

Tests with NONMEM

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```
Sys.setenv(RSTUDIO_PANDOC = "/usr/lib/rstudio-server/bin/pandoc")
```

```
.libPaths("/data/Rlibs")  
library(mrgsolve)  
library(dplyr)  
library(readr)  
library(ggplot2)
```

```
carry <- c("cmt", "amt", "ii", "addl", "rate", "evid", "ss")
```

1 Functions

1.1 Save mrgsim output as a nonmem input data set

```
to_data_set <- function(x, id = NULL) {  
  x <- as.data.frame(x)  
  x <- mutate(x, C = '.', DV = '.', cmt = if_else(cmt==0, 2, cmt))  
  x <- dplyr::select(x, "C", everything())  
  if(is.numeric(id)) x <- mutate(x, ID = id)  
  x  
}
```

1.2 Save the nonmem input data set

```
sv <- function(x, file) {  
  write.csv(file = file, row.names = FALSE, quote = FALSE, x)  
}
```

1.3 Run nonmem

```
run <- function(number) {  
  metrumrg::NONR(number, project = "model",  
                  command = "/opt/NONMEM/nm73/nmqual/autolog.pl",  
                  checkrunno=FALSE)  
  return(tabread(number))  
}
```

1.4 Read in nonmem simulation results

```
tabread <- function(number) {  
  tab <- file.path("model", number, "TAB")  
  if(file.exists(tab)) return(read_table(tab, skip=1))  
  stop("the run failed")  
}
```

1.5 Simulate a scenario with `mrsim`

```
sim <- function(x, e,...) {  
  mrgsim(x, events = e, carry.out = carry, digits = 5, ...)  
}
```

2 The mrgsim model

```
code <- '
$SET req = ""
$PARAM CL = 1.1, V = 20, KA = 1.5
LAGT = 0, MODE = 0, DUR2 = 2, RAT2 = 10, BIOAV = 1

$PKMODEL cmt = "GUT CENT", depot = TRUE

$MAIN

F_CENT = BIOAV;
ALAG_CENT = LAGT;

if(MODE==1) R_CENT = RAT2;
if(MODE==2) D_CENT = DUR2;

$TABLE
capture DV = (CENT/(V/1000));
capture CP = DV;

$CAPTURE LAGT MODE DUR2 RAT2 BIOAV
'

mod <- mcode_cache("tests1", code)
```

```
. Compiling tests1 ... done.
```

```
mod <- update(mod, end=130, delta = 1)
```

3 Scenarios

3.0.1 Bolus doses, with additional

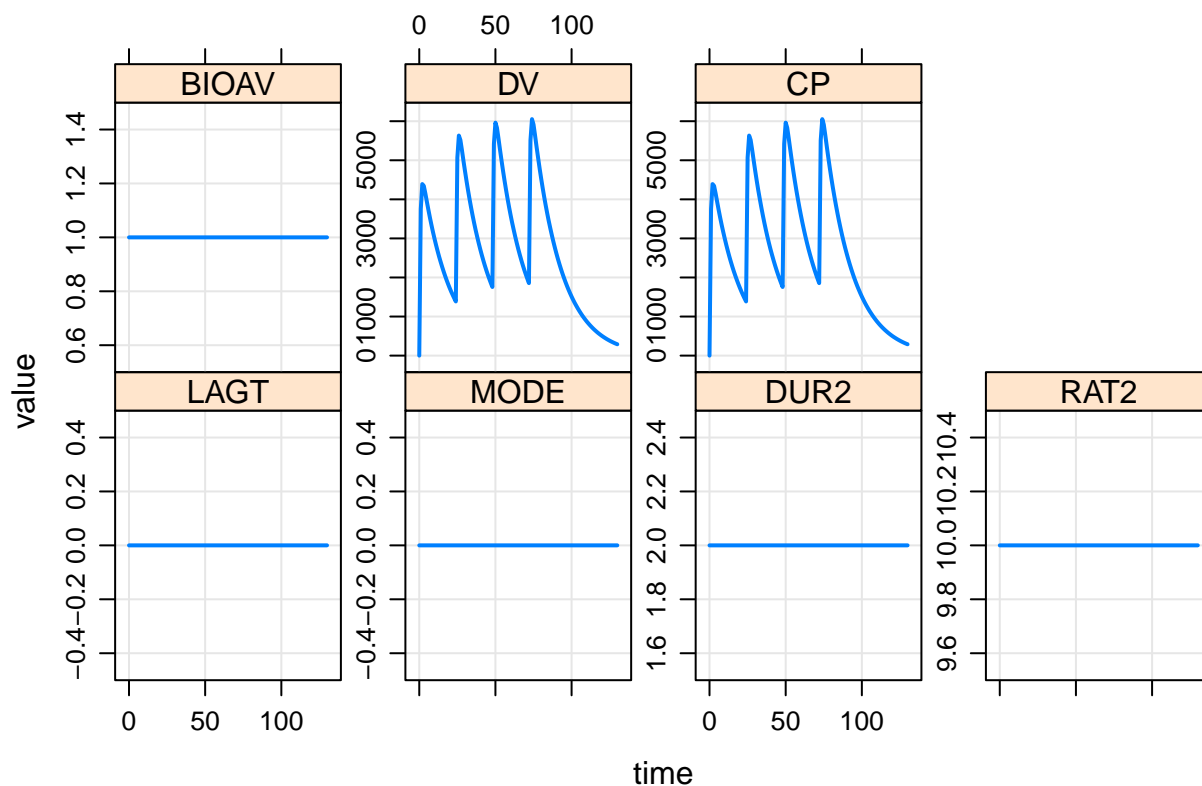
```
ev <- ev(amt = 100, ii = 24, addl = 3)
ev
```

```
. Events:
.   time cmt amt evid ii addl
. 1     0   1 100    1 24    3
```

```
out1 <- sim(mod, ev)
```

```
. 1
. 0
. 0
. 1 24 -600
. 1 48 -600
. 1 72 -600
. 1
. 24
. -600
. 1
. 48
. -600
. 1
. 72
. -600
```

```
plot(out1)
```



```
data1 <- to_data_set(out1, 1)
```

3.0.2 Bolus doses, lag time and bioav factor

```
ev <- ev(amt = 100, ii = 24, addl = 3, LAGT = 12.13, BIOAV = 2.23, cmt = 2)
ev
```

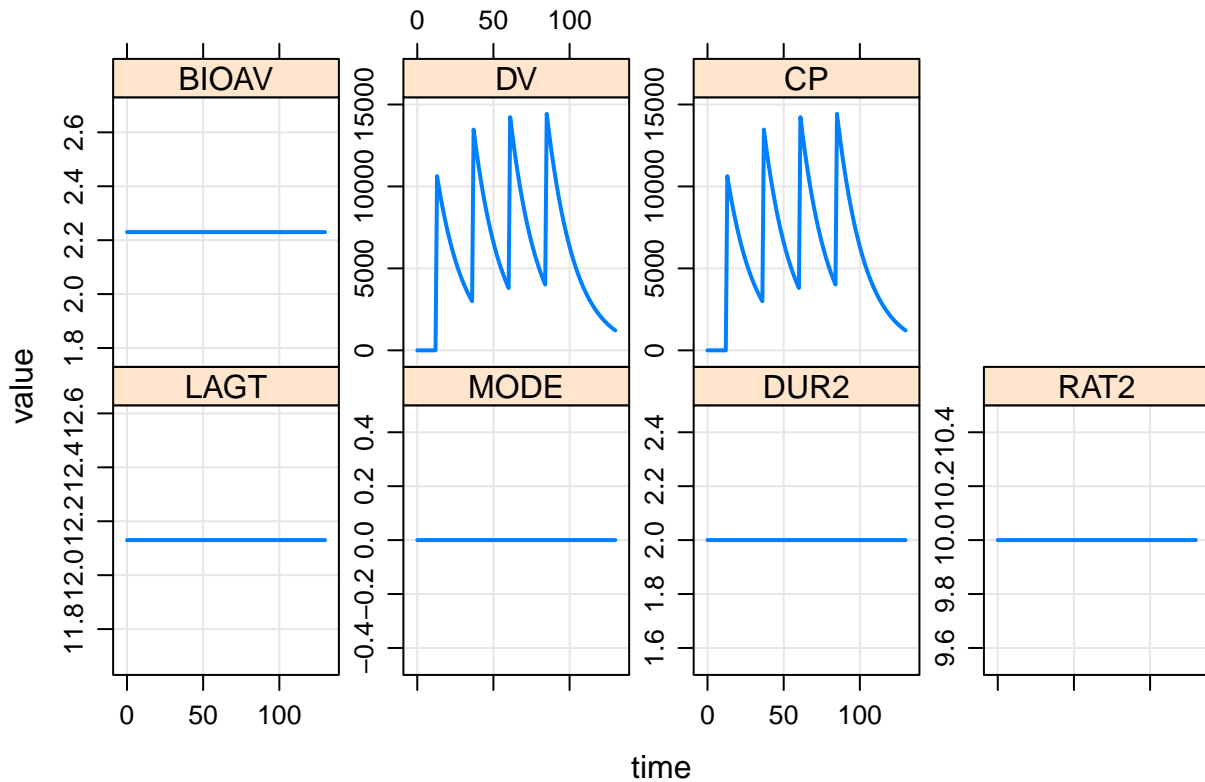
```
. Events:
.   time cmt amt evid ii addl  LAGT BIOAV
. 1     0   2 100    1 24    3 12.13 2.23
```

```
out1.1 <- sim(mod, ev)
```

```
. 2
. 0
. 0
. 2 36.13 -600
. 2 60.13 -600
. 2 84.13 -600
. 2
. 12.13
. -1200
. 2
. 36.13
. -600
. 2
. 60.13
. -600
```

```
. 2
. 84.13
. -600
```

```
plot(out1.1)
```



```
data1.1 <- to_data_set(out1.1, 1.1)
```

3.0.3 Infusion doses, with additional

```
ev <- ev(amt = 100, ii = 24, addl = 3, rate = 100/10, cmt = 2)
ev
```

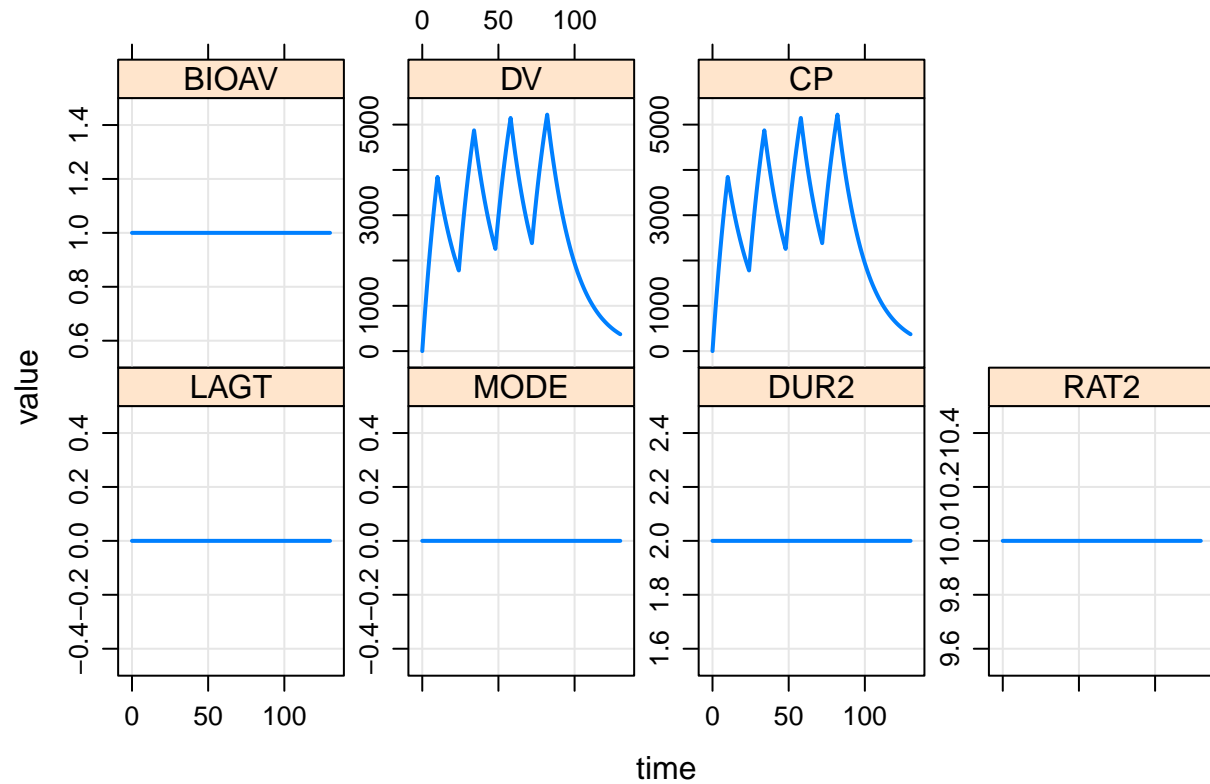
```
. Events:
.   time cmt amt evid ii addl rate
. 1     0   2 100    1 24    3   10
```

