Lab 1, Short Questions

Contents


```
library(tidyverse)
library(patchwork)
```

1 Strategic Placement of Products in Grocery Stores (5 points)

These questions are taken from Question 12 of chapter 3 of the textbook(Bilder and Loughin's "Analysis of Categorical Data with R.

> *In order to maximize sales, items within grocery stores are strategically placed to draw customer attention. This exercise examines one type of item—breakfast cereal. Typically, in large grocery stores, boxes of cereal are placed on sets of shelves located on one side of the aisle. By placing particular boxes of cereals on specific shelves, grocery stores may better attract customers to them. To investigate this further, a random sample of size 10 was taken from each of four shelves at a Dillons grocery store in Manhattan, KS. These data are given in the* cereal_dillons.csv *file. The response variable is the shelf number, which is numbered from bottom (1) to top (4), and the explanatory variables are the sugar, fat, and sodium content of the cereals.*

```
cereal <- read_csv('../data/short-questions/cereal_dillons.csv')
head(cereal) #TODO
```

```
## # A tibble: 6 x 7
##      ID Shelf Cereal                                size_g sugar_g fat_g sodium~1
##   <dbl> <dbl> <chr>                                  <dbl>   <dbl> <dbl>    <dbl>
## 1     1     1 Kellog's Razzle Dazzle Rice Crispies      28      10     0      170
## 2     2     1 Post Toasties Corn Flakes                 28       2     0      270
## 3     3     1 Kellogg's Corn Flakes                     28       2     0      300
## 4     4     1 Food Club Toasted Oats                    32       2     2      280
```

```
## 5     5     1 Frosted Cheerios                          30      13      1      210
## 6     6     1 Food Club Frosted Flakes                  31      11      0      180
## # ... with abbreviated variable name 1: sodium_mg
```

