The effect of messages on vaccinations

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Contents


```
## The file expanding the aggregated data
wrkdat <- read_csv(file.path(DATA_DIR, "dat_indiv.csv"))
## This next makes an error in case the original data changed. Mostly to make us pay attention.
```

```r
stopifnot(nrow(wrkdat) == 158103)

## The latest file from Kevin
wrkdat2 <- read_csv(file.path(DATA_DIR, "final_data_one_line_per_individual.csv"))
nrow(wrkdat2)
```

```
[1] 158103
```

```r
stopifnot(nrow(wrkdat2) == 158103)
stopifnot(all(!is.na(wrkdat2$date_sent)))
## This next fails

wrkdat_design_tab <- with(wrkdat, table(date_sent, assigned_message, exclude = c()))
wrkdat2_design_tab <- with(wrkdat2, table(date_sent, assigned_message, exclude = c()))
stopifnot(all.equal(wrkdat_design_tab, wrkdat2_design_tab, exclude = c()))

wrkdat_outcomes_tab <- with(wrkdat, table(date_sent, is_vax_after_send))
wrkdat2_outcomes_tab <- with(wrkdat2, table(date_sent, is_vax_after_send))
stopifnot(all.equal(wrkdat_design_tab, wrkdat2_design_tab, exclude = c()))

## Add ZCTA data to wrkdat2:

zctadat <- read_csv(file.path(DEMO_DATA_DIR, "combined_demo_data_by_zcta.csv"))
```

```
Warning: Missing column names filled in: 'X1' [1]
```

```r
## The first column, auto-named to X1 is noise
zctadat$X1 <- NULL

zctadat <- zctadat %>% mutate(
  pct_any_blk = any_black_population / total_population,
  pct_hisp = hispanic_population / total_population,
  pct_dem = dem_vote / total_vote,
  pct_gop = gop_vote / total_vote,
  pct_vote = total_vote / total_population
)

## Any mismatch in ZCTA ids?
## using https://stackoverflow.com/questions/19797954/function-to-find-symmetric-difference-opposite-of-intersection-in-r
sym_diff2 <- function(a, b) unique(c(setdiff(a, b), setdiff(b, a)))
sym_diff2(unique(wrkdat2$zcta), unique(zctadat$zcta))
```

```
[1] "00000"
```

```r
## So some people with no ZCTA. We will address this in the supplementary analyses later
wrkdat3 <- left_join(wrkdat2, zctadat, by = "zcta")
stopifnot(nrow(wrkdat3) == nrow(wrkdat2))
## We will use wrkdat3 for the rest of the time
```

Design

This study randomly assigned 8 sms message types plus 1 control arm (no msg) (9 arms total) to roughly 160,000 (exactly 158,103) Rhode Islanders and recorded whether or not these people were vaccinated during the study period.

The randomization occurred each week and then, within arm, people were randomly assigned to a day on which they could be sent a text message. This nested randomization can be represented as complete randomization to one of 9 arms within each active day of the study. The table below, created by `with(wrkdat3, table(date_sent, assigned_message, exclude = c()))`, shows a pattern of assignment by day consistent with this idea — roughly equal numbers assigned per message condition per day within each iteration.

The experiment also involve adaptive randomization, and the Thompson sampling algorithm assigned more people to arm 6 in the final week, for example. A block-randomized experiment can often have variation in probabilities assigned to treatment, and the analysis of such an experiment thus is no different whether there are changes in assignment probabilities between blocks or not.

Data Setup

We drop observations assigned to be sent a message on June 15, 2021 because those messages were not sent and because people were assigned to that date at random.

```
wrkdat3 <- wrkdat3 %>%
  filter(date_sent < "2021-06-15") %>%
  droplevels()
stopifnot(nrow(wrkdat3) == 142428)
```

```
## Some recoding to make things nicer for coin etc..
## Also coin wants factor variables for the CMH tests (since those are test of independence of contingency tables)
wrkdat3$messageF <- factor(wrkdat3$assigned_message)
wrkdat3$vaccinated <- as.numeric(wrkdat3$is_vax_after_send)
wrkdat3$vaccinatedF <- factor(wrkdat3$vaccinated)

wrkdat3$vac_in_week <- as.numeric(wrkdat3$is_within_one_week_after_send)
wrkdat3$vac_in_weekF <- factor(wrkdat3$vac_in_week)

## Checking that vaccinated in week is a subset of vaccinated
with(wrkdat3, table(vac_in_weekF, vaccinatedF, exclude = c()))
```

```
            vaccinatedF
vac_in_weekF      0      1
           0 139684   1453
           1      0   1291
```

```
wrkdat3$date_sentF <- factor(wrkdat3$date_sent)
##  A new variable that records the "any message" versus "no message" contrast
wrkdat3$not_control <- as.numeric(wrkdat3$messageF != "message_0")
with(wrkdat3, table(messageF, not_control, exclude = c()))
```

```
           not_control
messageF        0     1
  message_0 11327     0
  message_1     0 10491
  message_2     0 12440
  message_3     0 11962
  message_4     0 10110
  message_5     0 15243
  message_6     0 47058
  message_7     0 12363
  message_8     0 11434
```

```
wrkdat3$not_controlF <- factor(wrkdat3$not_control)

## This next does not involve all possible dates, only those existing in the data:
unique(wrkdat3$date_sent)
```

```
 [1] "2021-06-03" "2021-06-08" "2021-05-26" "2021-06-11" "2021-06-10" "2021-06-02" "2021-05-28" "2021-06-14" "2021-06-04"
[10] "2021-05-27" "2021-06-09" "2021-06-07" "2021-05-25"
```

```
## Any missing dates will be assigned NA and the code will stop if any NA are detected
wrkdat3 <- wrkdat3 %>% mutate(iteration = case_when(
  date_sent <= "2021-05-28" ~ 1,
  date_sent >= "2021-06-02" & date_sent <= "2021-06-08" ~ 2,
  date_sent > "2021-06-08" ~ 3
))
stopifnot(any(!is.na(wrkdat3$iteration)))
## Inspect by hand
with(wrkdat3, table(date_sent, iteration, exclude = c()))
```

```
             iteration
date_sent         1     2     3
  2021-05-25 10003     0     0
  2021-05-26  9999     0     0
  2021-05-27  9999     0     0
  2021-05-28  9999     0     0
  2021-06-02     0  7941     0
  2021-06-03     0  7941     0
  2021-06-04     0  7948     0
  2021-06-07     0  7942     0
  2021-06-08     0  7937     0
  2021-06-09     0     0 15682
  2021-06-10     0     0 15679
  2021-06-11     0     0 15679
  2021-06-14     0     0 15679
```

