

Function on Scalar-Regression: Modeling RCST-FA at the First Visit

Model Fitting:

Pilot estimates without random effects / smooth residuals $E(Y_i(t)) = g(\beta_{g_i}(t))$, followed by re-estimation with $E(Y_i(t)) = g(\beta_{g_i}(t) + E_i(t))$, where $E_i(t)$ uses the FPCs of the residuals from the pilot estimates. See file `pffr-models-utils.R` for source of `runModel()`.

Simple Gaussian model:

```
m_first_norandom <- runModel("first_norandom",  
  cca ~ 0 + c(case) + case,  
  data = subset(dti, visit == 1))
```

```
## Deviance = 52.5707509379244 Iterations - 1
```

```
## penalized deviance = 54.4723298298886
```

```
## Deviance = 52.3460989113051 Iterations - 1
```

```
## penalized deviance = 53.9575875280759
```

```
## Deviance = 52.0696157853728 Iterations - 1
```

```
## penalized deviance = 53.1648072544804
```

```
## Deviance = 51.9117155893429 Iterations - 1
```

```
## penalized deviance = 52.4704010915484
```

```
## Deviance = 51.8705881184469 Iterations - 1
```

```
## penalized deviance = 52.1420109385626
```

```
## Deviance = 51.8630507626019 Iterations - 1
```

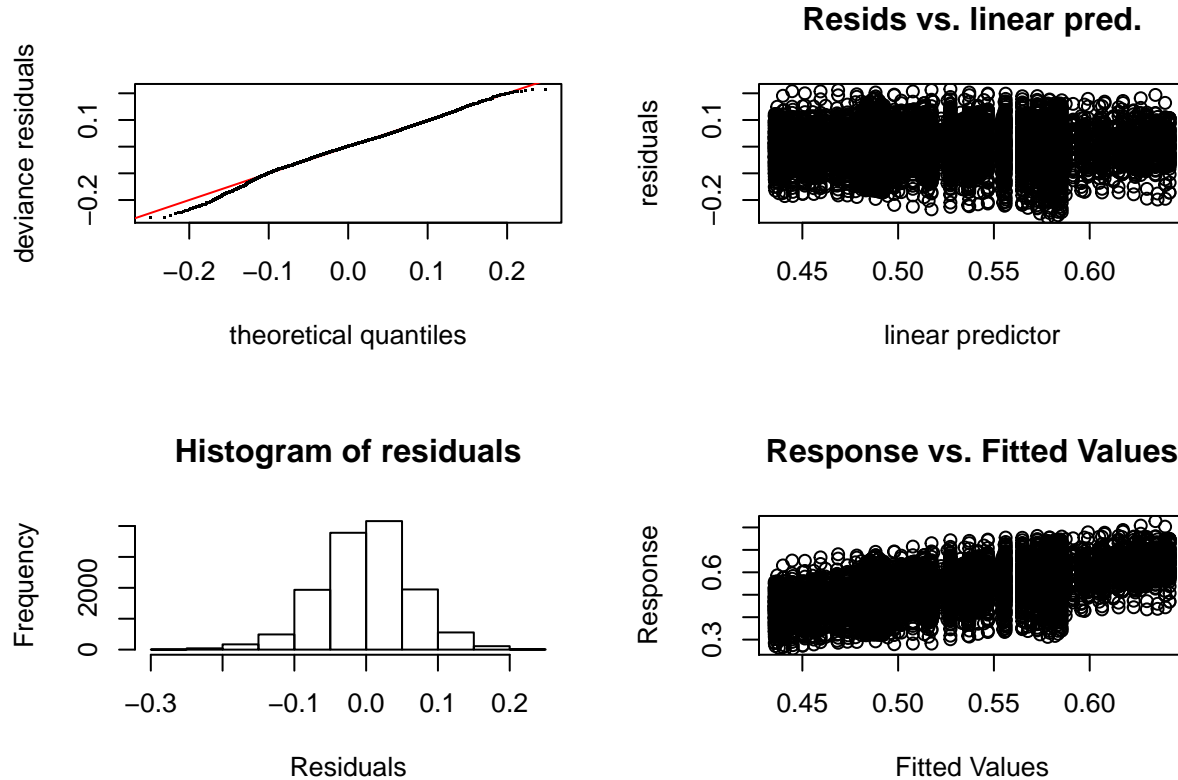
```
## penalized deviance = 52.0397124607266
```

```
## Deviance = 51.8619156392628 Iterations - 1
```

```
## penalized deviance = 52.0188596656878
```

```
## Deviance = 51.8618416726673 Iterations - 1
```

```
## penalized deviance = 52.0172884279903
```



