Experiments and Causality: Problem Set 3

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```
library(data.table)

library(sandwich)
library(lmtest)

library(ggplot2)
library(patchwork)

library(foreign)
```

1. Replicate Results

Skim Broockman and Green's paper on the effects of Facebook ads and download an anonymized version of the data for Facebook users only.

```
d <- fread("../data/broockman_green_anon_pooled_fb_users_only.csv")
d
```

```
##       studyno treat_ad                     cluster name_recall
##    1:       2        0   Study 2, Cluster Number 1           0
##    2:       2        0   Study 2, Cluster Number 2           1
##    3:       2        0   Study 2, Cluster Number 3           0
##    4:       2        0   Study 2, Cluster Number 4           1
##    5:       2        1   Study 2, Cluster Number 7           1
##   ---
## 2702:       1        1 Study 1, Cluster Number 802           0
## 2703:       1        1 Study 1, Cluster Number 802           1
## 2704:       1        1 Study 1, Cluster Number 802           0
## 2705:       1        1 Study 1, Cluster Number 802           1
## 2706:       1        1 Study 1, Cluster Number 802           0
##       positive_impression
##    1:                   0
##    2:                   0
##    3:                   0
##    4:                   0
##    5:                   1
##   ---
## 2702:                   0
## 2703:                   0
## 2704:                   0
## 2705:                   1
## 2706:                   0
```

1. Using regression without clustered standard errors (that is, ignoring the clustered assignment), compute a confidence interval for the effect of the ad on candidate name recognition in Study 1 only (the dependent variable is `name_recall`). After you estimate your model, write a narrative description about what you've learned.

- **Note**: Ignore the blocking the article mentions throughout this problem.
- **Note**: You will estimate something different than is reported in the study.

```
just_1 = d[d$studyno==1]
mod_study1 <- lm(data=just_1, name_recall~treat_ad) # should be a lm class object
confint(mod_study1)
```

```
##                    2.5 %     97.5 %
## (Intercept)  0.15080247 0.21413492
## treat_ad    -0.05101765 0.03142188
```

The 2.5% confidence interval is -0.0510177 and the 97.5% confidence interval is 0.0314219. I learned that any effect there is is negligible because both values are only very slightly lower/higher than 0. In addition, because the endpoints are both negative or positive, the true value could be either (or 0).

2. What are the clusters in Broockman and Green's study? Why might taking clustering into account increase the standard errors?

   Age range, gender, location informed the cluster assignment. Taking clustering into account increases the standard errors because if you have clusters, each has its own mean, so if the means are very different from each other, this will end up increasing the standard errors. Also your N is the number of clusters, so if your sample size of clusters is not big enough, your standard error will be higher.

3. Estimate a regression that estimates the effect of the ad on candidate name recognition in Study 1, but this time take take clustering into account when you compute the standard errors.

- The estimation of the *model* does not change, only the estimation of the standard errors.
- You can estimate these clustered standard errors using `sandwich::vcovCL`, which means: "The `vcovCL` function from the `sandwich` package.
- We talk about this more in code that is available in the course repo.

```
#redoing some stuff here so that it follows a similar format to in the async
m1 <- just_1[ , lm(name_recall~treat_ad)]
#m1$vcovHC_ <- vcovHC(m1)
#m1$vcovHC_
m1$vcovCL1_= coeftest(x= m1, vcov = sandwich::vcovCL(m1, cluster = just_1$cluster))
m1$cluster1.se <- sqrt(diag(m1$vcovCL1_))
#stargazer(m1, m1,
#          type = 'text',
#          se = list(sqrt(diag(m1$vcovCL1_)) ),
#          header=F
#)
#m1$cluster1.se

q3 = coeftest(x= mod_study1, vcov = sandwich::vcovCL(mod_study1, cluster = just_1$cluster))
q3
```

```
##
## t test of coefficients:
##
##                Estimate Std. Error t value Pr(>|t|)
```

```
## (Intercept)  0.1824687  0.0184915  9.8677   <2e-16 ***
## treat_ad    -0.0097979  0.0237536 -0.4125   0.6801
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

The standard error is 0.0237536

4. Change the context: estimate the treatment effect in Study 2, using clustered standard errors. If you've written your code for part 3 carefully, you should be able to simply change the row-scoping that you're calling. If you didn't write it carefully, for legibility for your colleagues, you might consider re-writing your solution to the last question. Descriptively, do the treatment effects look different between the two studies? Are you able to conduct a formal test by comparing these coefficients? Why, or why not?

```
just_2 = d[d$studyno==2]
mod_study2 <- lm(data=just_2, name_recall~treat_ad)
print("the estimated standard error is")
```

```
## [1] "the estimated standard error is"
```

```
q4_coefs = coeftest(x= mod_study2,  vcov = sandwich::vcovCL(mod_study2, cluster = just_2$cluster))
q4_coefs
```

```
##
## t test of coefficients:
##
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)  0.6057884  0.0181889  33.305   <2e-16 ***
## treat_ad    -0.0028033  0.0355033  -0.079   0.9371
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

The estimaated standard error is 0.0355033. The ATE is -0.0028033. The magnitude of the treatment effect is larger for study 2. The treatment effect looks very slightly different than study 1, however if you consider the very high p values, as well as the very small difference between the two, the treatment effects do not look very different. You cannot compare them formally becuase they are testing different things.

5. Run a regression to test for the effect of the ad on candidate name recognition, but this time use the entire sample from both studies – do not take into account which study the data is from (more on this in a moment), but just "pool" the data.

- Does this estimate tell you anything useful?
- Why or why not?
- Can you say that the treatment assignment procedure used is fully random when you estimate this model? Or is there some endogeneous process that could be confounding your estimate?

```
mod_pooled <-  lm(data=d, name_recall~treat_ad) # should be a lm class object
coefci(x = mod_pooled, vcov. = sandwich::vcovHC(mod_pooled))
```

```
##                  2.5 %     97.5 %
## (Intercept)  0.4294697  0.4789224
## treat_ad    -0.1914012 -0.1187453
```

The 95% confint is negative. From this, we can see that the ATE is negative. This is therefore useful. The treatment assignment precedure is fully random, but there would be an endogenous process, the clustering, that confounds this if the clustering is not taken into account.

6. Estimate a model that uses all the data, but this time include a variable that identifies whether an observation was generated during Study 1 or Study 2.

- What is estimated in the "Study 2 Fixed Effect"?
- What is the treatment effect estimate and associated p-value?
- Think a little bit more about the treatment effect that you've estimated: Can this treatment effect, as you've entered it in the model be *different* between Study 1 and Study 2?
- Why or why not?

```
mod_fe <- lm(d$name_recall ~ d$treat_ad + (d$studyno==2))
summary(mod_fe)
```

```
##
## Call:
## lm(formula = d$name_recall ~ d$treat_ad + (d$studyno == 2))
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -0.6068 -0.1807 -0.1739  0.3932  0.8261
##
## Coefficients:
##                      Estimate Std. Error t value Pr(>|t|)
## (Intercept)          0.180685   0.015994  11.297   <2e-16 ***
## d$treat_ad          -0.006775   0.018177  -0.373    0.709
## d$studyno == 2TRUE  0.426099   0.017955  23.731   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.4381 on 2698 degrees of freedom
##   (5 observations deleted due to missingness)
## Multiple R-squared:  0.1931, Adjusted R-squared:  0.1925
## F-statistic: 322.8 on 2 and 2698 DF,  p-value: < 2.2e-16
```

The study2 fixed effect is the effect of being in study 2 on name recall - regardless of treatment. The treatment effect estimate is -0.0067752 and the associated p-value is 0.7093688. The treatment effect could be different between the two studies because they are still different studies.

7. Estimate a model that lets the treatment effects be different between Study 1 and Study 2. With this model, conduct a formal test – it must have a p-value associated with the test – for whether the treatment effects are different in Study 1 than Study 2.

```
mod_fe <- lm(d$name_recall ~ d$treat_ad + (d$studyno==2))
summary(mod_fe)
```

```
##
## Call:
## lm(formula = d$name_recall ~ d$treat_ad + (d$studyno == 2))
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -0.6068 -0.1807 -0.1739  0.3932  0.8261
##
## Coefficients:
##                      Estimate Std. Error t value Pr(>|t|)
## (Intercept)          0.180685   0.015994  11.297   <2e-16 ***
## d$treat_ad          -0.006775   0.018177  -0.373    0.709
## d$studyno == 2TRUE  0.426099   0.017955  23.731   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
##
## Residual standard error: 0.4381 on 2698 degrees of freedom
##   (5 observations deleted due to missingness)
## Multiple R-squared:  0.1931, Adjusted R-squared:  0.1925
## F-statistic: 322.8 on 2 and 2698 DF,  p-value: < 2.2e-16
```

2. Peruvian Recycling

Look at this article about encouraging recycling in Peru. The paper contains two experiments, a "participation study" and a "participation intensity study." In this problem, we will focus on the latter study, whose results are contained in Table 4 in this problem. You will need to read the relevant section of the paper (starting on page 20 of the manuscript) in order to understand the experimental design and variables. (*Note that "indicator variable" is a synonym for "dummy variable," in case you haven't seen this language before.*)

1. In Column 3 of Table 4A, what is the estimated ATE of providing a recycling bin on the average weight of recyclables turned in per household per week, during the six-week treatment period? Provide a 95% confidence interval.

   The estimated average treatment effect of providing a recycling bin on the average weight of recyclables turned in per household per week is a .187kg increase. The 2.5% confidence interval is .155kg and the 97.5% confidence interval is .219kg

2. In Column 3 of Table 4A, what is the estimated ATE of sending a text message reminder on the average weight of recyclables turned in per household per week? Provide a 95% confidence interval.

   The estimated average treatment effect of sending a text message reminder on the average weight of recyclables turned in per household per week is a -.024 change. The 2.5% confidence interval is -.063 and the 97.5% confidence interval is .015%.

3. Which outcome measures in Table 4A show statistically significant effects (at the 5% level) of providing a recycling bin?

   Outcome measures in columns 1 through 4 show statistically significant results. These include "Percentage of visits turned in bag","Avg. no. of bins turned in per week", "Avg. weight (in kg) of recyclables turned in per week", "Avg. market value of recyclables given per week".

4. Which outcome measures in Table 4A show statistically significant effects (at the 5% level) of sending text messages?

   No outcome measures in Table 4A shows statistically significant effects of sending text messages.

5. Suppose that, during the two weeks before treatment, household A turns in 2kg per week more recyclables than household B does, and suppose that both households are otherwise identical (including being in the same treatment group). From the model, how much more recycling do we predict household A to have than household B, per week, during the six weeks of treatment? Provide only a point estimate, as the confidence interval would be a bit complicated. This question is designed to test your understanding of slope coefficients in regression.

   .281*2 = .562 kg more per week.

6. Suppose that the variable "percentage of visits turned in bag, baseline" had been left out of the regression reported in Column 1. What would you expect to happen to the results on providing a recycling bin? Would you expect an increase or decrease in the estimated ATE? Would you expect an increase or decrease in the standard error? Explain our reasoning.

   It would increase the standard error, however, it would not effect the ATE. This is becuase there is a fixed treatment effect for variables, however, the standard error that we estimate changes. The standard error would increase because of the removal of a covariate.

7. In column 1 of Table 4A, would you say the variable "has cell phone" is a bad control? Explain your reasoning.

   Having a cell phone is not a bad control because treatment would not effect having a phone at all.

8. If we were to remove the "has cell phone" variable from the regression, what would you expect to happen to the coefficient on "Any SMS message"? Would it go up or down? Explain your reasoning.

   The coefficient would increase because varaibles are correlated (based on the data we have). Having the cell phone variable will contain some of the SMS effect, which transfers back to "Any SMS Message" when it is taken away.

3. Multifactor Experiments

Staying with the same experiment, now think about multifactor experiments.

1. What is the full experimental design for this experiment? Tell us the dimensions, such as 2x2x3. (Hint: the full results appear in Panel 4B.)

   There are 3 variables, each with 3 potential options, and 2 cell phone options - giving us a dimensionality of 3x3x2.

2. In the results of Table 4B, describe the baseline category. That is, in English, how would you describe the attributes of the group of people for whom all dummy variables are equal to zero?

   People in the baseline category have no bins and no phones.

3. In column (1) of Table 4B, interpret the magnitude of the coefficient on "bin without sticker." What does it mean?

   The group who recieves a bin without a sticker turned in a bag by 3.5% on average more than the baseline group.

4. In column (1) of Table 4B, which seems to have a stronger treatment effect, the recycling bin with message sticker, or the recycling bin without sticker? How large is the magnitude of the estimated difference?

   The recycling bin with a message sticker has a stronger treatment. The bin with a message sticker has a 2% greater effect.

5. Is this difference you just described statistically significant? Explain which piece of information in the table allows you to answer this question.

   No, it is not statistically significant because the p value for the F-test testing whether the values are the same between the two groups is above the cutoff of .05.

6. Notice that Table 4C is described as results from "fully saturated" models. What does this mean? Looking at the list of variables in the table, explain in what sense the model is "saturated."

   Fully saturated models have values given for all combinations of covariates. This means that all the measurable variables and the combinations thereof are given a weight. This is the case for all the measurable variables.

4. Now! Do it with data

Download the data set for the recycling study in the previous problem, obtained from the authors. We'll be focusing on the outcome variable Y="number of bins turned in per week" (avg_bins_treat).