Notice that assignment is consistent with complete randomization in iteration 1 (equal numbers assigned to each message that week). It diverges from uniform assignment in iteration 2 and 3 because we are using the ε-Thompson adaptive algorithm for assignment. Notice that within `iteration`, roughly equal numbers are allocated to each day within message type. This was also done at random, making this a study that can be treated as if it were block-randomized by day.

```
with(wrkdat3, table(iteration, assigned_message, exclude = c()))
```

```
         assigned_message
iteration message_0 message_1 message_2 message_3 message_4 message_5 message_6 message_7 message_8
        1      4445      4445      4445      4445      4444      4444      4444      4444      4444
        2      3494      3069      5647      5053      2414      8502      1990      5591      3949
        3      3388      2977      2348      2464      3252      2297     40624      2328      3041
```

```
with(wrkdat3, table(date_sentF, assigned_message, exclude = c()))
```

```
            assigned_message
date_sentF   message_0 message_1 message_2 message_3 message_4 message_5 message_6 message_7 message_8
  2021-05-25      1112      1112      1112      1112      1111      1111      1111      1111      1111
  2021-05-26      1111      1111      1111      1111      1111      1111      1111      1111      1111
  2021-05-27      1111      1111      1111      1111      1111      1111      1111      1111      1111
  2021-05-28      1111      1111      1111      1111      1111      1111      1111      1111      1111
  2021-06-02       699       616      1131      1010       485      1698       398      1117       787
  2021-06-03       697       611      1131      1010       481      1700       399      1122       790
  2021-06-04       699       616      1132      1011       485      1701       397      1118       789
  2021-06-07       698       612      1124      1011       482      1704       398      1121       792
  2021-06-08       701       614      1129      1011       481      1699       398      1113       791
  2021-06-09       847       745       587       616       813       575     10156       582       761
  2021-06-10       847       744       587       616       813       574     10156       582       760
  2021-06-11       847       744       587       616       813       574     10156       582       760
  2021-06-14       847       744       587       616       813       574     10156       582       760
```

```
## Message types
## 0. Control
## 1. Ownership (baseline prompt)
## 2. Safety
## 3. Pros of vaccination (implicit choice): no hospitals
## 4. Epistemic humility + pros of vaccination (implicit choice): no hospitals
## 5. Access
## 6. Family concern
## 7. Social proof
## 8. Social proof + family concern
```

```
with(wrkdat3, table(iteration, exclude = FALSE))
```

```
iteration
    1     2     3
40000 39709 62719
```

```
with(wrkdat3, table(date_sent, exclude = FALSE))
```

```
date_sent
2021-05-25 2021-05-26 2021-05-27 2021-05-28 2021-06-02 2021-06-03 2021-06-04 2021-06-07 2021-06-08 2021-06-09 2021-06-10 2021-06
     10003       9999       9999       9999       7941       7941       7948       7942       7937      15682      15679      15
2021-06-14
     15679
```

Weight Creation

A block-randomized study is a collection of mini-experiments. Overall tests and estimates involve some kind of combination of those block-level quantities, using weights to give larger and more informative blocks more weight and/or to target specific kinds of treatment effects. We pre-specified that we would use block-size weights because we know that these produce unbiased estimators. Right now, the `difference_in_means` command will use those estimators by default, but only for a comparison of two arms. To make things easier later on, we therefore create weights here to be used in our standard linear regression command (`lm_robust`) that we use for general estimation in randomized studies (because, in part, it uses randomization justified standard errors by default, and thus allows less typing than `lm`).

Here we add weights to the data set since each block (`date_sent` involved different assignments to treatment (actually it was each `iteration` but the sms were then divided at random into days for sending and we are then treating each moment of administering the treatment as a block).

I'm doing this slow to convince myself, and perhaps, others that (1) there are different ways to weight blocks and (2) that what we are seeing from the canned R commands with weights makes sense. During the weight creation we will be doing some analyses of the effects of the study, they are mainly to help us ensure that we creating the weights correctly. A cleaner analysis is below, under "Pre-specified analyses".

```r
## The two arm version:
## Creating the weights following the examples in the randomizr vignettes
block_m_each_bin <- with(wrkdat3, table(date_sentF, not_control, exclude = c()))
declared_randomization_twoarm <- declare_ra(blocks = wrkdat3$date_sentF, block_m = block_m_each_bin[, "1"])
wrkdat3$IPW_weight_bin <- 1 / obtain_condition_probabilities(declaration = declared_randomization_twoarm, assignment = wrkdat3$n
## unique(wrkdat3$IPW_weight_bin)
## Now doing this by hand, following Gerber and Green Chap 3 (creating regression weights to reflect block-size weighting)
wrkdat3 <- wrkdat3 %>%
  group_by(date_sentF) %>%
  mutate(
    nb = n(),
    p_not_control = mean(not_control),
    nbwt_bin = ifelse(not_control == 1, 1 / p_not_control, 1 / (1 - p_not_control)),
  ) %>%
  ungroup()

stopifnot(all.equal(wrkdat3$IPW_weight_bin, wrkdat3$nbwt_bin))

lm_bin0 <- difference_in_means(vaccinated ~ not_control, blocks = date_sentF, data = wrkdat3)
lm_bin1 <- lm_robust(vaccinated ~ not_control, data = wrkdat3, weights = nbwt_bin)
lm_bin2 <- lm_robust(vaccinated ~ not_control, data = wrkdat3, weights = IPW_weight_bin)
lm_bin1
```

```
            Estimate Std. Error t value  Pr(>|t|)  CI Lower CI Upper     DF
(Intercept)  0.02061   0.001312  15.711 1.406e-55  0.018038 0.023180 142426
not_control -0.00147   0.001366  -1.077 2.817e-01 -0.004147 0.001207 142426
```

```r
stopifnot(all.equal(lm_bin0$coef, lm_bin1$coef["not_control"]))
stopifnot(all.equal(lm_bin0$coef, lm_bin2$coef["not_control"]))

## Now for the precision weighted version
```

```
## lm_bin3 <- lm_robust(vaccinated~not_control,fixed_effects=~date_sentF,data=wrkdat3)
## lm_bin3
```