Extract FPCs of residual curves from pilot estimate:

```
m_first_norandom <- readRDS("models/first_norandom.rds")
resid <- resid(m_first_norandom)
fpce <- fpca.sc(Y=resid, pve=.95, nbasis=20)
saveRDS(fpce, file="models/first_norandom-fpce.rds")
```

Refit with smooth residuals:

```
ef_first <- readRDS("models/first_norandom-fpce.rds")
ef <- ef_first$efunctions
ev <- ef_first$evalues
m_first_pcre <- runModel("first_pcre",
  cca ~ 0 + c(case) + case +
  pcre(id=subject, efunctions=ef, evalues=ev, yind=segm.t),
  data = subset(dti, visit == 1))
```

```
## Deviance = 4.3925890030262 Iterations - 1
```

```
## penalized deviance = 7.73996032777703
```

```
## Deviance = 3.61982842595184 Iterations - 1
```

```
## penalized deviance = 3.79616717983876
```

```
## Deviance = 3.62283295712796 Iterations - 1

## penalized deviance = 3.90103186272737

## Deviance = 3.62524026765864 Iterations - 1

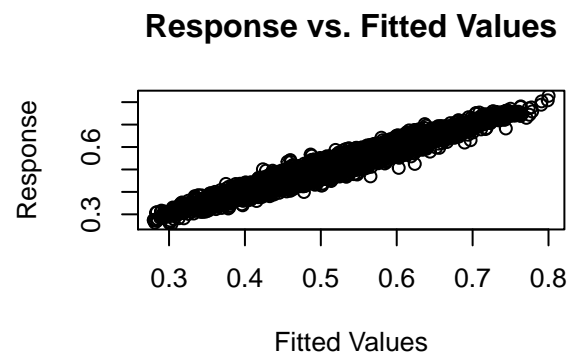
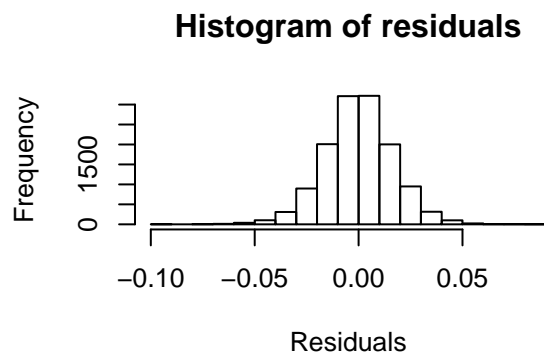
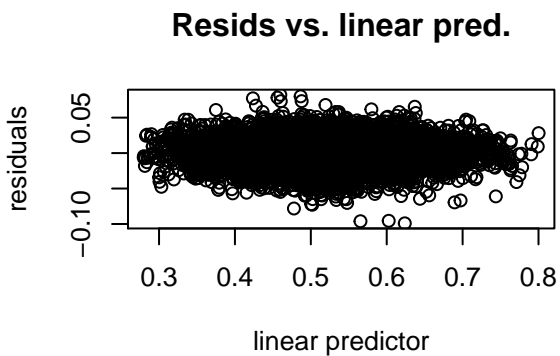
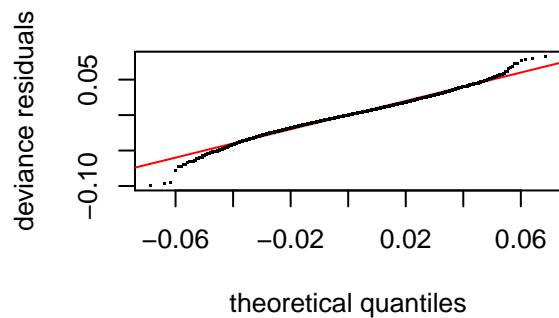
## penalized deviance = 3.96089641912217

## Deviance = 3.62555678109898 Iterations - 1

## penalized deviance = 3.96813544531571

## Deviance = 3.62554717260325 Iterations - 1

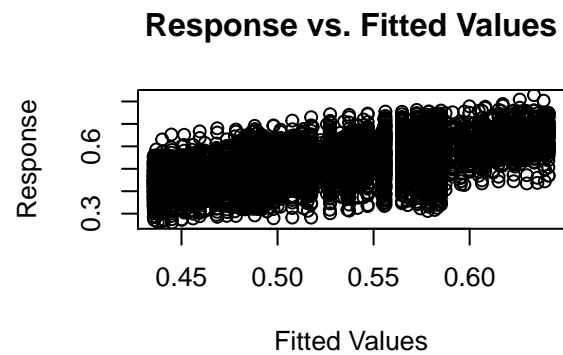
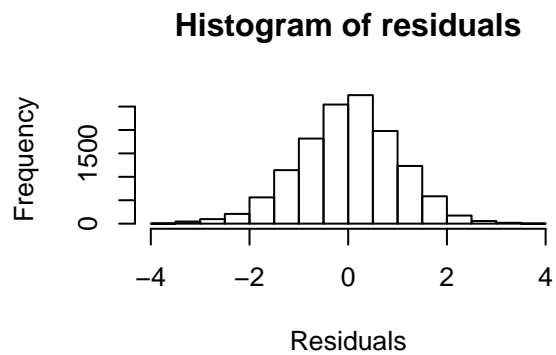
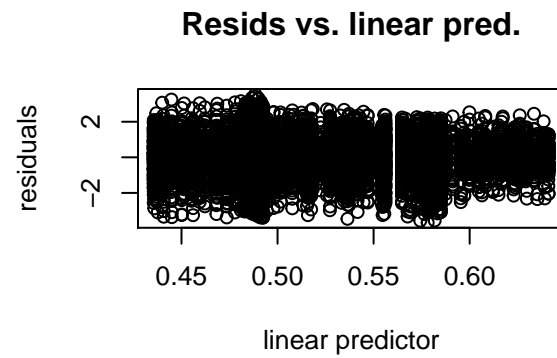
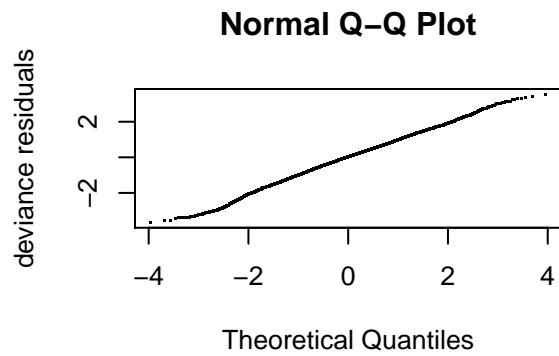
## penalized deviance = 3.96797826756608
```