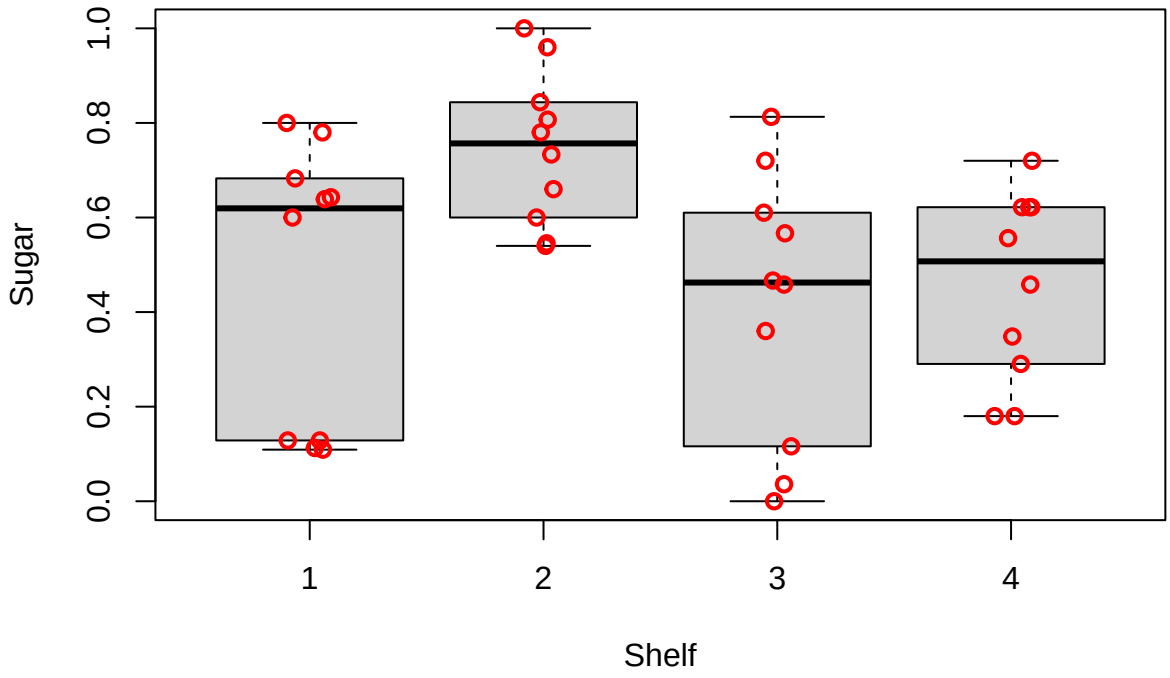
1.1 Recode Data

(1 point) The explanatory variables need to be reformatted before proceeding further (sample code is provided in the textbook). First, divide each explanatory variable by its serving size to account for the different serving sizes among the cereals. Second, rescale each variable to be within 0 and 1. Construct side-by-side box plots with dot plots overlaid for each of the explanatory variables. Also, construct a parallel coordinates plot for the explanatory variables and the shelf number. Discuss whether possible content differences exist among the shelves.

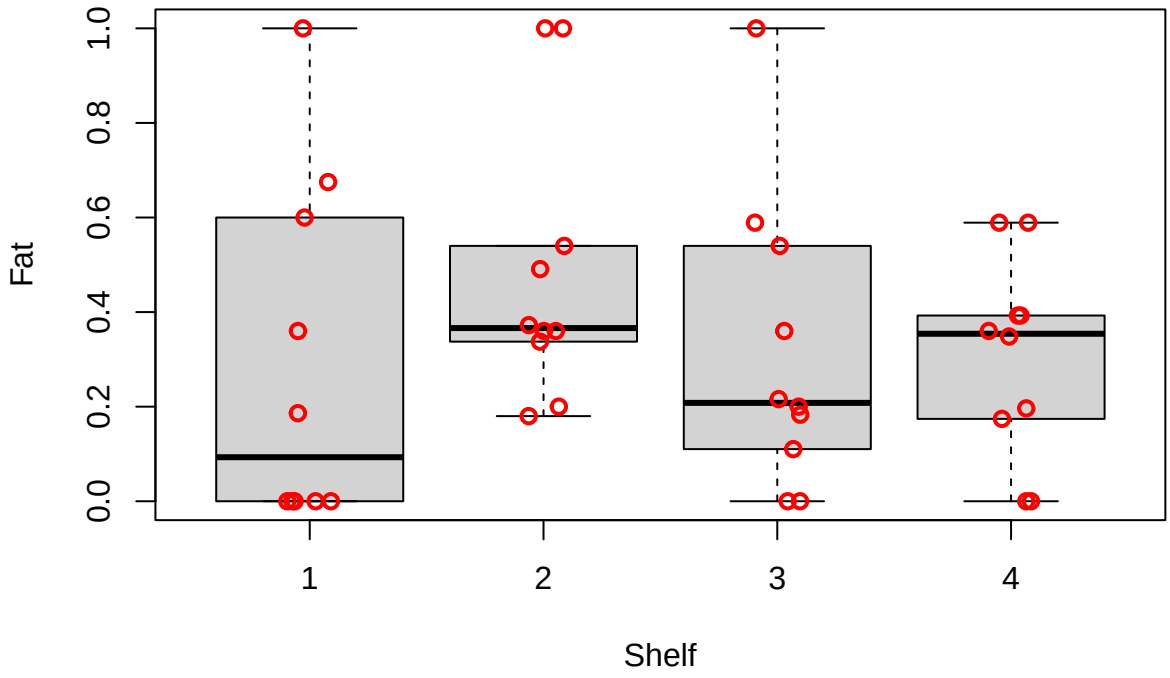
```
# Rescaling each variable to be within 0 and 1
stand01 <- function (x) { (x - min(x))/( max(x) - min(x)) }
cereal2<-data.frame(Shelf=cereal$Shelf, sugar=stand01(x=cereal$sugar_g/cereal$size_g),
                      fat = stand01 (x = cereal$fat_g / cereal$size_g),
                      sodium = stand01 (x = cereal$sodium_mg / cereal$size_g))
head(cereal2)
```

```
##   Shelf     sugar   fat    sodium
## 1     1 0.6428571 0.000 0.5666667
## 2     1 0.1285714 0.000 0.9000000
## 3     1 0.1285714 0.000 1.0000000
## 4     1 0.1125000 0.675 0.8166667
## 5     1 0.7800000 0.360 0.6533333
## 6     1 0.6387097 0.000 0.5419355
```