We cannot use `difference_of_means` for a multi-armed treatment, but we follow the same general approach:

```
### Multiple arm version
block_m_each <- with(wrkdat3, table(date_sentF, messageF, exclude = c()))
block_prob_each <- block_m_each / rowSums(block_m_each)
declared_randomization_multarm <- declare_ra(blocks = wrkdat3$date_sentF, block_m_each = block_m_each, conditions = sort(unique(
wrkdat3$IPW_weight_multarm <- 1 / obtain_condition_probabilities(declaration = declared_randomization_multarm, assignment = wrkd
## unique(wrkdat3$IPW_weight_multarm)

stopifnot(all.equal(sort(unique(1 / wrkdat3$IPW_weight_multarm)), sort(unique(block_prob_each))))

lm_multarm_ipw <- lm_robust(vaccinated ~ messageF, data = wrkdat3, weights = IPW_weight_multarm)
## lm1_mult_fe <- lm_robust(vaccinated~messageF,data=wrkdat3,fixed_effects=~date_sentF)
lm_multarm_ipw
```

```
                     Estimate Std. Error  t value  Pr(>|t|)  CI Lower  CI Upper     DF
(Intercept)        0.02060861   0.001312 15.71145 1.406e-55  0.018038 0.0231795 142419
messageFmessage_1 -0.00208199   0.001842 -1.13002 2.585e-01 -0.005693 0.0015291 142419
messageFmessage_2 -0.00002266   0.001898 -0.01194 9.905e-01 -0.003742 0.0036968 142419
messageFmessage_3  0.00232052   0.002012  1.15339 2.488e-01 -0.001623 0.0062638 142419
messageFmessage_4 -0.00222375   0.001863 -1.19395 2.325e-01 -0.005874 0.0014267 142419
messageFmessage_5  0.00015034   0.001886  0.07972 9.365e-01 -0.003546 0.0038467 142419
messageFmessage_6 -0.00260175   0.001719 -1.51333 1.302e-01 -0.005971 0.0007679 142419
messageFmessage_7 -0.00316289   0.001824 -1.73444 8.284e-02 -0.006737 0.0004113 142419
messageFmessage_8 -0.00012584   0.001844 -0.06826 9.456e-01 -0.003739 0.0034876 142419
```

```
## lm1_mult_fe

## Creating the weights by hand to verify understanding:
wrkdat3 <- wrkdat3 %>%
  group_by(date_sentF) %>%
  mutate(
    p_m_0 = mean(messageF == "message_0"),
    p_m_1 = mean(messageF == "message_1"),
    p_m_2 = mean(messageF == "message_2"),
    p_m_3 = mean(messageF == "message_3"),
    p_m_4 = mean(messageF == "message_4"),
    p_m_5 = mean(messageF == "message_5"),
    p_m_6 = mean(messageF == "message_6"),
    p_m_7 = mean(messageF == "message_7"),
    p_m_8 = mean(messageF == "message_8"),
    nbwt_mult = as.numeric(messageF == "message_0") / p_m_0 +
      as.numeric(messageF == "message_1") / p_m_1 +
      as.numeric(messageF == "message_2") / p_m_2 +
      as.numeric(messageF == "message_3") / p_m_3 +
      as.numeric(messageF == "message_4") / p_m_4 +
      as.numeric(messageF == "message_5") / p_m_5 +
      as.numeric(messageF == "message_6") / p_m_6 +
      as.numeric(messageF == "message_7") / p_m_7 +
      as.numeric(messageF == "message_8") / p_m_8
  ) %>%
  ungroup()
## Verify that the IPW weights using randomizr are the same as those we created by hand
stopifnot(all.equal(sort(unique(wrkdat3$IPW_weight_multarm)), sort(unique(wrkdat3$nbwt_mult))))
```

Now estimate effects by first aggregating to the block level and then weighting (this is just to check that we can get the same numbers as when we use `lm_robust` etc..):

```
wrkdat3_b <- wrkdat3 %>%
  group_by(date_sentF) %>%
  summarize(
    nb = n(),
    effect_1 = mean(vaccinated[messageF == "message_1"]) - mean(vaccinated[messageF == "message_0"]),
```

```r
    effect_2 = mean(vaccinated[messageF == "message_2"]) - mean(vaccinated[messageF == "message_0"]),
    effect_3 = mean(vaccinated[messageF == "message_3"]) - mean(vaccinated[messageF == "message_0"]),
    effect_4 = mean(vaccinated[messageF == "message_4"]) - mean(vaccinated[messageF == "message_0"]),
    effect_5 = mean(vaccinated[messageF == "message_5"]) - mean(vaccinated[messageF == "message_0"]),
    effect_6 = mean(vaccinated[messageF == "message_6"]) - mean(vaccinated[messageF == "message_0"]),
    effect_7 = mean(vaccinated[messageF == "message_7"]) - mean(vaccinated[messageF == "message_0"]),
    effect_8 = mean(vaccinated[messageF == "message_8"]) - mean(vaccinated[messageF == "message_0"]),
    effect_any_msg = mean(vaccinated[messageF != "message_0"]) - mean(vaccinated[messageF == "message_0"])
  )
## The ATE over all is just the weighted average of the block ATEs
simp_est <- wrkdat3_b %>% summarize(across(
  .cols = contains("effect"),
  .fns = function(x) {
    weighted.mean(x, w = nb)
  }
))
## Test the block-based algorithm itself
stopifnot(all.equal(with(wrkdat3_b, weighted.mean(x = effect_1, w = nb)), simp_est$effect_1))
stopifnot(all.equal(with(wrkdat3_b, weighted.mean(x = effect_6, w = nb)), simp_est$effect_6))

## Verifying that we get the same answer with explicit weighting (building up from the block-level estimates)
## versus regression weights
## The "any message" effect differs slightly but everything else is identical
rbind(by_hand = simp_est, by_lm = lm_multarm_ipw$coef[-1])
```

```
# A tibble: 2 x 9
  effect_1   effect_2 effect_3 effect_4 effect_5 effect_6 effect_7  effect_8 effect_any_msg
*    <dbl>      <dbl>    <dbl>    <dbl>    <dbl>    <dbl>    <dbl>     <dbl>          <dbl>
1 -0.00208 -0.0000227  0.00232 -0.00222 0.000150 -0.00260 -0.00316 -0.000126       -0.00147
2 -0.00208 -0.0000227  0.00232 -0.00222 0.000150 -0.00260 -0.00316 -0.000126       -0.00208
```

Ok. So, I'm satisfied with the regression weights as doing their job, and we can move on to basic descriptives and the pre-registered analyses using tools like `lm_robust`. Weighting the different blocks is implicit (and optimal from a statistical testing perspective) in `cmh_test`.