```
out2 <- sim(mod, ev)
```

```
. 2
. 0
. 0
. 2 24 -600
. 2 48 -600
. 2 72 -600
. 2
. 24
. -600
. 2
```

```
. 48
. -600
. 2
. 72
. -600
```

```
plot(out2)
```



```
data2 <- to_data_set(out2, 2)
```

3.0.4 Infusion doses to depot, with additional

```
ev <- ev(amt = 100, ii = 24, addl = 3, rate = 100/12, cmt = 1)
ev
```

```
. Events:
.   time cmt amt evid ii addl   rate
. 1     0   1 100   1 24    3 8.333333
```

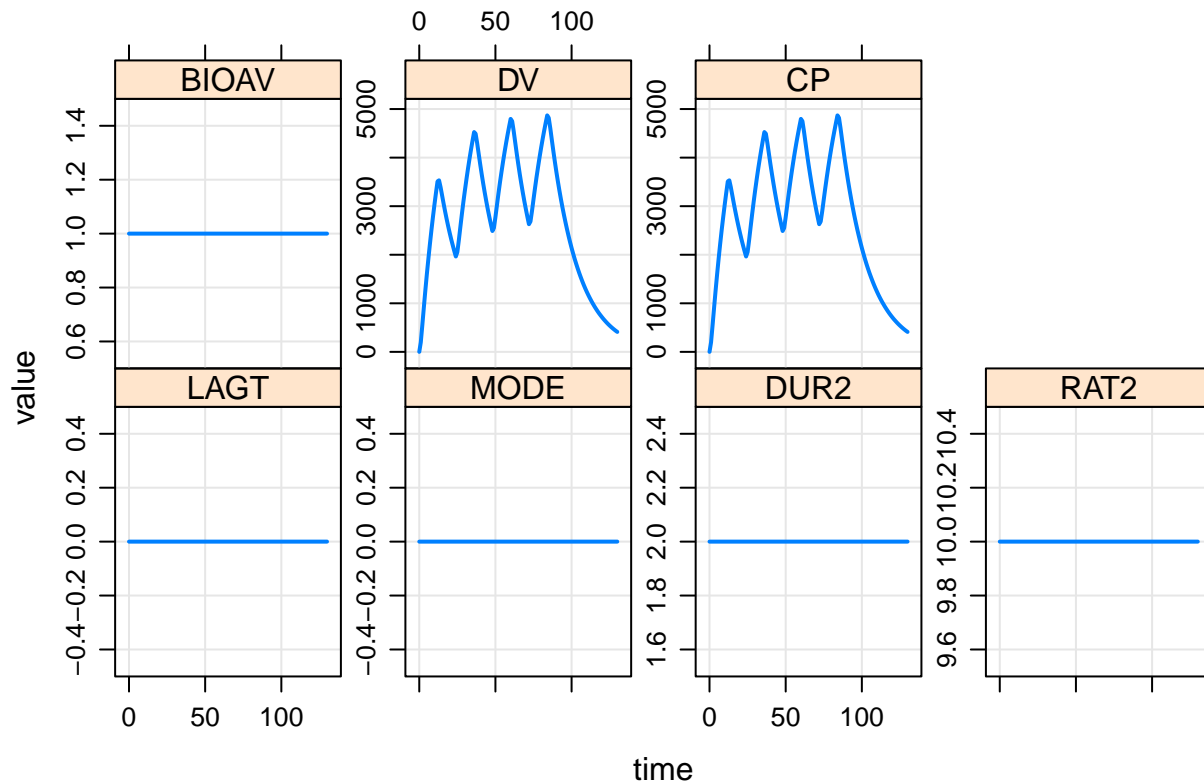
```
out2.1 <- sim(mod, ev)
```

```
. 1
. 0
. 0
. 1 24 -600
. 1 48 -600
. 1 72 -600
. 1
. 24
```



```
. -600
. 1
. 48
. -600
. 1
. 72
. -600
```

```
plot(out2.1)
```



```
data2.1 <- to_data_set(out2.1, 2.1)
```

3.0.5 Infusion doses, with additional and lag time

```
ev <- ev(amt = 100, ii = 24, addl=3, rate = 100/10, LAGT = 4.15, cmt = 2)
ev
```

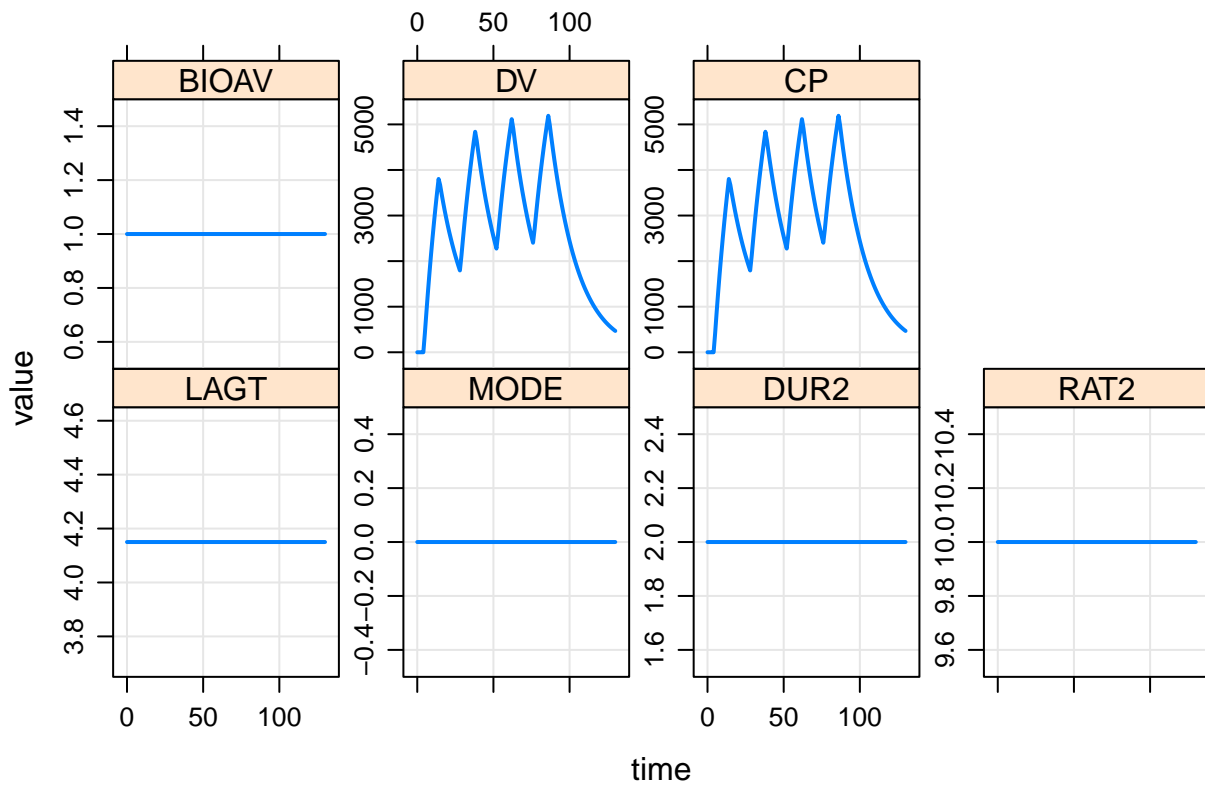
```
. Events:
.   time cmt amt evid ii addl rate LAGT
. 1     0   2 100    1 24    3   10 4.15
```

```
out3 <- sim(mod, ev)
```

```
. 2
. 0
. 0
. 2 28.15 -600
. 2 52.15 -600
. 2 76.15 -600
```

```
. 2
. 4.15
. -1200
. 2
. 28.15
. -600
. 2
. 52.15
. -600
. 2
. 76.15
. -600
```

```
plot(out3)
```



```
data3 <- to_data_set(out3, 3)
```

3.0.6 Infusion doses, with lag time and bioav factor

```
ev <- ev(amt = 100, ii = 24, addl = 3, rate = 100/10, LAGT = 3.25, BIOAV = 0.412, cmt = 2)
ev
```

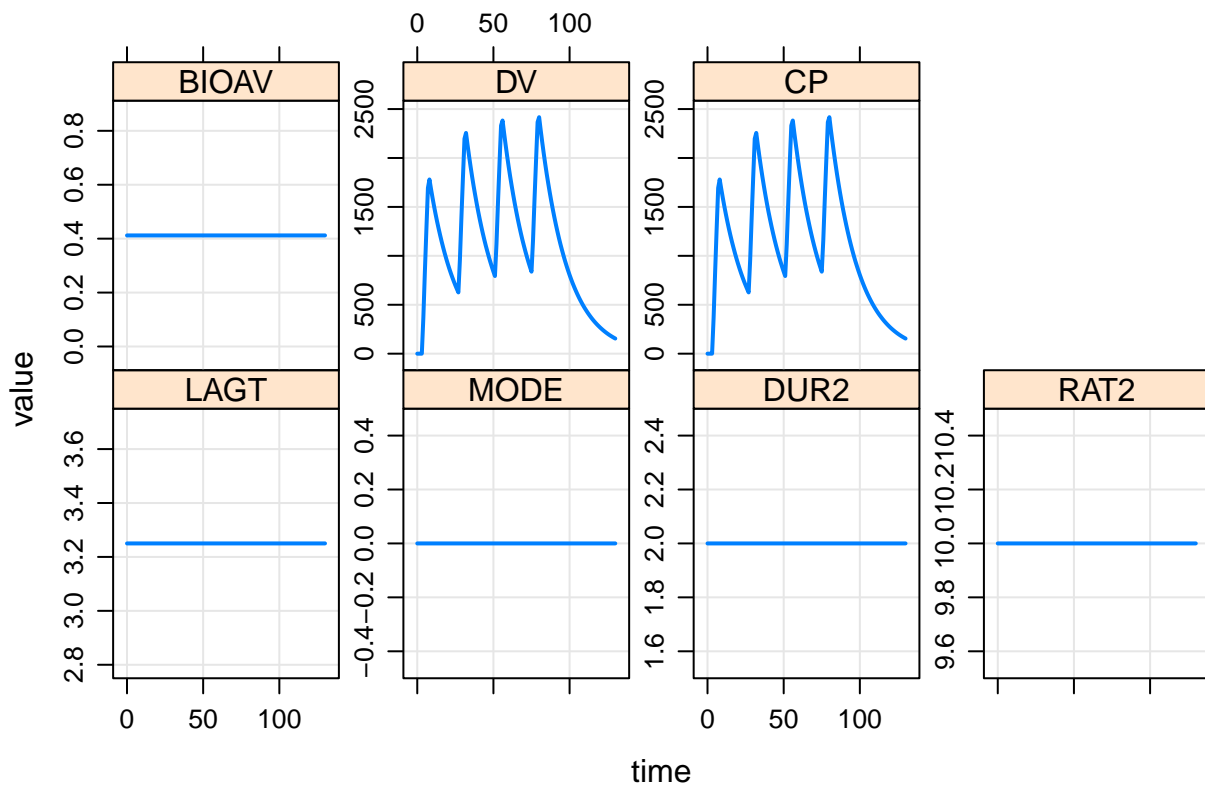
```
. Events:
.   time cmt amt evid ii addl rate LAGT BIOAV
. 1     0   2 100    1  24    3   10 3.25 0.412
```