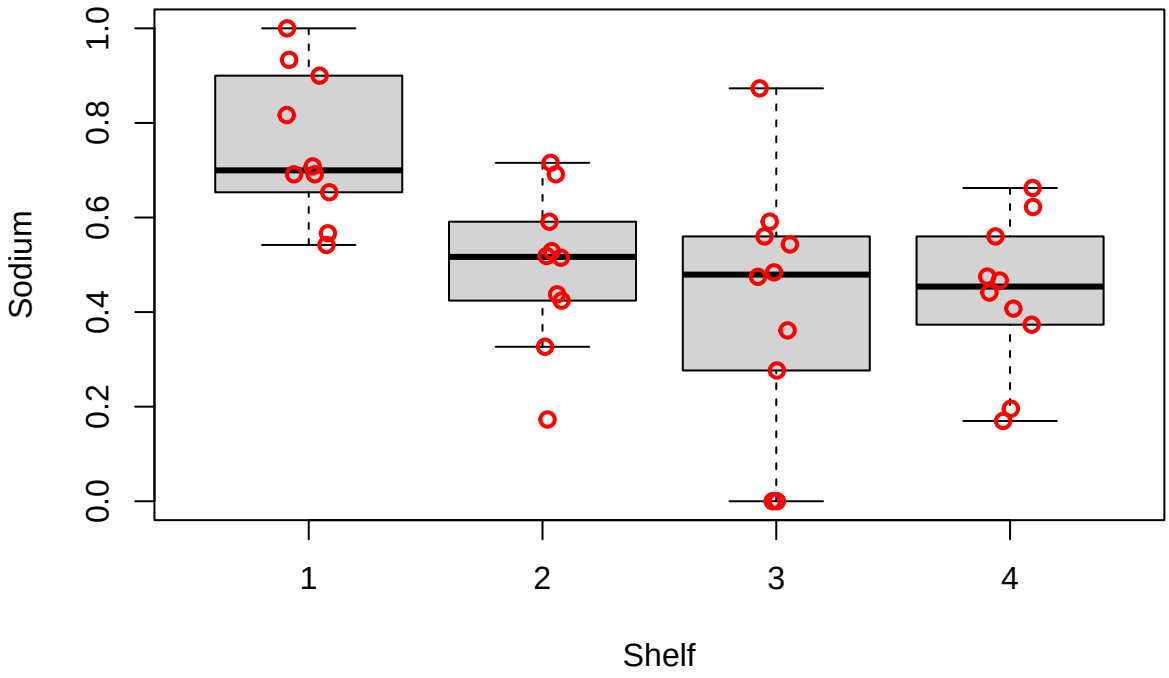
```
# Constructing side-by-side box plots with dot plots overlaid
boxplot(formula=sugar ~ Shelf, data=cereal2, ylab="Sugar",
        xlab="Shelf", pars=list(outpch =NA))
stripchart(x=cereal2$sugar ~ cereal2$Shelf, lwd=2, col="red",
           method="jitter", vertical=TRUE ,pch=1, add=TRUE)
```




```
boxplot(formula=fat ~ Shelf, data=cereal2, ylab="Fat",
        xlab="Shelf", pars=list(outpch =NA))
stripchart(x=cereal2$fat ~ cereal2$Shelf, lwd=2, col="red",
           method="jitter", vertical=TRUE, pch=1, add=TRUE)
```




```
boxplot(formula=sodium ~ Shelf, data=cereal2, ylab="Sodium",
        xlab="Shelf", pars=list(outpch =NA))
stripchart(x=cereal2$sodium ~ cereal2$Shelf, lwd=2, col="red",
           method="jitter", vertical=TRUE, pch=1, add=TRUE)
```



'Fill in: What do you observe in these boxplots?'

```
# Constructing a parallel coordinates plot
library(package = MASS)
```