Basic Descriptions and Visualization

Here is a rough plot to show the proportions vaccinated by message by date plus binomial 95% confidence intervals for those proportions. These are not effects, just proportions. Each panel shows a gray vertical line at the proportion vaccinated in the control condition.

```
                                    mtypeF
mtype                                Control Ownership Safety Preventing bad outcomes Epistemic humility+no bad outcomes Access
  Access                                   0         0      0                       0                                  0     13
  Control                                 13         0      0                       0                                  0      0
  Epistemic humility+no bad outcomes       0         0      0                       0                                 13      0
  Family concern                           0         0      0                       0                                  0      0
  Ownership                                0        13      0                       0                                  0      0
  Preventing bad outcomes                  0         0      0                      13                                  0      0
  Safety                                   0         0     13                       0                                  0      0
  Social proof                             0         0      0                       0                                  0      0
  Social proof+family concern              0         0      0                       0                                  0      0
                                    mtypeF
mtype                                Family concern Social proof Social proof+family concern
  Access                                          0            0                           0
  Control                                         0            0                           0
  Epistemic humility+no bad outcomes              0            0                           0
  Family concern                                 13            0                           0
  Ownership                                       0            0                           0
  Preventing bad outcomes                         0            0                           0
  Safety                                          0            0                           0
  Social proof                                    0           13                           0
  Social proof+family concern                     0            0                          13
```

```
                                   messageF
mtype                               message_0 message_1 message_2 message_3 message_4 message_5 message_6 message_7 message_8
  Access                                    0         0         0         0         0        13         0         0         0
  Control                                  13         0         0         0         0         0         0         0         0
  Epistemic humility+no bad outcomes        0         0         0         0        13         0         0         0         0
  Family concern                            0         0         0         0         0         0        13         0         0
  Ownership                                 0        13         0         0         0         0         0         0         0
  Preventing bad outcomes                   0         0         0        13         0         0         0         0         0
  Safety                                    0         0        13         0         0         0         0         0         0
  Social proof                              0         0         0         0         0         0         0        13         0
  Social proof+family concern               0         0         0         0         0         0         0         0        13

                                   messageF
mtypeF                              message_0 message_1 message_2 message_3 message_4 message_5 message_6 message_7 message_8
  Control                                  13         0         0         0         0         0         0         0         0
  Ownership                                 0        13         0         0         0         0         0         0         0
  Safety                                    0         0        13         0         0         0         0         0         0
  Preventing bad outcomes                   0         0         0        13         0         0         0         0         0
  Epistemic humility+no bad outcomes        0         0         0         0        13         0         0         0         0
  Access                                    0         0         0         0         0        13         0         0         0
  Family concern                            0         0         0         0         0         0        13         0         0
  Social proof                              0         0         0         0         0         0         0        13         0
  Social proof+family concern               0         0         0         0         0         0         0         0        13
```

Proportion vaccinated by date and message arm (these are the point values in the above plot):

```
prop_vac_arr <- matrix(plotdat1$prop_vac,
  nrow = 13, byrow = TRUE,
  dimnames = list(sort(unique(as.character(plotdat1$date_sent))), sort(unique(plotdat1$messageF)))
)

zapsmall(prop_vac_arr, digits = 2)
```

```
           message_0 message_1 message_2 message_3 message_4 message_5 message_6 message_7 message_8
2021-05-25     0.045     0.032     0.046     0.045     0.029     0.055     0.031     0.027     0.037
2021-05-26     0.037     0.047     0.039     0.032     0.032     0.026     0.028     0.027     0.032
2021-05-27     0.027     0.023     0.038     0.030     0.029     0.030     0.033     0.030     0.032
2021-05-28     0.034     0.029     0.025     0.025     0.029     0.045     0.031     0.021     0.041
2021-06-02     0.020     0.021     0.026     0.027     0.025     0.016     0.020     0.020     0.025
2021-06-03     0.014     0.020     0.022     0.021     0.027     0.017     0.025     0.020     0.027
2021-06-04     0.017     0.013     0.017     0.018     0.023     0.016     0.015     0.023     0.020
2021-06-07     0.013     0.008     0.008     0.014     0.012     0.011     0.008     0.015     0.020
2021-06-08     0.027     0.021     0.013     0.015     0.017     0.019     0.018     0.018     0.016
2021-06-09     0.014     0.011     0.017     0.016     0.012     0.028     0.013     0.022     0.018
2021-06-10     0.011     0.011     0.009     0.021     0.011     0.014     0.012     0.014     0.011
2021-06-11     0.014     0.013     0.014     0.019     0.012     0.005     0.009     0.003     0.007
2021-06-14     0.011     0.008     0.010     0.019     0.004     0.002     0.008     0.003     0.005
```

Can we see any patterns in the extent to which any given message, sent any given day, elicited more vaccinations than control? Not really, each message was, in absolute terms, sometimes better than and sometimes worse than control. No message stands out for always being worse or better than control (and notice this little table weighs all days equally).

```
prop_diffs <- apply(prop_vac_arr, 2, function(x) {
  x - prop_vac_arr[, 1]
})

prop_diffs
```

```
           message_0  message_1  message_2  message_3  message_4  message_5   message_6 message_7   message_8
2021-05-25         0 -0.0125899  0.0008993  0.0000000 -0.0161611  0.0099415 -0.01436097 -0.017961 -0.00806034
2021-05-26         0  0.0099010  0.0018002 -0.0045005 -0.0054005 -0.0108011 -0.00900090 -0.009901 -0.00540054
2021-05-27         0 -0.0045005  0.0108011  0.0027003  0.0018002  0.0027003  0.00630063  0.002700  0.00540054
2021-05-28         0 -0.0054005 -0.0090009 -0.0090009 -0.0054005  0.0108011 -0.00360036 -0.013501  0.00630063
2021-06-02         0  0.0010753  0.0056124  0.0067041  0.0047137 -0.0041276  0.00007189 -0.000333  0.00538435
2021-06-03         0  0.0052927  0.0077571  0.0064449  0.0126798  0.0027116  0.01071545  0.006152  0.01223508
2021-06-04         0 -0.0041804 -0.0003829  0.0006368  0.0055130 -0.0007065 -0.00205403  0.006088  0.00311145
2021-06-07         0 -0.0047240 -0.0048869  0.0009537 -0.0004459 -0.0017437 -0.00535629  0.002271  0.00730804
```

```
2021-06-08         0 -0.0059315 -0.0138180 -0.0122673 -0.0104721 -0.0076809 -0.00951620 -0.009135 -0.01066924
2021-06-09         0 -0.0034294  0.0028681  0.0020661 -0.0018675  0.0136584 -0.00067809  0.008169  0.00422920
2021-06-10         0  0.0001270 -0.0021079  0.0104782  0.0004444  0.0033115  0.00128840  0.003120 -0.00009942
2021-06-11         0 -0.0007268 -0.0005390  0.0053129 -0.0018675 -0.0089412 -0.00491204 -0.010731 -0.00758870
2021-06-14         0 -0.0025612 -0.0004043  0.0088548 -0.0069357 -0.0088836 -0.00304401 -0.007189 -0.00536258
```

```
signs_prop_diffs <- sign(prop_diffs)

signs_prop_diffs
```

```
           message_0 message_1 message_2 message_3 message_4 message_5 message_6 message_7 message_8
2021-05-25         0        -1         1         0        -1         1        -1        -1        -1
2021-05-26         0         1         1        -1        -1        -1        -1        -1        -1
2021-05-27         0        -1         1         1         1         1         1         1         1
2021-05-28         0        -1        -1        -1        -1         1        -1        -1         1
2021-06-02         0         1         1         1         1        -1         1        -1         1
2021-06-03         0         1         1         1         1         1         1         1         1
2021-06-04         0        -1        -1         1         1        -1        -1         1         1
2021-06-07         0        -1        -1         1        -1        -1        -1         1         1
2021-06-08         0        -1        -1        -1        -1        -1        -1        -1        -1
2021-06-09         0        -1         1         1        -1         1        -1         1         1
2021-06-10         0         1        -1         1         1         1         1         1        -1
2021-06-11         0        -1        -1         1        -1        -1        -1        -1        -1
2021-06-14         0        -1        -1         1        -1        -1        -1        -1        -1
```

```
## Number of times greater than control
gt_control <- apply(signs_prop_diffs, 2, function(x) {
  sum(x > 0)
})
lt_control <- apply(signs_prop_diffs, 2, function(x) {
  sum(x < 0)
})

rbind(gt_control, lt_control)
```

```
           message_0 message_1 message_2 message_3 message_4 message_5 message_6 message_7 message_8
gt_control         0         4         6         9         5         6         4         6         7
lt_control         0         9         7         3         8         7         9         7         6
```

