

Case Study Code

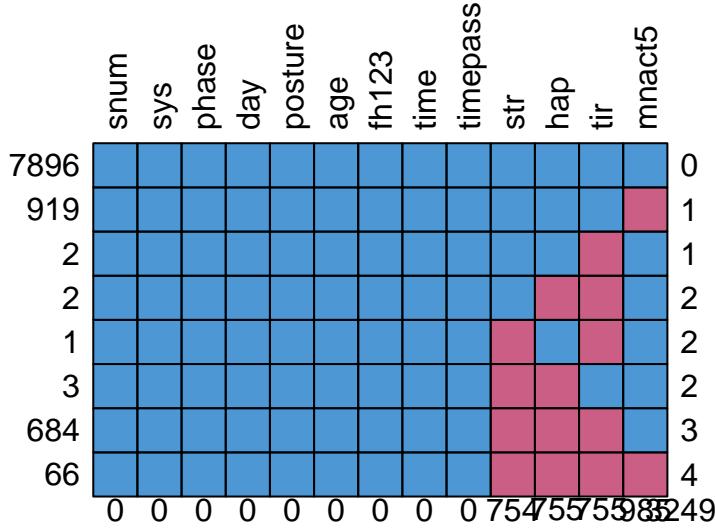
Kunwu Lyu

2025-02-15

Modeling

Data Wrangling

```
nurse <- read.csv("https://math.carleton.edu/kstclair/data/bmlr/nursebp.csv",
                     stringsAsFactors = TRUE) %>%
  as_tibble %>%
  select(-c(DIA, HRT, timept)) %>%
  janitor::clean_names() %>%
  mutate(snum = as.factor(snum))
glimpse(nurse)
## Rows: 9,573
## Columns: 13
## $ snum      <fct> 1002, 1002, 1002, 1002, 1002, 1002, 1002, 1002, 1002, 1~
## $ sys       <int> 136, 114, 130, 120, 117, 143, 118, 117, 91, 102, 118, 119, 14~
## $ mnact5   <dbl> NA, 230.4, 189.0, 228.8, 213.0, 247.4, 219.2, 203.6, 122.8, 1~
## $ phase     <fct> L, L~
## $ day       <fct> W, W~
## $ posture   <fct> SIT, STAND, STAND, STAND, STAND, STAND, STAND, STAND, STAND, ~
## $ str        <int> 1, 2, 1, 1, 1, 2, 1, 1, 2, 1, 1, NA, 1, 2, 1, 2, 2, ~
## $ hap        <int> 5, 4, 5, 5, 5, 5, 4, 5, 5, 1, 5, 5, NA, 5, 5, 5, 5, 5, ~
## $ tir        <int> 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, NA, 1, 1, 1, 1, 1, ~
## $ age        <int> 49, 49, 49, 49, 49, 49, 49, 49, 49, 49, 49, 49, 49, 49, 49, 49, 4~
## $ fh123     <fct> YES, Y~
## $ time       <int> 427, 450, 468, 489, 506, 527, 531, 549, 565, 569, 589, 610, 6~
## $ timepass   <int> 0, 23, 41, 62, 79, 100, 104, 122, 138, 142, 162, 183, 204, 20~
out<-md.pattern(nurse, rotate.names=T) #missingness pattern
```



```

nurse_complete <- nurse %>%
  drop_na() %>%
  mutate(mood = hap - (str + tir)/2,
         standing = case_when(posture == "RECLINE" ~ 0,
                               posture == "SIT" ~ 1,
                               posture == "STAND" ~ 2))
# new mood variable

nurse_filtered <- nurse_complete %>%
  mutate(
    age24 = age-24,
    phase2 = if_else(phase == "F", 0, 1),
    day2 = if_else(day == "W", 1, 0),
    posture2 = case_when(posture == "RECLINE" ~ 0,
                          posture == "SIT" ~ 1,
                          posture == "STAND" ~ 2),
    fh123 = case_when(fh123 == "NO" ~ 0,
                      fh123 == "YES" ~ 1,
                      fh123 == "YESYES" ~ 2)
  ) %>%
  mutate(fh123 = as.factor(fh123),
         phase2 = as.factor(phase2),
         day2 = as.factor(day2),
         posture2 = as.factor(posture2)) %>%
  mutate(day3 = if_else(day == "W", "Workday", "Non-Workday")) %>%
  mutate(standing = if_else(posture2 == 2, 1, 0),
         fh_yes = if_else(fh123 == 0, 0, 1)) %>% # New standing var
  mutate(standing = as.factor(standing),
         fh_yes = as.factor(fh_yes)) %>%
  mutate(fh_2 = if_else(fh_yes == 1, "Yes", "No")) %>%
  drop_na()

nurse_bysubject <- nurse_filtered %>%
  mutate(phase3 = if_else(phase2 == 0, "Follicular", "Luteal"),
         day3 = if_else(day2 == 1, "Workday", "Non-Workday")) %>%
  group_by(snum) %>%
  summarize(

```

```

    mean_sys = mean(sys),
    phase3 = first(phase3), day3 = first(day3),
    age2 = first(age24), fh_2 = first(fh_2), fh123 = first(fh123)
)

```

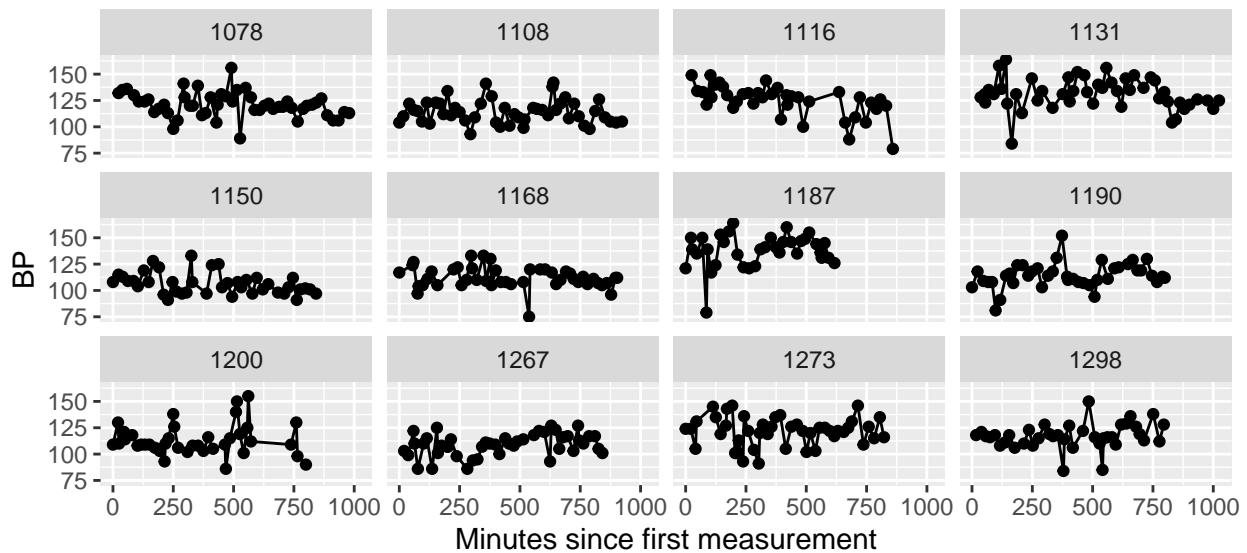
EDA

Level 1 by Clusters

```

# Subset of data to viz bp by time
set.seed(93487303)
nurse_all <- nurse_filtered %>%
  distinct(snum) %>%
  pull()
random_snums <- sample(nurse_all, 12)
nurse_small <- nurse_filtered %>%
  filter(snum %in% random_snums)
ggplot(nurse_small, aes(x = timepass, y = sys)) + geom_point() +
  geom_line() + facet_wrap(~snum) + labs(x = "Minutes since first measurement",
  y = "BP")

```

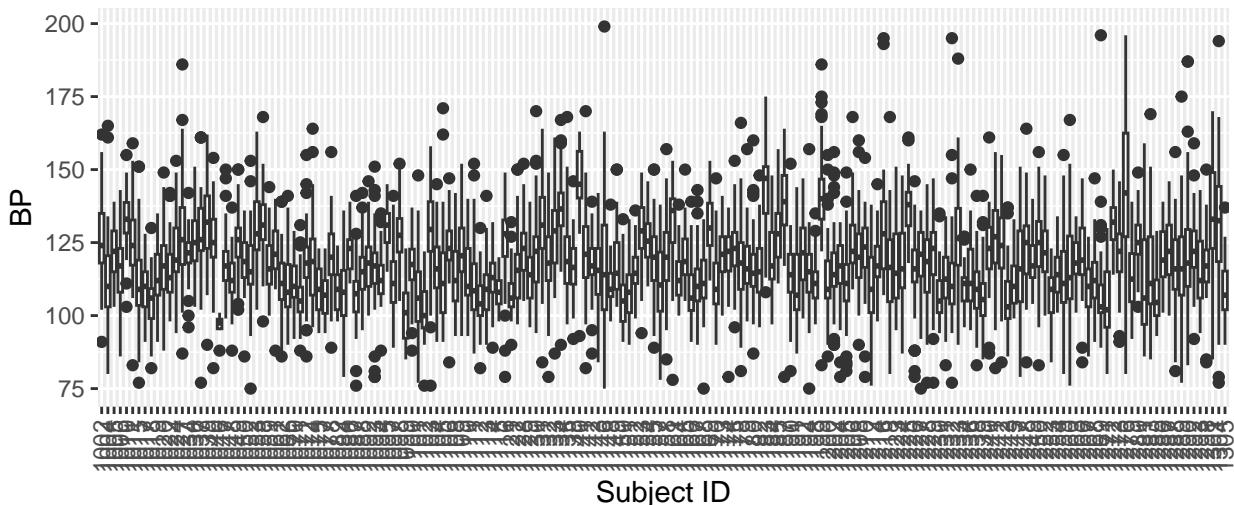


```

ggplot(nurse_filtered, aes(x = as.factor(snum), y = sys)) + geom_boxplot() +
  labs(x = "Subject ID", y = "BP", title = "BP by Subjects") +
  theme(axis.text.x = element_text(angle = 90, vjust = 0.5,
  hjust = 1))

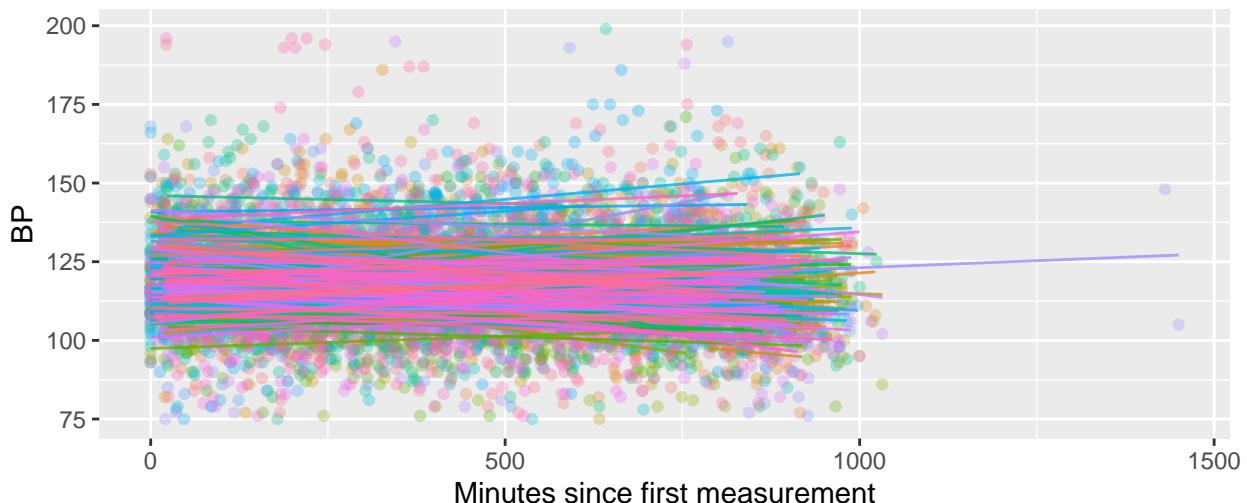
```

BP by Subjects



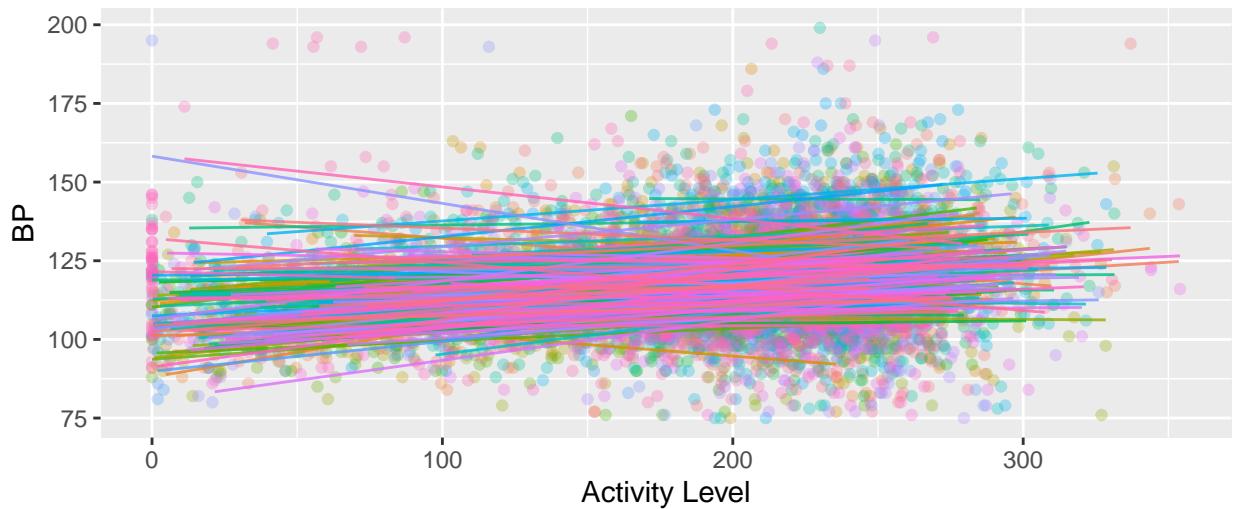
```
ggplot(nurse_filtered, aes(x = timepass, y = sys, color = as.factor(snum))) +  
  geom_point(alpha = 0.3) + geom_line(stat = "smooth", method = "lm",  
  se = F, alpha = 0.8) + labs(x = "Minutes since first measurement",  
  y = "BP", title = "BP vs. time passed by Subjects", color = "Subject ID") +  
  guides(color = "none")
```

BP vs. time passed by Subjects



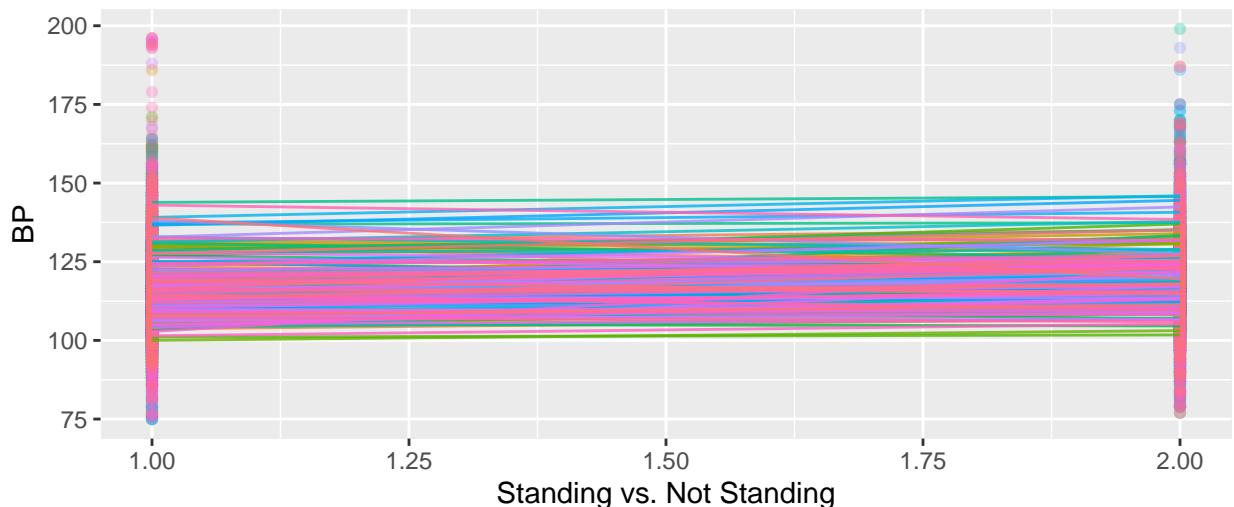
```
ggplot(nurse_filtered, aes(x = mnact5, y = sys, color = as.factor(snum))) +  
  geom_point(alpha = 0.3) + geom_line(stat = "smooth", method = "lm",  
  se = F, alpha = 0.8) + labs(x = "Activity Level", y = "BP",  
  title = "BP vs. Activity Level", color = "Subject ID") +  
  guides(color = "none")
```

BP vs. Activity Level



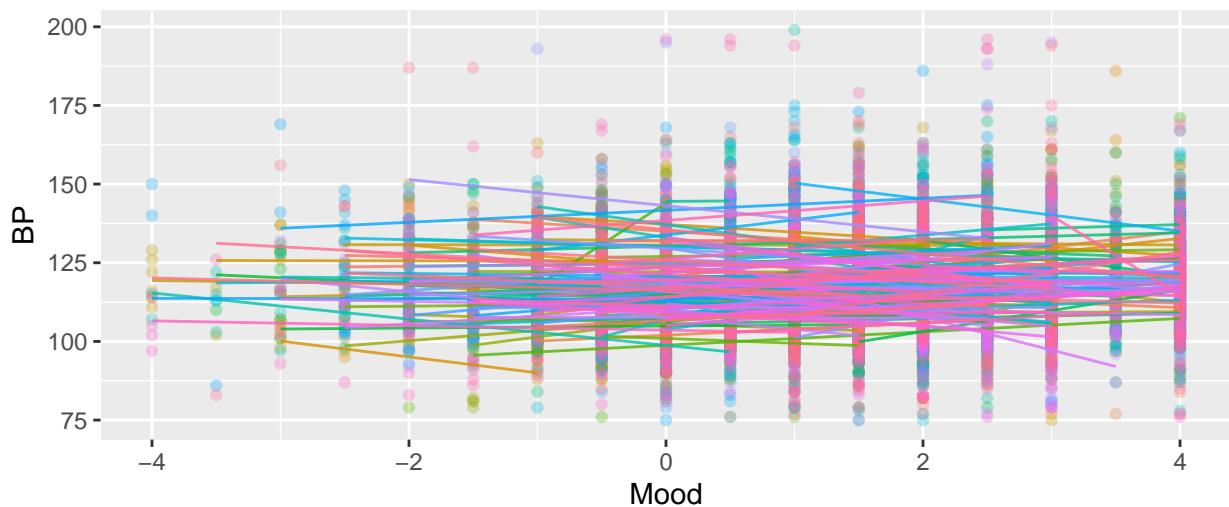
```
ggplot(nurse_filtered, aes(x = as.numeric(standing), y = sys,
  color = as.factor(snum))) + geom_point(alpha = 0.3) + geom_line(stat = "smooth",
method = "lm", se = F, alpha = 0.8) + labs(x = "Standing vs. Not Standing",
y = "BP", title = "BP vs. Posture (2 Levels)", color = "Subject ID") +
guides(color = "none")
```

BP vs. Posture (2 Levels)



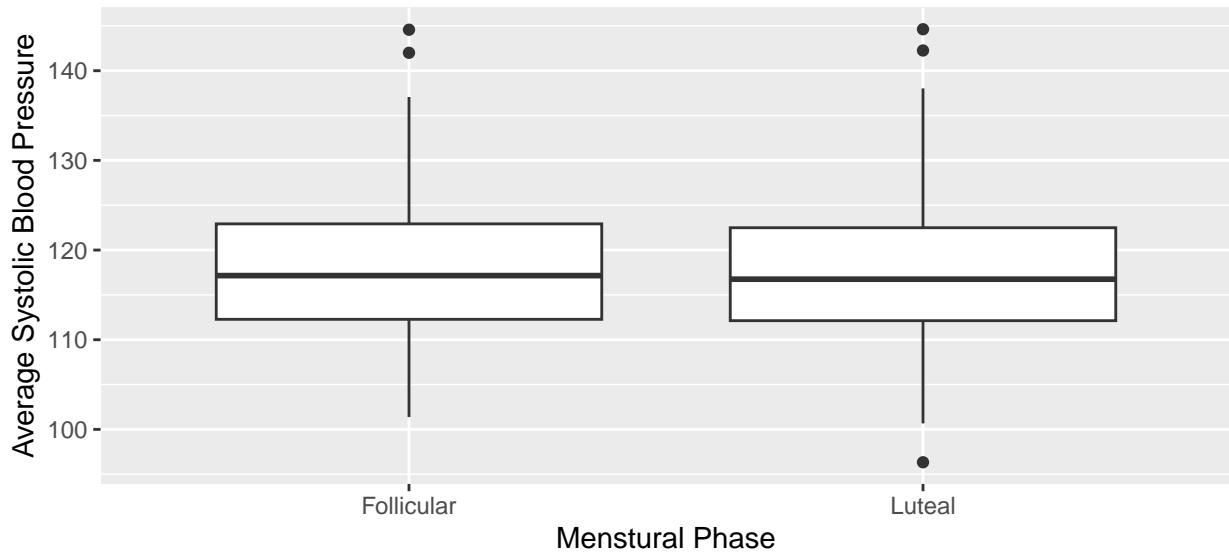
```
ggplot(nurse_filtered, aes(x = mood, y = sys, color = as.factor(snum))) +
  geom_point(alpha = 0.3) + geom_line(stat = "smooth", method = "lm",
se = F, alpha = 0.8) + labs(x = "Mood", y = "BP", title = "BP vs. Mood",
color = "Subject ID") + guides(color = "none")
```

BP vs. Mood

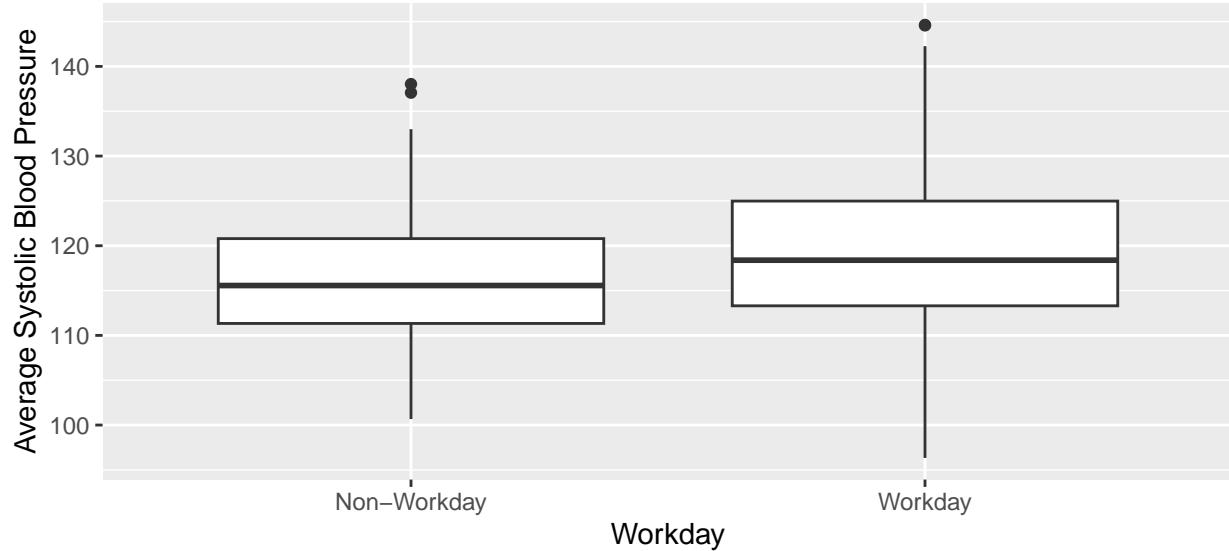


Level 2 Covariates

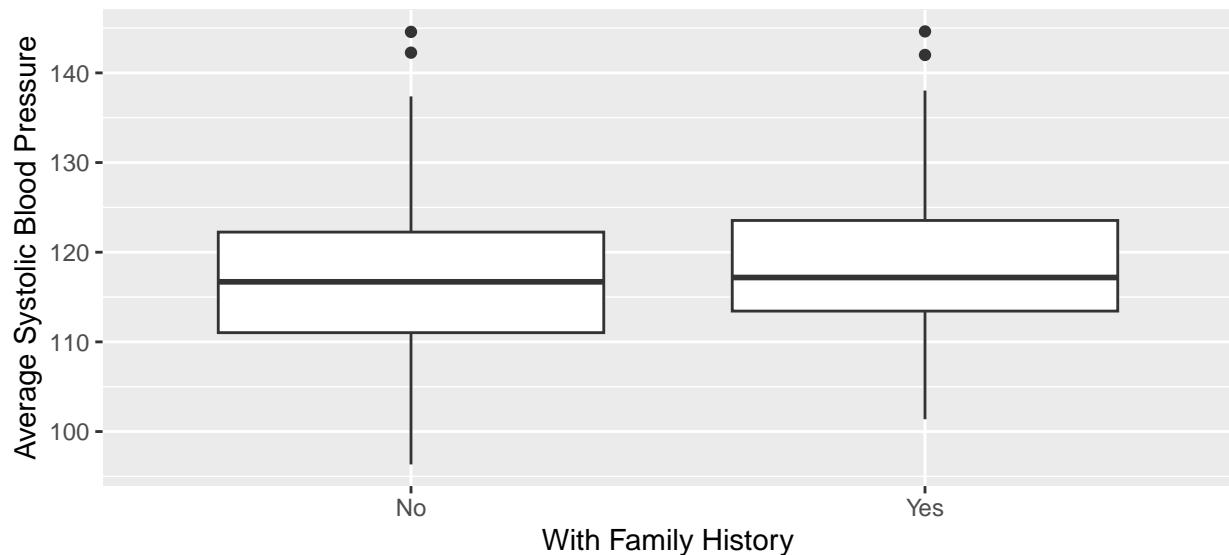
```
## Bivariate
ggplot(nurse_bysubject, aes(x = phase3, y = mean_sys)) + geom_boxplot() +
  labs(x = "Menstural Phase", y = "Average Systolic Blood Pressure")
```



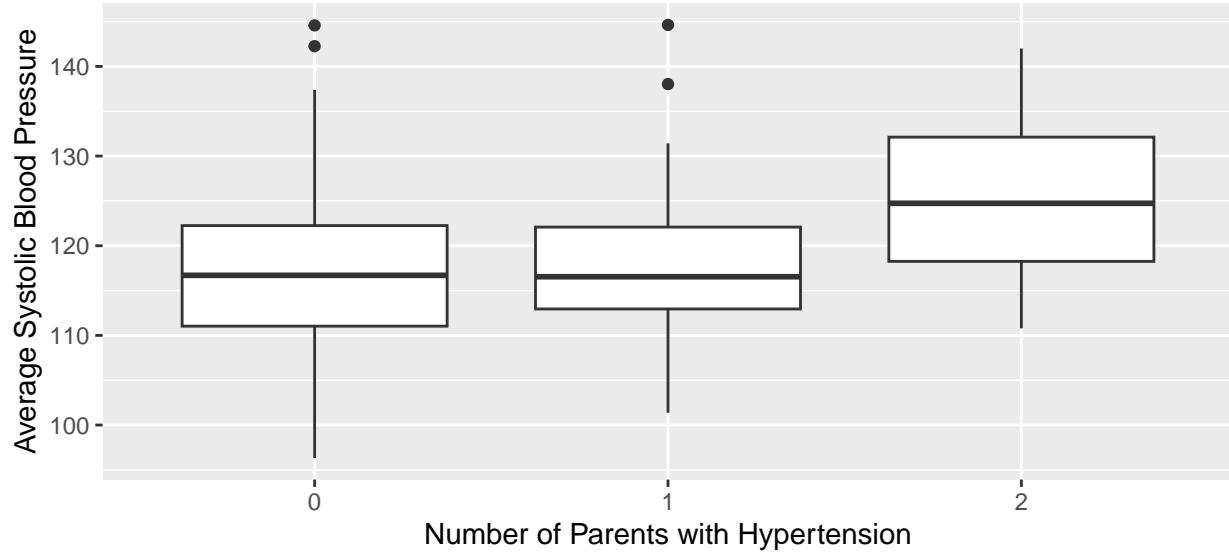
```
ggplot(nurse_bysubject, aes(x = day3, y = mean_sys)) + geom_boxplot() +
  labs(x = "Workday", y = "Average Systolic Blood Pressure")
```



