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> #####
> ##### Introductory Example of Multilevel Analysis
> #####
>
> ##### Read in the dataset
> example.data<-read.table("http://www.jkyleroberts.com/Rfiles/mlm/example1.txt",
header=T)
> ##### Make "GROUP" a factor
> example.data$GROUP<-factor(example.data$GROUP)
>
> ##### Run the linear model (OLS; Ordinary Least Squares)
> lm.model<-lm(SCIENCE~URBAN, example.data)
> summary(lm.model)

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Call:
lm(formula = SCIENCE ~ URBAN, data = example.data)

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Residuals:
    Min       1Q   Median       3Q      Max
-5.3358 -2.1292  0.4919  2.0432  5.0090

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Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) -1.25108    0.59371  -2.107   0.0367 *
URBAN         0.82763    0.03863  21.425  <2e-16 ***
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Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

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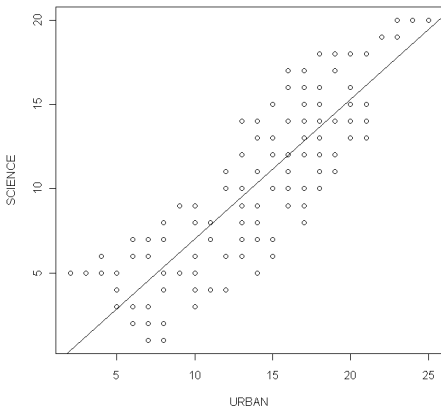
Residual standard error: 2.592 on 158 degrees of freedom
Multiple R-squared:  0.7439,    Adjusted R-squared:  0.7423
F-statistic:  459 on 1 and 158 DF,  p-value: < 2.2e-16

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> plot(SCIENCE~URBAN, example.data)
> abline(lm.model)

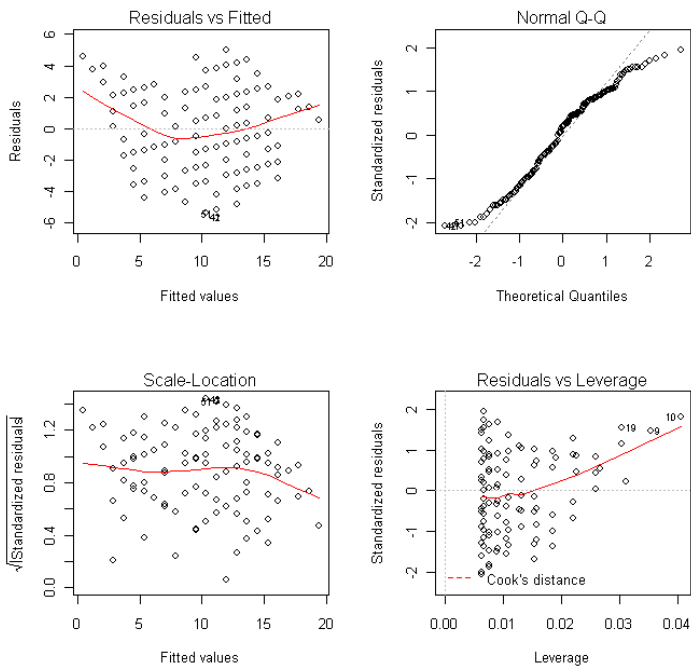
```



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> ## Checks Assumptions
> par(mfrow=c(2,2))
> plot(lm.model)

```



```

> names(lm.model)
[1] "coefficients" "residuals"      "effects"        "rank"
[5] "fitted.values" "assign"          "qr"             "df.residual"
[9] "xlevels"      "call"           "terms"         "model"
> lm.model$coefficients
(Intercept)      URBAN
-1.251078      0.827631

```

```

> ##### Run the Null Multilevel Model
> ## This is also called the multilevel ANOVA
> library(nlme)
> lme.null<-lme(data=example.data, SCIENCE~1, random = ~ 1 | GROUP)
> summary(lme.null)
Linear mixed-effects model fit by REML
Data: example.data
      AIC      BIC    logLik
643.8561 653.0628 -318.9281