What about patterns in the extent to which one message was higher ranked in a given day? Not really, the average rank out of 9 messages is about 4,5 or 6 for each message across the days. The number of times that a message is lowest or highest ranked is not huge (out of 13 days): like less than 3 days out of 13 does one message appear worst or best.

```
prop_rank <- t(apply(prop_vac_arr, 1, function(x) {
  rank(x)
}))

prop_rank
```

```
           message_0 message_1 message_2 message_3 message_4 message_5 message_6 message_7 message_8
2021-05-25       6.5       4.0       8.0       6.5       2.0         9         3         1       5.0
2021-05-26       7.0       9.0       8.0       6.0       4.5         1         3         2       4.5
2021-05-27       2.0       1.0       9.0       5.0       3.0         5         8         5       7.0
2021-05-28       7.0       4.5       2.5       2.5       4.5         9         6         1       8.0
2021-06-02       3.0       5.0       8.0       9.0       6.0         1         4         2       7.0
2021-06-03       1.0       3.0       6.0       5.0       9.0         2         7         4       8.0
2021-06-04       5.0       1.0       4.0       6.0       8.0         3         2         9       7.0
2021-06-07       6.0       3.0       2.0       7.0       5.0         4         1         8       9.0
2021-06-08       9.0       8.0       1.0       2.0       4.0         7         5         6       3.0
2021-06-09       4.0       1.0       6.0       5.0       2.0         9         3         8       7.0
2021-06-10       3.0       4.0       1.0       9.0       5.0         8         6         7       2.0
2021-06-11       8.0       6.0       7.0       9.0       5.0         2         4         1       3.0
2021-06-14       8.0       6.0       7.0       9.0       3.0         1         5         2       4.0
```

```
apply(prop_rank, 2, mean)
```

```
message_0 message_1 message_2 message_3 message_4 message_5 message_6 message_7 message_8
```

```
    5.346     4.269     5.346     6.231     4.692     4.692     4.385     4.308     5.731
```

```r
apply(prop_rank, 2, function(x) {
  sum(x == min(x))
})
```

```
message_0 message_1 message_2 message_3 message_4 message_5 message_6 message_7 message_8
        1         3         2         1         2         3         1         3         1
```

```r
apply(prop_rank, 2, function(x) {
  sum(x == max(x))
})
```

```
message_0 message_1 message_2 message_3 message_4 message_5 message_6 message_7 message_8
        1         1         1         4         1         3         1         1         1
```

As a reminder about the sample sizes in each message and day:

```r
with(wrkdat3, table(date_sent, messageF, exclude = c()))
```

```
            messageF
date_sent    message_0 message_1 message_2 message_3 message_4 message_5 message_6 message_7 message_8
  2021-05-25      1112      1112      1112      1112      1111      1111      1111      1111      1111
  2021-05-26      1111      1111      1111      1111      1111      1111      1111      1111      1111
  2021-05-27      1111      1111      1111      1111      1111      1111      1111      1111      1111
  2021-05-28      1111      1111      1111      1111      1111      1111      1111      1111      1111
  2021-06-02       699       616      1131      1010       485      1698       398      1117       787
  2021-06-03       697       611      1131      1010       481      1700       399      1122       790
  2021-06-04       699       616      1132      1011       485      1701       397      1118       789
  2021-06-07       698       612      1124      1011       482      1704       398      1121       792
  2021-06-08       701       614      1129      1011       481      1699       398      1113       791
  2021-06-09       847       745       587       616       813       575     10156       582       761
  2021-06-10       847       744       587       616       813       574     10156       582       760
  2021-06-11       847       744       587       616       813       574     10156       582       760
  2021-06-14       847       744       587       616       813       574     10156       582       760
```