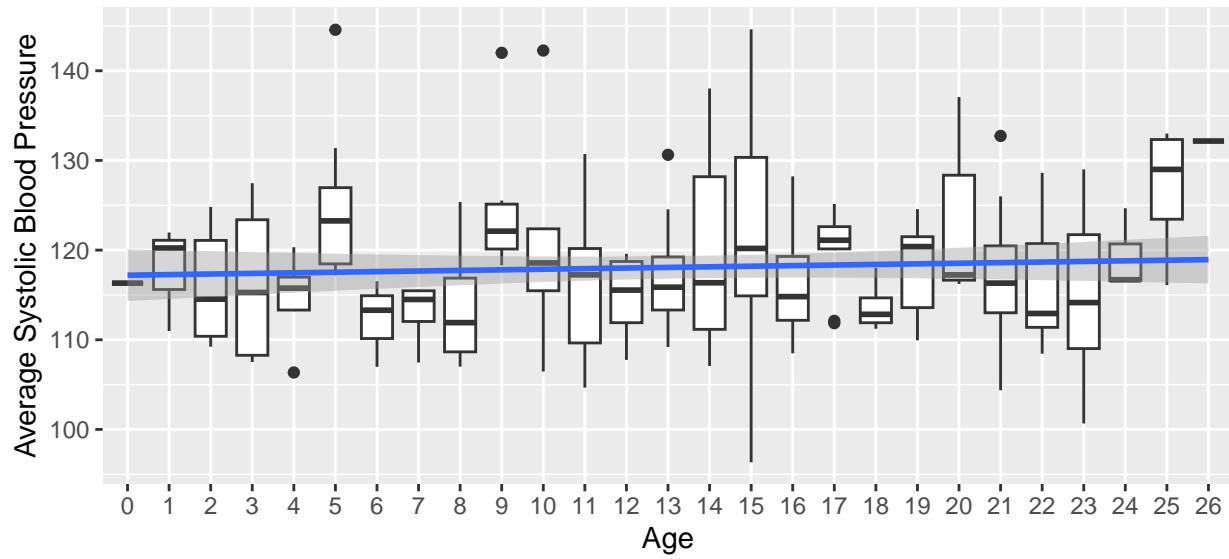
```
ggplot(nurse_bysubject, aes(x = fh_2, y = mean_sys)) + geom_boxplot() +
  labs(x = "With Family History", y = "Average Systolic Blood Pressure")
```



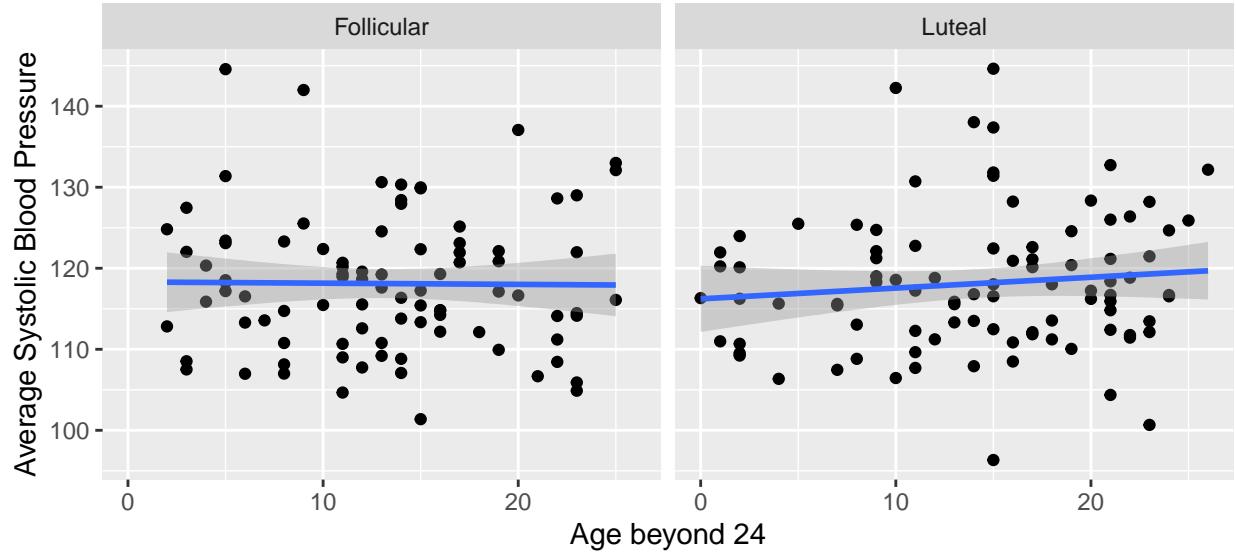
```
ggplot(nurse_bysubject, aes(x = fh123, y = mean_sys)) + geom_boxplot() +
  labs(x = "Number of Parents with Hypertension", y = "Average Systolic Blood Pressure")
```



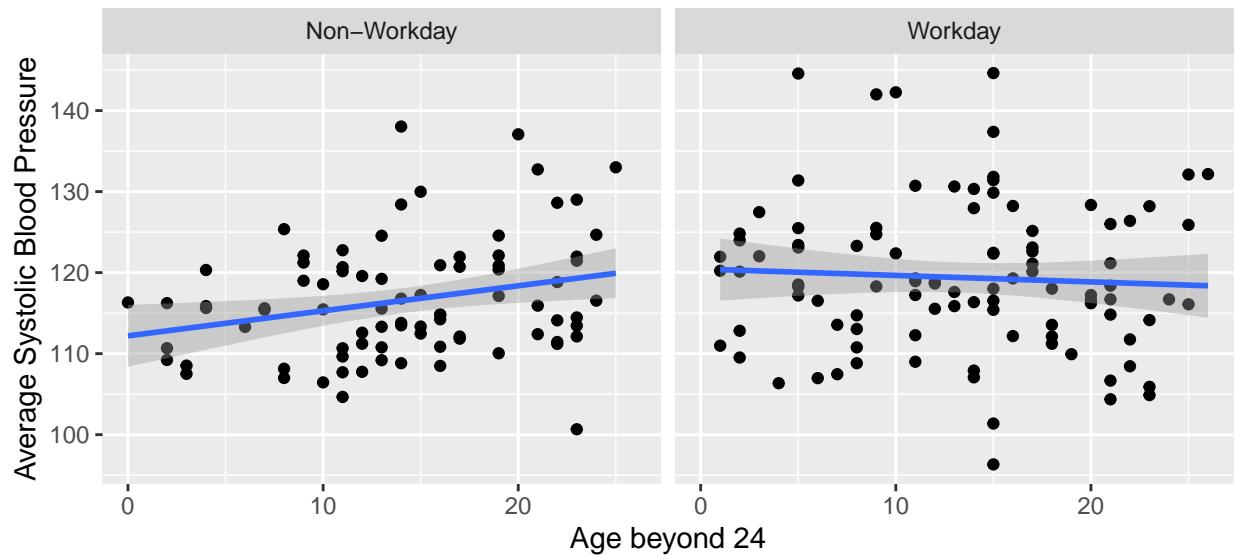
```
ggplot(nurse_bysubject, aes(x = as.factor(age2), y = mean_sys)) +
  geom_boxplot(show.legend = F) + geom_smooth(method = "lm",
  se = TRUE, aes(group = 1)) + labs(x = "Age", y = "Average Systolic Blood Pressure")
```



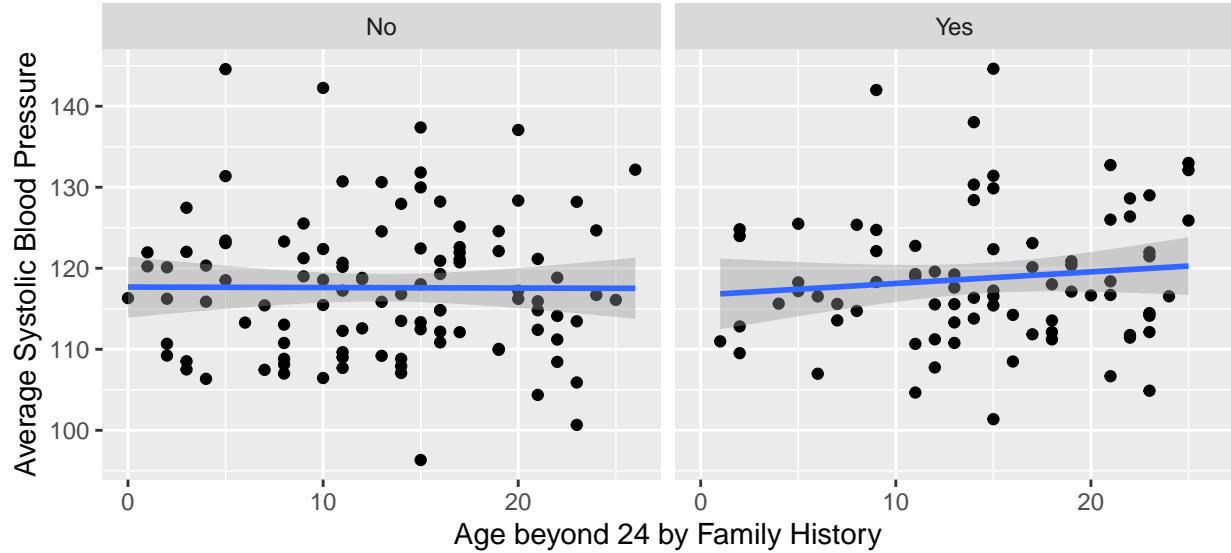
```
## By age
ggplot(nurse_bysubject, aes(x = age2, y = mean_sys)) + geom_point() +
  geom_smooth(method = "lm") + facet_wrap(~phase3) + labs(x = "Age beyond 24",
  y = "Average Systolic Blood Pressure")
```



```
ggplot(nurse_bysubject, aes(x = age2, y = mean_sys)) + geom_point() +
  geom_smooth(method = "lm") + facet_wrap(~day3) + labs(x = "Age beyond 24",
  y = "Average Systolic Blood Pressure")
```



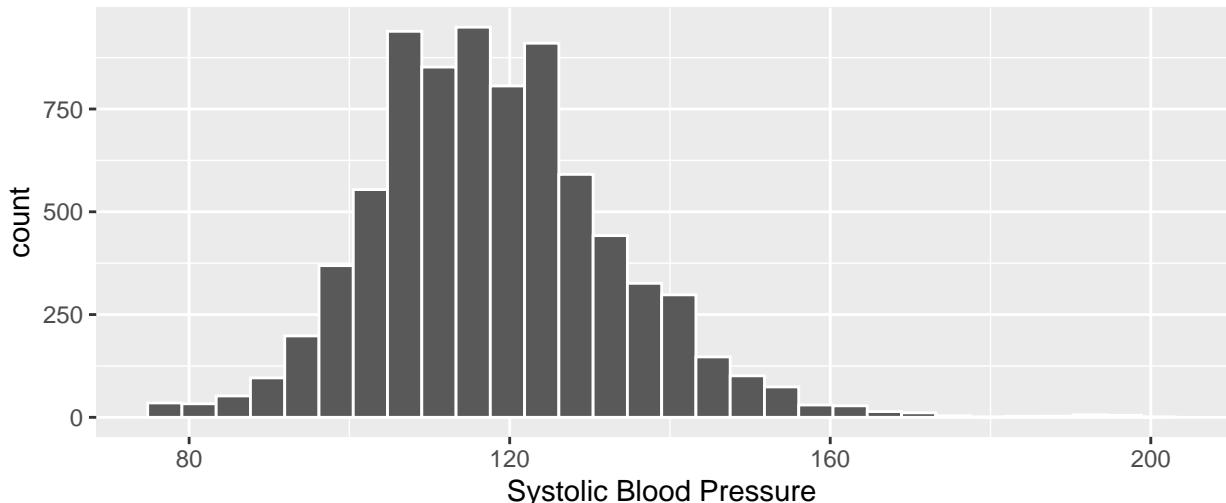
```
ggplot(nurse_bysubject, aes(x = age2, y = mean_sys)) + geom_point() +
  geom_smooth(method = "lm") + facet_wrap(~fh_2) + labs(x = "Age beyond 24 by Family History",
  y = "Average Systolic Blood Pressure")
```



Level 1 by Level 2 Covariates

```
ggplot(nurse_filtered, aes(x = sys)) + geom_histogram(color = "white") +
  labs(x = "Systolic Blood Pressure", title = "Level 1 BP Distribution")
```

Level 1 BP Distribution

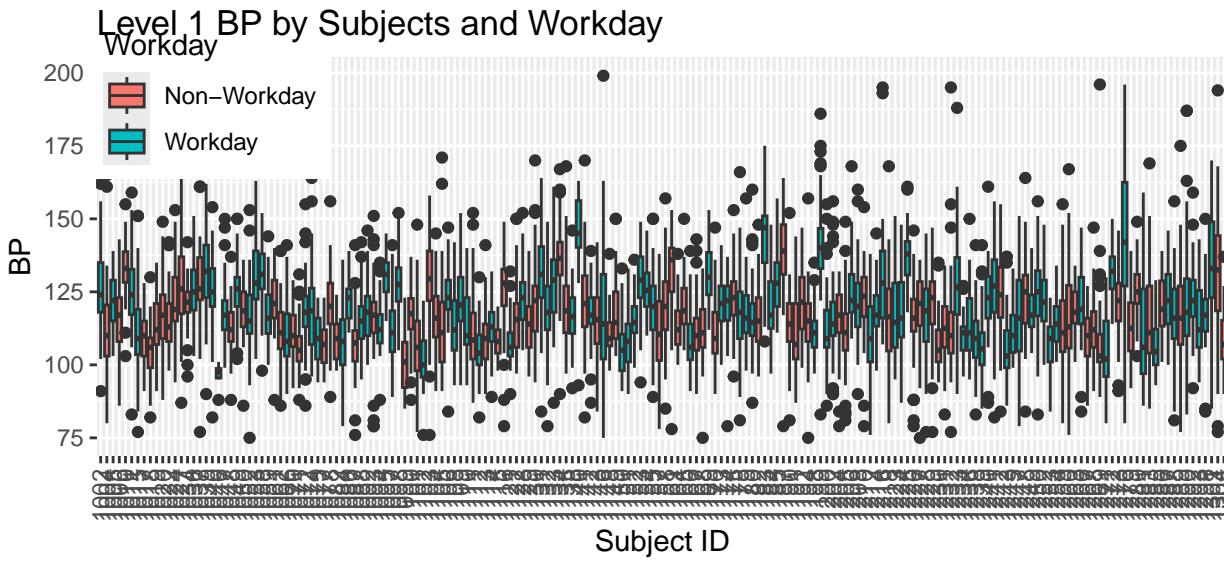


```
ggplot(nurse_filtered, aes(x = fh_2, y = sys)) + geom_boxplot() +
  facet_wrap(~day3) + labs(x = "Family History", y = "Systolic Blood Pressure",
  title = "Level 1 BP by Workday and Family History")
```

Level 1 BP by Workday and Family History

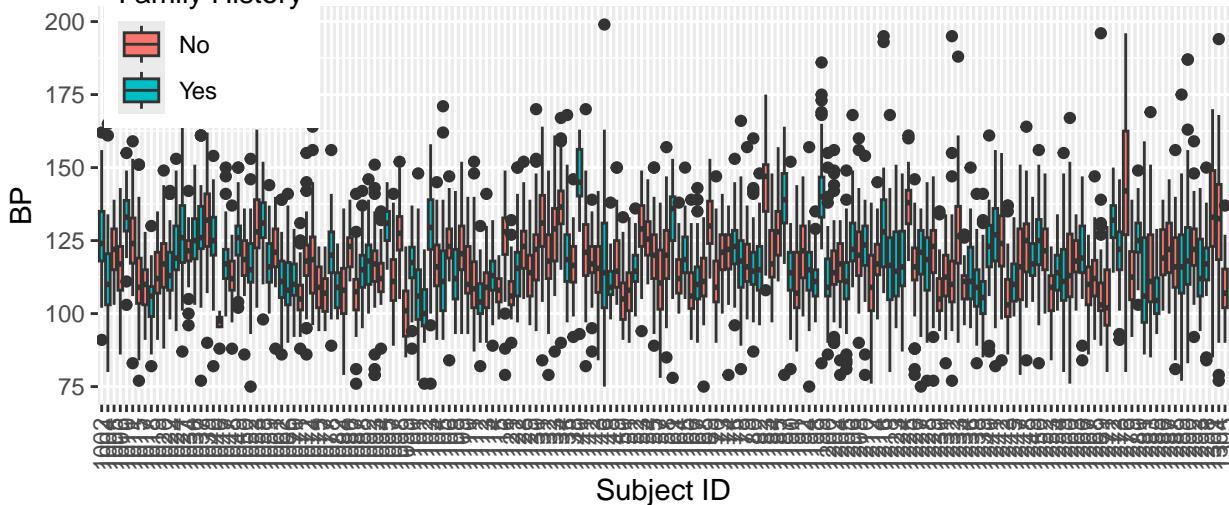


```
ggplot(nurse_filtered, aes(x = as.factor(snum), y = sys, fill = day3)) +
  geom_boxplot() + labs(x = "Subject ID", y = "BP", title = "Level 1 BP by Subjects and Workday",
  fill = "Workday") + theme(axis.text.x = element_text(angle = 90,
  vjust = 0.5, hjust = 1), legend.position = c(0.1, 0.9))
```



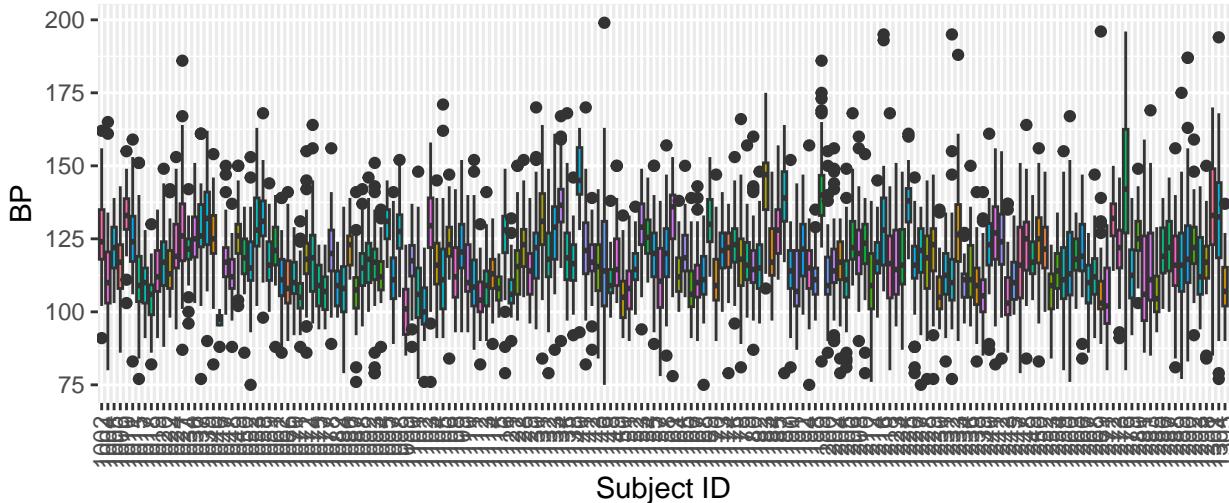
```
ggplot(nurse_filtered, aes(x = as.factor(snum), y = sys, fill = fh_2)) +
  geom_boxplot() + labs(x = "Subject ID", y = "BP", title = "Level 1 BP by Subjects and Family History",
  fill = "Family History") + theme(axis.text.x = element_text(angle = 90,
  vjust = 0.5, hjust = 1), legend.position = c(0.1, 0.9))
```

Level 1 BP by Subjects and Family History



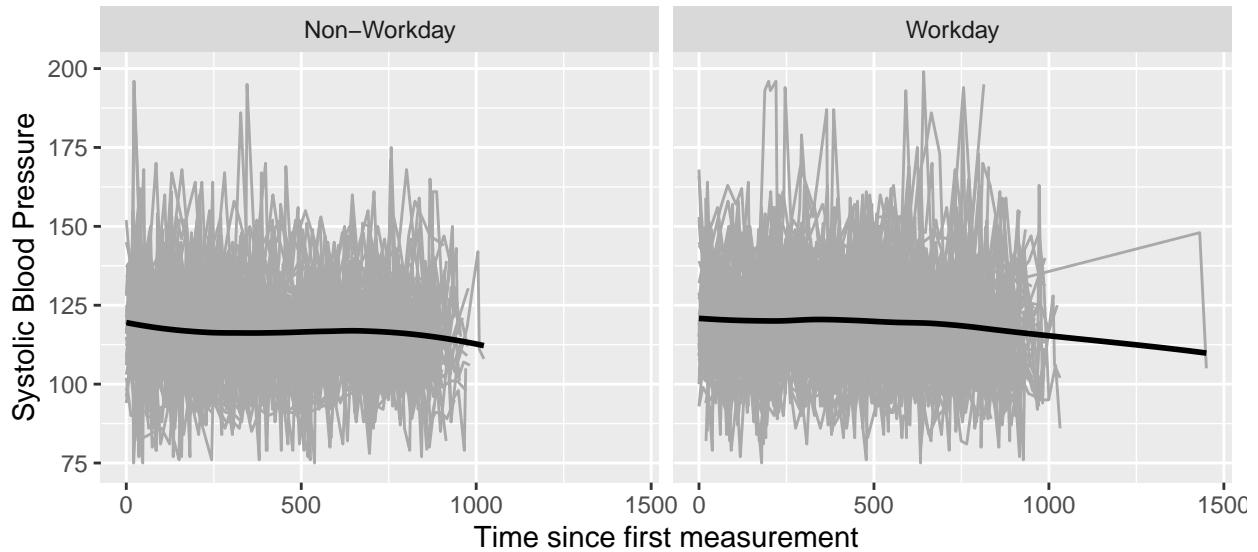
```
ggplot(nurse_filtered, aes(x = as.factor(snum), y = sys, fill = as.factor(age24))) +
  geom_boxplot() + labs(x = "Subject ID", y = "BP", title = "Level 1 BP by Subjects and Age",
  fill = "Age") + theme(axis.text.x = element_text(angle = 90,
  vjust = 0.5, hjust = 1)) + guides(fill = "none")
```

Level 1 BP by Subjects and Age

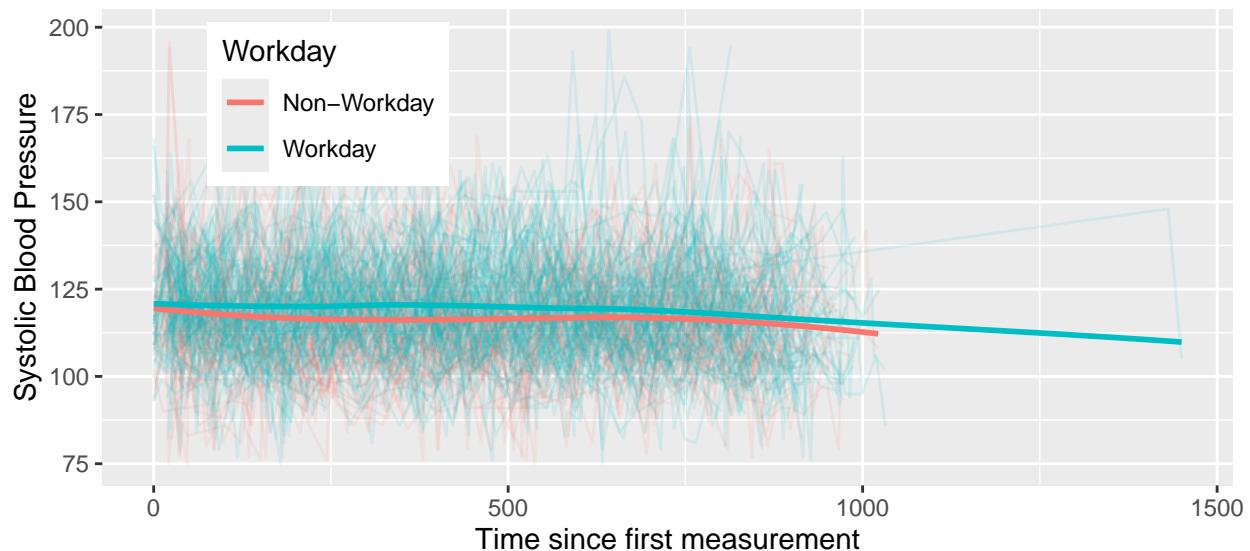


Spaghetti Plots

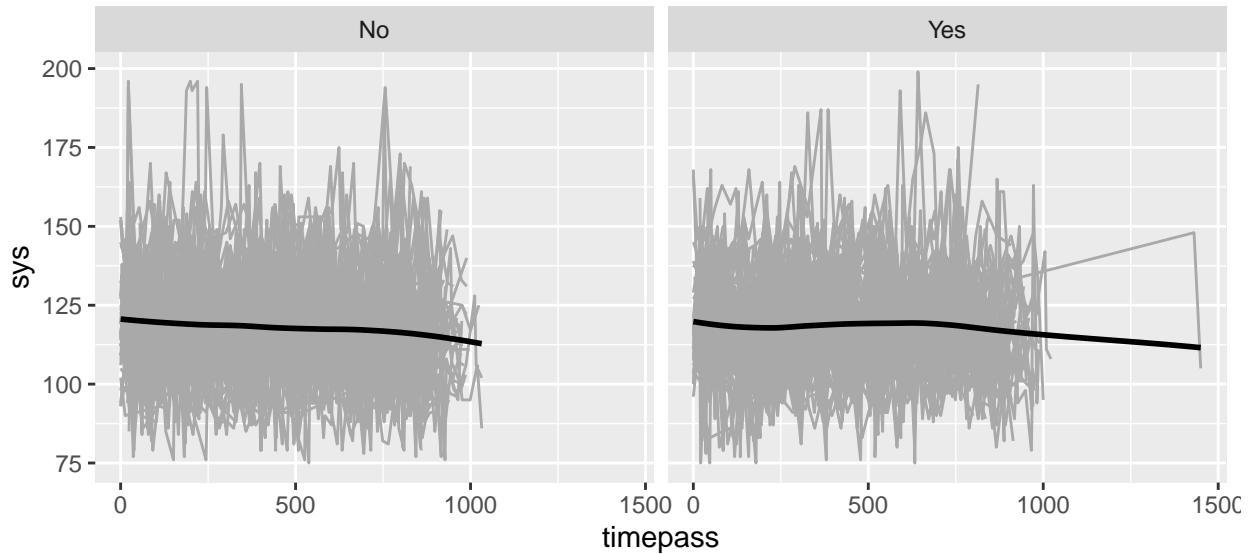
```
## Time
ggplot(nurse_filtered, aes(x = timepass, y = sys)) + geom_line(aes(group = snum),
  color = "dark grey") + geom_smooth(method = "loess", color = "black",
  se = F, size = 1) + facet_wrap(~day3) + labs(x = "Time since first measurement",
  y = "Systolic Blood Pressure")
```



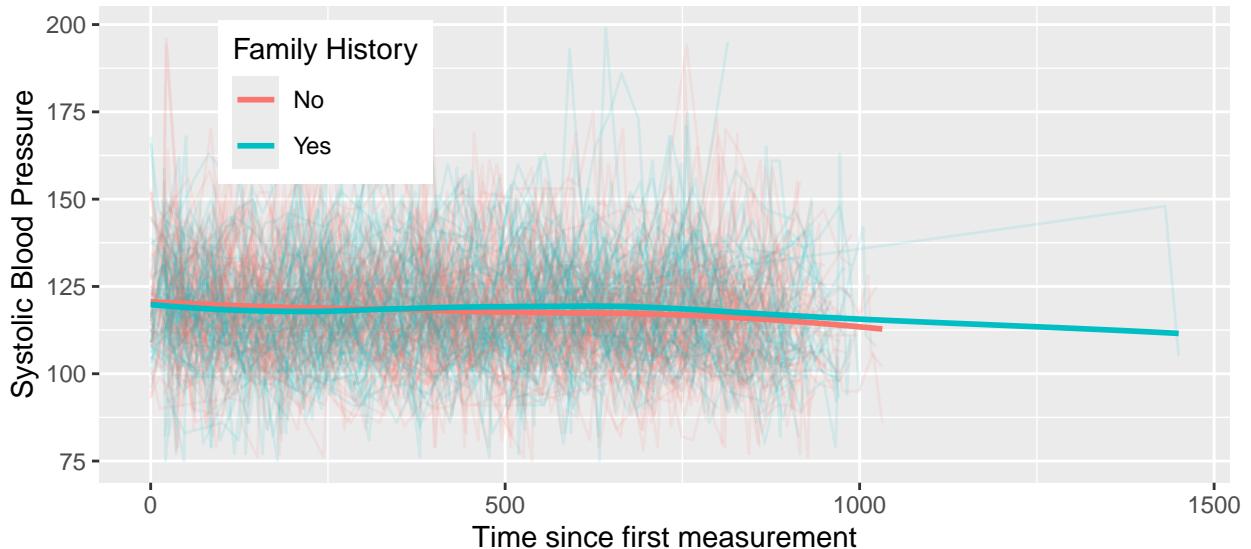
```
ggplot(nurse_filtered, aes(x = timepass, y = sys, color = as.factor(day3))) +
  geom_line(aes(group = interaction(snum, day)), alpha = 0.1) +
  geom_smooth(method = "loess", se = FALSE, size = 1) + labs(color = "Workday",
  x = "Time since first measurement", y = "Systolic Blood Pressure") +
  theme(legend.position = c(0.2, 0.8))
```



