel.

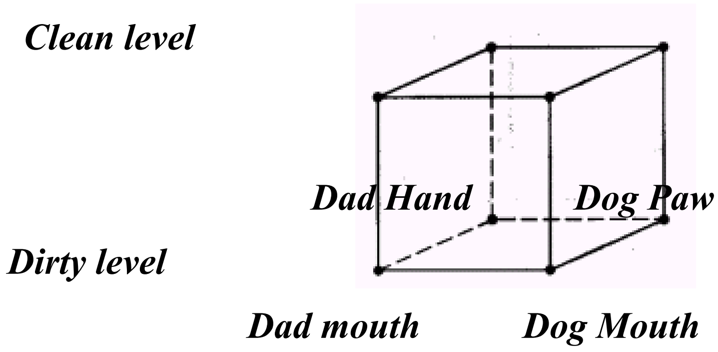
2^{nd} Example: Factorial Designs with Several Factors

High School Science experiment:

Is my Dad cleaner than my dog?
Setup a 2^3 experimental design

This is 8 experimental conditions forming the 8 corners of the cube:
3 factors at 2 levels each: Replicate each test run

Response: Rate of bacterial growth in a petri dish.



Planning, Conducting & Analyzing an Experiment

Remember the type of design determines the type of analysis! You cannot typically fit the data collected to a specific analysis!

1. Recognition of & statement of problem
2. Choice of factors, levels, and ranges
3. Selection of the response variable(s)
4. Choice of design<< Careful selection!
5. Conducting the experiment: RRB
6. Statistical analysis <<Software!
7. Drawing conclusions, recommendations

Planning, Conducting & Analyzing an Experiment

- Get **statistical thinking** involved early
- Your **non-statistical** knowledge is crucial to success
- Pre-experimental planning (steps 1-4) vital
- Think and **experiment** sequentially (use the KISS principle)
- See Coleman & Montgomery (1993) *Technometrics* paper + supplemental text material