A figure with proportion vaccinated at all, and another with proportion vaccinated within a week.

```r
plotdat1$line_thick <- ifelse(plotdat1$messageF == "message_0", 2, 1)
plotdat1$control_msg <- plotdat1$messageF == "message_0"

g_prop_vac <- ggplot(plotdat1, aes(x = date_sent, y = prop_vac, group = mtypeF, color = mtypeF, size = control_msg)) +
  geom_point() +
  geom_line() +
  guides(color = guide_legend(title = "Message")) +
  scale_colour_brewer(type = "div") +
  ylab("Vaccinated by June 22") +
  xlab("Date Assigned Message") +
  scale_size_manual(values = c(0.5, 1.2), guide = "none") +
  scale_linetype_manual(values = c("solid", "dashed"), guide = "none") +
  theme_classic(base_family = "Open Sans") +
  theme(
    text = element_text(size = 16),
    axis.text.x = element_text(angle = 0, hjust = 1),
    legend.position = c(.6, 0.8)
  )

# g_prop_vac

g_prop_vac_smooth <- ggplot(plotdat1, aes(x = date_sent, y = prop_vac, group = mtypeF, color = mtypeF, size = control_msg)) +
  geom_point() +
  geom_smooth(se = FALSE, method = "loess", span = 2 / 3, method.args = list(degree = 1, family = "symmetric")) +
  guides(color = guide_legend(title = "Message")) +
  scale_colour_brewer(type = "div") +
  ylab("Vaccinated by June 22") +
  xlab("Date Assigned Message") +
  scale_size_manual(values = c(0.5, 1.2), guide = "none") +
  scale_linetype_manual(values = c("solid", "dashed"), guide = "none") +
```

```r
  theme_classic(base_family = "Open Sans") +
  theme(
    text = element_text(size = 16),
    axis.text.x = element_text(angle = 0, hjust = 1),
    legend.position = c(.6, 0.8)
  )

# g_prop_vac_smooth

## Trying to break lines in between iterations. Not working well.
## blah <- tidyr::complete(plotdat1, date_sent = seq(min(date_sent), max(date_sent), by = "day"))

g_prop_vac_in_week <- ggplot(plotdat1, aes(x = date_sent, y = prop_vac_in_week, group = mtypeF, color = mtypeF, size = control_m
  geom_point() +
  geom_path() +
  # facet_wrap(~iteration,scales="free")+
  guides(color = guide_legend(title = "Message")) +
  scale_colour_brewer(type = "div") +
  ylab("Vaccinated within a Week of Message Assignment") +
  xlab("Date Assigned Message") +
  scale_size_manual(values = c(0.5, 1.2), guide = "none") +
  scale_linetype_manual(values = c("solid", "dashed"), guide = "none") +
  theme_classic(base_family = "Open Sans") +
  theme(
    text = element_text(size = 16),
    axis.text.x = element_text(angle = 0, hjust = 1)
  )

# g_prop_vac_in_week

g_prop_vac_smooth_in_week <- ggplot(plotdat1, aes(x = date_sent, y = prop_vac_in_week, group = mtypeF, color = mtypeF, size = co
  geom_point() +
  geom_smooth(se = FALSE, method = "loess", span = 2 / 3, method.args = list(degree = 1, family = "symmetric")) +
  guides(color = guide_legend(title = "Message")) +
  ylab("Vaccinated within a Week of Message Assignment") +
  xlab("Date Assigned Message") +
  # geom_vline(xintercept=as.Date(c("2021-05-31","2021-06-08")))+
  scale_size_manual(values = c(0.5, 1.2), guide = "none") +
  scale_colour_brewer(type = "div") +
  scale_linetype_manual(values = c("solid", "dashed"), guide = "none") +
  theme_classic(base_family = "Open Sans") +
  theme(
    text = element_text(size = 16),
    axis.text.x = element_text(angle = 0, hjust = 1)
  )

# g_prop_vac_smooth_in_week

ggsave(file = "prop_vac.png", path = OUTPUT_DIR, plot = g_prop_vac, type = "cairo-png", dpi = 300)
ggsave(file = "prop_vac_in_week.png", path = OUTPUT_DIR, plot = g_prop_vac_in_week, type = "cairo-png", dpi = 300)
ggsave(file = "prop_vac_smooth.png", path = OUTPUT_DIR, plot = g_prop_vac_smooth, type = "cairo-png", dpi = 300)
ggsave(file = "prop_vac_smooth_in_week.png", path = OUTPUT_DIR, plot = g_prop_vac_smooth_in_week, type = "cairo-png", dpi = 300)
```

Pre-specified analyses

These analyses were registered at https://osf.io/pkhae/.

RQ0: Is there any effect of condition assignment?

The following suggests that we have some evidence of differences among the messages:

```r
## This is the asymptotic approx to the randomization inference
rq0_asym <- cmh_test(vaccinatedF ~ messageF | date_sentF, data = wrkdat3, distribution = asymptotic())
```

```r
## This next is the permutation approx to the randomization inference
set.seed(12345)
rq0_perm <- cmh_test(vaccinatedF ~ messageF | date_sentF, data = wrkdat3, distribution = approximate(nresample = 10000, paralle

rq0_asym
```

```
    Asymptotic Generalized Cochran-Mantel-Haenszel Test

data:  vaccinatedF by
     messageF (message_0, message_1, message_2, message_3, message_4, message_5, message_6, message_7, message_8)
     stratified by date_sentF
chi-squared = 13, df = 8, p-value = 0.1
```

```r
rq0_perm
```

```
    Approximative Generalized Cochran-Mantel-Haenszel Test

data:  vaccinatedF by
     messageF (message_0, message_1, message_2, message_3, message_4, message_5, message_6, message_7, message_8)
     stratified by date_sentF
chi-squared = 13, p-value = 0.1
```

```r
pvalue(rq0_asym)
```

```
[1] 0.1153
```

```r
thetab <- with(wrkdat3, table(messageF, vaccinatedF, date_sentF))

rq0a <- mantelhaen.test(thetab)
rq0a
```

```
    Cochran-Mantel-Haenszel test

data:  thetab
Cochran-Mantel-Haenszel M^2 = 13, df = 8, p-value = 0.1
```

RQ1: Is there an effect of receiving a message as opposed to not receiving a message?

The below shows little evidence of effect of "any message" versus "control".

```r
rq1_asym <- cmh_test(vaccinatedF ~ not_controlF | date_sentF, data = wrkdat3, distribution = asymptotic())
rq1_perm <- cmh_test(vaccinatedF ~ not_controlF | date_sentF, data = wrkdat3, distribution = approximate(nresample = 10000, para

rq1_asym
```

```
    Asymptotic Generalized Cochran-Mantel-Haenszel Test

data:  vaccinatedF by not_controlF (0, 1)
     stratified by date_sentF
chi-squared = 1.2, df = 1, p-value = 0.3
```

```r
rq1_perm
```

```
    Approximative Generalized Cochran-Mantel-Haenszel Test

data:  vaccinatedF by not_controlF (0, 1)
     stratified by date_sentF
chi-squared = 1.2, p-value = 0.3
```

```r
pvalue(rq1_asym)
```

```
[1] 0.2663
```