```
d <- foreign::read.dta("../data/karlan_data_subset_for_class.dta")
d <- data.table(d)
head(d)
```

```
##    street havecell avg_bins_treat base_avg_bins_treat bin sms bin_s bin_g sms_p
## 1:      7        1      1.0416666               0.750   1   1     1     0     0
## 2:      7        1      0.0000000               0.000   0   1     0     0     1
## 3:      7        1      0.7500000               0.500   0   0     0     0     0
## 4:      7        1      0.5416667               0.500   0   0     0     0     0
## 5:      6        1      0.9583333               0.375   1   0     0     1     0
## 6:      8        0      0.2083333               0.000   1   0     0     1     0
##    sms_g
## 1:     1
## 2:     0
## 3:     0
## 4:     0
## 5:     0
## 6:     0
```

```
## Do some quick exploratory data analysis with this data.
## There are some values in this data that seem a bit strange.

## Determine what these are.
## Don't make an assessment about keeping, changing, or
## dropping just yet, but at any point that your analysis touches
## these variables, you'll have to determine what is appropriate
## given the analysis you are conducting.
```

1. For simplicity, let's start by measuring the effect of providing a recycling bin, ignoring the SMS message treatment (and ignoring whether there was a sticker on the bin or not). Run a regression of Y on only the bin treatment dummy, so you estimate a simple difference in means. Provide a 95% confidence interval for the treatment effect, using **of course** robust standard errors (use these throughout).

```
mod_1 <- lm(data=d, avg_bins_treat ~ bin)
RCI<- coefci(x = mod_1, vcov. = vcovHC(mod_1))
RCI
```

```
##                   2.5 %    97.5 %
## (Intercept) 0.61284046 0.6578589
## bin         0.09454001 0.1762200
```

2. Now add the pre-treatment value of Y as a covariate. Provide a 95% confidence interval for the treatment effect. Explain how and why this confidence interval differs from the previous one.

```
mod_2 <- lm(data = d, avg_bins_treat ~ bin + base_avg_bins_treat)
RCI2<- coefci(x = mod_2, vcov. = vcovHC(mod_2))
RCI2
```

```
##                           2.5 %    97.5 %
## (Intercept)          0.30809489 0.3911102
## bin                  0.09097306 0.1584129
## base_avg_bins_treat 0.33346489 0.4524644
```

3. Now add the street fixed effects. (You'll need to use the R command factor().) Provide a 95% confidence interval for the treatment effect.

```
mod_3 <- lm(data = d, avg_bins_treat ~ bin + base_avg_bins_treat + as.factor(street))
RCI3<- coefci(x = mod_3, vcov. = vcovHC(mod_3))
summary(mod_3)
```

```
##
## Call:
```

```
## lm(formula = avg_bins_treat ~ bin + base_avg_bins_treat + as.factor(street),
##     data = d)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.45533 -0.19344 -0.01766  0.16125  1.87095
##
## Coefficients:
##                       Estimate Std. Error t value Pr(>|t|)
## (Intercept)           0.367744   0.031616  11.632  < 2e-16 ***
## bin                   0.113887   0.017058   6.677 3.36e-11 ***
## base_avg_bins_treat   0.373707   0.014328  26.082  < 2e-16 ***
## as.factor(street)2   -0.094610   0.101972  -0.928 0.353652
## as.factor(street)3   -0.044717   0.106534  -0.420 0.674725
## as.factor(street)4   -0.135044   0.111944  -1.206 0.227858
## as.factor(street)5   -0.094211   0.111835  -0.842 0.399683
## as.factor(street)6   -0.050772   0.118232  -0.429 0.667673
## as.factor(street)7   -0.054652   0.147788  -0.370 0.711579
## as.factor(street)8   -0.054018   0.091422  -0.591 0.554690
## as.factor(street)9   -0.086854   0.097983  -0.886 0.375524
## as.factor(street)10  -0.027558   0.079904  -0.345 0.730226
## as.factor(street)11  -0.070972   0.098099  -0.723 0.469495
## as.factor(street)15  -0.020059   0.164690  -0.122 0.903073
## as.factor(street)17   0.039600   0.135366   0.293 0.769910
## as.factor(street)20  -0.235987   0.118238  -1.996 0.046118 *
## as.factor(street)21  -0.075977   0.135477  -0.561 0.575002
## as.factor(street)22  -0.125263   0.068936  -1.817 0.069392 .
## as.factor(street)23  -0.160186   0.072352  -2.214 0.026970 *
## as.factor(street)26  -0.027731   0.189159  -0.147 0.883466
## as.factor(street)32   0.156098   0.189272   0.825 0.409650
## as.factor(street)37   0.173033   0.147823   1.171 0.241957
## as.factor(street)38  -0.071115   0.147787  -0.481 0.630442
## as.factor(street)40  -0.062329   0.189274  -0.329 0.741970
## as.factor(street)41   0.012736   0.147710   0.086 0.931301
## as.factor(street)42  -0.144842   0.189445  -0.765 0.444647
## as.factor(street)43   0.053135   0.147716   0.360 0.719114
## as.factor(street)44   0.134674   0.118247   1.139 0.254906
## as.factor(street)45  -0.038879   0.164508  -0.236 0.813203
## as.factor(street)46   0.010186   0.135367   0.075 0.940028
## as.factor(street)47   0.419417   0.164694   2.547 0.010969 *
## as.factor(street)53   0.036236   0.189132   0.192 0.848088
## as.factor(street)58  -0.030505   0.094515  -0.323 0.746924
## as.factor(street)60   0.028028   0.086168   0.325 0.745023
## as.factor(street)61  -0.008546   0.189571  -0.045 0.964047
## as.factor(street)62   0.057493   0.125857   0.457 0.647868
## as.factor(street)63  -0.028462   0.118224  -0.241 0.809780
## as.factor(street)64   0.050966   0.135362   0.377 0.706584
## as.factor(street)66  -0.060219   0.125823  -0.479 0.632286
## as.factor(street)67  -0.012977   0.111827  -0.116 0.907628
## as.factor(street)68   0.072712   0.118154   0.615 0.538380
## as.factor(street)69   0.078076   0.102070   0.765 0.444428
## as.factor(street)70  -0.008509   0.091435  -0.093 0.925868
## as.factor(street)72  -0.047284   0.101973  -0.464 0.642936
## as.factor(street)73  -0.171194   0.118231  -1.448 0.147822
```

```
## as.factor(street)74  -0.065090   0.078239  -0.832 0.405568
## as.factor(street)75  -0.056325   0.098076  -0.574 0.565845
## as.factor(street)77  -0.033274   0.125958  -0.264 0.791688
## as.factor(street)78  -0.051755   0.086180  -0.601 0.548226
## as.factor(street)79   0.306711   0.164512   1.864 0.062453 .
## as.factor(street)80   0.011624   0.068956   0.169 0.866160
## as.factor(street)81  -0.031054   0.164626  -0.189 0.850403
## as.factor(street)82   0.032780   0.189279   0.173 0.862528
## as.factor(street)83  -0.118848   0.126338  -0.941 0.346993
## as.factor(street)84  -0.017871   0.125839  -0.142 0.887088
## as.factor(street)85   0.065053   0.086175   0.755 0.450426
## as.factor(street)86  -0.067039   0.079936  -0.839 0.401786
## as.factor(street)88  -0.097565   0.106515  -0.916 0.359817
## as.factor(street)89  -0.003589   0.118325  -0.030 0.975806
## as.factor(street)91  -0.210831   0.189221  -1.114 0.265360
## as.factor(street)93  -0.070146   0.125872  -0.557 0.577415
## as.factor(street)94  -0.037034   0.111973  -0.331 0.740880
## as.factor(street)96  -0.038942   0.125888  -0.309 0.757104
## as.factor(street)98   0.052375   0.098139   0.534 0.593638
## as.factor(street)99   0.231437   0.112059   2.065 0.039054 *
## as.factor(street)100  0.074337   0.106645   0.697 0.485874
## as.factor(street)101  0.197295   0.111855   1.764 0.077949 .
## as.factor(street)102 -0.085358   0.190053  -0.449 0.653402
## as.factor(street)103  0.086170   0.111921   0.770 0.441463
## as.factor(street)105  0.116023   0.147731   0.785 0.432358
## as.factor(street)106  0.400456   0.098016   4.086 4.61e-05 ***
## as.factor(street)107  0.064349   0.164453   0.391 0.695633
## as.factor(street)109 -0.014534   0.118164  -0.123 0.902123
## as.factor(street)110  0.140764   0.147707   0.953 0.340738
## as.factor(street)111  0.001375   0.147720   0.009 0.992577
## as.factor(street)112  0.184788   0.118348   1.561 0.118629
## as.factor(street)113  0.081779   0.126077   0.649 0.516665
## as.factor(street)115  0.292385   0.097997   2.984 0.002892 **
## as.factor(street)117  0.557327   0.190438   2.927 0.003476 **
## as.factor(street)118  0.032871   0.189137   0.174 0.862047
## as.factor(street)119 -0.010963   0.118173  -0.093 0.926095
## as.factor(street)120 -0.058569   0.111845  -0.524 0.600585
## as.factor(street)121  0.178156   0.118277   1.506 0.132198
## as.factor(street)122 -0.160709   0.164464  -0.977 0.328634
## as.factor(street)124  0.039485   0.101961   0.387 0.698622
## as.factor(street)125  0.299596   0.086581   3.460 0.000554 ***
## as.factor(street)126 -0.103519   0.135691  -0.763 0.445635
## as.factor(street)127  0.073502   0.135670   0.542 0.588049
## as.factor(street)128  0.145329   0.098014   1.483 0.138342
## as.factor(street)129  0.377069   0.189301   1.992 0.046551 *
## as.factor(street)130  0.176068   0.118208   1.489 0.136560
## as.factor(street)131  0.275638   0.118560   2.325 0.020203 *
## as.factor(street)132  0.234648   0.088804   2.642 0.008315 **
## as.factor(street)133  0.315866   0.164511   1.920 0.055032 .
## as.factor(street)134 -0.010497   0.125905  -0.083 0.933563
## as.factor(street)136  0.180841   0.118323   1.528 0.126618
## as.factor(street)137  0.255094   0.189137   1.349 0.177617
## as.factor(street)138  0.121117   0.102458   1.182 0.237334
## as.factor(street)147  0.192718   0.189265   1.018 0.308715
```

```
## as.factor(street)148  0.106016   0.164453   0.645 0.519240
## as.factor(street)149  0.281703   0.112106   2.513 0.012075 *
## as.factor(street)151 -0.263411   0.189299  -1.392 0.164265
## as.factor(street)152  0.124616   0.189139   0.659 0.510082
## as.factor(street)153 -0.027731   0.189159  -0.147 0.883466
## as.factor(street)154 -0.059365   0.106542  -0.557 0.577468
## as.factor(street)155 -0.244906   0.189137  -1.295 0.195555
## as.factor(street)156  0.195743   0.189145   1.035 0.300882
## as.factor(street)157  0.148808   0.164797   0.903 0.366676
## as.factor(street)158  0.398033   0.147823   2.693 0.007163 **
## as.factor(street)160 -0.121491   0.101980  -1.191 0.233703
## as.factor(street)163 -0.078009   0.125982  -0.619 0.535870
## as.factor(street)164 -0.097875   0.147713  -0.663 0.507681
## as.factor(street)165  0.009606   0.164752   0.058 0.953513
## as.factor(street)166 -0.147684   0.189137  -0.781 0.435018
## as.factor(street)168  0.150960   0.189601   0.796 0.426035
## as.factor(street)170 -0.007431   0.088625  -0.084 0.933186
## as.factor(street)171 -0.047097   0.135362  -0.348 0.727934
## as.factor(street)172 -0.025327   0.118170  -0.214 0.830321
## as.factor(street)175  0.251211   0.094541   2.657 0.007959 **
## as.factor(street)179  0.003689   0.164553   0.022 0.982116
## as.factor(street)180 -0.097587   0.076558  -1.275 0.202605
## as.factor(street)182 -0.145546   0.135382  -1.075 0.282501
## as.factor(street)183 -0.083011   0.078228  -1.061 0.288780
## as.factor(street)185 -0.062043   0.135376  -0.458 0.646798
## as.factor(street)186  0.003562   0.118214   0.030 0.975968
## as.factor(street)187 -0.009848   0.091489  -0.108 0.914295
## as.factor(street)188 -0.028579   0.111834  -0.256 0.798334
## as.factor(street)189 -0.055111   0.076577  -0.720 0.471828
## as.factor(street)190  0.011191   0.118476   0.094 0.924758
## as.factor(street)191 -0.015508   0.111835  -0.139 0.889731
## as.factor(street)192 -0.104845   0.070026  -1.497 0.134534
## as.factor(street)193  0.061953   0.118173   0.524 0.600169
## as.factor(street)196 -0.227437   0.135387  -1.680 0.093170 .
## as.factor(street)197  0.071174   0.189150   0.376 0.706757
## as.factor(street)198  0.083495   0.088627   0.942 0.346292
## as.factor(street)200 -0.044273   0.125936  -0.352 0.725223
## as.factor(street)202  0.006735   0.147776   0.046 0.963657
## as.factor(street)203 -0.226019   0.125813  -1.796 0.072608 .
## as.factor(street)206 -0.237769   0.106535  -2.232 0.025763 *
## as.factor(street)207 -0.236796   0.164508  -1.439 0.150228
## as.factor(street)208 -0.116935   0.106535  -1.098 0.272533
## as.factor(street)209 -0.309619   0.094484  -3.277 0.001072 **
## as.factor(street)210 -0.229654   0.106627  -2.154 0.031404 *
## as.factor(street)213  0.042379   0.098141   0.432 0.665934
## as.factor(street)215 -0.058930   0.065191  -0.904 0.366153
## as.factor(street)216 -0.456416   0.148989  -3.063 0.002225 **
## as.factor(street)217 -0.179470   0.118199  -1.518 0.129118
## as.factor(street)220 -0.205278   0.125822  -1.632 0.102981
## as.factor(street)221 -0.150632   0.111837  -1.347 0.178208
## as.factor(street)222 -0.174347   0.147751  -1.180 0.238175
## as.factor(street)223 -0.179522   0.118181  -1.519 0.128947
## as.factor(street)225 -0.090250   0.112059  -0.805 0.420718
## as.factor(street)227 -0.046607   0.147712  -0.316 0.752405
```