```
out4 <- sim(mod, ev)
```

```
. 2
```

```
. 0
. 0
. 2 27.25 -600
. 2 51.25 -600
. 2 75.25 -600
. 2
. 3.25
. -1200
. 2
. 27.25
. -600
. 2
. 51.25
. -600
. 2
. 75.25
. -600
```

```
plot(out4)
```



```
data4 <- to_data_set(out4, 4)
```

3.0.7 Infusion doses at steady-state, with lag time and bioav factor

```
ev <- ev(amt = 100, ii = 24, addl = 3, rate = 100/10, LAGT = 3.16, BIOAV = 0.412, ss = 1, cmt = 2)
ev
```

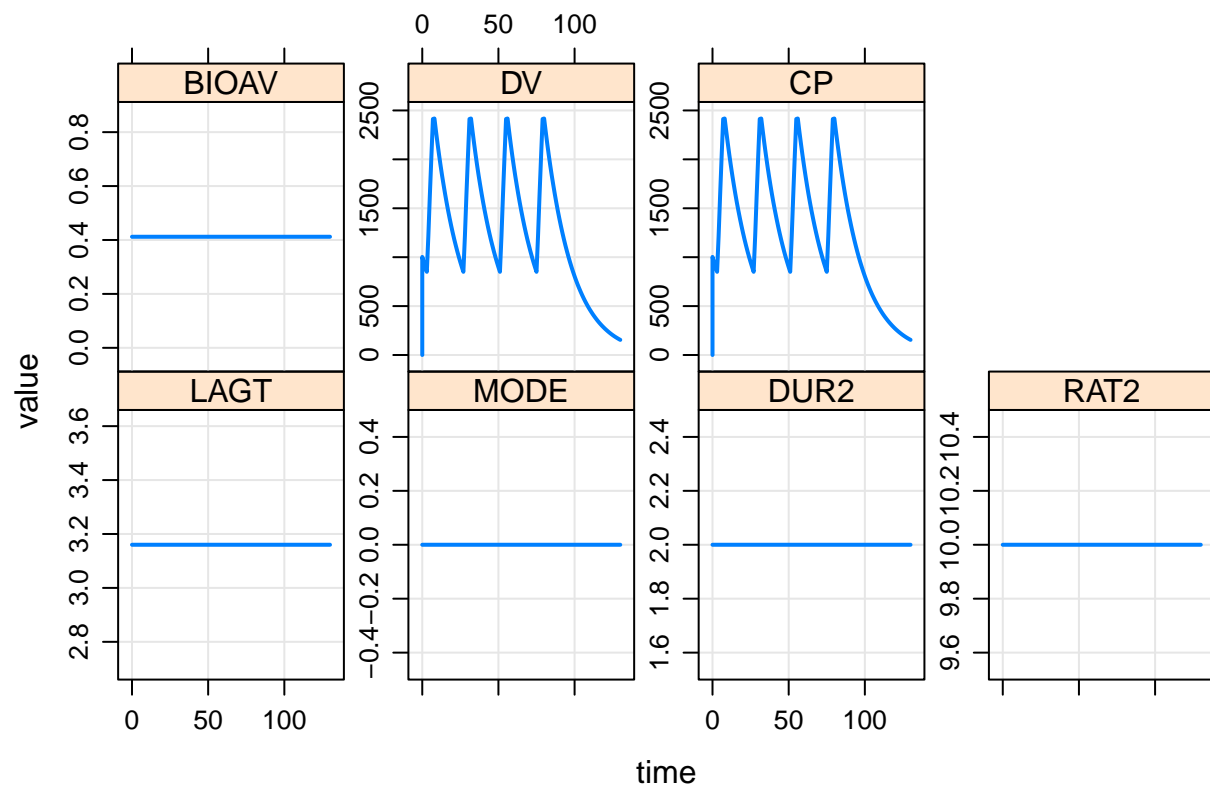
```
. Events:
```

```
.   time cmt amt evid ii addl rate LAGT BIOAV ss
. 1     0   2 100    1 24    3   10 3.16 0.412 1
```

```
out5 <- sim(mod,ev)
```

```
. 2
. 0
. 0
. 2 27.16 -600
. 2 51.16 -600
. 2 75.16 -600
. 2
. 3.16
. -1200
. 2
. 27.16
. -600
. 2
. 51.16
. -600
. 2
. 75.16
. -600
```

```
plot(out5)
```



```
data5 <- to_data_set(out5, 5)
```

3.0.8 Infusion doses at steady state, $II < DUR$, with bioav factor

```
ev <- ev(amt = 100, ii = 6, addl = 12, rate = 100/10, BIOAV = 0.812, ss = 1, cmt = 2)
ev
```

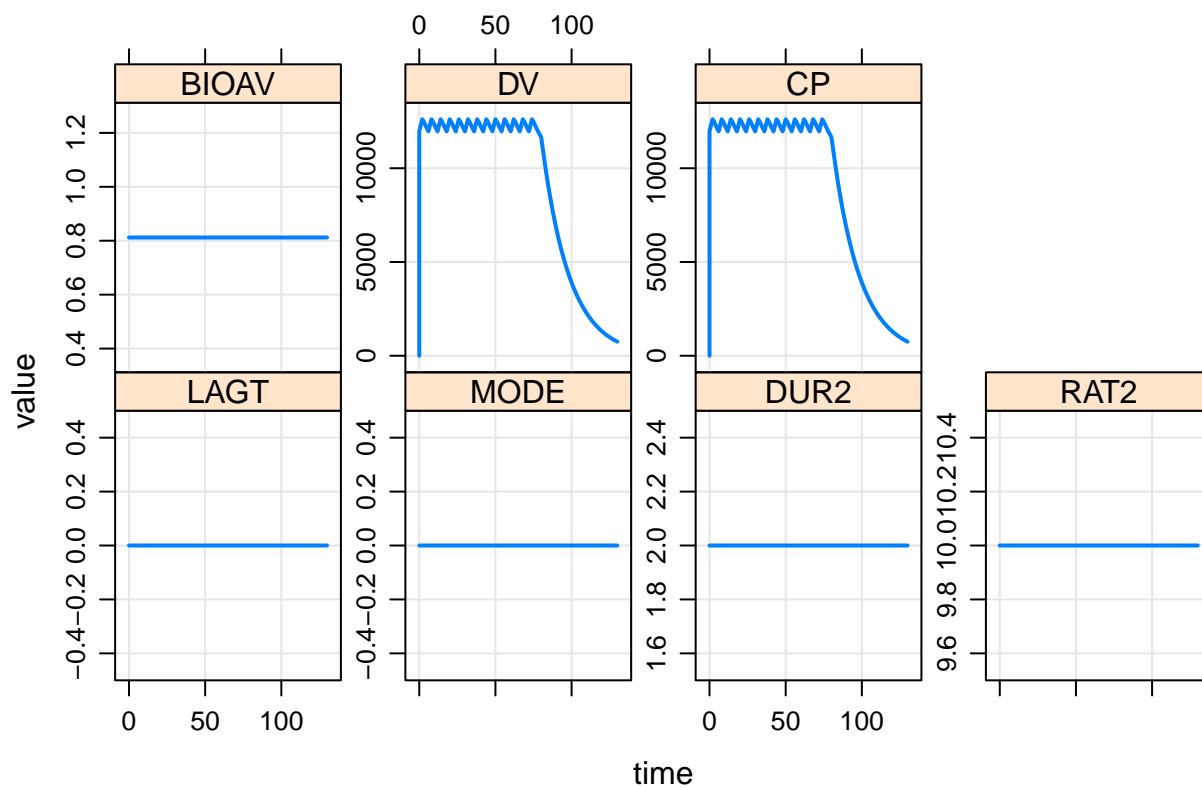
```
. Events:
.   time cmt amt evid ii addl rate BIOAV ss
. 1     0  2 100    1  6   12   10 0.812  1
```

```
out6 <- sim(mod, ev)
```

```
. 2
. 0
. 0
. 2 6 -600
. 2 12 -600
. 2 18 -600
. 2 24 -600
. 2 30 -600
. 2 36 -600
. 2 42 -600
. 2 48 -600
. 2 54 -600
. 2 60 -600
. 2 66 -600
. 2 72 -600
. 2
. 6
. -600
. 2
. 12
. -600
. 2
. 18
. -600
. 2
. 24
. -600
. 2
. 30
. -600
. 2
. 36
. -600
. 2
. 42
. -600
. 2
. 48
. -600
. 2
. 54
. -600
. 2
```

```
. 60
. -600
. 2
. 66
. -600
. 2
. 72
. -600
```

```
plot(out6)
```



```
data6 <- to_data_set(out6, 6)
```

3.0.9 Infusion doses at steady state, $II < DUR$, no bioav factor

```
ev <- ev(amt = 100, ii = 6, addl = 12, rate = 100/10, ss = 1, cmt = 2)
ev
```

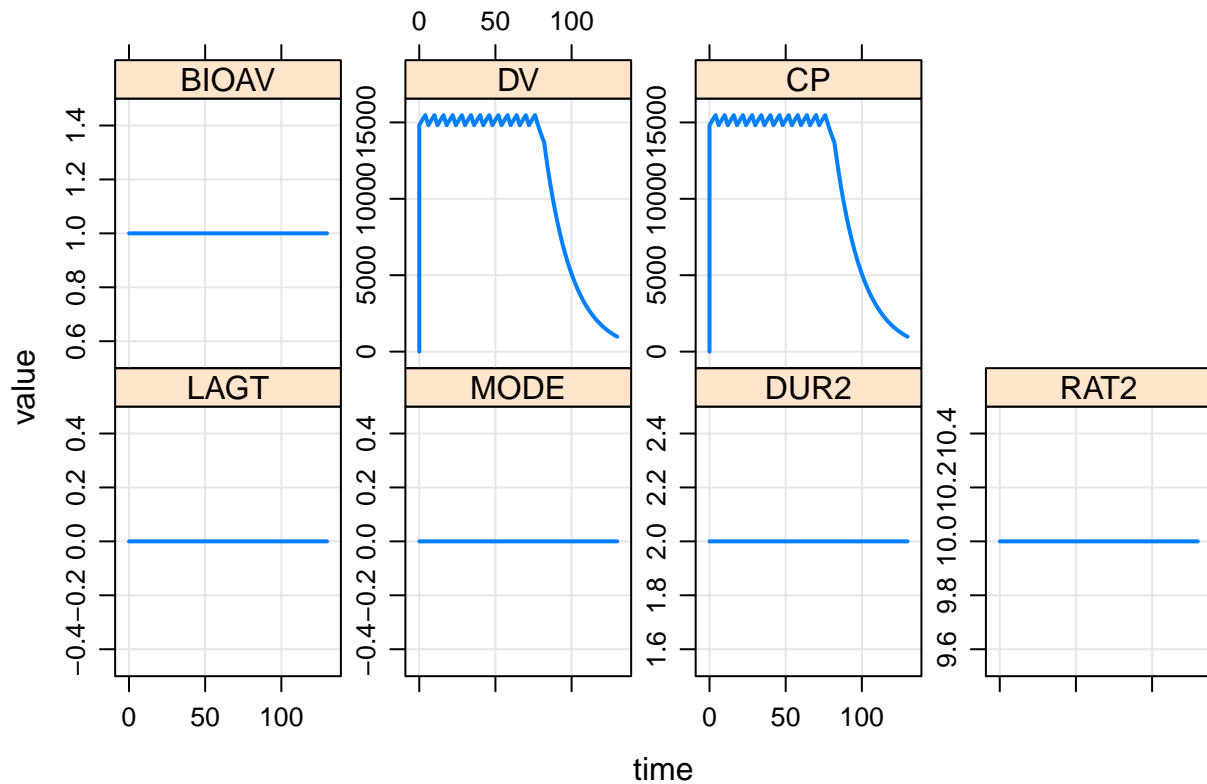
```
. Events:
.   time cmt amt evid ii addl rate ss
. 1     0   2 100    1   6   12  10  1
```

