# *Multivariate Analysis for the Behavioral Sciences*, Second Edition (Chapman and Hall/CRC, 2019)

# Exercises of Chapter 9: Analysis of Longitudinal Data II: Linear Mixed Effects Models for Normal Response Variables

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## Exercises

### Exercise 9.1

See Table 9.7 in the book and use the BtB data, modifying the related R code given in the **Examples of Chapter 9**.

### Exercise 9.2

Continue with the BtB data, modifying the related R code given in the **Examples of Chapter 9**.

## Exercise 9.3

Use the oestrogen data (see below) and modify the R codes given in the **Examples of Chapter 9** to create suitable graphics and to analyse the data. *Obs: Instead of -9, the missing observations are already indicated by NA in the data.*

```
oestrogen <- read.table("data/oestrogen.txt", sep = "\t", header = TRUE)

str(oestrogen)
```

```
## 'data.frame':    366 obs. of  6 variables:
##  $ subject   : int  1 1 1 1 1 1 2 2 2 2 ...
##  $ treatment : Factor w/ 2 levels "oespatch","placebo": 2 2 2 2 2 2 2 2 2 2 ...
##  $ BL1       : int  18 18 18 18 18 18 25 25 25 25 ...
##  $ BL2       : int  18 18 18 18 18 18 27 27 27 27 ...
##  $ time      : int  1 2 3 4 5 6 1 2 3 4 ...
##  $ depression: num  17 26 17 14 12 19 13 26 26 9 ...
```

```
# the data are readily in the long form:
head(oestrogen, n = 10); tail(oestrogen, n = 10)
```

```
##    subject treatment BL1 BL2 time depression
## 1        1   placebo  18  18    1         17
## 2        1   placebo  18  18    2         26
## 3        1   placebo  18  18    3         17
## 4        1   placebo  18  18    4         14
## 5        1   placebo  18  18    5         12
## 6        1   placebo  18  18    6         19
## 7        2   placebo  25  27    1         13
## 8        2   placebo  25  27    2         26
## 9        2   placebo  25  27    3         26
## 10       2   placebo  25  27    4          9
```

```
##     subject treatment BL1 BL2 time depression
## 357      60  oespatch  18  22    3          1
## 358      60  oespatch  18  22    4         10
## 359      60  oespatch  18  22    5          5
## 360      60  oespatch  18  22    6          6
## 361      61  oespatch  23  26    1         NA
## 362      61  oespatch  23  26    2          3
## 363      61  oespatch  23  26    3          4
## 364      61  oespatch  23  26    4         NA
## 365      61  oespatch  23  26    5         NA
## 366      61  oespatch  23  26    6         NA
```