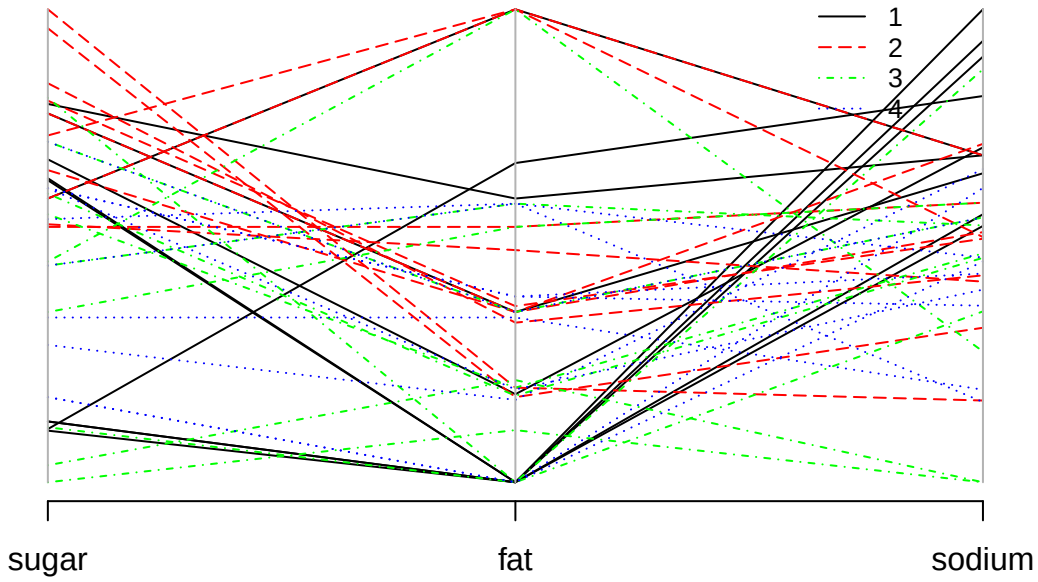
```
##
## Attaching package: 'MASS'
```

```
## The following object is masked from 'package:patchwork':
##
##     area
```

```
## The following object is masked from 'package:dplyr':
##
##     select
```

```
# Colors by condition:
cereal2.colors <- ifelse(test = cereal2$Shelf==1, yes = "black",
  no = ifelse(test = cereal2$Shelf==2, yes = "red",
  no = ifelse(test = cereal2$Shelf==3, yes = "green", no = "blue")))
# Line type by condition:
cereal2.lty<-ifelse(test = cereal2$Shelf==1, yes = "solid",
  no = ifelse(test = cereal2$Shelf==2, yes = "longdash",
  no = ifelse(test = cereal2$Shelf==3, yes = "dotdash", no = "dotted")))
# Plot
```

```
parcoord(x = cereal2[,2:4], col = cereal2.colors, lty = cereal2.lty)
legend(x = 2.6, y = 1.05, legend = c("1", "2", "3", "4"),
       lty = c("solid", "longdash", "dotdash", "dotted"),
  col=c("black", "red", "green", "blue"), cex=0.8, bty="n")
```



> 'Fill in: What do you observe in these parallel coordinates plots?'
> > Fill in: Do content differences exist between the shelves?' > > 'Majority of the food items tend to have a "V" shape with high suger, low-to-medium fat and high sodium.'
> 'Low-to-medium sugar cereals generally available on shelf 1, 3 & 4 and high sugar cereals on shelf 2. High fat cereals generally available on self 1, 3 & 4 and low fat on shelf 2 & 3. Low sodium cereals are generally available on slef 2, 3 & 4 and high sodium on shelf 1' > > 'Shelf 1 tend to have low fat and high sodium. Shelf 2 tend to have high sugar, high-to-medium fat and medium sodium. Shelf 3 tend to have all types of cereals. Sheld 4 tend to have medium sugar, low-to-medium fat and medium sodium cereals.' >

1.2 Evaluate Ordinal vs. Categorical

(1 point) The response has values of $1, 2, 3$, and 4. Explain under what setting would it be desirable to take into account ordinality, and whether you think that this setting occurs here. Then estimate a suitable multinomial regression model with linear forms of the sugar, fat, and sodium variables. Perform LRTs to examine the importance of each explanatory variable. Show that there are no significant interactions among the explanatory variables (including an interaction among all three variables).

