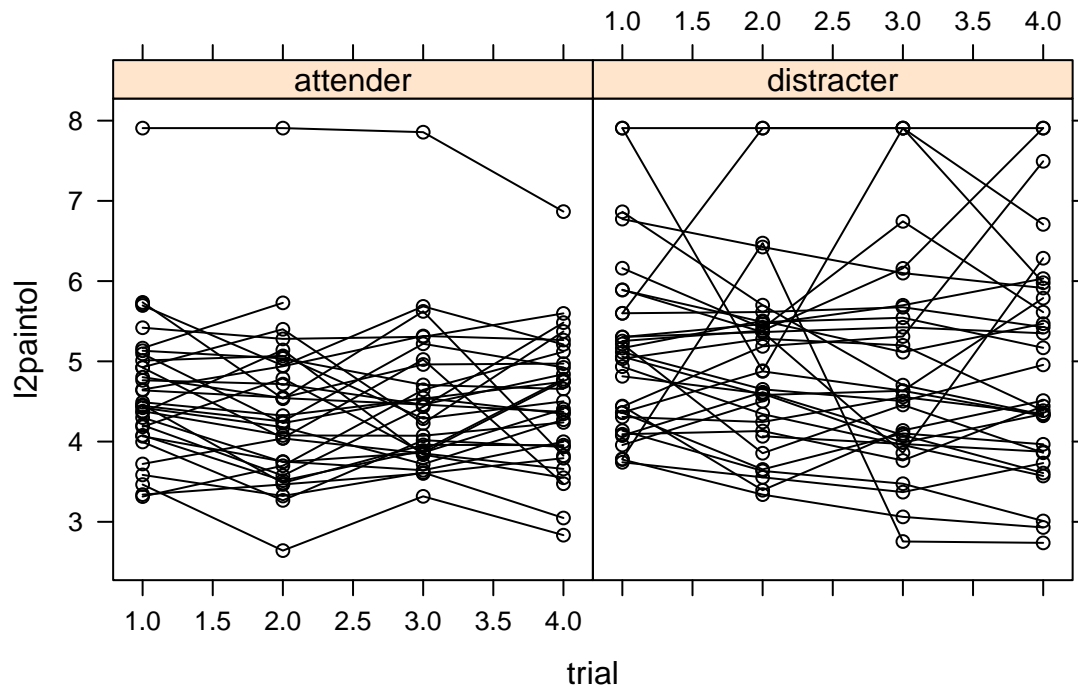```
> pp <- read.delim("http://rem.ph.ucla.edu/rob/mld/data/tabdelimiteddata/pain.txt")
> pp <- subset(pp, !is.na(l2paintol))

> p <- xyplot(l2paintol ~ trial | cs, group = id, data = pp, par.settings = allblack.theme,
+   type = "b")
> plot(p)
```



```
> m1 <- lme(l2paintol ~ cs, random = ~1 | id, data = pp)
> summary(m1)

Linear mixed-effects model fit by REML
 Data: pp
       AIC       BIC     logLik
  598.7033  612.6755  -295.3516


Random effects:
 Formula: ~1 | id
        (Intercept)  Residual
StdDev:   0.9126583 0.5980737

Fixed effects: l2paintol ~ cs
               Value Std.Error  DF   t-value  p-value
(Intercept) 4.535474 0.1706990 181 26.570004   0.0000
csdistracter 0.455178 0.2411448  62  1.887571   0.0638
 Correlation:
            (Intr)
csdistracter -0.708

Standardized Within-Group Residuals:
        Min          Q1         Med          Q3         Max
```

```
-2.71432262 -0.43740240 -0.05526611  0.43449895  4.06992454


Number of Observations: 245
Number of Groups: 64

> fixef(m1)

 (Intercept) csdistracter
   4.5354736    0.4551779

> vcov(m1)

            (Intercept) csdistracter
(Intercept)   0.02913816  -0.02913816
csdistracter -0.02913816   0.05815081

> library(multcomp)
> K1 <- rbind(attender = c(1, 0), distracter = c(1, 1), difference = c(0,
+     1))
> K1

          [,1] [,2]
attender     1    0
distracter   1    1
difference   0    1

> t1 <- glht(m1, linfct = K1)
> (sum.t1 <- summary(t1, test = adjusted(type = "none")))

        Simultaneous Tests for General Linear Hypotheses

Fit: lme.formula(fixed = l2paintol ~ cs, data = pp, random = ~1 |
    id)


