Age of acquisition and borrowing: English

Load libraries

```
library(mgcv)
library(sjPlot)
library(lattice)
library(ggplot2)
library(dplyr)
library(party)
library(lmtest)
library(gridExtra)
library(scales)
library(itsadug)

logit2per = function(X){
  return(exp(X)/(1+exp(X)))
}

rescaleGam = function(px, n, xvar, xlab=""){
  y = logit2per(px[[n]]$fit)
  x = px[[n]]$x *attr(xvar,"scaled:scale") + attr(xvar,"scaled:center")
  se.upper = logit2per(px[[n]]$fit+px[[n]]$se)
  se.lower = logit2per(px[[n]]$fit-px[[n]]$se)
  dx = data.frame(x=x,y=y,ci.upper=se.upper,ci.lower=se.lower)
  plen = ggplot(dx, aes(x=x,y=y))+
    geom_ribbon(aes(ymin=ci.lower,ymax=ci.upper), alpha=0.3)+
    geom_line(size=1) +
    xlab(xlab)+
    ylab("Probability of borrowing")+
    coord_cartesian(ylim = c(0,1))
  return(plen)
}
```

Load data

- word: Orthographic form
- borrowing: variable from WOLD indicating level of evidence for borrowing:
- 1 = definately borrowed
- 5 = no evidence of borrowing
- age_oldest, age_youngest: Dates from WOLD indicating estiamte of data of entry into English
- phonology: Phonological form
- phonlength: Number of segments in the phonological form
- AoA: Age of acquisition ratings from Kuperman, Stadthagen-Gonzalez, and Brysbaert (2012).
- AoA_obj: Objective, test-based age of acuqisition from Brysbaert & Biemiller (2017)
- subtlexzipf: Log frequency of word from the SUBTLEX database
- conc: Concreteness ratings from Brysbaert, Warriner, & Kuperman (2014)
- cat: Dominant part of speech according to SUBTLEX.
- bor15: Conversion of the WOLD borrowing variable into a numeric (0 = not borrowed, 1 = borrowed)

```r
dataloan <- read.csv("../data/loanword8.csv",stringsAsFactors = F)
dataloan$bor15 <- ifelse(dataloan$borrowing==1,1, ifelse(dataloan$borrowing==5,0,NA))
dataloan$bor15.cat <- factor(dataloan$bor15)
```

Convert to numbers.

```r
dataloan$subtlexzipf = as.numeric(dataloan$subtlexzipf)
dataloan$AoA = as.numeric(dataloan$AoA)
dataloan$conc = as.numeric(dataloan$conc)

aoaSD = sd(dataloan$AoA,na.rm = T)
aoaMean = mean(dataloan$AoA/aoaSD,na.rm=T)
dataloan$cat = factor(dataloan$cat)
```

Select only complete cases.

```r
dataloan2 = dataloan[complete.cases(dataloan[,
               c("phonlength","AoA",
               "subtlexzipf", "cat",
               'conc','bor15')]),]
```

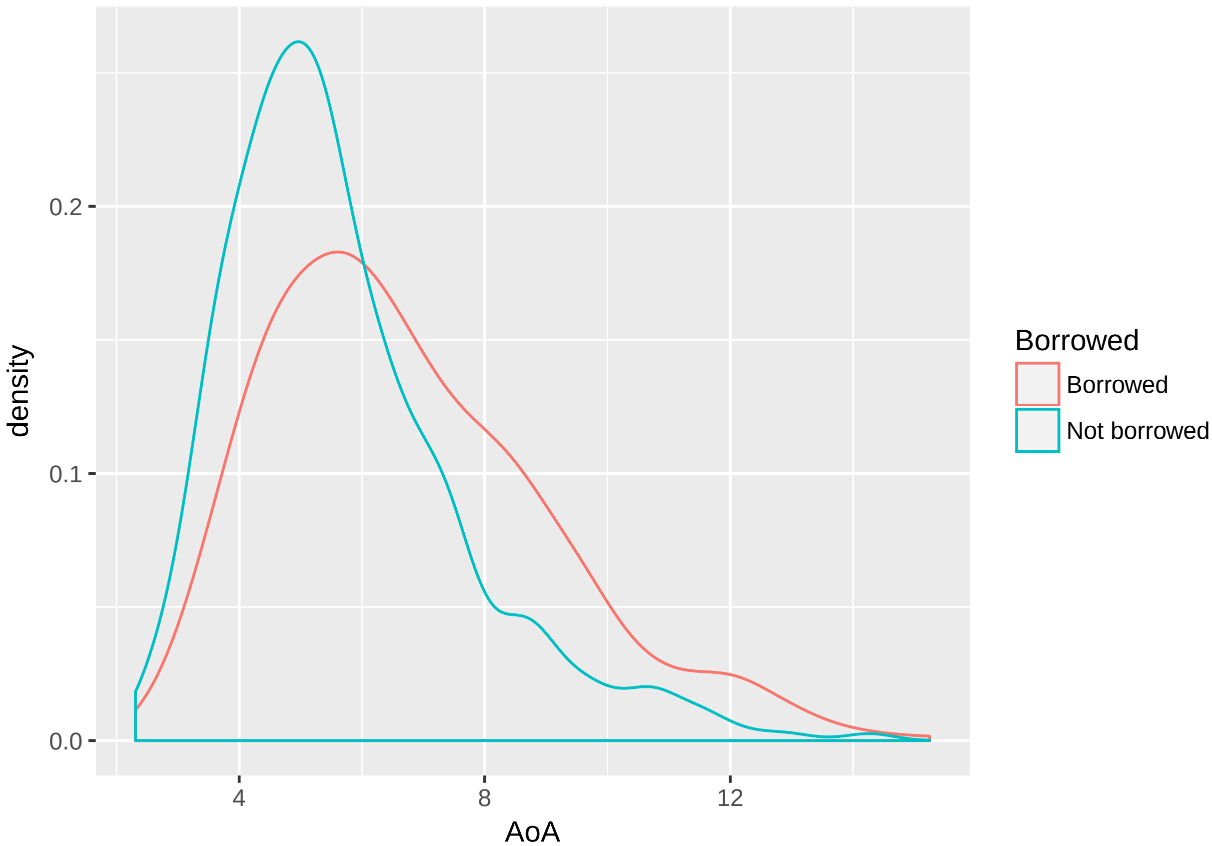
Scale and center:

```r
dataloan2$AoAscale <- scale(dataloan2$AoA)

dataloan2$subtlexzipfscale <- scale(dataloan2$subtlexzipf)

phonlength.center = median(dataloan2$phonlength)
dataloan2$phonlengthscale <-
  dataloan2$phonlength - phonlength.center
phonlength.scale = sd(dataloan2$phonlengthscale)
dataloan2$phonlengthscale = dataloan2$phonlengthscale/phonlength.scale

attr(dataloan2$phonlengthscale,"scaled:scale") = phonlength.scale
attr(dataloan2$phonlengthscale,"scaled:center") = phonlength.center

dataloan2$concscale <- scale(dataloan2$conc)

dataloan2$cat = relevel(dataloan2$cat,"Noun")

dataloan2$AoA_objscaled = scale(dataloan2$AoA_obj)
```

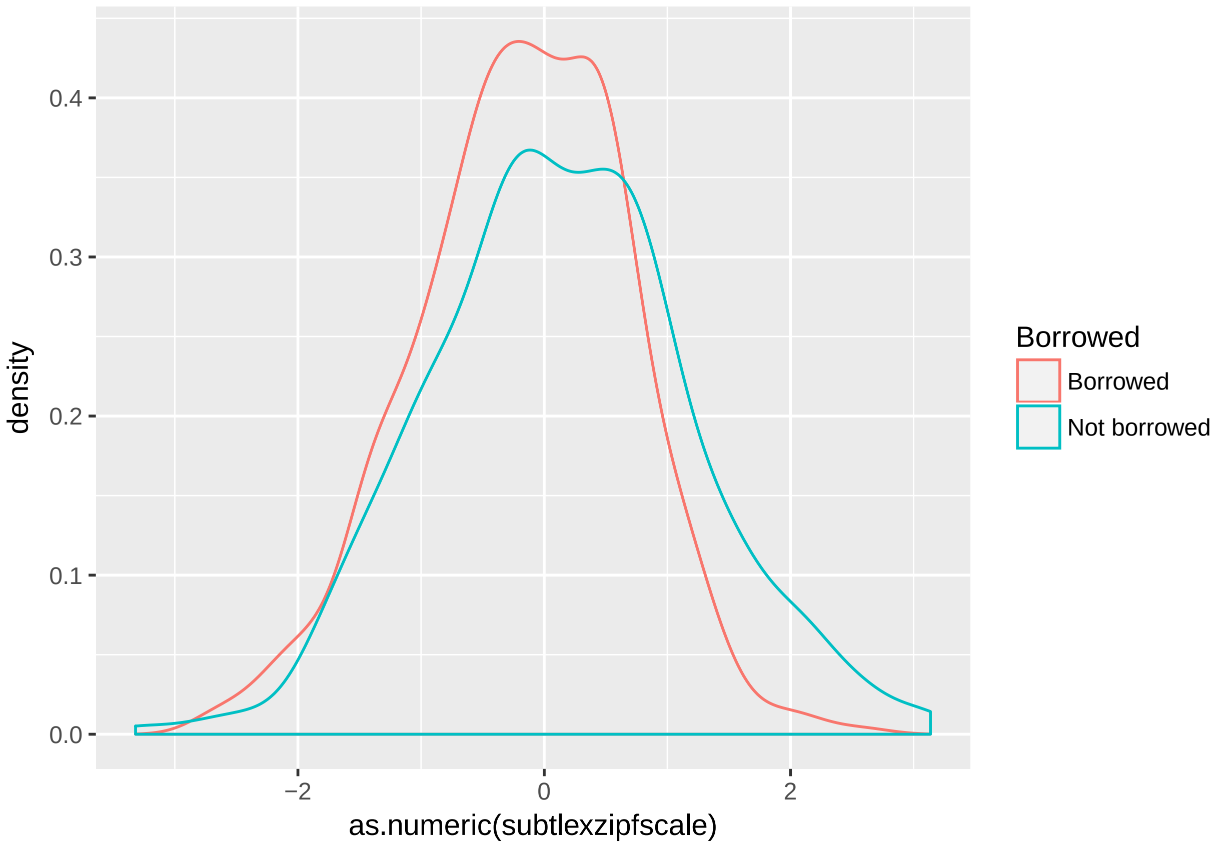
Plots

Raw data

```r
dataloan2$Borrowed = c("Not borrowed", "Borrowed")[dataloan2$bor15+1]
ggplot(dataloan2[!is.na(dataloan2$Borrowed),], aes(x=AoA, colour=Borrowed)) +
  geom_density()
```

