

# 432 Quiz 2

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Deadline: 9 AM 2022-04-19. Version: 2022-04-14 15:15:59

## Links

All links for the Quiz will be made available at <https://github.com/THOMASELOVE/432-2022/tree/main/quiz/quiz2> at 5 PM on 2022-04-14.

This will include links to:

- the Main Document (this document) containing the instructions and questions
- the Google Form Answer Sheet, and
- the data sets we are providing

## Instructions

This PDF document is **31** pages long. There are **30** questions on this Quiz. It is to your advantage to answer all of the Questions. Your score is based on the number of correct responses, so there's no chance a blank response will be correct, and a guess might be, so you should definitely answer all of the questions.

## The Google Form Answer Sheet

All of your answers must be submitted through the Google Form Answer Sheet found at <https://bit.ly/432-2022-quiz-02-answer-sheet> by the deadline, without exception. The form will close at that time, and no extensions will be made available, so please do not wait until the last moment to submit. We will not accept any responses except through the Google Form.

The Google Form contains places to provide your responses to each question, and a final affirmation where you'll type in your name to tell us that you followed the rules for the Quiz. You must complete that affirmation and then submit your results. When you submit your results (in the same way you submit a Minute Paper) you will receive an email copy of your submission, with a link that will allow you to edit your results. The Answer Sheet works like a Minute Paper, in that you must be logged into Google via CWRU to access it.

If you wish to work on some of the quiz and then return later, you can do this by [1] completing the final question (the affirmation) which asks you to type in your full name, and then [2] submitting the quiz. You will then receive a link at your CWRU email which will allow you to return to the Quiz Answer Sheet as often as you like without losing your progress.

## The Data Sets

I have provided **5** data sets (called **quized01.csv**, **quized08.Rds**, **quized17.Rds**, **quized24.csv** and **quized30.Rds**) that are mentioned in the Quiz. They may be helpful to you.

## Getting Help

This is an open book, open notes quiz. You are welcome to consult the materials provided on the course website and that we've been reading in the class, but you are not allowed to discuss the questions on this quiz with anyone other than Professor Love and the teaching assistants. You will be required to complete a short affirmation that you have obeyed these rules as part of submitting the Quiz.

If you need clarification on a Quiz question, you have exactly two ways of getting help:

1. You can ask your question in a **private** post on Piazza to the instructors.
2. You can ask your question via email to **431-help at case dot edu**.

During the Quiz period (2022-04-14 through 2022-04-19) we will not answer questions about the Quiz except through the two approaches listed above. We promise to respond to all questions received before 9 PM on 2022-04-18 in a timely fashion.

A few cautions:

- Specific questions are more likely to get helpful answers.
- We will not review your code or your English for you.
- We will not tell you if your answer is correct, or if it is complete.
- We will post to Piazza in the **quiz2** folder if we find an error in the Quiz that needs fixing.

## When Should I ask for help?

We recommend the following process.

- If you encounter a tough question, skip it, and build up your confidence by tackling other questions.
- When you return to the tough question, spend no more than 10-15 minutes on it. If you still don't have it, take a break (not just to do other questions) but an actual break.
- When you return to the question, it may be much clearer to you. If so, great. If not, spend 5-10 minutes on it, at most, and if you are still stuck, ask us for help.
- This is not to say that you cannot ask us sooner than this, but you should **never, ever** spend more than 20 minutes on any question without asking for help.

## Scoring and Timing

All questions are worth between **3** and **5** points, as indicated, adding to a total of **100** available points. The questions are not in any particular order, and range in difficulty from "things Dr. Love expects everyone to get right" to "things that are deliberately tricky". Some questions will take more time than others to answer.

The Quiz is meant to take 4-6 hours to complete. I expect most students will take 3-8 hours, and some will take as little as 2 or as many as 10. Again, it is **not** a good idea to spend a long time on any one question.

Dr. Love will grade the Quiz, and results (including an answer sketch) will be available by class time on Thursday 2022-04-21. Remember that we have a Project B working day (with no 432 class) on Tuesday 2022-04-19.

## What does the Quiz cover?

Quiz B includes material from the first 22 classes in 432, including:

- all of Jeff Leek's *How to be a Modern Scientist* and
- all of Nate Silver's *The Signal and the Noise*.

## Writing Code into the Answer Sheet

Occasionally, we ask you to provide R code in your response. Do not include the `library` command at any time for any of your code. Instead, assume in all questions that all relevant packages have been loaded in R. A list of R packages that Dr. Love used in building the Quiz and its answer sketch is available in the next section.

## Packages and Settings used by Dr. Love

This doesn't mean you need to use all of these packages, nor does it mean that you are prevented from using other packages we've discussed in class to complete the Quiz.

```
library(conflicted)
library(here)
library(knitr)
library(janitor)
library(magrittr)
library(naniar)
library(patchwork)
library(countreg)
library(equatiomatic)
library(fivethirtyeight)
library(GGally)
library(ggrepel)
library(lars)
library(nhanesA)
library(nnet)
library(pROC)
library(pscl)
library(simputation)
library(survey)
library(survival)
library(survminer)
library(rms)           # includes Hmisc
library(tidymodels)    # includes broom, rsample, etc.
library(tidyverse)     # includes dplyr, ggplot, etc.

# Note that all data files were downloaded onto
# my machine into a subfolder called data below
# my main R Project directory for Quiz 2.

theme_set(theme_bw())
opts_chunk$set(comment = NA)
options(dplyr.summarise.inform = FALSE)
conflict_prefer("summarize", "dplyr")
conflict_prefer("filter", "dplyr")
conflict_prefer("select", "dplyr")
conflict_prefer("zeroinfl", "pscl")
```

## Setup for Questions 1-3

The `quizd01.csv` file available on the course web site contains information on 1000 animal subjects who took part in an observational study. You will use this data set for Questions 1-3. The data includes information on:

- `alive` = the subject's vital status at the end of the study (`alive` = 1 if alive at the end of the study, 0 otherwise)
- `treated` = 1 if the subject received the treatment of interest and 0 if the subject received usual care
- `age`, in years, at the start of the study
- `female` = 1 if the subject is female, biologically
- `comor` = a count of comorbid conditions (maximum = 7)

### 1 Question 1 (3 points)

Create a tibble called `quizd01` in R containing the data in `quizd01.csv`. How many rows in your `quizd01` data contain at least one missing value?

### 2 Question 2 (5 points)

Specify the R code you would use to fit a logistic regression model to predict `alive` on the basis of main effects of `treated`, `age`, `female` and `comor`, using multiple imputation to deal with missing values, and setting a seed of 43237 for the imputation work. In your response, don't show any of the code you used to create the tibble in Question 1. Assume all necessary packages have been pre-loaded using the `library()` function, and that the `quizd01` data have been successfully imported into R already.

In your imputation process, you should include all variables in the `quizd01` data other than the subject identifying code, run 20 imputations, and use `nk = c(0, 3)`, `tlinear = TRUE`, `B = 10` and `pr = FALSE`. Do not show the results here, just the code.

### 3 Question 3 (5 points)

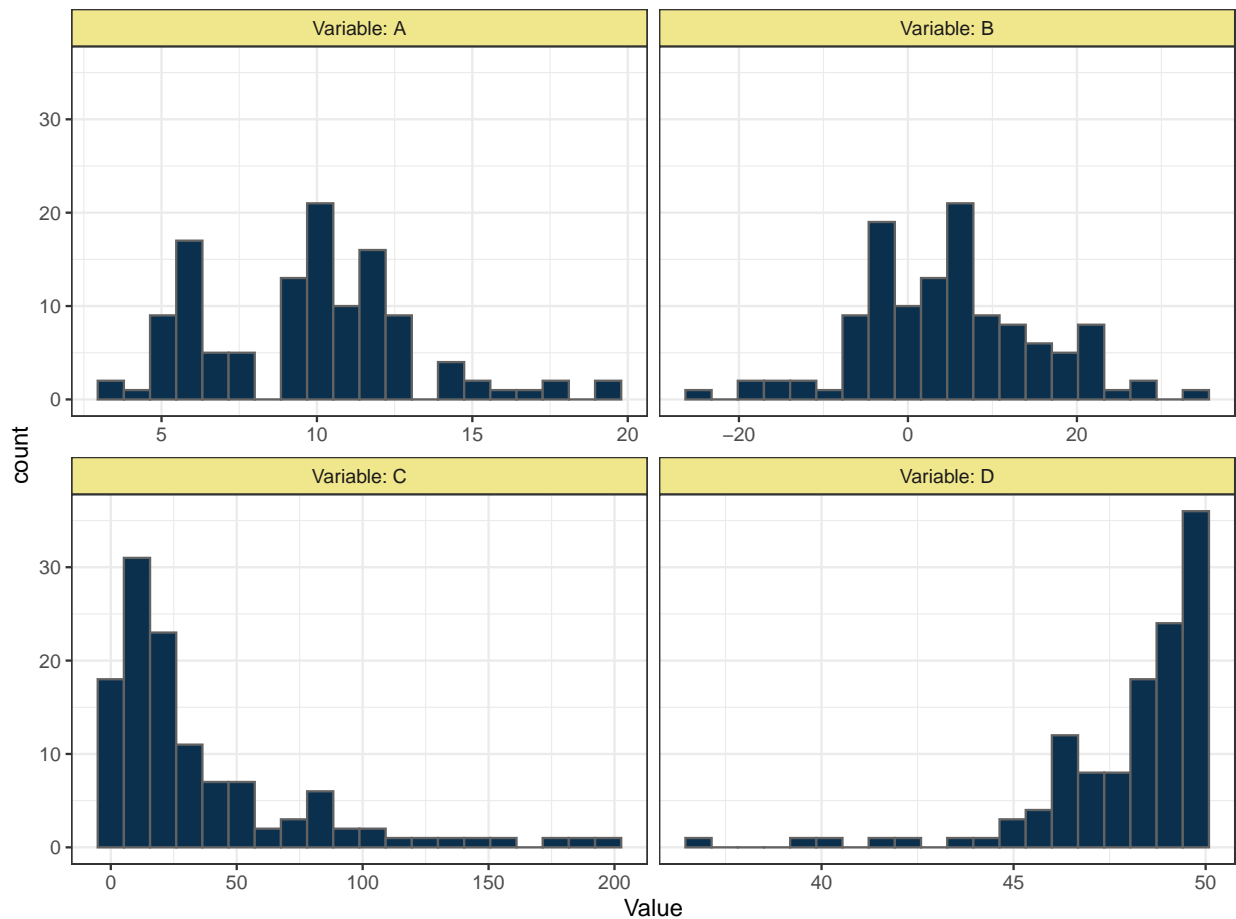
Using the model you specified in Question 2, estimate the effect of treatment (vs. control) on the odds of being alive at the end of the study. Your odds ratio estimate should compare `treated` to `control`, while adjusting for the effects of `age`, `female` and `comor`. Provide both a point estimate and a 95% confidence interval. Use the format 1.23 (0.78, 1.89) for your response, rounding your estimates to two decimal places. Then interpret your point estimate concisely and correctly in complete English sentences. Do not include any R code or output in your response.