```
## as.factor(street)228  0.049694   0.189188   0.263 0.792841
## as.factor(street)229  0.036597   0.136004   0.269 0.787898
## as.factor(street)230  0.010059   0.125851   0.080 0.936306
## as.factor(street)232  0.077799   0.164682   0.472 0.636690
## as.factor(street)233  0.052433   0.098023   0.535 0.592794
## as.factor(street)235 -0.111021   0.147948  -0.750 0.453120
## as.factor(street)236 -0.013447   0.081821  -0.164 0.869476
## as.factor(street)238 -0.108161   0.111950  -0.966 0.334110
## as.factor(street)240 -0.297069   0.147702  -2.011 0.044464 *
## as.factor(street)241 -0.103647   0.164531  -0.630 0.528813
## as.factor(street)242  0.039600   0.189135   0.209 0.834181
## as.factor(street)243  0.158286   0.164695   0.961 0.336655
## as.factor(street)244  0.090768   0.091445   0.993 0.321056
## as.factor(street)246 -0.137251   0.135552  -1.013 0.311436
## as.factor(street)247 -0.002803   0.094481  -0.030 0.976340
## as.factor(street)248 -0.005662   0.071139  -0.080 0.936570
## as.factor(street)249  0.086777   0.086118   1.008 0.313776
## as.factor(street)250  0.045419   0.062216   0.730 0.465491
## as.factor(street)253  0.109028   0.083878   1.300 0.193843
## as.factor(street)254  0.101117   0.125963   0.803 0.422239
## as.factor(street)255  0.027598   0.088754   0.311 0.755883
## as.factor(street)256  0.024798   0.064495   0.384 0.700659
## as.factor(street)257 -0.103616   0.081832  -1.266 0.205627
## as.factor(street)258  0.096686   0.076697   1.261 0.207628
## as.factor(street)259  0.701560   0.189274   3.707 0.000217 ***
## as.factor(street)260 -0.032152   0.063600  -0.506 0.613247
## as.factor(street)261 -0.043543   0.118333  -0.368 0.712943
## as.factor(street)262  0.035645   0.111880   0.319 0.750073
## as.factor(street)263  0.026889   0.083859   0.321 0.748521
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.3236 on 1600 degrees of freedom
##   (3 observations deleted due to missingness)
## Multiple R-squared:  0.4362, Adjusted R-squared:  0.3725
## F-statistic:  6.84 on 181 and 1600 DF,  p-value: < 2.2e-16
```

4. Recall that the authors described their experiment as "stratified at the street level," which is a synonym for blocking by street. Does including these block fixed effects change the standard errors of the estimates *very much*? Conduct the appropriate test for the inclusion of these block fixed effects, and interpret them in the context of the other variables in the regression.

```r
no_nulls <- d[complete.cases(d)]
no_null_no_blocking<- lm(data=no_nulls, avg_bins_treat ~ bin + base_avg_bins_treat)
mod_4 <- lm(data=no_nulls, avg_bins_treat ~ bin + base_avg_bins_treat + factor(street))
mod_4
```

```
##
## Call:
## lm(formula = avg_bins_treat ~ bin + base_avg_bins_treat + factor(street),
##     data = no_nulls)
##
## Coefficients:
##         (Intercept)                  bin  base_avg_bins_treat
##            0.367814             0.113709             0.373671
```

```
##     factor(street)2      factor(street)3      factor(street)4
##           -0.094611            -0.044692            -0.135061
##     factor(street)5      factor(street)6      factor(street)7
##           -0.094219            -0.050728            -0.054673
##     factor(street)8      factor(street)9     factor(street)10
##           -0.054030            -0.086858            -0.027547
##    factor(street)11     factor(street)15     factor(street)17
##           -0.070943            -0.019973             0.039614
##    factor(street)20     factor(street)21     factor(street)22
##           -0.235974            -0.075941            -0.125270
##    factor(street)23     factor(street)26     factor(street)32
##           -0.160183            -0.027706             0.156170
##    factor(street)37     factor(street)38     factor(street)40
##            0.173092            -0.071099            -0.062248
##    factor(street)41     factor(street)42     factor(street)43
##            0.012766            -0.144787             0.053159
##    factor(street)44     factor(street)45     factor(street)46
##            0.134715            -0.038888             0.010176
##    factor(street)47     factor(street)53     factor(street)58
##            0.419483             0.036253            -0.030483
##    factor(street)60     factor(street)61     factor(street)62
##            0.028033            -0.008414             0.057523
##    factor(street)63     factor(street)64     factor(street)66
##           -0.028472             0.050982            -0.060239
##    factor(street)67     factor(street)68     factor(street)69
##           -0.012979             0.072710             0.078127
##    factor(street)70     factor(street)72     factor(street)73
##           -0.008495            -0.047287            -0.171150
##    factor(street)74     factor(street)75     factor(street)77
##           -0.065089            -0.056350            -0.033221
##    factor(street)78     factor(street)79     factor(street)80
##           -0.051751             0.306756             0.011608
##    factor(street)81     factor(street)82     factor(street)83
##           -0.031024             0.032850            -0.118750
##    factor(street)84     factor(street)85     factor(street)86
##           -0.017870             0.065046            -0.067012
##    factor(street)88     factor(street)89     factor(street)91
##           -0.097551            -0.003555            -0.210829
##    factor(street)93     factor(street)94     factor(street)96
##           -0.070173            -0.037010            -0.038970
##    factor(street)98     factor(street)99    factor(street)100
##            0.052433             0.231512             0.074361
##   factor(street)101    factor(street)102    factor(street)103
##            0.197317            -0.085294             0.086175
##   factor(street)105    factor(street)106    factor(street)107
##            0.116057             0.400424             0.064350
##   factor(street)109    factor(street)110    factor(street)111
##           -0.014556             0.140792             0.001408
##   factor(street)112    factor(street)113    factor(street)115
##            0.184806             0.081867             0.292377
##   factor(street)117    factor(street)118    factor(street)119
##            0.557399             0.032891            -0.010937
##   factor(street)120    factor(street)121    factor(street)122
##           -0.067734             0.178171            -0.160703
```

```
## factor(street)124 factor(street)125 factor(street)126
##           0.039503           0.299631          -0.103451
## factor(street)127 factor(street)128 factor(street)129
##           0.073542           0.145363           0.377154
## factor(street)130 factor(street)131 factor(street)132
##           0.176099           0.275707           0.234679
## factor(street)133 factor(street)134 factor(street)136
##           0.315912          -0.010455           0.180859
## factor(street)137 factor(street)138 factor(street)147
##           0.255113           0.121207           0.192794
## factor(street)148 factor(street)149 factor(street)151
##           0.106017           0.281774          -0.263374
## factor(street)152 factor(street)153 factor(street)154
##           0.124628          -0.027707          -0.059341
## factor(street)155 factor(street)156 factor(street)157
##          -0.244887           0.195753           0.148883
## factor(street)158 factor(street)160 factor(street)163
##           0.398092          -0.121475          -0.077959
## factor(street)164 factor(street)165 factor(street)166
##          -0.097850           0.009684          -0.147664
## factor(street)168 factor(street)170 factor(street)171
##           0.151086          -0.007423          -0.047081
## factor(street)172 factor(street)175 factor(street)179
##          -0.025301           0.251187           0.003745
## factor(street)180 factor(street)182 factor(street)183
##          -0.097575          -0.145566          -0.082975
## factor(street)185 factor(street)186 factor(street)187
##          -0.062031           0.003594          -0.009851
## factor(street)188 factor(street)189 factor(street)190
##          -0.028562          -0.055134           0.011277
## factor(street)191 factor(street)192 factor(street)193
##          -0.015515          -0.104829           0.061980
## factor(street)196 factor(street)197 factor(street)198
##          -0.227415           0.071196           0.083491
## factor(street)200 factor(street)202 factor(street)203
##          -0.044216           0.006740          -0.226013
## factor(street)206 factor(street)207 factor(street)208
##          -0.237738          -0.236805          -0.116905
## factor(street)209 factor(street)210 factor(street)213
##          -0.309605          -0.229631           0.042437
## factor(street)215 factor(street)216 factor(street)217
##          -0.058926          -0.456339          -0.179498
## factor(street)220 factor(street)221 factor(street)222
##          -0.205275          -0.150613          -0.174365
## factor(street)223 factor(street)225 factor(street)227
##          -0.179494          -0.090174          -0.046575
## factor(street)228 factor(street)229 factor(street)230
##           0.049698           0.036701           0.010094
## factor(street)232 factor(street)233 factor(street)235
##           0.077891           0.052441          -0.111014
## factor(street)236 factor(street)238 factor(street)240
##          -0.013457          -0.108135          -0.297083
## factor(street)241 factor(street)242 factor(street)243
##          -0.103608           0.039614           0.158371
```

```
##   factor(street)244    factor(street)246    factor(street)247
##            0.090767            -0.137178            -0.002791
##   factor(street)248    factor(street)249    factor(street)250
##           -0.005665             0.086767             0.045447
##   factor(street)253    factor(street)254    factor(street)255
##            0.109032             0.101182             0.027647
##   factor(street)256    factor(street)257    factor(street)258
##            0.024798            -0.103602             0.096665
##   factor(street)259    factor(street)260    factor(street)261
##            0.701641            -0.032151            -0.043478
##   factor(street)262    factor(street)263
##            0.035679             0.026901
```

```r
test_fixed_effects <- anova(no_null_no_blocking,mod_4,test="F")
test_fixed_effects
```

```
## Analysis of Variance Table
##
## Model 1: avg_bins_treat ~ bin + base_avg_bins_treat
## Model 2: avg_bins_treat ~ bin + base_avg_bins_treat + factor(street)
##   Res.Df    RSS  Df Sum of Sq      F    Pr(>F)
## 1   1778 196.78
## 2   1599 167.50 179    29.284 1.5618 9.689e-06 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

5. Perhaps having a cell phone helps explain the level of recycling behavior. Instead of "has cell phone," we find it easier to interpret the coefficient if we define the variable " no cell phone." Give the R command to define this new variable, which equals one minus the "has cell phone" variable in the authors' data set. Use "no cell phone" instead of "has cell phone" in subsequent regressions with this dataset.

```r
no_cell_phone = 1-no_nulls$havecell
no_null_no_blocking <- cbind(no_nulls, no_cell_phone)
head(no_null_no_blocking)
```

```
##    street havecell avg_bins_treat base_avg_bins_treat bin sms bin_s bin_g sms_p
## 1:      7        1      1.0416666               0.750   1   1     1     0     0
## 2:      7        1      0.0000000               0.000   0   1     0     0     1
## 3:      7        1      0.7500000               0.500   0   0     0     0     0
## 4:      7        1      0.5416667               0.500   0   0     0     0     0
## 5:      6        1      0.9583333               0.375   1   0     0     1     0
## 6:      8        0      0.2083333               0.000   1   0     0     1     0
##    sms_g no_cell_phone
## 1:     1             0
## 2:     0             0
## 3:     0             0
## 4:     0             0
## 5:     0             0
## 6:     0             1
```