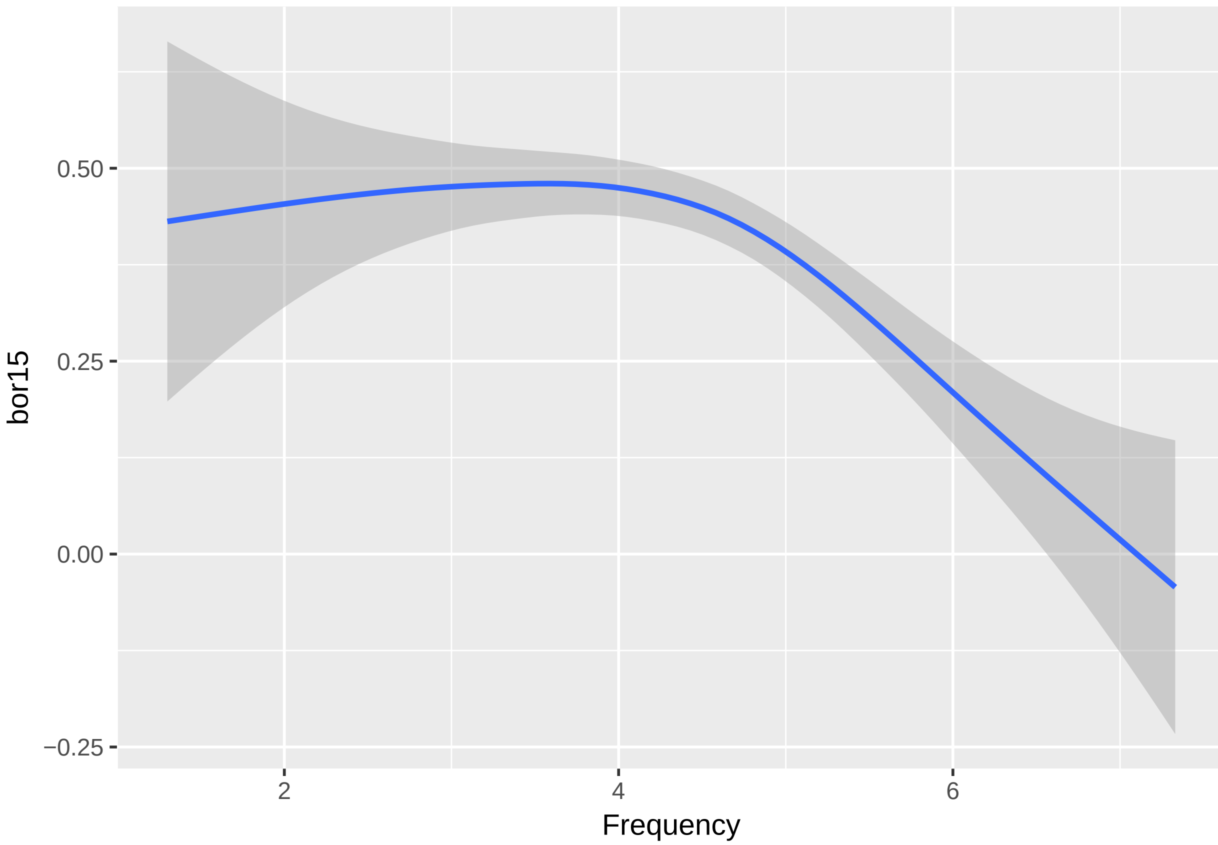



```
ggplot(dataloan2[!is.na(dataloan2$Borrowed),], aes(x=as.numeric(subtlexzipfscale), colour=Borrowed)) +
  geom_density()
```



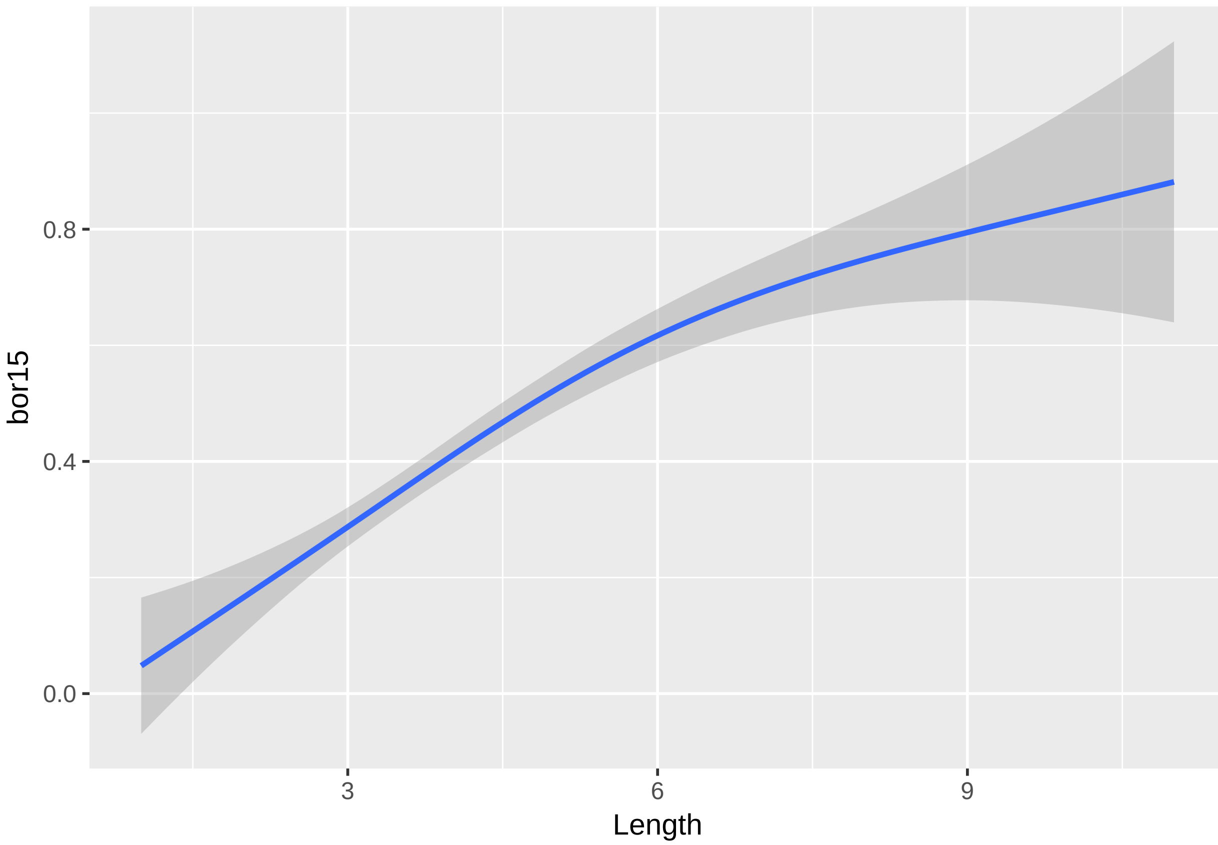

```r
ggplot(dataloan2[!is.na(dataloan2$Borrowed),], aes(x=as.numeric(subtlexzipf), y=bor15)) +
  stat_smooth()+
  xlab("Frequency")
```

```
## `geom_smooth()` using method = 'gam' and formula 'y ~ s(x, bs = "cs")'
```




```
ggplot(dataloan2[!is.na(dataloan2$Borrowed),], aes(x=as.numeric(phonlength), y=bor15)) +
  stat_smooth() +
  xlab("Length")
```

```
## `geom_smooth()` using method = 'gam' and formula 'y ~ s(x, bs = "cs")'
```




```
dataloan2$subtlexzipf.cat = cut(
  dataloan2$subtlexzipf,
  breaks = quantile(dataloan2$subtlexzipf,
                  prob=seq(0,1,length.out=4)),
  include.lowest = T)
```

Look at variation between parts of speech:

```
catx = data.frame(
  PoS = tapply(dataloan2$cat, dataloan2$cat, function(X){as.character(X[1])}),
  mean = tapply(dataloan2$bor15, dataloan2$cat, mean),
  n = tapply(dataloan2$bor15, dataloan2$cat, length)
)
catx = catx[order(catx$mean, decreasing = T),]
catx$PoS = factor(catx$PoS, levels = catx[order(catx$mean, decreasing = T),]$PoS)

posg = ggplot(catx, aes(x=mean, y=PoS)) +
  geom_point(size=2) +
  ylab("Part of speech") +
  xlab("Proportion of words borrowed")+
  scale_x_continuous(labels=percent_format()) +
  geom_text(aes(label=n), nudge_y=0.4)

pdf("../results/graphs/POS_Borrowing.pdf",
    width = 6,
    height = 4)
posg
dev.off()
```

```
## pdf
##   2
```

```r
catx$mean= catx$mean*100
write.csv(catx, "../results/English_POS_BorrowingProportions.csv", row.names = F)
```