## 4 Question 4 (3 points)

Which of the four variables plotted in the Display for Question 4 can be most effectively modeled by assuming a Normal distribution of the natural logarithm of the variable?

- a. A
- b. B
- c. C
- d. D
- e. It is impossible to tell from the information provided.

Display for Question 4



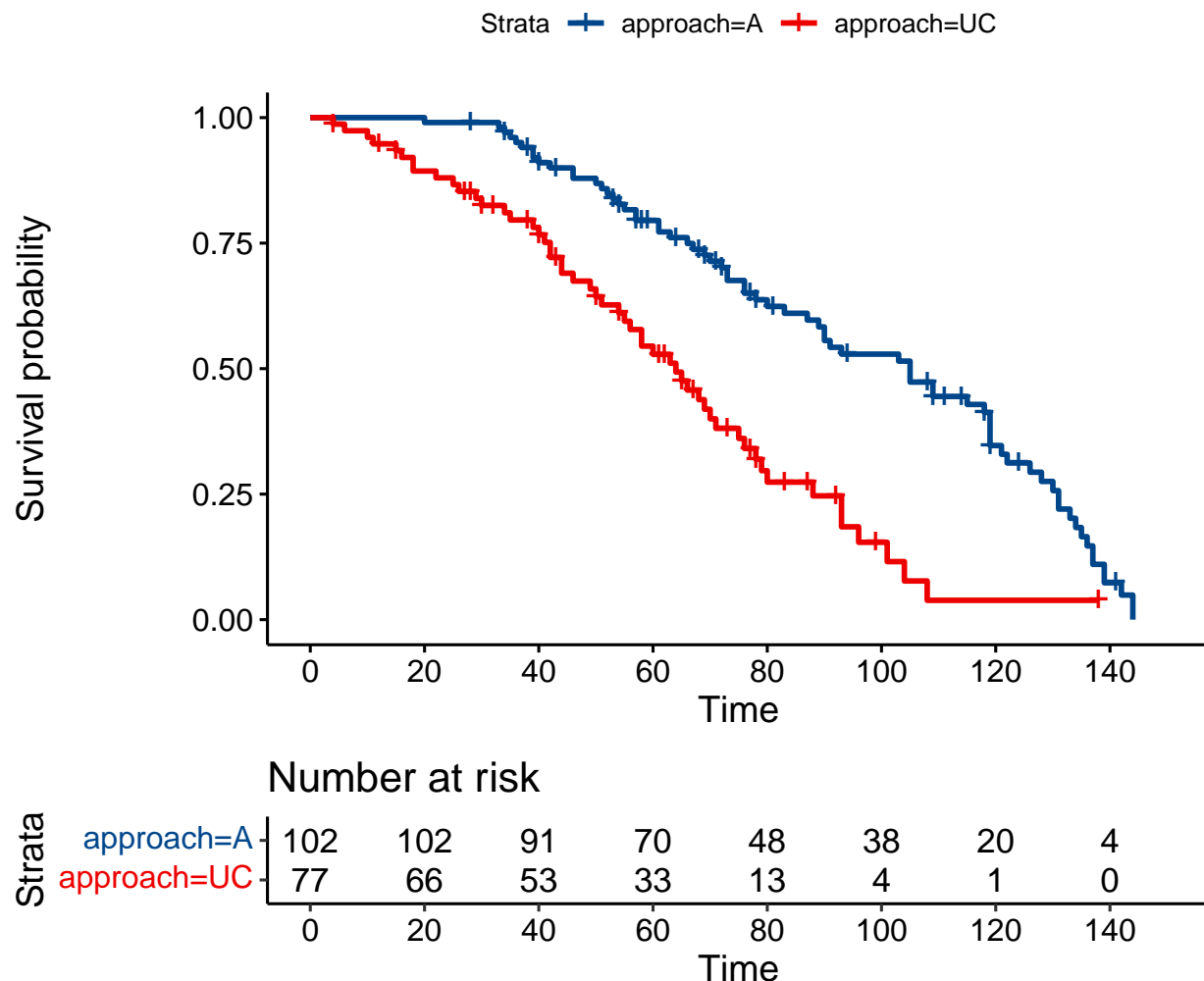
## 5 Question 5 (4 points)

The Display for Question 5 shows Kaplan-Meier estimated survival curves for 179 patients, each of whom either received approach A, or received usual care (UC). Time is measured in days. Censoring is indicated with cross marks, and be sure to CAREFULLY determine which group is represented in each of the lines in the plot. The log rank test (not shown here) has a chi-square estimate of 24.8 with one degree of freedom. Which of the following statements are true?

**CHECK ALL RESPONSES THAT ARE TRUE.**

- The UC patients had a median survival time about 40 days longer than the Approach A patients.
- The UC patients had a median survival time about 40 days shorter than the Approach A patients.
- The log rank test will have a  $p$  value which suggests no detectable difference at the 5% significance level between the survival curves of the two approaches.
- The log rank test will have a  $p$  value which suggests a detectable difference at the 5% significance level between the survival curves of the two approaches.
- None of the statements above are true.

Display for Question 5

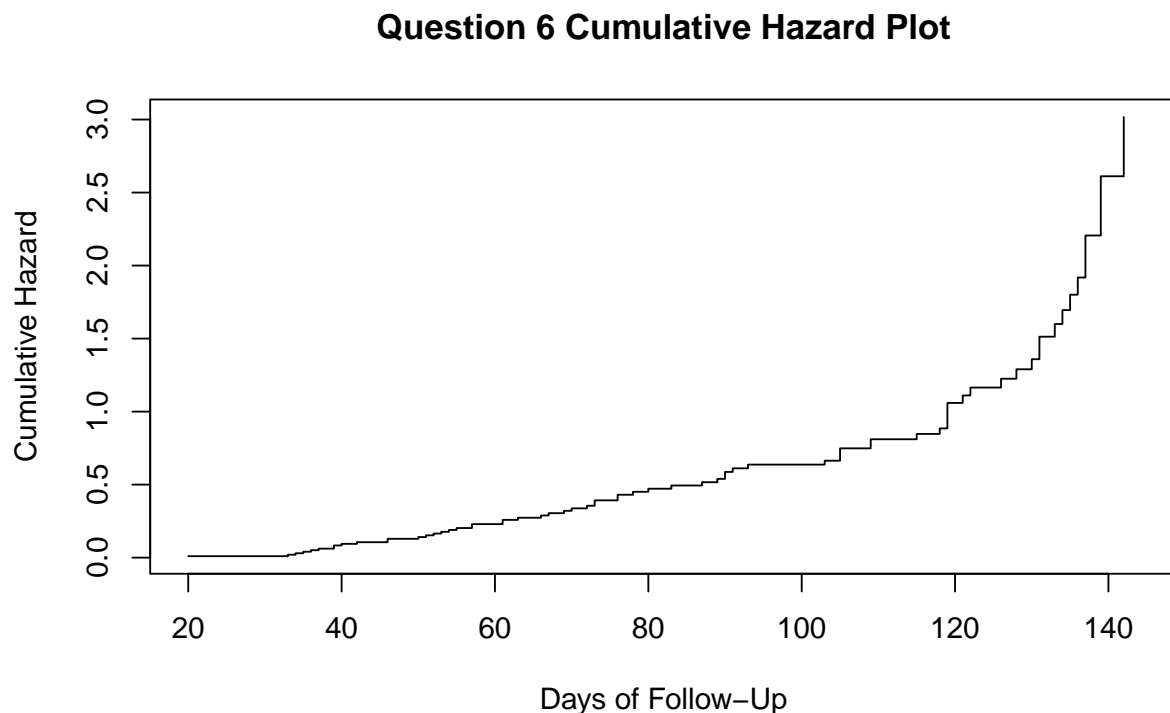


## 6 Question 6 (3 points)

A cumulative hazard function (using the inverse Kaplan-Meier methodology) was fit to one of the two approaches (A or UC) discussed in Question 5, to produce the Display for Question 6. In building this plot, I used the same data that produced the Kaplan-Meier curve shown in Question 5. If one of the two approaches (A or UC) produced this cumulative hazard plot, which approach was it?

- a. Approach A
- b. Usual Care
- c. It is impossible to tell from the information provided.

Display for Question 6



## 7 Question 7 (3 points)

In *The Signal and The Noise*, Nate Silver writes repeatedly about a Bayesian way of thinking about uncertainty, for instance in Chapters 8 and 13. Which one of the following statistical methods are consistent with a Bayesian approach to thinking about variation and uncertainty?

**CHECK ALL OF THE CORRECT RESPONSES.**

- a. Updating our forecasts as new information appears.
- b. Gambling using a strategy derived from a probability model.
- c. Combining information from multiple sources to build a model.
- d. Significance testing of a null hypothesis, using, say, Fisher's exact test.
- e. Establishing a researchable hypothesis prior to data collection.

## Setup for Questions 8 - 10

The `quizzd08.Rds` data used in Questions 8-10 has been provided to you. Dr. Love created these data from NHANES 2011-12 Demographics and Questionnaire data, specifically the `DEMO_G` (Demographics), `HSQ_G` (Current Health Status) and `PAQ_G` files, which are described at <https://wwwn.cdc.gov/nchs/nhanes/ContinuousNhanes/Default.aspx?BeginYear=2011>.

| Item     | Description                         | Possible Responses       |
|----------|-------------------------------------|--------------------------|
| SEQN     | Subject id code                     | 62161 through 71912      |
| WTINT2YR | Full sample 2 year interview weight | min = 8045, max = 168807 |
| RIDAGEYR | Age in years at screening           | min = 21, max = 49       |
| RIAGENDR | Sex                                 | 1 = Male, 2 = Female     |
| FEMALE   | Sex                                 | 1 = Female, 0 = Male     |
| RIDRETH3 | Race/Ethnicity                      | categories listed below  |
| HSD010   | General Health Condition            | see below                |
| HSQ571   | Donated blood in past year          | see below                |
| PAQ665   | Moderate recreational activities    | see below                |

- RIDRETH3 categories are
  - 1 = Mexican American,
  - 2 = Other Hispanic,
  - 3 = Non-Hispanic White,
  - 4 = Non-Hispanic Black,
  - 6 = Non-Hispanic Asian,
  - 7 = Other Race including Multi-Racial
- HSD010 Would you say your health in general is
  - 1 = Excellent,
  - 2 = Very Good,
  - 3 = Good,
  - 4 = Fair, or
  - 5 = Poor?
  - (Note that 7 = Refused, 9 = Don't know in this variable)
- HSQ571 During the past 12 months have you donated blood?
  - 1 = Yes,
  - 2 = No,
  - 7 = Refused to answer
  - 9 = Don't Know.
- PAQ665 Do you do any moderate-intensity sports, fitness, or recreational activities that cause a small increase in breathing or heart rate such as brisk walking, bicycling, swimming, or golf for at least 10 minutes continuously?
  - 1 = Yes,
  - 2 = No,
  - 7 = Refused to answer
  - 9 = Don't Know.