6. Now add "no cell phone" as a covariate to the previous regression. Provide a 95% confidence interval for the treatment effect. Explain why this confidence interval does not differ much from the previous one.

```r
mod_5 <-lm(data = no_null_no_blocking, avg_bins_treat ~ bin + base_avg_bins_treat + factor(street) + no_
RCI5<- coefci(x = mod_5, vcov. = vcovHC(mod_5))
```

```
RCI5
```

```
##                             2.5 %       97.5 %
## (Intercept)          0.317084465  0.457902627
## bin                  0.078012761  0.152188727
## base_avg_bins_treat  0.313759946  0.433004654
## factor(street)2     -0.217184229  0.015155885
## factor(street)3     -0.264213537  0.154550368
## factor(street)4     -0.264951353  0.010078934
## factor(street)5     -0.305054815  0.099003185
## factor(street)6     -0.289151044  0.172085701
## factor(street)7     -0.380151801  0.231090127
## factor(street)8     -0.168296553  0.055958114
## factor(street)9     -0.286471174  0.106048822
## factor(street)10    -0.188401514  0.124729278
## factor(street)11    -0.298728314  0.141934028
## factor(street)15    -0.272734245  0.216456434
## factor(street)17    -0.166793401  0.239124900
## factor(street)20    -0.376119114 -0.085762523
## factor(street)21    -0.225749356  0.115908851
## factor(street)22    -0.249077401  0.013933124
## factor(street)23    -0.263443286 -0.047021400
## factor(street)26    -0.209785328  0.180650410
## factor(street)32    -0.367255592  0.704752816
## factor(street)37    -0.253336184  0.558836113
## factor(street)38    -0.265652472  0.103016225
## factor(street)40    -0.746909398  0.614708850
## factor(street)41    -0.339779212  0.384711709
## factor(street)42    -0.437494918  0.205821403
## factor(street)43    -0.262263870  0.348272268
## factor(street)44    -0.116621601  0.345642246
## factor(street)45    -0.277911559  0.185086198
## factor(street)46    -0.209109115  0.206621257
## factor(street)47    -0.202776932  1.026485224
## factor(street)53    -0.389157418  0.421807524
## factor(street)58    -0.153741710  0.090801118
## factor(street)60    -0.110076133  0.163355693
## factor(street)61    -0.367490413  0.341909815
## factor(street)62    -0.225384039  0.300247612
## factor(street)63    -0.211292378  0.151677824
## factor(street)64    -0.167403519  0.246003372
## factor(street)66    -0.165789534  0.062528032
## factor(street)67    -0.309982684  0.299513900
## factor(street)68    -0.150325095  0.317945593
## factor(street)69    -0.092027273  0.225779525
## factor(street)70    -0.184864078  0.141990864
## factor(street)72    -0.209255293  0.120361438
## factor(street)73    -0.294720211 -0.063180005
## factor(street)74    -0.209472355  0.064132638
## factor(street)75    -0.148587975  0.054065808
## factor(street)77    -0.375250639  0.296479052
## factor(street)78    -0.217719756  0.099040809
## factor(street)79    -0.716586353  1.364026306
## factor(street)80    -0.086779566  0.110803944
```

```
## factor(street)81    -0.314696489  0.261587931
## factor(street)82    -0.411441429  0.469269481
## factor(street)83    -0.368523210  0.131950721
## factor(street)84    -0.141410972  0.136564335
## factor(street)85    -0.082038164  0.215688769
## factor(street)86    -0.217473239  0.069614053
## factor(street)88    -0.306519758  0.101427008
## factor(street)89    -0.208668142  0.185795489
## factor(street)91    -0.582152173  0.120398601
## factor(street)93    -0.252428881  0.115040923
## factor(street)94    -0.215810008  0.112435507
## factor(street)96    -0.374085620  0.299082120
## factor(street)98    -0.127118711  0.207895525
## factor(street)99     0.049536701  0.416688737
## factor(street)100   -0.217501403  0.356382943
## factor(street)101   -0.022699036  0.443570916
## factor(street)102   -0.446934979  0.336256066
## factor(street)103   -0.186872336  0.363192109
## factor(street)105   -0.076683064  0.308466007
## factor(street)106    0.127856574  0.650250358
## factor(street)107   -0.332492975  0.421551745
## factor(street)109   -0.273120461  0.229460935
## factor(street)110   -0.313935873  0.555463838
## factor(street)111   -0.361538055  0.324384644
## factor(street)112    0.008855785  0.358536482
## factor(street)113   -0.287424264  0.410304554
## factor(street)115    0.006778160  0.546920642
## factor(street)117   -0.583323655  1.725169250
## factor(street)118   -0.711100470  0.737075755
## factor(street)119   -0.243694566  0.206640621
## factor(street)120   -0.291863161  0.129560855
## factor(street)121   -0.187646743  0.529337353
## factor(street)122   -0.442586195  0.106384661
## factor(street)124   -0.190558280  0.238558859
## factor(street)125    0.005887504  0.584873020
## factor(street)126   -0.400940353  0.154055259
## factor(street)127   -0.681341928  0.821937377
## factor(street)128   -0.066855543  0.367047130
## factor(street)129   -0.871412580  1.618088716
## factor(street)130   -0.110500599  0.459977012
## factor(street)131   -0.053921930  0.590122573
## factor(street)132    0.031502711  0.431227512
## factor(street)133    0.035808027  0.605207260
## factor(street)134   -0.268827658  0.250379026
## factor(street)136   -0.135140289  0.457486534
## factor(street)137   -0.021285433  0.524711687
## factor(street)138   -0.239905416  0.450937739
## factor(street)147    0.055518801  0.322292923
## factor(street)148   -0.435412332  0.632559441
## factor(street)149    0.032724686  0.512586312
## factor(street)151   -0.753056648  0.219771356
## factor(street)152   -0.498513964  0.773856161
## factor(street)153   -0.295334248  0.266199309
## factor(street)154   -0.285987325  0.176701655
```

```
## factor(street)155   -0.746295900  0.216715573
## factor(street)156   -0.266259531  0.683827994
## factor(street)157   -0.004695226  0.310702967
## factor(street)158   -0.065529160  0.840833045
## factor(street)160   -0.287236584  0.049250771
## factor(street)163   -0.271864840  0.075285067
## factor(street)164   -0.221175132  0.044789005
## factor(street)165   -0.261721111  0.289386373
## factor(street)166   -0.459728232  0.190605535
## factor(street)168   -0.844237835  1.170569033
## factor(street)170   -0.133485885  0.125237707
## factor(street)171   -0.251023636  0.183020214
## factor(street)172   -0.104734047  0.088443055
## factor(street)175   -0.067910770  0.591726730
## factor(street)179   -0.362251332  0.329565553
## factor(street)180   -0.223781027  0.036122166
## factor(street)182   -0.402046519  0.104421794
## factor(street)183   -0.219893141  0.078107835
## factor(street)185   -0.250329340  0.135836912
## factor(street)186   -0.188184234  0.180281642
## factor(street)187   -0.142663093  0.146708220
## factor(street)188   -0.132404968  0.068432010
## factor(street)189   -0.174116208  0.071590561
## factor(street)190   -0.213116785  0.256471411
## factor(street)191   -0.216957912  0.179315885
## factor(street)192   -0.227413062  0.023506916
## factor(street)193   -0.150904881  0.309194137
## factor(street)196   -0.485494271  0.007409085
## factor(street)197   -0.884465119  0.987098906
## factor(street)198   -0.126005765  0.306372336
## factor(street)200   -0.165986597  0.093589358
## factor(street)202   -0.278318598  0.331732642
## factor(street)203   -0.410121149 -0.067512698
## factor(street)206   -0.428323640 -0.047549038
## factor(street)207   -0.351236202 -0.112667559
## factor(street)208   -0.319933411  0.115433325
## factor(street)209   -0.493027453 -0.135477390
## factor(street)210   -0.379436715 -0.040169384
## factor(street)213   -0.110031363  0.220319081
## factor(street)215   -0.192960993  0.086587085
## factor(street)216   -1.287356586  0.375024485
## factor(street)217   -0.420879072  0.047236377
## factor(street)220   -0.490176381  0.096415156
## factor(street)221   -0.356716327  0.037662992
## factor(street)222   -0.444070481  0.134883956
## factor(street)223   -0.430294635  0.080907700
## factor(street)225   -0.321536637  0.144423265
## factor(street)227   -0.412872777  0.299528238
## factor(street)228   -0.478011085  0.570367047
## factor(street)229   -0.263951921  0.363028066
## factor(street)230   -0.165683717  0.188208476
## factor(street)232   -0.508353662  0.672648856
## factor(street)233   -0.220304099  0.318205450
## factor(street)235   -0.469043737  0.226431982
```

```
## factor(street)236   -0.140112812  0.139557571
## factor(street)238   -0.289385362  0.087793333
## factor(street)240   -0.454769992 -0.159176420
## factor(street)241   -0.578087597  0.355199609
## factor(street)242   -0.092713427  0.198051537
## factor(street)243   -0.509578665  0.785215618
## factor(street)244   -0.116912908  0.329309406
## factor(street)246   -0.349719191  0.100545681
## factor(street)247   -0.107426742  0.100134200
## factor(street)248   -0.144415104  0.144937177
## factor(street)249   -0.148875727  0.338644992
## factor(street)250   -0.043495213  0.148106978
## factor(street)253   -0.047373826  0.289674099
## factor(street)254   -0.136944190  0.355476588
## factor(street)255   -0.168969342  0.243220554
## factor(street)256   -0.086972123  0.156058609
## factor(street)257   -0.241829124  0.039037043
## factor(street)258   -0.011735347  0.203123372
## factor(street)259    0.072372983  1.389217472
## factor(street)260   -0.179792432  0.108900646
## factor(street)261   -0.190624077  0.124834137
## factor(street)262   -0.176574265  0.273740446
## factor(street)263   -0.157496667  0.218184325
## no_cell_phone       -0.084357190 -0.014662584
```