```
out6.1 <- sim(mod, ev)
```

```
. 2
. 0
. 0
. 2 6 -600
. 2 12 -600
```

```
. 2 18 -600
. 2 24 -600
. 2 30 -600
. 2 36 -600
. 2 42 -600
. 2 48 -600
. 2 54 -600
. 2 60 -600
. 2 66 -600
. 2 72 -600
. 2
. 6
. -600
. 2
. 12
. -600
. 2
. 18
. -600
. 2
. 24
. -600
. 2
. 30
. -600
. 2
. 36
. -600
. 2
. 42
. -600
. 2
. 48
. -600
. 2
. 54
. -600
. 2
. 60
. -600
. 2
. 66
. -600
. 2
. 72
. -600
```

```
plot(out6.1)
```



```
data6.1 <- to_data_set(out6.1, 6.1)
```

3.0.10 Infusion doses at steady state where II is a multiple of DUR

```
ev <- ev(amt = 100, ii = 6, addl = 12, rate = signif(100/12,5), ss = 1, cmt = 2)
ev
```

```
. Events:
.   time cmt amt evid ii addl  rate ss
. 1    0   2 100    1   6   12 8.3333 1
```

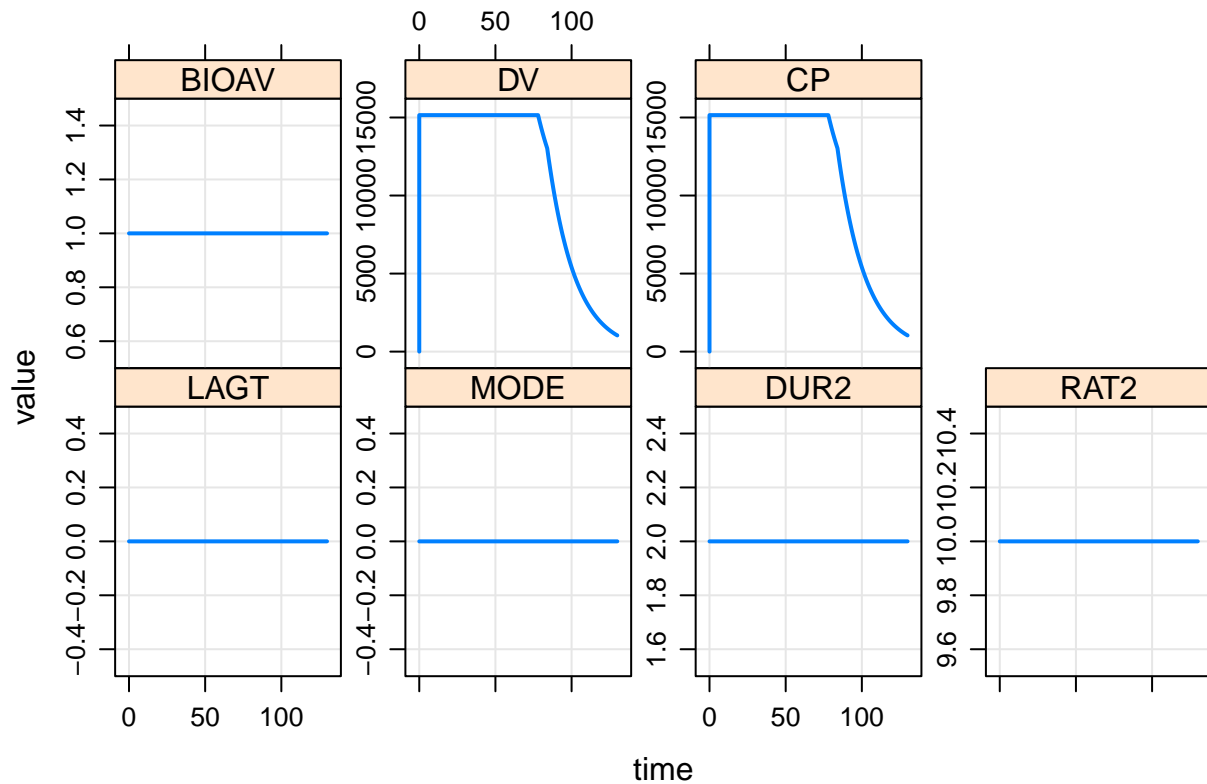
```
out6.2 <- sim(mod, ev)
```

```
. 2
. 0
. 0
. 2 6 -600
. 2 12 -600
. 2 18 -600
. 2 24 -600
. 2 30 -600
. 2 36 -600
. 2 42 -600
. 2 48 -600
. 2 54 -600
. 2 60 -600
. 2 66 -600
. 2 72 -600
```



```
. 2
. 6
. -600
. 2
. 12
. -600
. 2
. 18
. -600
. 2
. 24
. -600
. 2
. 30
. -600
. 2
. 36
. -600
. 2
. 42
. -600
. 2
. 48
. -600
. 2
. 54
. -600
. 2
. 60
. -600
. 2
. 66
. -600
. 2
. 72
. -600
```

```
plot(out6.2)
```



```
data6.2 <- to_data_set(out6.2, 6.2)
```

3.0.11 Infusion doses at steady state where $II == DUR$, with bioav factor

```
ev <- ev(amt = 100, ii = 10, addl = 8, rate = 100/10, LAGT = 0, BIOAV = 0.412, ss = 1, cmt = 2)
ev
```

```
. Events:
.   time cmt amt evid ii addl rate LAGT BIOAV ss
. 1    0   2 100   1 10    8   10    0 0.412  1
```

```
out7 <- sim(mod, ev)
```

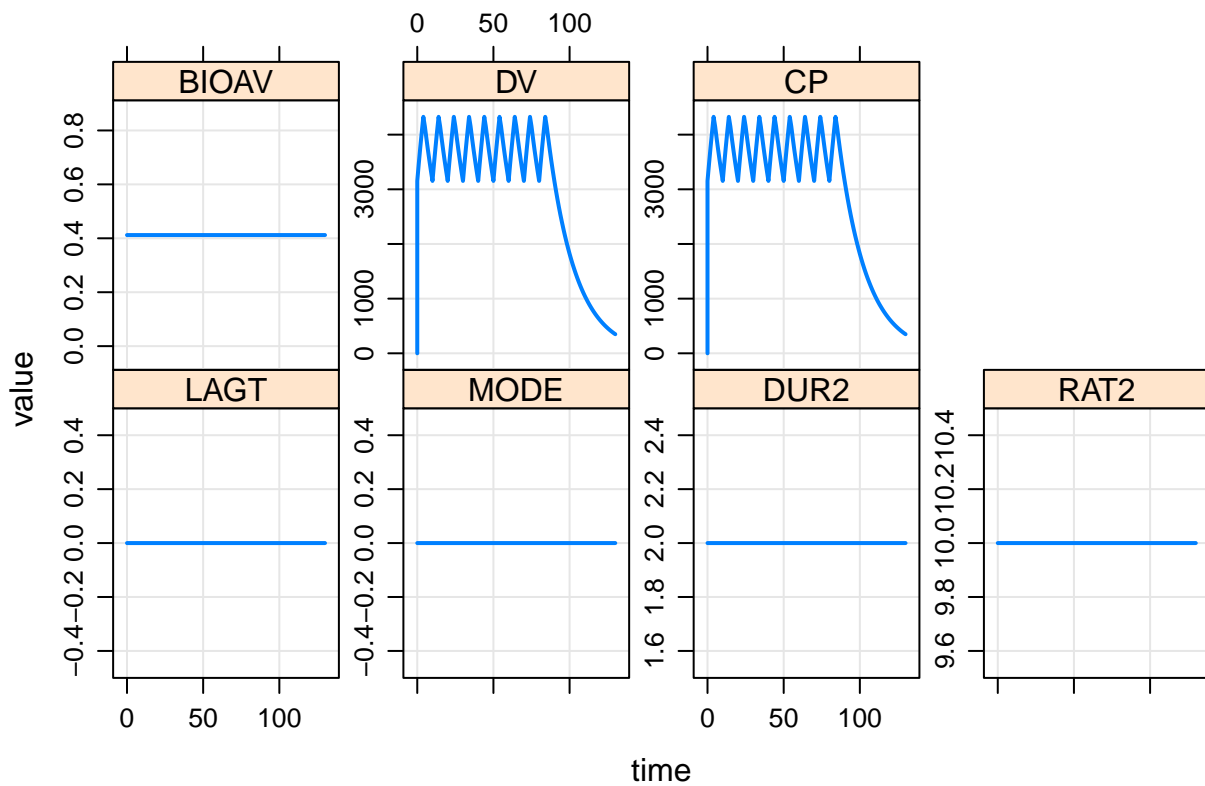
```
. 2
. 0
. 0
. 2 10 -600
. 2 20 -600
. 2 30 -600
. 2 40 -600
. 2 50 -600
. 2 60 -600
. 2 70 -600
. 2 80 -600
. 2
. 10
. -600
. 2
```

```

. 20
. -600
. 2
. 30
. -600
. 2
. 40
. -600
. 2
. 50
. -600
. 2
. 60
. -600
. 2
. 70
. -600
. 2
. 80
. -600

```