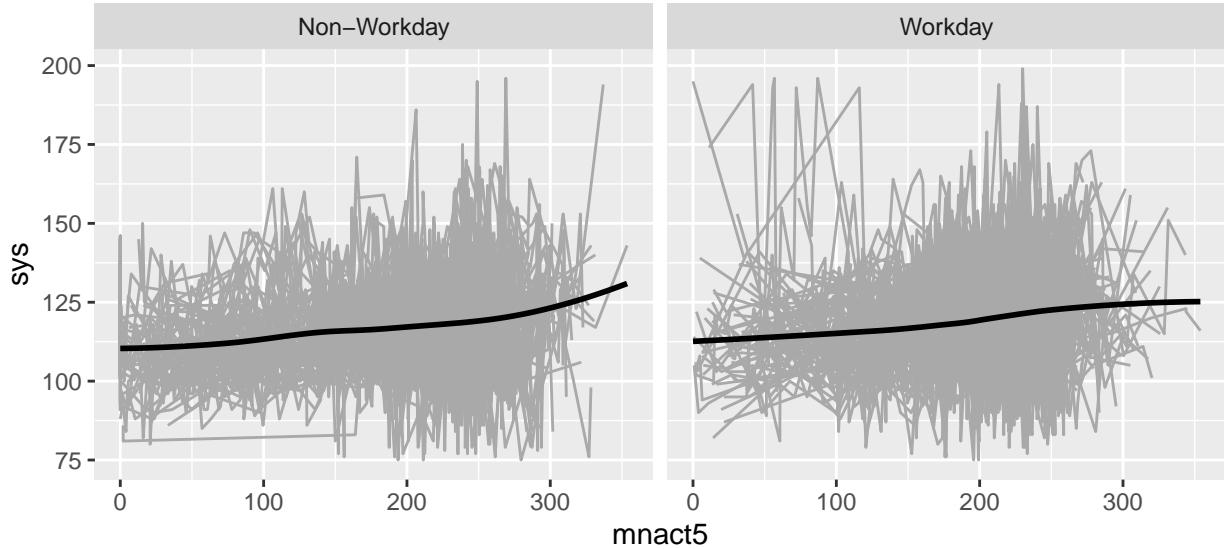
```
ggplot(nurse_filtered, aes(x = timepass, y = sys)) + geom_line(aes(group = snum),
  color = "dark grey") + geom_smooth(method = "loess", color = "black",
  se = F, size = 1) + facet_wrap(~fh_2)
```



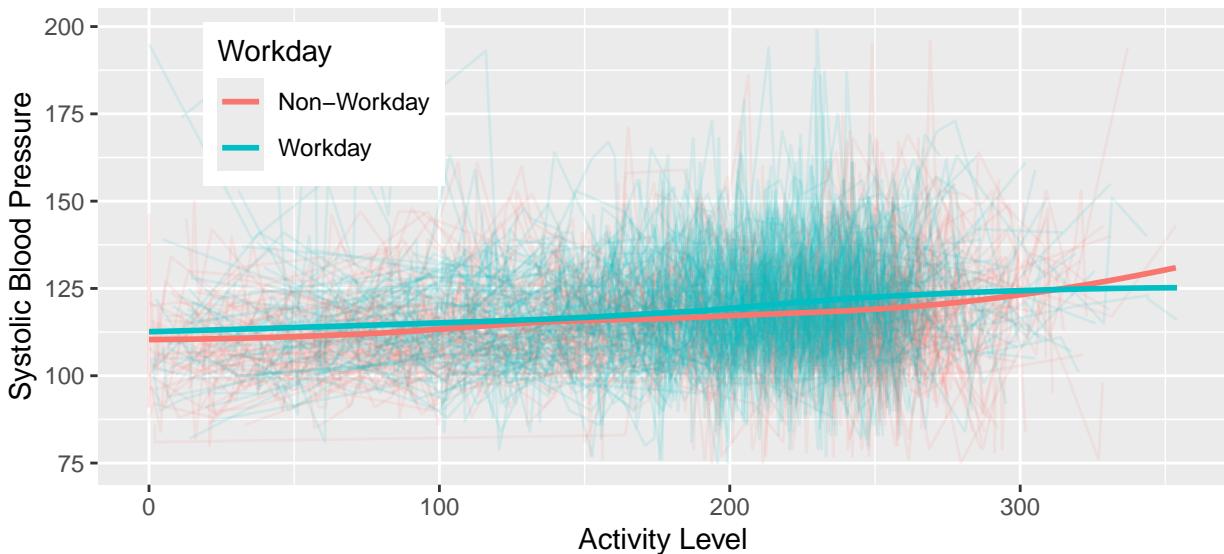
```
ggplot(nurse_filtered, aes(x = timepass, y = sys, color = as.factor(fh_2))) +
  geom_line(aes(group = interaction(snum, day)), alpha = 0.1) +
  geom_smooth(method = "loess", se = FALSE, size = 1) + labs(color = "Family History",
  x = "Time since first measurement", y = "Systolic Blood Pressure") +
  theme(legend.position = c(0.2, 0.8))
```



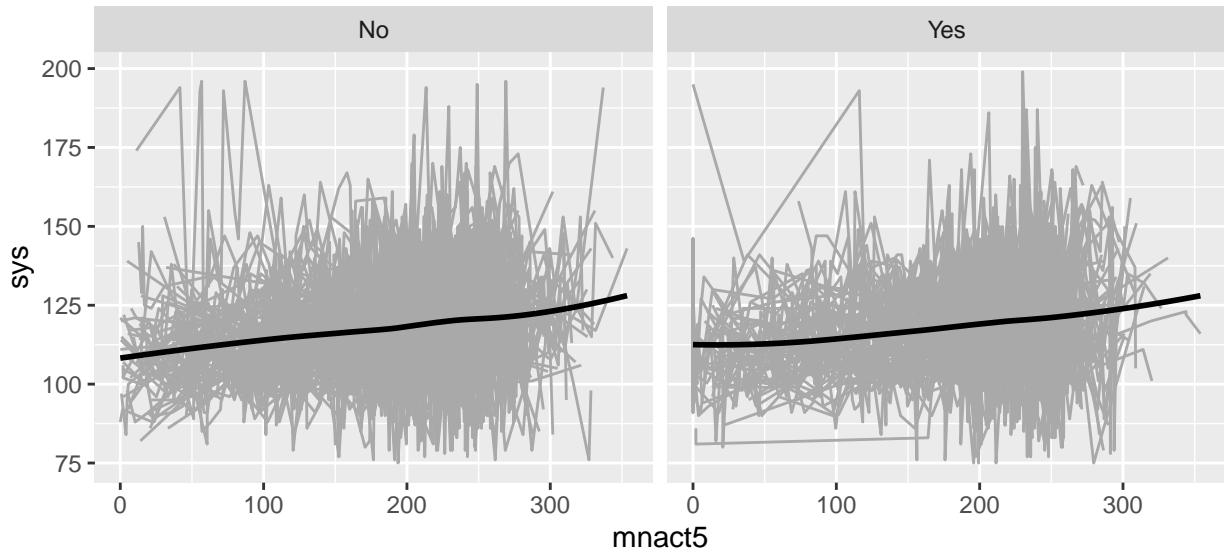
```
## Activity level
ggplot(nurse_filtered, aes(x = mnact5, y = sys)) + geom_line(aes(group = snum),
  color = "dark grey") + geom_smooth(method = "loess", color = "black",
  se = F, size = 1) + facet_wrap(~day3)
```



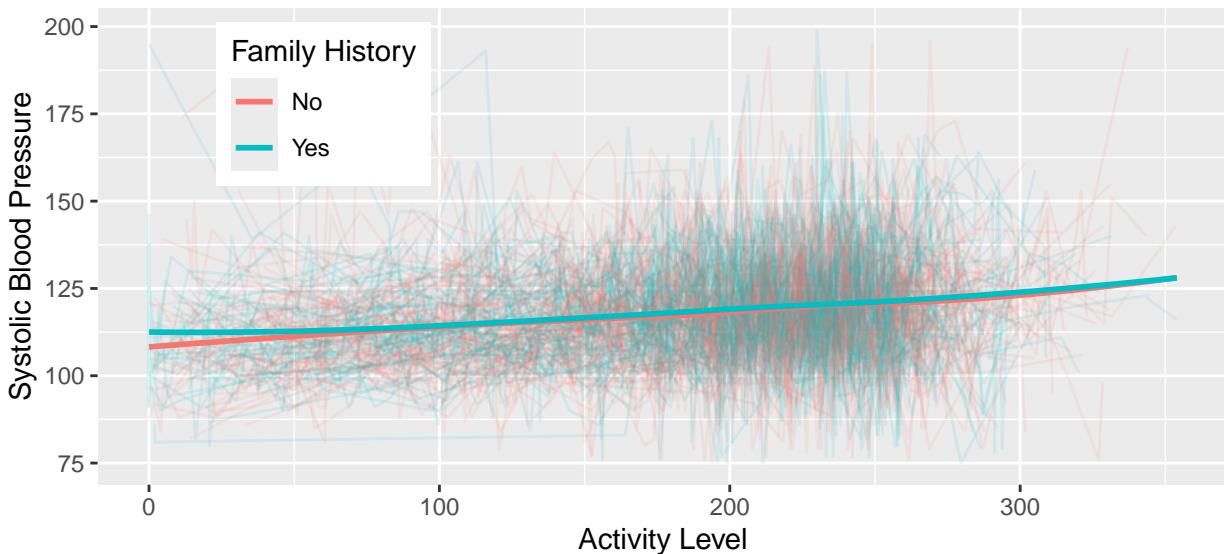
```
ggplot(nurse_filtered, aes(x = mnact5, y = sys, color = as.factor(day3))) +
  geom_line(aes(group = interaction(snum, day)), alpha = 0.1) +
  geom_smooth(method = "loess", se = FALSE, size = 1) + labs(color = "Workday",
  x = "Activity Level", y = "Systolic Blood Pressure") + theme(legend.position = c(0.2,
  0.8))
```



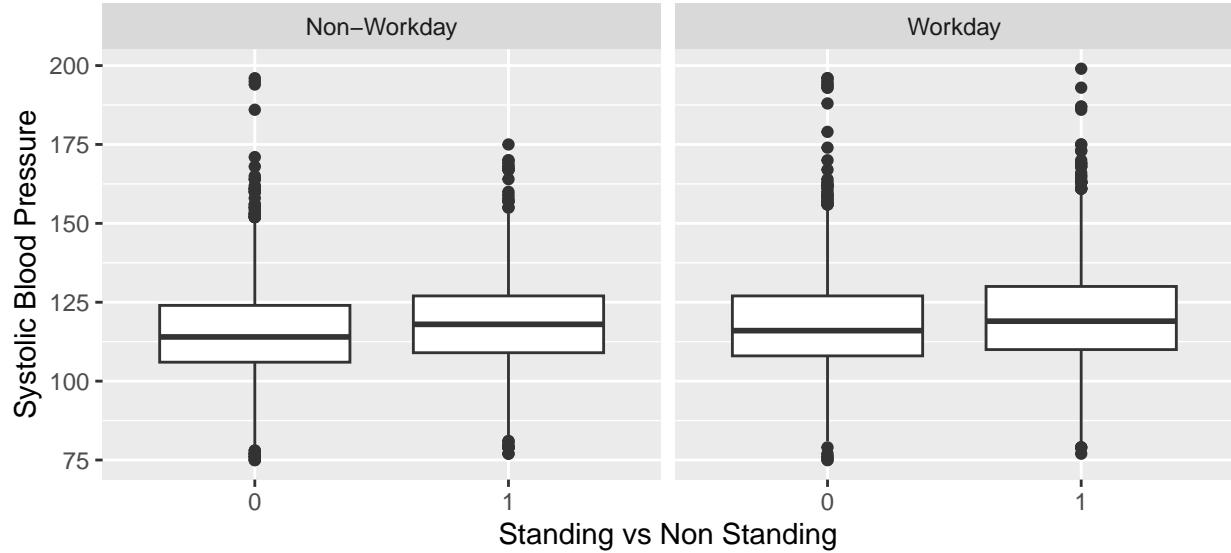
```
ggplot(nurse_filtered, aes(x = mnact5, y = sys)) + geom_line(aes(group = snum),
  color = "dark grey") + geom_smooth(method = "loess", color = "black",
  se = F, size = 1) + facet_wrap(~fh_2)
```



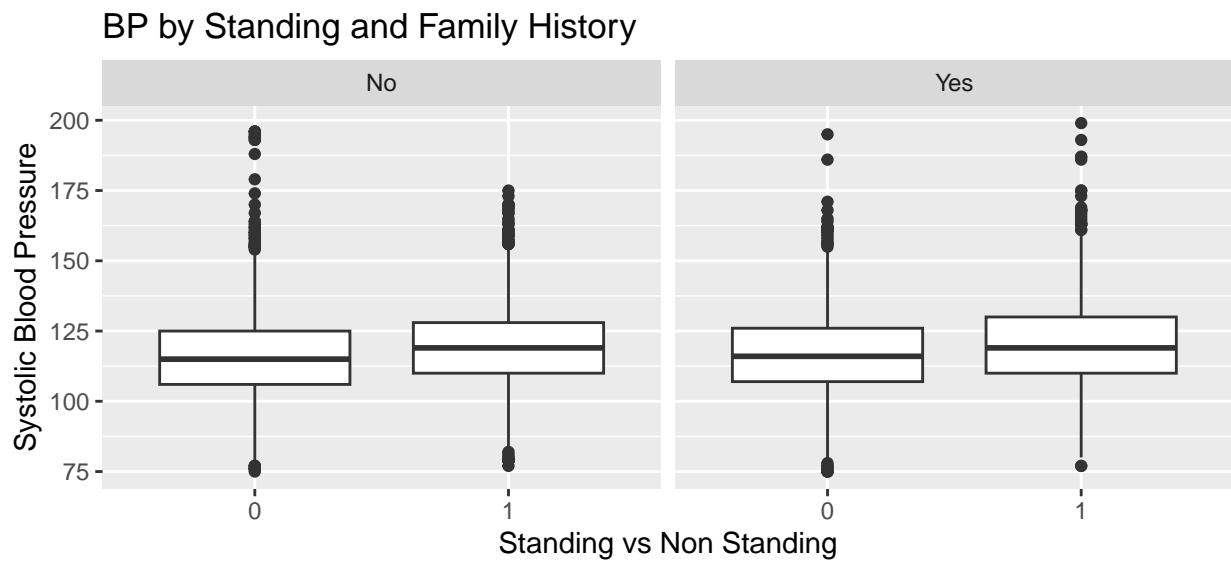
```
ggplot(nurse_filtered, aes(x = mnact5, y = sys, color = as.factor(fh_2))) +
  geom_line(aes(group = interaction(snum, day)), alpha = 0.1) +
  geom_smooth(method = "loess", se = FALSE, size = 1) + labs(color = "Family History",
  x = "Activity Level", y = "Systolic Blood Pressure") + theme(legend.position = c(0.2,
  0.8))
```



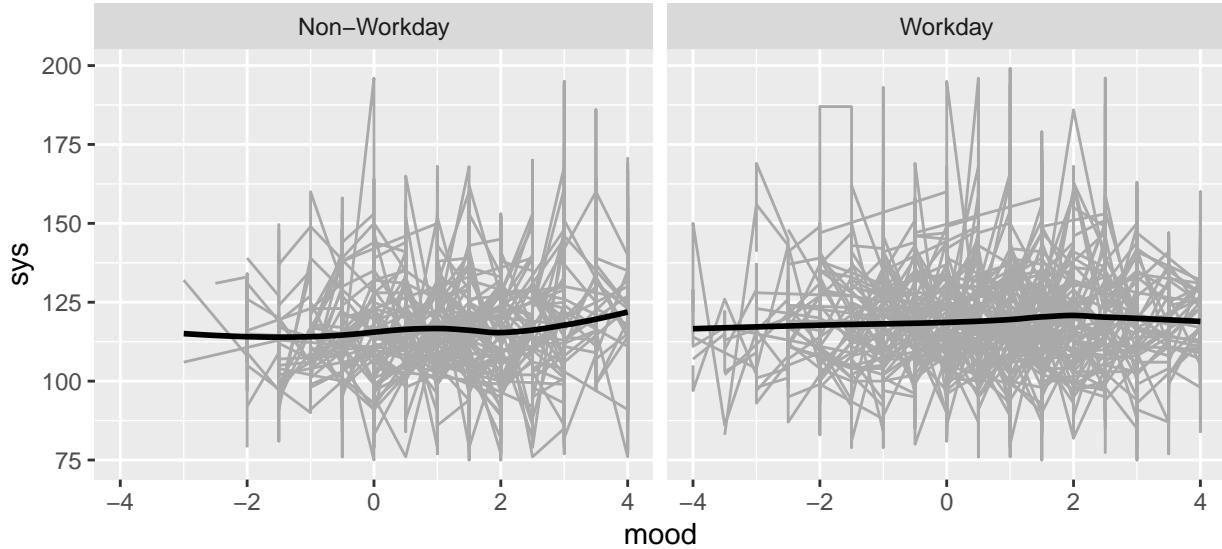
```
## Posture - 2 levels
ggplot(nurse_filtered, aes(x = standing, y = sys)) + geom_boxplot() +
  facet_wrap(~day3) + labs(x = "Standing vs Non Standing",
  y = "Systolic Blood Pressure")
```



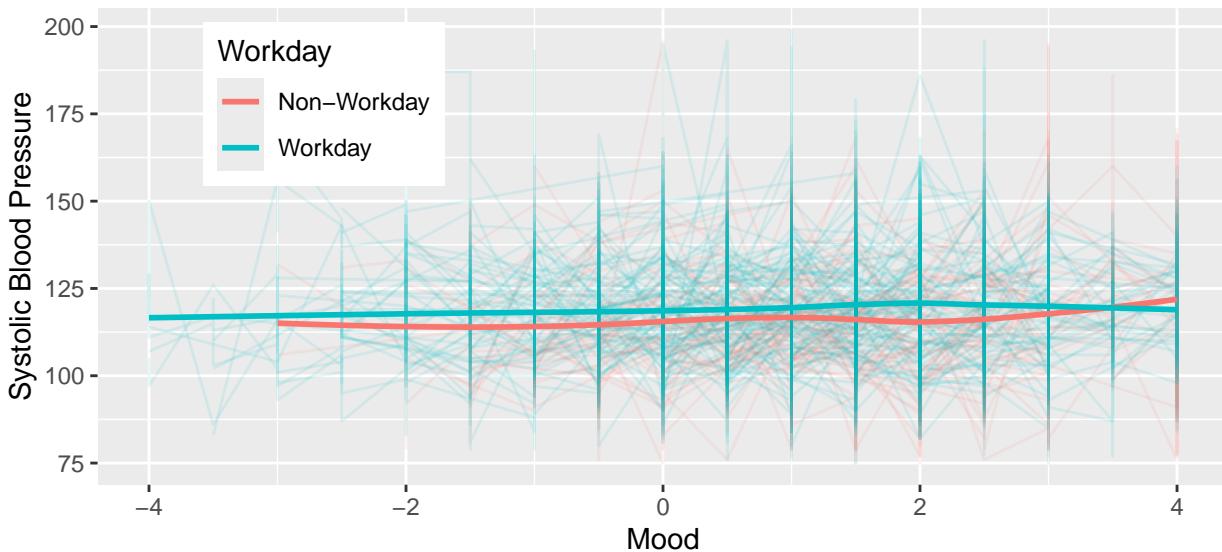
```
ggplot(nurse_filtered, aes(x = standing, y = sys)) + geom_boxplot() +
  facet_wrap(~fh_2) + labs(x = "Standing vs Non Standing",
  y = "Systolic Blood Pressure", title = "BP by Standing and Family History")
```



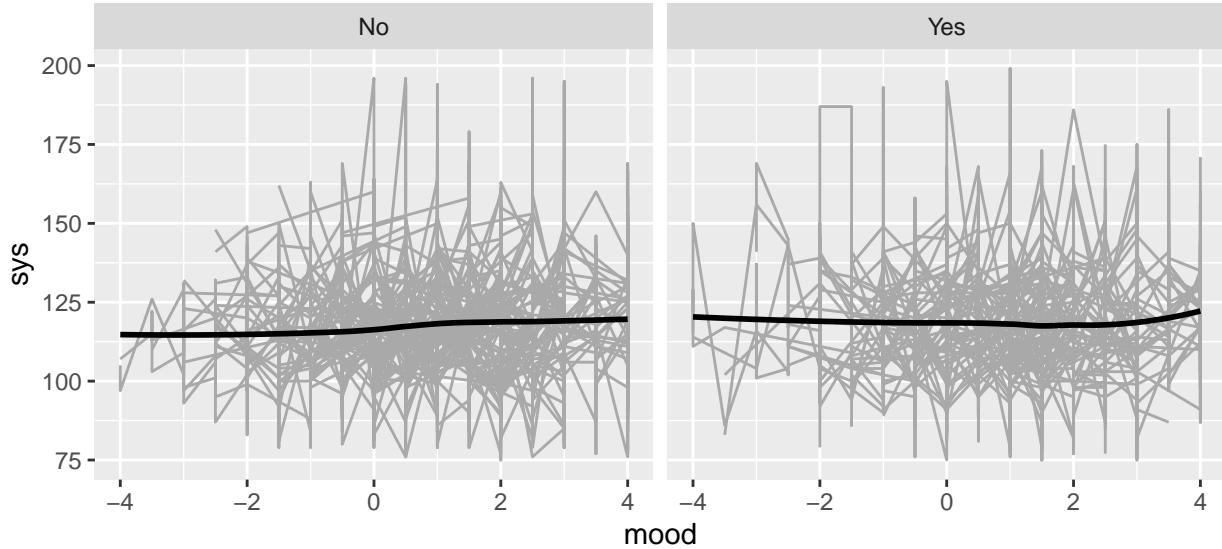
```
## Mood Ratings
ggplot(nurse_filtered, aes(x = mood, y = sys)) + geom_line(aes(group = snum),
  color = "dark grey") + geom_smooth(method = "loess", color = "black",
  se = F, size = 1) + facet_wrap(~day3)
```



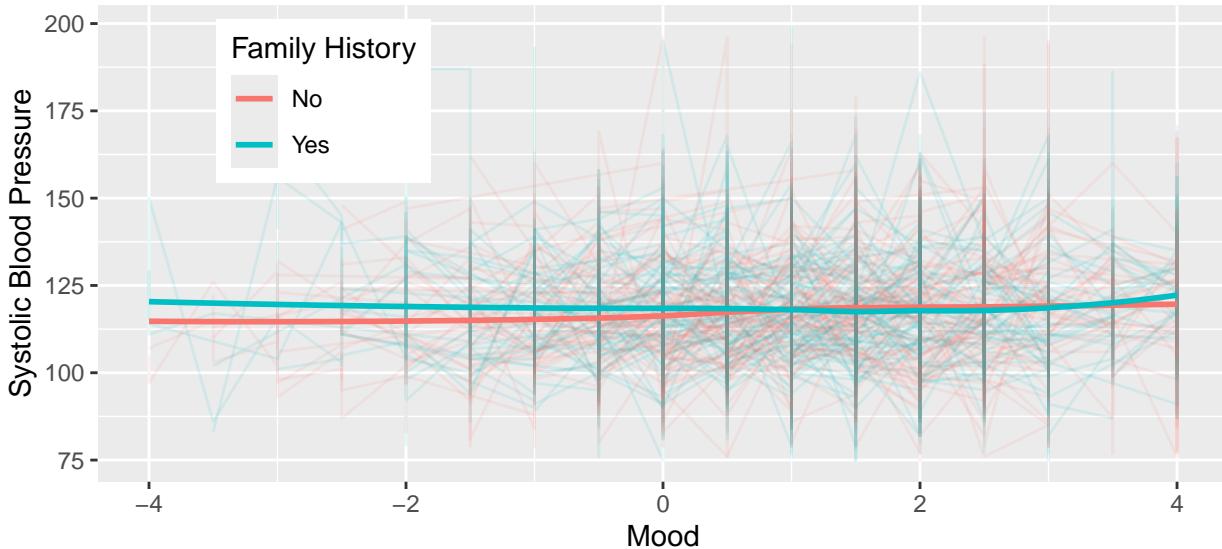
```
ggplot(nurse_filtered, aes(x = mood, y = sys, color = as.factor(day3))) +
  geom_line(aes(group = interaction(snum, day)), alpha = 0.1) +
  geom_smooth(method = "loess", se = FALSE, size = 1) + labs(color = "Workday",
  x = "Mood", y = "Systolic Blood Pressure") + theme(legend.position = c(0.2,
  0.8))
```



```
ggplot(nurse_filtered, aes(x = mood, y = sys)) + geom_line(aes(group = snum),
  color = "dark grey") + geom_smooth(method = "loess", color = "black",
  se = F, size = 1) + facet_wrap(~fh_2)
```



```
ggplot(nurse_filtered, aes(x = mood, y = sys, color = fh_2)) +
  geom_line(aes(group = interaction(snum, day)), alpha = 0.1) +
  geom_smooth(method = "loess", se = FALSE, size = 1) + labs(color = "Family History",
  x = "Mood", y = "Systolic Blood Pressure") + theme(legend.position = c(0.2,
  0.8))
```