7. Now let's add in the SMS treatment. Re-run the previous regression with "any SMS" included. You should get the same results as in Table 4A. Provide a 95% confidence interval for the treatment effect of the recycling bin. Explain why this confidence interval does not differ much from the previous one.

```
mod_6 <- lm(data = no_null_no_blocking, avg_bins_treat ~ bin + base_avg_bins_treat + no_cell_phone +sms
summary(mod_6)
```

```
##
## Call:
## lm(formula = avg_bins_treat ~ bin + base_avg_bins_treat + no_cell_phone +
##     sms + factor(street), data = no_null_no_blocking)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.47159 -0.19213 -0.01836  0.15973  1.84352
##
## Coefficients:
##                      Estimate Std. Error t value Pr(>|t|)
## (Intercept)          0.3846423  0.0342882  11.218  < 2e-16 ***
## bin                  0.1150536  0.0170510   6.748  2.1e-11 ***
## base_avg_bins_treat  0.3734829  0.0143095  26.100  < 2e-16 ***
## no_cell_phone       -0.0467021  0.0203751  -2.292 0.022028 *
## sms                  0.0051244  0.0208556   0.246 0.805941
## factor(street)2     -0.1008330  0.1018158  -0.990 0.322155
## factor(street)3     -0.0551531  0.1064075  -0.518 0.604307
## factor(street)4     -0.1278803  0.1117884  -1.144 0.252816
## factor(street)5     -0.1031284  0.1116766  -0.923 0.355909
## factor(street)6     -0.0589896  0.1180658  -0.500 0.617402
## factor(street)7     -0.0747800  0.1476822  -0.506 0.612676
## factor(street)8     -0.0561956  0.0912612  -0.616 0.538136
```

```
## factor(street)9      -0.0900519  0.0978168  -0.921 0.357389
## factor(street)10     -0.0323522  0.0798024  -0.405 0.685235
## factor(street)11     -0.0789033  0.0979783  -0.805 0.420758
## factor(street)15     -0.0272983  0.1644550  -0.166 0.868184
## factor(street)17      0.0363216  0.1351309   0.269 0.788128
## factor(street)20     -0.2315102  0.1180623  -1.961 0.050063 .
## factor(street)21     -0.0552876  0.1354326  -0.408 0.683160
## factor(street)22     -0.1176622  0.0688640  -1.709 0.087716 .
## factor(street)23     -0.1553459  0.0722436  -2.150 0.031681 *
## factor(street)26     -0.0153769  0.1889026  -0.081 0.935133
## factor(street)32      0.1679884  0.1890084   0.889 0.374251
## factor(street)37      0.1524945  0.1477255   1.032 0.302096
## factor(street)38     -0.0821245  0.1476007  -0.556 0.578018
## factor(street)40     -0.0659497  0.1889419  -0.349 0.727100
## factor(street)41      0.0225463  0.1474834   0.153 0.878517
## factor(street)42     -0.1157787  0.1893640  -0.611 0.541016
## factor(street)43      0.0432001  0.1474951   0.293 0.769643
## factor(street)44      0.1141227  0.1182469   0.965 0.334630
## factor(street)45     -0.0468578  0.1642443  -0.285 0.775456
## factor(street)46     -0.0014988  0.1351848  -0.011 0.991155
## factor(street)47      0.4126170  0.1644494   2.509 0.012203 *
## factor(street)53      0.0157003  0.1889338   0.083 0.933783
## factor(street)58     -0.0321108  0.0943832  -0.340 0.733738
## factor(street)60      0.0264769  0.0860184   0.308 0.758270
## factor(street)61     -0.0126031  0.1892409  -0.067 0.946910
## factor(street)62      0.0380424  0.1258432   0.302 0.762463
## factor(street)63     -0.0306034  0.1180580  -0.259 0.795496
## factor(street)64      0.0399174  0.1352025   0.295 0.767848
## factor(street)66     -0.0519096  0.1256376  -0.413 0.679538
## factor(street)67     -0.0051510  0.1116587  -0.046 0.963211
## factor(street)68      0.0835728  0.1180076   0.708 0.478925
## factor(street)69      0.0668481  0.1019596   0.656 0.512154
## factor(street)70     -0.0219545  0.0914026  -0.240 0.810210
## factor(street)72     -0.0448205  0.1018069  -0.440 0.659815
## factor(street)73     -0.1794086  0.1180642  -1.520 0.128813
## factor(street)74     -0.0726046  0.0781421  -0.929 0.352959
## factor(street)75     -0.0477899  0.0979736  -0.488 0.625770
## factor(street)77     -0.0395635  0.1257532  -0.315 0.753097
## factor(street)78     -0.0594692  0.0860667  -0.691 0.489687
## factor(street)79      0.3244166  0.1643440   1.974 0.048553 *
## factor(street)80      0.0121503  0.0688349   0.177 0.859913
## factor(street)81     -0.0276770  0.1644022  -0.168 0.866330
## factor(street)82      0.0308021  0.1891017   0.163 0.870629
## factor(street)83     -0.1188355  0.1261328  -0.942 0.346261
## factor(street)84     -0.0023519  0.1257245  -0.019 0.985077
## factor(street)85      0.0668074  0.0860237   0.777 0.437500
## factor(street)86     -0.0743133  0.0798436  -0.931 0.352131
## factor(street)88     -0.1031723  0.1063690  -0.970 0.332220
## factor(street)89     -0.0118665  0.1181574  -0.100 0.920016
## factor(street)91     -0.2297515  0.1890621  -1.215 0.224463
## factor(street)93     -0.0685520  0.1256500  -0.546 0.585432
## factor(street)94     -0.0525852  0.1119441  -0.470 0.638601
## factor(street)96     -0.0373561  0.1256658  -0.297 0.766302
## factor(street)98      0.0418770  0.0982370   0.426 0.669957
```

```
## factor(street)99      0.2335374  0.1118742   2.088 0.037001 *
## factor(street)100     0.0693009  0.1064690   0.651 0.515203
## factor(street)101     0.2113416  0.1118057   1.890 0.058904 .
## factor(street)102    -0.0554857  0.1899885  -0.292 0.770288
## factor(street)103     0.0880275  0.1117244   0.788 0.430873
## factor(street)105     0.1154956  0.1474762   0.783 0.433657
## factor(street)106     0.3900988  0.0980104   3.980  7.2e-05 ***
## factor(street)107     0.0460390  0.1644125   0.280 0.779497
## factor(street)109    -0.0203859  0.1181249  -0.173 0.863004
## factor(street)110     0.1225363  0.1477775   0.829 0.407118
## factor(street)111    -0.0178444  0.1476434  -0.121 0.903816
## factor(street)112     0.1847431  0.1182139   1.563 0.118301
## factor(street)113     0.0627747  0.1261620   0.498 0.618854
## factor(street)115     0.2772493  0.0979783   2.830 0.004717 **
## factor(street)117     0.5716874  0.1901793   3.006 0.002688 **
## factor(street)118     0.0140626  0.1889719   0.074 0.940688
## factor(street)119    -0.0170823  0.1181363  -0.145 0.885046
## factor(street)120    -0.0793720  0.1182756  -0.671 0.502269
## factor(street)121     0.1722527  0.1182310   1.457 0.145336
## factor(street)122    -0.1673088  0.1642215  -1.019 0.308452
## factor(street)124     0.0256179  0.1021286   0.251 0.801970
## factor(street)125     0.2959510  0.0864698   3.423 0.000636 ***
## factor(street)126    -0.1215559  0.1358372  -0.895 0.370994
## factor(street)127     0.0712364  0.1354858   0.526 0.599111
## factor(street)128     0.1506259  0.0978764   1.539 0.124017
## factor(street)129     0.3734761  0.1889679   1.976 0.048281 *
## factor(street)130     0.1758178  0.1180794   1.489 0.136690
## factor(street)131     0.2694959  0.1185131   2.274 0.023100 *
## factor(street)132     0.2324989  0.0887728   2.619 0.008901 **
## factor(street)133     0.3219031  0.1643232   1.959 0.050291 .
## factor(street)134    -0.0091209  0.1256814  -0.073 0.942156
## factor(street)136     0.1613545  0.1183039   1.364 0.172792
## factor(street)137     0.2518522  0.1888039   1.334 0.182415
## factor(street)138     0.1070801  0.1026124   1.044 0.296856
## factor(street)147     0.1907771  0.1890850   1.009 0.313152
## factor(street)148     0.1006623  0.1643983   0.612 0.540421
## factor(street)149     0.2742236  0.1121314   2.446 0.014570 *
## factor(street)151    -0.2665497  0.1889643  -1.411 0.158562
## factor(street)152     0.1386033  0.1888918   0.734 0.463196
## factor(street)153    -0.0153769  0.1889026  -0.081 0.935133
## factor(street)154    -0.0547768  0.1063653  -0.515 0.606633
## factor(street)155    -0.2654233  0.1889388  -1.405 0.160272
## factor(street)156     0.2080125  0.1888858   1.101 0.270949
## factor(street)157     0.1531740  0.1645105   0.931 0.351948
## factor(street)158     0.3878598  0.1476044   2.628 0.008679 **
## factor(street)160    -0.1188555  0.1018025  -1.168 0.243178
## factor(street)163    -0.0976582  0.1259744  -0.775 0.438323
## factor(street)164    -0.0891228  0.1475341  -0.604 0.545874
## factor(street)165     0.0139933  0.1644655   0.085 0.932206
## factor(street)166    -0.1353582  0.1888801  -0.717 0.473704
## factor(street)168     0.1641418  0.1893497   0.867 0.386143
## factor(street)170    -0.0047058  0.0885059  -0.053 0.957603
## factor(street)171    -0.0339362  0.1351943  -0.251 0.801833
## factor(street)172    -0.0081016  0.1181033  -0.069 0.945319
```

```
## factor(street)175    0.2618048  0.0944440   2.772 0.005635 **
## factor(street)179   -0.0174120  0.1644596  -0.106 0.915696
## factor(street)180   -0.0938521  0.0764318  -1.228 0.219658
## factor(street)182   -0.1495080  0.1351743  -1.106 0.268876
## factor(street)183   -0.0711987  0.0782063  -0.910 0.362751
## factor(street)185   -0.0575521  0.1351496  -0.426 0.670282
## factor(street)186   -0.0038034  0.1180323  -0.032 0.974298
## factor(street)187    0.0019410  0.0914160   0.021 0.983062
## factor(street)188   -0.0318390  0.1116424  -0.285 0.775537
## factor(street)189   -0.0512665  0.0764519  -0.671 0.502591
## factor(street)190    0.0214650  0.1183213   0.181 0.856066
## factor(street)191   -0.0186662  0.1116429  -0.167 0.867237
## factor(street)192   -0.1020235  0.0699088  -1.459 0.144657
## factor(street)193    0.0791854  0.1181066   0.670 0.502663
## factor(street)196   -0.2384439  0.1352247  -1.763 0.078038 .
## factor(street)197    0.0506754  0.1889513   0.268 0.788586
## factor(street)198    0.0900944  0.0884993   1.018 0.308820
## factor(street)200   -0.0357270  0.1257560  -0.284 0.776372
## factor(street)202    0.0261859  0.1476844   0.177 0.859287
## factor(street)203   -0.2378875  0.1257206  -1.892 0.058646 .
## factor(street)206   -0.2383209  0.1063561  -2.241 0.025177 *
## factor(street)207   -0.2318179  0.1642235  -1.412 0.158263
## factor(street)208   -0.1024520  0.1064649  -0.962 0.336041
## factor(street)209   -0.3146950  0.0943455  -3.336 0.000871 ***
## factor(street)210   -0.2098070  0.1066504  -1.967 0.049328 *
## factor(street)213    0.0548025  0.0980711   0.559 0.576374
## factor(street)215   -0.0535041  0.0651169  -0.822 0.411392
## factor(street)216   -0.4556552  0.1487375  -3.063 0.002224 **
## factor(street)217   -0.1872818  0.1180288  -1.587 0.112768
## factor(street)220   -0.1971474  0.1256341  -1.569 0.116795
## factor(street)221   -0.1602102  0.1117132  -1.434 0.151734
## factor(street)222   -0.1540216  0.1476595  -1.043 0.297066
## factor(street)223   -0.1745960  0.1179815  -1.480 0.139108
## factor(street)225   -0.0892763  0.1118985  -0.798 0.425086
## factor(street)227   -0.0564965  0.1474904  -0.383 0.701732
## factor(street)228    0.0446508  0.1889565   0.236 0.813229
## factor(street)229    0.0495418  0.1358323   0.365 0.715363
## factor(street)230    0.0113873  0.1256281   0.091 0.927788
## factor(street)232    0.0809895  0.1644617   0.492 0.622468
## factor(street)233    0.0486941  0.0978611   0.498 0.618846
## factor(street)235   -0.1210622  0.1477288  -0.819 0.412629
## factor(street)236   -0.0001984  0.0817992  -0.002 0.998065
## factor(street)238   -0.1006686  0.1117788  -0.901 0.367934
## factor(street)240   -0.3078066  0.1475159  -2.087 0.037083 *
## factor(street)241   -0.1118899  0.1642690  -0.681 0.495883
## factor(street)242    0.0518889  0.1888763   0.275 0.783564
## factor(street)243    0.1393642  0.1646704   0.846 0.397500
## factor(street)244    0.1062748  0.0914330   1.162 0.245277
## factor(street)246   -0.1244971  0.1353784  -0.920 0.357908
## factor(street)247   -0.0039049  0.0943185  -0.041 0.966981
## factor(street)248    0.0003658  0.0710417   0.005 0.995893
## factor(street)249    0.0944909  0.0860236   1.098 0.272183
## factor(street)250    0.0521115  0.0621543   0.838 0.401920
## factor(street)253    0.1212342  0.0838304   1.446 0.148322
```

```
## factor(street)254    0.1097144  0.1257818   0.872 0.383198
## factor(street)255    0.0372245  0.0886556   0.420 0.674631
## factor(street)256    0.0345142  0.0644651   0.535 0.592452
## factor(street)257   -0.1015814  0.0816930  -1.243 0.213883
## factor(street)258    0.0959810  0.0765698   1.254 0.210204
## factor(street)259    0.7307820  0.1891973   3.863 0.000117 ***
## factor(street)260   -0.0353039  0.0634986  -0.556 0.578303
## factor(street)261   -0.0331163  0.1181807  -0.280 0.779347
## factor(street)262    0.0489456  0.1117766   0.438 0.661527
## factor(street)263    0.0302991  0.0837181   0.362 0.717461
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.323 on 1597 degrees of freedom
## Multiple R-squared:  0.4392, Adjusted R-squared:  0.3749
## F-statistic: 6.834 on 183 and 1597 DF,  p-value: < 2.2e-16
```

```
RCI6<- coefci(x = mod_6, vcov. = vcovHC(mod_6))
RCI6
```

```
##                            2.5 %       97.5 %
## (Intercept)           0.309184673  0.460099955
## bin                   0.077940398  0.152166899
## base_avg_bins_treat   0.313926871  0.433038849
## no_cell_phone        -0.091806576 -0.001597533
## sms                  -0.041132580  0.051381329
## factor(street)2      -0.217196698  0.015530725
## factor(street)3      -0.264874361  0.154568068
## factor(street)4      -0.265472394  0.009711886
## factor(street)5      -0.304681784  0.098424923
## factor(street)6      -0.290662264  0.172683060
## factor(street)7      -0.381797969  0.232237954
## factor(street)8      -0.168794341  0.056403148
## factor(street)9      -0.287120735  0.107016841
## factor(street)10     -0.188383821  0.123679469
## factor(street)11     -0.298819481  0.141012884
## factor(street)15     -0.271001970  0.216405462
## factor(street)17     -0.165317830  0.237960970
## factor(street)20     -0.377348474 -0.085671955
## factor(street)21     -0.225998004  0.115422842
## factor(street)22     -0.249123252  0.013798841
## factor(street)23     -0.263763961 -0.046927843
## factor(street)26     -0.211853129  0.181099304
## factor(street)32     -0.369887538  0.705864292
## factor(street)37     -0.252996833  0.557985819
## factor(street)38     -0.267495036  0.103246098
## factor(street)40     -0.746784497  0.614885088
## factor(street)41     -0.339119442  0.384212033
## factor(street)42     -0.437434573  0.205877130
## factor(street)43     -0.264621478  0.351021684
## factor(street)44     -0.118212427  0.346457748
## factor(street)45     -0.277640894  0.183925263
## factor(street)46     -0.210638697  0.207641082
## factor(street)47     -0.201906060  1.027140121
## factor(street)53     -0.387158144  0.418558770
```

```
## factor(street)58    -0.154093328  0.089871795
## factor(street)60    -0.110035483  0.162989370
## factor(street)61    -0.369844700  0.344638538
## factor(street)62    -0.224985830  0.301070622
## factor(street)63    -0.211836928  0.150630146
## factor(street)64    -0.166581061  0.246415930
## factor(street)66    -0.167141441  0.063322218
## factor(street)67    -0.309842190  0.299540267
## factor(street)68    -0.150799675  0.317945363
## factor(street)69    -0.092739152  0.226435421
## factor(street)70    -0.185382021  0.141473115
## factor(street)72    -0.209349680  0.119708613
## factor(street)73    -0.295241119 -0.063576099
## factor(street)74    -0.209355813  0.064146611
## factor(street)75    -0.149691523  0.054111663
## factor(street)77    -0.374673717  0.295546694
## factor(street)78    -0.217931754  0.098993259
## factor(street)79    -0.715560584  1.364393791
## factor(street)80    -0.087024030  0.111324602
## factor(street)81    -0.316981315  0.261627258
## factor(street)82    -0.409104542  0.470708644
## factor(street)83    -0.369002507  0.131331580
## factor(street)84    -0.141042821  0.136338928
## factor(street)85    -0.082329333  0.215944230
## factor(street)86    -0.217857946  0.069231437
## factor(street)88    -0.306350588  0.100006018
## factor(street)89    -0.209270887  0.185537797
## factor(street)91    -0.578250492  0.118747491
## factor(street)93    -0.253413866  0.116309931
## factor(street)94    -0.216093105  0.110922667
## factor(street)96    -0.373657981  0.298945686
## factor(street)98    -0.126262667  0.210016645
## factor(street)99     0.049290588  0.417784295
## factor(street)100   -0.217752999  0.356354801
## factor(street)101   -0.022340536  0.445023726
## factor(street)102   -0.447006714  0.336035376
## factor(street)103   -0.187723285  0.363778225
## factor(street)105   -0.076266213  0.307257494
## factor(street)106    0.128015041  0.652182562
## factor(street)107   -0.330101107  0.422179147
## factor(street)109   -0.271393451  0.230621740
## factor(street)110   -0.313278121  0.558350664
## factor(street)111   -0.361954102  0.326265351
## factor(street)112    0.008691813  0.360794381
## factor(street)113   -0.285525039  0.411074469
## factor(street)115    0.007032359  0.547466149
## factor(street)117   -0.582239206  1.725613984
## factor(street)118   -0.711488311  0.739613607
## factor(street)119   -0.243078754  0.208914175
## factor(street)120   -0.290931293  0.132187334
## factor(street)121   -0.186636292  0.531141643
## factor(street)122   -0.439859240  0.105241633
## factor(street)124   -0.190413043  0.241648884
## factor(street)125    0.006318397  0.585583544
```

```
## factor(street)126   -0.399724630  0.156612809
## factor(street)127   -0.681319632  0.823792388
## factor(street)128   -0.066657604  0.367909438
## factor(street)129   -0.875233358  1.622185493
## factor(street)130   -0.110830207  0.462465743
## factor(street)131   -0.053064808  0.592056602
## factor(street)132    0.032328521  0.432669238
## factor(street)133    0.038130716  0.605675457
## factor(street)134   -0.269439953  0.251198104
## factor(street)136   -0.135229375  0.457938426
## factor(street)137   -0.023129309  0.526833685
## factor(street)138   -0.238932658  0.453092918
## factor(street)147    0.053539468  0.328014785
## factor(street)148   -0.435251431  0.636576080
## factor(street)149    0.033768806  0.514678461
## factor(street)151   -0.753946108  0.220846758
## factor(street)152   -0.499655773  0.776862354
## factor(street)153   -0.295580149  0.264826305
## factor(street)154   -0.287186420  0.177632732
## factor(street)155   -0.752225313  0.221378747
## factor(street)156   -0.266602432  0.682627410
## factor(street)157   -0.005886329  0.312234307
## factor(street)158   -0.067286754  0.843006311
## factor(street)160   -0.287588990  0.049877930
## factor(street)163   -0.271084517  0.075768150
## factor(street)164   -0.222727862  0.044482248
## factor(street)165   -0.263192315  0.291178958
## factor(street)166   -0.462228296  0.191511833
## factor(street)168   -0.845849636  1.174133151
## factor(street)170   -0.134122147  0.124710455
## factor(street)171   -0.251736674  0.183864370
## factor(street)172   -0.104438771  0.088235596
## factor(street)175   -0.069147862  0.592757393
## factor(street)179   -0.367222254  0.332398351
## factor(street)180   -0.224045001  0.036340786
## factor(street)182   -0.403091045  0.104075090
## factor(street)183   -0.220437707  0.078040326
## factor(street)185   -0.250074170  0.134970010
## factor(street)186   -0.188389869  0.180783030
## factor(street)187   -0.142733819  0.146615896
## factor(street)188   -0.131929806  0.068251730
## factor(street)189   -0.174518693  0.071985713
## factor(street)190   -0.213261656  0.256191711
## factor(street)191   -0.216246287  0.178913817
## factor(street)192   -0.227871630  0.023824711
## factor(street)193   -0.150522822  0.308893610
## factor(street)196   -0.486012245  0.009124365
## factor(street)197   -0.885069465  0.986420253
## factor(street)198   -0.126233725  0.306422625
## factor(street)200   -0.166323500  0.094869423
## factor(street)202   -0.279522446  0.331894277
## factor(street)203   -0.409948623 -0.065826367
## factor(street)206   -0.428974863 -0.047666852
## factor(street)207   -0.351653379 -0.111982382
```

```
## factor(street)208   -0.319968290  0.115064217
## factor(street)209   -0.493468696 -0.135921366
## factor(street)210   -0.379142499 -0.040471519
## factor(street)213   -0.110451173  0.220056254
## factor(street)215   -0.193037991  0.086029881
## factor(street)216   -1.286346643  0.375036313
## factor(street)217   -0.422625854  0.048062260
## factor(street)220   -0.489840183  0.095545467
## factor(street)221   -0.357677743  0.037257373
## factor(street)222   -0.442851444  0.134808212
## factor(street)223   -0.431128836  0.081936829
## factor(street)225   -0.321843023  0.143290424
## factor(street)227   -0.411692375  0.298699418
## factor(street)228   -0.480724673  0.570026307
## factor(street)229   -0.264364011  0.363447640
## factor(street)230   -0.166040885  0.188815524
## factor(street)232   -0.508430642  0.670409610
## factor(street)233   -0.220496475  0.317884736
## factor(street)235   -0.468837240  0.226712823
## factor(street)236   -0.139845201  0.139448323
## factor(street)238   -0.289194929  0.087857732
## factor(street)240   -0.455300234 -0.160312902
## factor(street)241   -0.580424965  0.356645115
## factor(street)242   -0.093784701  0.197562565
## factor(street)243   -0.508411031  0.787139488
## factor(street)244   -0.116961464  0.329511121
## factor(street)246   -0.349055113  0.100060878
## factor(street)247   -0.107965480  0.100155714
## factor(street)248   -0.144541886  0.145273426
## factor(street)249   -0.148858223  0.337839940
## factor(street)250   -0.043856270  0.148079180
## factor(street)253   -0.047415015  0.289883402
## factor(street)254   -0.136705775  0.356134648
## factor(street)255   -0.169197200  0.243646206
## factor(street)256   -0.087109729  0.156138219
## factor(street)257   -0.242333698  0.039170989
## factor(street)258   -0.011475434  0.203437337
## factor(street)259    0.072370880  1.389193187
## factor(street)260   -0.179706798  0.109099046
## factor(street)261   -0.191276347  0.125043776
## factor(street)262   -0.176390161  0.274281267
## factor(street)263   -0.158047219  0.218645369
```