Gaussian location-scale model:

$Y_i(t) \sim N(\beta_{g_i}(t), \sigma(t))$:

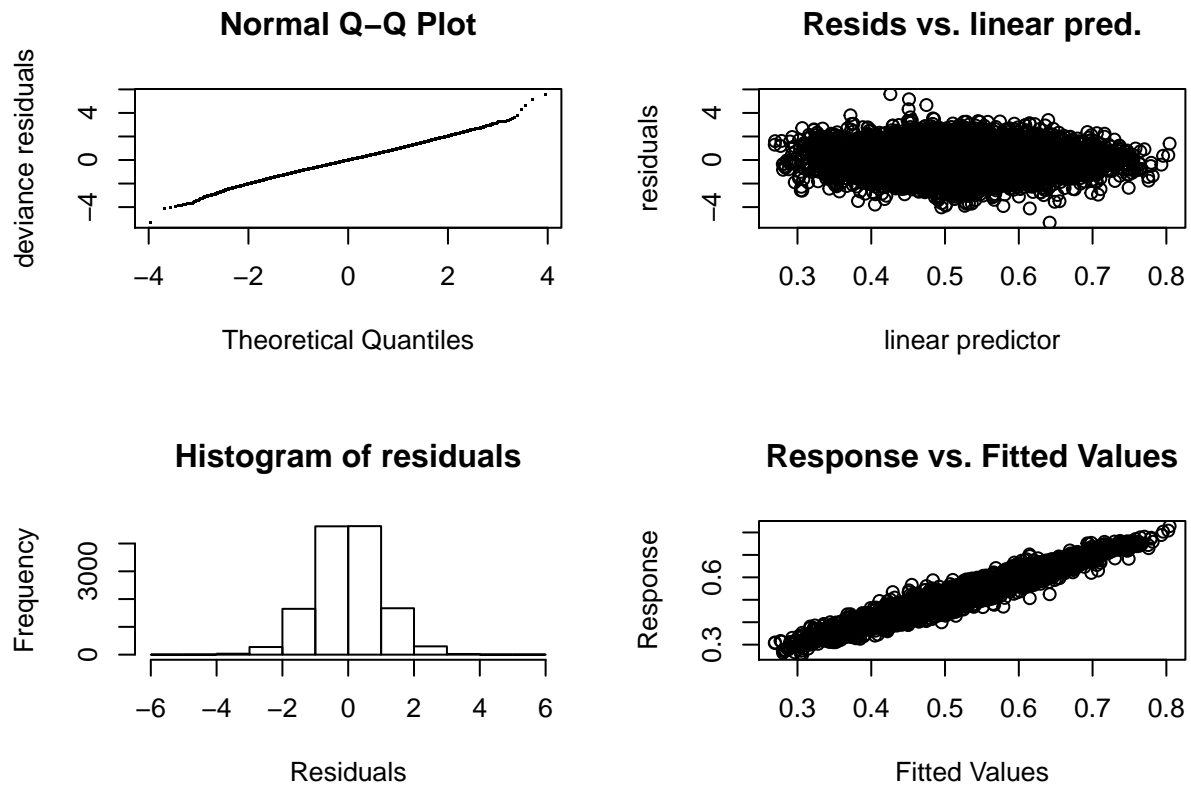
```
m_first_norandom_gaulss <- runModel("first_norandom_gaulss",
  cca ~ 0 + c(case) + case,
  data = subset(dti, visit == 1),
  family=gaulss(link=list("identity","logb"), b=0.001))
```



```
saveRDS(fitted(m_first_norandom_gaulss), "models/first_norandom_gaulss-fit.rds")
```