Here are a few summaries of the data in quizd08.Rds.

```
quizd08 <- readRDS("data/quizd08.Rds")
```

```
glimpse(quizd08)
```

Rows: 2,640

Columns: 9

```
$ SEQN      <labelled> 62161, 62164, 62169, 62172, 62176, 62180, 62184, 62189, ~
$ WTINT2YR  <labelled> 102641.41, 127351.37, 14391.78, 26960.77, 53830.60, 2045~
$ RIDAGEYR  <labelled> 22, 44, 21, 43, 34, 35, 26, 30, 35, 42, 36, 28, 35, 38, ~
$ RIAGENDR  <fct> 1, 2, 1, 2, 2, 1, 1, 2, 1, 1, 1, 1, 2, 1, 2, 2, 2, 2, 1, 2, 2~
$ RIDRETH3  <fct> 3, 3, 6, 4, 3, 3, 4, 6, 4, 6, 1, 3, 3, 2, 4, 4, 4, 4, 3, 2, 3~
$ HSD010    <fct> 3, NA, 3, 3, 2, 3, 3, 2, NA, 2, 2, 3, NA, 3, 3, 3, 3, 3, 3, 3~
$ HSQ571    <fct> 2, NA, 2, 2, 2, 2, 2, 2, NA, 2, 2, 1, NA, 2, 2, 2, 2, 2, 2, 2~
$ PAQ665    <fct> 2, 1, 2, 2, 1, 2, 2, 2, 2, 1, 1, 1, 2, 1, 2, 2, 1, 1, 2, 1, 1~
$ FEMALE    <labelled> 0, 1, 0, 1, 1, 0, 0, 1, 0, 0, 0, 0, 1, 0, 1, 1, 1, 1, 0,~
```

```
describe(quizd08)
```

```
quizd08
```

```
9 Variables      2640 Observations
```

```
SEQN : Respondent sequence number
```

| n     | missing | distinct | Info  | Mean  | Gmd  | .05   | .10   |
|-------|---------|----------|-------|-------|------|-------|-------|
| 2640  | 0       | 2640     | 1     | 67061 | 3295 | 62631 | 63115 |
| .25   | .50     | .75      | .90   | .95   |      |       |       |
| 64612 | 67015   | 69584    | 70967 | 71467 |      |       |       |

```
lowest : 62161 62164 62169 62172 62176, highest: 71901 71904 71909 71911 71912
```

```
WTINT2YR : Full sample 2 year interview weight
```

| n     | missing | distinct | Info   | Mean   | Gmd   | .05   | .10   |
|-------|---------|----------|--------|--------|-------|-------|-------|
| 2640  | 0       | 1464     | 1      | 42760  | 34431 | 13367 | 15267 |
| .25   | .50     | .75      | .90    | .95    |       |       |       |
| 19076 | 29123   | 48995    | 105142 | 123110 |       |       |       |

```
lowest : 8044.550 9131.449 9145.762 9177.296 9585.653
```

```
highest: 154664.072 154825.467 155208.038 163194.688 168806.615
```

```
RIDAGEYR : Age in years at screening
```

| n    | missing | distinct | Info  | Mean  | Gmd   | .05 | .10 |
|------|---------|----------|-------|-------|-------|-----|-----|
| 2640 | 0       | 29       | 0.999 | 34.65 | 9.656 | 22  | 23  |
| .25  | .50     | .75      | .90   | .95   |       |     |     |
| 27   | 35      | 42       | 46    | 48    |       |     |     |

```
lowest : 21 22 23 24 25, highest: 45 46 47 48 49
```

```
RIAGENDR
```

| n    | missing | distinct |
|------|---------|----------|
| 2640 | 0       | 2        |

```
Value      1      2
```

```
Frequency 1304 1336
```

Proportion 0.494 0.506

---

RIDRETH3

| n    | missing | distinct |
|------|---------|----------|
| 2640 | 0       | 6        |

lowest : 1 2 3 4 6, highest: 2 3 4 6 7

| Value      | 1     | 2     | 3     | 4     | 6     | 7     |
|------------|-------|-------|-------|-------|-------|-------|
| Frequency  | 312   | 240   | 919   | 634   | 440   | 95    |
| Proportion | 0.118 | 0.091 | 0.348 | 0.240 | 0.167 | 0.036 |

---

HSD010

| n    | missing | distinct |
|------|---------|----------|
| 2249 | 391     | 5        |

lowest : 1 2 3 4 5, highest: 1 2 3 4 5

| Value      | 1     | 2     | 3     | 4     | 5     |
|------------|-------|-------|-------|-------|-------|
| Frequency  | 269   | 690   | 927   | 322   | 41    |
| Proportion | 0.120 | 0.307 | 0.412 | 0.143 | 0.018 |

---

HSQ571

| n    | missing | distinct |
|------|---------|----------|
| 2249 | 391     | 3        |

| Value      | 1     | 2     | 9     |
|------------|-------|-------|-------|
| Frequency  | 107   | 2139  | 3     |
| Proportion | 0.048 | 0.951 | 0.001 |

---

PAQ665

| n    | missing | distinct |
|------|---------|----------|
| 2640 | 0       | 2        |

| Value      | 1     | 2     |
|------------|-------|-------|
| Frequency  | 1244  | 1396  |
| Proportion | 0.471 | 0.529 |

---

FEMALE : Gender

| n    | missing | distinct | Info | Sum  | Mean   | Gmd    |
|------|---------|----------|------|------|--------|--------|
| 2640 | 0       | 2        | 0.75 | 1336 | 0.5061 | 0.5001 |

## 8 Question 8 (5 points)

Three of the following five commands were used in creating the `quizd08.Rds` data frame that we have made available for you, in some cases when the variables involved were numeric (as `nhanesA` provides them) and not yet specified as factors. Which two of the commands below were not used?

**CHECK EACH of the two commands that were NOT used.**

- a. `filter(RIDAGEYR > 20 & RIDAGEYR < 50)`
- b. `filter(PAQ665 < 3)`
- c. `quizd08 <- zap_label(quizd08)`
- d. `mutate(RIDRETH3 = factor(RIDRETH3))`
- e. `mutate(FEMALE = 2 - RIAGENDR)`

## 9 Question 9 (3 points)

What percentage of the rows included in the `quizd08` data describe subjects who have described their General Health as either “Excellent” or “Very Good”?

Be sure to use a **complete-case** analysis to deal with missing data on the General Health variable.

Please express your response as a percentage between 0 and 100, including a single decimal place.

## 10 Question 10 (4 points)

Next, please answer the question asked in Question 9 again, but this time accounting for the sampling weights used in `WTINT2YR`, again using a **complete-case** analysis to deal with missing General Health values.

What is the resulting estimate of the percentage of the US non-institutionalized adult population within the ages of 21-49 who would describe their General Health as either “Excellent” or “Very Good”?

As you did in Question 9, express your response to Question 10 as a percentage, with a single decimal place.

## 11 Question 11 (3 points)

Suppose you are trying to build a regression model to predict a patient’s self-reported overall health (where the available responses are Excellent, Very Good, Good, Fair or Poor) where you want to treat the health assessments as categorical. Which of the following models would represent the most appropriate choice?

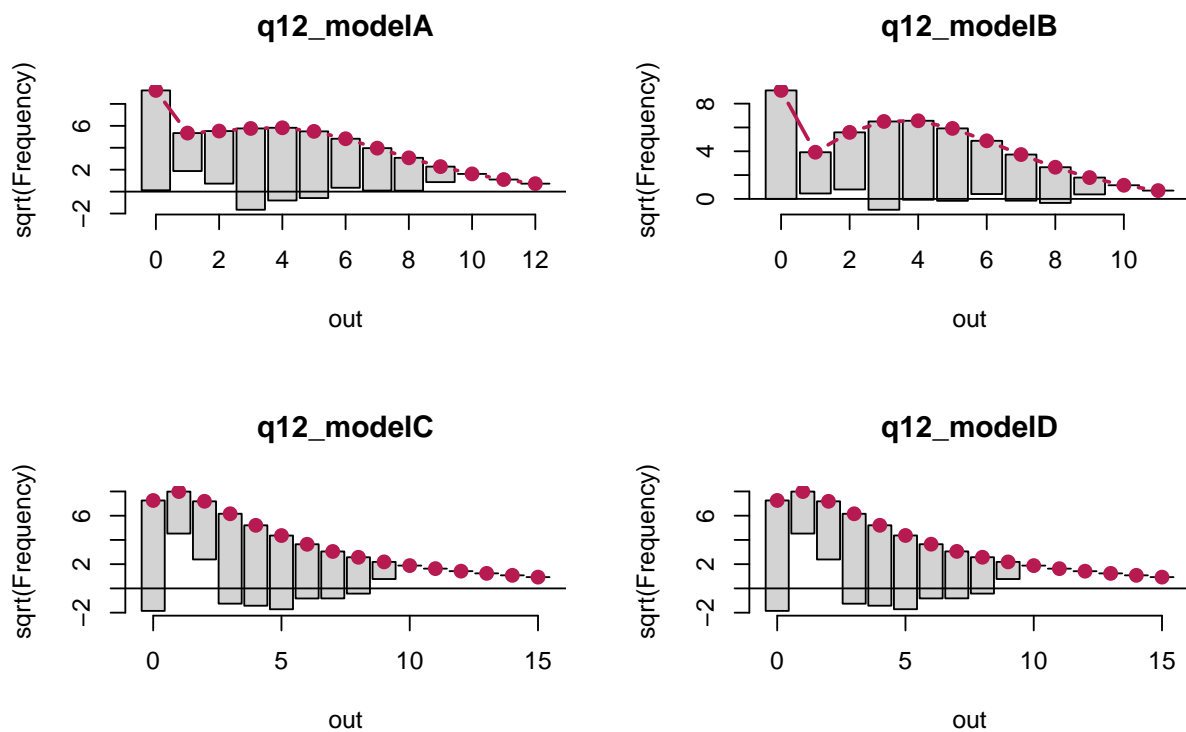
- a. An ordinary least squares model.
- b. A Cox proportional hazards model.
- c. A proportional odds logistic regression model.
- d. A zero-inflated negative binomial model.
- e. A binary logistic regression model.
- f. None of these models would be appropriate.

## 12 Question 12 (3 points)

The Display for Question 12 shows four rootograms, using four different count regression models to fit the same outcome, which is named `out`. Which model (A, B, C, D) shows the best fit to the data?