GAM

```r
m0 = bam(bor15.cat ~
      s(phonlengthscale) +
      s(AoAscale) +
      s(subtlexzipfscale) +
      s(concscale) +
      s(cat,bs='re')+
      s(cat,phonlengthscale,bs='re')+
      s(cat,AoAscale,bs='re')+
      s(cat,subtlexzipfscale,bs='re')+
      s(cat,concscale,bs='re'),
    data = dataloan2,
    family='binomial')
```

```r
summary(m0)
```

```
##
## Family: binomial
## Link function: logit
##
## Formula:
## bor15.cat ~ s(phonlengthscale) + s(AoAscale) + s(subtlexzipfscale) +
##     s(concscale) + s(cat, bs = "re") + s(cat, phonlengthscale,
##     bs = "re") + s(cat, AoAscale, bs = "re") + s(cat, subtlexzipfscale,
##     bs = "re") + s(cat, concscale, bs = "re")
##
## Parametric coefficients:
##             Estimate Std. Error z value Pr(>|z|)
## (Intercept)  -1.4908     0.4402  -3.386 0.000709 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Approximate significance of smooth terms:
##                               edf Ref.df Chi.sq  p-value
## s(phonlengthscale)      1.622e+00  2.036 32.336 1.12e-07 ***
## s(AoAscale)             1.000e+00  1.000 35.555 2.48e-09 ***
## s(subtlexzipfscale)     3.407e+00  4.328 32.599 2.74e-06 ***
## s(concscale)            2.680e+00  3.343  7.640   0.0728 .
## s(cat)                  5.878e+00 11.000 39.654 1.24e-08 ***
## s(cat,phonlengthscale)  1.191e+00 11.000  3.186   0.0626 .
## s(cat,AoAscale)         2.542e-06 11.000  0.000   0.7221
## s(cat,subtlexzipfscale) 8.010e-06 11.000  0.000   0.7499
## s(cat,concscale)        9.244e-06 11.000  0.000   0.7037
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## R-sq.(adj) =   0.19   Deviance explained = 16.2%
## fREML = 1864.5  Scale est. = 1         n = 1317
```

Interactions

Test whether an interaction between AoA and frequency is warranted using likelihood ratio comparisons:

```r
m1 = bam(bor15.cat ~
      s(phonlengthscale) +
      s(AoAscale) +
      s(subtlexzipfscale) +
      s(concscale) +
      s(cat,bs='re')+
      s(cat,phonlengthscale,bs='re')+
      s(cat,AoAscale,bs='re')+
      s(cat,subtlexzipfscale,bs='re')+
      s(cat,concscale,bs='re') +
      te(AoAscale,subtlexzipfscale),
    data = dataloan2,
    family='binomial')

lrtest(m0,m1)
```

```
## Likelihood ratio test
##
## Model 1: bor15.cat ~ s(phonlengthscale) + s(AoAscale) + s(subtlexzipfscale) +
##     s(concscale) + s(cat, bs = "re") + s(cat, phonlengthscale,
##     bs = "re") + s(cat, AoAscale, bs = "re") + s(cat, subtlexzipfscale,
##     bs = "re") + s(cat, concscale, bs = "re")
## Model 2: bor15.cat ~ s(phonlengthscale) + s(AoAscale) + s(subtlexzipfscale) +
##     s(concscale) + s(cat, bs = "re") + s(cat, phonlengthscale,
##     bs = "re") + s(cat, AoAscale, bs = "re") + s(cat, subtlexzipfscale,
##     bs = "re") + s(cat, concscale, bs = "re") + te(AoAscale,
##     subtlexzipfscale)
##      #Df  LogLik      Df  Chisq Pr(>Chisq)
## 1 19.758 -749.22
## 2 20.708 -748.38 0.95022 1.6707     0.1962
```

No significant improvement.

Test whether an interaction between AoA and length is warranted:

```r
m2 = bam(bor15.cat ~
      s(phonlengthscale) +
      s(AoAscale) +
      s(subtlexzipfscale) +
      s(concscale) +
      s(cat,bs='re')+
      s(cat,phonlengthscale,bs='re')+
      s(cat,AoAscale,bs='re')+
      s(cat,subtlexzipfscale,bs='re')+
      s(cat,concscale,bs='re') +
      te(AoAscale,phonlengthscale),
    data = dataloan2,
    family='binomial')

lrtest(m0,m2)
```

```
## Likelihood ratio test
##
## Model 1: bor15.cat ~ s(phonlengthscale) + s(AoAscale) + s(subtlexzipfscale) +
##     s(concscale) + s(cat, bs = "re") + s(cat, phonlengthscale,
```

```
##     bs = "re") + s(cat, AoAscale, bs = "re") + s(cat, subtlexzipfscale,
##     bs = "re") + s(cat, concscale, bs = "re")
## Model 2: bor15.cat ~ s(phonlengthscale) + s(AoAscale) + s(subtlexzipfscale) +
##     s(concscale) + s(cat, bs = "re") + s(cat, phonlengthscale,
##     bs = "re") + s(cat, AoAscale, bs = "re") + s(cat, subtlexzipfscale,
##     bs = "re") + s(cat, concscale, bs = "re") + te(AoAscale,
##     phonlengthscale)
##      #Df  LogLik         Df Chisq Pr(>Chisq)
## 1 19.758 -749.22
## 2 19.758 -749.22 1.2566e-05     0  < 2.2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

No significant improvement.

Test whether an interaction between Frequency and length is warranted:

```
m3 = bam(bor15.cat ~
      s(phonlengthscale) +
      s(AoAscale) +
      s(subtlexzipfscale) +
      s(concscale) +
      s(cat,bs='re')+
      s(cat,phonlengthscale,bs='re')+
      s(cat,AoAscale,bs='re')+
      s(cat,subtlexzipfscale,bs='re')+
      s(cat,concscale,bs='re') +
      te(subtlexzipfscale,phonlengthscale),
    data = dataloan2,
    family='binomial')