Refit with smooth residuals:

```
ef_first <- readRDS("models/first_norandom-fpce.rds")
ef <- ef_first$efunctions
ev <- ef_first$evaluations
m_first_pcre_gaulss <- runModel("first_pcre_gaulss",
  cca ~ 0 + c(case) + case +
    pcre(id=subject, efunctions=ef, evaluations=ev, yind=segm.t),
  data = subset(dti, visit == 1),
  family=gaulss(link=list("identity", "logb"), b=0.001))
```

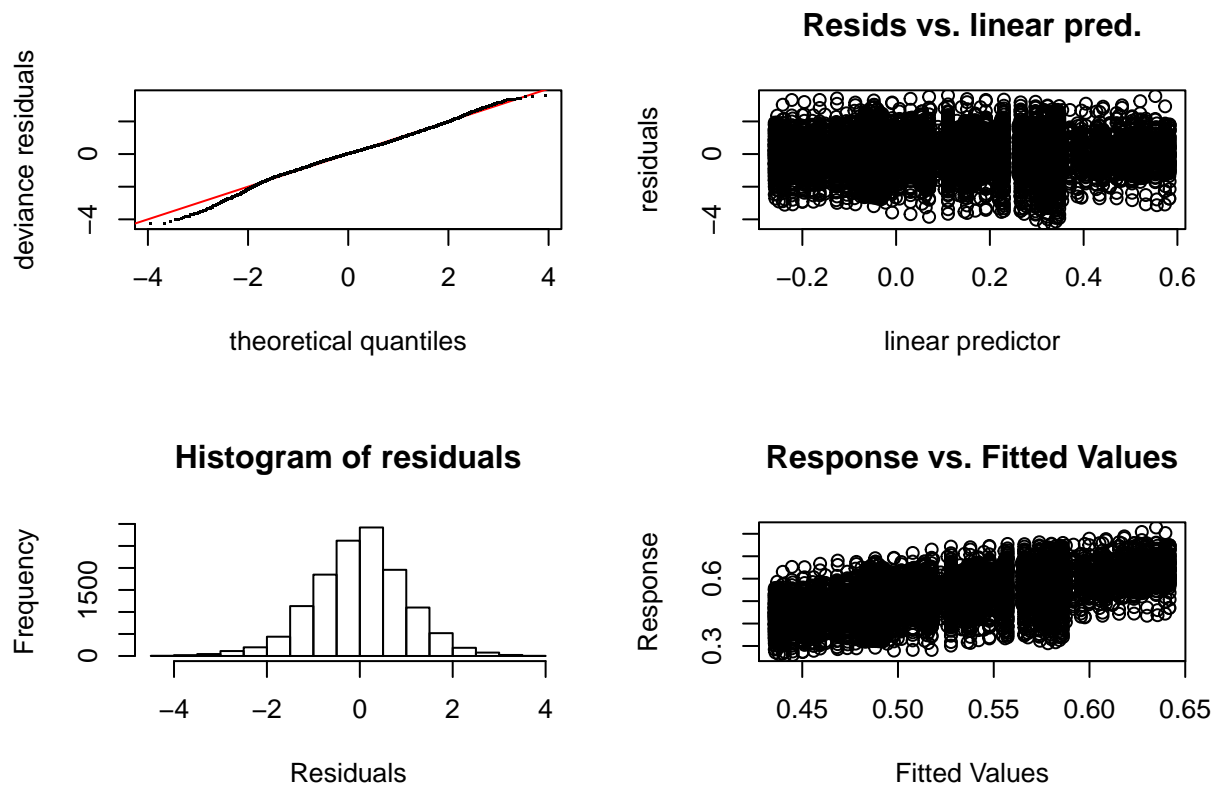



```
saveRDS(fitted(m_first_pcre_gaulss), "models/first_pcre_gaulss-fit.rds")
```