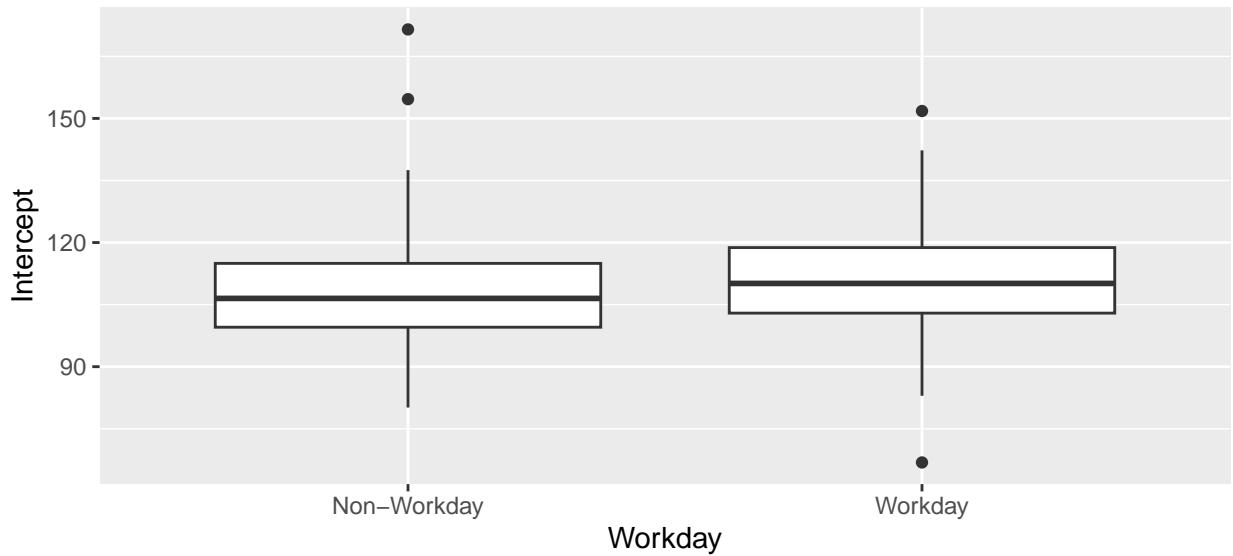


Separate MLR

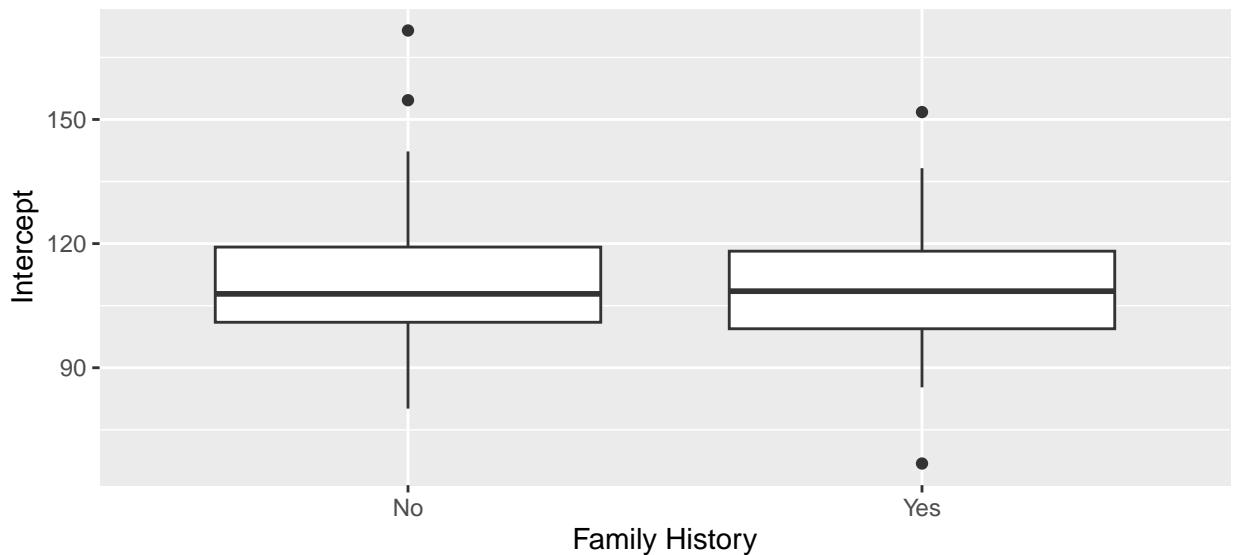
```
ls_fits <- group_modify(group_by(nurse_complete, snum), ~tidy(lm(sys ~
  timepass + mnact5 + standing + mood, data = .x))[, 1:2])
ls_fits_final <- ls_fits %>%
  pivot_wider(names_from = term, values_from = estimate) %>%
  rename(Intercept = `Intercept`, Time = timepass, Activity = mnact5,
  Standing = standing, Mood = mood) %>%
  left_join(nurse_bysubject, by = "snum")

## Intercept
ggplot(ls_fits_final, aes(x = day3, y = Intercept)) + geom_boxplot() +
```

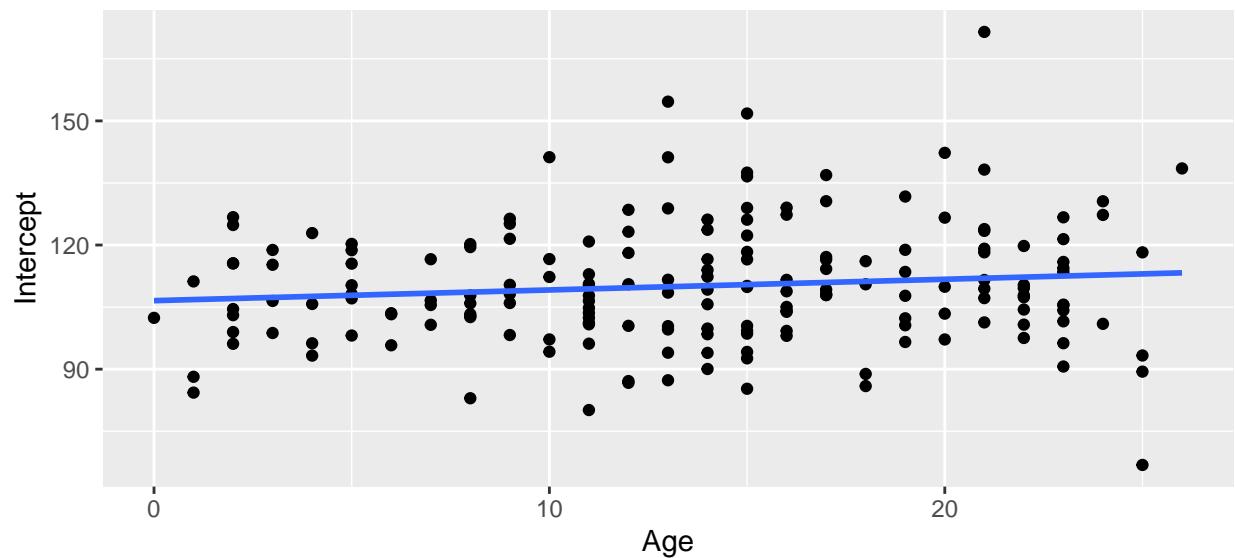
```
labs(x = "Workday")
```



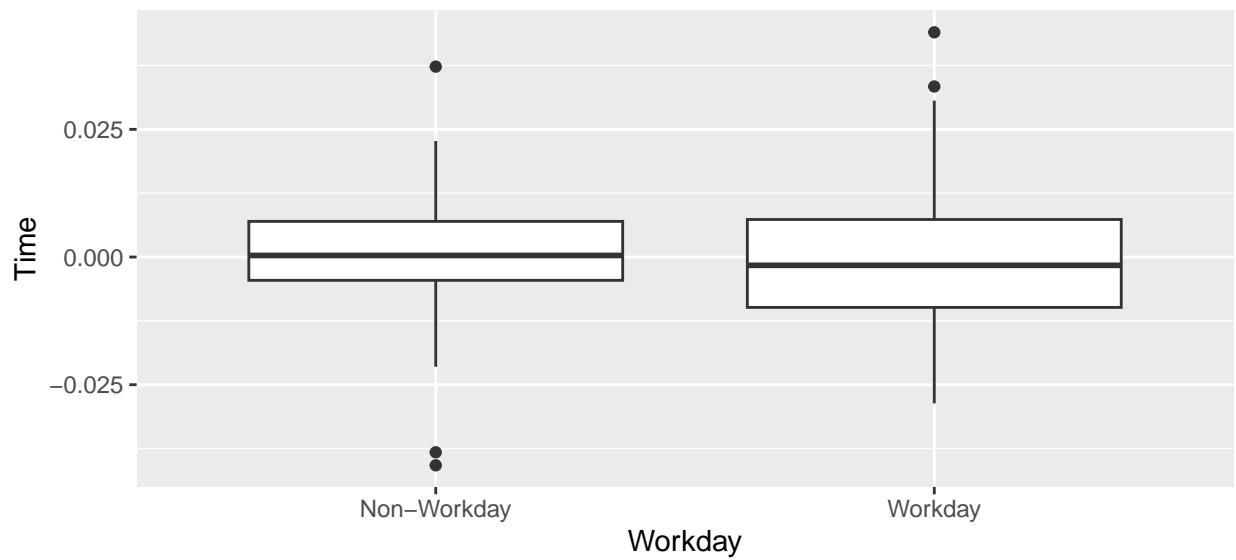
```
ggplot(ls.fits_final, aes(x = fh_2, y = Intercept)) + geom_boxplot() +  
  labs(x = "Family History")
```



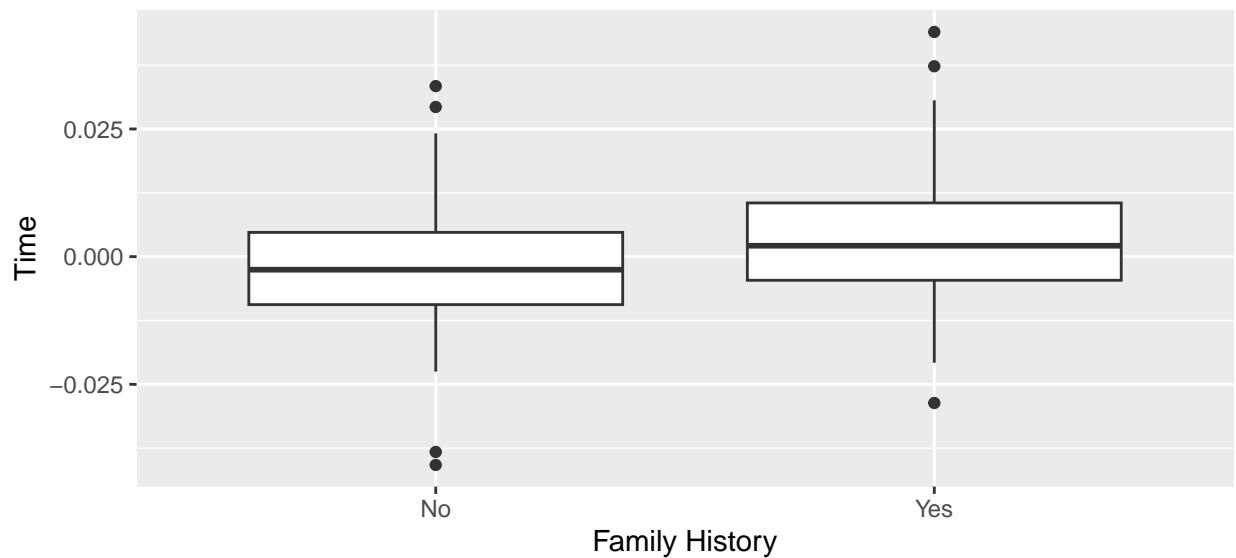
```
ggplot(ls.fits_final, aes(x = age2, y = Intercept)) + geom_point() +  
  geom_smooth(method = "lm", se = F) + labs(x = "Age")
```



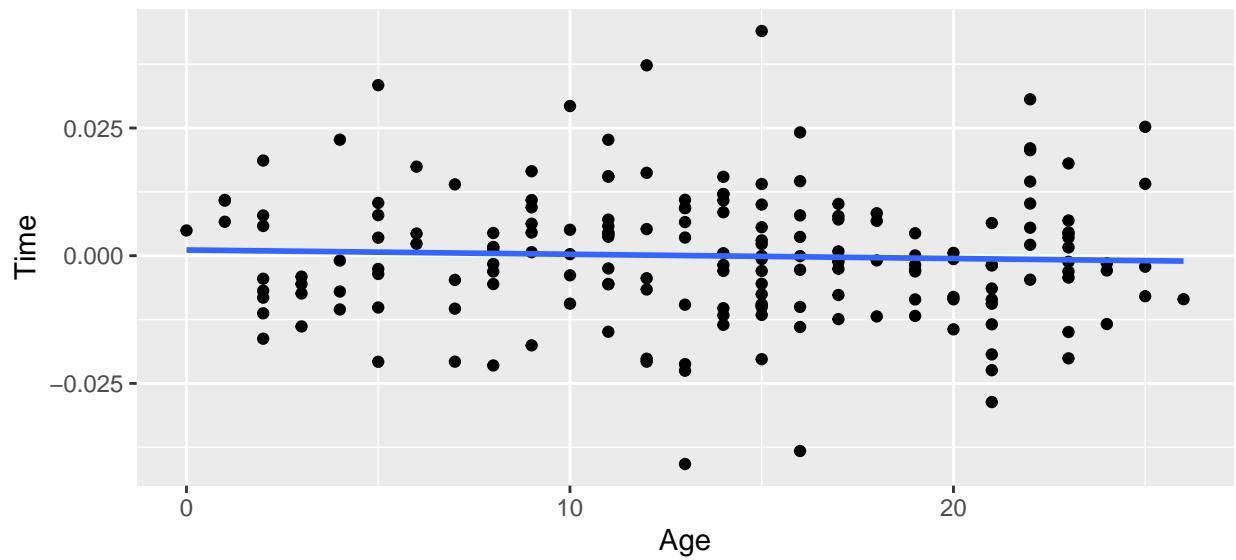
```
## Timepass
ggplot(ls.fits_final, aes(x = day3, y = Time)) + geom_boxplot() +
  labs(x = "Workday")
```



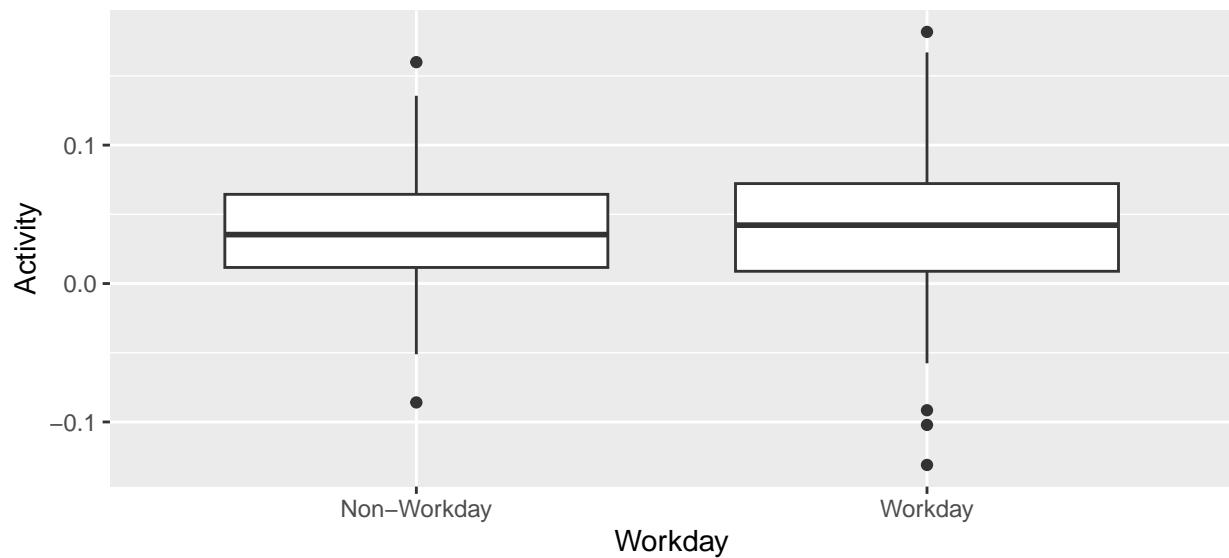
```
ggplot(ls.fits_final, aes(x = fh_2, y = Time)) + geom_boxplot() +
  labs(x = "Family History")
```



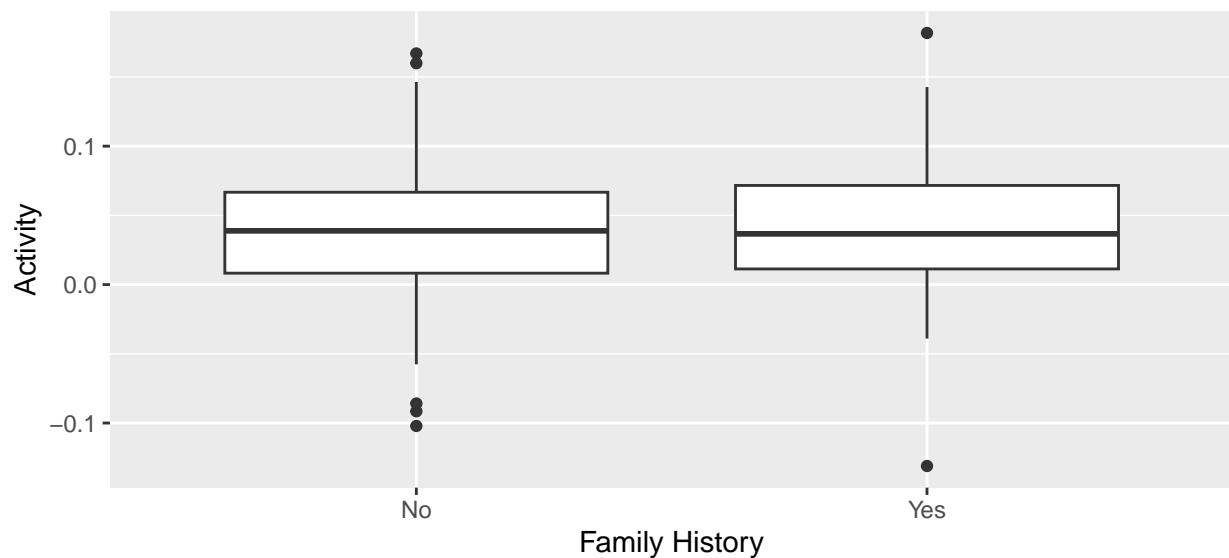
```
ggplot(ls_fits_final, aes(x = age2, y = Time)) + geom_point() +
  geom_smooth(method = "lm", se = F) + labs(x = "Age")
```



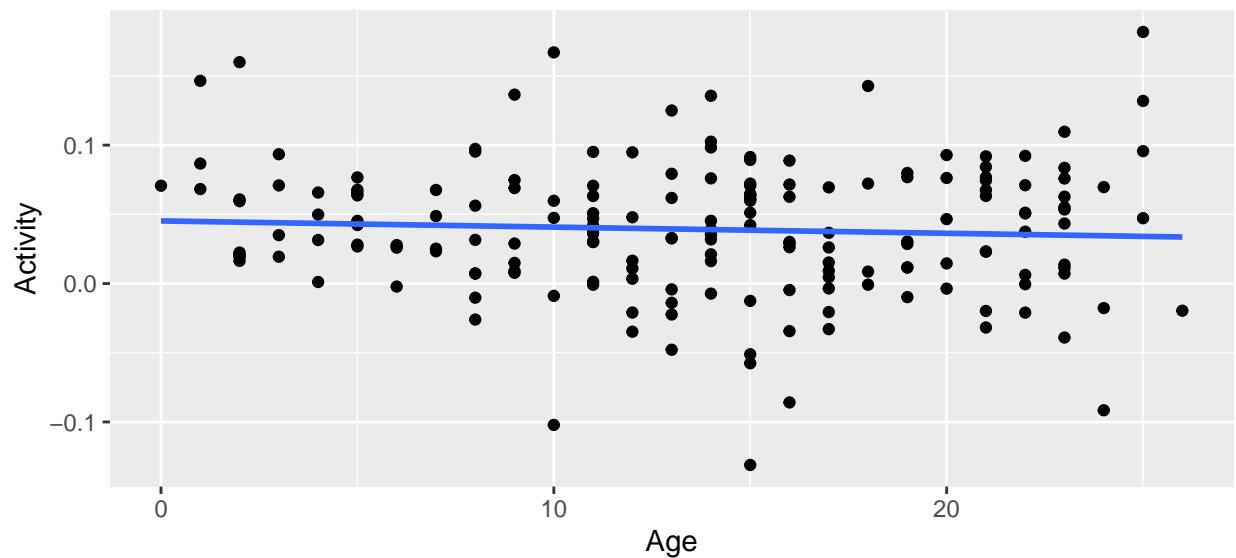
```
## Activity Level
ggplot(ls_fits_final, aes(x = day3, y = Activity)) + geom_boxplot() +
  labs(x = "Workday")
```



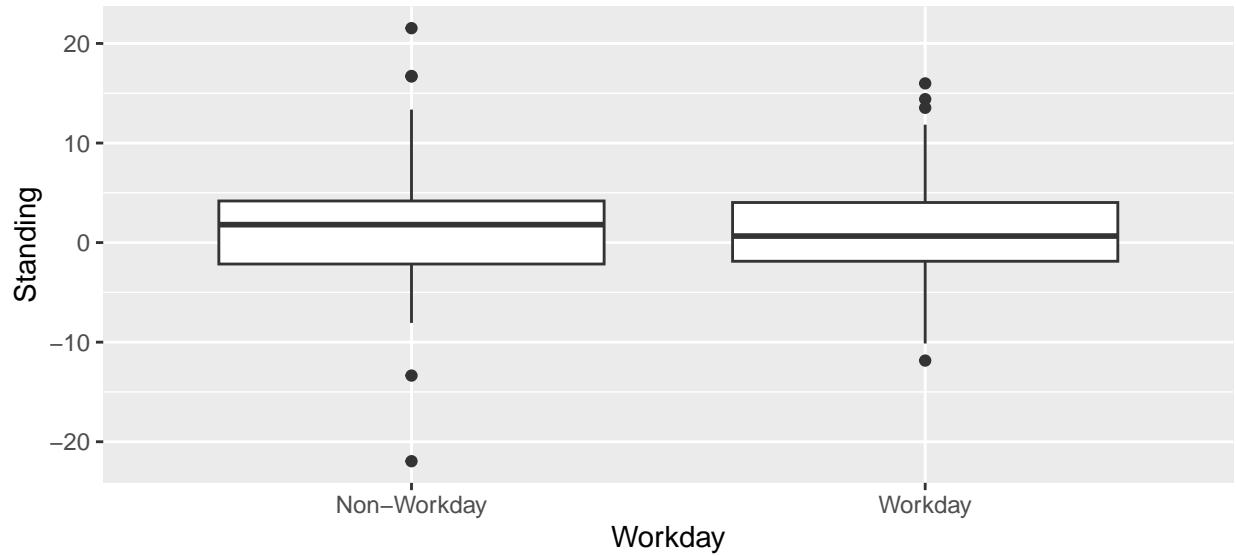
```
ggplot(ls_fits_final, aes(x = fh_2, y = Activity)) + geom_boxplot() +
  labs(x = "Family History")
```



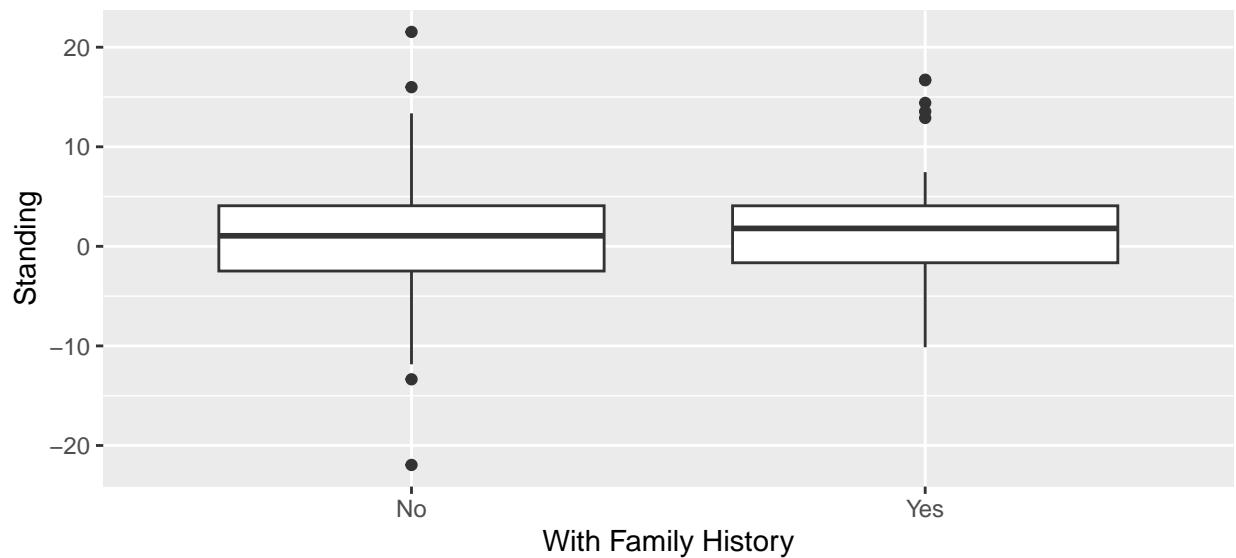
```
ggplot(ls_fits_final, aes(x = age2, y = Activity)) + geom_point() +
  geom_smooth(method = "lm", se = F) + labs(x = "Age")
```



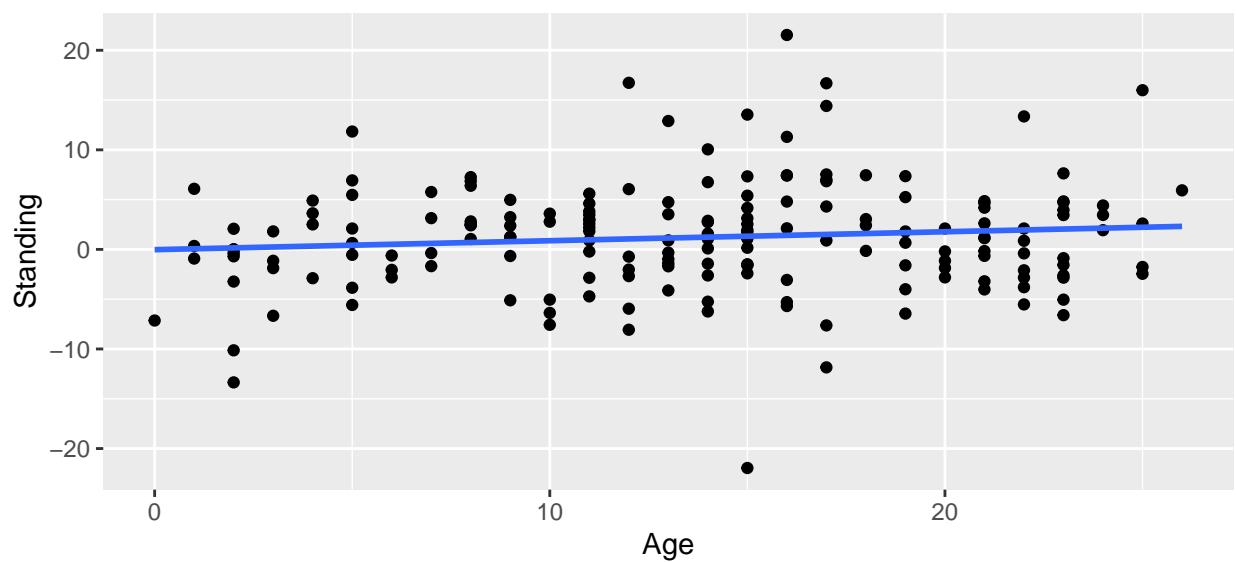
```
## Standing
ggplot(ls.fits_final, aes(x = day3, y = Standing)) + geom_boxplot() +
  labs(x = "Workday")
```



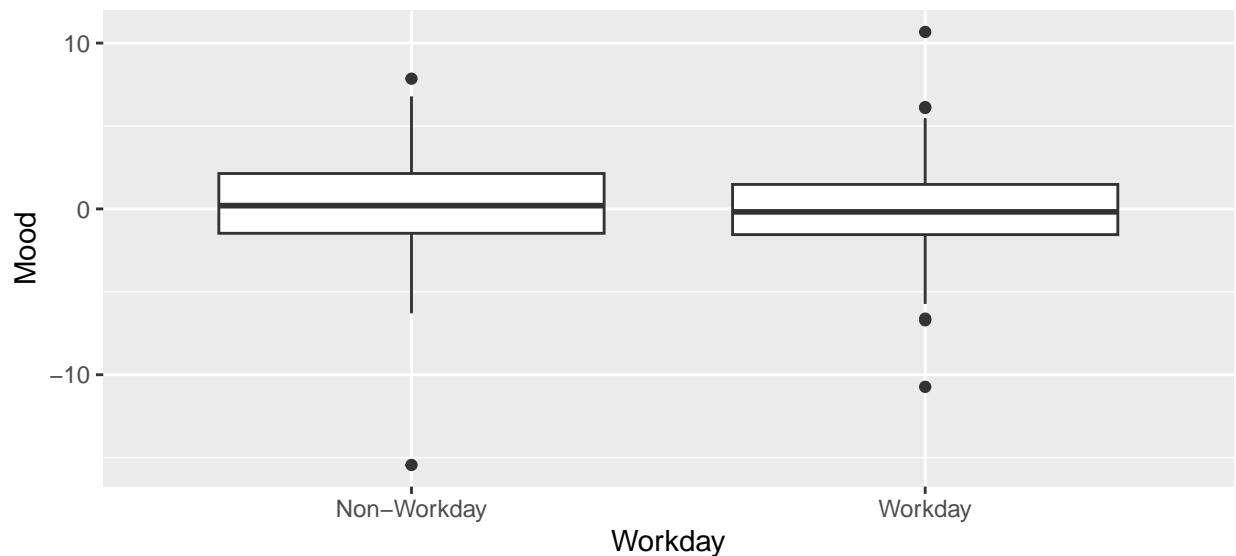
```
ggplot(ls.fits_final, aes(x = fh_2, y = Standing)) + geom_boxplot() +
  labs(x = "With Family History")
```