```

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Random effects:
Formula: ~1 | GROUP
(Intercept) Residual
StdDev:      5.052846 1.406829

Fixed effects: SCIENCE ~ 1
      Value Std.Error DF t-value p-value
(Intercept) 10.6875  1.268098 144  8.427975  0

```

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Standardized Within-Group Residuals:
      Min          Q1          Med          Q3          Max
-1.463671294 -0.721412585 -0.006493055  0.708426475  1.450685184

```

```

Number of Observations: 160
Number of Groups: 16

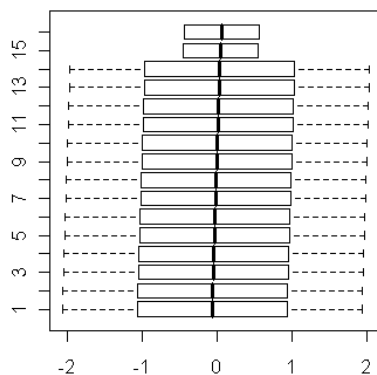
```

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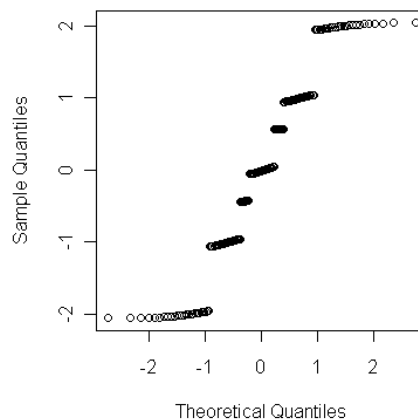
> coef(lme.null)
  (Intercept)
1      3.059135
2      4.051442
3      5.043750
4      6.036058
5      7.028365
6      8.020673
7      9.012981
8     10.005288
9     10.997596
10    11.989904
11    12.982212
12    13.974519
13    14.966827
14    15.959135
15    18.439904
16    19.432212
>
> ## Compare Estimates
> cbind(means=tapply(example.data$SCIENCE, example.data$GROUP, mean), coef(lme.null))
means (Intercept)
1      3.0      3.059135
2      4.0      4.051442
3      5.0      5.043750
4      6.0      6.036058
5      7.0      7.028365
6      8.0      8.020673
7      9.0      9.012981
8     10.0     10.005288
9     11.0     10.997596
10    12.0     11.989904
11    13.0     12.982212
12    14.0     13.974519
13    15.0     14.966827
14    16.0     15.959135
15    18.5     18.439904
16    19.5     19.432212
>
> ## Check assumptions
> par(mfrow=c(1,2))
> boxplot(resid(lme.null)~GROUP, example.data, horizontal=T,
+         main="Homogeneity of Variance")
> qqnorm(resid(lme.null), main="QQplot for Null Model")

```

**Homogeneity of Variance**



**QQplot for Null Model**



```

> ##### Run the Model with Fixed Effect for Slopes
> lme.one<-lme(data=example.data, SCIENCE~URBAN, random = ~ 1 | GROUP)
> summary(lme.one)
Linear mixed-effects model fit by REML
Data: example.data
      AIC      BIC    logLik
508.094 520.3444 -250.047