```
plot(out7)
```



```
data7 <- to_data_set(out7, 7)
```

3.0.12 Infusion doses at steady state, where $II == DUR$

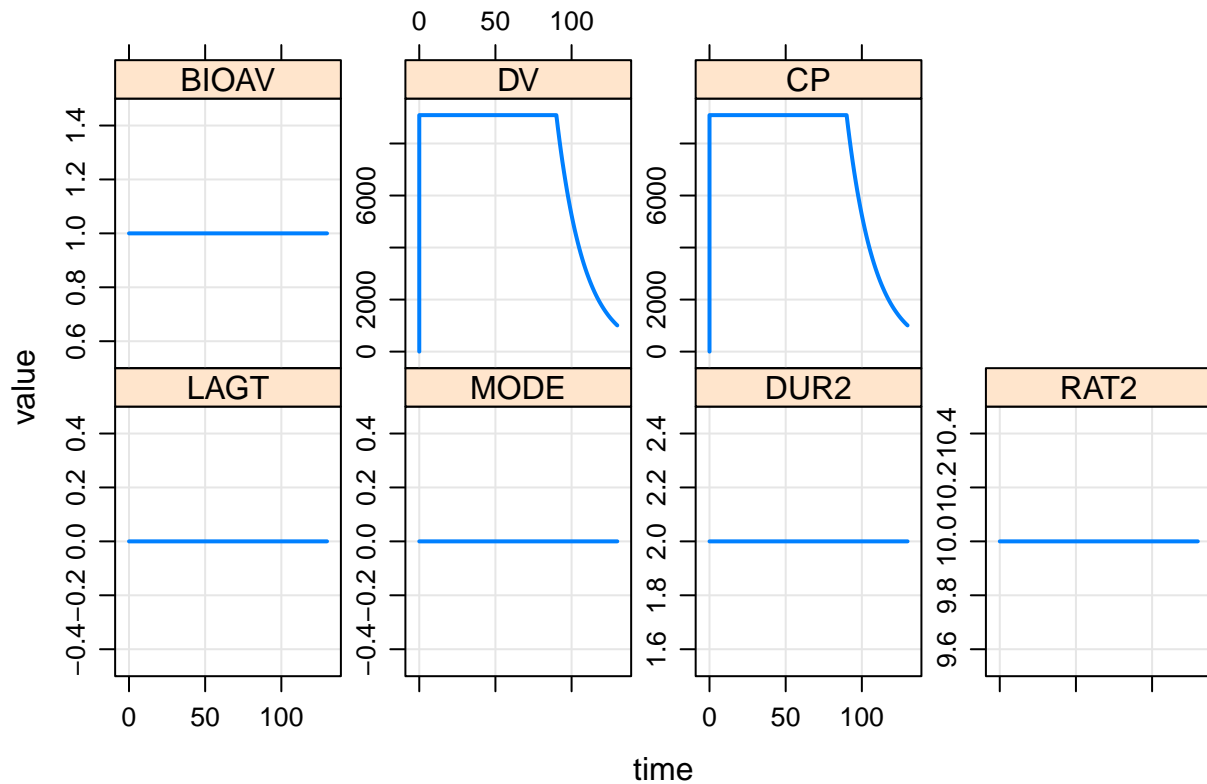
```
ev <- ev(amt = 100, ii = 10, addl = 8, rate = 100/10, ss = 1, cmt = 2)
ev
```

```
. Events:
.   time cmt amt evid ii addl rate ss
. 1     0  2 100    1 10    8   10  1
```

```
out7.1 <- sim(mod, ev)
```

```
. 2
. 0
. 0
. 2 10 -600
. 2 20 -600
. 2 30 -600
. 2 40 -600
. 2 50 -600
. 2 60 -600
. 2 70 -600
. 2 80 -600
. 2
. 10
. -600
. 2
. 20
. -600
. 2
. 30
. -600
. 2
. 40
. -600
. 2
. 50
. -600
. 2
. 60
. -600
. 2
. 70
. -600
. 2
. 80
. -600
```

```
plot(out7.1)
```



```
data7.1 <- to_data_set(out7.1, 7.1)
```

3.0.13 Bolus doses at steady state, with bioav factor and lag time

```
ev <- ev(amt = 100, ii = 24, addl=3, LAGT = 4, BIOAV = 0.412, ss = 1, cmt = 2)
ev
```

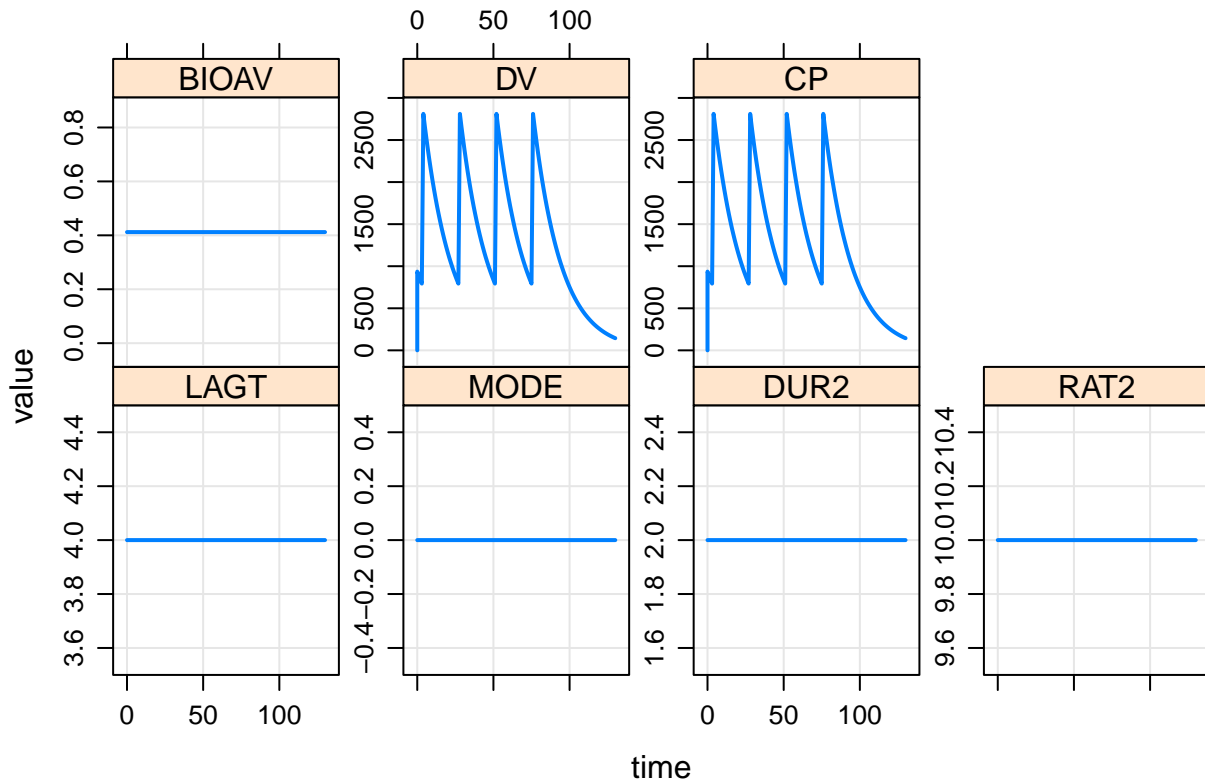
```
. Events:
.   time cmt amt evid ii addl LAGT BIOAV ss
. 1     0  2 100   1 24    3    4 0.412  1
```

```
out8 <- sim(mod, ev)
```

```
. 2
. 0
. 0
. 2 28 -600
. 2 52 -600
. 2 76 -600
. 2
. 4
. -1200
. 2
. 28
. -600
. 2
. 52
. -600
```

```
. 2
. 76
. -600
```

```
plot(out8)
```



```
data8 <- to_data_set(out8, 8)
```

3.0.14 Bolus doses with lag time and bioavailability factor

```
ev <- ev(amt = 100, ii = 24, addl=3, LAGT = 5, BIOAV = 0.412, cmt = 2)
ev
```

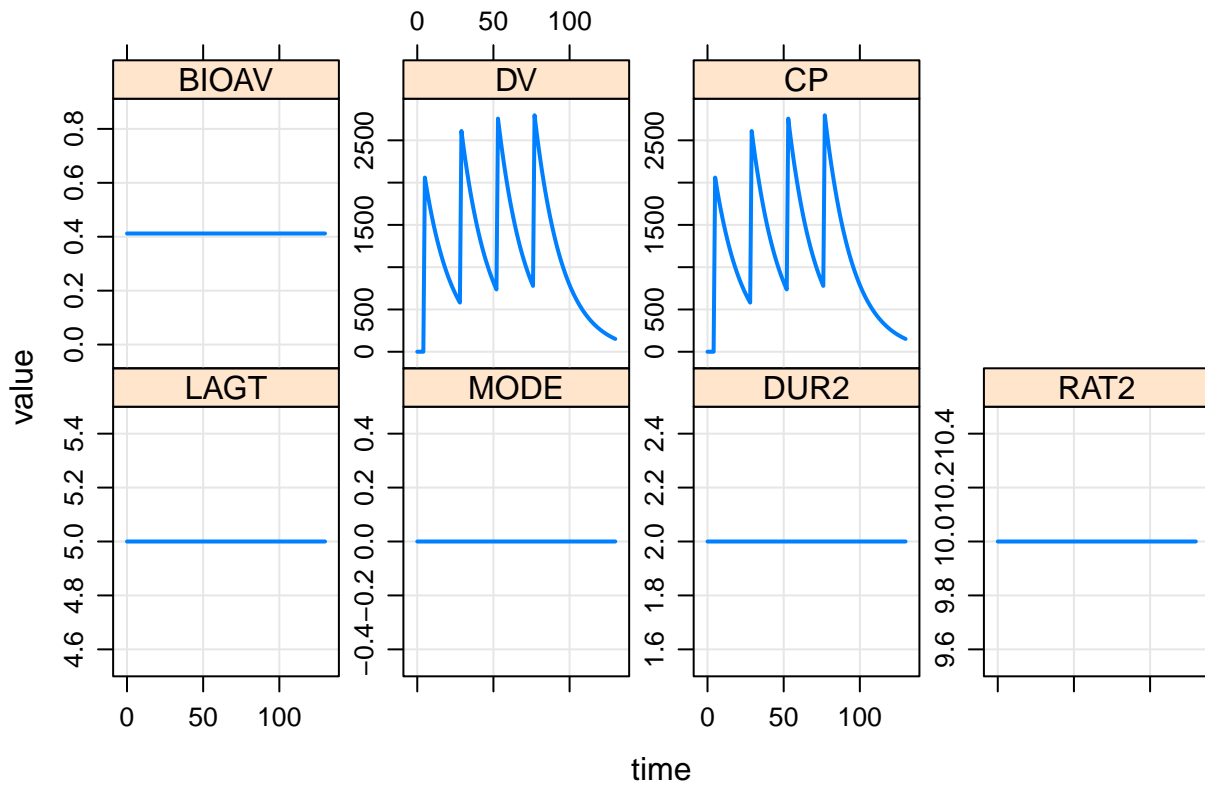
```
. Events:
.   time cmt amt evid ii addl LAGT BIOAV
. 1     0   2 100    1 24    3    5 0.412
```

```
out9 <- sim(mod, ev)
```

```
. 2
. 0
. 0
. 2 29 -600
. 2 53 -600
. 2 77 -600
. 2
. 5
. -1200
. 2
```

```
. 29
. -600
. 2
. 53
. -600
. 2
. 77
. -600
```

```
plot(out9)
```



```
data9 <- to_data_set(out9, 9)
```

3.0.15 Bolus / infusion

```
ev <- ev(amt = 100, cmt = 2, LAGT = 1) + ev(time = 13, amt = 50, ii = 24, addl = 2, rate = 24)
ev
```

```
. Events:
.   time cmt amt evid LAGT ii addl rate
. 1     0   2 100    1    1  0    0    0
. 2    13   1  50    1    0 24    2   24
```