8. Now reproduce the results of column 2 in Table 4B, estimating separate treatment effects for the two types of SMS treatments and the two types of recycling-bin treatments. Provide a 95% confidence interval for the effect of the unadorned recycling bin. Explain how your answer differs from that in part (g), and explain why you think it differs.

```r
mod_7 <- lm(data = no_null_no_blocking, avg_bins_treat ~ bin_s + bin_g + base_avg_bins_treat + no_cell_p
summary(mod_7)
```

```
##
## Call:
## lm(formula = avg_bins_treat ~ bin_s + bin_g + base_avg_bins_treat +
##     no_cell_phone + sms_p + sms_g + factor(street), data = no_null_no_blocking)
```

```
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.48037 -0.19632 -0.01729  0.15867  1.84297
##
## Coefficients:
##                      Estimate Std. Error t value Pr(>|t|)
## (Intercept)          3.849e-01  3.429e-02  11.225  < 2e-16 ***
## bin_s                1.278e-01  2.224e-02   5.748 1.08e-08 ***
## bin_g                1.032e-01  2.189e-02   4.714 2.64e-06 ***
## base_avg_bins_treat  3.739e-01  1.431e-02  26.119  < 2e-16 ***
## no_cell_phone       -4.638e-02  2.038e-02  -2.276 0.022972 *
## sms_p               -8.041e-03  2.504e-02  -0.321 0.748122
## sms_g                1.971e-02  2.520e-02   0.782 0.434271
## factor(street)2     -1.007e-01  1.018e-01  -0.989 0.322935
## factor(street)3     -5.491e-02  1.064e-01  -0.516 0.605954
## factor(street)4     -1.304e-01  1.118e-01  -1.166 0.243790
## factor(street)5     -1.041e-01  1.117e-01  -0.932 0.351245
## factor(street)6     -5.712e-02  1.181e-01  -0.484 0.628696
## factor(street)7     -7.541e-02  1.478e-01  -0.510 0.609882
## factor(street)8     -5.727e-02  9.127e-02  -0.627 0.530441
## factor(street)9     -9.205e-02  9.785e-02  -0.941 0.346967
## factor(street)10    -3.145e-02  7.981e-02  -0.394 0.693548
## factor(street)11    -8.224e-02  9.805e-02  -0.839 0.401741
## factor(street)15    -3.497e-02  1.646e-01  -0.212 0.831756
## factor(street)17     3.118e-02  1.353e-01   0.231 0.817727
## factor(street)20    -2.310e-01  1.181e-01  -1.956 0.050613 .
## factor(street)21    -6.484e-02  1.357e-01  -0.478 0.632854
## factor(street)22    -1.172e-01  6.887e-02  -1.702 0.088916 .
## factor(street)23    -1.590e-01  7.233e-02  -2.199 0.028039 *
## factor(street)26    -7.901e-03  1.890e-01  -0.042 0.966659
## factor(street)32     1.703e-01  1.893e-01   0.900 0.368373
## factor(street)37     1.467e-01  1.481e-01   0.991 0.322072
## factor(street)38    -8.602e-02  1.476e-01  -0.583 0.560255
## factor(street)40    -5.438e-02  1.892e-01  -0.287 0.773799
## factor(street)41     1.374e-02  1.477e-01   0.093 0.925891
## factor(street)42    -1.168e-01  1.894e-01  -0.617 0.537635
## factor(street)43     3.722e-02  1.477e-01   0.252 0.801032
## factor(street)44     1.116e-01  1.184e-01   0.943 0.345912
## factor(street)45    -4.479e-02  1.643e-01  -0.273 0.785163
## factor(street)46     1.775e-03  1.352e-01   0.013 0.989530
## factor(street)47     4.017e-01  1.647e-01   2.439 0.014832 *
## factor(street)53     1.040e-02  1.890e-01   0.055 0.956147
## factor(street)58    -3.232e-02  9.439e-02  -0.342 0.732054
## factor(street)60     2.622e-02  8.603e-02   0.305 0.760553
## factor(street)61    -5.212e-03  1.893e-01  -0.028 0.978042
## factor(street)62     4.030e-02  1.260e-01   0.320 0.749053
## factor(street)63    -3.165e-02  1.181e-01  -0.268 0.788679
## factor(street)64     3.891e-02  1.352e-01   0.288 0.773576
## factor(street)66    -5.115e-02  1.257e-01  -0.407 0.683999
## factor(street)67    -8.914e-03  1.117e-01  -0.080 0.936428
## factor(street)68     8.255e-02  1.180e-01   0.699 0.484389
## factor(street)69     6.694e-02  1.020e-01   0.656 0.511628
## factor(street)70    -2.219e-02  9.141e-02  -0.243 0.808192
```

```
## factor(street)72    -4.595e-02  1.018e-01  -0.451 0.651851
## factor(street)73    -1.806e-01  1.181e-01  -1.530 0.126299
## factor(street)74    -7.358e-02  7.815e-02  -0.941 0.346604
## factor(street)75    -5.079e-02  9.804e-02  -0.518 0.604460
## factor(street)77    -3.874e-02  1.258e-01  -0.308 0.758101
## factor(street)78    -6.367e-02  8.616e-02  -0.739 0.460047
## factor(street)79     3.172e-01  1.646e-01   1.928 0.054050 .
## factor(street)80     1.075e-02  6.886e-02   0.156 0.875937
## factor(street)81    -2.883e-02  1.644e-01  -0.175 0.860826
## factor(street)82     3.809e-02  1.893e-01   0.201 0.840566
## factor(street)83    -1.181e-01  1.262e-01  -0.936 0.349237
## factor(street)84    -1.779e-03  1.258e-01  -0.014 0.988720
## factor(street)85     6.364e-02  8.615e-02   0.739 0.460229
## factor(street)86    -7.689e-02  7.988e-02  -0.963 0.335879
## factor(street)88    -9.930e-02  1.064e-01  -0.933 0.350967
## factor(street)89    -9.898e-03  1.182e-01  -0.084 0.933271
## factor(street)91    -2.393e-01  1.892e-01  -1.265 0.206188
## factor(street)93    -7.119e-02  1.257e-01  -0.566 0.571203
## factor(street)94    -5.101e-02  1.120e-01  -0.456 0.648754
## factor(street)96    -3.647e-02  1.257e-01  -0.290 0.771738
## factor(street)98     3.987e-02  9.827e-02   0.406 0.685016
## factor(street)99     2.324e-01  1.119e-01   2.077 0.037974 *
## factor(street)100    6.930e-02  1.065e-01   0.651 0.515230
## factor(street)101    2.090e-01  1.118e-01   1.869 0.061870 .
## factor(street)102   -5.290e-02  1.900e-01  -0.278 0.780742
## factor(street)103    8.721e-02  1.118e-01   0.780 0.435339
## factor(street)105    1.143e-01  1.475e-01   0.775 0.438630
## factor(street)106    3.892e-01  9.803e-02   3.970 7.50e-05 ***
## factor(street)107    4.557e-02  1.645e-01   0.277 0.781805
## factor(street)109   -2.444e-02  1.182e-01  -0.207 0.836159
## factor(street)110    1.293e-01  1.479e-01   0.875 0.381913
## factor(street)111   -2.386e-02  1.478e-01  -0.161 0.871800
## factor(street)112    1.850e-01  1.183e-01   1.564 0.117915
## factor(street)113    5.636e-02  1.264e-01   0.446 0.655674
## factor(street)115    2.774e-01  9.800e-02   2.830 0.004706 **
## factor(street)117    5.661e-01  1.903e-01   2.975 0.002976 **
## factor(street)118    1.255e-02  1.891e-01   0.066 0.947100
## factor(street)119   -2.090e-02  1.183e-01  -0.177 0.859799
## factor(street)120   -8.037e-02  1.183e-01  -0.679 0.497005
## factor(street)121    1.699e-01  1.183e-01   1.436 0.151242
## factor(street)122   -1.687e-01  1.643e-01  -1.027 0.304680
## factor(street)124    2.700e-02  1.022e-01   0.264 0.791566
## factor(street)125    2.955e-01  8.648e-02   3.417 0.000649 ***
## factor(street)126   -1.183e-01  1.359e-01  -0.871 0.383949
## factor(street)127    6.774e-02  1.355e-01   0.500 0.617251
## factor(street)128    1.465e-01  9.799e-02   1.495 0.135152
## factor(street)129    3.768e-01  1.890e-01   1.993 0.046410 *
## factor(street)130    1.746e-01  1.181e-01   1.478 0.139531
## factor(street)131    2.700e-01  1.185e-01   2.278 0.022855 *
## factor(street)132    2.339e-01  8.880e-02   2.634 0.008520 **
## factor(street)133    3.148e-01  1.645e-01   1.913 0.055892 .
## factor(street)134   -8.563e-03  1.257e-01  -0.068 0.945691
## factor(street)136    1.601e-01  1.183e-01   1.354 0.176077
## factor(street)137    2.420e-01  1.890e-01   1.281 0.200462
```

```
## factor(street)138    1.092e-01  1.027e-01   1.064 0.287535    
## factor(street)147    1.898e-01  1.891e-01   1.004 0.315694    
## factor(street)148    1.030e-01  1.644e-01   0.626 0.531217    
## factor(street)149    2.678e-01  1.125e-01   2.381 0.017404 *  
## factor(street)151   -2.765e-01  1.891e-01  -1.462 0.143888    
## factor(street)152    1.418e-01  1.889e-01   0.751 0.453029    
## factor(street)153   -1.611e-02  1.891e-01  -0.085 0.932110    
## factor(street)154   -5.725e-02  1.064e-01  -0.538 0.590592    
## factor(street)155   -2.708e-01  1.890e-01  -1.432 0.152272    
## factor(street)156    2.156e-01  1.890e-01   1.141 0.254061    
## factor(street)157    1.394e-01  1.650e-01   0.845 0.398293    
## factor(street)158    3.892e-01  1.476e-01   2.636 0.008463 ** 
## factor(street)160   -1.186e-01  1.018e-01  -1.165 0.244259    
## factor(street)163   -1.077e-01  1.263e-01  -0.853 0.393946    
## factor(street)164   -9.032e-02  1.476e-01  -0.612 0.540549    
## factor(street)165    1.326e-02  1.646e-01   0.081 0.935790    
## factor(street)166   -1.371e-01  1.890e-01  -0.725 0.468334    
## factor(street)168    1.671e-01  1.894e-01   0.882 0.377768    
## factor(street)170   -5.872e-03  8.852e-02  -0.066 0.947116    
## factor(street)171   -3.679e-02  1.353e-01  -0.272 0.785815    
## factor(street)172   -6.304e-03  1.182e-01  -0.053 0.957473    
## factor(street)175    2.620e-01  9.446e-02   2.773 0.005617 ** 
## factor(street)179   -2.231e-02  1.645e-01  -0.136 0.892168    
## factor(street)180   -9.261e-02  7.645e-02  -1.211 0.225970    
## factor(street)182   -1.462e-01  1.352e-01  -1.081 0.279773    
## factor(street)183   -7.243e-02  7.822e-02  -0.926 0.354594    
## factor(street)185   -6.272e-02  1.353e-01  -0.464 0.642955    
## factor(street)186   -4.780e-03  1.181e-01  -0.040 0.967715    
## factor(street)187    6.120e-06  9.143e-02   0.000 0.999947    
## factor(street)188   -3.000e-02  1.117e-01  -0.269 0.788224    
## factor(street)189   -5.397e-02  7.652e-02  -0.705 0.480729    
## factor(street)190    2.022e-02  1.183e-01   0.171 0.864342    
## factor(street)191   -2.118e-02  1.117e-01  -0.190 0.849582    
## factor(street)192   -1.017e-01  6.992e-02  -1.454 0.146123    
## factor(street)193    7.828e-02  1.182e-01   0.663 0.507728    
## factor(street)196   -2.395e-01  1.352e-01  -1.771 0.076736 .  
## factor(street)197    4.531e-02  1.891e-01   0.240 0.810622    
## factor(street)198    8.985e-02  8.851e-02   1.015 0.310163    
## factor(street)200   -3.484e-02  1.258e-01  -0.277 0.781813    
## factor(street)202    2.468e-02  1.477e-01   0.167 0.867348    
## factor(street)203   -2.423e-01  1.258e-01  -1.926 0.054288 .  
## factor(street)206   -2.395e-01  1.064e-01  -2.252 0.024479 *  
## factor(street)207   -2.323e-01  1.643e-01  -1.414 0.157605    
## factor(street)208   -1.061e-01  1.065e-01  -0.995 0.319673    
## factor(street)209   -3.159e-01  9.436e-02  -3.347 0.000835 ***
## factor(street)210   -2.059e-01  1.067e-01  -1.929 0.053850 .  
## factor(street)213    5.142e-02  9.812e-02   0.524 0.600281    
## factor(street)215   -5.381e-02  6.512e-02  -0.826 0.408791    
## factor(street)216   -4.495e-01  1.488e-01  -3.020 0.002567 ** 
## factor(street)217   -1.898e-01  1.181e-01  -1.608 0.108126    
## factor(street)220   -1.982e-01  1.256e-01  -1.577 0.114913    
## factor(street)221   -1.643e-01  1.118e-01  -1.470 0.141695    
## factor(street)222   -1.524e-01  1.477e-01  -1.032 0.302381    
## factor(street)223   -1.773e-01  1.180e-01  -1.502 0.133330    
```

```