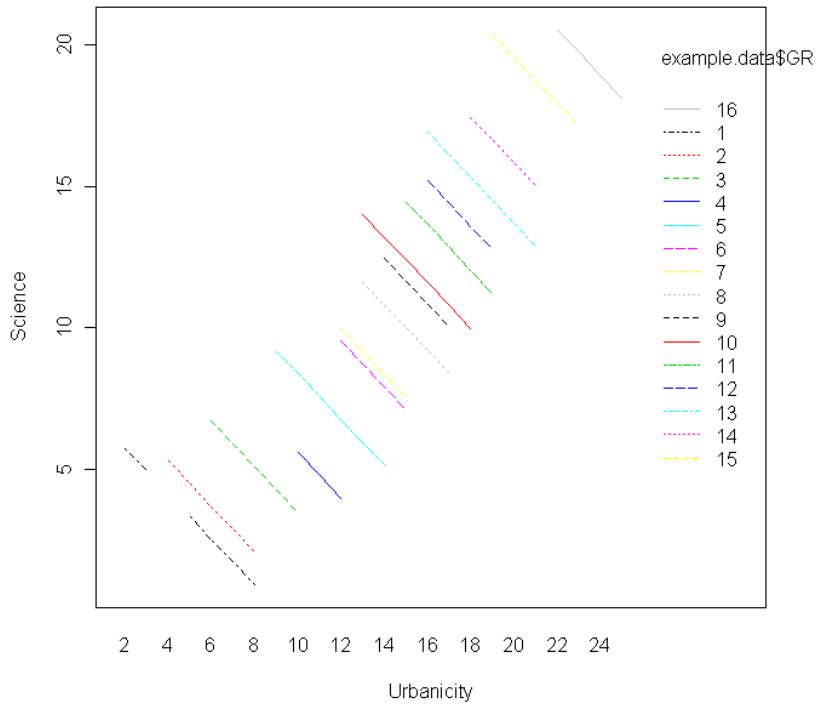
Random effects:
Formula: ~1 | GROUP
(Intercept) Residual
StdDev:      9.29817 0.809449

Fixed effects: SCIENCE ~ URBAN
              Value Std.Error DF   t-value p-value
(Intercept) 22.302911 2.4263101 143   9.192111     0
URBAN        -0.805228 0.0479985 143 -16.776087     0
Correlation:
(Intr)
URBAN -0.285

Standardized Within-Group Residuals:
      Min      Q1      Med      Q3      Max
-2.89322140 -0.68749176  0.01311717  0.63037383  2.32376882

Number of Observations: 160
Number of Groups: 16
> coef(lme.one)
      (Intercept)      URBAN
1      7.359555 -0.8052278
2      8.519721 -0.8052278
3     11.530509 -0.8052278
4     13.656217 -0.8052278
5     16.425619 -0.8052278
6     19.195021 -0.8052278
7     19.631031 -0.8052278
8     22.078586 -0.8052278
9     23.721524 -0.8052278
10    24.479381 -0.8052278
11    26.524627 -0.8052278
12    28.087102 -0.8052278
13    29.810501 -0.8052278
14    31.936209 -0.8052278
15    35.641243 -0.8052278
16    38.249722 -0.8052278
>
> ## Plotting the Fitted Regression Lines for Each Person
> fit1 <- unlist(fitted.values(lme.one))
> interaction.plot(example.data$URBAN, example.data$GROUP, fit1,
+   xlab="Urbanicity", ylab="Science", col=1:16)

```

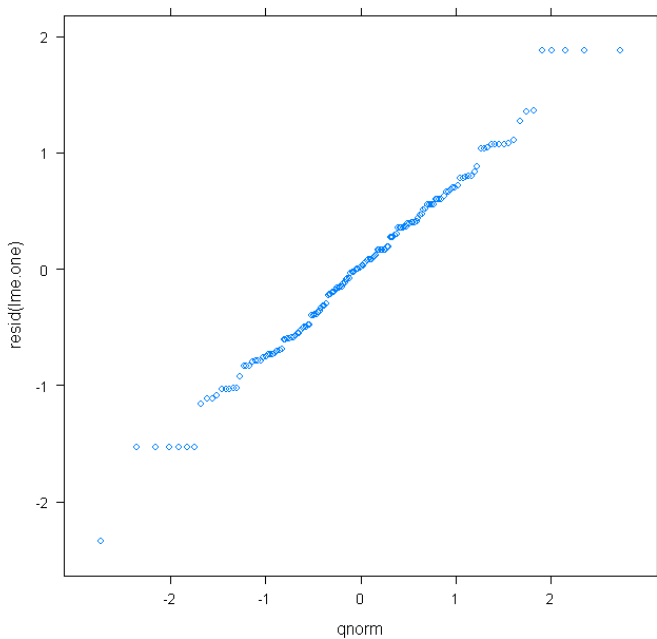