Fill in: What do you think about ordinal data?'

'TODO: Re-write it as it is mostly copy-paste'.

'Suppose response variables have a natural ordering to their levels and can be arranged so that category 1 < category 2 < ... < category J in some conceptual scale of measurement, then we can account for this ordinality of response variables in our regression models. In this problem, the shelf number has a natural ordering, which can be arranged as $1 < 2 < 3 < 4$. As a result, we can take into account the sheld ordinality.'

```
cereal2$Shelf.order <- factor(cereal2$Shelf, levels = c(1, 2, 3, 4))
model_cereal_shelves_linear    <- polr(formula = Shelf.order ~ sugar + fat + sodium,
                                       data = cereal2, method = "logistic")
summary(model_cereal_shelves_linear)
```

```
##
## Re-fitting to get Hessian
```

```
## Call:
## polr(formula = Shelf.order ~ sugar + fat + sodium, data = cereal2,
##     method = "logistic")
##
## Coefficients:
##           Value Std. Error  t value
## sugar  -1.61101     1.2830 -1.25565
## fat    -0.05123     0.9657 -0.05305
## sodium -4.85950     1.6302 -2.98094
##
## Intercepts:
##     Value   Std. Error t value
## 1|2 -4.7534  1.4837    -3.2037
## 2|3 -3.3435  1.3810    -2.4210
## 3|4 -1.9823  1.2867    -1.5407
##
## Residual Deviance: 98.52912
## AIC: 110.5291
```

```
model_cereal_shelves_quadratic <- polr(formula = Shelf.order ~ sugar + fat + sodium
                                       + sugar:fat + sugar:sodium + fat:sodium
                                       + sugar:fat:sodium,
                                       data = cereal2, method = "logistic")
summary(model_cereal_shelves_quadratic)
```

```
##
## Re-fitting to get Hessian
```

```
## Call:
## polr(formula = Shelf.order ~ sugar + fat + sodium + sugar:fat +
##     sugar:sodium + fat:sodium + sugar:fat:sodium, data = cereal2,
##     method = "logistic")
##
```

```
## Coefficients:
##                     Value Std. Error  t value
## sugar            -1.2159      4.699 -0.25877
## fat              -1.5502     10.337 -0.14997
## sodium           -3.7239      2.999 -1.24168
## sugar:fat         7.0254     21.042  0.33388
## sugar:sodium     -1.8919      8.367 -0.22612
## fat:sodium        0.6864     14.841  0.04625
## sugar:fat:sodium -8.3985     32.260 -0.26034
##
## Intercepts:
##     Value   Std. Error t value
## 1|2 -4.3330  2.3488    -1.8448
## 2|3 -2.8897  2.2998    -1.2565
## 3|4 -1.5219  2.2653    -0.6718
##
## Residual Deviance: 97.15974
## AIC: 117.1597
```

```
library(package = car)
```

```
## Loading required package: carData
```

```
##
## Attaching package: 'car'
```

```
## The following object is masked from 'package:dplyr':
##
##     recode
```

```
## The following object is masked from 'package:purrr':
##
##     some
```

```
lrt_cereal_main_effects <- Anova(model_cereal_shelves_linear)
lrt_cereal_main_effects
```

```
## Analysis of Deviance Table (Type II tests)
##
## Response: Shelf.order
##         LR Chisq Df Pr(>Chisq)
## sugar     1.6794  1  0.1950069
## fat       0.0028  1  0.9577007
## sodium   11.5685  1  0.0006708 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
lrt_cereal_quadratic_effects <- Anova(model_cereal_shelves_quadratic)
lrt_cereal_quadratic_effects
```

```
## Analysis of Deviance Table (Type II tests)
```

```
##
## Response: Shelf.order
##                  LR Chisq Df Pr(>Chisq)
## sugar              1.1760  1  0.2781685
## fat                0.0419  1  0.8377311
## sodium            11.1699  1  0.0008314 ***
## sugar:fat          0.1014  1  0.7501457
## sugar:sodium       0.3945  1  0.5299556
## fat:sodium         0.2607  1  0.6096643
## sugar:fat:sodium   0.1077  1  0.7427907
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

'Fill in: Write about what you learn as a result of these tests, using inline code evaluation.'

'Because of the large test statistic values for sodium, there is sufficient evidence that it is important explanatory variables given that `sugar` and `fat` are in the model.'

'As the amount of sugar or fat or sodium increases, their probability of being on the higher shelf number increases.'

1.3 Where do you think Apple Jacks will be placed?

(1 point) Kellogg's Apple Jacks (http://www.applejacks.com) is a cereal marketed toward children. For a serving size of 28 grams, its sugar content is 12 grams, fat content is 0.5 grams, and sodium content is 130 milligrams. Estimate the shelf probabilities for Apple Jacks.