```
out10 <- sim(mod, ev)
```

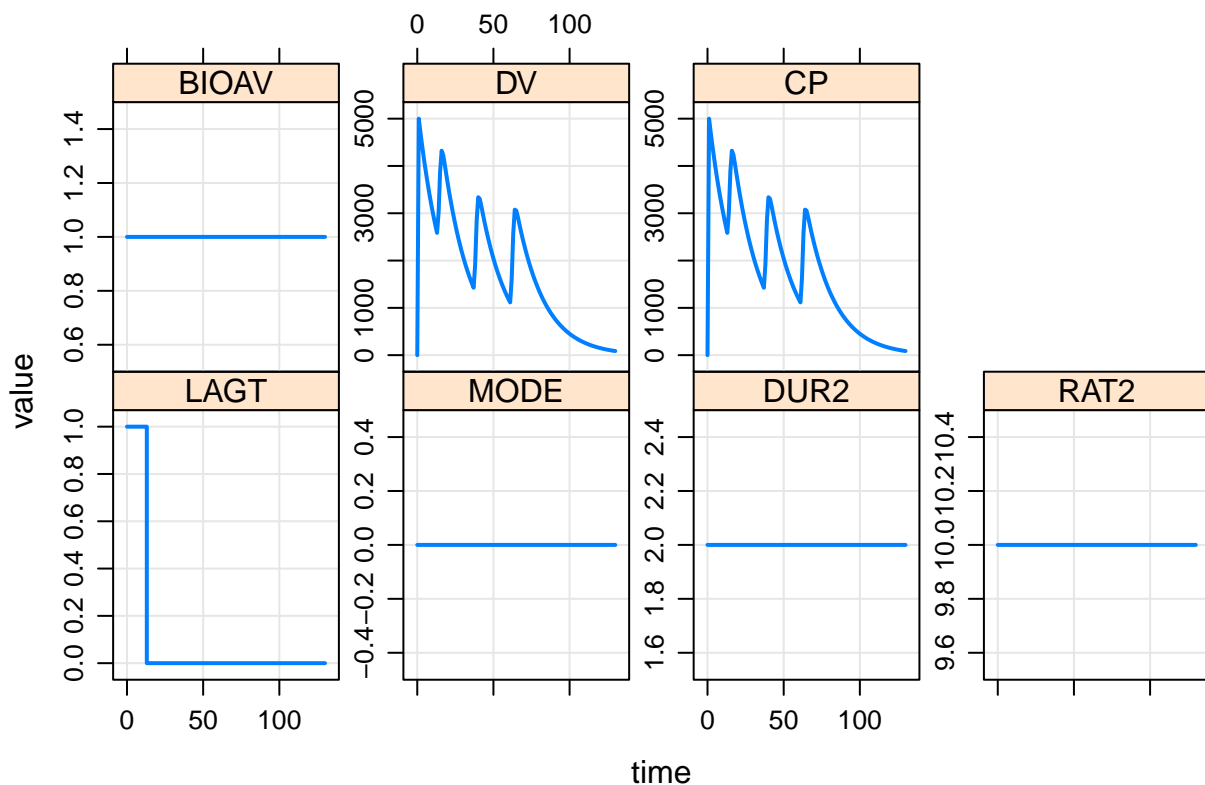
```
. 2
. 0
. 0
. 2
```

```

. 1
. -1200
. 1
. 13
. 1
. 1 37 -600
. 1 61 -600
. 1
. 37
. -600
. 1
. 61
. -600

```

```
plot(out10)
```



```
data10 <- to_data_set(out10, 10)
```

3.0.16 Infusion with modeled duration, lag time, and bioav factor

```
ev <- ev(amt = 100, rate = -2, DUR2 = 9, MODE = 2, cmt = 2, ii = 24, addl = 3, LAGT = 5, BIOAV = 0.61)
ev
```

```

. Events:
.   time cmt amt evid rate DUR2 MODE ii addl LAGT BIOAV
. 1      0  2 100    1   -2     9    2 24    3    5  0.61

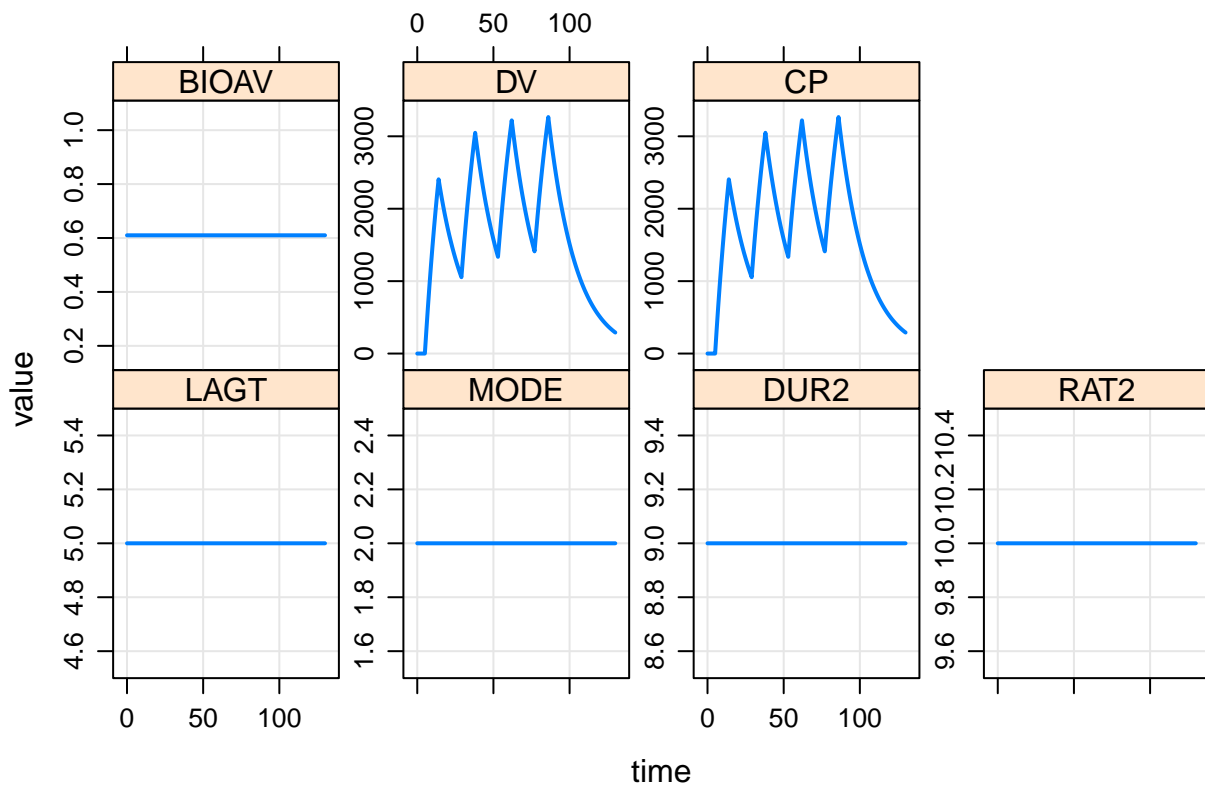
```

```
out11 <- sim(mod, ev)
```



```
. 2
. 0
. 0
. 2 29 -600
. 2 53 -600
. 2 77 -600
. 2
. 5
. -1200
. 2
. 29
. -600
. 2
. 53
. -600
. 2
. 77
. -600
```

```
plot(out11)
```



```
data11 <- to_data_set(out11,11)
```

3.0.17 Infusion with modeled duration, at steady state with bioav factor

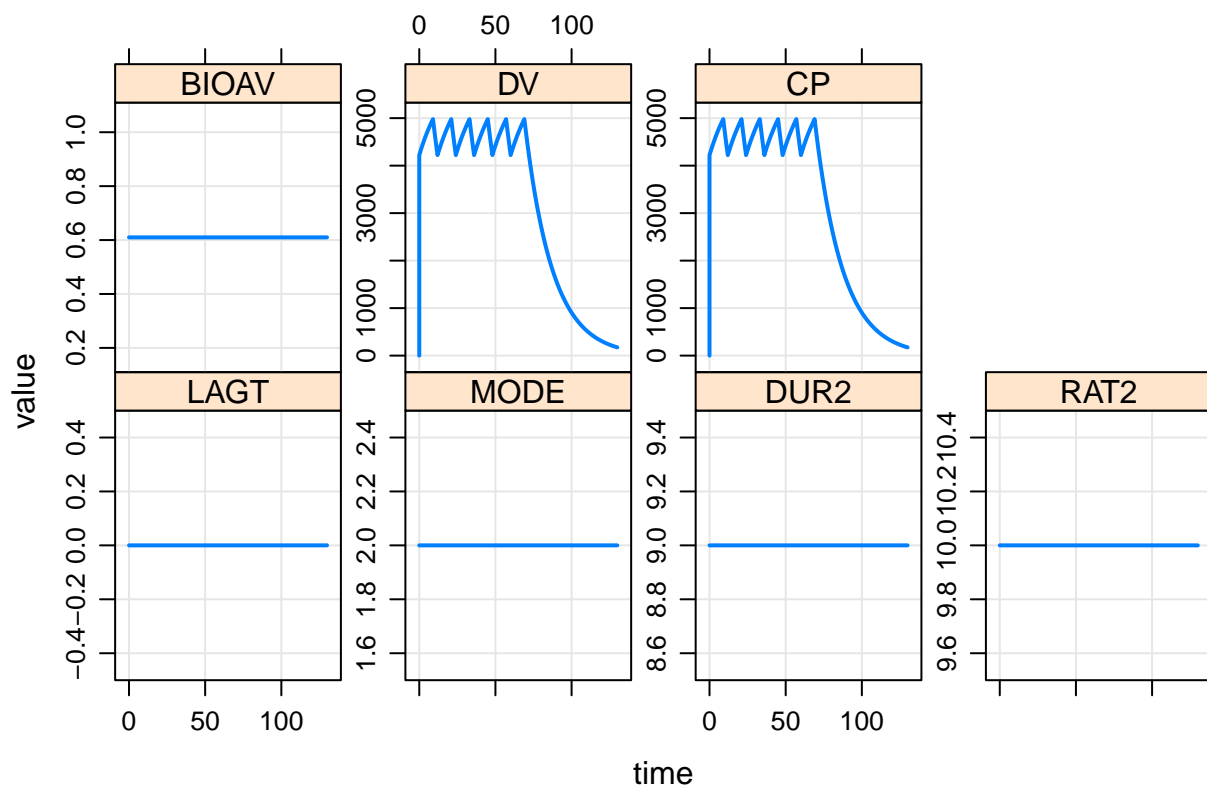
```
ev <- ev(amt = 100, rate = -2, DUR2 = 9, MODE = 2, cmt = 2, ii = 12, addl = 5, ss = 1, BIOAV = 0.61)
ev
```

```
. Events:
.   time cmt amt evid rate DUR2 MODE ii addl ss BIOAV
. 1     0  2 100    1  -2    9    2 12    5  1  0.61
```

```
out12 <- sim(mod,ev)
```

```
. 2
. 0
. 0
. 2 12 -600
. 2 24 -600
. 2 36 -600
. 2 48 -600
. 2 60 -600
. 2
. 12
. -600
. 2
. 24
. -600
. 2
. 36
. -600
. 2
. 48
. -600
. 2
. 60
. -600
```

```
plot(out12)
```



```
data12 <- to_data_set(out12,12)
```

3.0.18 Reset and dose (EVID 4) with additional

```
ev <-
  ev(amt = 100, ii = 12, addl = 5, rate = 50, BIOAV = 0.61) +
  ev(amt = 120, evid = 4, time = 80, BIOAV = 0.5, ii = 12, addl = 2)
ev
```

```
. Events:
.   time cmt amt evid ii addl rate BIOAV
. 1     0   1 100   1 12    5   50   0.61
. 2    80   1 120   4 12    2    0   0.50
```