- a. Model A
- b. Model B
- c. Model C
- d. Model D
- e. It is impossible to tell from the information provided.

### 12.1 Display for Question 12



### 13 Question 13 (3 points)

Patients with genital herpes (HSV-2) were enrolled in a study of a new recombinant herpes vaccine based on the antigen glycoprotein, gD2. Patients were required to have a history of at least 6 HSV-2 episodes in the 12 months prior to study enrollment and be in remission at the time of vaccination. Patients were randomly assigned to receive either a single gD2 vaccine injection or a placebo, and their conditions were followed for 1 year. The response is the time (in weeks) to first recurrence of HSV-2 following immunization for each patient. Our aim is to determine whether the distributions of the times to recurrence differ between the two vaccination groups. A few subjects dropped out of the study before the year was up and before their HSV-2 recurred.

Which of the possible modeling strategies listed below might be appropriate for the study. More than one strategy might be appropriate, and you should indicate all appropriate choices.

#### CHECK ALL APPROPRIATE CHOICES

- a. Linear regression to predict the outcome.
- b. (Binary) Logistic regression to predict the outcome.
- c. Poisson regression to predict the outcome.
- d. Multinomial logistic regression to predict the outcome.
- e. Ordinal logistic regression to predict the outcome.
- f. Cox proportional hazards model to predict the outcome.
- g. Log rank test of the intervention's impact on the outcome.
- h. None of these modeling strategies are appropriate.

### Setup for Questions 14 - 16

141 subjects were enrolled in a study comparing two treatments (`trt` = A or B). The outcome of interest is a binary result (1 = good, 0 = bad), and we also have information on baseline severity of illness (on a 0-10 scale, where 10 is most severe) and on insurance status (`ins` = Private, Public or None). Consider the output and plot below.

```
dat14 <- read_csv("data/dat14.csv")

d <- datadist(dat14)
options(datadist="d")
model14 <- lrm(result ~ trt, data=dat14, x=TRUE, y=TRUE)
model14
```

#### Logistic Regression Model

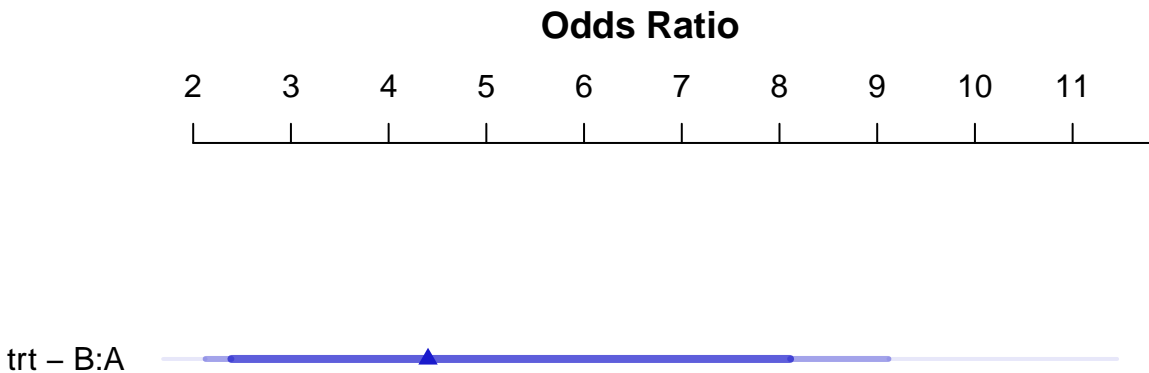
```
lrm(formula = result ~ trt, data = dat14, x = TRUE, y = TRUE)
```

|            |       | Model Likelihood |         | Discrimination | Rank Discrim. |
|------------|-------|------------------|---------|----------------|---------------|
|            |       | Ratio Test       |         | Indexes        | Indexes       |
| Obs        | 141   | LR chi2          | 17.27   | R2             | 0.155         |
| 0          | 58    | d.f.             | 1       | g              | 0.746         |
| 1          | 83    | Pr(> chi2)       | <0.0001 | gr             | 2.108         |
| max  deriv | 5e-12 |                  |         | gp             | 0.171         |
|            |       |                  |         | Brier          | 0.213         |

|           | Coef    | S.E.   | Wald Z | Pr(> Z ) |
|-----------|---------|--------|--------|----------|
| Intercept | -0.3037 | 0.2368 | -1.28  | 0.1997   |
| trt=B     | 1.4823  | 0.3712 | 3.99   | <0.0001  |

### Display for Question 14

```
plot(summary(model14))
```



### 14 Question 14 (4 points)

Which of the following statements are true, according to the Model provided in the Setup for Questions 14 and 15, and the Display for Question 14?

**CHECK ALL OF THE TRUE STATEMENTS.**

- a. The odds of a good result are estimated to be 1.48 times as large with treatment B as with treatment A.
- b. The odds of a good result are more than 4 times as large with treatment B as with treatment A.
- c. The probability of a good result is nearly 5 times as high with treatment B as with treatment A.
- d. More people had a good result than a bad result in this study.
- e. None of the above statements are true.

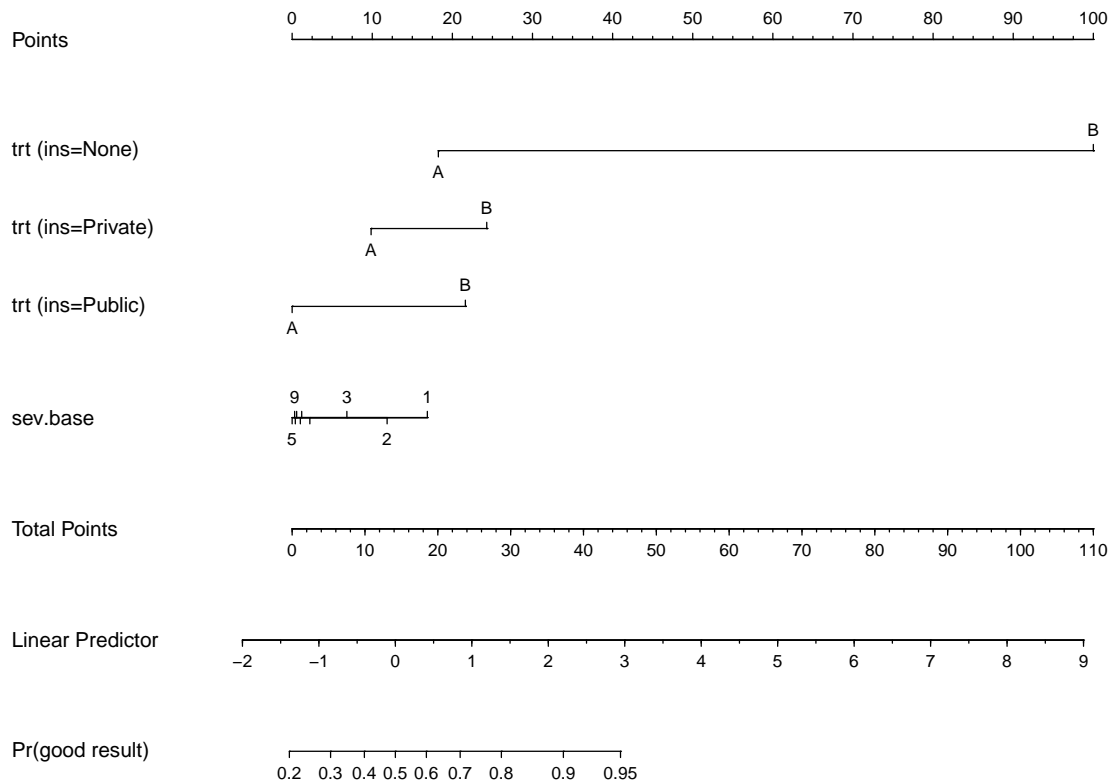
## 15 Question 15 (3 points)

An augmented model was fit to the data discussed in Question 14, incorporating some non-linear terms in the predictors we've seen, and a nomogram of that augmented model in the Display for Question 15. If you want to see a larger version of the nomogram, it is available on our Shared Google Drive, in the file called `q15-nomogram.png`.

Based on the nomogram provided in the Display for Question 15 and 16, which of the following responses includes the predicted probability of a good result for a subject with Private insurance, treatment A, and baseline severity 1?

- a. Less than 0.25
- b. Between 0.25 and 0.49
- c. Between 0.5 and 0.74
- d. 0.75 or larger
- e. It is impossible to tell from the information provided.

### 15.1 Display for Question 15 and 16



## 16 Question 16 (3 points)

Based on the nomogram shown in the Display for Question 15 and 16, which of the following augmentations to the model shown in Question 14 were made?

**CHECK ALL OF THE RESPONSES THAT APPLY.**

- a. A restricted cubic spline or polynomial function in `sev.base`
- b. An interaction term between `sev.base` and `treatment`
- c. An interaction term between `sev.base` and `insured`
- d. An interaction term between `treatment` and `insured`
- e. None of the above

## Setup for Questions 17 and 18

A subset of the data from the BRFSS SMART study developed in Chapter 2 of the Course Notes are used in Questions 17 and 18 with some modifications. The three variables of interest are:

- `mmsa`, which is either CIN (Cincinnati), CLE (Cleveland-Elyria), COL (Columbus), or DAY (Dayton)
- `vax_pneumo`, which is either “Vax” if the subject had received a vaccination against pneumonia, and “NoVax” if not
- `binge`, which is either “Yes” or “No” (the standard for “Yes” is sex-specific: males having five or more drinks on one occasion in the past 30 days, females having four or more drinks on one occasion in the past 30 days)

The `quizd17.Rds` data set of interest is available to you on our web site, if you want it. I used it to fit the following four models to predict `mmsa` based on the two predictors.

```
quizd17 <- readRDS("data/quizd17.Rds")
options(contrasts = c("contr.treatment", "contr.poly"))

m17_1 <- multinom(mmsa ~ 1,
                  data = quizd17, trace = FALSE)
m17_B <- multinom(mmsa ~ binge,
                  data = quizd17, trace = FALSE)
m17_V <- multinom(mmsa ~ vax_pneumo,
                  data = quizd17, trace = FALSE)
m17_BV <- multinom(mmsa ~ binge + vax_pneumo,
                  data = quizd17, trace = FALSE)
m17_SAT <- multinom(mmsa ~ binge * vax_pneumo,
                  data = quizd17, trace = FALSE)
```

Here are the AIC results for these models:

```
AIC(m17_1, m17_B, m17_V, m17_BV, m17_SAT)
```

|         | df | AIC      |
|---------|----|----------|
| m17_1   | 3  | 11944.56 |
| m17_B   | 6  | 11937.27 |
| m17_V   | 6  | 11940.38 |
| m17_BV  | 9  | 11934.83 |
| m17_SAT | 12 | 11936.76 |



## 17 Question 17 (3 points)

Note that one of the models I fit is preferable to the others, on the basis of the Akaike Information Criterion. Call that the preferred model. Which of the models is the preferred model?