```
size   <- 28
sugar  <- 12/size
fat    <- 0.5/size
sodium <- 130/size

# Re-scaling each variable to be within 0 and 1
sugar_all  <- cereal$sugar_g/cereal$size_g
sugar      <- (sugar - min(sugar_all)) / (max(sugar_all) - min(sugar_all))
fat_all    <- cereal$fat_g/cereal$size_g
fat        <- (fat - min(fat_all)) / (max(fat_all) - min(fat_all))
sodium_all <- cereal$sodium_mg/cereal$size_g
sodium     <- (sodium - min(sodium_all)) / (max(sodium_all) - min(sodium_all))

predict.data <- data.frame(sugar  = sugar,
                           fat    = fat,
                           sodium = sodium)

aj_shelf_probs <- predict(object = model_cereal_shelves_linear,
                          newdata = predict.data, type = "probs")
aj_shelf_probs
```

```
##         1         2         3         4
## 0.1986192 0.3051178 0.2946317 0.2016313
```

'Fill this in: Where does your model predict apple jacks will be placed?'

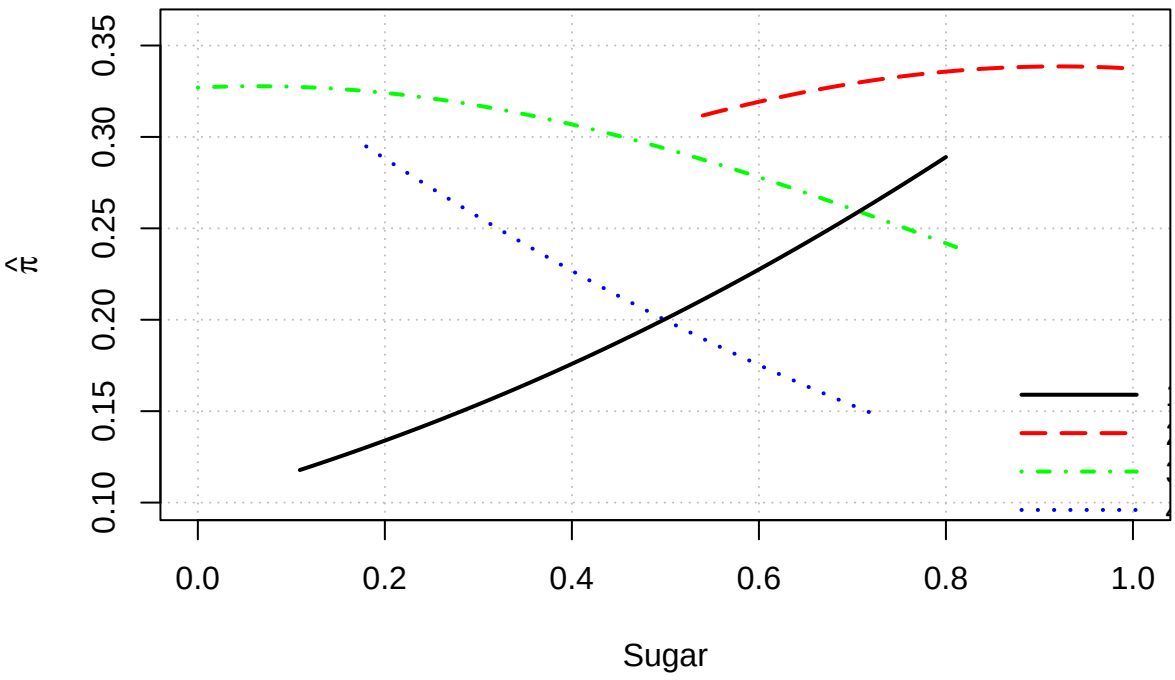
'Shelf 2 has the largest estimated probability for apple jacks cereal placement.'

1.4 Figure 3.3

(1 point) Construct a plot similar to Figure 3.3 where the estimated probability for a shelf is on the *y-axis* and the sugar content is on the *x-axis*. Use the mean overall fat and sodium content as the corresponding variable values in the model. Interpret the plot with respect to sugar content.