lrtest(m0,m3)
```

```
## Likelihood ratio test
##
## Model 1: bor15.cat ~ s(phonlengthscale) + s(AoAscale) + s(subtlexzipfscale) +
##     s(concscale) + s(cat, bs = "re") + s(cat, phonlengthscale,
##     bs = "re") + s(cat, AoAscale, bs = "re") + s(cat, subtlexzipfscale,
##     bs = "re") + s(cat, concscale, bs = "re")
## Model 2: bor15.cat ~ s(phonlengthscale) + s(AoAscale) + s(subtlexzipfscale) +
##     s(concscale) + s(cat, bs = "re") + s(cat, phonlengthscale,
##     bs = "re") + s(cat, AoAscale, bs = "re") + s(cat, subtlexzipfscale,
##     bs = "re") + s(cat, concscale, bs = "re") + te(subtlexzipfscale,
##     phonlengthscale)
##      #Df  LogLik     Df  Chisq Pr(>Chisq)
## 1 19.758 -749.22
## 2 22.651 -747.83 2.8934 2.7782     0.4271
```

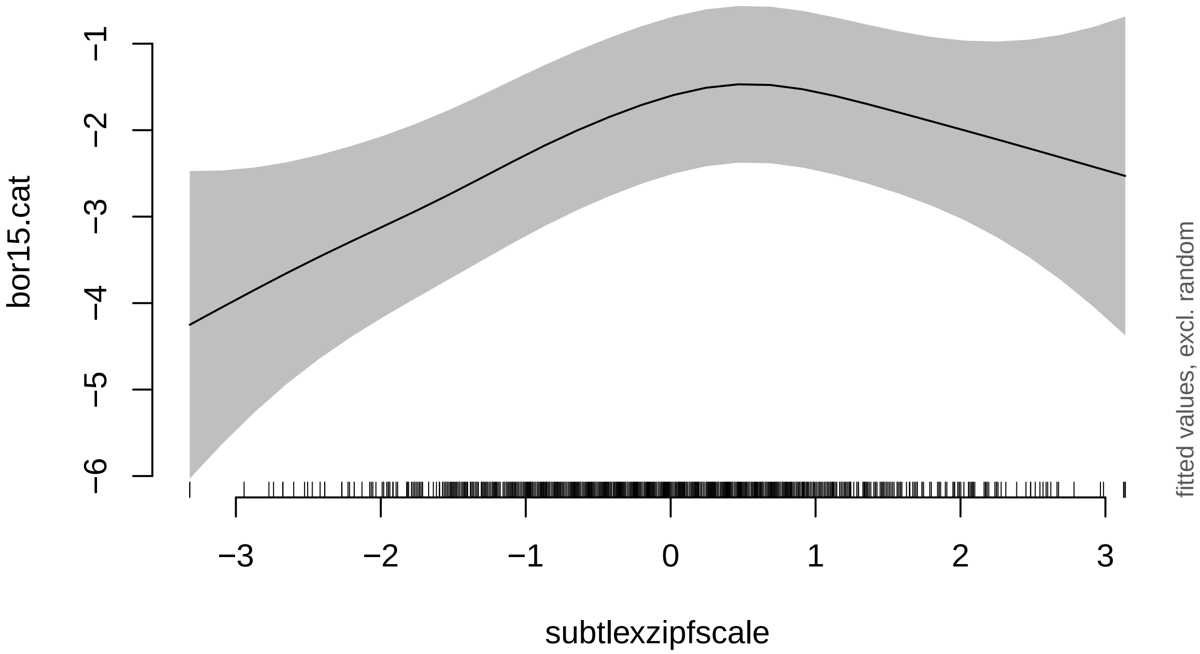
No significant improvement.

So no interactions are necessary.

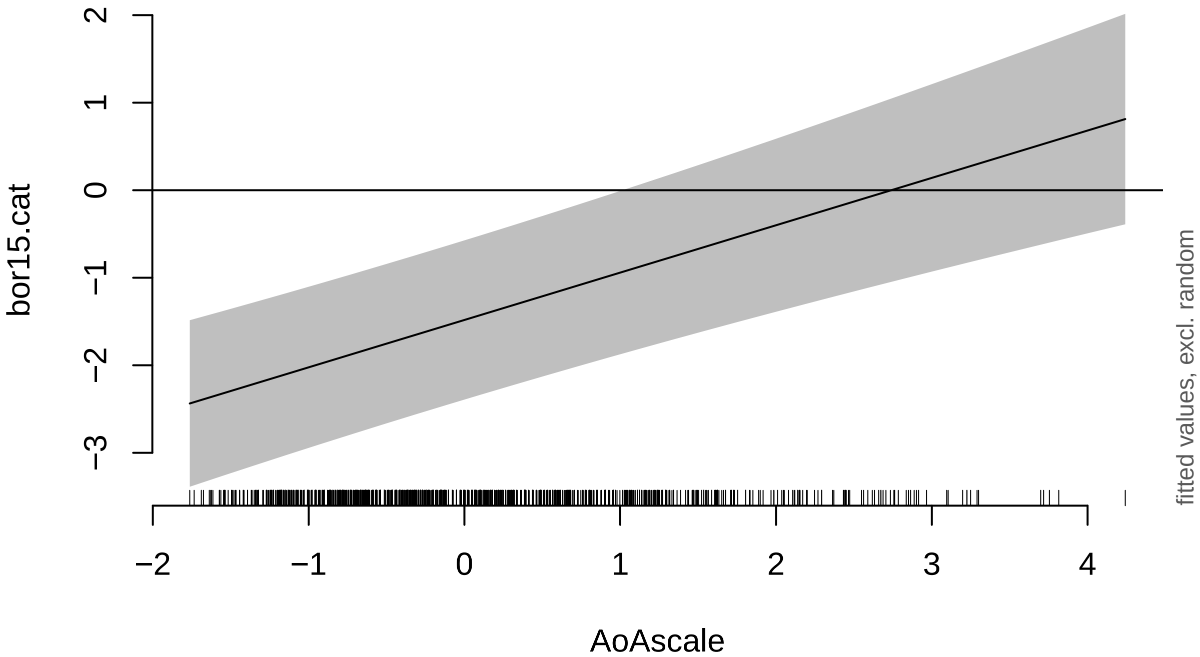
Model plots

Plot the model estimates, changing the dependent scale to probability and the independent variables to their original scales. The code uses the `itsadug` package and then rescales the variables back to the original units. This code is hidden, but you can view it in the Rmd file.

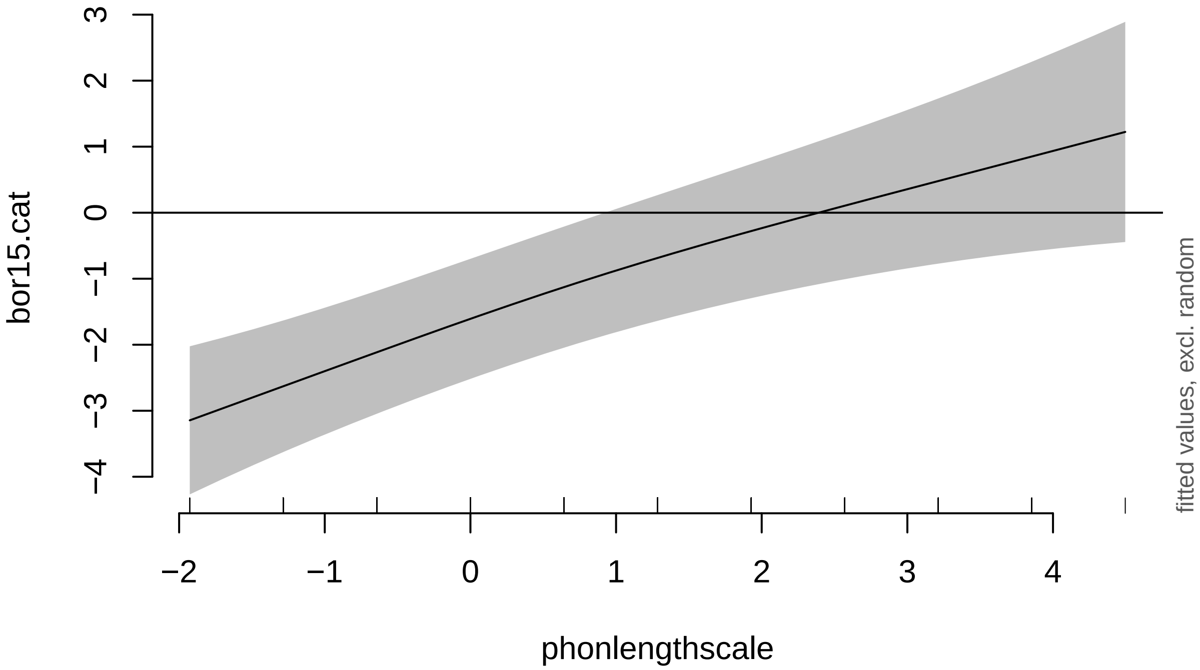
```
# from itsadug: plot ignoring random effects
px = plot_smooth(m0,view="subtlexzipfscale", rm.ranef = T, print.summary=F)
```



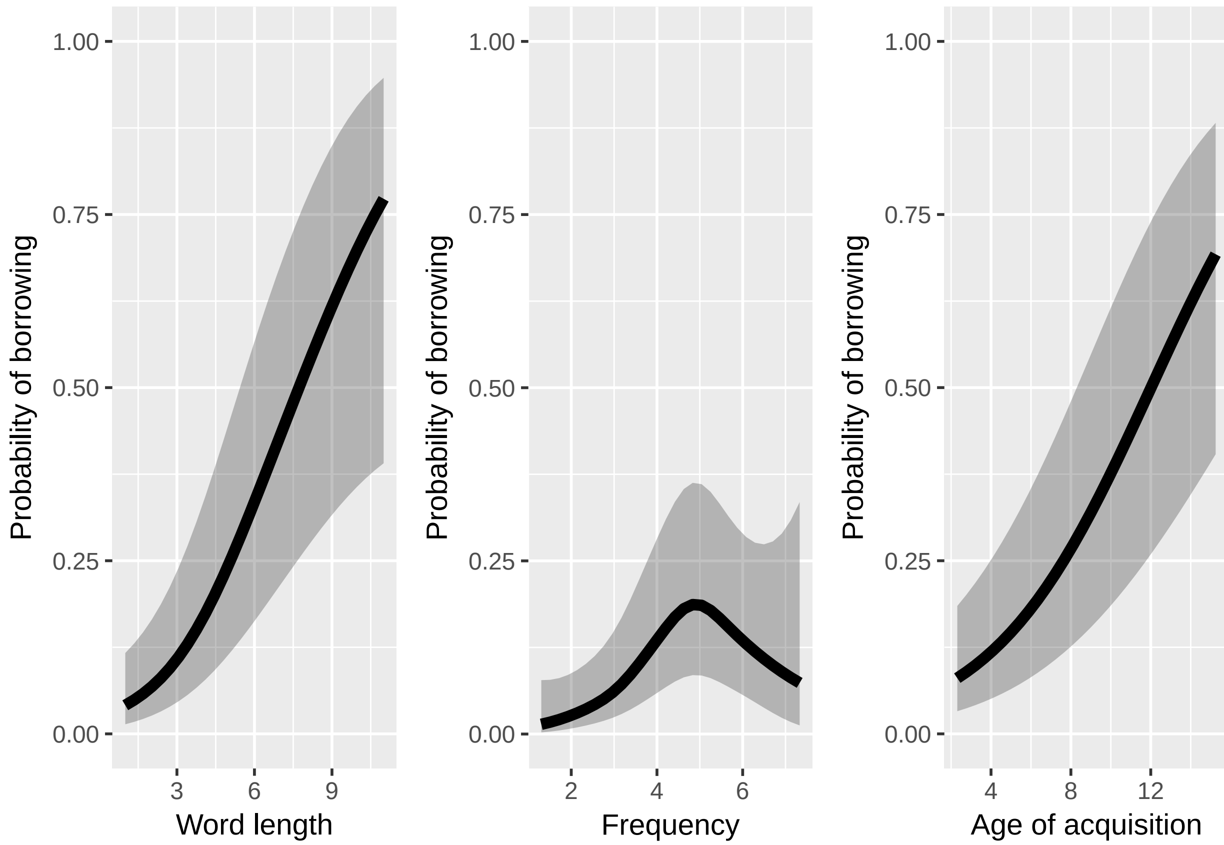

```
px$fv$fit = logit2per(px$fv$fit)
px$fv$ul = logit2per(px$fv$ul)
px$fv$ll = logit2per(px$fv$ll)
px$fv$subtlexzipfscale = px$fv$subtlexzipfscale * attr(dataloan2$subtlexzipfscale,"scaled:scale") + att

gFreq = ggplot(px$fv, aes(x=subtlexzipfscale,y=fit)) +
  geom_ribbon(aes(ymin=ll,ymax=ul), alpha=0.3) +
  geom_line(size=2) +
  ylab("Probability of borrowing") +
  xlab("Frequency") +
  coord_cartesian(ylim=c(0,1))

px = plot_smooth(m0,view="AoAscale", rm.ranef = T, print.summary=F)
```




```
px$fv$fit = logit2per(px$fv$fit)
px$fv$ul = logit2per(px$fv$ul)
px$fv$ll = logit2per(px$fv$ll)
px$fv$AoAscale = px$fv$AoAscale * attr(dataloan2$AoAscale,"scaled:scale") + attr(dataloan2$AoAscale,"sca

gAoA = ggplot(px$fv, aes(x=AoAscale,y=fit)) +
  geom_ribbon(aes(ymin=ll,ymax=ul), alpha=0.3) +
  geom_line(size=2) +
  ylab("Probability of borrowing") +
  xlab("Age of acquisition")+
  coord_cartesian(ylim=c(0,1))

px = plot_smooth(m0,view="phonlengthscale", rm.ranef = T, print.summary = F)
```




```
px$fv$fit = logit2per(px$fv$fit)
px$fv$ul = logit2per(px$fv$ul)
px$fv$ll = logit2per(px$fv$ll)
px$fv$phonlengthscale = px$fv$phonlengthscale * phonlength.scale + phonlength.center

gLen = ggplot(px$fv, aes(x=phonlengthscale,y=fit)) +
  geom_ribbon(aes(ymin=ll,ymax=ul), alpha=0.3) +
  geom_line(size=2) +
  ylab("Probability of borrowing") +
  xlab("Word length")+
  coord_cartesian(ylim=c(0,1))

grid.arrange(gLen, gFreq, gAoA, nrow=1)
```




```
pdf("../results/graphs/English_ModelResults_NoRF.pdf",
    height =3,width = 8)
grid.arrange(gLen, gFreq, gAoA, nrow=1)
dev.off()
```