Beta model with logit-link:

Pilot estimate:

```
m_first_norandom_beta <- runModel("first_norandom_beta",
  cca ~ 0 + c(case) + case,
  data = subset(dti, visit == 1), family = betar(link = "logit"))
```

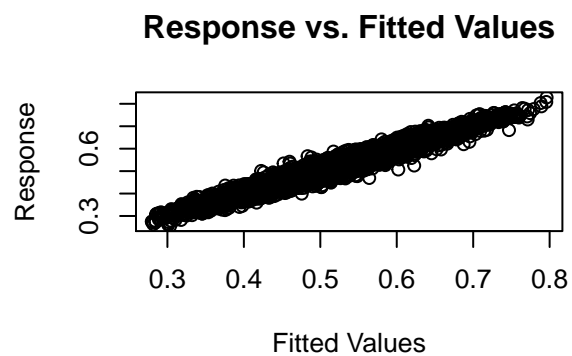
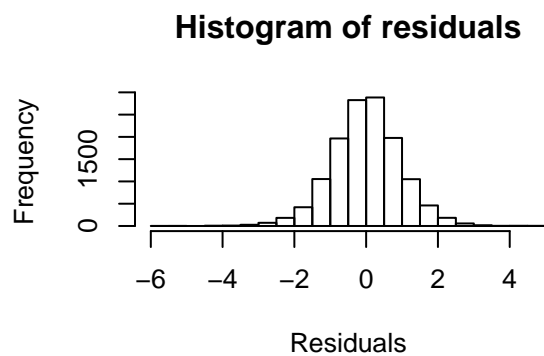
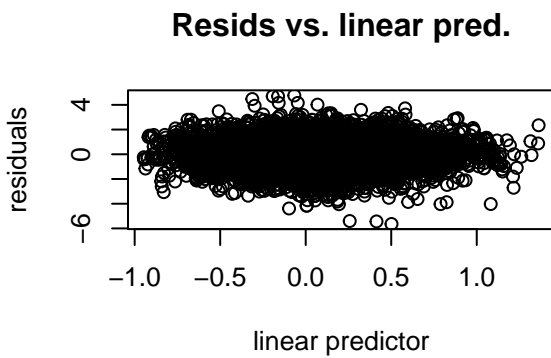
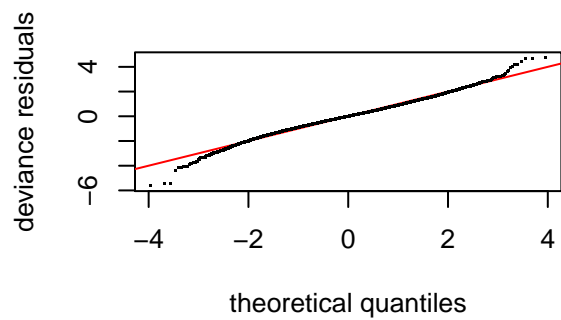


Extract FPCs of residuals (on logit scale):

```
m_first_norandom_beta <- readRDS("models/first_norandom_beta.rds")
resid <- resid(m_first_norandom_beta)
fpce <- fpca.sc(Y=resid, pve=.95, nbasis=20)
saveRDS(fpce, file="models/first_norandom_beta-fpce.rds")
```

Refit with smooth residuals:

```
ef_first <- readRDS("models/first_norandom_beta-fpce.rds")
ef <- ef_first$efunctions
ev <- ef_first$evaluations
m_first_pcre_beta <- runModel("first_pcre_beta",
  cca ~ 0 + c(case) + case +
  pcre(id=subject, efunctions=ef, evaluations=ev, yind=segm.t),
  data = subset(dti, visit == 1), family = betar(link = "logit"))
```