- a. The model with an intercept only.
- b. The model using only the main effect of `binge`.
- c. The model using only the main effect of `vax_pneumo`.
- d. The model using only the main effects of `binge` and `vax_pneumo`.
- e. The model including the interaction of `binge` and `vax_pneumo`.

## 18 Question 18 (3 points)

Your job is to consider the five displays for Question 18 that follow, and determine which of those displays describe the preferred model that you identified back in Question 17. More than one response may be correct.

**CHECK ALL RESPONSES THAT APPLY.**

- a. Display A for Question 18
- b. Display B for Question 18
- c. Display C for Question 18
- d. Display D for Question 18
- e. Display E for Question 18
- f. None of these.

## Display A for Question 18

```
tidy(displayA, exponentiate = TRUE, conf.int = TRUE) %>%
  kable(digits = 3)
```

| y.level | term          | estimate | std.error | statistic | p.value | conf.low | conf.high |
|---------|---------------|----------|-----------|-----------|---------|----------|-----------|
| CLE     | (Intercept)   | 0.601    | 0.063     | -8.067    | 0.000   | 0.531    | 0.680     |
| CLE     | bingeYes      | 0.938    | 0.116     | -0.557    | 0.578   | 0.748    | 1.176     |
| CLE     | vax_pneumoVax | 1.255    | 0.084     | 2.695     | 0.007   | 1.064    | 1.481     |
| COL     | (Intercept)   | 1.149    | 0.053     | 2.616     | 0.009   | 1.036    | 1.275     |
| COL     | bingeYes      | 0.776    | 0.102     | -2.489    | 0.013   | 0.636    | 0.948     |
| COL     | vax_pneumoVax | 1.125    | 0.073     | 1.627     | 0.104   | 0.976    | 1.297     |
| DAY     | (Intercept)   | 0.333    | 0.078     | -14.087   | 0.000   | 0.285    | 0.388     |
| DAY     | bingeYes      | 0.645    | 0.161     | -2.732    | 0.006   | 0.470    | 0.883     |
| DAY     | vax_pneumoVax | 1.219    | 0.105     | 1.884     | 0.060   | 0.992    | 1.497     |

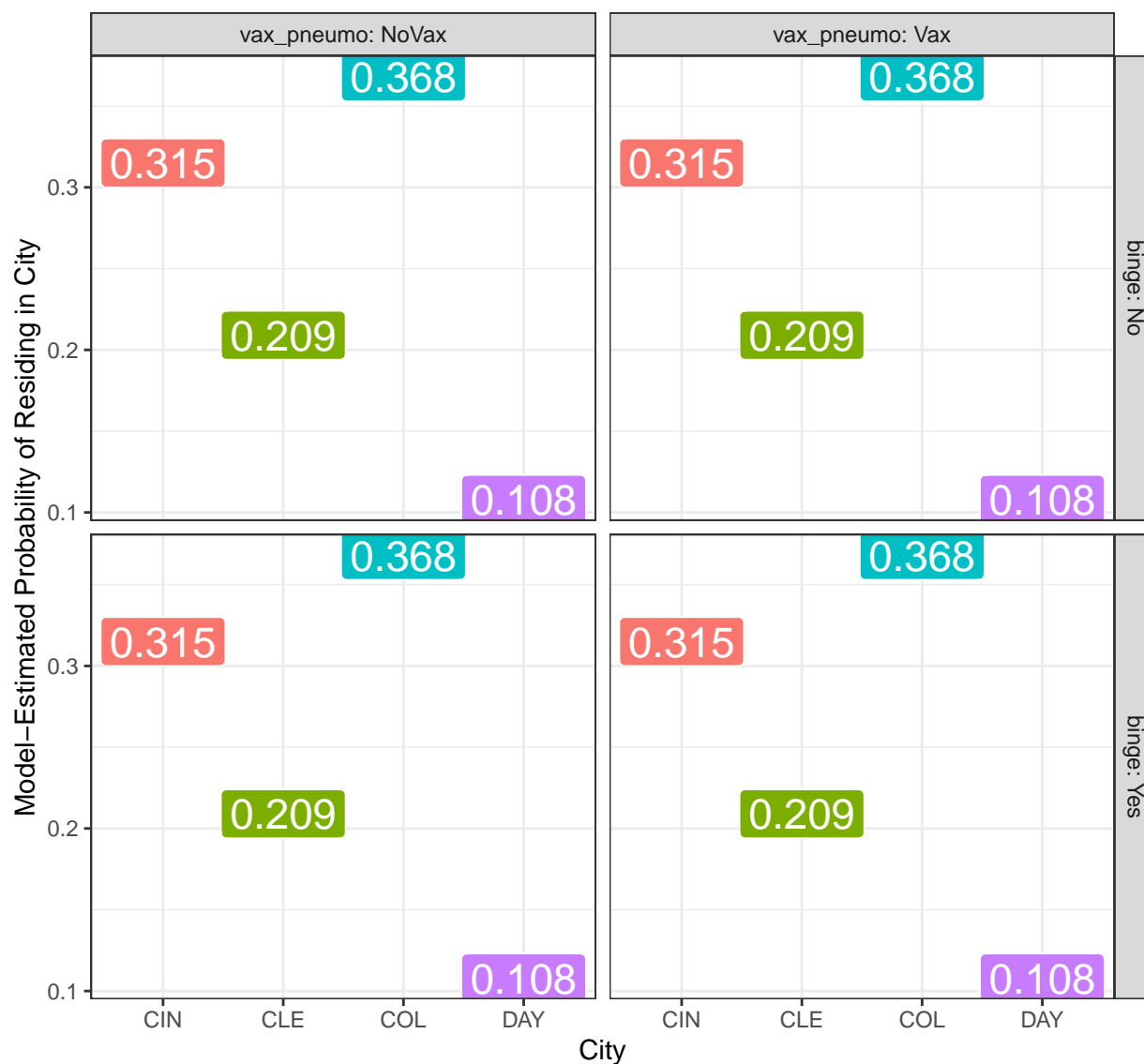
## Display B for Question 18

```
tidy(displayB, exponentiate = TRUE, conf.int = TRUE) %>%
  kable(digits = 3)
```

| y.level | term                   | estimate | std.error | statistic | p.value | conf.low | conf.high |
|---------|------------------------|----------|-----------|-----------|---------|----------|-----------|
| CLE     | (Intercept)            | 0.601    | 0.066     | -7.743    | 0.000   | 0.529    | 0.684     |
| CLE     | bingeYes               | 0.934    | 0.143     | -0.479    | 0.632   | 0.705    | 1.237     |
| CLE     | vax_pneumoVax          | 1.252    | 0.091     | 2.472     | 0.013   | 1.048    | 1.497     |
| CLE     | bingeYes:vax_pneumoVax | 1.016    | 0.243     | 0.066     | 0.948   | 0.632    | 1.635     |
| COL     | (Intercept)            | 1.144    | 0.055     | 2.445     | 0.014   | 1.027    | 1.275     |
| COL     | bingeYes               | 0.797    | 0.124     | -1.832    | 0.067   | 0.626    | 1.016     |
| COL     | vax_pneumoVax          | 1.135    | 0.078     | 1.622     | 0.105   | 0.974    | 1.321     |
| COL     | bingeYes:vax_pneumoVax | 0.925    | 0.218     | -0.359    | 0.720   | 0.603    | 1.418     |
| DAY     | (Intercept)            | 0.344    | 0.080     | -13.419   | 0.000   | 0.294    | 0.402     |
| DAY     | bingeYes               | 0.511    | 0.213     | -3.151    | 0.002   | 0.336    | 0.776     |
| DAY     | vax_pneumoVax          | 1.145    | 0.111     | 1.220     | 0.222   | 0.921    | 1.424     |
| DAY     | bingeYes:vax_pneumoVax | 1.777    | 0.325     | 1.768     | 0.077   | 0.939    | 3.363     |

## Display C for Question 18

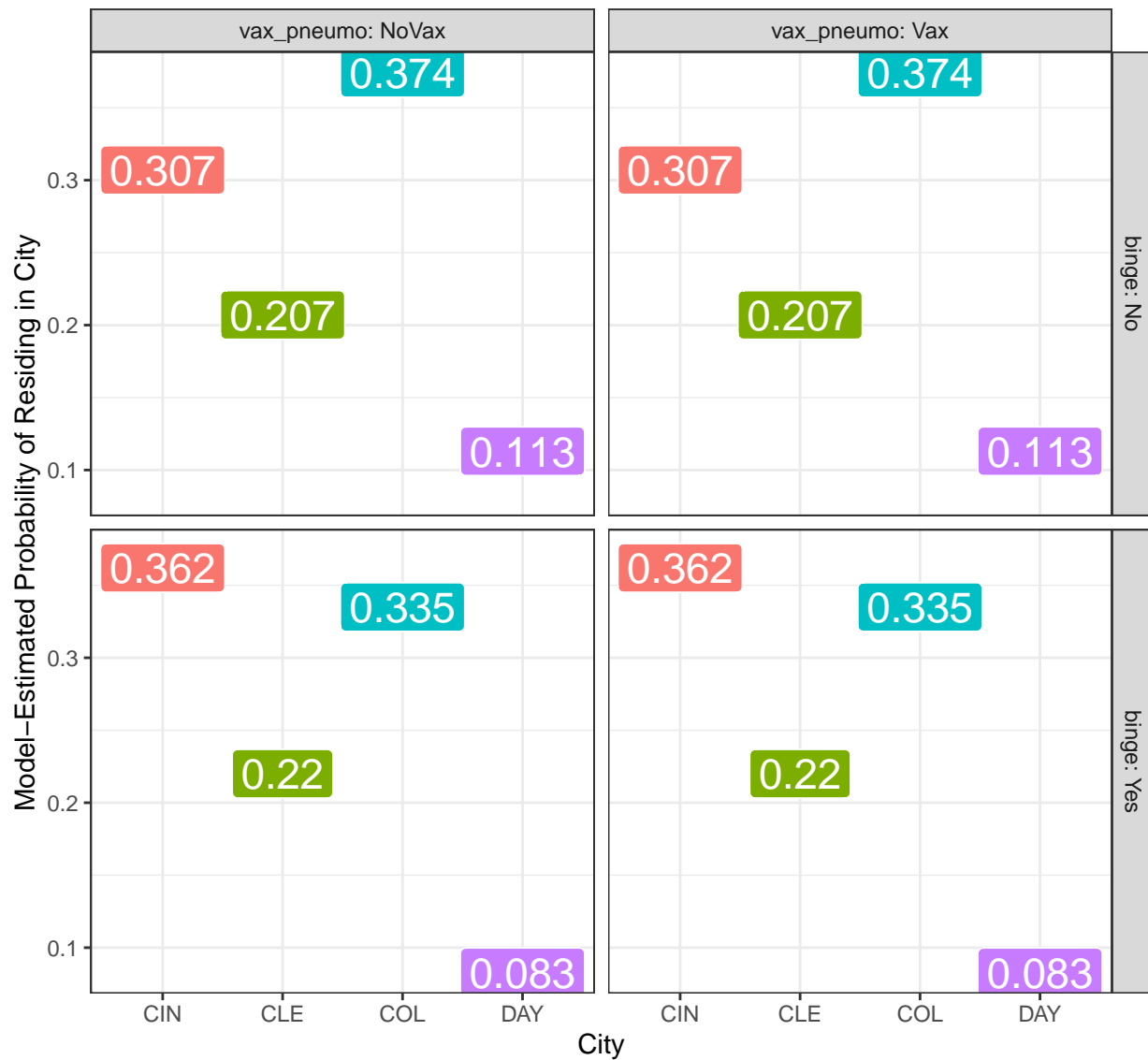
```
ggplot(displayC, aes(x = city, y = prob, fill = city)) +
  geom_label(aes(label = prob), col = "white", size = 6) +
  guides(fill = "none") +
  facet_grid(binge ~ vax_pneumo, labeller = "label_both") +
  labs(y = "Model-Estimated Probability of Residing in City",
       x = "City")
```



Note that the `prob` variable shows the fitted probability of the subject residing in each city, according to the model fit for this display.