## Exercise 9.4

Use the phosphate data (see below) and modify the R codes given in the **Examples of Chapter 9** to create suitable graphics of the data.

```
phosphate <- structure(list(

    group = structure(c(1L, 1L, 1L, 1L, 1L, 1L, 1L, 1L, 1L, 1L, 1L, 1L, 1L, 1L,
                        1L, 1L, 1L, 1L, 1L, 1L, 2L, 2L, 2L, 2L, 2L, 2L, 2L, 2L,
                        2L, 2L, 2L, 2L, 2L),
                      .Label = c("control", "obese"), class = "factor"),

  t0 = c(4.3, 3.7, 4, 3.6, 4.1, 3.8, 3.8, 4.4, 5, 3.7, 3.7, 4.4, 4.7, 4.3, 5,
         4.6, 4.3, 3.1, 4.8, 3.7, 5.4, 3, 4.9, 4.8, 4.4, 4.9, 5.1, 4.8, 4.2,
         6.6, 3.6, 4.5, 4.6),

  t0.5 = c(3.3, 2.6, 4.1, 3, 3.8, 2.2, 3, 3.9, 4, 3.1, 2.6, 3.7, 3.1, 3.3, 4.9,
           4.4, 3.9, 3.1, 5, 3.1, 4.7, 2.5, 5, 4.3, 4.2, 4.3, 4.1, 4.6, 3.5, 6.1,
           3.4, 4, 4.4),

  t1 = c(3, 2.6, 3.1, 2.2, 2.1, 2, 2.4, 2.8, 3.4, 2.9, 2.6, 3.1, 3.2, 3, 4.1,
         3.9, 3.1, 3.3, 2.9, 3.3, 3.9, 2.3, 4.1, 4.7, 4.2, 4, 4.6, 4.6, 3.8,
         5.2, 3.1, 3.7, 3.8),

  t1.5 = c(2.6, 1.9, 2.3, 2.8, 3, 2.6, 2.5, 2.1, 3.4, 2.2, 2.3, 3.2, 3.3, 2.6,
           3.7, 3.9, 3.1, 2.6, 2.8, 2.8, 4.1, 2.2, 3.7, 4.6, 3.4, 4, 4.1, 4.4,
           3.6, 4.1, 2.8, 3.3, 3.8),

  t2 = c(2.2, 2.9, 2.9, 2.9, 3.6, 3.8, 3.1, 3.6, 3.3, 1.5, 2.9, 3.7, 3.2, 2.2,
         3.7, 3.7, 3.1, 2.6, 2.2, 2.9, 2.8, 2.1, 3.7, 4.7, 3.5, 3.3, 3.4, 4.1,
         3.3, 4.3, 2.1, 2.4, 3.8),

  t3 = c(2.5, 3.2, 3.1, 3.9, 3.4, 3.6, 3.4, 3.8, 3.6, 2.3, 2.2, 4.3, 4.2, 2.5,
         4.1, 4.2, 3.1, 1.9, 3.1, 3.6, 3.7, 2.6, 4.1, 3.7, 3.4, 4.1, 4.2, 4,
         3.1, 3.8, 2.4, 2.3, 3.6),

  t4 = c(3.4, 3.1, 3.9, 3.8, 3.6, 3, 3.5, 4, 4, 2.7, 3.1, 3.9, 3.7, 2.4, 4.7,
         4.8, 3.6, 2.3, 3.5, 4.3, 3.5, 3.2, 4.7, 3.6, 3.8, 4.2, 4.4, 3.8, 3.5,
         4.2, 2.5, 3.1, 3.8),

  t5 = c(4.4, 3.9, 4, 4, 3.7, 3.5, 3.7, 3.9, 4.3, 2.8, 3.9, 4.8, 4.3, 3.4, 4.9,
         5, 4, 2.7, 3.6, 4.4, 3.7, 3.5, 4.9, 3.9, 4, 4.3, 4.9, 3.8, 3.9, 4.8,
         3.5, 3.3, 3.8)),

.Names = c("group", "t0", "t0.5", "t1", "t1.5", "t2", "t3", "t4", "t5"),

row.names = c("1", "2", "3", "4", "5", "6", "7", "8", "9", "10", "11", "12",
              "13", "14", "15", "16", "17", "18", "19", "20", "21", "22", "23",
              "24", "25", "26", "27", "28", "29", "30", "31", "32", "33"),
class = "data.frame")
```

```r
str(phosphate)
```

```
## 'data.frame':    33 obs. of  9 variables:
##  $ group: Factor w/ 2 levels "control","obese": 1 1 1 1 1 1 1 1 1 ...
##  $ t0   : num  4.3 3.7 4 3.6 4.1 3.8 3.8 4.4 5 3.7 ...
##  $ t0.5 : num  3.3 2.6 4.1 3 3.8 2.2 3 3.9 4 3.1 ...
##  $ t1   : num  3 2.6 3.1 2.2 2.1 2 2.4 2.8 3.4 2.9 ...
##  $ t1.5 : num  2.6 1.9 2.3 2.8 3 2.6 2.5 2.1 3.4 2.2 ...
##  $ t2   : num  2.2 2.9 2.9 2.9 3.6 3.8 3.1 3.6 3.3 1.5 ...
##  $ t3   : num  2.5 3.2 3.1 3.9 3.4 3.6 3.4 3.8 3.6 2.3 ...
##  $ t4   : num  3.4 3.1 3.9 3.8 3.6 3 3.5 4 4 2.7 ...
##  $ t5   : num  4.4 3.9 4 4 3.7 3.5 3.7 3.9 4.3 2.8 ...
```

```r
head(phosphate)
```

```
##     group  t0 t0.5  t1 t1.5  t2  t3  t4  t5
## 1 control 4.3  3.3 3.0  2.6 2.2 2.5 3.4 4.4
## 2 control 3.7  2.6 2.6  1.9 2.9 3.2 3.1 3.9
## 3 control 4.0  4.1 3.1  2.3 2.9 3.1 3.9 4.0
## 4 control 3.6  3.0 2.2  2.8 2.9 3.9 3.8 4.0
## 5 control 4.1  3.8 2.1  3.0 3.6 3.4 3.6 3.7
## 6 control 3.8  2.2 2.0  2.6 3.8 3.6 3.0 3.5
```

```r
tail(phosphate, n = 14)
```

```
##      group  t0 t0.5  t1 t1.5  t2  t3  t4  t5
## 20 control 3.7  3.1 3.3  2.8 2.9 3.6 4.3 4.4
## 21   obese 5.4  4.7 3.9  4.1 2.8 3.7 3.5 3.7
## 22   obese 3.0  2.5 2.3  2.2 2.1 2.6 3.2 3.5
## 23   obese 4.9  5.0 4.1  3.7 3.7 4.1 4.7 4.9
## 24   obese 4.8  4.3 4.7  4.6 4.7 3.7 3.6 3.9
## 25   obese 4.4  4.2 4.2  3.4 3.5 3.4 3.8 4.0
## 26   obese 4.9  4.3 4.0  4.0 3.3 4.1 4.2 4.3
## 27   obese 5.1  4.1 4.6  4.1 3.4 4.2 4.4 4.9
## 28   obese 4.8  4.6 4.6  4.4 4.1 4.0 3.8 3.8
## 29   obese 4.2  3.5 3.8  3.6 3.3 3.1 3.5 3.9
## 30   obese 6.6  6.1 5.2  4.1 4.3 3.8 4.2 4.8
## 31   obese 3.6  3.4 3.1  2.8 2.1 2.4 2.5 3.5
## 32   obese 4.5  4.0 3.7  3.3 2.4 2.3 3.1 3.3
## 33   obese 4.6  4.4 3.8  3.8 3.8 3.6 3.8 3.8
```