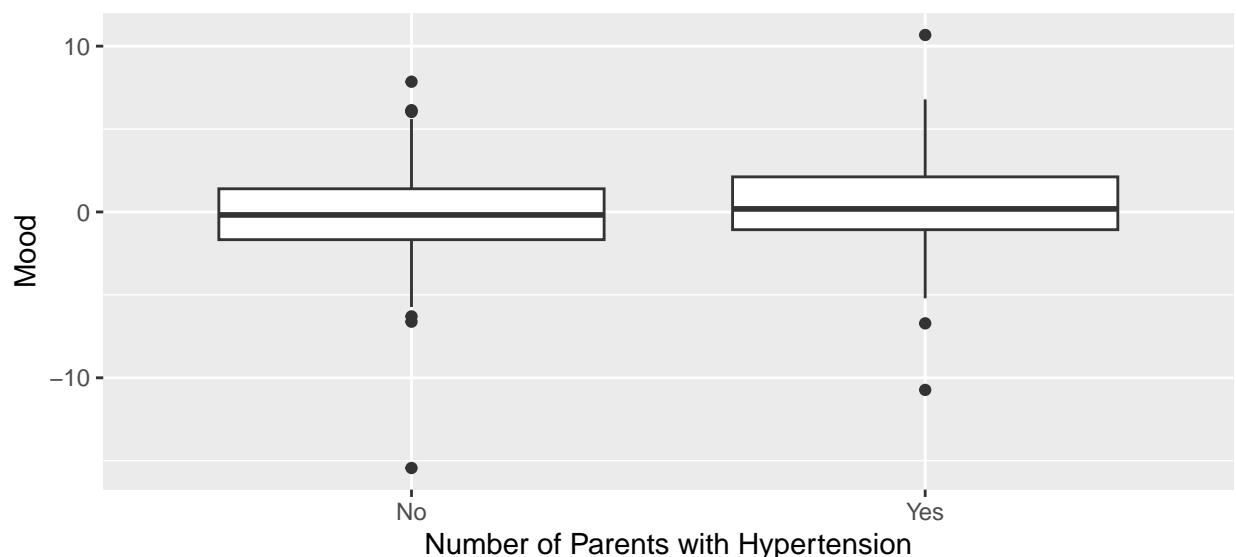
```
ggplot(ls_fits_final, aes(x = age2, y = Standing)) + geom_point() +
  geom_smooth(method = "lm", se = F) + labs(x = "Age")
```



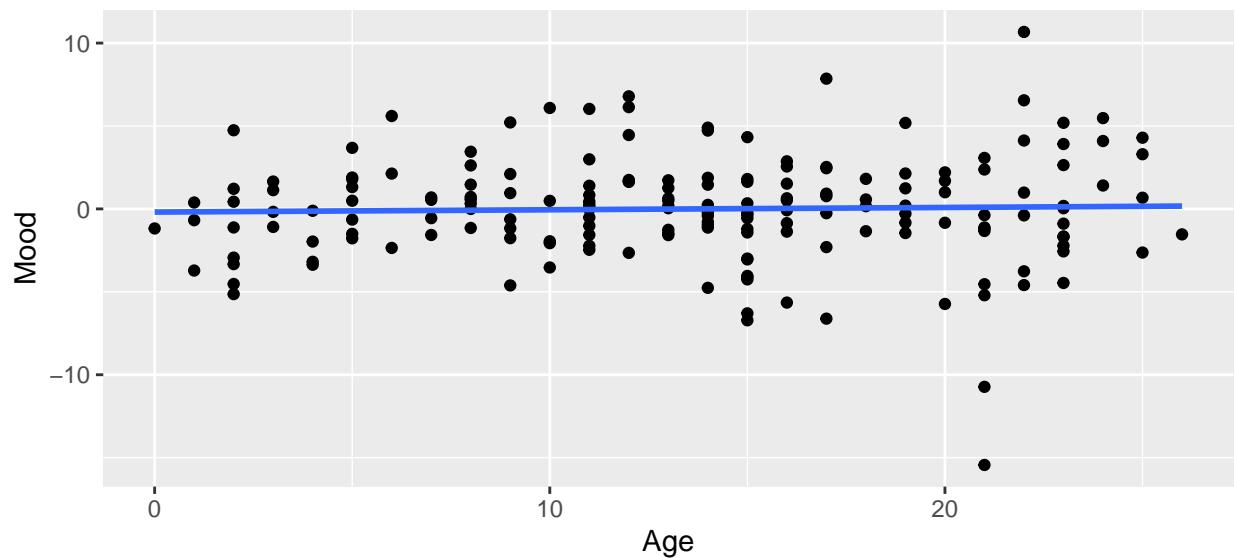
```
## Mood
ggplot(ls_fits_final, aes(x = day3, y = Mood)) + geom_boxplot() +
  labs(x = "Workday")
```



```
ggplot(ls_fits_final, aes(x = fh_2, y = Mood)) + geom_boxplot() +
  labs(x = "Number of Parents with Hypertension")
```



```
ggplot(ls_fits_final, aes(x = age2, y = Mood)) + geom_point() +
  geom_smooth(method = "lm", se = F) + labs(x = "Age")
```



Model Selection

Base Model (Random Intercept)

```
nurse_lmm_RI <- lmer(sys ~ timepass + (1 | snum), data = nurse_filtered)
summary(nurse_lmm_RI)
## Linear mixed model fit by REML ['lmerMod']
## Formula: sys ~ timepass + (1 | snum)
##   Data: nurse_filtered
##
## REML criterion at convergence: 63155.6
##
## Scaled residuals:
##    Min     1Q Median     3Q    Max 
## -4.6450 -0.5715 -0.0592  0.5358  6.5907 
##
## Random effects:
## Groups   Name        Variance Std.Dev.
## snum     (Intercept) 66.81    8.174
## Residual           165.93   12.881
## Number of obs: 7877, groups: snum, 182
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept) 1.193e+02  6.717e-01 177.631
## timepass    -2.603e-03  5.542e-04 -4.697
##
## Correlation of Fixed Effects:
##          (Intr) 
## timepass -0.371

nurse_lm <- lm(sys ~ timepass, data = nurse_filtered)
summary(nurse_lm)
##
## Call:
## lm(formula = sys ~ timepass, data = nurse_filtered)
```

```

## 
## Residuals:
##      Min       1Q   Median       3Q      Max
## -44.459 -10.182  -1.283   8.910  81.390
## 
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)    
## (Intercept) 119.521347   0.335984 355.735 < 2e-16 ***
## timepass     -0.002976   0.000642  -4.636 3.61e-06 ***
## ---      
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## 
## Residual standard error: 15.16 on 7875 degrees of freedom
## Multiple R-squared:  0.002722, Adjusted R-squared:  0.002595 
## F-statistic: 21.49 on 1 and 7875 DF, p-value: 3.61e-06

(lrt_RI <- as.numeric(2 * (logLik(nurse_lmm_RI, REML = TRUE) -
  logLik(nurse_lm, REML = TRUE))))
## [1] 2044.143
0.5 * (1 - pchisq(lrt_RI, df = 0)) + 0.5 * (1 - pchisq(lrt_RI,
  df = 1))
## [1] 0

```

Random Intercept with Level 1 Covariates

```

nurse_lmm_RI_lv1 <- lmer(sys ~ timepass + mnact5 + standing +
  mood + (1 | snum), data = nurse_filtered)

summary(nurse_lmm_RI_lv1)
## Linear mixed model fit by REML ['lmerMod']
## Formula: sys ~ timepass + mnact5 + standing + mood + (1 | snum)
##   Data: nurse_filtered
##
## REML criterion at convergence: 62803.1
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -4.9291 -0.5545 -0.0339  0.5256  6.4425
## 
## Random effects:
##   Groups   Name        Variance Std.Dev.
##   snum     (Intercept) 66.3     8.142
##   Residual           158.3    12.583
##   Number of obs: 7877, groups: snum, 182
## 
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept) 1.099e+02 8.622e-01 127.514
## timepass    -6.072e-04 5.600e-04 -1.084
## mnact5      4.245e-02 2.476e-03 17.144
## standing1    1.143e+00 3.154e-01  3.626
## mood        -9.358e-02 1.409e-01 -0.664

```

```

## 
## Correlation of Fixed Effects:
##          (Intr) timpss mnact5 stndn1
## timepass -0.418
## mnact5   -0.533  0.132
## standing1 -0.056  0.115 -0.286
## mood      -0.269  0.154 -0.006  0.035
anova(nurse_lmm_RI, nurse_lmm_RI_lv1)
## Data: nurse_filtered
## Models:
## nurse_lmm_RI: sys ~ timepass + (1 | snum)
## nurse_lmm_RI_lv1: sys ~ timepass + mnact5 + standing + mood + (1 | snum)
##          npar AIC BIC logLik deviance Chisq Df Pr(>Chisq)
## nurse_lmm_RI        4 63151 63179 -31572    63143
## nurse_lmm_RI_lv1    7 62792 62841 -31389    62778 365.37  3 < 2.2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

# No mood
nurse_lmm_RI_noMood <- lmer(sys ~ timepass + mnact5 + standing +
  (1 | snum), data = nurse_filtered)
anova(nurse_lmm_RI_noMood, nurse_lmm_RI_lv1)
## Data: nurse_filtered
## Models:
## nurse_lmm_RI_noMood: sys ~ timepass + mnact5 + standing + (1 | snum)
## nurse_lmm_RI_lv1: sys ~ timepass + mnact5 + standing + mood + (1 | snum)
##          npar AIC BIC logLik deviance Chisq Df Pr(>Chisq)
## nurse_lmm_RI_noMood     6 62790 62832 -31389    62778
## nurse_lmm_RI_lv1        7 62792 62841 -31389    62778 0.4349  1     0.5096

# No mood or time
nurse_lmm_RI_noMoodTime <- lmer(sys ~ mnact5 + standing + (1 |
  snum), data = nurse_filtered) #still use time
anova(nurse_lmm_RI_noMoodTime, nurse_lmm_RI_noMood)
## Data: nurse_filtered
## Models:
## nurse_lmm_RI_noMoodTime: sys ~ mnact5 + standing + (1 | snum)
## nurse_lmm_RI_noMood: sys ~ timepass + mnact5 + standing + (1 | snum)
##          npar AIC BIC logLik deviance Chisq Df Pr(>Chisq)
## nurse_lmm_RI_noMoodTime     5 62789 62824 -31390    62779
## nurse_lmm_RI_noMood        6 62790 62832 -31389    62778  0.99  1     0.3197
anova(nurse_lmm_RI_noMoodTime, nurse_lmm_RI_lv1)
## Data: nurse_filtered
## Models:
## nurse_lmm_RI_noMoodTime: sys ~ mnact5 + standing + (1 | snum)
## nurse_lmm_RI_lv1: sys ~ timepass + mnact5 + standing + mood + (1 | snum)
##          npar AIC BIC logLik deviance Chisq Df Pr(>Chisq)
## nurse_lmm_RI_noMoodTime     5 62789 62824 -31390    62779
## nurse_lmm_RI_lv1           7 62792 62841 -31389    62778 1.4249  2     0.4904

```

Random Intercept and Slope

```

nurse_lmm_RIS_stand <- lmer(sys ~ timepass + mnact5 + standing +
  (1 + standing | snum), data = nurse_filtered)
summary(nurse_lmm_RIS_stand)
## Linear mixed model fit by REML ['lmerMod']
## Formula: sys ~ timepass + mnact5 + standing + (1 + standing | snum)
##   Data: nurse_filtered
##
## REML criterion at convergence: 62778.2
##
## Scaled residuals:
##   Min     1Q Median     3Q    Max
## -4.8545 -0.5533 -0.0304  0.5235  6.4537
##
## Random effects:
##   Groups   Name        Variance Std.Dev. Corr
##   snum     (Intercept) 68.540   8.279
##           standing1    9.286   3.047  -0.20
##   Residual            156.195 12.498
## Number of obs: 7877, groups: snum, 182
##
## Fixed effects:
##   Estimate Std. Error t value
## (Intercept) 1.098e+02 8.404e-01 130.614
## timepass    -5.224e-04 5.547e-04 -0.942
## mnact5      4.257e-02 2.487e-03 17.118
## standing1    1.167e+00 3.885e-01  3.003
##
## Correlation of Fixed Effects:
##   (Intr) timepass mnact5
## timepass -0.394
## mnact5   -0.553  0.138
## standing1 -0.123  0.088 -0.233

(lrt_RIS_stand <- as.numeric(2 * (logLik(nurse_lmm_RIS_stand,
  REML = TRUE) - logLik(nurse_lmm_RI, REML = TRUE))))
## [1] 377.3417
0.5 * (1 - pchisq(lrt_RIS_stand, df = 1)) + 0.5 * (1 - pchisq(lrt_RIS_stand,
  df = 2))
## [1] 0

```

Random Intercept and Slope with Level 2 Covariates

```

# Age
nurse_lmm_RIS_age <- lmer(sys ~ timepass + mnact5 + standing *
  age24 + (1 + standing | snum), data = nurse_filtered)

summary(nurse_lmm_RIS_age)
## Linear mixed model fit by REML ['lmerMod']
## Formula: sys ~ timepass + mnact5 + standing * age24 + (1 + standing |
##   snum)
##   Data: nurse_filtered
## 
```

```

## REML criterion at convergence: 62784
##
## Scaled residuals:
##      Min     1Q Median     3Q    Max
## -4.8529 -0.5529 -0.0296  0.5246  6.4566
##
## Random effects:
## Groups   Name        Variance Std.Dev. Corr
## snum     (Intercept) 68.62     8.284
##          standing1    9.49     3.081  -0.20
## Residual           156.19   12.497
## Number of obs: 7877, groups: snum, 182
##
## Fixed effects:
##                  Estimate Std. Error t value
## (Intercept)      1.086e+02  1.591e+00 68.222
## timepass       -5.162e-04  5.549e-04 -0.930
## mnact5         4.260e-02  2.487e-03 17.127
## standing1      1.042e+00  8.783e-01  1.186
## age24          8.722e-02  9.856e-02  0.885
## standing1:age24 9.095e-03  5.743e-02  0.158
##
## Correlation of Fixed Effects:
##            (Intr) timppss mnact5 stndn1 age24
## timepass    -0.208
## mnact5      -0.299  0.138
## standing1   -0.244  0.019 -0.109
## age24        -0.849  0.000  0.008  0.259
## stndng1:g24  0.240  0.023  0.007 -0.896 -0.290
anova(nurse_lmm_RIS_stand, nurse_lmm_RIS_age)
## Data: nurse_filtered
## Models:
## nurse_lmm_RIS_stand: sys ~ timepass + mnact5 + standing + (1 + standing | snum)
## nurse_lmm_RIS_age: sys ~ timepass + mnact5 + standing * age24 + (1 + standing | snum)
##                   npar AIC BIC logLik deviance Chisq Df Pr(>Chisq)
## nurse_lmm_RIS_stand 8 62772 62827 -31378    62756
## nurse_lmm_RIS_age    10 62775 62844 -31377   62755 0.9735  2      0.6146

# Workday
nurse_lmm_RIS_day <- lmer(sys ~ day2 * (timepass + standing) +
  mnact5 + (1 + standing | snum), data = nurse_filtered)

summary(nurse_lmm_RIS_day)
## Linear mixed model fit by REML ['lmerMod']
## Formula: sys ~ day2 * (timepass + standing) + mnact5 + (1 + standing |
##           snum)
## Data: nurse_filtered
##
## REML criterion at convergence: 62778.3
##
## Scaled residuals:
##      Min     1Q Median     3Q    Max
## -4.8422 -0.5486 -0.0314  0.5224  6.5115
## 
```

```

## Random effects:
## Groups   Name        Variance Std.Dev. Corr
## snum     (Intercept) 67.524   8.217
##           standing1    9.541   3.089  -0.20
## Residual           156.101  12.494
## Number of obs: 7877, groups: snum, 182
##
## Fixed effects:
##                         Estimate Std. Error t value
## (Intercept)      1.078e+02  1.119e+00 96.340
## day21          3.574e+00  1.396e+00  2.560
## timepass       8.071e-04  8.325e-04  0.969
## standing1      1.387e+00  5.771e-01  2.403
## mnact5         4.273e-02  2.496e-03 17.118
## day21:timepass -2.413e-03  1.108e-03 -2.177
## day21:standing1 -5.135e-01  7.653e-01 -0.671
##
## Correlation of Fixed Effects:
##             (Intr) day21  timppss stndn1 mnact5 dy21:t
## day21      -0.662
## timepass   -0.397  0.273
## standing1  -0.154  0.194  0.044
## mnact5     -0.413 -0.008  0.133 -0.207
## day21:tmpss  0.279 -0.386 -0.745 -0.043 -0.052
## dy21:stndn1  0.154 -0.303 -0.045 -0.735  0.066  0.111
anova(nurse_lmm_RIS_stand, nurse_lmm_RIS_day)
## Data: nurse_filtered
## Models:
## nurse_lmm_RIS_stand: sys ~ timepass + mnact5 + standing + (1 + standing | snum)
## nurse_lmm_RIS_day: sys ~ day2 * (timepass + standing) + mnact5 + (1 + standing | snum)
##                      npar   AIC   BIC logLik deviance Chisq Df Pr(>Chisq)
## nurse_lmm_RIS_stand  8 62772 62827 -31378    62756
## nurse_lmm_RIS_day     11 62769 62846 -31374    62747 8.2201  3     0.04168 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

nurse_lmm_RIS_day_nostand <- lmer(sys ~ day2 * (timepass) + standing +
mnact5 + (1 + standing | snum), data = nurse_filtered)
anova(nurse_lmm_RIS_day, nurse_lmm_RIS_day_nostand)
## Data: nurse_filtered
## Models:
## nurse_lmm_RIS_day_nostand: sys ~ day2 * (timepass) + standing + mnact5 + (1 + standing | snum)
## nurse_lmm_RIS_day: sys ~ day2 * (timepass + standing) + mnact5 + (1 + standing | snum)
##                      npar   AIC   BIC logLik deviance Chisq Df Pr(>Chisq)
## nurse_lmm_RIS_day_nostand 10 62768 62838 -31374    62748
## nurse_lmm_RIS_day          11 62769 62846 -31374    62747 0.4514  1     0.5017
anova(nurse_lmm_RIS_day_nostand, nurse_lmm_RIS_stand)
## Data: nurse_filtered
## Models:
## nurse_lmm_RIS_stand: sys ~ timepass + mnact5 + standing + (1 + standing | snum)
## nurse_lmm_RIS_day_nostand: sys ~ day2 * (timepass) + standing + mnact5 + (1 + standing | snum)
##                      npar   AIC   BIC logLik deviance Chisq Df Pr(>Chisq)
## nurse_lmm_RIS_stand      8 62772 62827 -31378    62756

```

```

## nurse_lmm_RIS_day_nostand 10 62768 62838 -31374      62748 7.7687 2     0.02056
##
## nurse_lmm_RIS_stand
## nurse_lmm_RIS_day_nostand *
## ---
## Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

nurse_lmm_RIS_day_nointer <- lmer(sys ~ day2 + timepass + standing +
  mnact5 + (1 + standing | snum), data = nurse_filtered)
anova(nurse_lmm_RIS_day_nostand, nurse_lmm_RIS_day_nointer)
## Data: nurse_filtered
## Models:
## nurse_lmm_RIS_day_nointer: sys ~ day2 + timepass + standing + mnact5 + (1 + standing | snum)
## nurse_lmm_RIS_day_nostand: sys ~ day2 * (timepass) + standing + mnact5 + (1 + standing | snum)
##          npar   AIC   BIC logLik deviance Chisq Df Pr(>Chisq)
## nurse_lmm_RIS_day_nointer    9 62770 62833 -31376     62752
## nurse_lmm_RIS_day_nostand   10 62768 62838 -31374     62748 4.4646  1     0.0346
##
## nurse_lmm_RIS_day_nointer
## nurse_lmm_RIS_day_nostand *
## ---
## Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

# Family history
nurse_lmm_RIS_day_fh <- lmer(sys ~ (day2 + fh_yes) * timepass +
  standing + mnact5 + (1 + standing | snum), data = nurse_filtered)
anova(nurse_lmm_RIS_day_fh, nurse_lmm_RIS_day_nostand)
## Data: nurse_filtered
## Models:
## nurse_lmm_RIS_day_nostand: sys ~ day2 * (timepass) + standing + mnact5 + (1 + standing | snum)
## nurse_lmm_RIS_day_fh: sys ~ (day2 + fh_yes) * timepass + standing + mnact5 + (1 + standing | snum)
##          npar   AIC   BIC logLik deviance Chisq Df Pr(>Chisq)
## nurse_lmm_RIS_day_nostand   10 62768 62838 -31374     62748
## nurse_lmm_RIS_day_fh        12 62756 62839 -31366     62732 16.3  2  0.0002887
##
## nurse_lmm_RIS_day_nostand
## nurse_lmm_RIS_day_fh      ***
## ---
## Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
anova(nurse_lmm_RIS_day_fh, nurse_lmm_RIS_stand)
## Data: nurse_filtered
## Models:
## nurse_lmm_RIS_stand: sys ~ timepass + mnact5 + standing + (1 + standing | snum)
## nurse_lmm_RIS_day_fh: sys ~ (day2 + fh_yes) * timepass + standing + mnact5 + (1 + standing | snum)
##          npar   AIC   BIC logLik deviance Chisq Df Pr(>Chisq)
## nurse_lmm_RIS_stand     8 62772 62827 -31378     62756
## nurse_lmm_RIS_day_fh    12 62756 62839 -31366     62732 24.069  4  7.736e-05 ***
##
## Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

nurse_lmm_RIS_day_fh_nocorr <- lmer(sys ~ (day2 + fh_yes) * timepass +
  standing + mnact5 + (1 + standing || snum), data = nurse_filtered) #Convergence issue, have corr
anova(nurse_lmm_RIS_day_fh, nurse_lmm_RIS_day_fh_nocorr, refit = FALSE)
## Data: nurse_filtered

```

```

## Models:
## nurse_lmm_RIS_day_fh: sys ~ (day2 + fh_yes) * timepass + standing + mnact5 + (1 + standing / snum)
## nurse_lmm_RIS_day_fh_nocorr: sys ~ (day2 + fh_yes) * timepass + standing + mnact5 + ((1 / snum) + (0
##                                     npar   AIC   BIC logLik deviance Chisq Df
## nurse_lmm_RIS_day_fh          12 62797 62881 -31387    62773
## nurse_lmm_RIS_day_fh_nocorr  13 62799 62890 -31387    62773     0  1
##                                     Pr(>Chisq)
## nurse_lmm_RIS_day_fh
## nurse_lmm_RIS_day_fh_nocorr      1

```

Model Diagnostics

Residual Analysis

```

final_model <- nurse_lmm_RIS_day_fh

nurse_resid1 <- hlm_resid(final_model, level = 1, standardize = TRUE)
nurse_resid2 <- hlm_resid(final_model, level = "snum", include.ls = FALSE)

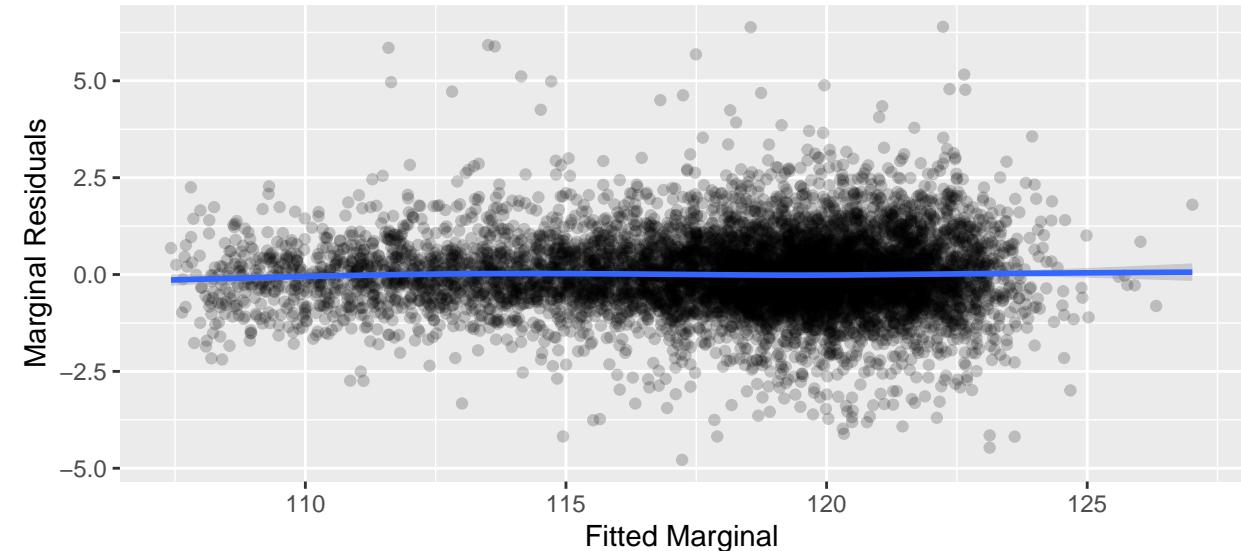
```

```

ggplot(data = nurse_resid1, aes(x = .mar.fitted, y = .chol.mar.resid)) +
  geom_point(alpha = 0.2) + geom_smooth() + labs(x = "Fitted Marginal",
y = "Marginal Residuals")

```

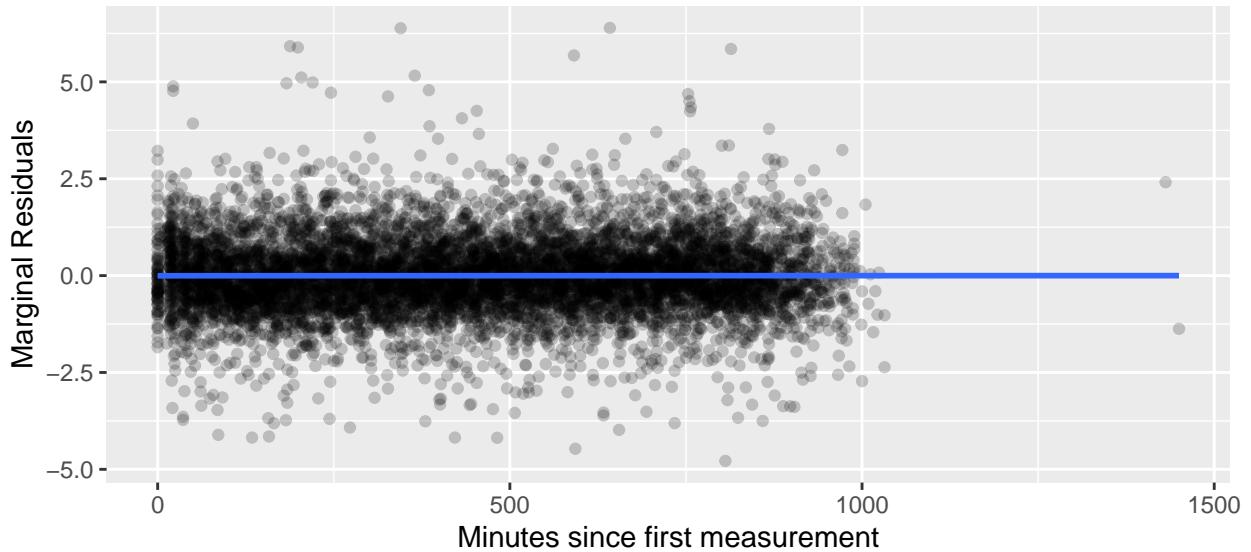
Marginal Residuals



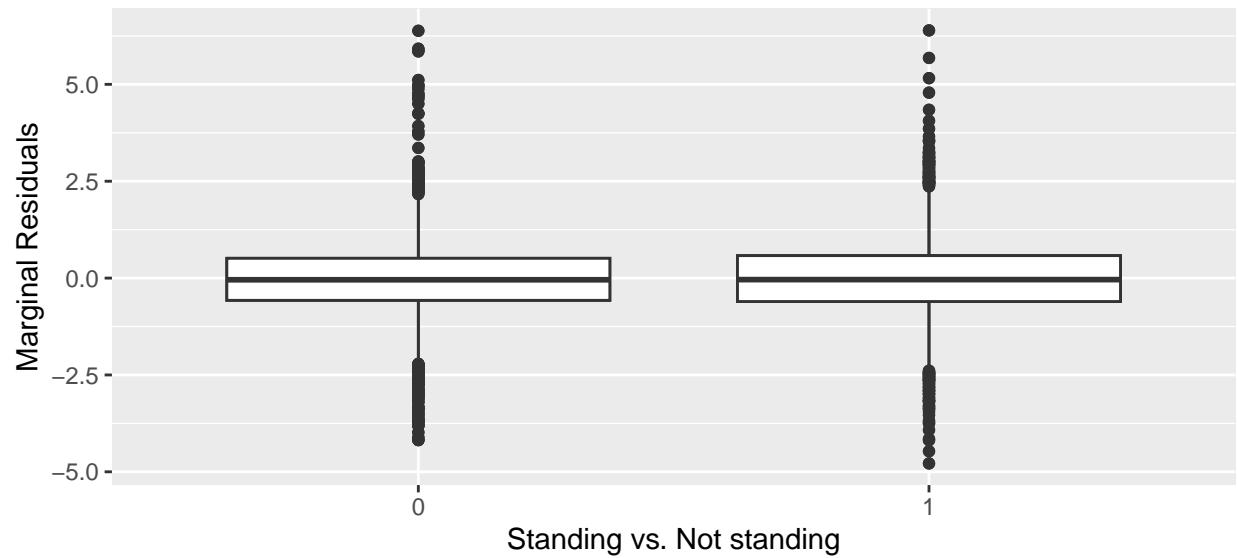
```

ggplot(data = nurse_resid1, aes(x = timepass, y = .chol.mar.resid)) +
  geom_point(alpha = 0.2) + geom_smooth() + labs(x = "Minutes since first measurement",
y = "Marginal Residuals")

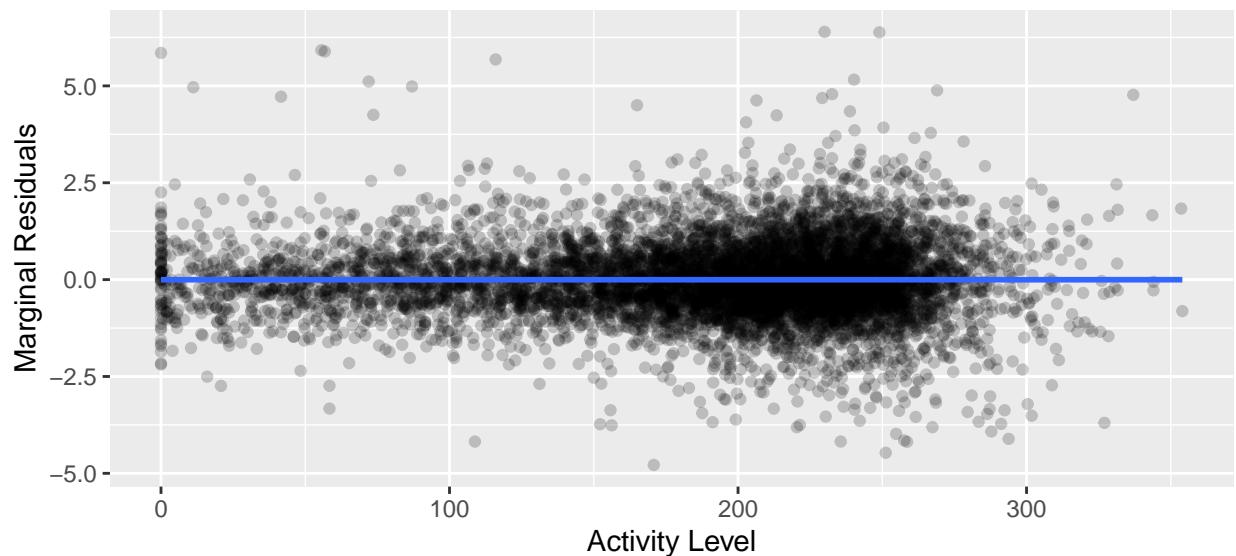
```



```
ggplot(data = nurse_resid1, aes(x = as.factor(standing), y = .chol.mar.resid)) +
  geom_boxplot() + # geom_smooth() + geom_boxplot() + #
  geom_boxplot() + # geom_smooth() + geom_smooth() +
  labs(x = "Standing vs. Not standing", y = "Marginal Residuals")
```