## Display D for Question 18

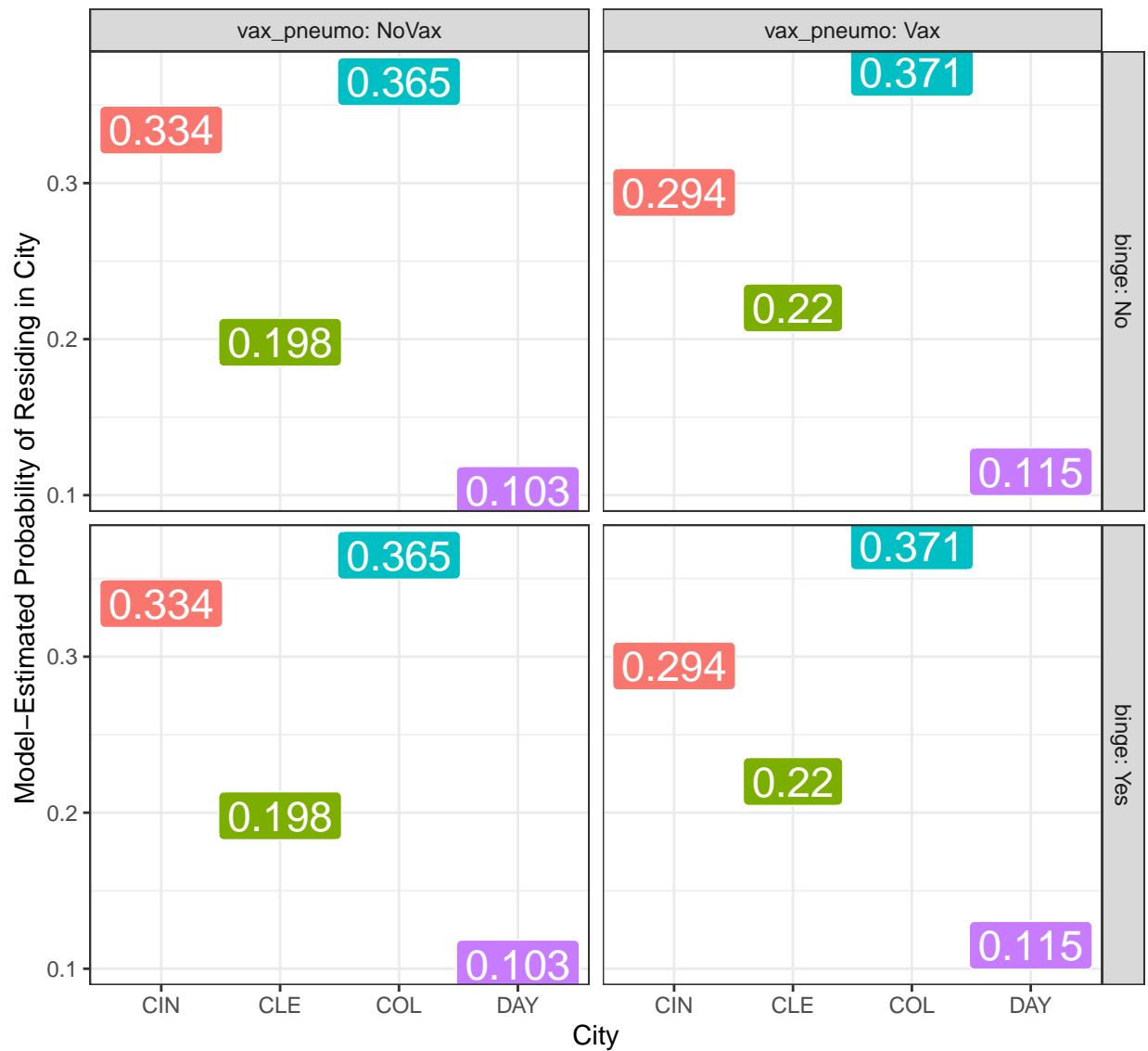
```
ggplot(displayD, aes(x = city, y = prob, fill = city)) +
  geom_label(aes(label = prob), col = "white", size = 6) +
  guides(fill = "none") +
  facet_grid(binge ~ vax_pneumo, labeller = "label_both") +
  labs(y = "Model-Estimated Probability of Residing in City",
       x = "City")
```



Note that the `prob` variable shows the fitted probability of the subject residing in each city, according to the model fit for this display.

## Display E for Question 18

```
ggplot(displayE, aes(x = city, y = prob, fill = city)) +
  geom_label(aes(label = prob), col = "white", size = 6) +
  guides(fill = "none") +
  facet_grid(binge ~ vax_pneumo, labeller = "label_both") +
  labs(y = "Model-Estimated Probability of Residing in City",
       x = "City")
```



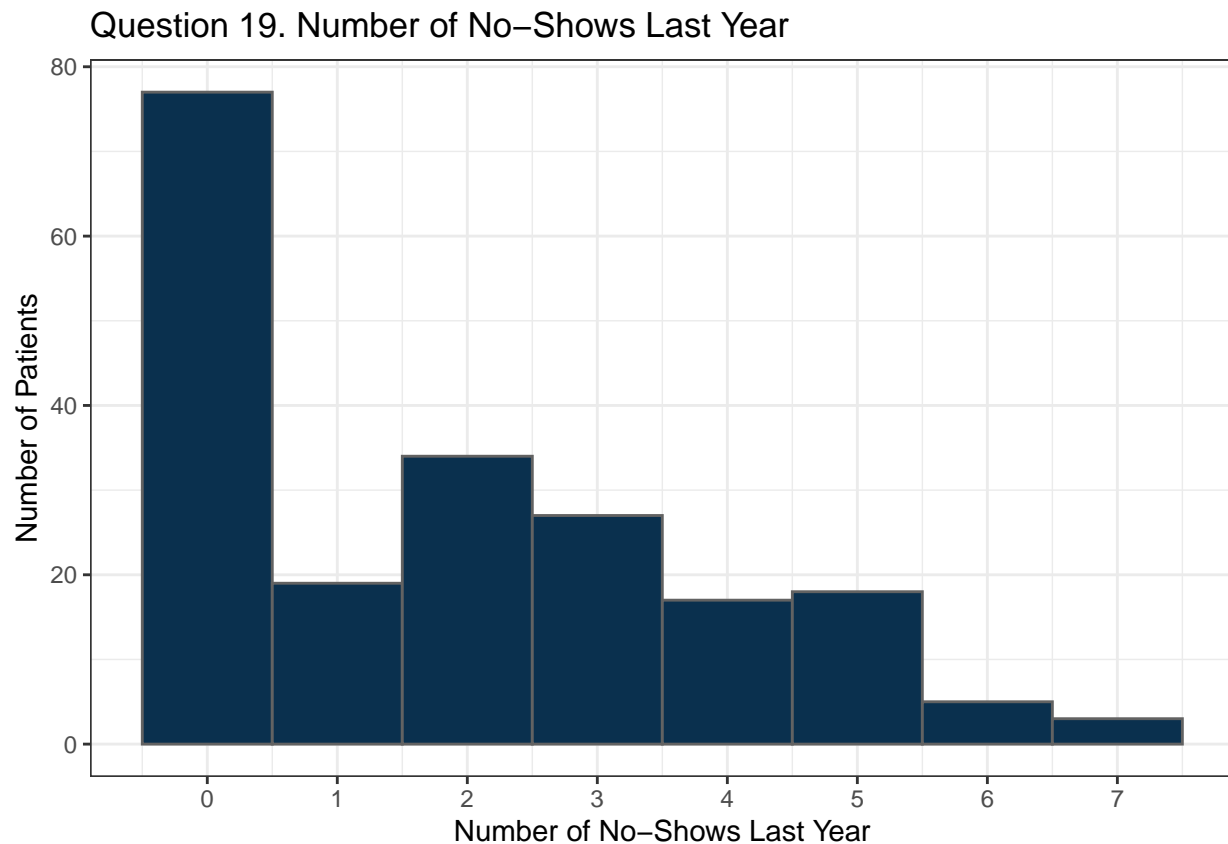
Note that the `prob` variable shows the fitted probability of the subject residing in each city, according to the model fit for this display.

## 19 Question 19 (3 points)

Suppose you are trying to build a regression model to predict **noshow**, the number of times a patient will “no show” an appointment for medical care in the next 12 months, on the basis of several characteristics related to their health, demographics, and satisfaction levels with prior visits. The **noshow** data on 200 patients from last year are visualized in the Display for Question 19. Which of the following models is most likely to be appropriate?

- a. A Cox proportional-hazards model.
- b. A proportional odds logistic regression.
- c. A binary logistic regression model.
- d. A zero-inflated Poisson model.
- e. A multinomial logistic regression model.
- f. None of these models will be appropriate.

### Display for Question 19



## 20 Question 20 (3 points)

Which of the following strategies is described as a sound (or more fox-like) strategy for making predictions according to Nate Silver in *The Signal and the Noise*?

**CHECK ALL RESPONSES THAT APPLY.**

- a. Betting on the forecast for next year made by the individual who had the best result last year in a prediction contest.
- b. Focusing on the principal cause of an outcome, more than correlating factors.
- c. Extrapolating (on an exponential scale) from a current trend.
- d. Calculating the basic reproduction number  $R_0$  at the start of a disease's sweep through a community.
- e. Applying an SIR model (susceptible - infectious - recovery) to the prediction of infectious disease in a similar way for all members of a population.