Linear Hypotheses:
              Estimate Std. Error z value Pr(>|z|)
attender == 0    4.5355     0.1707  26.570   <2e-16
distracter == 0  4.9907     0.1703  29.300   <2e-16
difference == 0  0.4552     0.2411   1.888   0.0591
(Adjusted p values reported -- none method)

> (ci.t1 <- confint(t1, calpha = qnorm(1 - 0.05/2)))

        Simultaneous Confidence Intervals

Fit: lme.formula(fixed = l2paintol ~ cs, data = pp, random = ~1 |
    id)


Quantile = 1.96
95% confidence level


Linear Hypotheses:
              Estimate lwr       upr
attender == 0    4.53547  4.20091  4.87004
distracter == 0  4.99065  4.65681  5.32449
difference == 0  0.45518 -0.01746  0.92781
```

```
> table.t1 <- with(sum.t1$test, data.frame(coefficients, sigma,
+     tstat, pvalues))
> table.t1 <- cbind(table.t1, ci.t1$confint[, 2:3])
> print(table.t1, digits = 2)

          coefficients sigma tstat pvalues    lwr  upr
attender          4.54  0.17  26.6   0.000  4.201 4.87
distracter        4.99  0.17  29.3   0.000  4.657 5.32
difference        0.46  0.24   1.9   0.059 -0.017 0.93

> print(2^table.t1[, c("coefficients", "lwr", "upr")], digits = 2)

          coefficients   lwr  upr
attender          23.2 18.39 29.2
distracter        31.8 25.23 40.1
difference         1.4  0.99  1.9
```

additive treatment effect

```
> pp$trt <- as.character(pp$treatment)
> pp$trt[pp$trial < 4] <- "baseline"
> pp$trt <- factor(pp$trt, levels = c("baseline", "attend", "distract",
+     "no directions"))

> m2 <- lme(l2paintol ~ cs + trt, random = ~1 | id, data = pp)
> summary(m2)

Linear mixed-effects model fit by REML
 Data: pp
       AIC      BIC    logLik
  601.4867 625.8512 -293.7433

Random effects:
 Formula: ~1 | id
        (Intercept) Residual
StdDev:    0.902751 0.590359

Fixed effects: l2paintol ~ cs + trt
                     Value Std.Error  DF   t-value p-value
(Intercept)       4.543575 0.1701072 178 26.710068  0.0000
csdistracter      0.454465 0.2384804  62  1.905671  0.0613
trtattend        -0.121734 0.1507937 178 -0.807289  0.4206
trtdistract       0.320344 0.1471982 178  2.176275  0.0309
trtno directions -0.292247 0.1524969 178 -1.916410  0.0569
 Correlation:
                 (Intr) csdstr trtttn trtdst
csdistracter     -0.702
trtattend        -0.072  0.000
trtdistract      -0.070 -0.005  0.010
trtno directions -0.074 -0.004  0.011  0.011

Standardized Within-Group Residuals:
        Min          Q1         Med          Q3         Max
-2.62947623 -0.43718802 -0.04995017  0.45249894  4.01074113
```

```
Number of Observations: 245
Number of Groups: 64

> anova(m1, m2)

   Model df      AIC      BIC    logLik   Test  L.Ratio p-value
m1     1  4 598.7033 612.6755 -295.3516
m2     2  7 601.4867 625.8512 -293.7434 1 vs 2 3.216586  0.3594

> m1ML <- update(m1, method = "ML")
> m2ML <- update(m2, method = "ML")
> anova(m1ML, m2ML)

     Model df      AIC      BIC    logLik   Test  L.Ratio p-value
m1ML     1  4 595.2714 609.2764 -293.6357
m2ML     2  7 592.1204 616.6292 -289.0602 1 vs 2 9.150968  0.0273