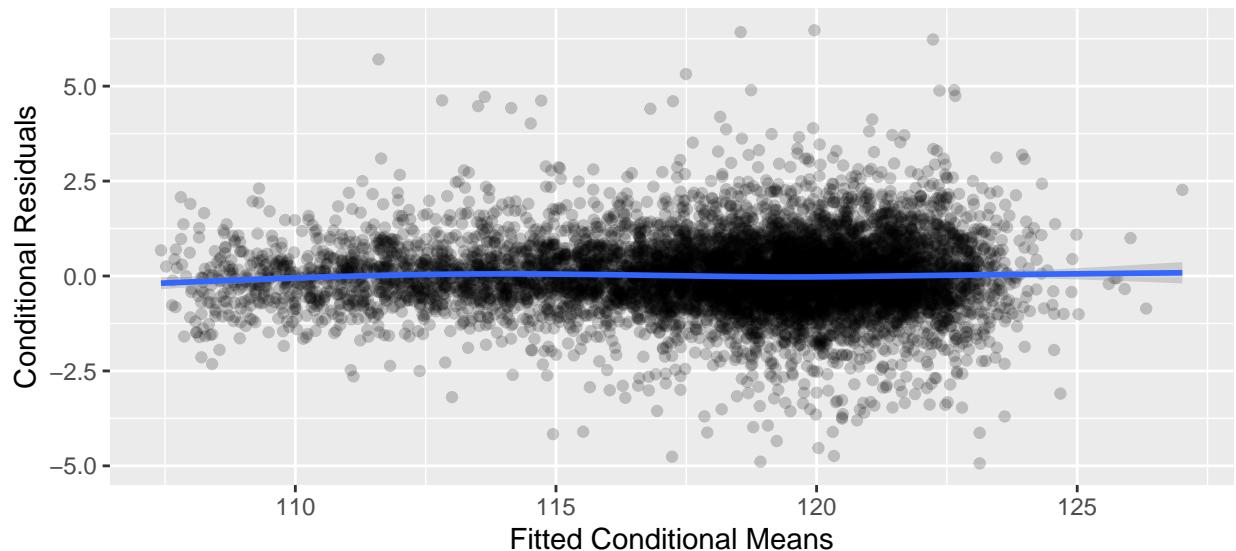


```
ggplot(data = nurse_resid1, aes(x = mnact5, y = .chol.mar.resid)) +
  geom_point(alpha = 0.2) + geom_smooth() + labs(x = "Activity Level",
  y = "Marginal Residuals")
```

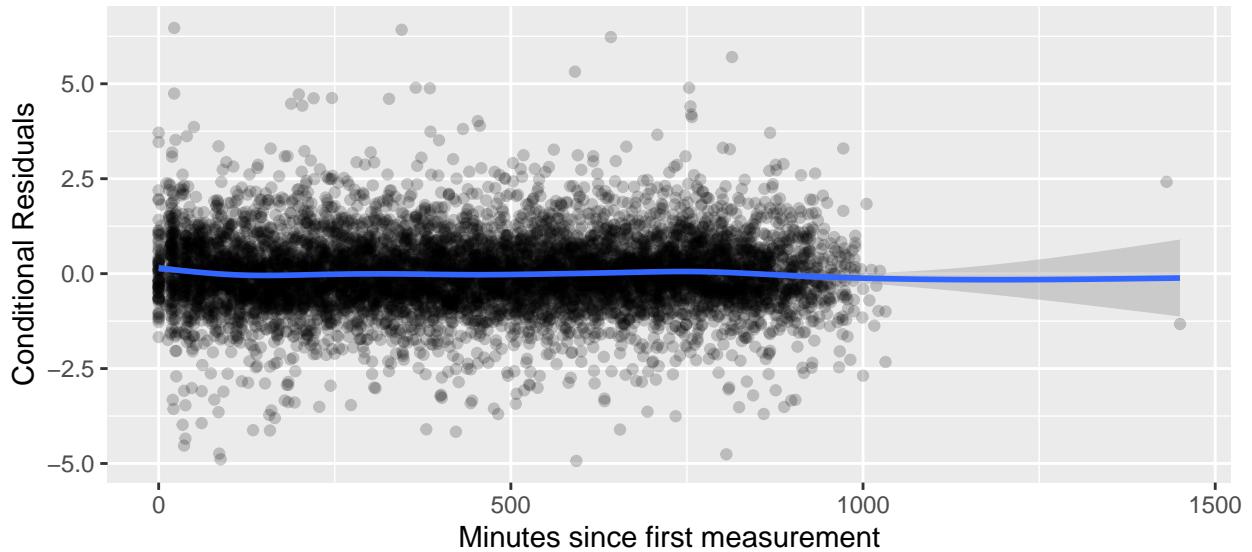


```
ggplot(data = nurse_resid1, aes(x = .mar.fitted, y = .std.resid)) +
  geom_point(alpha = 0.2) + geom_smooth() + labs(x = "Fitted Conditional Means",
y = "Conditional Residuals")
```

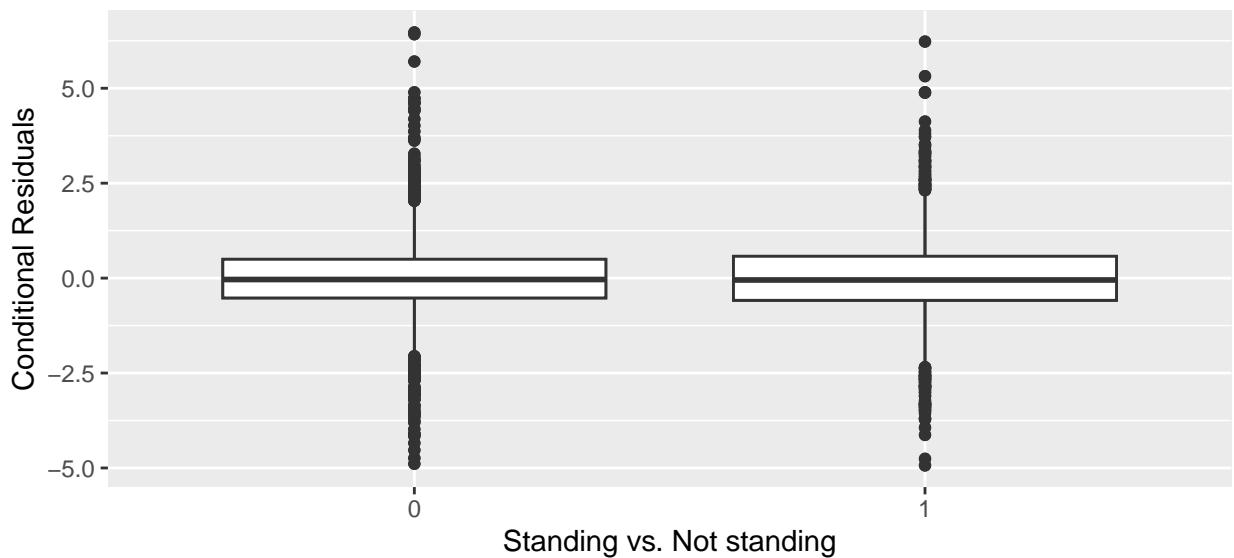
Conditional Residuals



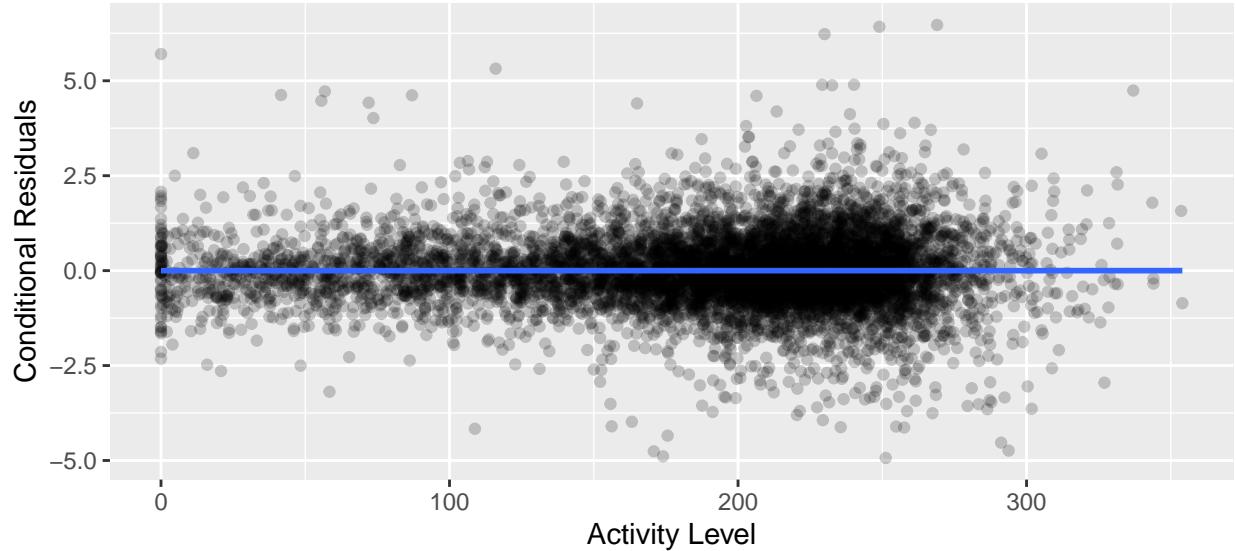
```
ggplot(data = nurse_resid1, aes(x = timepass, y = .std.resid)) +
  geom_point(alpha = 0.2) + geom_smooth() + labs(x = "Minutes since first measurement",
y = "Conditional Residuals")
```



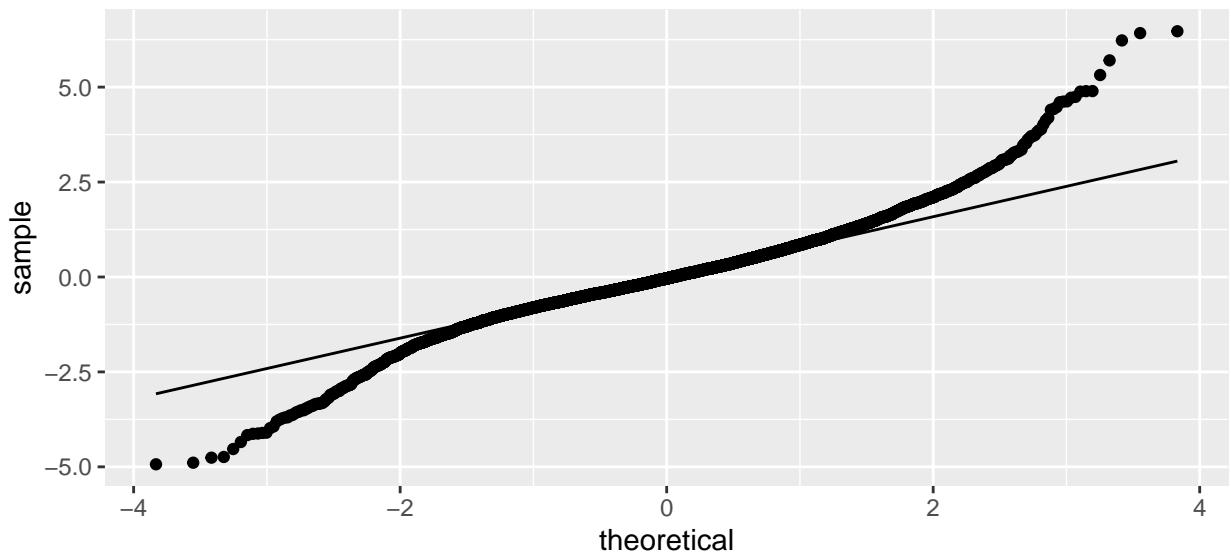
```
ggplot(data = nurse_resid1, aes(x = as.factor(standing), y = .std.resid)) +
  geom_boxplot() + # geom_smooth() + geom_boxplot() + #
  geom_boxplot() + # geom_smooth() + geom_smooth() +
  labs(x = "Standing vs. Not standing", y = "Conditional Residuals")
```



```
ggplot(data = nurse_resid1, aes(x = mnact5, y = .std.resid)) +
  geom_point(alpha = 0.2) + geom_smooth() + labs(x = "Activity Level",
  y = "Conditional Residuals")
```



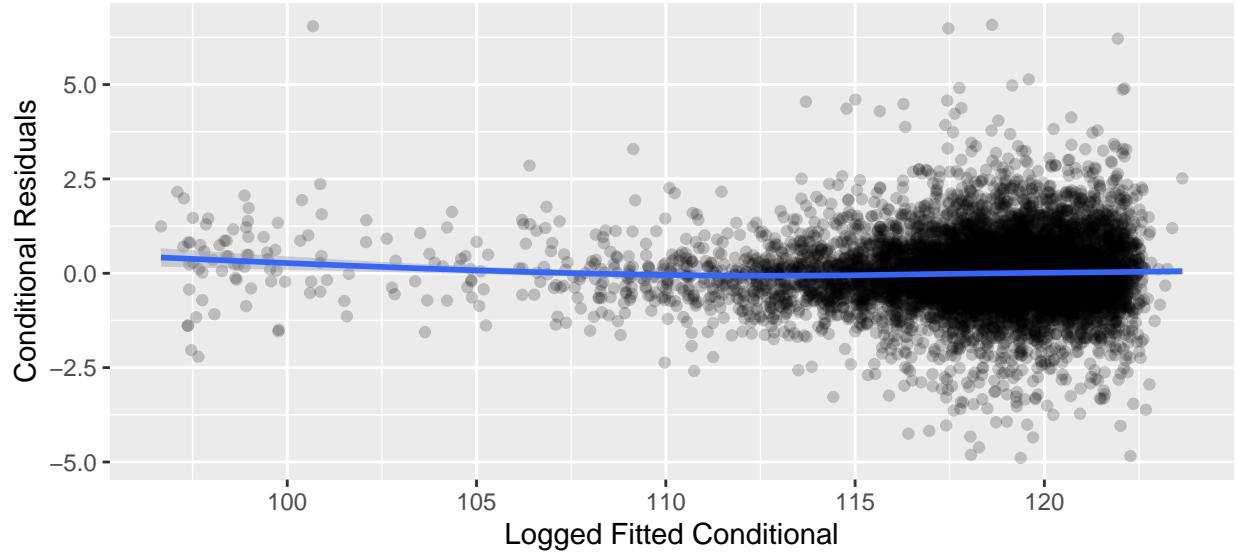
```
ggplot(nurse_resid1, aes(sample = .std.resid)) + stat_qq_line() +
  stat_qq()
```



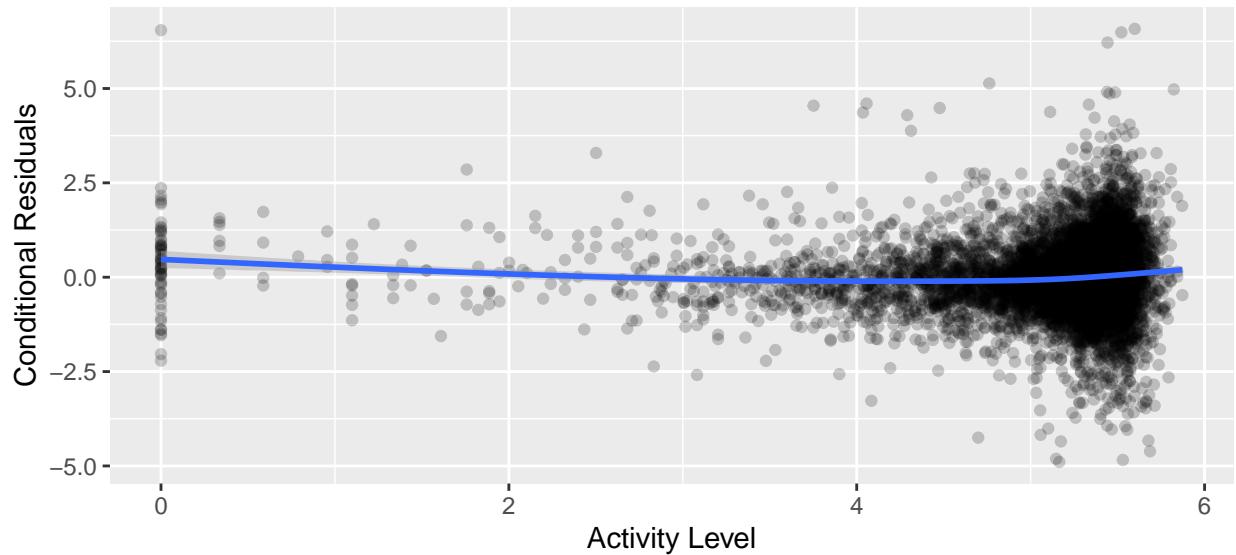
```
# Exponential model
nurse_lmm_RIS_logx <- lmer(sys ~ (day2 + fh_yes) * timepass +
  standing + log(mnact5 + 1) + mood + (1 + mood + standing |
  snum), data = nurse_filtered)
nurse_resid1_logx <- hlm_resid(nurse_lmm_RIS_logx, level = 1,
  standardize = TRUE)

ggplot(data = nurse_resid1_logx, aes(x = .mar.fitted, y = .std.resid)) +
  geom_point(alpha = 0.2) + geom_smooth() + labs(x = "Logged Fitted Conditional",
  y = "Conditional Residuals")
```

Try transformations — Didn't work

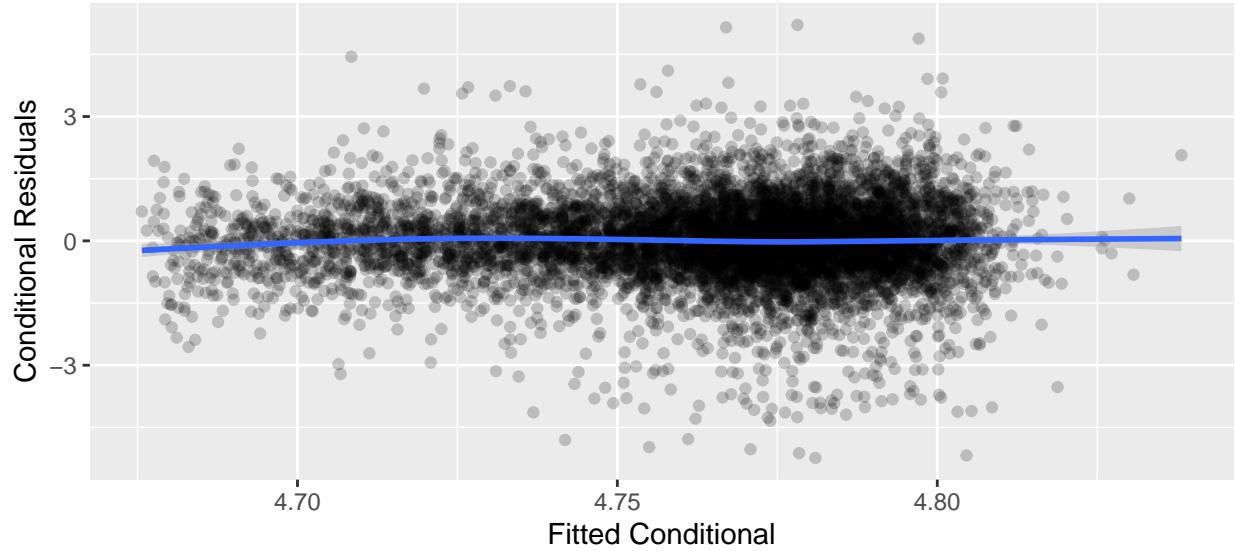


```
ggplot(data = nurse_resid1_logx, aes(x = `log(mnact5 + 1)`, y = .std.resid)) +
  geom_point(alpha = 0.2) + geom_smooth() + labs(x = "Activity Level",
y = "Conditional Residuals")
```

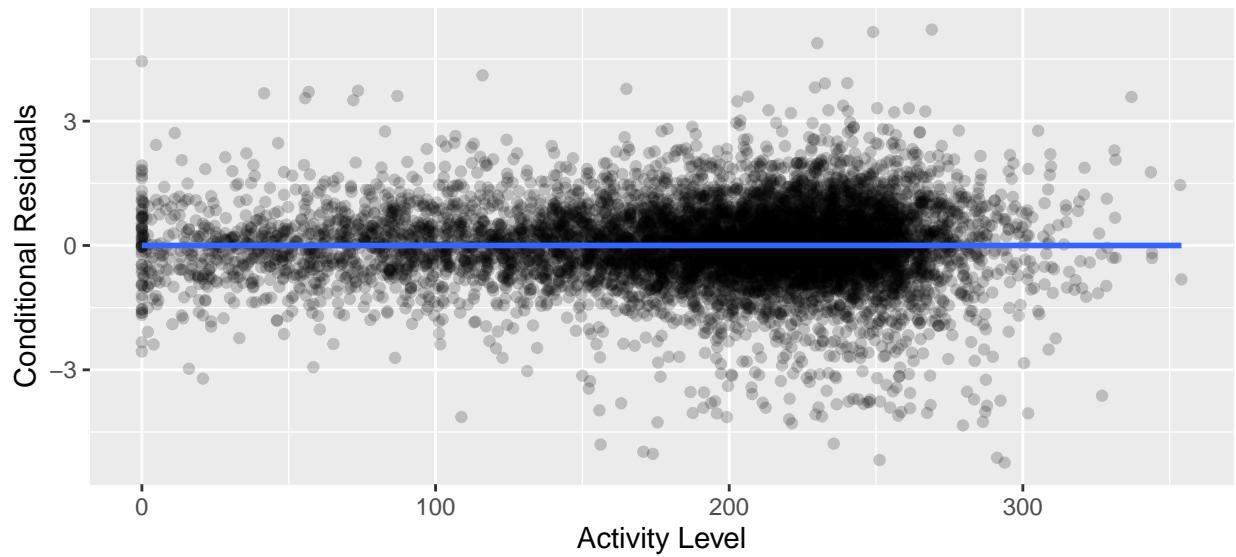


```
# Logarithmic
nurse_lmm_RIS_logy <- lmer(log(sys) ~ (day2 + fh_yes) * timepass +
  standing + mnact5 + mood + (1 + mood + standing | snum),
  data = nurse_filtered)
nurse_resid1_logy <- hlm_resid(nurse_lmm_RIS_logy, level = 1,
  standardize = TRUE)

ggplot(data = nurse_resid1_logy, aes(x = .mar.fitted, y = .std.resid)) +
  geom_point(alpha = 0.2) + geom_smooth() + labs(x = "Fitted Conditional",
y = "Conditional Residuals")
```

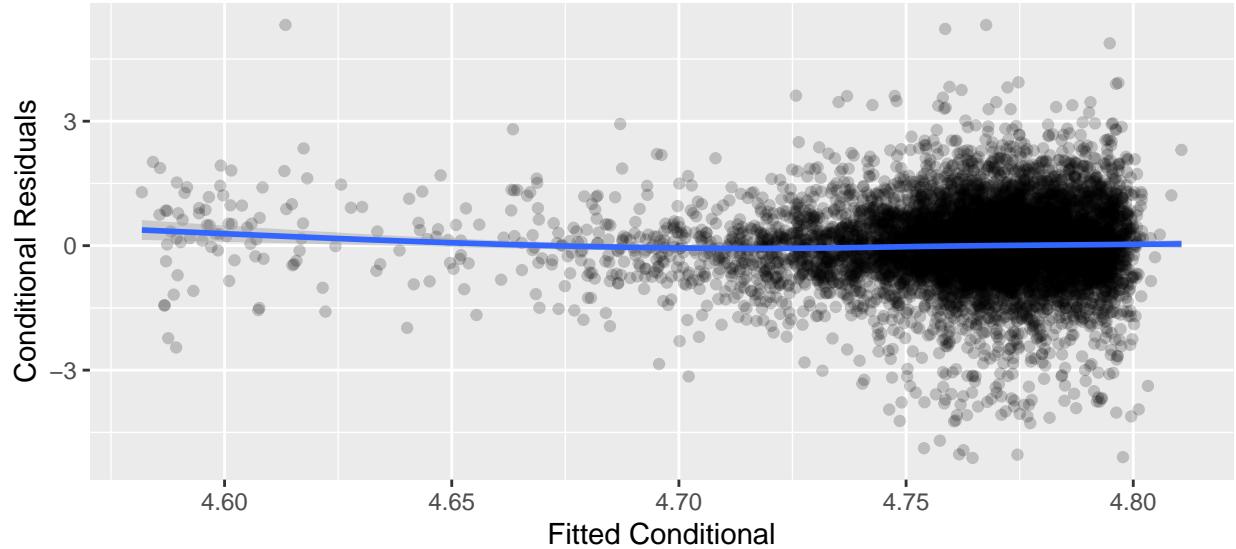


```
ggplot(data = nurse_resid1_logy, aes(x = mnact5, y = .std.resid)) +
  geom_point(alpha = 0.2) + geom_smooth() + labs(x = "Activity Level",
  y = "Conditional Residuals")
```