## factor(street)225   -9.061e-02  1.119e-01  -0.810 0.418247
## factor(street)227   -6.255e-02  1.477e-01  -0.424 0.671882
## factor(street)228    4.757e-02  1.890e-01   0.252 0.801306
## factor(street)229    5.036e-02  1.359e-01   0.371 0.710924
## factor(street)230    1.202e-02  1.256e-01   0.096 0.923770
## factor(street)232    8.263e-02  1.645e-01   0.502 0.615502
## factor(street)233    4.881e-02  9.788e-02   0.499 0.618107
## factor(street)235   -1.269e-01  1.479e-01  -0.858 0.391080
## factor(street)236   -5.401e-04  8.181e-02  -0.007 0.994734
## factor(street)238   -9.894e-02  1.118e-01  -0.885 0.376352
## factor(street)240   -3.037e-01  1.476e-01  -2.058 0.039765 *
## factor(street)241   -1.192e-01  1.645e-01  -0.725 0.468702
## factor(street)242    5.022e-02  1.890e-01   0.266 0.790466
## factor(street)243    1.387e-01  1.648e-01   0.842 0.399988
## factor(street)244    1.088e-01  9.149e-02   1.190 0.234329
## factor(street)246   -1.321e-01  1.355e-01  -0.975 0.329921
## factor(street)247   -2.047e-03  9.434e-02  -0.022 0.982688
## factor(street)248    3.572e-04  7.105e-02   0.005 0.995990
## factor(street)249    9.026e-02  8.612e-02   1.048 0.294730
## factor(street)250    4.957e-02  6.222e-02   0.797 0.425744
## factor(street)253    1.218e-01  8.384e-02   1.453 0.146517
## factor(street)254    1.136e-01  1.260e-01   0.901 0.367473
## factor(street)255    3.703e-02  8.867e-02   0.418 0.676314
## factor(street)256    3.462e-02  6.447e-02   0.537 0.591381
## factor(street)257   -1.050e-01  8.174e-02  -1.284 0.199327
## factor(street)258    9.395e-02  7.661e-02   1.226 0.220228
## factor(street)259    7.295e-01  1.892e-01   3.856 0.000120 ***
## factor(street)260   -3.442e-02  6.351e-02  -0.542 0.587859
## factor(street)261   -3.585e-02  1.182e-01  -0.303 0.761720
## factor(street)262    4.910e-02  1.118e-01   0.439 0.660660
## factor(street)263    2.767e-02  8.375e-02   0.330 0.741165
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.323 on 1595 degrees of freedom
## Multiple R-squared:  0.4398, Adjusted R-squared:  0.3748
## F-statistic: 6.769 on 185 and 1595 DF,  p-value: < 2.2e-16
```

```
RCI7<- coefci(x = mod_7, vcov. = vcovHC(mod_7))
RCI7
```

```
##                            2.5 %        97.5 %
## (Intercept)          0.309540422  0.4603462103
## bin_s                0.080176818  0.1754489652
## bin_g                0.054035624  0.1523448086
## base_avg_bins_treat  0.314212458  0.4334918975
## no_cell_phone       -0.091572890 -0.0011940290
## sms_p               -0.063293287  0.0472109821
## sms_g               -0.034633139  0.0740473724
## factor(street)2     -0.215170201  0.0138127090
## factor(street)3     -0.259056241  0.1492298224
## factor(street)4     -0.267881008  0.0071328984
## factor(street)5     -0.308633232  0.1003421800
## factor(street)6     -0.289225524  0.1749879044
## factor(street)7     -0.369430577  0.2186056642
```

```
## factor(street)8      -0.169426146  0.0548817247
## factor(street)9      -0.290121977  0.1060168707
## factor(street)10     -0.188378241  0.1254682400
## factor(street)11     -0.300405593  0.1359265162
## factor(street)15     -0.277088027  0.2071496723
## factor(street)17     -0.174055235  0.2364129845
## factor(street)20     -0.375715414 -0.0862972880
## factor(street)21     -0.236998181  0.1073159371
## factor(street)22     -0.247659475  0.0131991204
## factor(street)23     -0.267277153 -0.0508057246
## factor(street)26     -0.207517596  0.1917150885
## factor(street)32     -0.389448050  0.7300324422
## factor(street)37     -0.250514670  0.5438467042
## factor(street)38     -0.275217099  0.1031849579
## factor(street)40     -0.736061750  0.6272965625
## factor(street)41     -0.345692673  0.3731695478
## factor(street)42     -0.423886583  0.1903696338
## factor(street)43     -0.269247004  0.3436818403
## factor(street)44     -0.123895440  0.3470793926
## factor(street)45     -0.283972773  0.1943957959
## factor(street)46     -0.203282647  0.2068318823
## factor(street)47     -0.210301977  1.0137777473
## factor(street)53     -0.412678958  0.4334726323
## factor(street)58     -0.152394471  0.0877454207
## factor(street)60     -0.113167737  0.1656100233
## factor(street)61     -0.346953559  0.3365293387
## factor(street)62     -0.221523438  0.3021286282
## factor(street)63     -0.215719642  0.1524161968
## factor(street)64     -0.164056470  0.2418735407
## factor(street)66     -0.162548779  0.0602468611
## factor(street)67     -0.313541725  0.2957133400
## factor(street)68     -0.148724465  0.3138184614
## factor(street)69     -0.095078576  0.2289683108
## factor(street)70     -0.187328159  0.1429397316
## factor(street)72     -0.210168605  0.1182694037
## factor(street)73     -0.293537434 -0.0677054100
## factor(street)74     -0.210028743  0.0628671429
## factor(street)75     -0.150224453  0.0486376449
## factor(street)77     -0.376067612  0.2985792226
## factor(street)78     -0.223209458  0.0958778124
## factor(street)79     -0.717460932  1.3519241062
## factor(street)80     -0.088817010  0.1103205153
## factor(street)81     -0.305851521  0.2481895292
## factor(street)82     -0.412470650  0.4886473899
## factor(street)83     -0.376211082  0.1399505244
## factor(street)84     -0.140805265  0.1372479527
## factor(street)85     -0.086427729  0.2136985287
## factor(street)86     -0.220352669  0.0665670335
## factor(street)88     -0.306517199  0.1079266751
## factor(street)89     -0.208561462  0.1887661555
## factor(street)91     -0.581417919  0.1028387118
## factor(street)93     -0.256777707  0.1143921419
## factor(street)94     -0.216376685  0.1143544371
## factor(street)96     -0.377933588  0.3050010944
```

```
## factor(street)98    -0.127659392  0.2073944019
## factor(street)99     0.045677728  0.4190766125
## factor(street)100   -0.218777579  0.3573818933
## factor(street)101   -0.025036096  0.4430014685
## factor(street)102   -0.445742067  0.3399324436
## factor(street)103   -0.188297949  0.3627259458
## factor(street)105   -0.074892794  0.3034187476
## factor(street)106    0.127128767  0.6512249543
## factor(street)107   -0.342124135  0.4332724183
## factor(street)109   -0.275470530  0.2265826680
## factor(street)110   -0.312149990  0.5708419761
## factor(street)111   -0.370869725  0.3231583836
## factor(street)112    0.010330420  0.3597006429
## factor(street)113   -0.292777950  0.4054949016
## factor(street)115    0.006400846  0.5483534135
## factor(street)117   -0.593838936  1.7259880489
## factor(street)118   -0.726803676  0.7518985651
## factor(street)119   -0.245445386  0.2036413138
## factor(street)120   -0.292104292  0.1313640892
## factor(street)121   -0.186805239  0.5266300850
## factor(street)122   -0.439941730  0.1025568611
## factor(street)124   -0.193914652  0.2479156266
## factor(street)125    0.005246129  0.5857552771
## factor(street)126   -0.399499636  0.1628453482
## factor(street)127   -0.679036797  0.8145200118
## factor(street)128   -0.072034923  0.3649931977
## factor(street)129   -0.890455778  1.6440346878
## factor(street)130   -0.114070646  0.4632574403
## factor(street)131   -0.048776708  0.5888465951
## factor(street)132    0.032390470  0.4353927387
## factor(street)133    0.026322207  0.6032501486
## factor(street)134   -0.266638931  0.2495120497
## factor(street)136   -0.131229225  0.4515265824
## factor(street)137   -0.042472323  0.5265187798
## factor(street)138   -0.237213789  0.4556447891
## factor(street)147    0.038408377  0.3411802918
## factor(street)148   -0.428844301  0.6348084717
## factor(street)149    0.029033282  0.5065676378
## factor(street)151   -0.780039310  0.2269434993
## factor(street)152   -0.488305059  0.7719321499
## factor(street)153   -0.296722918  0.2645052738
## factor(street)154   -0.293495608  0.1790013591
## factor(street)155   -0.751521351  0.2100062792
## factor(street)156   -0.266648825  0.6979021078
## factor(street)157   -0.028353149  0.3071194686
## factor(street)158   -0.071570806  0.8499379027
## factor(street)160   -0.285374373  0.0481623059
## factor(street)163   -0.281177726  0.0657366279
## factor(street)164   -0.222143768  0.0415085129
## factor(street)165   -0.256400231  0.2829214414
## factor(street)166   -0.477309525  0.2031378626
## factor(street)168   -0.854063414  1.1882625627
## factor(street)170   -0.133137458  0.1213927988
## factor(street)171   -0.255051586  0.1814808555
```

```
## factor(street)172   -0.102590154  0.0899819133
## factor(street)175   -0.068710629  0.5926192347
## factor(street)179   -0.367499752  0.3228873263
## factor(street)180   -0.223173662  0.0379600725
## factor(street)182   -0.392671904  0.1002966466
## factor(street)183   -0.221526789  0.0766686386
## factor(street)185   -0.259234558  0.1337849727
## factor(street)186   -0.187726552  0.1781661728
## factor(street)187   -0.145424211  0.1454364497
## factor(street)188   -0.128629901  0.0686314340
## factor(street)189   -0.177618303  0.0696854186
## factor(street)190   -0.216894317  0.2573363156
## factor(street)191   -0.217994946  0.1756318131
## factor(street)192   -0.228139288  0.0248117983
## factor(street)193   -0.152450233  0.3090186029
## factor(street)196   -0.479440582  0.0003964097
## factor(street)197   -0.875438394  0.9660591232
## factor(street)198   -0.127323875  0.3070275226
## factor(street)200   -0.162347964  0.0926630560
## factor(street)202   -0.284815367  0.3341752202
## factor(street)203   -0.415478836 -0.0691995062
## factor(street)206   -0.432345311 -0.0466786340
## factor(street)207   -0.350032448 -0.1146439214
## factor(street)208   -0.324006636  0.1118880834
## factor(street)209   -0.491170245 -0.1405299979
## factor(street)210   -0.376998927 -0.0347881796
## factor(street)213   -0.114722019  0.2175667745
## factor(street)215   -0.193178890  0.0855652960
## factor(street)216   -1.286109950  0.3871485639
## factor(street)217   -0.426090567  0.0464748544
## factor(street)220   -0.491024451  0.0946411117
## factor(street)221   -0.356957289  0.0283036255
## factor(street)222   -0.444214276  0.1394907411
## factor(street)223   -0.434698690  0.0801832525
## factor(street)225   -0.322476785  0.1412476713
## factor(street)227   -0.413253829  0.2881477757
## factor(street)228   -0.468043165  0.5631867788
## factor(street)229   -0.268744532  0.3694693256
## factor(street)230   -0.166842956  0.1908908413
## factor(street)232   -0.491056847  0.6563133597
## factor(street)233   -0.220851020  0.3184634201
## factor(street)235   -0.473850438  0.2201115039
## factor(street)236   -0.141125856  0.1400457091
## factor(street)238   -0.286608189  0.0887350842
## factor(street)240   -0.453463321 -0.1538592749
## factor(street)241   -0.592473675  0.3540491912
## factor(street)242   -0.105821650  0.2062674199
## factor(street)243   -0.516776601  0.7942197259
## factor(street)244   -0.115886970  0.3335854965
## factor(street)246   -0.361300079  0.0971209433
## factor(street)247   -0.107752848  0.1036581021
## factor(street)248   -0.144446928  0.1451612341
## factor(street)249   -0.149809854  0.3303326204
## factor(street)250   -0.046640246  0.1457787340
```

```
## factor(street)253   -0.046441496  0.2900227307
## factor(street)254   -0.132631323  0.3597999180
## factor(street)255   -0.166381148  0.2404359334
## factor(street)256   -0.087670526  0.1569052303
## factor(street)257   -0.245513258  0.0356057005
## factor(street)258   -0.012872039  0.2007784551
## factor(street)259    0.052402642  1.4066787191
## factor(street)260   -0.178602600  0.1097539296
## factor(street)261   -0.197425136  0.1257155694
## factor(street)262   -0.180656847  0.2788514324
## factor(street)263   -0.160792937  0.2161308581
```