We can show the estimated difference in proportion here:

```r
rq1_est <- difference_in_means(vaccinated ~ not_controlF, blocks = date_sentF, data = wrkdat3)
rq1_est
```

```
Design:  Blocked
             Estimate Std. Error t value Pr(>|t|)  CI Lower CI Upper     DF
not_controlF -0.00147   0.001363  -1.079   0.2806 -0.004141 0.001201 142402
```

```r
rq1_week_est <- difference_in_means(vaccinated ~ not_controlF, blocks = iteration, data = wrkdat3)
rq1_week_est
```

```
Design:  Blocked
              Estimate Std. Error t value Pr(>|t|)  CI Lower CI Upper     DF
not_controlF -0.001473   0.001363  -1.081   0.2797 -0.004145 0.001198 142422
```

```r
lm_bin0 <- difference_in_means(vaccinated ~ not_control, blocks = date_sentF, data = wrkdat3)
lm_bin1 <- lm_robust(vaccinated ~ not_control, data = wrkdat3, weights = nbwt_bin)
lm_bin2 <- lm_robust(vaccinated ~ not_control, data = wrkdat3, weights = IPW_weight_bin)
lm_bin1
```

```
            Estimate Std. Error t value  Pr(>|t|)  CI Lower CI Upper     DF
(Intercept)  0.02061   0.001312  15.711 1.406e-55  0.018038 0.023180 142426
not_control -0.00147   0.001366  -1.077 2.817e-01 -0.004147 0.001207 142426
```

```r
stopifnot(all.equal(lm_bin0$coef, lm_bin1$coef["not_control"]))
stopifnot(all.equal(lm_bin0$coef, lm_bin2$coef["not_control"]))
stopifnot(all.equal(lm_bin0$coef[[1]], rq1_est$coef[["not_controlF"]]))

## Proportion vaccinated by end in the "not control" combination condition
sum(coef(lm_bin1))
```

```
[1] 0.01914
```

RQ2: Does any given message differ from control (focal tests)?

Overall, we have approx 2% of the control group getting vaccinated (weighted average across the days), and very small differences from that rate for each message — all less than 1/3 pct point different in magnitude from the control group.

```r
rq2_est <- lm_robust(vaccinated ~ messageF, weights = IPW_weight_multarm, data = wrkdat3)
rq2_est
```

```
                    Estimate Std. Error  t value  Pr(>|t|)  CI Lower  CI Upper     DF
(Intercept)       0.02060861   0.001312 15.71145 1.406e-55  0.018038 0.0231795 142419
messageFmessage_1 -0.00208199   0.001842 -1.13002 2.585e-01 -0.005693 0.0015291 142419
messageFmessage_2 -0.00002266   0.001898 -0.01194 9.905e-01 -0.003742 0.0036968 142419
messageFmessage_3  0.00232052   0.002012  1.15339 2.488e-01 -0.001623 0.0062638 142419
messageFmessage_4 -0.00222375   0.001863 -1.19395 2.325e-01 -0.005874 0.0014267 142419
messageFmessage_5  0.00015034   0.001886  0.07972 9.365e-01 -0.003546 0.0038467 142419
messageFmessage_6 -0.00260175   0.001719 -1.51333 1.302e-01 -0.005971 0.0007679 142419
messageFmessage_7 -0.00316289   0.001824 -1.73444 8.284e-02 -0.006737 0.0004113 142419
messageFmessage_8 -0.00012584   0.001844 -0.06826 9.456e-01 -0.003739 0.0034876 142419
```

```r
## In percentage point differences from messsage_0 (except for Intercept which is proportion vaccinated (on average, weighted by
zapsmall(rq2_est$coef * 100)
```

```
      (Intercept) messageFmessage_1 messageFmessage_2 messageFmessage_3 messageFmessage_4 messageFmessage_5 messageFmessage_6
           2.0609           -0.2082           -0.0023            0.2321           -0.2224            0.0150           -0.2602
messageFmessage_7 messageFmessage_8
          -0.3163           -0.0126
```

```r
## Adding the fixed effects estimates (biased, but more precise/statistically powerful)
rq2_fe_est <- lm_robust(vaccinated ~ messageF, fixed_effects = ~date_sentF, data = wrkdat3)
rq2_fe_est
```

```
                    Estimate Std. Error t value Pr(>|t|)  CI Lower  CI Upper     DF
messageFmessage_1 -0.0022322   0.002007 -1.1125  0.26595 -0.006165 0.0017006 142407
messageFmessage_2 -0.0002051   0.001966 -0.1044  0.91688 -0.004058 0.0036474 142407
messageFmessage_3  0.0005308   0.002000  0.2654  0.79071 -0.003390 0.0044514 142407
messageFmessage_4 -0.0029133   0.002013 -1.4469  0.14792 -0.006860 0.0010330 142407
messageFmessage_5 -0.0006247   0.001874 -0.3334  0.73881 -0.004297 0.0030474 142407
messageFmessage_6 -0.0027722   0.001567 -1.7690  0.07689 -0.005844 0.0002992 142407
```

```
messageFmessage_7 -0.0034071   0.001902 -1.7915  0.07321 -0.007135 0.0003204 142407
messageFmessage_8  0.0004312   0.002011  0.2144  0.83020 -0.003510 0.0043723 142407
```

The unadjusted tests tests of independence of each message versus control using permutation approximations to the randomization inference and the Cochrane-Mantel-Haenszel test for 2x2xK experiments show no differences between any message and control at $\alpha = .05$.

```r
test_msgs <- function(msg1, msg2) {
  ## msg1 and msg2 are strings indicating message assignment in messageF
  effect_test <- cmh_test(vaccinatedF ~ messageF | date_sentF,
    data = wrkdat3,
    subset = wrkdat3$messageF %in% c(msg1, msg2),
    distribution = approximate(nresample = 10000, parallel = "multicore", ncpu = 6)
  )
  return(pvalue(effect_test)[1])
}

message_test_ps <- sapply(levels(wrkdat3$messageF)[-1], function(msg) {
  test_msgs("message_0", msg)
})

message_test_ps
```

```
message_1 message_2 message_3 message_4 message_5 message_6 message_7 message_8
   0.2731    1.0000    0.6918    0.1839    0.9351    0.0976    0.0513    0.8961
```

We specified that we would report adjusted p-values, although it is hardly necessary since we are not reporting any discoveries.

The FDR adjustments (direct and q-values):

```r
cbind(message_test_ps, fdr_adjusted = p.adjust(message_test_ps, method = "fdr"))
```

```
          message_test_ps fdr_adjusted
message_1          0.2731       0.5462
message_2          1.0000       1.0000
message_3          0.6918       1.0000
message_4          0.1839       0.4904
message_5          0.9351       1.0000
message_6          0.0976       0.3904
message_7          0.0513       0.3904
message_8          0.8961       1.0000
```

Here are the q-values (same as the "adjusted p-values" above) (not clearly worth diving into since we have no effects but including a link to an explanation here https://www.bioconductor.org/packages/devel/bioc/vignettes/qvalue/inst/doc/qvalue.pdf)

```r
library(qvalue)
rq2_qvals <- qvalue(message_test_ps, lambda = seq(0.05, 0.65, 0.05))
rq2_qvals$qvalues
```

```
message_1 message_2 message_3 message_4 message_5 message_6 message_7 message_8
   0.5462    1.0000    1.0000    0.4904    1.0000    0.3904    0.3904    1.0000
```