```

> anova(lme.null, lme.one)
      Model df      AIC      BIC    logLik   Test  L.Ratio p-value
lme.null   1   3 643.8561 653.0628 -318.9281
lme.one    2   4 508.0940 520.3444 -250.0470 1 vs 2 137.7621 <.0001
Warning message:
In anova.lme(lme.null, lme.one) :
  Fitted objects with different fixed effects. REML comparisons are not meaningful.
>
> ## Check assumptions
> library(lattice)
> qqmath(resid(lme.one), main="QQplot for First Model")

```

**QQplot for First Model**



```

> ##### Run the Model adding a Random Component to the Slopes
> lme.two<-lme(data=example.data, SCIENCE~URBAN, random = ~ URBAN | GROUP)
> summary(lme.two)
Linear mixed-effects model fit by REML
Data: example.data
      AIC      BIC    logLik
424.1713 442.5469 -206.0857

Random effects:
Formula: ~URBAN | GROUP
Structure: General positive-definite, Log-Cholesky parametrization
      StdDev   Corr
(Intercept) 10.6585056 (Intr)
URBAN        0.5019947 -0.625
Residual     0.5202539

Fixed effects: SCIENCE ~ URBAN
      Value Std.Error DF  t-value p-value
(Intercept) 22.391245 2.7170231 143  8.241095    0
URBAN       -0.867005 0.1298106 143 -6.679002    0
Correlation:
  (Intr)
URBAN -0.641

Standardized Within-Group Residuals:
      Min      Q1      Med      Q3      Max
-2.376493573 -0.791486914  0.007393827  0.622106026  2.169879124