```
# Get the mean and re-scale each variable to be within 0 and 1
fat    <- (mean(fat_all) - min(fat_all)) / (max(fat_all) - min(fat_all))
sodium <- (mean(sodium_all)-min(sodium_all))/(max(sodium_all)-min(sodium_all))

# Plotting sugar only model
curve(expr = predict(object = model_cereal_shelves_linear,
    newdata = data.frame(sugar=x, fat=fat, sodium=sodium), type = "probs")[,1],
    ylab = expression(hat(pi)), xlab = "Sugar", type = "n",
    xlim = c(min(cereal2$sugar), max(cereal2$sugar)),
    col = "black", lty = "solid", lwd = 2, n = 1000,
    panel.first = grid(col = "gray", lty = "dotted"))
curve(expr = predict(object = model_cereal_shelves_linear,
  newdata = data.frame(sugar=x, fat=fat, sodium=sodium), type = "probs")[,4],
  col = "blue", lty = "dotted", lwd = 2, n = 1000, add = TRUE,
  xlim = c(min(cereal2$sugar[cereal2$Shelf.order == 4]),
           max(cereal2$sugar[cereal2$Shelf.order == 4])))  # Shelf 4
curve(expr = predict(object = model_cereal_shelves_linear,
  newdata = data.frame(sugar=x, fat=fat, sodium=sodium), type = "probs")[,3],
  col = "green", lty = "dotdash", lwd = 2, n = 1000, add = TRUE,
  xlim = c(min(cereal2$sugar[cereal2$Shelf.order == 3]),
           max(cereal2$sugar[cereal2$Shelf.order == 3])))  # Shelf 3
curve(expr = predict(object = model_cereal_shelves_linear,
  newdata = data.frame(sugar=x, fat=fat, sodium=sodium), type = "probs")[,2],
  col = "red", lty = "longdash", lwd = 2, n = 1000, add = TRUE,
  xlim = c(min(cereal2$sugar[cereal2$Shelf.order == 2]),
           max(cereal2$sugar[cereal2$Shelf.order == 2])))  # Shelf 2
curve(expr = predict(object = model_cereal_shelves_linear,
  newdata = data.frame(sugar=x, fat=fat, sodium=sodium), type = "probs")[,1],
  col = "black", lty = "solid", lwd = 2, n = 1000, add = TRUE,
  xlim = c(min(cereal2$sugar[cereal2$Shelf.order == 1]),
           max(cereal2$sugar[cereal2$Shelf.order == 1])))  # Shelf 1
legend(x = 0.85, y = 0.18, legend=c(1, 2, 3, 4),
       lty=c("solid", "longdash", "dotdash", "dotted"),
       col=c("black", "red", "green", "blue"),
       bty="n", lwd = c(2,2,2,2), seg.len = 4)
```




```
#shelf_vs_sugar_plot <- 'fill this in'
```

'Fill this in: What message does your plot give?'

'The estimated shelf 2 probability is the largest for the high sugar content cereals. The estimated shelf 3 probability is the largest for the low sugar content cereals. The estimated shelf 1 probability is the largest for the high sugar content cereals and vice verse for shelf 4 with highly varying probability compared to sheld 2 & 3.'

1.5 Odds ratios

(1 point) Estimate odds ratios and calculate corresponding confidence intervals for each explanatory variable. Relate your interpretations back to the plots constructed for this exercise.