> K2 <- rbind(`TMT D-A` = c(0, 0, -1, 1, 0), `TMT D-N` = c(0, 0,
+     0, 1, -1), `TMT A-N` = c(0, 0, 1, 0, -1), AB = c(1, 0, 0,
+     0, 0), DB = c(1, 1, 0, 0, 0), AA = c(1, 0, 1, 0, 0), AD = c(1,
+     0, 0, 1, 0), AN = c(1, 0, 0, 0, 1), DA = c(1, 1, 1, 0, 0),
+     DD = c(1, 1, 0, 1, 0), DN = c(1, 1, 0, 0, 1))
> t2 <- glht(m2, linfct = K2)
> sum.t2 <- summary(t2, test = adjusted(type = "none"))
> ci.t2 <- confint(t2, calpha = qnorm(1 - 0.05/2))
> table.t2 <- with(sum.t2$test, data.frame(coefficients, sigma,
+     tstat, pvalues))
> table.t2 <- cbind(table.t2, 2^ci.t2$confint)
> names(table.t2) <- c("est", "se", "t", "p", "in seconds: est",
+     "lwr", "upr")
> print(table.t2, digits = 3)

            est    se     t       p in seconds: est    lwr    upr
TMT D-A  0.442 0.210  2.11 0.03497            1.36  1.022   1.81
TMT D-N  0.613 0.211  2.91 0.00366            1.53  1.148   2.04
TMT A-N  0.171 0.213  0.80 0.42405            1.13  0.842   1.50
AB       4.544 0.170 26.71 0.00000           23.32 18.509  29.38
DB       4.998 0.170 29.42 0.00000           31.96 25.370  40.25
AA       4.422 0.219 20.18 0.00000           21.43 15.916  28.87
AD       4.864 0.217 22.41 0.00000           29.12 21.684  39.11
AN       4.251 0.220 19.34 0.00000           19.04 14.128  25.67
DA       4.876 0.219 22.27 0.00000           29.37 21.813  39.55
DD       5.318 0.216 24.61 0.00000           39.90 29.750  53.52
DN       4.706 0.219 21.49 0.00000           26.10 19.380  35.14
```

Interaction

```
> m3 <- lme(l2paintol ~ cs * trt, random = ~1 | id, data = pp)
> summary(m3)

Linear mixed-effects model fit by REML
 Data: pp
      AIC      BIC    logLik
  601.9478 636.6284 -290.9739
```

```
Random effects:
 Formula: ~1 | id
        (Intercept) Residual
StdDev:   0.8909409 0.5858537

Fixed effects: l2paintol ~ cs * trt
                                   Value Std.Error  DF   t-value p-value
(Intercept)                     4.532592 0.1693017 175 26.772276  0.0000
csdistracter                    0.478031 0.2393500  62  1.997206  0.0502
trtattend                       0.108192 0.2116055 175  0.511289  0.6098
trtdistract                     0.038954 0.2116055 175  0.184088  0.8542
trtno directions               -0.108203 0.2125829 175 -0.508990  0.6114
csdistracter:trtattend         -0.459945 0.2992544 175 -1.536971  0.1261
csdistracter:trtdistract        0.537127 0.2924447 175  1.836679  0.0680
csdistracter:trtno directions  -0.373634 0.3026533 175 -1.234529  0.2187
 Correlation:
                               (Intr) csdstr trtttn trtdst trtndr csdstrctr:trtt
csdistracter                   -0.707
trtattend                      -0.101  0.071
trtdistract                    -0.101  0.071  0.010
trtno directions               -0.104  0.074  0.010  0.010
csdistracter:trtattend          0.071 -0.101 -0.707 -0.007 -0.007
csdistracter:trtdistract        0.073 -0.103 -0.007 -0.724 -0.008  0.010
csdistracter:trtno directions   0.073 -0.109 -0.007 -0.007 -0.702  0.011
                               csdstrctr:trtd
csdistracter
trtattend
trtdistract
trtno directions
csdistracter:trtattend
csdistracter:trtdistract
csdistracter:trtno directions   0.011

Standardized Within-Group Residuals:
        Min          Q1         Med          Q3         Max
-2.55068593 -0.44842862 -0.04568367  0.45001553  3.96485063

Number of Observations: 245
Number of Groups: 64

> anova(m2, m3)

    Model df      AIC      BIC     logLik   Test  L.Ratio p-value
m2      1  7 601.4867 625.8512 -293.7434
m3      2 10 601.9478 636.6284 -290.9739 1 vs 2 5.538849  0.1363

> m3ML <- update(m3, method = "ML")
> anova(m2ML, m3ML)

      Model df      AIC      BIC     logLik   Test  L.Ratio p-value
m2ML      1  7 592.1204 616.6292 -289.0602
m3ML      2 10 590.6603 625.6728 -285.3301 1 vs 2 7.460178  0.0586