```
## pdf
##   2
```

Objective measures of AoA

Below we run the same model, but with objective, test-based AoA from Brysbaert et al. (2017). Note that the values for objective AoA are only whole numbers, so there are not as many unique values and we have to limit the number of knots that the model uses.

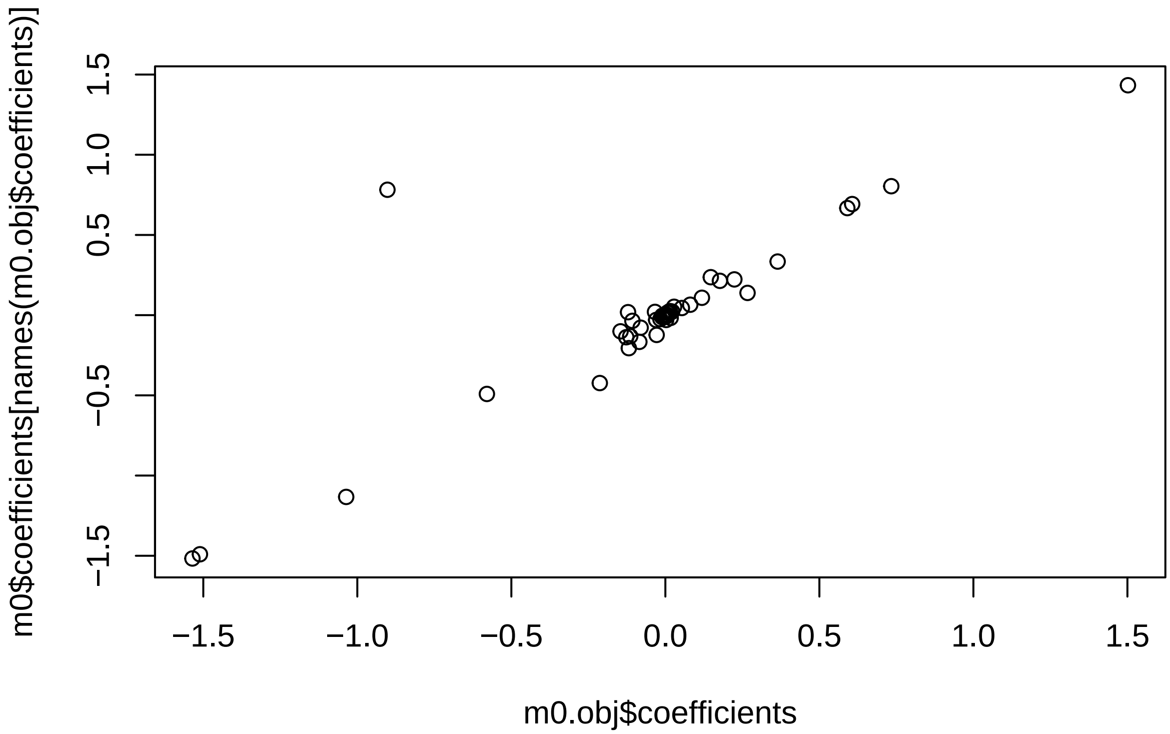
```
m0.obj = bam(bor15.cat ~
      s(phonlengthscale) +
      s(AoA_objscaled, k=3) +
      s(subtlexzipfscale) +
      s(concscale) +
      s(cat,bs='re')+
      s(cat,phonlengthscale,bs='re')+
      s(cat,AoA_objscaled,bs='re')+
      s(cat,subtlexzipfscale,bs='re')+
      s(cat,concscale,bs='re'),
    data = dataloan2[!is.na(dataloan2$AoA_objscaled),],
    family='binomial')
```

```
summary(m0.obj)
```

```
##
## Family: binomial
## Link function: logit
##
## Formula:
## bor15.cat ~ s(phonlengthscale) + s(AoA_objscaled, k = 3) + s(subtlexzipfscale) +
##     s(concscale) + s(cat, bs = "re") + s(cat, phonlengthscale,
##     bs = "re") + s(cat, AoA_objscaled, bs = "re") + s(cat, subtlexzipfscale,
##     bs = "re") + s(cat, concscale, bs = "re")
##
## Parametric coefficients:
##             Estimate Std. Error z value Pr(>|z|)
## (Intercept)   -1.511      0.439  -3.442 0.000577 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Approximate significance of smooth terms:
##                             edf Ref.df Chi.sq  p-value
## s(phonlengthscale)      2.119e+00  2.694 34.748 2.13e-07 ***
## s(AoA_objscaled)        1.762e+00  1.940 28.249 3.47e-06 ***
## s(subtlexzipfscale)     3.437e+00  4.373 25.330 7.77e-05 ***
## s(concscale)            2.220e+00  2.773  7.034   0.0428 *
## s(cat)                  5.869e+00 11.000 46.705 1.79e-10 ***
## s(cat,phonlengthscale)  1.171e+00 11.000  3.044   0.0670 .
## s(cat,AoA_objscaled)    1.879e-06 11.000  0.000   0.7107
## s(cat,subtlexzipfscale) 8.312e-06 11.000  0.000   0.7457
## s(cat,concscale)        8.632e-06 11.000  0.000   0.7968
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## R-sq.(adj) =  0.181   Deviance explained = 15.7%
## fREML = 1834.3  Scale est. = 1         n = 1296
```

Very similar results. For example, almost all coefficients are the same:

```
plot(m0.obj$coefficients, m0$coefficients[names(m0.obj$coefficients)])
```



The outlier is the coefficient for `subtlexzipfscale`.

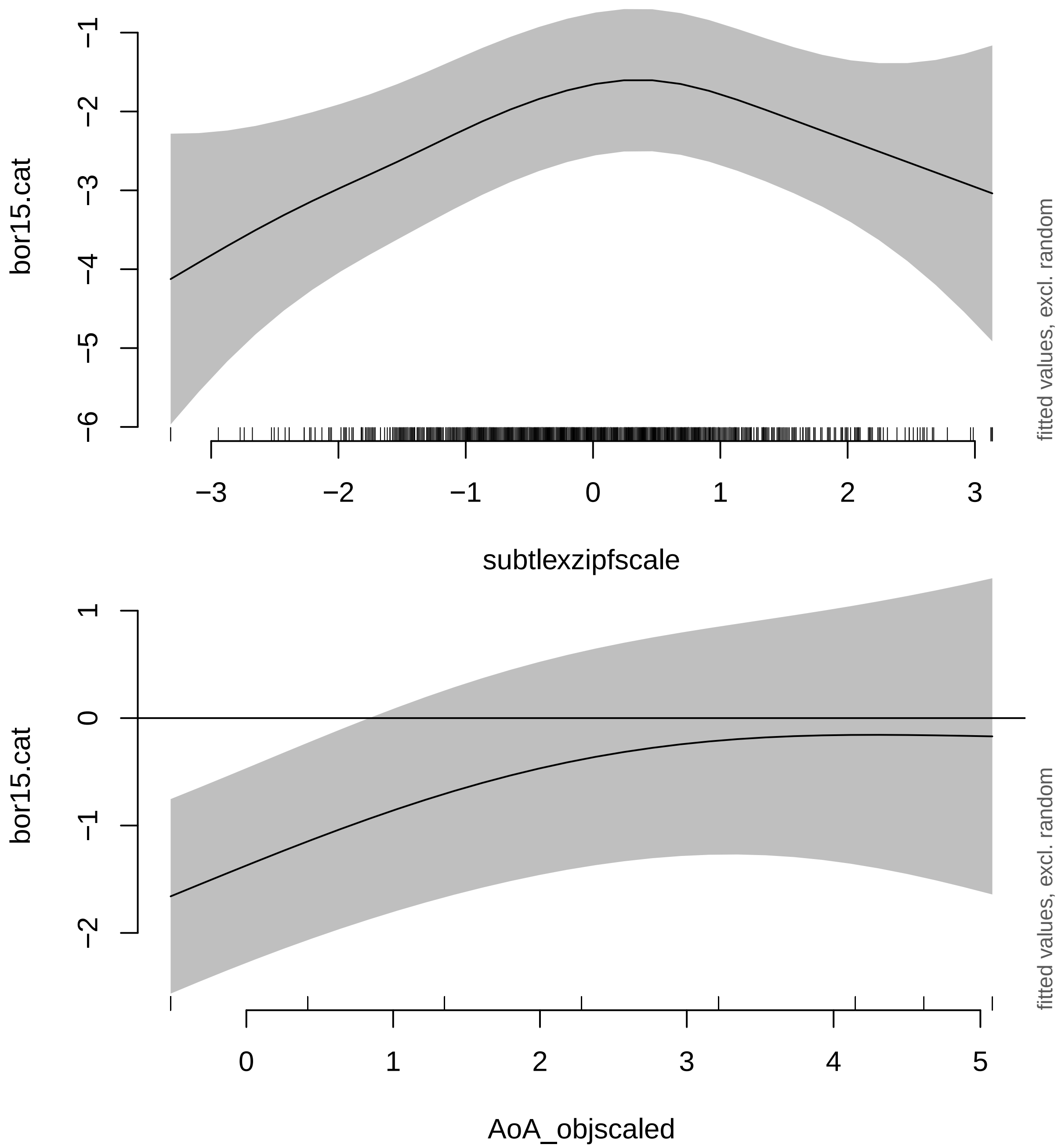
And chi squared terms are similar:

```
m0S = summary(m0)
m0.objS = summary(m0.obj)
cbind(m0=m0S$chi.sq,m0.obj=m0.objS$chi.sq)[1:4,]
```

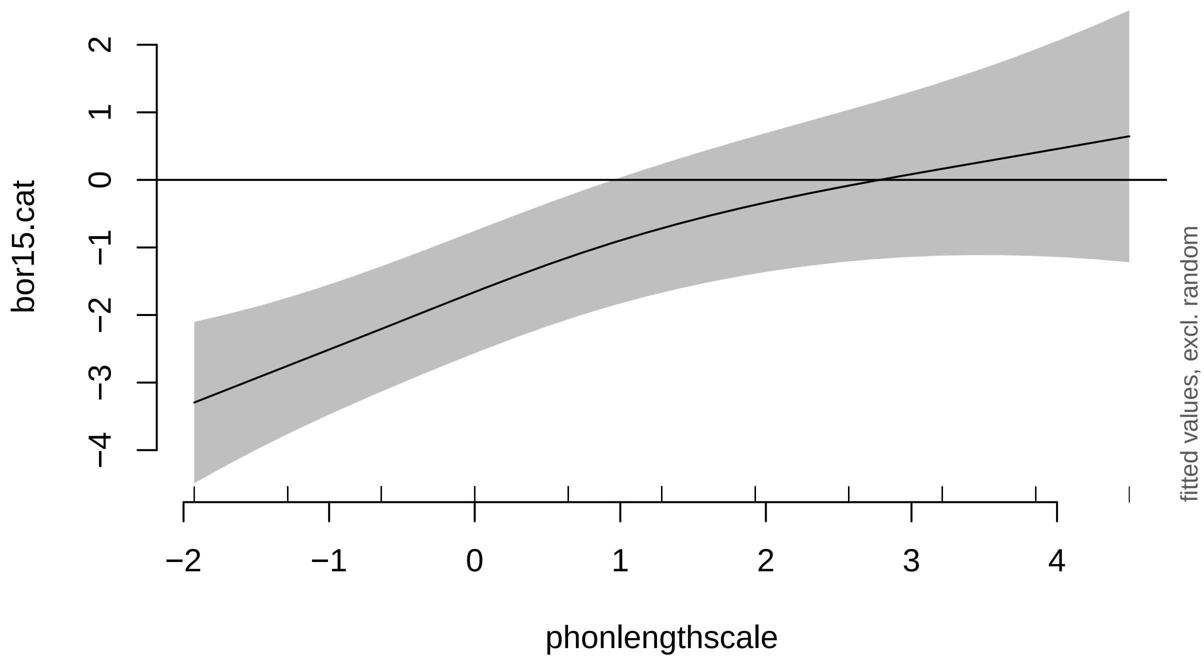
```
##                             m0    m0.obj
## s(phonlengthscale)  32.336043 34.748289
## s(AoAscale)         35.555290 28.248903
## s(subtlexzipfscale) 32.599058 25.329646
## s(concscale)         7.639604  7.033877
```

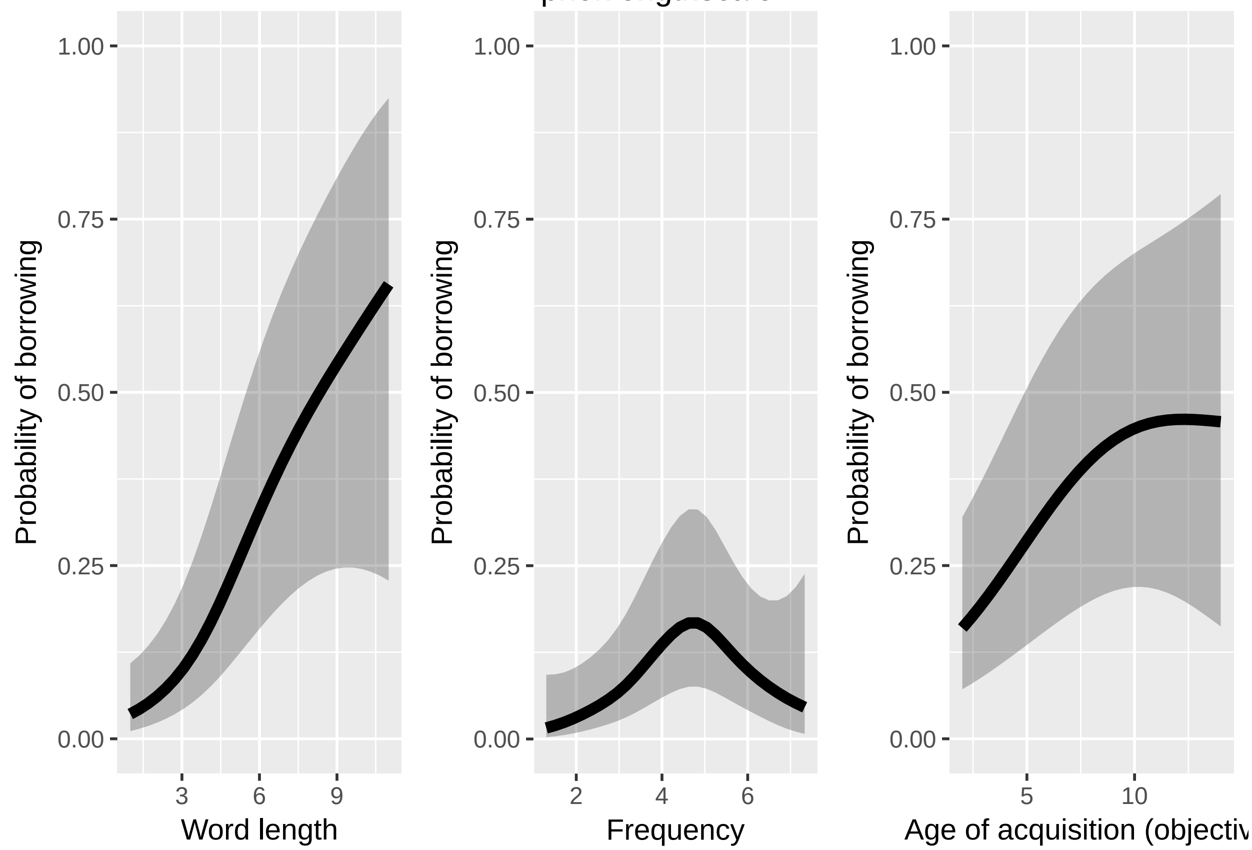
Objective AoA: Model plots

Visualise the model smooth terms, independent of influence of random effects. The code is hidden, but you can view it in the Rmd file.



bor15.cat
−1
−2
−3
−4
−5
−6
−3
−2
−1
0
1
2
3
subtlexzipfscale
fitted values, excl. random
bor15.cat
1
0
−1
−2
0
1
2
3
4
5
AoA_objscaled
fitted values, excl. random


bor15.cat
2
1
0
−1
−2
−3
−4
−2
−1
0
1
2
3
4
phonlengthscale
fitted values, excl. random


Probability of borrowing
1.00
0.75
0.50
0.25
0.00
3
6
9
Word length
Probability of borrowing
2
4
6
Frequency
Probability of borrowing
5
10
Age of acquisition (objectiv

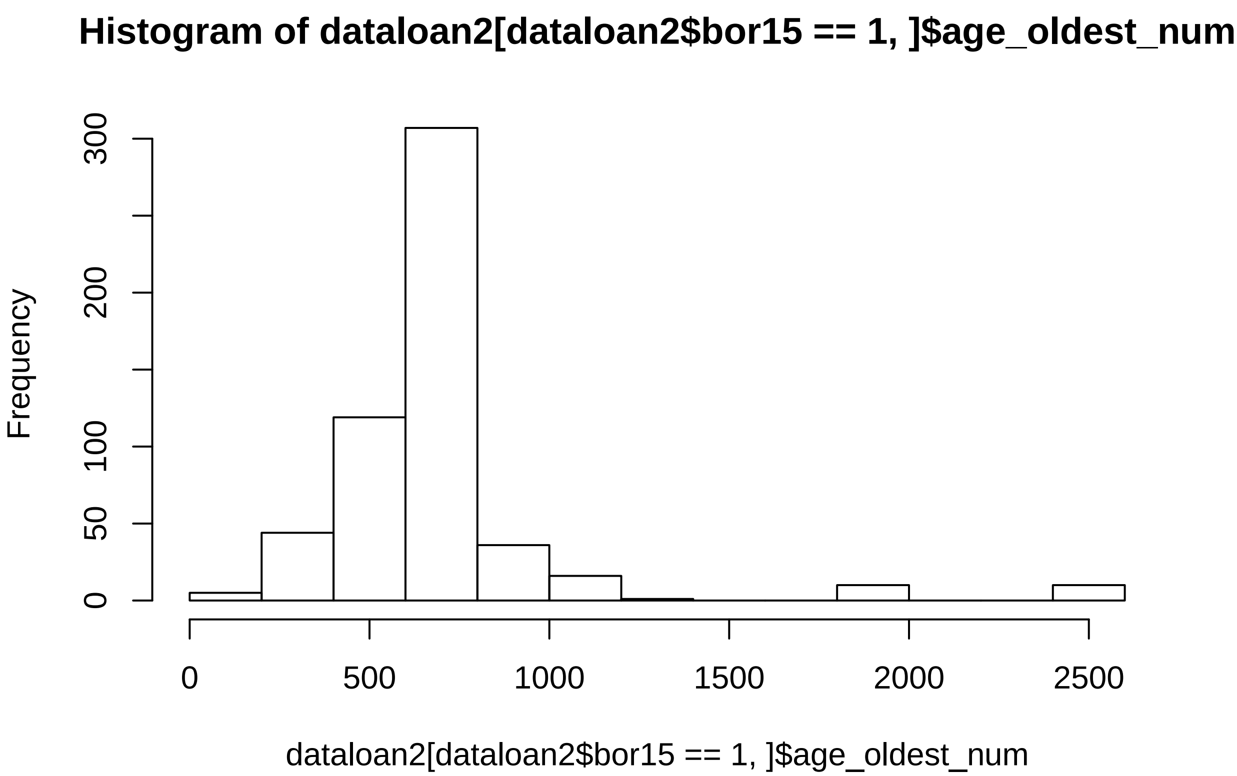
```
## pdf
##   2
```

Predicting date of entry