```
sd.cereal   <- apply(X = cereal2[,2:4], MARGIN = 2, FUN = sd)
print("Standard deviation")
```

```
## [1] "Standard deviation"
```

```
sd.cereal
```

```
##     sugar       fat    sodium
## 0.2692078 0.2990292 0.2298359
```

```
print("Odds ratio confidence interval")
```

```
## [1] "Odds ratio confidence interval"
```

```
round(exp(sd.cereal * (-model_cereal_shelves_linear$coefficients)), 2)
```

```
##  sugar    fat sodium
##   1.54   1.02   3.06
```

```
print("Odds ratio")
```

```
## [1] "Odds ratio"
```

```
conf.beta   <- confint(object = model_cereal_shelves_linear, level = 0.95)
```

```
## Waiting for profiling to be done...
```

```
##
## Re-fitting to get Hessian
```

```
odds_ratios <- round(exp(sd.cereal * (-conf.beta)), 2)
odds_ratios <- round (data.frame (low = odds_ratios[,2] , up = odds_ratios[ ,1]) , 2)
odds_ratios
```

```
##         low   up
## sugar  0.81 3.18
## fat    0.57 1.80
## sodium 1.56 6.95
```

```
odds_ratios["sugar", "up"]
```

```
## [1] 3.18
```

'Fill this in: What do you learn about each of these variables?'

'The estimated odds of shelf number being below a particular level change by 0.81 to 3.18 times for a 0.27 increase in the sugar level, holding the other variables constant.'
'The estimated odds of shelf number being below a particular level change by 0.57 to 1.8 times for a 0.3 increase in the fat level, holding the other variables constant.'
'The estimated odds of shelf number being below a particular level change by 1.56 to 6.95 times for a 0.23 increase in the sodium level, holding the other variables constant.'

'As seen on the box plot, the median of sodium decreases as the shelf number increases, and the parallel coordinates show that high sodium cereals generally concentrate on the lower shelf. This relationship is reflected with an above 1 confidence interval, which shows us that the more likely the shelf number to be lower as the larger the sodium content is. On the other hand, sugar and fat content does not show a clear ordinal relationship with a shelf number, which might be why 1 odds-ratio is between the given confidence interval.'

2 Alcohol, self-esteem and negative relationship interactions (5 points)

Read the example **'Alcohol Consumption'** in chapter 4.2.2 of the textbook(Bilder and Loughin's "Analysis of Categorical Data with R). This is based on a study in which moderate-to-heavy drinkers (defined as at least 12 alcoholic drinks/week for women, 15 for men) were recruited to keep a daily

record of each drink that they consumed over a 30-day study period. Participants also completed a variety of rating scales covering daily events in their lives and items related to self-esteem. The data are given in the *DeHartSimplified.csv* data set. Questions 24-26 of chapter 3 of the textbook also relate to this data set and give definitions of its variables: the number of drinks consumed (`numall`), positive romantic-relationship events (`prel`), negative romantic-relationship events (`nrel`), age (`age`), trait (long-term) self-esteem (`rosn`), state (short-term) self-esteem (`state`).

The researchers stated the following hypothesis:

> *We hypothesized that negative interactions with romantic partners would be associated with alcohol consumption (and an increased desire to drink). We predicted that people with low trait self-esteem would drink more on days they experienced more negative relationship interactions compared with days during which they experienced fewer negative relationship interactions. The relation between drinking and negative relationship interactions should not be evident for individuals with high trait self-esteem.*

```
drinks <- read_csv('../data/short-questions/DeHartSimplified.csv')
```

2.1 EDA

(2 points) Conduct a thorough EDA of the data set, giving special attention to the relationships relevant to the researchers' hypotheses. Address the reasons for limiting the study to observations from only one day.

'Fill this in: What do you learn?'

2.2 Hypothesis One

(2 points) The researchers hypothesize that negative interactions with romantic partners would be associated with alcohol consumption and an increased desire to drink. Using appropriate models, evaluate the evidence that negative relationship interactions are associated with higher alcohol consumption and an increased desire to drink.

'Fill this in: What do you learn?'

2.3 Hypothesis Two

(1 point) The researchers hypothesize that the relation between drinking and negative relationship interactions should not be evident for individuals with high trait self-esteem. Conduct an analysis to address this hypothesis.

'Fill this in: What do you learn?'