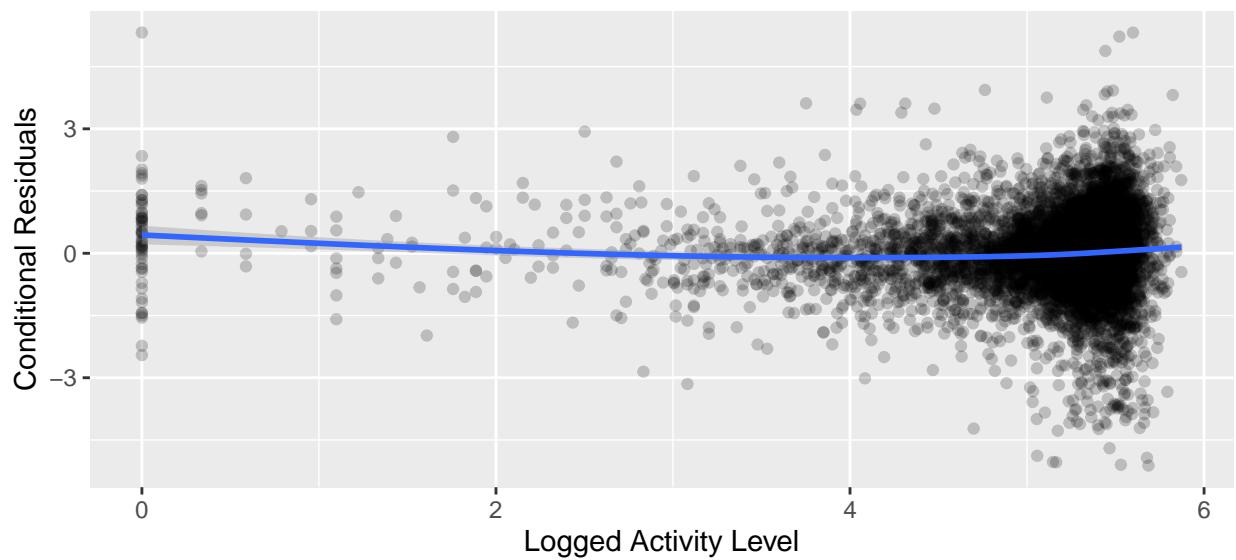


```
# power
nurse_lmm_RIS_loglog <- lmer(log(sys) ~ (day2 + fh_yes) * timepass +
  standing + log(mnact5 + 1) + mood + (1 + mood + standing |
  snum), data = nurse_filtered)
nurse_resid1_loglog <- hlm_resid(nurse_lmm_RIS_loglog, level = 1,
  standardize = TRUE)

ggplot(data = nurse_resid1_loglog, aes(x = .mar.fitted, y = .std.resid)) +
  geom_point(alpha = 0.2) + geom_smooth() + labs(x = "Fitted Conditional",
  y = "Conditional Residuals")
```

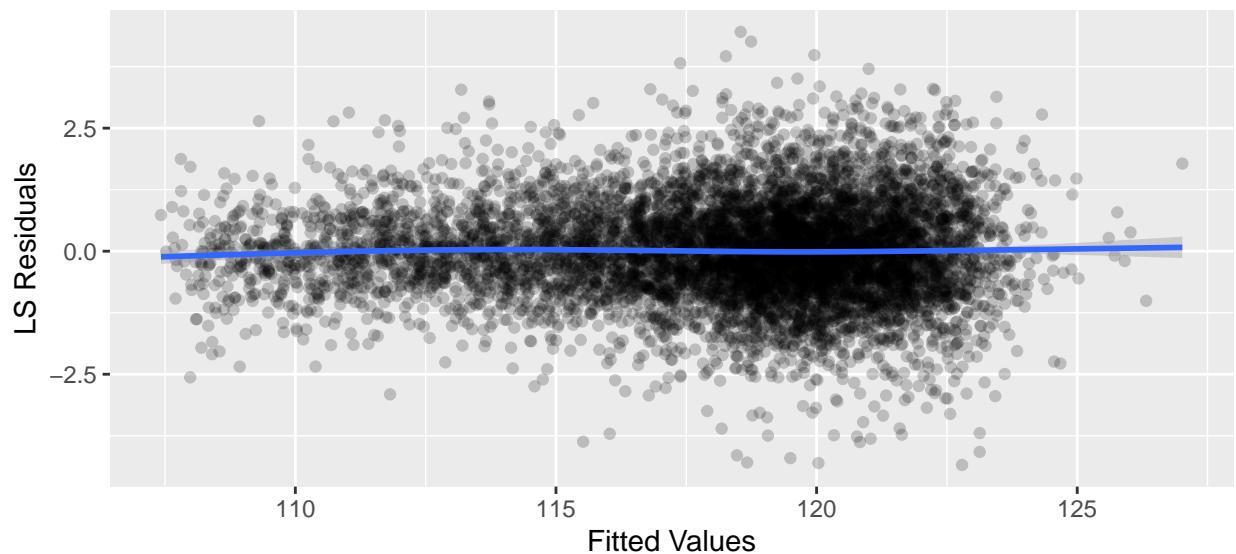


```
ggplot(data = nurse_resid1_loglog, aes(x = `log(mnact5 + 1)`,
y = .std.resid)) + geom_point(alpha = 0.2) + geom_smooth() +
labs(x = "Logged Activity Level", y = "Conditional Residuals")
```

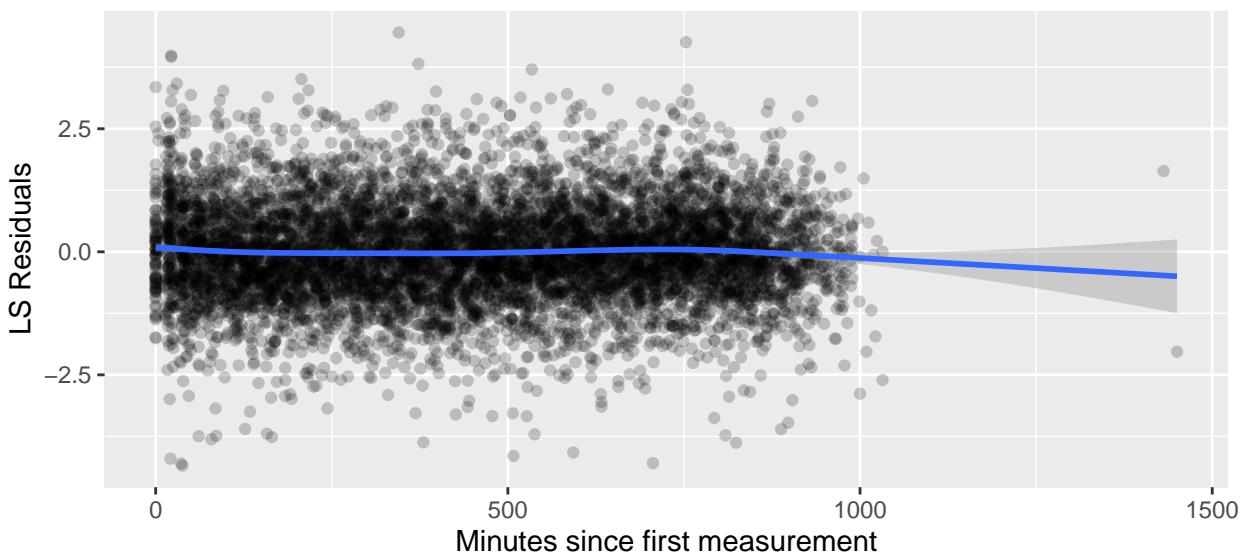


```
ggplot(data = nurse_resid1, aes(x = .mar.fitted, y = .std.ls.resid)) +
geom_point(alpha = 0.2) + geom_smooth() + labs(x = "Fitted Values",
y = "LS Residuals")
```

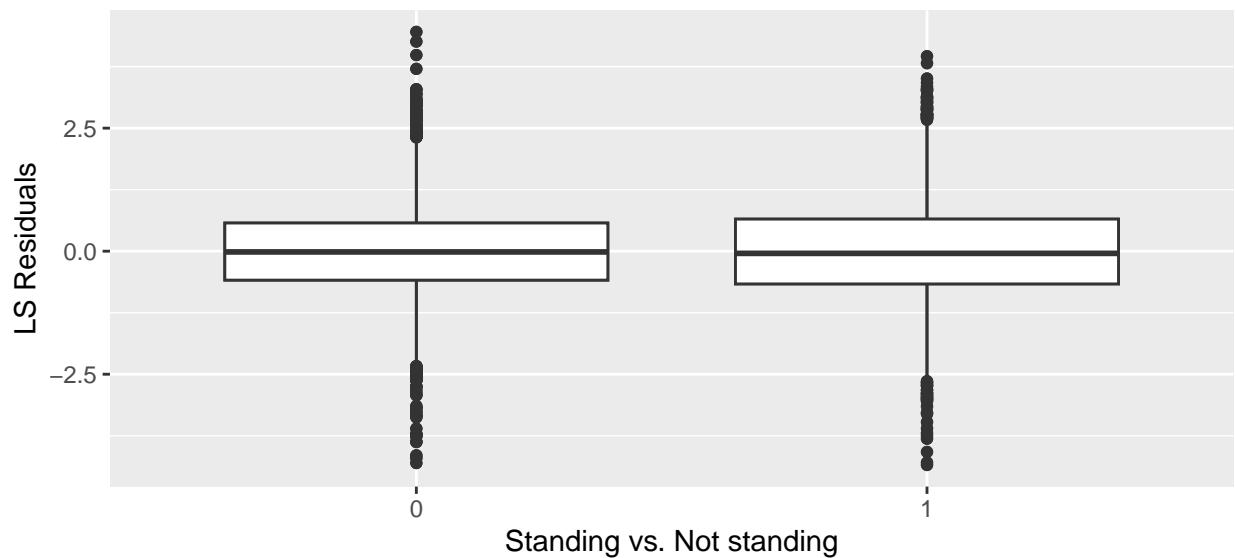
LS Residuals



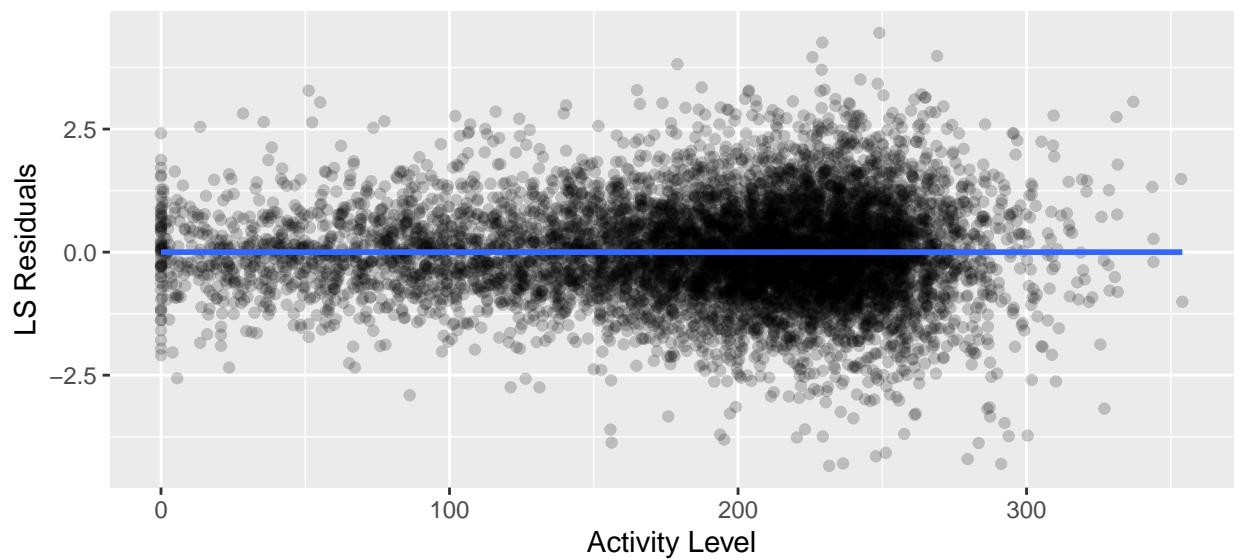
```
ggplot(data = nurse_resid1, aes(x = timepass, y = .std.ls.resid)) +
  geom_point(alpha = 0.2) + geom_smooth() + labs(x = "Minutes since first measurement",
y = "LS Residuals")
```



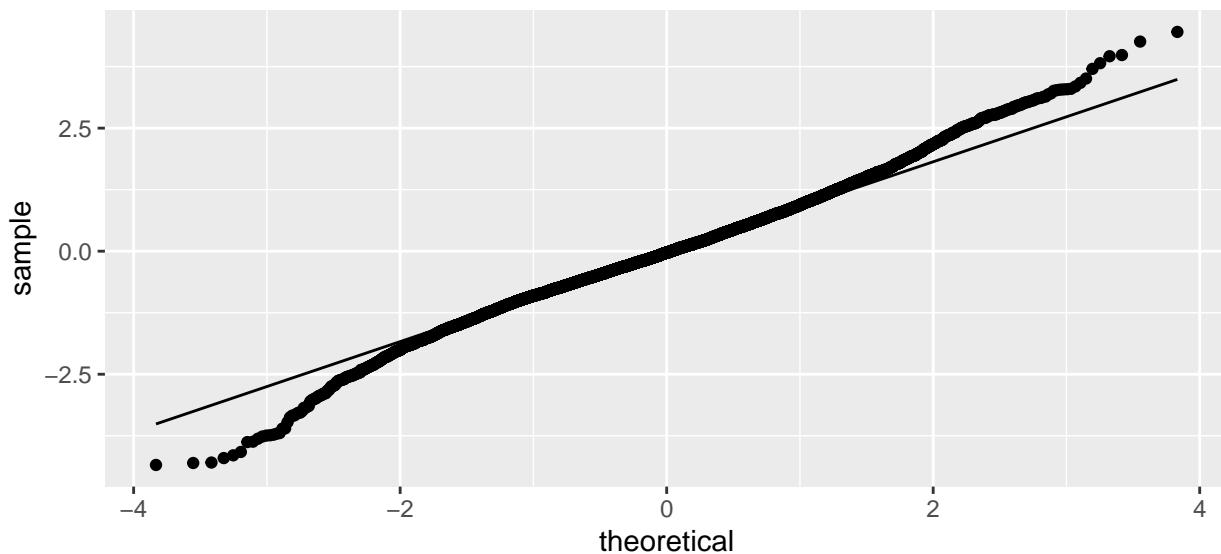
```
ggplot(data = nurse_resid1, aes(x = as.factor(standing), y = .std.ls.resid)) +
  geom_boxplot() + # geom_smooth() + geom_boxplot() + #
  geom_boxplot() + # geom_smooth() + geom_smooth() +
  labs(x = "Standing vs. Not standing", y = "LS Residuals")
```



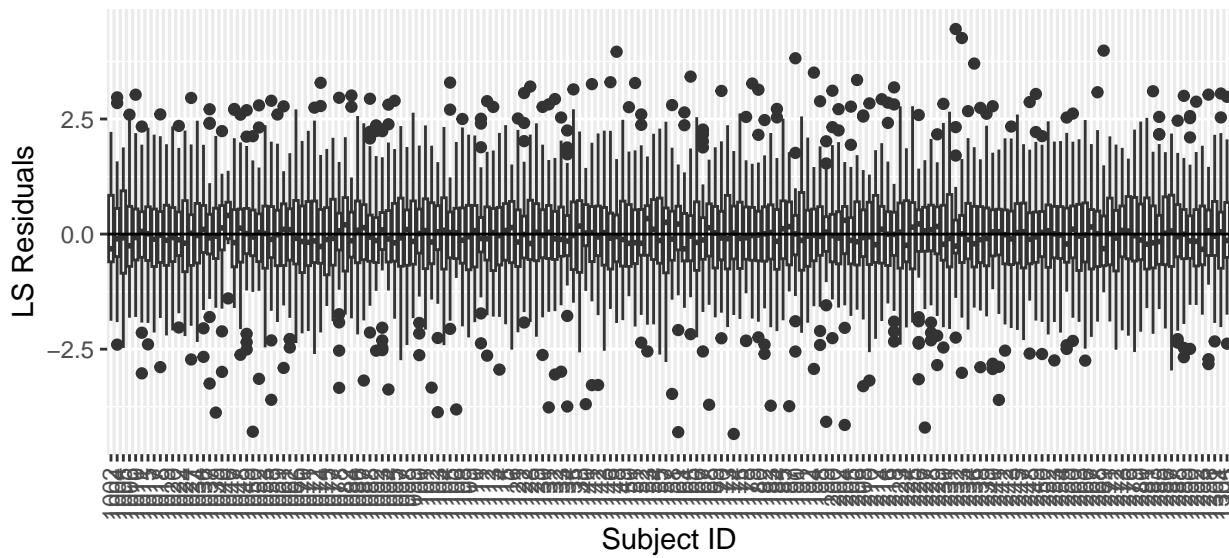
```
ggplot(data = nurse_resid1, aes(x = mnact5, y = .std.ls.resid)) +
  geom_point(alpha = 0.2) + geom_smooth() + labs(x = "Activity Level",
  y = "LS Residuals")
```



```
ggplot(nurse_resid1, aes(sample = .std.ls.resid)) + stat_qq_line() +
  stat_qq()
```

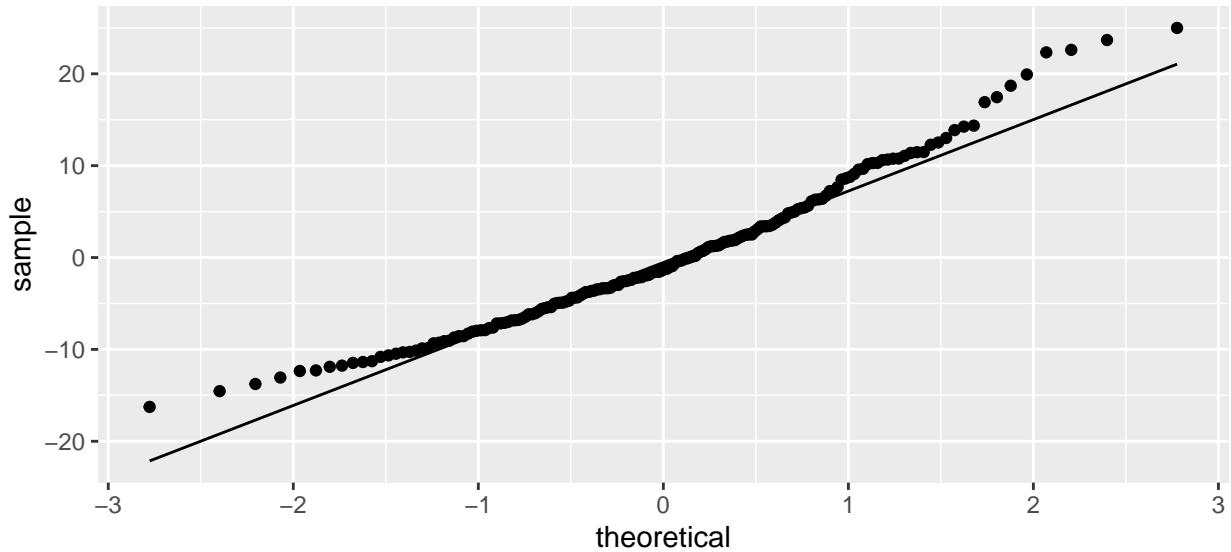


```
ggplot(nurse_resid1, aes(x = as.factor(snum), y = .std.ls.resid)) +
  geom_boxplot() + geom_hline(yintercept = 0) + labs(x = "Subject ID",
  y = "LS Residuals") + theme(axis.text.x = element_text(angle = 90,
  vjust = 0.5, hjust = 1))
```

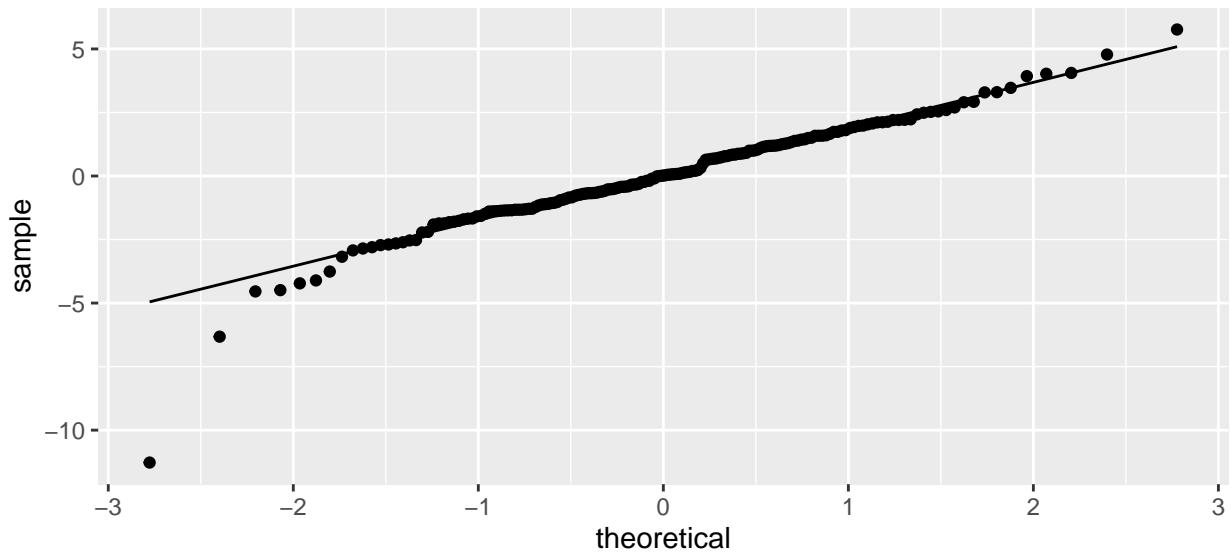


```
ggplot(nurse_resid2, aes(sample = .ranef.intercept)) + stat_qq_line() +
  stat_qq()
```

Lv 2 RE



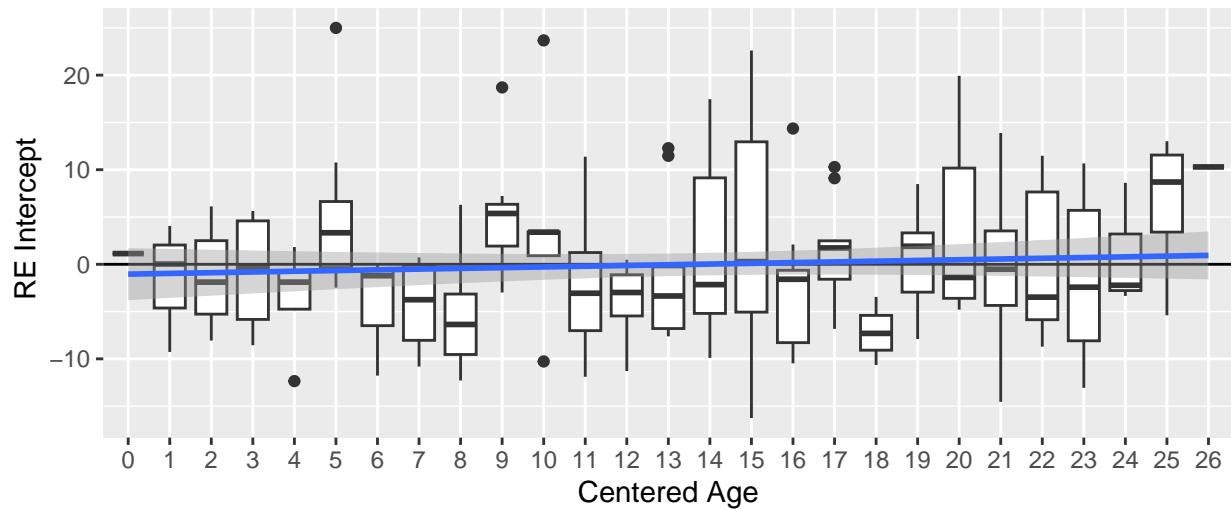
```
ggplot(nurse_resid2, aes(sample = .ranef.standing1)) + stat_qq_line() +
  stat_qq()
```



```
nurse_age_phase <- nurse_filtered %>%
  mutate(snum = as.character(snum)) %>%
  group_by(snum) %>%
  summarize(nurse_age = first(age24), nurse_phase = first(phase)) %>%
  left_join(nurse_resid2, by = "snum")

## Intercept
ggplot(nurse_age_phase, aes(x = as.factor(nurse_age), y = .ranef.intercept)) +
  geom_boxplot() + geom_hline(yintercept = 0) + geom_smooth(method = "lm",
  se = TRUE, aes(group = 1)) + labs(title = "RE intercept vs Centered Age",
  x = "Centered Age", y = " RE Intercept")
```

RE intercept vs Centered Age



```
ggplot(nurse_age_phase, aes(x = nurse_phase, y = .ranef.intercept)) +
  geom_boxplot() + geom_hline(yintercept = 0) + labs(title = "RE intercept vs Menstrual Phase",
  x = "Menstrual Phase", y = " RE Intercept")
```

RE intercept vs Menstrual Phase

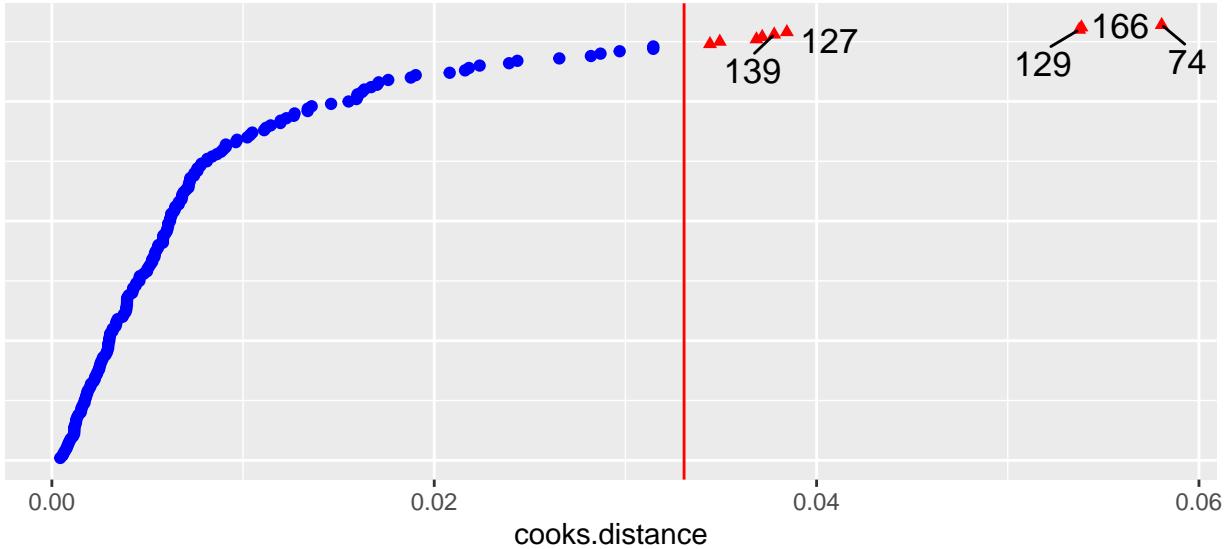


Influential Statistics

```
nurse_infl2 <- hlm_influence(final_model, level = "snum", approx = FALSE,
  leverage = c("overall", "fixef", "ranef.uc"))
```

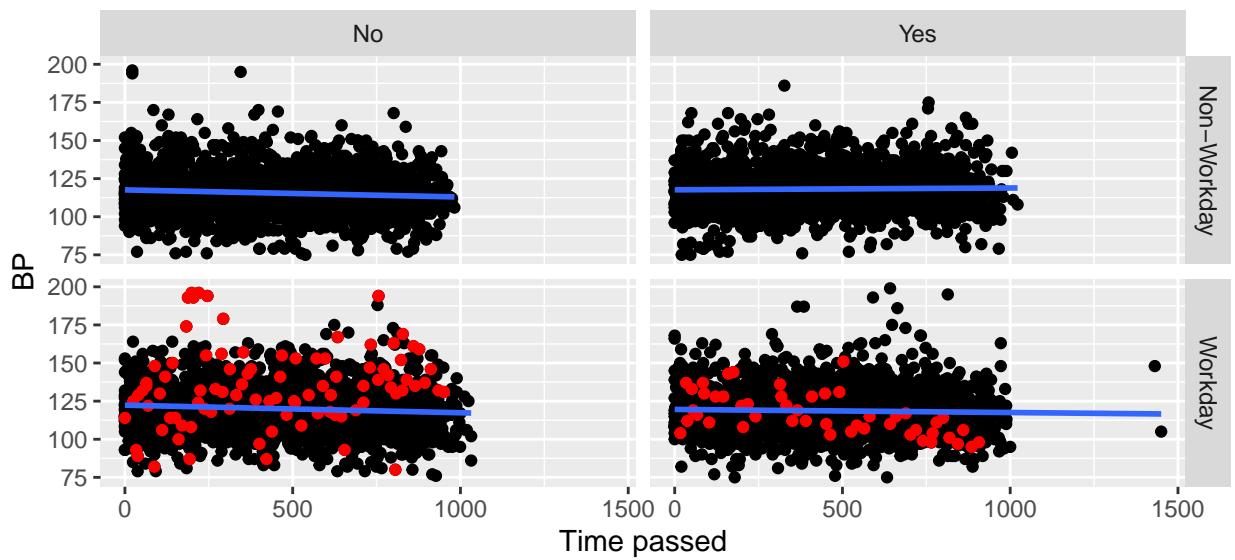
```
dotplot_diag(nurse_infl2$cooksdi, name = "cooks.distance", cutoff = "internal")
```