> K3 <- rbind(AB = c(1, 0, 0, 0, 0, 0, 0, 0), DB = c(1, 1, 0, 0,
+     0, 0, 0, 0), AA = c(1, 0, 1, 0, 0, 0, 0, 0), AD = c(1, 0,
```
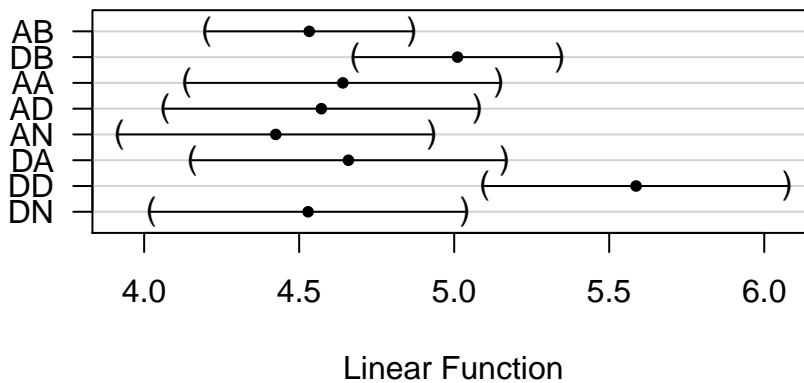
```
+      0, 1, 0, 0, 0, 0), AN = c(1, 0, 0, 0, 1, 0, 0, 0), DA = c(1,
+      1, 1, 0, 0, 1, 0, 0), DD = c(1, 1, 0, 1, 0, 0, 1, 0), DN = c(1,
+      1, 0, 0, 1, 0, 0, 1))
> t3 <- glht(m3, linfct = K3)
> sum.t3 <- summary(t3, test = adjusted(type = "none"))
> ci.t3 <- confint(t3, calpha = qnorm(1 - 0.05/2))
> table.t3 <- with(sum.t3$test, data.frame(coefficients, sigma,
+      tstat, pvalues))
> table.t3 <- cbind(table.t3, 2^ci.t3$confint)
> names(table.t3) <- c("est", "se", "t", "p", "in seconds: est",
+      "lwr", "upr")
> print(table.t3, digits = 3)

     est   se    t p in seconds: est  lwr  upr
AB 4.53 0.169 26.8 0             23.1 18.4 29.1
DB 5.01 0.169 29.6 0             32.2 25.6 40.6
AA 4.64 0.257 18.0 0             24.9 17.6 35.4
AD 4.57 0.257 17.8 0             23.8 16.8 33.7
AN 4.42 0.258 17.2 0             21.5 15.1 30.5
DA 4.66 0.257 18.1 0             25.3 17.8 35.8
DD 5.59 0.249 22.4 0             48.1 34.3 67.4
DN 4.53 0.258 17.5 0             23.1 16.3 32.8

> plot(confint(t3, calpha = qnorm(1 - 0.05/2)))
```

95% confidence level


```
> confint(t3, calpha = qnorm(1 - 0.05/2))

        Simultaneous Confidence Intervals

Fit: lme.formula(fixed = l2paintol ~ cs * trt, data = pp, random = ~1 |
    id)

Quantile = 1.96
95% confidence level
```

```
Linear Hypotheses:
        Estimate lwr    upr
AB == 0 4.5326   4.2008 4.8644
DB == 0 5.0106   4.6790 5.3422
AA == 0 4.6408   4.1364 5.1451
AD == 0 4.5715   4.0672 5.0759
AN == 0 4.4244   3.9195 4.9293
DA == 0 4.6589   4.1546 5.1631
DD == 0 5.5867   5.0980 6.0754
DN == 0 4.5288   4.0224 5.0352


> confint(t3)


        Simultaneous Confidence Intervals

Fit: lme.formula(fixed = l2paintol ~ cs * trt, data = pp, random = ~1 |
    id)


Quantile = 2.6932
95% family-wise confidence level



Linear Hypotheses:
        Estimate lwr    upr
AB == 0 4.5326   4.0766 4.9886
DB == 0 5.0106   4.5550 5.4663
AA == 0 4.6408   3.9477 5.3338
AD == 0 4.5715   3.8785 5.2646
AN == 0 4.4244   3.7306 5.1182
DA == 0 4.6589   3.9660 5.3518
DD == 0 5.5867   4.9152 6.2582
DN == 0 4.5288   3.8330 5.2246
```