```
dataloan2$age_oldest_num = as.numeric(dataloan2$age_oldest_num)
# remove non-borrowed words
dataloan2[dataloan2$bor15!=1,]$age_oldest_num = NA
# Take log years
dataloan2$age_oldest_num.scaled = log10(dataloan2$age_oldest_num)
# Scale and center
dataloan2$age_oldest_num.scaled = scale(dataloan2$age_oldest_num.scaled)
```

Plot raw data

```
hist(dataloan2[dataloan2$bor15==1,]$age_oldest_num)
```




```
g.ageAoA = ggplot(dataloan2[dataloan2$bor15==1,],
      aes(x=AoA, y=age_oldest_num))+
         geom_smooth() +
  coord_cartesian(ylim=c(250,1000))
  scale_y_reverse()
```

```
## <ScaleContinuousPosition>
##  Range:
##  Limits:    0 --    1
```

```
g.ageLen = ggplot(dataloan2[dataloan2$bor15==1,],
  aes(x=phonlength, y=age_oldest_num))+
         geom_smooth()+
  coord_cartesian(ylim=c(250,1000))
  scale_y_reverse()
```

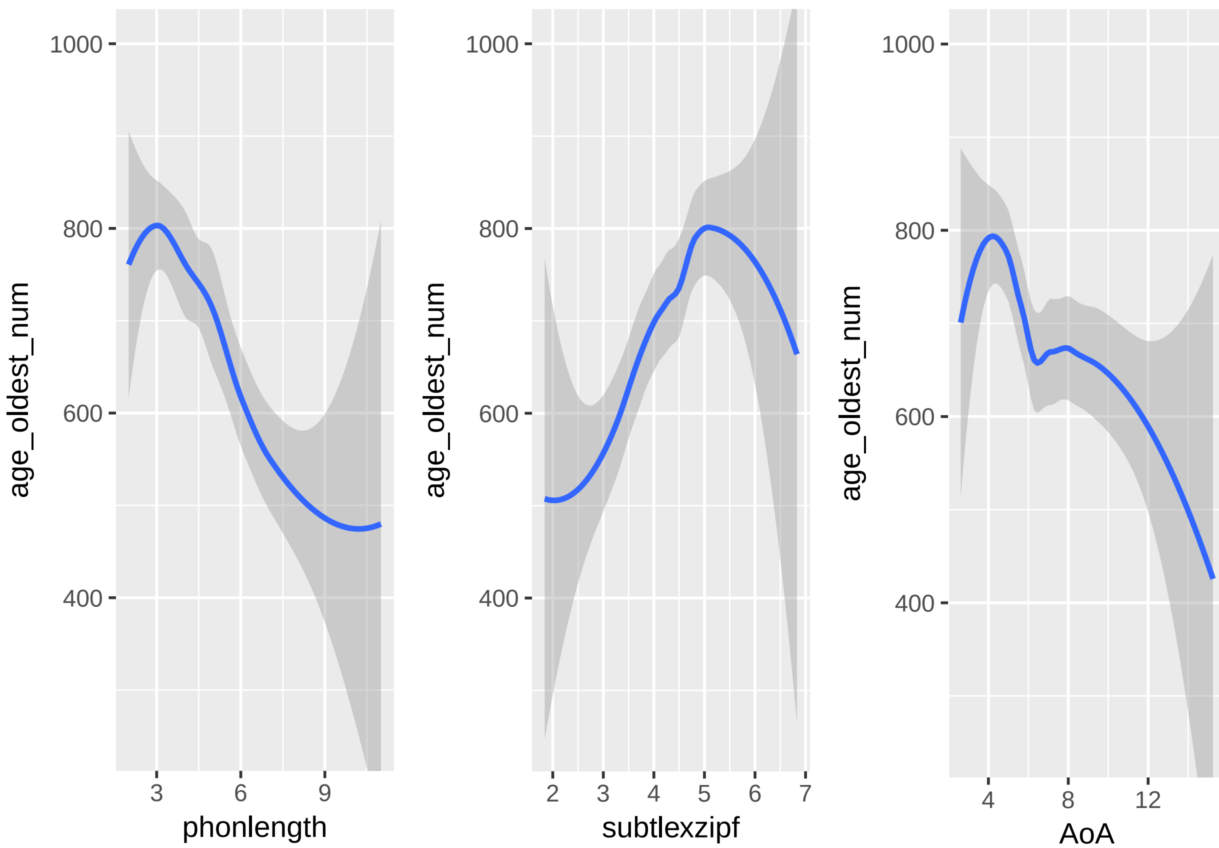
```
## <ScaleContinuousPosition>
##  Range:
##  Limits:    0 --    1
```

```
g.ageFreq = ggplot(dataloan2[dataloan2$bor15==1,],
  aes(x=subtlexzipf, y=age_oldest_num))+
         geom_smooth()+
  coord_cartesian(ylim=c(250,1000))
  scale_y_reverse()
```