Analysis:

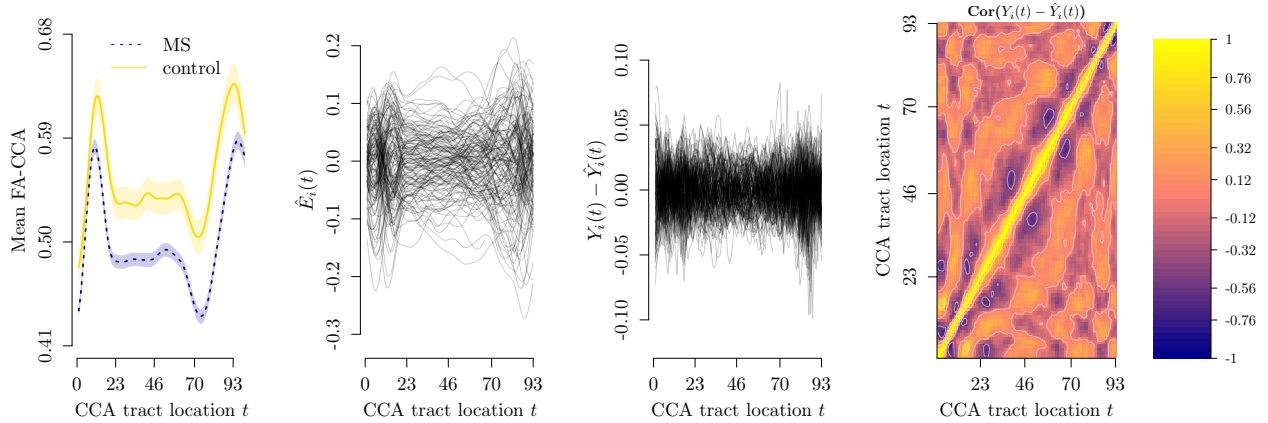
AICs of the 4 models:

- $\sim N$, no $E_i(t)$: -3.5589536×10^4
- $\sim N$, with $E_i(t)$: -6.8520188×10^4
- $\sim N$, with $E_i(t)$ and $\sigma(t)$: -6.9823724×10^4
- $\sim \text{Beta}$, no $E_i(t)$: -3.5543003×10^4
- $\sim \text{Beta}$, with $E_i(t)$: -6.8518634×10^4

(Graphical) Summaries:

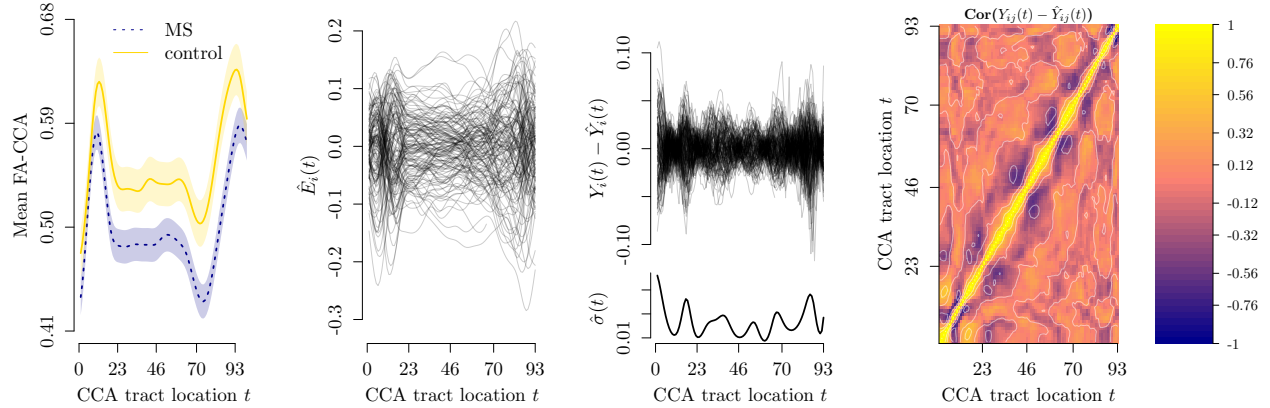
Gaussian model:

```
## [1] ""
## [2] "Family: gaussian "
## [3] "Link function: identity "
## [4] ""
## [5] "Formula:"
## [6] "cca ~ 0 + c(case) + case + pcre(id = subject, efunctions = ef, "
## [7] "     evalues = ev, yind = segm.t)"
## [8] ""
## [9] "Constant coefficients:"
## [10] "      Estimate Std. Error t value Pr(>|t|)      "
## [11] "case0 0.555079    0.006044   91.84  <2e-16 ***"
## [12] "case1 0.500368    0.002543  196.78  <2e-16 ***"
## [13] "----"
## [14] "Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1"
## [15] ""
## [16] "Smooth terms & functional coefficients:"
## [17] "              edf Ref.df      F p-value      "
## [18] "case0(yind)      22.04    24  64.97  <2e-16 ***"
## [19] "case1(yind)      23.04    24 269.62  <2e-16 ***"
## [20] "pcre(subject,ef,ev,segm.t) 1094.22  1128 141.29  <2e-16 ***"
## [21] "----"
## [22] "Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1"
## [23] ""
## [24] "R-sq.(adj) =  0.953   Deviance explained = 95.7%"
## [25] "-REML score = -32306   Scale est. = 0.00030056   n = 13204 (142 x 93)"
## [26] "[1] \"AIC:\"              \"-68520.1884187922\""
## [27] "[1] \"BIC:\"              \"-59965.4100303848\""
## [28] "Time difference of 3.917881 mins"
```