## 21 Question 21 (3 points)

Suppose you are trying to build a regression model to predict whether or not a patient hospitalized with heart failure will need to return to the hospital in the 30 days after they are released. You gather a series of predictors that should be useful.

Which of the following models would be most appropriate?

**SELECT THE SINGLE BEST RESPONSE.**

- a. A multinomial logit model.
- b. A binary logistic regression model.
- c. An ordinary least squares model.
- d. A Cox proportional hazards model.
- e. None of these models would be appropriate.

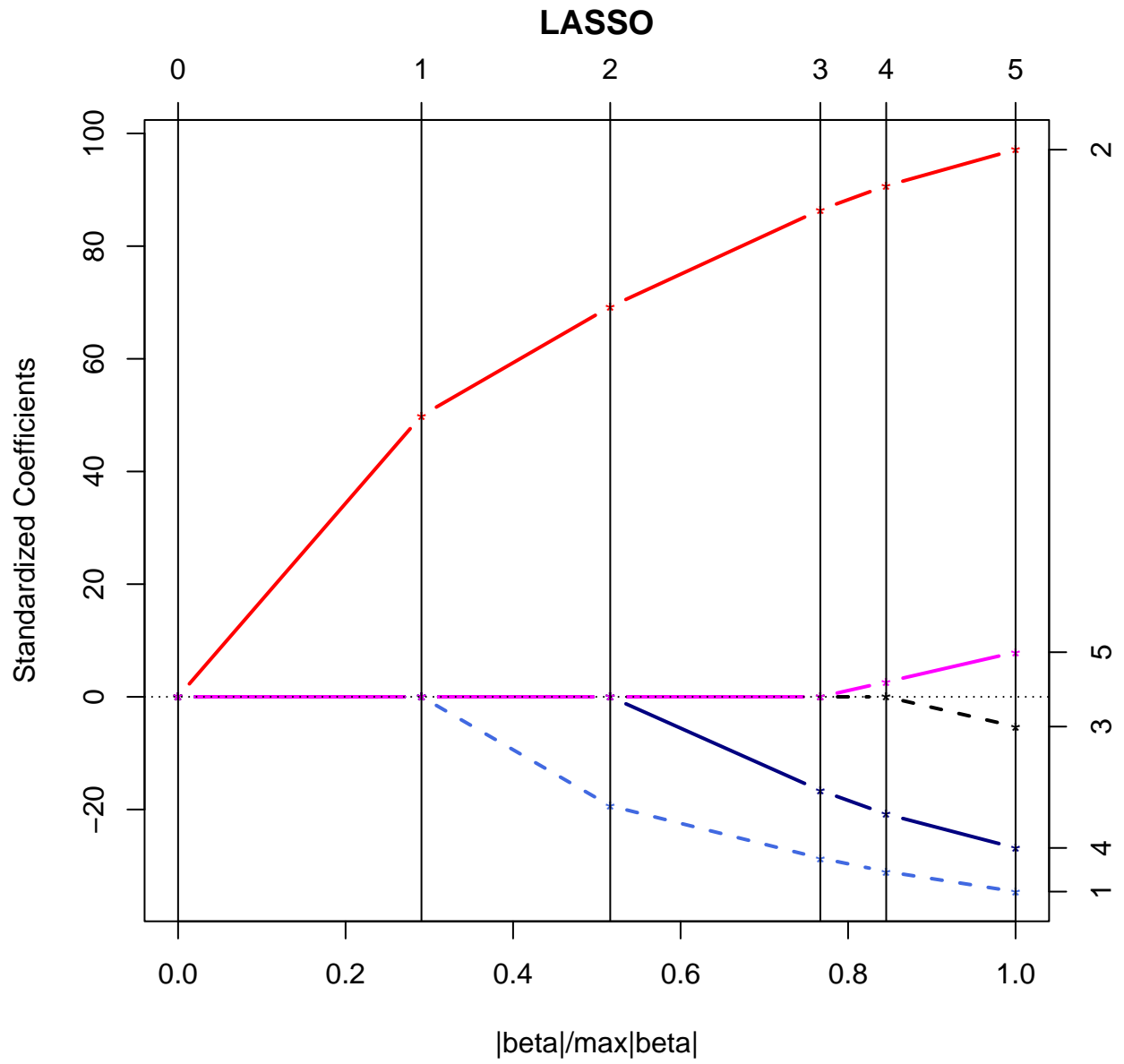
## 22 Question 22 (3 points)

Consider the lasso plot shown in the Display for Question 22 describing a situation with five candidate predictors. If the  $|\text{beta}| / \max|\text{beta}|$  value at which the cross-validated mean square error was minimized in this situation was 0.6, then specify the predictors that the plot suggests should be included in the model.

**CHECK ALL PREDICTORS THAT SHOULD BE INCLUDED.**

- a. Variable 1
- b. Variable 2
- c. Variable 3
- d. Variable 4
- e. Variable 5
- f. None of the above

Display for Question 22



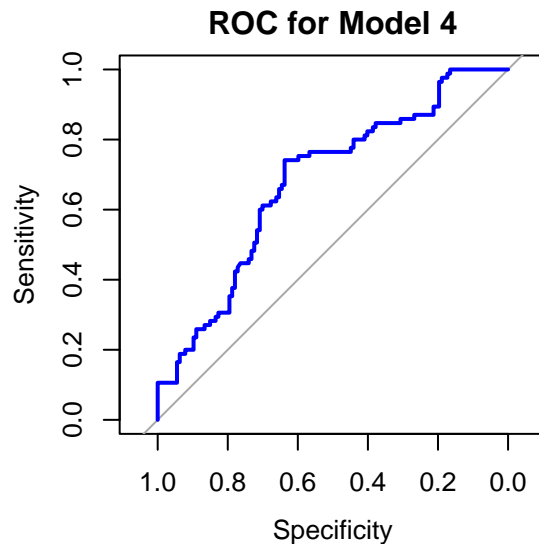
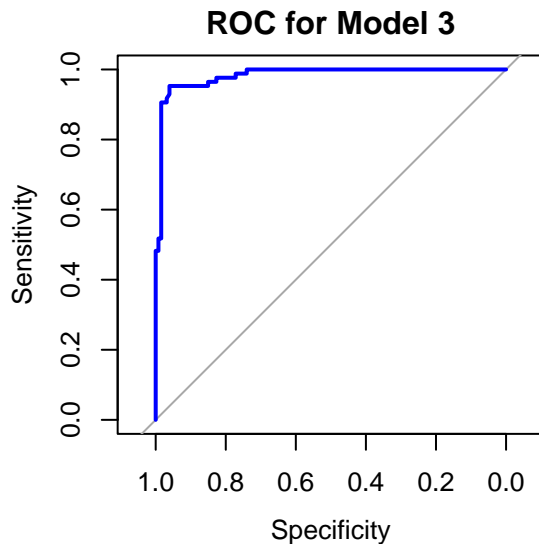
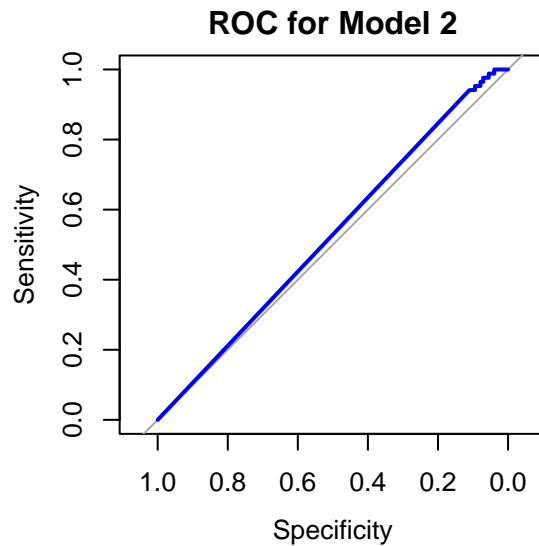
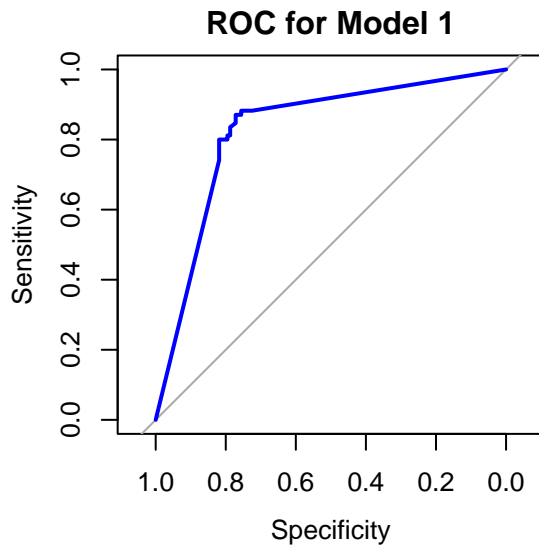


## 23 Question 23 (4 points)

The grid of four receiver operating characteristic curve plots shown in the Display for Question 23 describes four different logistic regression models fit to predict the same outcome. Indicate the C statistic associated with each model.

- Rows are Model 1, 2, 3, 4
- Columns are C statistics equal to 0.53, 0.68, 0.83, 0.98

### Display for Question 23



## Setup for Questions 24 - 26

The `quized24.csv` data set (which will be used in Questions 24-26) is available to you on the course web site.

The outcome of interest in that data set, labeled `y`, is the number of standards (out of 6) met by subjects involved in an alcoholism treatment program. Subjects are released from the program when they meet all six standards. The data in `y` describe the number of standards met after one week of treatment for 200 recent subjects. Measures `x1`, `x2` and `x3` are predictors of `y`, whose main effects (only) are of interest to us. `x1` and `x3` are quantitative measures, and `x2` indicates whether or not the subject has completed a specific group of tasks.

### 24 Question 24 (3 points)

Fit a Poisson regression model to the data in the `quized24.csv` file, and compare your result to what you obtain using a negative binomial regression. Treat variable `x2` as a number (1/0) rather than converting it to a factor.

Which of the statements listed in the Display for Question 24 are true?

**CHECK EACH OF THE CORRECT RESPONSES.**

- a. Statement I
- b. Statement II
- c. Statement III
- d. None of these three statements.

### Display for Question 24

- Statement I. A main effects model fit with Poisson regression provides a statistically significantly worse fit (at the 95% confidence level) than a model fit with Negative Binomial regression.
- Statement II. The rootogram for the Poisson model indicates a substantially better fit than the rootogram for the Negative Binomial model.
- Statement III. The rootogram for the Poisson model indicates a substantially worse fit than the rootogram for the Negative Binomial model.

