A Handbook of Statistical Analyses Using R

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CHAPTER 10

Analysing Longitudinal Data I: Computerised Delivery of Cognitive Behavioural Therapy–Beat the Blues

10.1 Introduction

10.2 Analysing Longitudinal Data

10.3 Analysis Using R

We shall fit both random intercept and random intercept and slope models to the data including the baseline BDI values (`pre.bdi`), `treatment` group, `drug` and `length` as fixed effect covariates. Linear mixed effects models are fitted in R by using the `lmer` function contained in the *lme4* package (Bates and Sarkar, 2005, Pinheiro and Bates, 2000, Bates, 2005), but an essential first step is to rearrange the data from the 'wide form' in which they appear in the `BtheB` data frame into the 'long form' in which each separate repeated measurement and associated covariate values appear as a separate row in a *data.frame*. This rearrangement can be made using the following code:

```
R> data("BtheB", package = "HSAUR")
R> BtheB$subject <- factor(rownames(BtheB))
R> nobs <- nrow(BtheB)
R> BtheB_long <- reshape(BtheB, idvar = "subject",
+     varying = c("bdi.2m", "bdi.4m", "bdi.6m", "bdi.8m"),
+     direction = "long")
R> BtheB_long$time <- rep(c(2, 4, 6, 8), rep(nobs,
+     4))
```

such that the data are now in the form (here shown for the first three subjects)

```
R> subset(BtheB_long, subject %in% c("1", "2", "3"))
```

	drug	length	treatment	bdi.pre	subject	time	bdi
1.2m	No	>6m	TAU	29	1	2	2
2.2m	Yes	>6m	BtheB	32	2	2	16
3.2m	Yes	<6m	TAU	25	3	2	20
1.4m	No	>6m	TAU	29	1	4	2
2.4m	Yes	>6m	BtheB	32	2	4	24
3.4m	Yes	<6m	TAU	25	3	4	NA
1.6m	No	>6m	TAU	29	1	6	NA
2.6m	Yes	>6m	BtheB	32	2	6	17
3.6m	Yes	<6m	TAU	25	3	6	NA

```
R> data("BtheB", package = "HSAUR")
R> layout(matrix(1:2, nrow = 1))
R> ylim <- range(BtheB[, grep("bdi", names(BtheB))],
+     na.rm = TRUE)
R> boxplot(subset(BtheB, treatment == "TAU")[, grep("bdi",
+     names(BtheB))], main = "Treated as usual", ylab = "BDI",
+     xlab = "Time (in months)", names = c(0, 2, 4,
+         6, 8), ylim = ylim)
R> boxplot(subset(BtheB, treatment == "BtheB")[, grep("bdi",
+     names(BtheB))], main = "Beat the Blues", ylab = "BDI",
+     xlab = "Time (in months)", names = c(0, 2, 4,
+         6, 8), ylim = ylim)
```

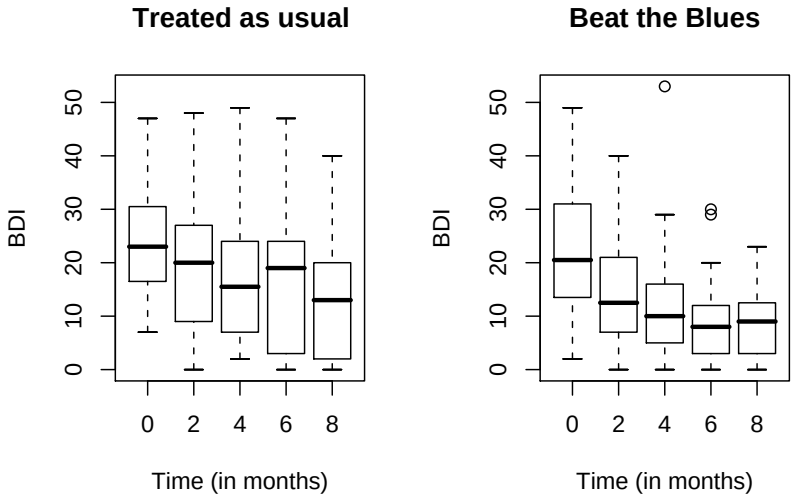

Figure 10.1 Boxplots for the repeated measures by treatment group for the `BtheB` data.

```
1.8m   No    >6m      TAU      29       1    8  NA
2.8m  Yes    >6m    BtheB      32       2    8  20
3.8m  Yes    <6m      TAU      25       3    8  NA
```