Gaussian location-scale model:

```
## [1] ""
## [2] "Family: gaulss "
## [3] "Link function: identity logb "
## [4] ""
## [5] "Formula:"
## [6] "cca ~ 0 + c(case) + case + pcre(id = subject, efunctions = ef, "
## [7] "     evalues = ev, yind = segm.t)"
## [8] ""
## [9] "Constant coefficients:"
## [10] "      Estimate Std. Error z value Pr(>|z|)      "
## [11] "case0      0.554644   0.006102   90.9  <2e-16 ***"
## [12] "case1      0.500540   0.002567  195.0  <2e-16 ***"
## [13] "(Intercept).1 -4.220229   0.006617 -637.8  <2e-16 ***"
## [14] "----"
## [15] "Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1"
## [16] ""
## [17] "Smooth terms & functional coefficients:"
## [18] "      edf Ref.df Chi.sq p-value      "
## [19] "case0(yind)      21.92    24  1066  <2e-16 ***"
## [20] "case1(yind)      22.84    24  4715  <2e-16 ***"
## [21] "pcre(subject,ef,ev,segm.t) 1099.59  1128 211739  <2e-16 ***"
## [22] "NA      18.31    19  1355  <2e-16 ***"
## [23] "----"
## [24] "Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1"
## [25] ""
## [26] "R-sq.(adj) =      Deviance explained =      NA%"
## [27] "-REML score = -32764  Scale est. = 1      n = 13204 (142 x 93)"
## [28] "[1] \"AIC:\"      \"-69823.7235855093\""
## [29] "[1] \"BIC:\"      \"-61086.8107696159\""
## [30] "Time difference of 32.65177 mins"
```



Beta model with logit-link:

```
## [1] ""
## [2] "Family: Beta regression(812.136) "
## [3] "Link function: logit "
## [4] ""
## [5] "Formula:"
## [6] "cca ~ 0 + c(case) + case + pcre(id = subject, efunctions = ef, "
## [7] "     evalues = ev, yind = segm.t)"
## [8] ""
## [9] "Constant coefficients:"
## [10] "      Estimate Std. Error z value Pr(>|z|)      "
## [11] "case0 0.225583   0.024884   9.066 <2e-16 ***"
## [12] "case1 0.002416   0.010468   0.231   0.818    "
## [13] "----"
## [14] "Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1"
## [15] ""
## [16] "Smooth terms & functional coefficients:"
## [17] "              edf Ref.df Chi.sq p-value      "
## [18] "case0(yind)          22.06    24   1614 <2e-16 ***"
## [19] "case1(yind)          23.03    24   6503 <2e-16 ***"
## [20] "pcre(subject,ef,ev,segm.t) 1094.35   1128 154890 <2e-16 ***"
## [21] "----"
## [22] "Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1"
## [23] ""
## [24] "R-sq.(adj) =  0.953   Deviance explained =   96%"
## [25] "-REML score = -32331   Scale est. = 1         n = 13204 (142 x 93)"
## [26] "[1] \"AIC:\"              \"-68518.6340579784\""
## [27] "[1] \"BIC:\"              \"-59962.8249382263\""
## [28] "Time difference of 7.256707 mins"
```