## 25 Question 25 (3 points)

Consider three new subjects, who are named Abigail, Brad and Chen. Here are their values of the predictors.

| Name    | x1 | x2 | x3 |
|---------|----|----|----|
| Abigail | 4  | 1  | 0  |
| Brad    | 3  | 0  | 4  |
| Chen    | 2  | 1  | 6  |

Use the Poisson regression model you fit in Question 24 to make a prediction for  $y$  for the three new subjects listed here. Rank the three new subjects in order of their predicted  $y$ , from highest (first) to lowest.

- a. Abigail has the highest predicted  $y$ , then Brad then Chen
- b. Abigail is highest, then Chen then Brad
- c. Brad is highest, then Abigail then Chen
- d. Brad is highest, then Chen then Abigail
- e. Chen is highest, then Abigail then Brad
- f. Chen is highest, then Brad then Abigail

## 26 Question 26 (3 points)

Now, instead of treating  $y$  in `quized24.csv` as a count variable, treat it as an ordinal category, and fit a new model that is appropriate for such an outcome using again the main effects of  $x_1$ ,  $x_2$  and  $x_3$  as predictors. Use that model to predict the actual category that our three new subjects (Abigail, Brad and Chen) will fall into, and compare that to the results you found in Question 25.

Which of the three new subjects get a different predicted count with this ordinal categorical regression model, than they do when you round the predicted count made with the Poisson model to an integer?

**CHECK EACH OF THE CORRECT RESPONSES.**

- a. Abigail
- b. Brad
- c. Chen
- d. None of the three subjects.
- e. It is impossible to tell from the information provided.

## 27 Question 27 (3 points)

We have available the `startday` and `exitday` for each subject in a tobacco cessation study, comparing three treatments (called A, B and usual care.) The study began collecting subjects on day 0. The `exitreason` variable shows the reason why each subject exited the study, either because they achieved the outcome (`achieved`), they stopped coming to appointments and were thus lost to follow up (`lost`), or because the study ended (`studyend`).

A summary of the relevant data from the study follows.

```
dat27
```

```
# A tibble: 140 x 4
  startday exitday exitreason treatment
    <dbl>    <dbl> <fct>      <fct>
1      0     31.5 achieved      UC
2      0     38.2 achieved      B
3      0     24.8 lost         UC
4      0     47.3 lost         UC
5      0     38.1 lost         UC
6      0     19.6 achieved      B
7      0     28.1 achieved      UC
8      0     14.3 achieved      B
9      0     39.3 lost         B
10     0     23.8 achieved      UC
# ... with 130 more rows
```

```
describe(dat27)
```

```
dat27
```

```
4 Variables      140 Observations
```

```
startday
```

| n    | missing | distinct | Info  | Mean  | Gmd   | .05  | .10  |
|------|---------|----------|-------|-------|-------|------|------|
| 140  | 0       | 23       | 0.975 | 20.14 | 14.56 | 0.00 | 0.00 |
| .25  | .50     | .75      | .90   | .95   |       |      |      |
| 0.00 | 25.50   | 30.25    | 34.00 | 35.10 |       |      |      |

```
lowest : 0 16 18 20 21, highest: 35 37 38 39 40
```

```
exitday
```

| n     | missing | distinct | Info  | Mean  | Gmd   | .05   | .10   |
|-------|---------|----------|-------|-------|-------|-------|-------|
| 140   | 0       | 140      | 1     | 57.08 | 21.57 | 23.81 | 31.38 |
| .25   | .50     | .75      | .90   | .95   |       |       |       |
| 42.71 | 58.75   | 72.30    | 80.31 | 85.29 |       |       |       |

```
lowest : 14.29152 18.29017 19.62402 21.25336 22.37179
```

```
highest: 87.49991 87.53402 87.93659 91.80623 94.05758
```

```
exitreason
```

| n   | missing | distinct |
|-----|---------|----------|
| 140 | 0       | 3        |

| Value     | achieved | lost | studyend |
|-----------|----------|------|----------|
| Frequency | 43       | 31   | 66       |

|            |       |       |       |
|------------|-------|-------|-------|
| Proportion | 0.307 | 0.221 | 0.471 |
|------------|-------|-------|-------|

---

treatment

|     |         |          |
|-----|---------|----------|
| n   | missing | distinct |
| 140 | 0       | 3        |

|            |       |       |       |
|------------|-------|-------|-------|
| Value      | A     | UC    | B     |
| Frequency  | 32    | 72    | 36    |
| Proportion | 0.229 | 0.514 | 0.257 |

---

Suppose you want to add a survival object called `S` to the `dat27` data, and want to treat the subjects who did not achieve the outcome as being right-censored, then fit a log rank test to compare the three `treatment` groups in terms of that survival object. Which of the chunks of R code shown in the Display for Question 27 will accomplish this?

**CHECK ALL THE ANSWERS THAT ARE CORRECT.**

- a. Chunk I
- b. Chunk II
- c. Chunk III
- d. None of these Chunks

## Display for Question 27

### Chunk I

```
data27$S = Surv(time = data27$exitday - data27$startday,
               event = data27$exitreason %in% c("lost", "studyend"))
survdif(S ~ treatment, data = data27)
```

### Chunk II

```
survdif(Surv(time = data27$exitday,
            event = data27$exitreason) ~ treatment)
```

### Chunk III

```
data27$S = Surv(time = data27$exitday - data27$startday,
               event = data27$exitreason == "achieved")
survdif(S ~ treatment, data = data27)
```

## 28 Question 28 (3 points)

The experimental anti-hypertensive agent, GB2995, was studied in 4 study centers to compare 12 weeks of treatment using GB2995 as the sole therapy vs. using GB2995 in combination with a stable dose of a marketed calcium-channel blocker when given to patients with moderate to severe hypertension. Our response is the decrease in diastolic blood pressure at 12 weeks, adjusted for the patient's age and a measure of the severity of hypertension at study entry. Our aim is to determine whether the data show any difference in response between the two treatment groups. Which of the following modeling approaches would be the single best choice in this scenario?

- Linear regression to predict the outcome.
- (Binary) Logistic regression to predict the outcome.
- Poisson regression to predict the outcome.
- Multinomial logistic regression to predict the outcome.
- Ordinal logistic regression to predict the outcome.
- Cox proportional hazards model to predict the outcome.
- Log rank test of the intervention's impact on the outcome.
- None of these modeling strategies are appropriate.

## 29 Question 29 (3 points)

In *How To Be a Modern Scientist*, Jeff Leek describes some hurdles likely to affect the transition towards reproducibility in scientific work, and some potential solutions related to data sharing. According to Leek, which of these statements are true?

**CHECK ALL OF THE TRUE STATEMENTS.**

- It is hard to create serious research quality data sets that can be used by others.
- Existing structures for advancement in academia sometimes are in conflict with the promotion of reproducible research.
- There is no intermediate form of credit for data generators that counts more heavily than a regular publication.
- Code books are often formatted using Word or another text editor.
- The person collecting the data should provide pseudocode to help the statistician in tidying and data management activities.
- None of the statements above are true.

## 30 Question 30 (3 points)

A study of self-reported mental health status (recorded in the `status` variable as 1 = good, 0 = not good) was completed in 198 working adults ages 30-35 for whom the following variables were collected:

- `alone` = do they live alone (1 = yes, 0 = no)
- `bmi` = body-mass index category (normal, overweight or obese)
- `employed` = years of employment in current job
- `sex` = M or F
- `sbp` = systolic blood pressure (in mm Hg)

I have provided the `quizd30.Rds` file, which may be useful to you.

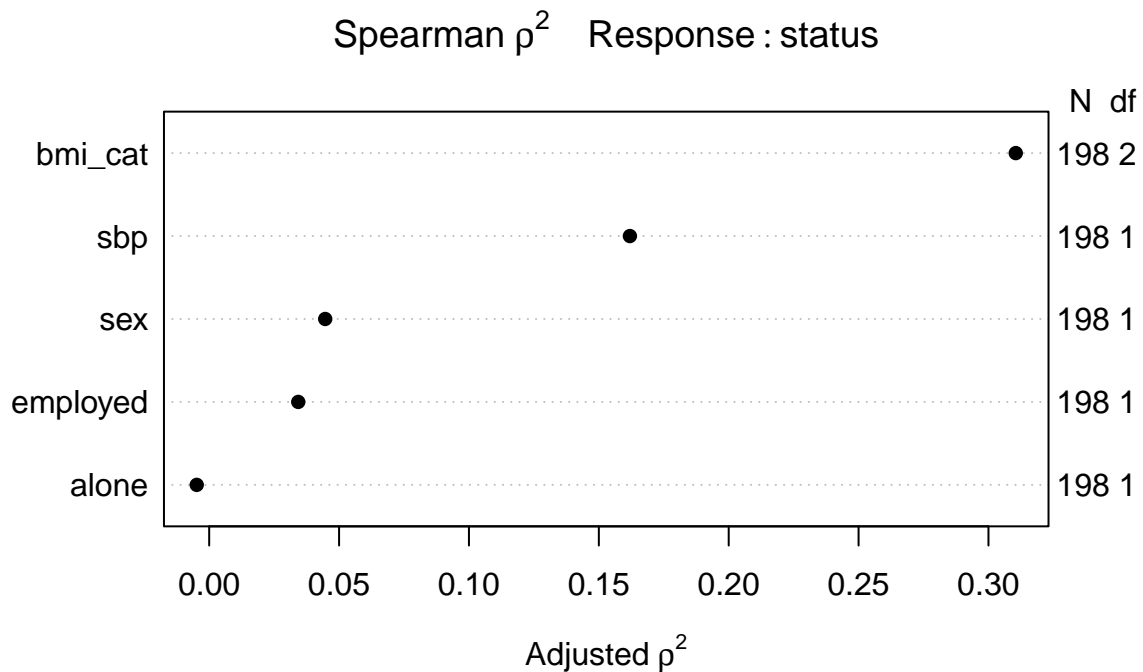
Question 30 continues on the next page.

Consider the Display for Item 30. Suppose you are willing to fit a model that uses exactly two additional non-linear predictor terms, using a maximum of four additional degrees of freedom beyond those contained in the main effects model. **Which two** of the following terms would be the most appropriate ones to choose?

- A restricted cubic spline in `alone` with four knots
- A restricted cubic spline in `bmi` with four knots
- A restricted cubic spline in `employed` with four knots
- A restricted cubic spline in `sex` with four knots
- A restricted cubic spline in `sbp` with four knots
- An interaction term between `bmi` and the main effect of `alone`
- An interaction term between `bmi` and the main effect of `employed`
- An interaction term between `bmi` and the main effect of `sex`
- An interaction term between `bmi` and the main effect of `sbp`

### Display for Item 30

```
quizd30 <- readRDS("data/quizd30.Rds")
plot(spearman2(status ~ alone + bmi_cat + employed + sex + sbp,
              data = quizd30), pch = 16)
```



**This is the end of the Quiz.**

Be sure to complete the Affirmation at the end of the Answer Sheet, and that you have submitted your Answer Sheet, and received your copy in your CWRU email by the deadline.