The resulting *data.frame* `BtheB_long` contains a number of missing values and in applying the `lmer` function these will be dropped. But notice it is only the missing values that are removed, *not* participants that have at least one missing value. All the available data is used in the model fitting process. The `lmer` function is used in a similar way to the `lm` function met in Chapter **??** with the addition of a random term to identify the source of the repeated

measurements, here `subject`. We can fit the two models (??) and (??) and test which is most appropriate using

```
R> library("lme4")
R> BtheB_lmer1 <- lmer(bdi ~ bdi.pre + time + treatment +
+     drug + length + (1 | subject), data = BtheB_long,
+     method = "ML", na.action = na.omit)
R> BtheB_lmer2 <- lmer(bdi ~ bdi.pre + time + treatment +
+     drug + length + (time | subject), data = BtheB_long,
+     method = "ML", na.action = na.omit)
R> anova(BtheB_lmer1, BtheB_lmer2)
```

```
Data: BtheB_long
Models:
BtheB_lmer1: bdi ~ bdi.pre + time + treatment + drug + length + (1 | subject)
BtheB_lmer2: bdi ~ bdi.pre + time + treatment + drug + length + (time | subject)
            Df     AIC     BIC  logLik  Chisq Chi Df
BtheB_lmer1  8 1886.62 1915.70 -935.31
BtheB_lmer2 10 1889.81 1926.16 -934.90 0.8161      2
            Pr(>Chisq)
BtheB_lmer1
BtheB_lmer2      0.665
```

```
R> summary(BtheB_lmer1)

Linear mixed-effects model fit by maximum likelihood
Formula: bdi ~ bdi.pre + time + treatment + drug + length + (1 | subject)
   Data: BtheB_long
      AIC      BIC   logLik MLdeviance REMLdeviance
 1886.624 1915.702 -935.312   1870.624     1866.149
Random effects:
 Groups   Name        Variance Std.Dev.
 subject  (Intercept) 49.362   7.0258
 Residual             25.678   5.0673
# of obs: 280, groups: subject, 97

Fixed effects:
                 Estimate Std. Error  DF t value  Pr(>|t|)
(Intercept)      5.943659   2.249224 274  2.6425  0.008702 **
bdi.pre          0.638192   0.077591 274  8.2250 7.928e-15 ***
time            -0.717018   0.146055 274 -4.9092 1.573e-06 ***
treatmentBtheB  -2.373078   1.663747 274 -1.4263  0.154907
drugYes         -2.797837   1.719997 274 -1.6267  0.104960
length>6m        0.256348   1.632189 274  0.1571  0.875315
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
            (Intr) bdi.pr time   trtmBB drugYs
bdi.pre     -0.678
time        -0.264  0.023
tretmntBthB -0.389  0.121  0.022
drugYes     -0.071 -0.237 -0.025 -0.323
length>6m   -0.238 -0.242 -0.043  0.002  0.158
```

Figure 10.2 R output of the linear mixed-effects model fit for the `BtheB` data.

Bibliography

Bates, D. (2005), "Fitting linear mixed models in R," *R News*, 5, 27–30, URL http://CRAN.R-project.org/doc/Rnews/. 3

Bates, D. and Sarkar, D. (2005), *lme4: Linear Mixed-Effects Models Using S4 Classes*, URL http://CRAN.R-project.org, R package version 0.98-1. 3

Pinheiro, J. C. and Bates, D. M. (2000), *Mixed-Effects Models in S and S-PLUS*, New York, USA: Springer. 3