Cook's Dist



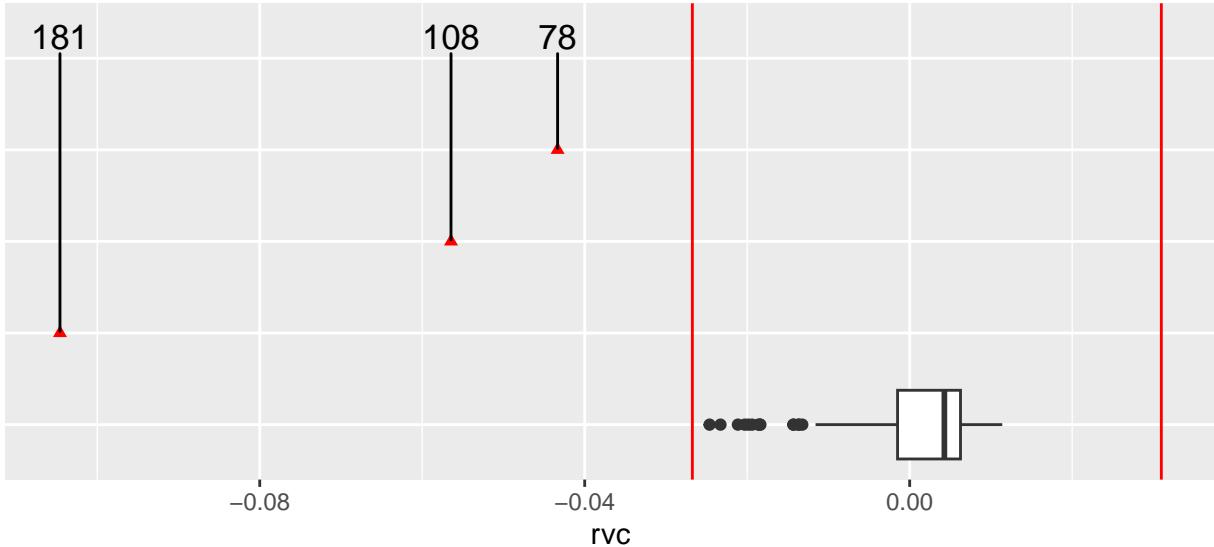
```
cd_flagged <- nurse_infl2 %>%
  arrange(desc(cooksd)) %>%
  slice(1:3) %>%
  pull(snum)

ggplot(nurse_filtered, aes(x = timepass, y = sys)) + geom_point() +
  geom_point(data = nurse_filtered %>%
    filter(snum %in% cd_flagged), color = "red") + geom_smooth(method = "lm",
  se = F) + facet_grid(rows = vars(day3), cols = vars(fh_2)) +
  labs(x = "Time passed", y = "BP")
```

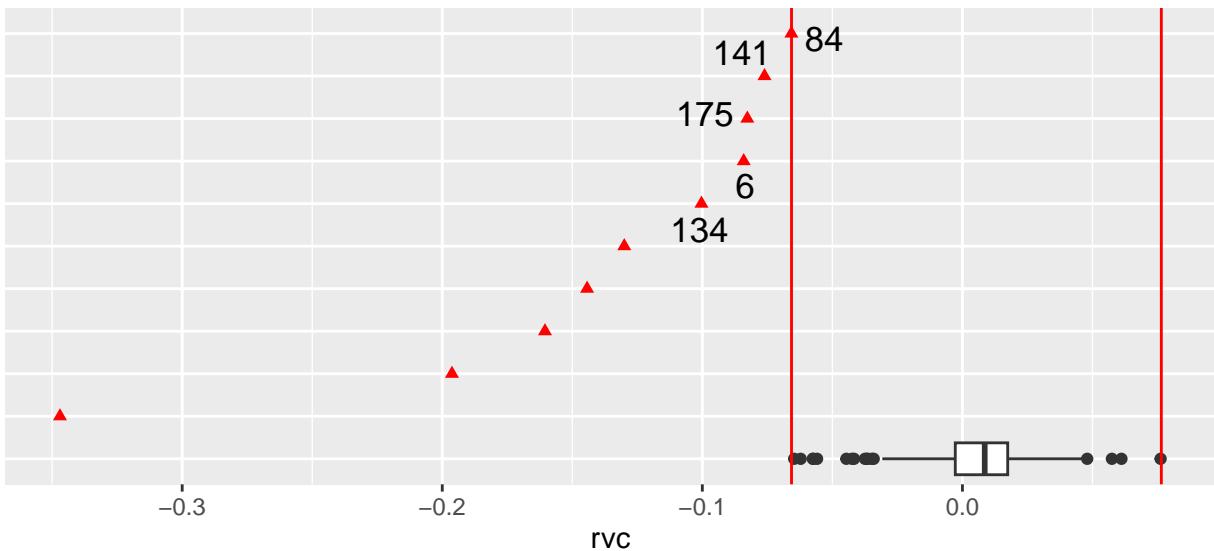


```
dotplot_diag(nurse_infl2$rvc.D11, name = "rvc", cutoff = "internal",
  modify = "boxplot")
```

RVC

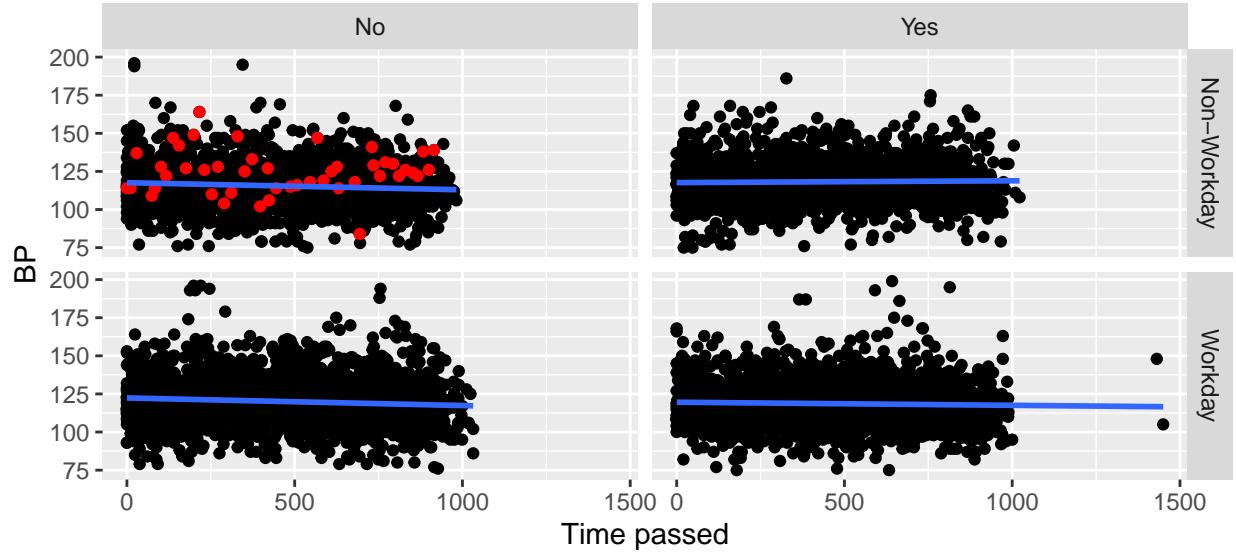


```
dotplot_diag(nurse_infl2$rvc.D22, name = "rvc", cutoff = "internal",
             modify = "boxplot")
```

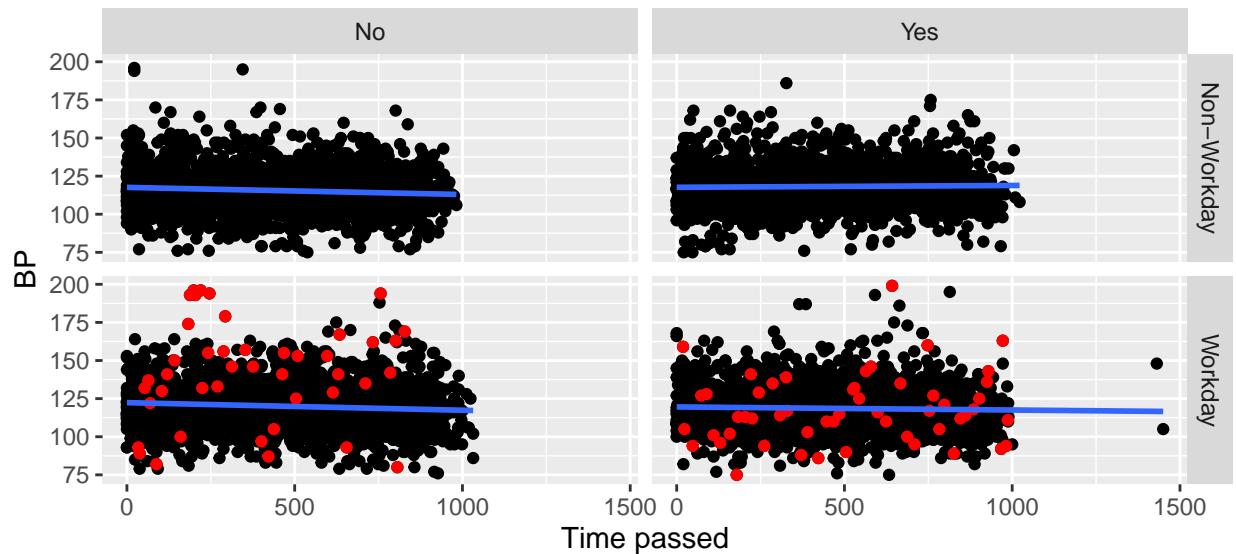


```
rvc1_flagged <- nurse_infl2 %>%
  arrange(desc(rvc.D11)) %>%
  slice(1) %>%
  pull(snum)
rvc2_flagged <- nurse_infl2 %>%
  arrange(desc(rvc.D22)) %>%
  slice(1:2) %>%
  pull(snum)

ggplot(nurse_filtered, aes(x = timepass, y = sys)) + geom_point() +
  geom_point(data = nurse_filtered %>%
    filter(snum %in% rvc1_flagged), color = "red") + geom_smooth(method = "lm",
  se = F) + facet_grid(rows = vars(day3), cols = vars(fh_2)) +
  labs(x = "Time passed", y = "BP")
```

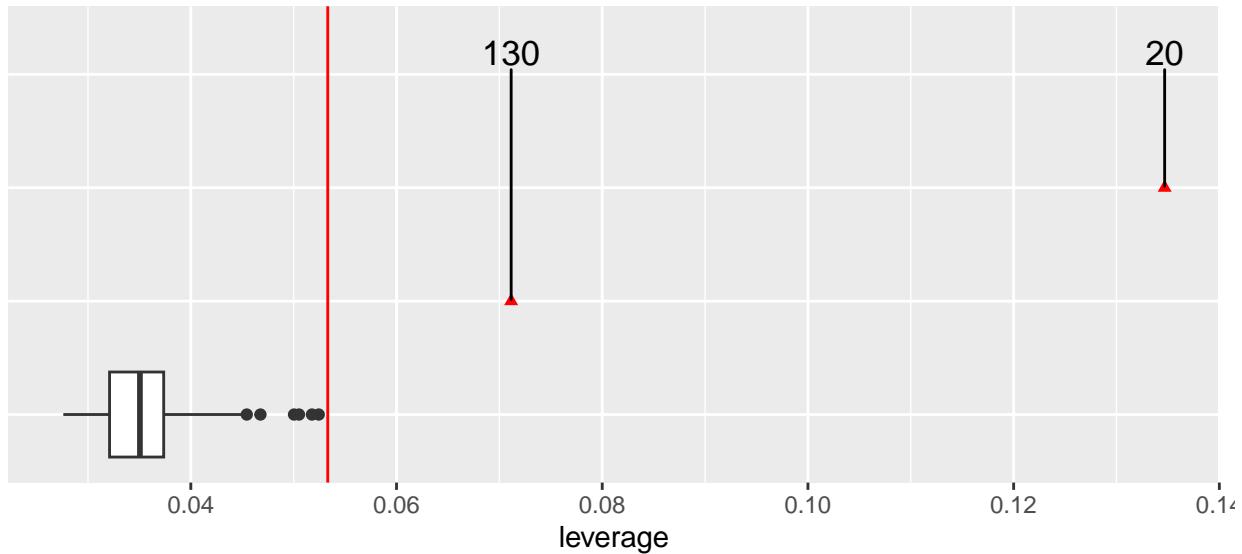


```
ggplot(nurse_filtered, aes(x = timepass, y = sys)) + geom_point() +
  geom_point(data = nurse_filtered %>%
    filter(snum %in% rvc2_flagged), color = "red") + geom_smooth(method = "lm",
  se = F) + facet_grid(rows = vars(day3), cols = vars(fh_2)) +
  labs(x = "Time passed", y = "BP")
```

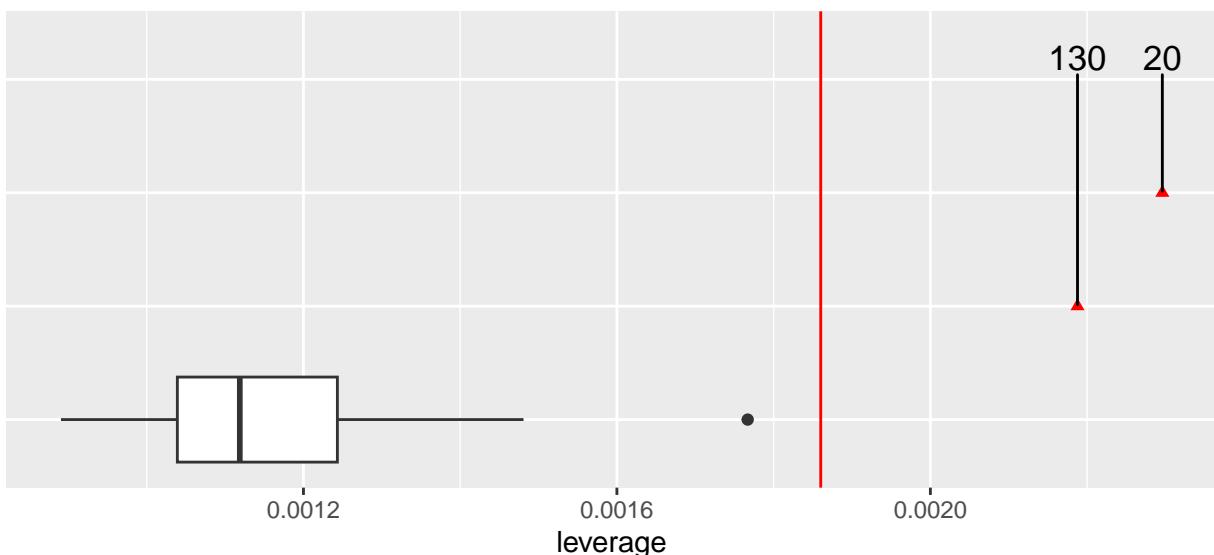


```
dotplot_diag(nurse_infl2$leverage.overall, name = "leverage",
  cutoff = "internal", modify = "boxplot")
```

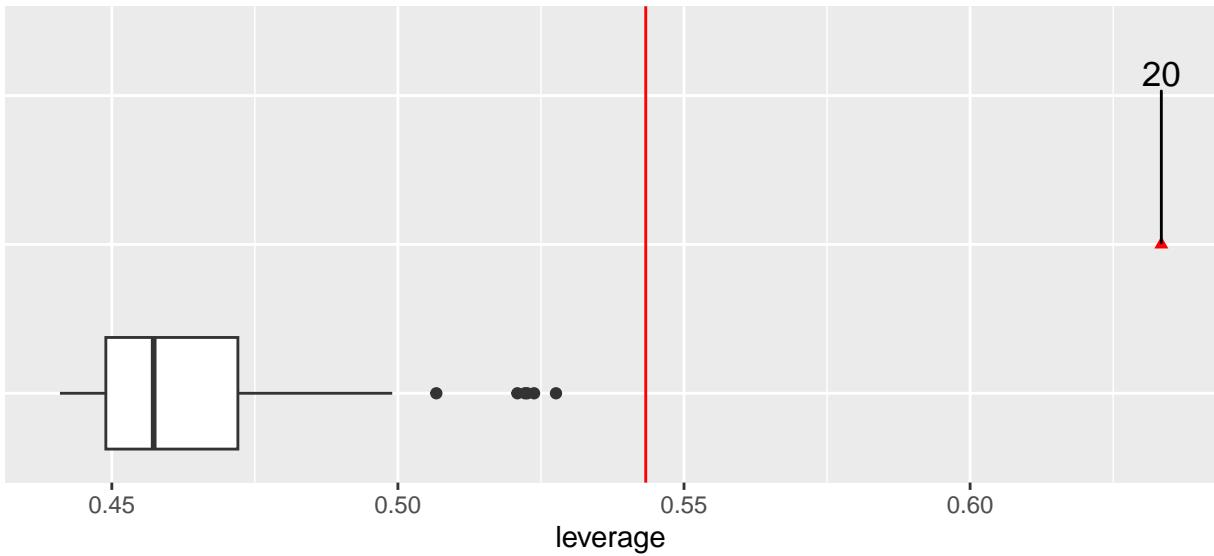
Leverage



```
dotplot_diag(nurse_infl2$leverage.fixef, name = "leverage", cutoff = "internal",
             modify = "boxplot")
```

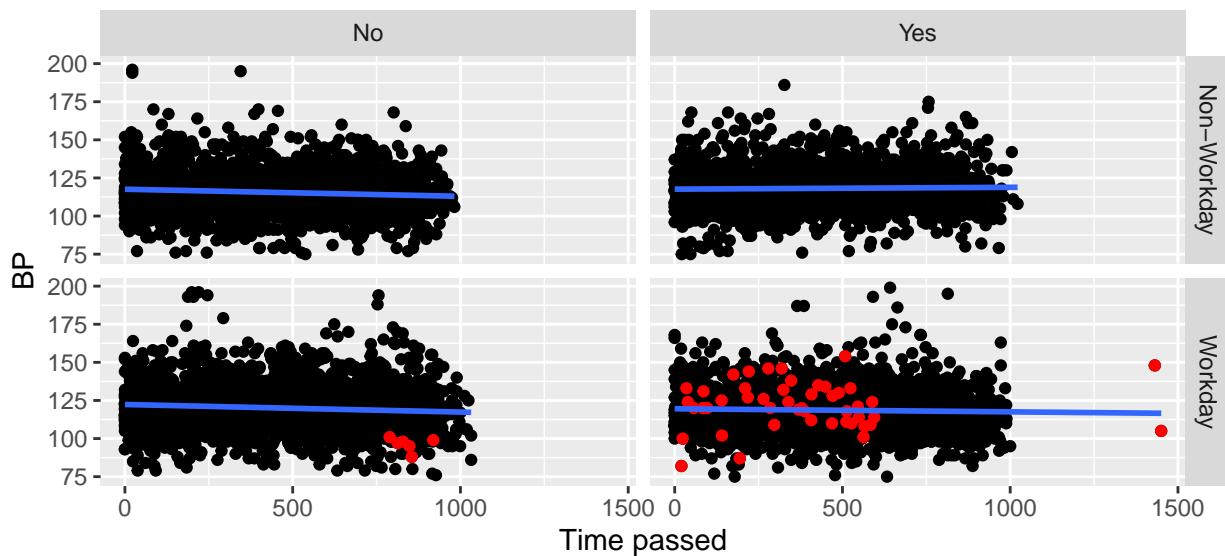


```
dotplot_diag(nurse_infl2$leverage.ranef.uc, name = "leverage",
             cutoff = "internal", modify = "boxplot")
```



```
lev_flagged <- nurse_infl2 %>%
  arrange(desc(leverage.overall)) %>%
  slice(1:3) %>%
  pull(snum)

ggplot(nurse_filtered, aes(x = timepass, y = sys)) + geom_point() +
  geom_point(data = nurse_filtered %>%
    filter(snum %in% lev_flagged), color = "red") + geom_smooth(method = "lm",
  se = F) + facet_grid(rows = vars(day3), cols = vars(fh_2)) +
  labs(x = "Time passed", y = "BP")
```



Effects Interpretation

Confidence Intervals

```
confint(final_model, parm = "beta_", method = "boot") -> boot_ci
kable(boot_ci)
```

	2.5 %	97.5 %
(Intercept)	106.3424279	111.3250936
day21	0.6210927	6.0598835
fh_yes1	-3.7928198	2.0956648
timepass	-0.0030215	0.0008926
standing1	0.3790055	1.8798636
mnact5	0.0368592	0.0476568
mood	-0.3817023	0.2557547
day21:timepass	-0.0047740	-0.0003932
fh_yes1:timepass	0.0020092	0.0065242

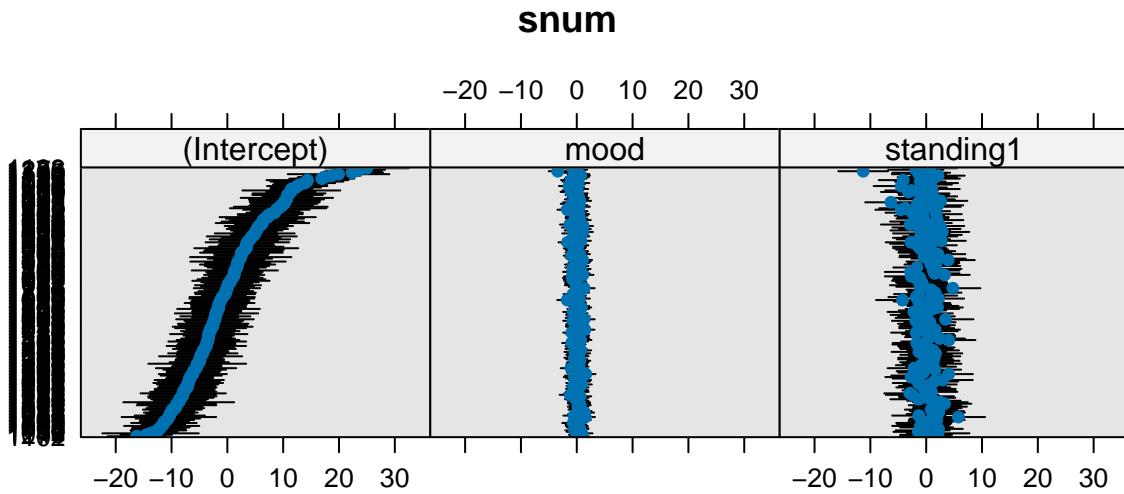
```
confint(final_model, parm = "beta_") -> ci
kable(ci)
```

	2.5 %	97.5 %
(Intercept)	106.0594276	111.1460292
day21	0.7423544	6.0646814
fh_yes1	-3.5648238	1.7407507
timepass	-0.0031063	0.0006840
standing1	0.2952229	1.8391249
mnact5	0.0374499	0.0472143
mood	-0.3951650	0.2862227
day21:timepass	-0.0047248	-0.0003240
fh_yes1:timepass	0.0021600	0.0065600

```
kable(tidy(final_model))
```

effect	group	term	estimate	std.error	statistic
fixed	NA	(Intercept)	108.5975606	1.2960412	83.7917510
fixed	NA	day21	3.4058398	1.3513764	2.5202748
fixed	NA	fh_yes1	-0.9142930	1.3556202	-0.6744463
fixed	NA	timepass	-0.0012123	0.0009663	-1.2545696
fixed	NA	standing1	1.0662225	0.3931126	2.7122575
fixed	NA	mnact5	0.0423330	0.0024894	17.0052371
fixed	NA	mood	-0.0588241	0.1718623	-0.3422743
fixed	NA	day21:timepass	-0.0025274	0.0011227	-2.2511555
fixed	NA	fh_yes1:timepass	0.0043626	0.0011203	3.8942712
ran_pars	snum	sd_(Intercept)	8.7136914	NA	NA
ran_pars	snum	cor_(Intercept).mood	-0.3359972	NA	NA
ran_pars	snum	cor_(Intercept).standing1	-0.3247593	NA	NA
ran_pars	snum	sd_mood	1.1307403	NA	NA
ran_pars	snum	cor_mood.standing1	0.6364044	NA	NA
ran_pars	snum	sd_standing1	3.1434507	NA	NA
ran_pars	Residual	sd_Observation	12.4260930	NA	NA

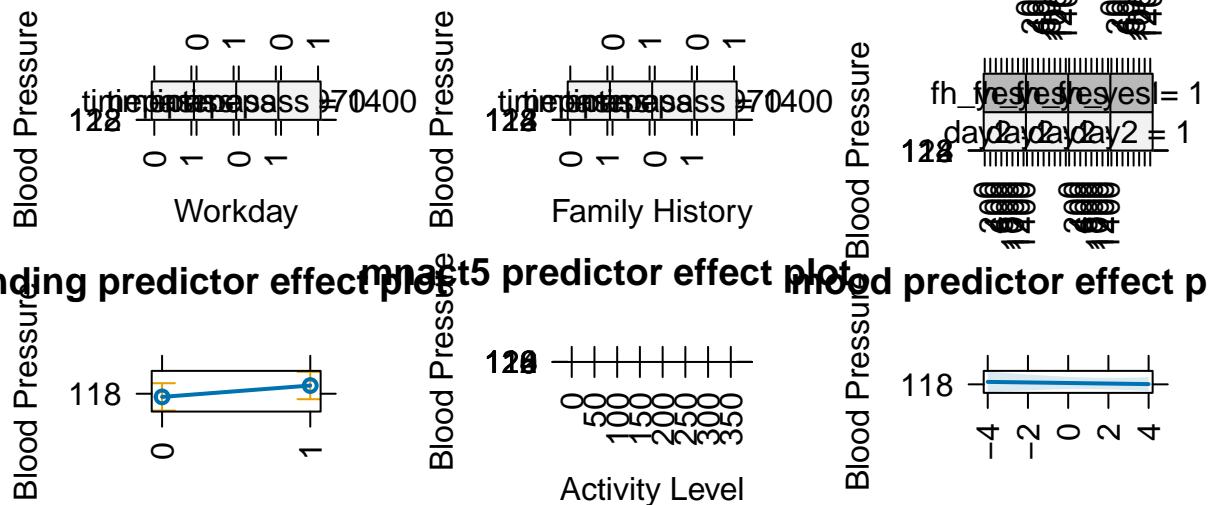
```
lattice::dotplot(ranef(final_model))
## $snum
```



Effects Plots

```
timepass_all <- nurse_filtered %>%
  distinct(timepass) %>%
  pull()
random_timepass <- sample(timepass_all, 3)
# plot(predictorEffects(final_model, xlevels =
# list(timepass = random_timepass)))
plot(predictorEffects(final_model, xlevels = 4), axes = list(x = list(rug = F,
  rotate = 90, day2 = list(lab = "Workday"), fh_yes = list(lab = "Family History"),
  timepass = "Time Passed", standing = "Standing", mnact5 = list(lab = "Activity Level"),
  mood = "Mood"), y = list(ticks = list(at = c(110, 114, 118,
  122, 126)), lab = "Blood Pressure")))
```

l1 predictor effect l2 yes predictor effect plot



```
nurse_filtered <- nurse_filtered %>%
  # predicted means with RE
  mutate(fit_cond = predict(final_model), fit_marg = predict(final_model,
    re.form = NA))
# predicted means without RE
```

```

ggplot(nurse_filtered, aes(x = timepass, y = sys)) + geom_point() +
  geom_line(aes(y = fit_cond, group = snum), color = "darkgrey") +
  geom_line(aes(y = fit_marg), color = "red", size = 1, alpha = 0.5) +
  facet_grid(rows = vars(day3), cols = vars(fh_2)) + labs(title = "Blood Pressure vs Time Passed, by Workday",
  x = "Minutes since first measurement", y = "Systolic Blood Pressure") +
  theme_minimal(base_size = 17)

```