5. A Final Practice Problem

Now for a fictional scenario. An emergency two-week randomized controlled trial of the experimental drug ZMapp is conducted to treat Ebola. (The control represents the usual standard of care for patients identified with Ebola, while the treatment is the usual standard of care plus the drug.)

Here are the (fake) data.

```r
d <- fread("../data/ebola_rct2.csv")
head(d)
```

```
##    temperature_day0 dehydrated_day0 treat_zmapp temperature_day14
## 1:         99.53168               1           0          98.62634
## 2:         97.37372               0           0          98.03251
## 3:         97.00747               0           1          97.93340
## 4:         99.74761               1           0          98.40457
## 5:         99.57559               1           1          99.31678
## 6:         98.28889               1           1          99.82623
##    dehydrated_day14 male
## 1:                1    0
## 2:                1    0
## 3:                0    1
## 4:                1    0
## 5:                1    0
## 6:                1    1
```

You are asked to analyze it. Patients' temperature and whether they are dehydrated is recorded on day 0 of the experiment, then ZMapp is administered to patients in the treatment group on day 1. Dehydration and temperature is again recorded on day 14.

1. Without using any covariates, answer this question with regression: What is the estimated effect of ZMapp (with standard error in parentheses) on whether someone was dehydrated on day 14? What is the p-value associated with this estimate?

```r
mod_1 <- lm(data=d,dehydrated_day14 ~ treat_zmapp)
mod_1_coef= coeftest(mod_1,vcov=vcovHC(mod_1,type="HC1"))
mod_1_coef
```

```
##
## t test of coefficients:
##
##              Estimate Std. Error t value  Pr(>|t|)
## (Intercept)  0.847458   0.047284 17.9227 < 2.2e-16 ***
## treat_zmapp -0.237702   0.090322 -2.6317  0.009869 **
```

```
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

The estimated effect of ZMapp is -0.2377015 with SE(0.0903215). The P Value is 0.0098693.

2. Add covariates for dehydration on day 0 and patient temperature on day 0 to the regression from part (a) and report the ATE (with standard error). Also report the p-value.

```
mod_2 <- lm(data = d, dehydrated_day14 ~  dehydrated_day0 + temperature_day0 + treat_zmapp)
mod_2_coef = coeftest(mod_2,vcov=vcovHC(mod_2,type="HC1"))
mod_2_coef
```

```
##
## t test of coefficients:
##
##                    Estimate Std. Error t value Pr(>|t|)
## (Intercept)      -19.469655   7.374569 -2.6401 0.009674 **
## dehydrated_day0    0.064557   0.172849  0.3735 0.709608
## temperature_day0   0.205548   0.075667  2.7165 0.007827 **
## treat_zmapp       -0.165537   0.079999 -2.0692 0.041211 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

The estimated effect of ZMapp is -0.1655367 SE(0.0799991). The P Value is 0.0412113.

3. Do you prefer the estimate of the ATE reported in part (a) or part (b)? Why? Report the results of the F-test that you used to form this opinion.

```
test_object <- anova(mod_1,mod_2,test="F")
test_object
```

```
## Analysis of Variance Table
##
## Model 1: dehydrated_day14 ~ treat_zmapp
## Model 2: dehydrated_day14 ~ dehydrated_day0 + temperature_day0 + treat_zmapp
##   Res.Df    RSS Df Sum of Sq      F    Pr(>F)
## 1     98 17.383
## 2     96 12.918  2    4.4653 16.592 6.472e-07 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

I prefer the estimate of the ATE reported in part b because it includes an additional covariate and is therefore more accurate. Part B also has a lower standard error. When looking at the F test, this view is backed up, with the null hypothesis rejected.

4. The regression from part (2) suggests that temperature is highly predictive of dehydration. Add, temperature on day 14 as a covariate and report the ATE, the standard error, and the p-value.

```
mod_3 <-  lm(data=d, dehydrated_day14 ~ treat_zmapp + dehydrated_day0 + temperature_day0 + temperature_d
mod_3_coef = coeftest(mod_3,vcov=vcovHC(mod_3,type="HC1"))
mod_3_coef
```

```
##
## t test of coefficients:
##
##                     Estimate Std. Error t value Pr(>|t|)
## (Intercept)       -22.591585   7.463374 -3.0270 0.003179 **
## treat_zmapp        -0.120101   0.083586 -1.4369 0.154044
## dehydrated_day0     0.046038   0.167425  0.2750 0.783930
```

```
## temperature_day0    0.176642   0.074357  2.3756 0.019528 *
## temperature_day14   0.060148   0.024856  2.4199 0.017428 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

The ATE is -0.1201006, the standard error is 0.0835856, and the p-value is 0.1540436.

5. Do you prefer the estimate of the ATE reported in part (b) or part (d)? What is this preference based on?

   I prefer the estimate reported in part b. This is because temperature on day 14 is affected by the treatment with zmapp, and it is therefore a bad covariate to use as a control. Becuase we added temperature on day 14 to the model in part d, we diminished the significance of our estimation of the real effect of zmapp by falsely raising the p value to be much above a 5% cutoff.

6. Now let's switch from the outcome of dehydration to the outcome of temperature, and use the same regression covariates as in the chunk titled `add pre-treatment measures`. Test the hypothesis that ZMapp is especially likely to reduce mens' temperatures, as compared to womens', and describe how you did so. What do the results suggest?

```
mod_4 <- lm(data=d, temperature_day14 ~ treat_zmapp + dehydrated_day0 + temperature_day0 + treat_zmapp*m
mod_4_coef = coeftest(mod_4,vcov=vcovHC(mod_4,type="HC1"))
mod_4_coef
```

```
##
## t test of coefficients:
##
##                    Estimate Std. Error  t value  Pr(>|t|)
## (Intercept)       48.712690   9.828279   4.9564 3.170e-06 ***
## treat_zmapp       -0.230866   0.114979  -2.0079   0.04753 *
## dehydrated_day0    0.041131   0.187341   0.2196   0.82670
## temperature_day0   0.504797   0.100759   5.0099 2.547e-06 ***
## male               3.085486   0.117866  26.1779 < 2.2e-16 ***
## treat_zmapp:male  -2.076686   0.190818 -10.8831 < 2.2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

I tested the hypothesis that ZMapp is especially likely to reduce mens' temperatures, as compared to womens', by adding an interaction between treat_zmapp and male. In the test, it appeared that zmapp is especially likely to reduce mens' temperatures s compared to womens', as the estimate is much lower for men and the p value is highly significant. This fails to include, however, other possible explanations, such as men being more likely to begin with a higher temperature and therefore having a higher ability to have their temperature lowered more.

7. Which group – those that are coded as `male == 0` or `male == 1` have better health outcomes in control? What about in treatment? How does this help to contextualize whatever heterogeneous treatment effect you might have estimated?

```
mod_5 <- lm(data=d, temperature_day14 ~ treat_zmapp + dehydrated_day0 + temperature_day0 + treat_zmapp*m
mod_5_coef = coeftest(mod_4,vcov=vcovHC(mod_4,type="HC1"))
mod_5_coef
```

```
##
## t test of coefficients:
##
##                    Estimate Std. Error  t value  Pr(>|t|)
## (Intercept)       48.712690   9.828279   4.9564 3.170e-06 ***
## treat_zmapp       -0.230866   0.114979  -2.0079   0.04753 *
```

```
## dehydrated_day0   0.041131   0.187341   0.2196   0.82670
## temperature_day0  0.504797   0.100759   5.0099 2.547e-06 ***
## male              3.085486   0.117866  26.1779 < 2.2e-16 ***
## treat_zmapp:male -2.076686   0.190818 -10.8831 < 2.2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

`Male == 0` have better health outcomes in control. The treatment effect is much more negative when including an interaction with "male", so male==1 has a better health outcome in treatment if we consider health outcome as treatment effect here. The treatment seems to work better for males, but this could have to do with something other than a different treatment effect. Males start with a higher temperature, so we see a higher possibility for them to have their temperature lowered.

8. Suppose that you had not run the regression in part (7). Instead, you speak with a colleague to learn about heterogeneous treatment effects. This colleague has access to a non-anonymized version of the same dataset and reports that they looked at heterogeneous effects of the ZMapp treatment by each of 80 different covariates to examine whether each predicted the effectiveness of ZMapp on each of 20 different indicators of health. Across these regressions your colleague ran, the treatment's interaction with gender on the outcome of temperature is the only heterogeneous treatment effect that he found to be statistically significant. They reason that this shows the importance of gender for understanding the effectiveness of the drug, because nothing else seemed to indicate why it worked. Bolstering your colleague's confidence, after looking at the data, they also returned to his medical textbooks and built a theory about why ZMapp interacts with processes only present in men to cure. Another doctor, unfamiliar with the data, hears your colleague's theory and finds it plausible. How likely do you think it is ZMapp works especially well for curing Ebola in men, and why? (This question is conceptual can be answered without performing any computation.)

   While it is certainly possible that the drug works better for men, there are several other possible explanations. Men starting with a higher temperature before treatment, for example, would give a higher possibnility for the drug to lower temperature. It is possible that men take care of their health less well to begin with, or several other explanations. It would therefore be quite dangerous to assume that this is the case without further investigation. Furthermore, the medical theroy was based on seeing the statistical analysis, rather than a statistical test being done to confirm a hypothesis, which is concerning. Furthermore, it was discovered during a fishing expedition and not indpendently.

9. Now, imagine that your colleague's fishing expedition did not happen, but that you had tested this heterogeneous treatment effect, and only this heterogeneous treatment effect, of your own accord. Would you be more or less inclined to believe that the heterogeneous treatment effect really exists? Why?

   I would be more inclined to believe thatr the heterogenous treatment effect really exists because it was discovered with better statistics practices. I would still, however, be quite skeptical of the finding for the other reasons stated in question 8.

10. Now, imagine that your colleague's fishing expedition **did** happen, but that you on your own tested this and only this HTE, discover a positive result and conclude there is an effect. How does your colleague's behavior change the interpretation of your test? Does this seem fair or reasonable?

   If I tested this on my own, without knowing about their fishing expedition first, then my answer would be identical to my answer in question 9. This is fair and reasonable.