```
## <ScaleContinuousPosition>
##  Range:
##  Limits:    0 --    1
```

```
grid.arrange(g.ageLen,g.ageFreq,g.ageAoA, nrow=1)
```

```
## `geom_smooth()` using method = 'loess' and formula 'y ~ x'
## `geom_smooth()` using method = 'loess' and formula 'y ~ x'
## `geom_smooth()` using method = 'loess' and formula 'y ~ x'
```



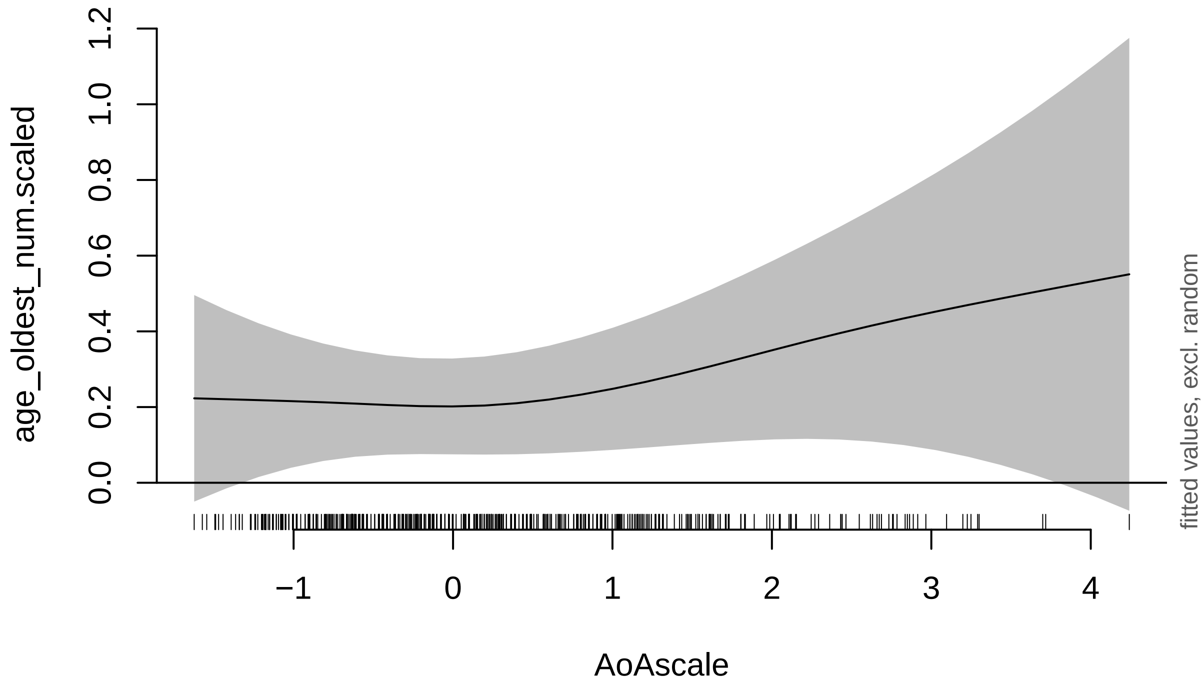
GAM model:

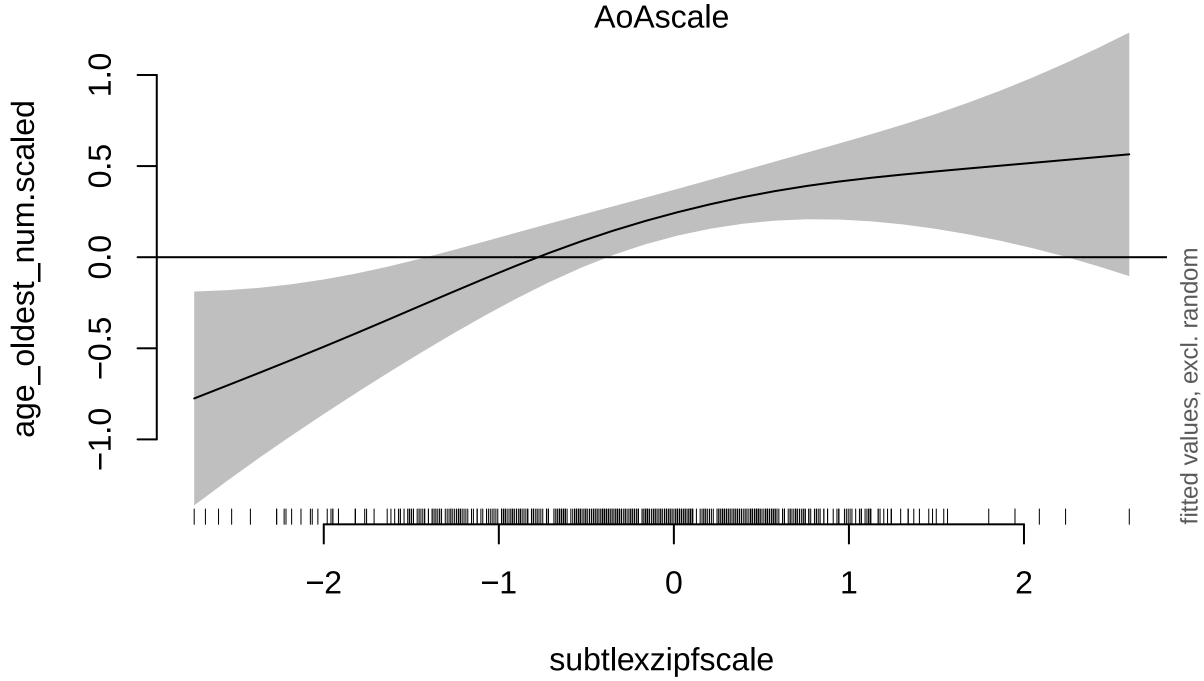
```
m0.age = bam(age_oldest_num.scaled~
    s(phonlengthscale) +
    s(AoAscale) +
    s(subtlexzipfscale) +
    s(concscale) +
    s(cat,bs='re')+
    s(cat,phonlengthscale,bs='re')+
```

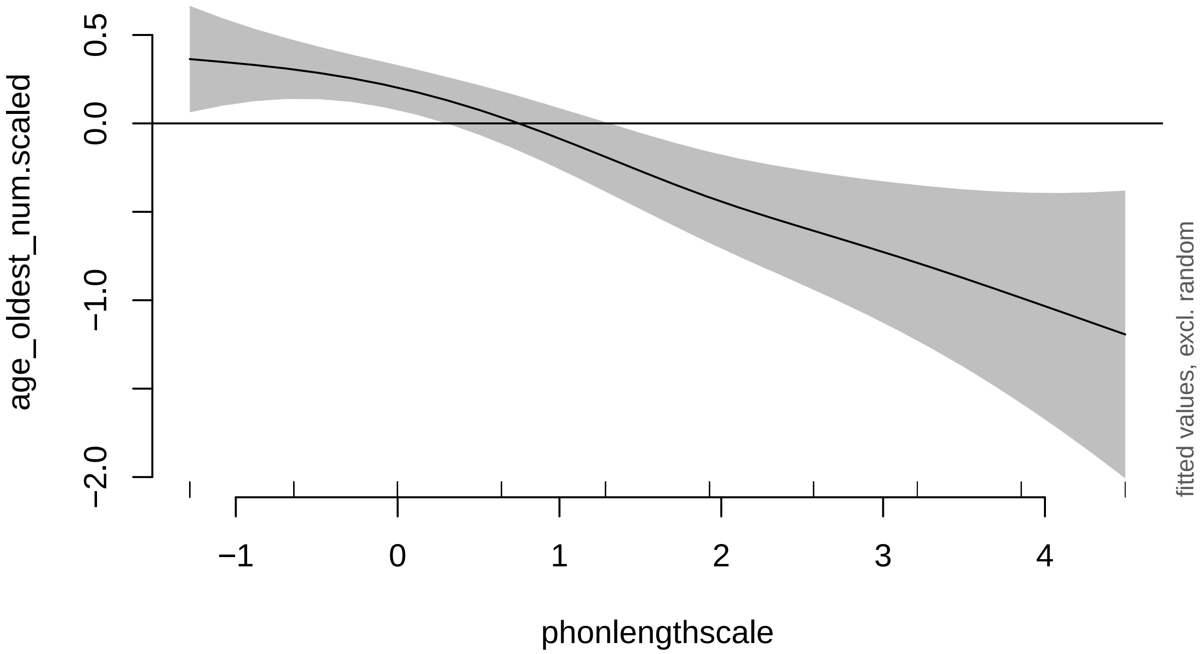
```r
    s(cat,AoAscale,bs='re')+
    s(cat,subtlexzipfscale,bs='re')+
    s(cat,concscale,bs='re'),
    data = dataloan2[dataloan2$bor15==1,])
summary(m0.age)
```

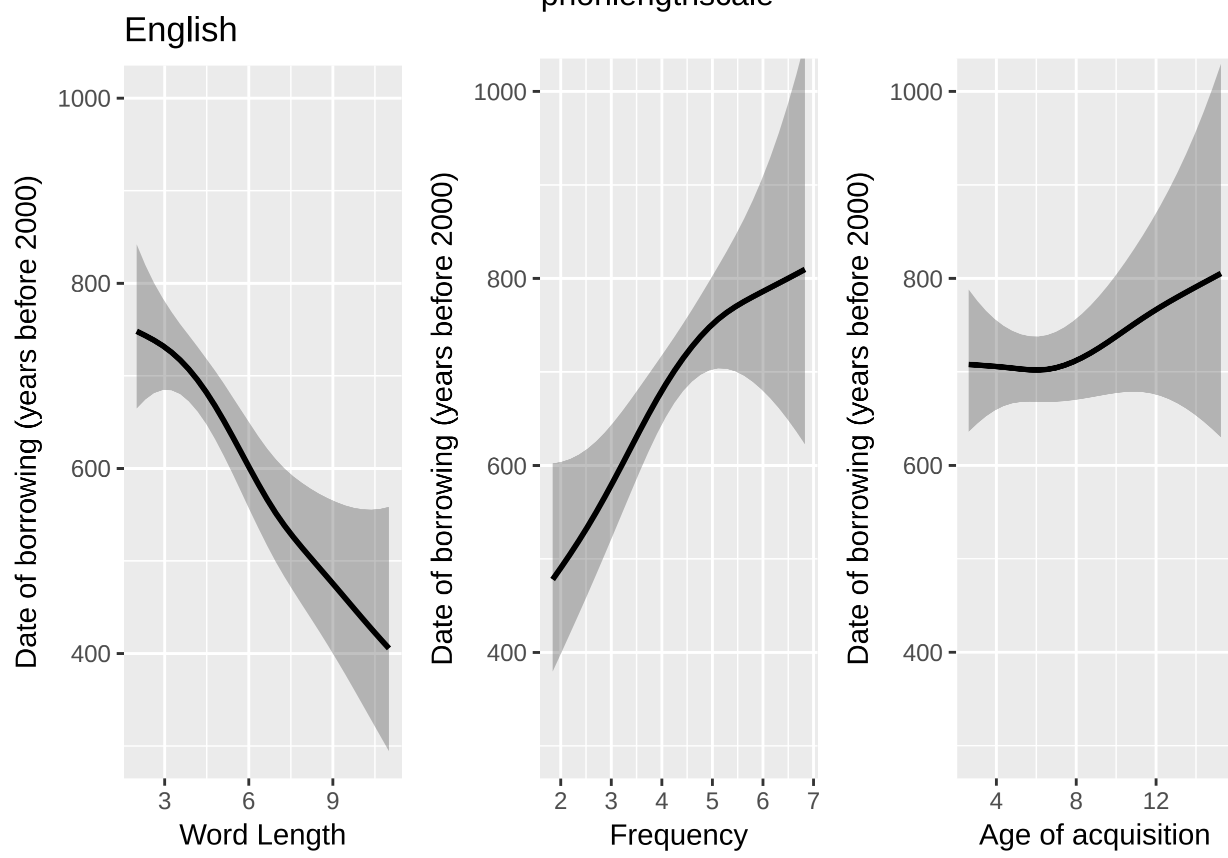
```
##
## Family: gaussian
## Link function: identity
##
## Formula:
## age_oldest_num.scaled ~ s(phonlengthscale) + s(AoAscale) + s(subtlexzipfscale) +
##     s(concscale) + s(cat, bs = "re") + s(cat, phonlengthscale,
##     bs = "re") + s(cat, AoAscale, bs = "re") + s(cat, subtlexzipfscale,
##     bs = "re") + s(cat, concscale, bs = "re")
##
## Parametric coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) -0.004986   0.047084  -0.106    0.916
##
## Approximate significance of smooth terms:
##                              edf Ref.df     F  p-value
## s(phonlengthscale)      2.450e+00  3.117 7.436 6.06e-05 ***
## s(AoAscale)             1.804e+00  2.276 0.805  0.40780
## s(subtlexzipfscale)     2.182e+00  2.797 5.487  0.00164 **
## s(concscale)            1.000e+00  1.000 0.141  0.70762
## s(cat)                  6.237e-06  8.000 0.000  0.65025
## s(cat,phonlengthscale)  1.023e+00  7.000 0.297  0.13964
## s(cat,AoAscale)         2.113e-06  8.000 0.000  0.80034
## s(cat,subtlexzipfscale) 5.838e-01  8.000 0.112  0.22496
## s(cat,concscale)        7.439e-06  8.000 0.000  0.99367
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## R-sq.(adj) =  0.175   Deviance explained = 18.8%
## fREML = 737.37  Scale est. = 0.82539    n = 548
```

Plot the model estimates. The code is hidden, but you can view it in the Rmd file.


age_oldest_num.scaled
0.0
0.2
0.4
0.6
0.8
1.0
1.2
fitted values, excl. random
−1
0
1
2
3
4
AoAscale


age_oldest_num.scaled
−1.0
−0.5
0.0
0.5
1.0
fitted values, excl. random
−2
−1
0
1
2
subtlexzipfscale


age_oldest_num.scaled
0.5
0.0
−1.0
−2.0
−1
0
1
2
3
4
phonlengthscale
fitted values, excl. random


English
Date of borrowing (years before 2000)
1000
800
600
400
3
6
9
Word Length
2
3
4
5
6
7
Frequency
4
8
12
Age of acquisition

```
## pdf
##   2
```