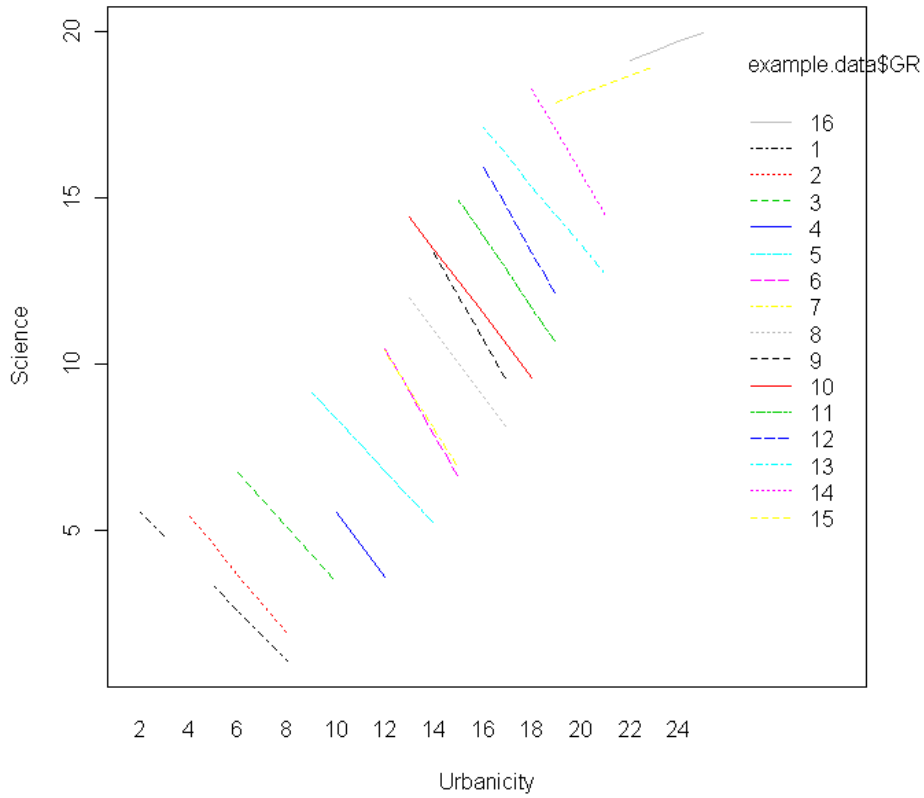
Number of Observations: 160
Number of Groups: 16
> coef(lme.two)
  (Intercept)      URBAN
1      7.038481 -0.7468700
2      8.901292 -0.8742813
3     11.668625 -0.8227973
4     15.130282 -0.9607320
5     16.185686 -0.7849302
6     26.028956 -1.2969889
7     24.550953 -1.1780441
8     24.894022 -0.9929564
9     31.570299 -1.3020020
10    26.967206 -0.9657086
11    30.982600 -1.0705300
12    36.360107 -1.2779107
13    31.267607 -0.8842929
14    41.201528 -1.2730697
15    12.724036  0.2710720
16    12.788245  0.2879618
> cbind(coef(lme.one), coef(lme.two))
  (Intercept)      URBAN (Intercept)      URBAN
1      7.359555 -0.8052278   7.038481 -0.7468700
2      8.519721 -0.8052278   8.901292 -0.8742813
3     11.530509 -0.8052278  11.668625 -0.8227973
4     13.656217 -0.8052278  15.130282 -0.9607320
5     16.425619 -0.8052278  16.185686 -0.7849302
6     19.195021 -0.8052278  26.028956 -1.2969889
7     19.631031 -0.8052278  24.550953 -1.1780441
8     22.078586 -0.8052278  24.894022 -0.9929564
9     23.721524 -0.8052278  31.570299 -1.3020020
10    24.479381 -0.8052278  26.967206 -0.9657086
11    26.524627 -0.8052278  30.982600 -1.0705300
12    28.087102 -0.8052278  36.360107 -1.2779107
13    29.810501 -0.8052278  31.267607 -0.8842929

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14  31.936209 -0.8052278  41.201528 -1.2730697
15  35.641243 -0.8052278  12.724036  0.2710720
16  38.249722 -0.8052278  12.788245  0.2879618
>
> fit2 <- unlist(fitted.values(lme.two))
> interaction.plot(example.data$URBAN, example.data$GROUP, fit2,
+   xlab="Urbanicity", ylab="Science", col=1:16)

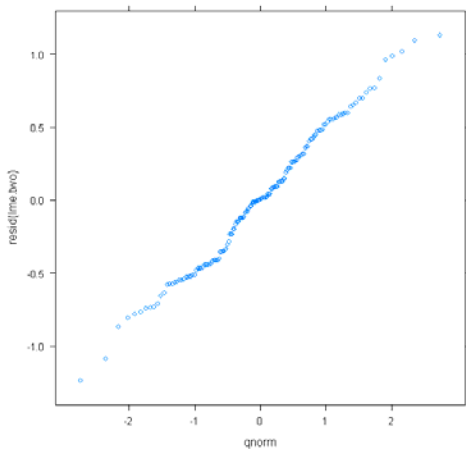
```



```

> anova(lme.one, lme.two)
      Model df      AIC      BIC   logLik   Test  L.Ratio p-value
lme.one    1  4 508.0940 520.3444 -250.0470
lme.two    2  6 424.1713 442.5469 -206.0856 1 vs 2 87.92267 <.0001
>
> ## Check assumptions
> qqmath(resid(lme.two), main="QQplot for Second Model")
      QQplot for Second Model

```



```
> xyplot(resid(lme.two)~fitted(lme.two))
```