```
out13 <- sim(mod,ev)
```

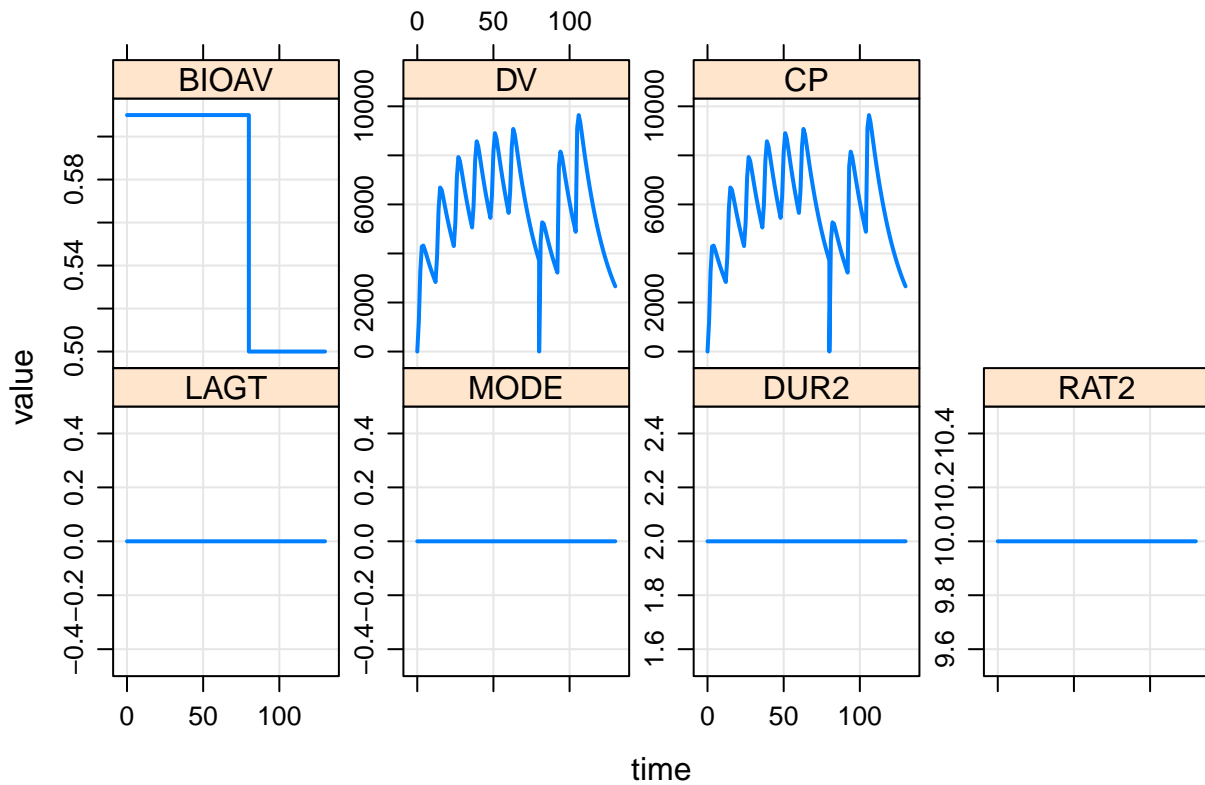
```
. 1
. 0
. 0
. 1 12 -600
. 1 24 -600
. 1 36 -600
. 1 48 -600
. 1 60 -600
. 1
. 12
. -600
. 1
. 24
```

```

. -600
. 1
. 36
. -600
. 1
. 48
. -600
. 1
. 60
. -600
. 1 92 -600
. 1 104 -600
. 1
. 92
. -600
. 1
. 104
. -600

```

```
plot(out13)
```



```
data13 <- to_data_set(out13,13)
```

3.0.19 Reset (EVID 3) with additional

```

ev <-
  ev(amt = 100, ii = 12, addl = 3, rate = 50, BIOAV = 0.61) +
  ev(amt = 0, evid = 3, time = 50, cmt = 2) +

```

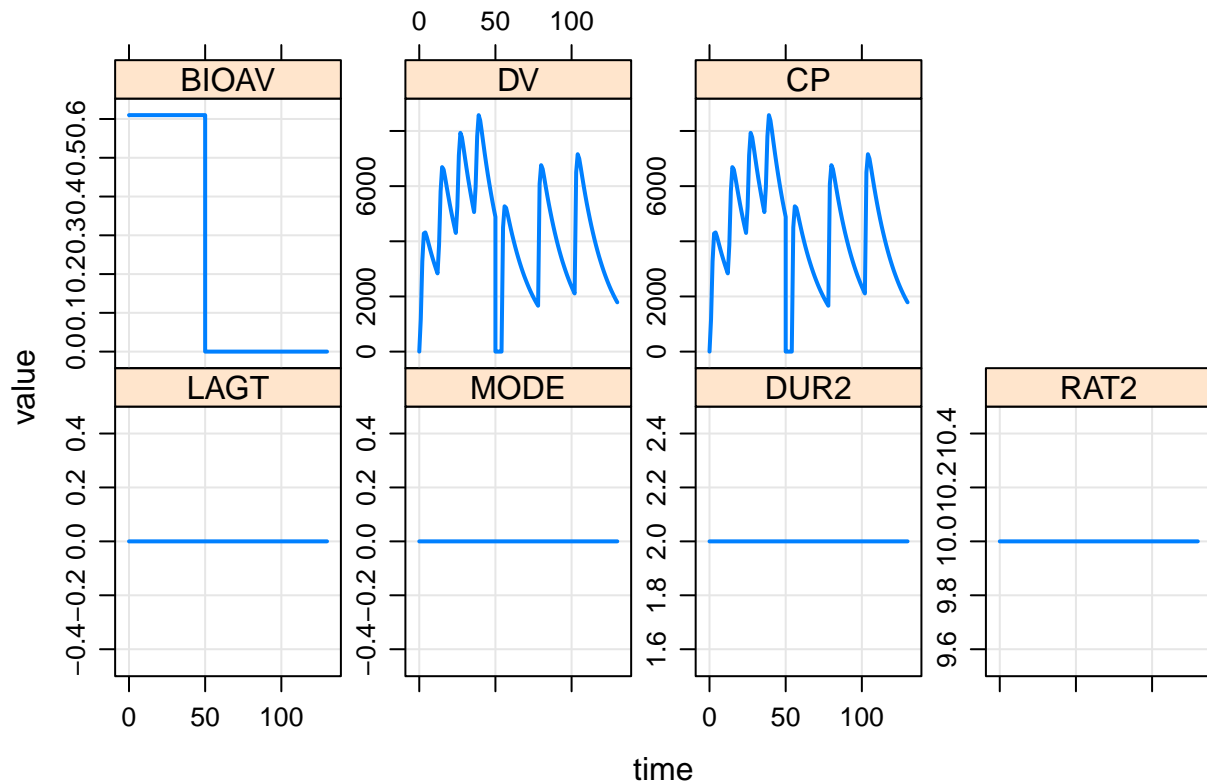
```
ev(amt = 120, ii = 24, addl = 2, time = 54)
ev
```

```
. Events:
.   time cmt amt evid ii addl rate BIOAV
. 1     0   1 100    1 12    3   50  0.61
. 2    50   2   0    3  0    0    0  0.00
. 3    54   1 120    1 24    2    0  0.00
```

```
out14 <- sim(mod, ev)
```

```
. 1
. 0
. 0
. 1 12 -600
. 1 24 -600
. 1 36 -600
. 1
. 12
. -600
. 1
. 24
. -600
. 1
. 36
. -600
. 1
. 54
. 2
. 1 78 -600
. 1 102 -600
. 1
. 78
. -600
. 1
. 102
. -600
```

```
plot(out14)
```



```
data14 <- to_data_set(out14,14)
```

3.0.20 Steady state 1 and 2

```
ev <-
  ev(amt = 100, ii = 24, addl = 3, ss = 1) +
  ev(amt = 50, ii = 24, addl = 3, ss = 2, time = 12)
ev
```

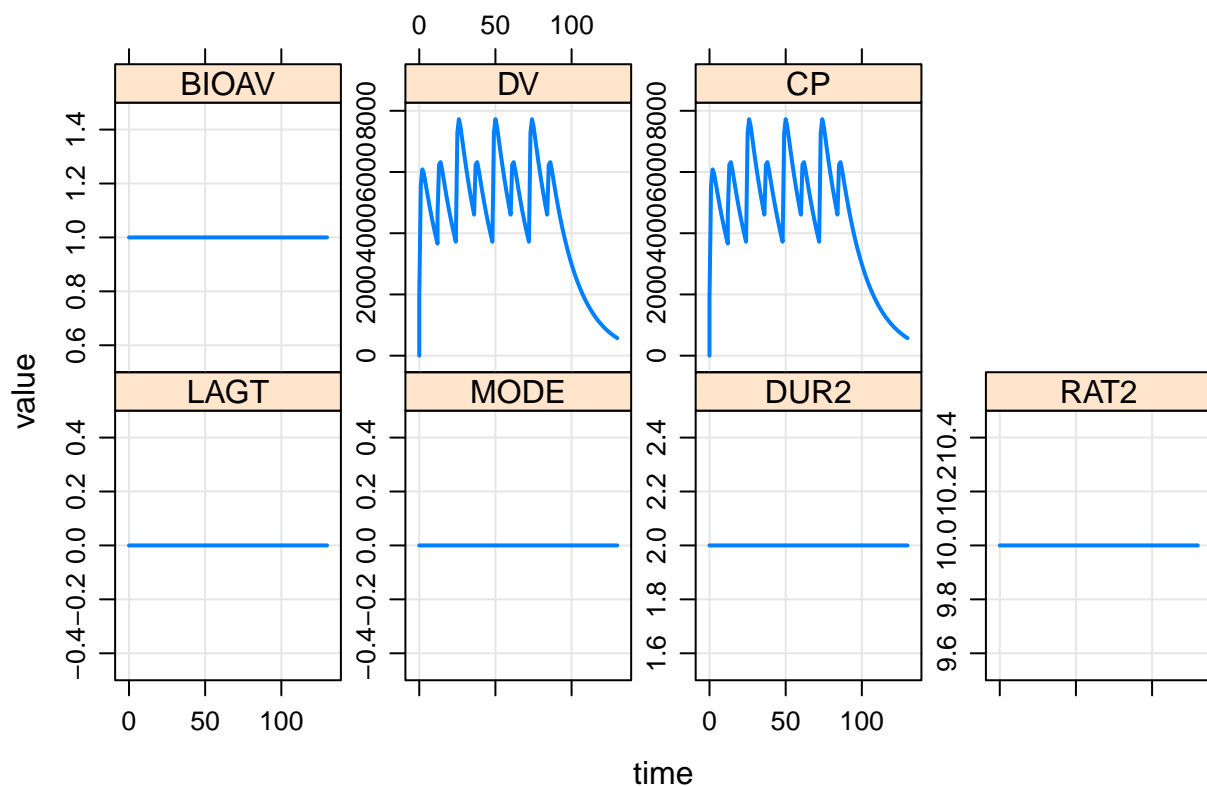
```
. Events:
.   time cmt amt evid ii addl ss
. 1     0   1 100   1 24   3   1
. 2    12   1  50   1 24   3   2
```

```
out15 <- sim(mod,ev)
```

```
. 1
. 0
. 0
. 1 24 -600
. 1 48 -600
. 1 72 -600
. 1
. 12
. 1
. 1 36 -600
. 1 60 -600
. 1 84 -600
. 1
```

```
. 24
. -600
. 1
. 36
. -600
. 1
. 48
. -600
. 1
. 60
. -600
. 1
. 72
. -600
. 1
. 84
. -600
```

```
plot(out15)
```



```
data15 <- to_data_set(out15,15)
```

4 Collect mrgsim output

```
sims <- list(out1,out1.1,out2,out2.1,out3,out4,out5,out6,out6.1,out6.2,out7,out7.1,
             out8,out9,out10,out11,out12,out13,out14,out15)
sims <- lapply(sims, as.data.frame)
```

```
sims <- bind_rows(sims)
```

5 Create a single data set for nonmem

```
data <- bind_rows(data1,data1.1,data2,data2.1,data3,data4,data5,data6,data6.1,data6.2,data7,data7.1,
                  data8,data9,data10,data11,data12,data13,data14,data15)

sv(data, "data/1001.csv")
```

6 Simulate with nonmem

```
out <- run(1001)

. Run 1001 complete.
. NONR complete.
. Parsed with column specification:
. cols(
.   TIME = col_double(),
.   EVID = col_double(),
.   CP = col_double(),
.   IPRED = col_double(),
.   PRED = col_double(),
.   DV = col_double()
. )
```

7 Overall Summary

Dimensions for mrgsim and nonmem output