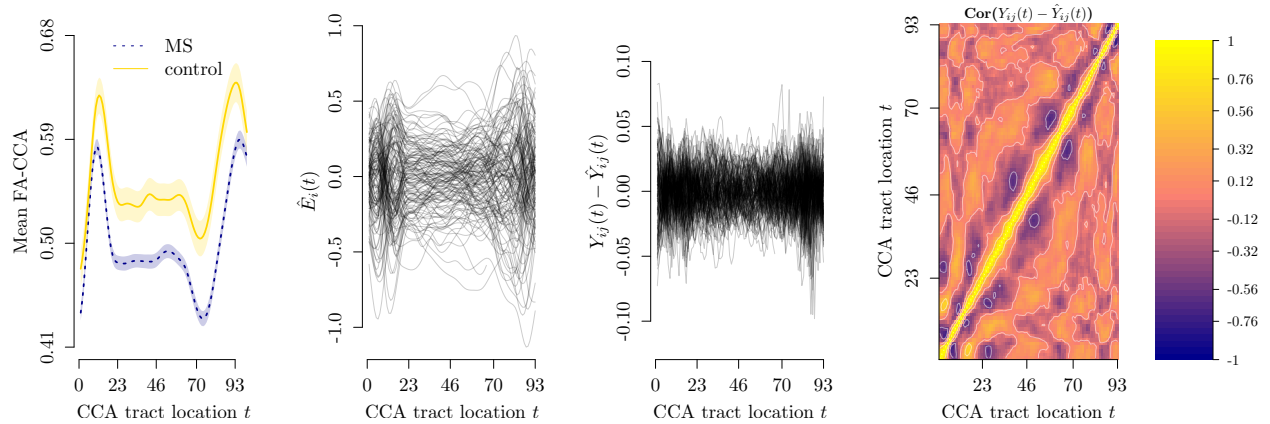


Figure 1: first visits, pcre, Beta

Computational Details:

```
sessionInfo()
```

```

## R version 3.3.0 (2016-05-03)
## Platform: x86_64-pc-linux-gnu (64-bit)
## Running under: Ubuntu 14.04.4 LTS
##
## locale:
## [1] LC_CTYPE=en_US.UTF-8      LC_NUMERIC=C
## [3] LC_TIME=de_DE.UTF-8      LC_COLLATE=en_US.UTF-8
## [5] LC_MONETARY=de_DE.UTF-8  LC_MESSAGES=en_US.UTF-8
## [7] LC_PAPER=de_DE.UTF-8     LC_NAME=C
## [9] LC_ADDRESS=C             LC_TELEPHONE=C
## [11] LC_MEASUREMENT=de_DE.UTF-8 LC_IDENTIFICATION=C
##
## attached base packages:
## [1] parallel stats      graphics grDevices utils      datasets methods
## [8] base
##
## other attached packages:
## [1] FDboost_0.1-0      mboost_2.6-0      stabs_0.5-1
## [4] Matrix_1.2-6      zoo_1.7-13      mgcv_1.8-12
## [7] nlme_3.1-128      refundDevel_0.1-16
##
## loaded via a namespace (and not attached):
## [1] modeltools_0.2-21  coin_1.1-2      splines_3.3.0
## [4] lattice_0.20-33   colorspace_1.2-6  htmltools_0.3.5
## [7] gamm4_0.2-3      stats4_3.3.0    yaml_2.1.13
## [10] MCMCpack_1.3-6    survival_2.39-4  gamboostLSS_1.2-1
## [13] nloptr_1.0.4      multcomp_1.4-5   plyr_1.8.3
## [16] stringr_1.0.0     MatrixModels_0.4-1 munsell_0.4.3
## [19] gtable_0.2.0      mvtnorm_1.0-5    codetools_0.2-14
## [22] coda_0.18-1      evaluate_0.9     knitr_1.13
## [25] magic_1.5-6      SparseM_1.7      strucchange_1.5-1
## [28] RLRsim_3.1-2     quantreg_5.24    TH.data_1.0-7
## [31] Rcpp_0.12.5      pbs_1.1         party_1.0-25
## [34] scales_0.4.0     formatR_1.4      lme4_1.1-12
## [37] mcmc_0.9-4       grpreg_3.0-0     ggplot2_2.1.0
## [40] digest_0.6.9     stringi_1.1.1    grid_3.3.0
## [43] quadprog_1.5-5    tools_3.3.0     sandwich_2.3-4
## [46] magrittr_1.5     MASS_7.3-44     fda_2.4.4
## [49] nnls_1.4         minqa_1.2.4     rmarkdown_0.9.6
## [52] boot_1.3-17      refund_0.1-14

```