```
dim(out)
```

```
. [1] 2645    6
```

```
dim(sims)
```

```
. [1] 2645   16
```

This is the nonmem minus mrgsim summary

```
summary(out$CP - sims$CP)
```

```
.   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
.      0      0      0      0      0      0
```

```
data$NM <- out$CP
```

```
data$MRGSIM <- sims$CP
```


8 Summary by RUN

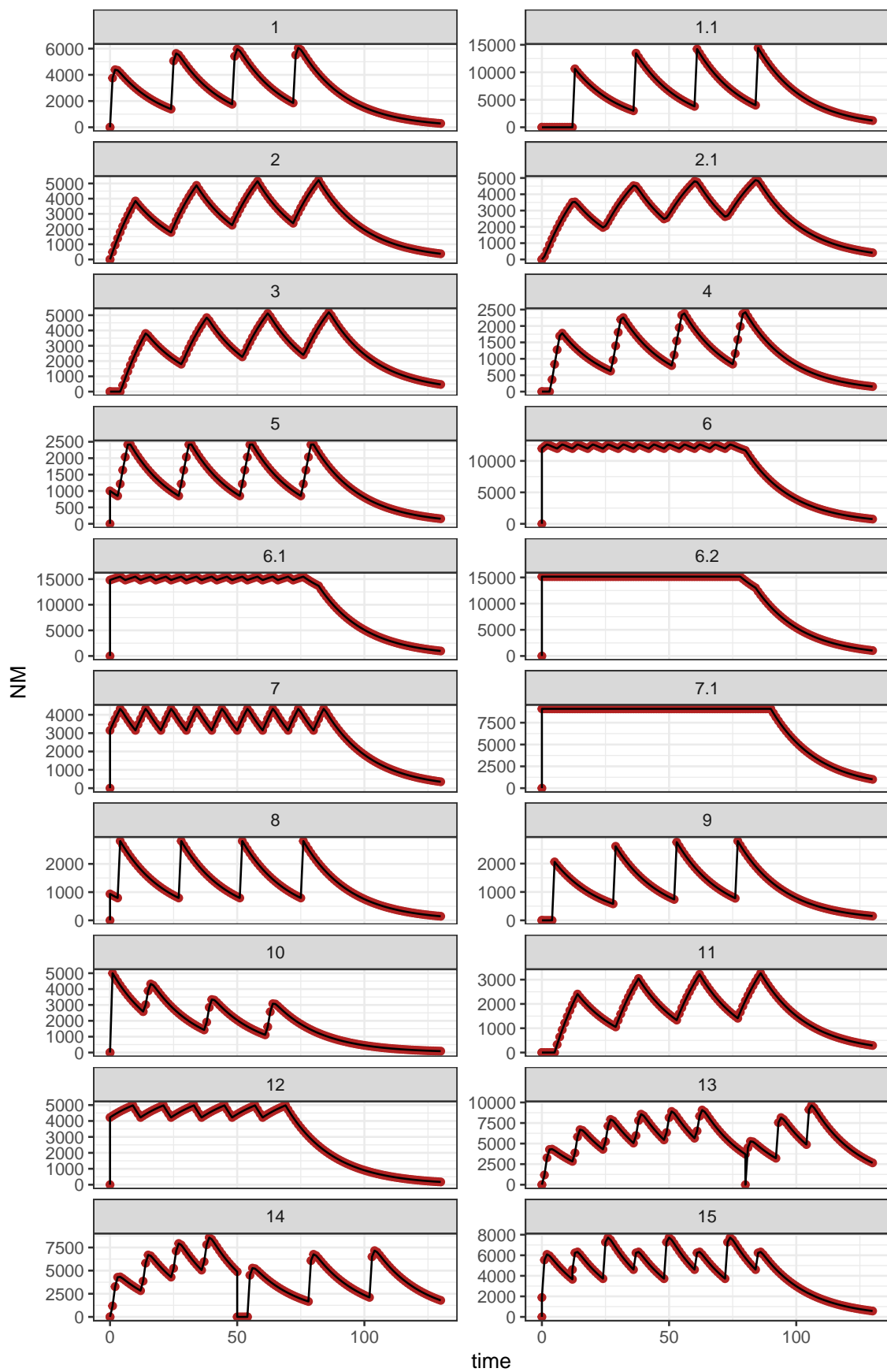
diff is the simulated CP from nonmem minus the simulated CP from mrgsim

```
group_by(data, ID) %>%  
  mutate(diff = NM - MRGSIM) %>%  
  summarise(mean = mean(diff), max = max(diff), min = min(diff))
```

```
. # A tibble: 20 x 4  
.   ID mean max min  
.   <dbl> <dbl> <dbl> <dbl>  
. 1 1 0 0 0  
. 2 1.1 0 0 0  
. 3 2 0 0 0  
. 4 2.1 0 0 0  
. 5 3 0 0 0  
. 6 4 0 0 0  
. 7 5 0 0 0  
. 8 6 0 0 0  
. 9 6.1 0 0 0  
. 10 6.2 0 0 0  
. 11 7 0 0 0  
. 12 7.1 0 0 0  
. 13 8 0 0 0  
. 14 9 0 0 0  
. 15 10 0 0 0  
. 16 11 0 0 0  
. 17 12 0 0 0  
. 18 13 0 0 0  
. 19 14 0 0 0  
. 20 15 0 0 0
```

9 Plot

```
ggplot(data = data) +  
  geom_point(aes(time, NM), color = "firebrick") +  
  geom_line(aes(time, MRGSIM, group = ID)) +  
  facet_wrap(~ID, scales = "free_y", ncol = 2) +  
  theme_bw()
```



10 Control stream

```
writeLines(readLines("model/1001.ctl"))
```

```
$PROB RUN# 101

$INPUT C ID TIME EVID AMT CMT SS II ADDL RATE LAGT MODE DUR2 RAT2 BIOAV DV

$DATA ../../data/1001.csv IGNORE=C

$SUBROUTINES ADVAN2 TRANS2

$PK

TVCL=THETA(1)
CL=TVCL*EXP(ETA(1))

TVV2=THETA(2)
V=TVV2*EXP(ETA(2))

TVKA=THETA(3)
KA=TVKA*EXP(ETA(3))

ALAG2 = LAGT
F2 = BIOAV

IF(MODE.EQ.1) R2 = RAT2
IF(MODE.EQ.2) D2 = DUR2

$ERROR
IPRED=A(2)/(V/1000)
Y=IPRED*EXP(ERR(1))

CP = IPRED

$THETA
(1.1, FIX) ;; CL
(20, FIX) ;; V
(1.5, FIX) ;; KA

$OMEGA
0.0 FIX
0.0 FIX
0.0 FIX

$SIGMA
0.00 FIX

$TABLE FILE=TAB TIME EVID CP IPRED PRED DV NOPRINT ONEHEADER NOAPPEND

$SIMULATION (2674474) ONLYSIMULATION
```

11 Session Info

```
devtools::session_info()
```

```
. Session info -----
. setting      value
. version      R version 3.3.3 (2017-03-06)
. system       x86_64, linux-gnu
. ui           X11
. language     (EN)
. collate      en_US.UTF-8
. tz           Etc/UTC
. date         2018-10-12

. Packages -----
. package      * version      date
. assertthat   0.2.0        2017-04-11
. backports    1.1.2        2017-12-13
. base         * 3.3.3       2017-03-06
. bindr        0.1.1        2018-03-13
. bindrcpp     * 0.2.2       2018-03-29
. cli          1.0.0        2017-11-05
. colorspace   1.3-2        2016-12-14
. crayon       1.3.4        2017-09-16
. datasets     * 3.3.3       2017-03-06
. devtools     1.13.6       2018-06-27
. digest       0.6.15       2018-01-28
. dplyr        * 0.7.6       2018-06-29
. evaluate     0.10.1       2017-06-24
. fansi        0.3.0        2018-08-13
. ggplot2      * 3.0.0       2018-07-03
. glue         1.3.0        2018-07-17
. graphics     * 3.3.3       2017-03-06
. grDevices    * 3.3.3       2017-03-06
. grid         3.3.3        2017-03-06
. gtable       0.2.0        2016-02-26
. hms          0.4.2        2018-03-10
. htmltools    0.3.6        2017-04-28
. knitr        1.20         2018-02-20
. labeling     0.3          2014-08-23
. lattice      0.20-34      2016-09-06
. lazyeval     0.2.1        2017-10-29
. magrittr     1.5          2014-11-22
. MASS         7.3-50       2018-04-30
. memoise      1.0.0        2016-01-29
. methods     * 3.3.3       2017-03-06
. metrumrg     5.57         2017-10-14
. mrgsolve     * 0.8.12.9000 2018-09-21
. munsell      0.5.0        2018-06-12
. pillar       1.3.0        2018-07-14
. pkgconfig    2.0.2        2018-08-16
. plyr         1.8.4        2016-06-08
. purrr        0.2.5        2018-05-29
```

```

. R6                2.2.2          2017-06-17
. Rcpp              0.12.18        2018-07-23
. RcppArmadillo     0.9.100.5.0    2018-08-16
. readr             * 1.1.1        2017-05-16
. reshape           0.8.7          2017-08-06
. rlang             0.2.2          2018-08-16
. rmarkdown         1.10           2018-06-11
. rprojroot         1.3-2          2018-01-03
. scales            0.5.0.9000     2018-06-20
. stats             * 3.3.3        2017-03-06
. stringi           1.2.3          2018-06-12
. stringr           1.3.1          2018-05-10
. tibble            1.4.2          2018-01-22
. tidyselect        0.2.4          2018-02-26
. tools             3.3.3          2017-03-06
. utf8              1.1.4          2018-05-24
. utils             * 3.3.3        2017-03-06
. withr             2.1.2          2018-03-15
. XML               3.98-1.11      2018-04-16
. yaml              2.1.19         2018-05-01
. source
. CRAN (R 3.3.3)
. cran (@1.1.2)
. local
. CRAN (R 3.3.3)
. CRAN (R 3.3.3)
. cran (@1.0.0)
. CRAN (R 3.3.2)
. cran (@1.3.4)
. local
. CRAN (R 3.3.3)
. cran (@0.6.15)
. CRAN (R 3.3.3)
. cran (@0.10.1)
. CRAN (R 3.3.3)
. CRAN (R 3.3.3)
. CRAN (R 3.3.3)
. local
. local
. local
. CRAN (R 3.3.2)
. CRAN (R 3.3.3)
. cran (@0.3.6)
. CRAN (R 3.3.3)
. CRAN (R 3.3.2)
. CRAN (R 3.3.2)
. CRAN (R 3.3.3)
. CRAN (R 3.3.2)
. CRAN (R 3.3.3)
. CRAN (R 3.3.2)
. local
. Github (metrumresearchgroup/metrumrg@2e5a541)
. local
. cran (@0.5.0)

```

```
. CRAN (R 3.3.3)
. CRAN (R 3.3.3)
. CRAN (R 3.3.2)
. CRAN (R 3.3.3)
. cran (@2.2.2)
. CRAN (R 3.3.3)
. CRAN (R 3.3.3)
. CRAN (R 3.3.3)
. CRAN (R 3.3.3)
. CRAN (R 3.3.3)
. CRAN (R 3.3.3)
. cran (@1.3-2)
. Github (hadley/scales@80fe94c)
. local
. CRAN (R 3.3.3)
. CRAN (R 3.3.3)
. cran (@1.4.2)
. CRAN (R 3.3.3)
. local
. CRAN (R 3.3.3)
. local
. CRAN (R 3.3.3)
. CRAN (R 3.3.3)
. CRAN (R 3.3.3)
```