A figure showing the results from rq2 estimation with 95% confidence intervals.

```r
rq2plot_dat <- tidy(rq2_est)

rq2plot_dat$term <- c("Control", paste("M", 1:8, " v Ctrl", sep = ""))

rq2plot_dat$mtype <- c("Control", "Ownership", "Safety", "Preventing bad outcomes", "Epistemic humility+no bad outcomes", "Acces

rq2plot_dat <- rq2plot_dat %>%
  filter(term != "Control") %>%
  arrange(estimate)
rq2plot_dat$termF <- factor(rq2plot_dat$term, levels = rq2plot_dat$term)
```

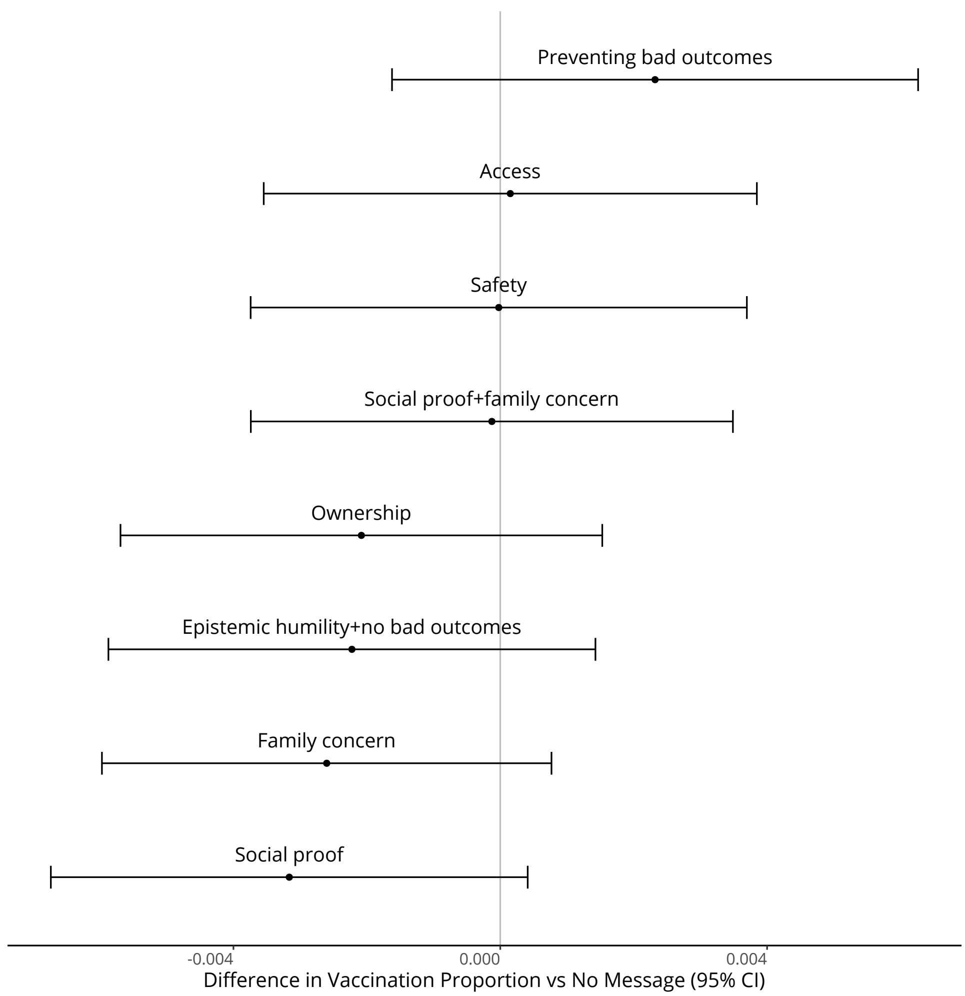
```r
rq2xlim <- range(c(rq2plot_dat$conf.low, rq2plot_dat$conf.high))

rq2plot <- ggplot(rq2plot_dat, aes(x = estimate, y = termF)) +
  geom_vline(aes(xintercept = 0), color = "grey") +
  geom_point() +
  geom_errorbarh(mapping = aes(xmin = conf.low, xmax = conf.high), height = .2) +
  xlab("Difference in Vaccination Proportion vs No Message (95% CI)") +
  geom_text(aes(label = mtype), check_overlap = TRUE, nudge_y = .2, family = "Open Sans", size = 4.5) +
  ylab("") +
  theme_classic(base_family = "Open Sans") +
  xlim(rq2xlim) +
  theme(
    text = element_text(size = 13),
    axis.line.y = element_blank(),
    axis.text.y = element_blank(),
    axis.ticks.y = element_blank(),
    axis.text.x = element_text(angle = 0, hjust = 1)
  )

# print(rq2plot)
```

```r
ggsave(file = "rq2plot.pdf", path = OUTPUT_DIR, plot = rq2plot, device = cairo_pdf)
ggsave(file = "rq2plot.png", path = OUTPUT_DIR, plot = rq2plot, type = "cairo-png", dpi = 300)
```

```r
include_graphics(here(OUTPUT_DIR, "rq2plot.pdf"))
```



RQ3: Does epistemic humility help?

Message 4 vs. 3 (CMH test, difference of proportions estimator). Only very small differences between those two arms.

```
rq3_est <- difference_in_means(vaccinated ~ messageF, blocks = date_sent, data = wrkdat3, subset = wrkdat3$messageF %in% c("mess
rq3_est
```

```
Design:  Blocked
                   Estimate Std. Error t value Pr(>|t|) CI Lower  CI Upper    DF
messageFmessage_4 -0.003194   0.002074   -1.54   0.1235 -0.00726 0.0008707 22046
```

```
rq3_test <- test_msgs("message_3", "message_4")
rq3_test
```

```
[1] 0.1071
```

RQ5: How do social proof and appeals to the family interact?

We will test the overall hypothesis of no difference between 6 (family concern), 7 (social proof), and 8 (family concern + social proof). If we reject this, we test 6 versus 8 and 7 versus 8.

```
rq5_overall <- cmh_test(vaccinatedF ~ messageF | date_sentF, data = wrkdat3, subset = wrkdat3$messageF %in% c("message_6", "mess
rq5_overall_perm <- cmh_test(vaccinatedF ~ messageF | date_sentF, data = wrkdat3, subset = wrkdat3$messageF %in% c("message_6",
rq5_overall
```

```
    Asymptotic Generalized Cochran-Mantel-Haenszel Test

data:  vaccinatedF by
     messageF (message_6, message_7, message_8)
     stratified by date_sentF
chi-squared = 5.1, df = 2, p-value = 0.08
```

```
rq5_overall_perm
```

```
    Approximative Generalized Cochran-Mantel-Haenszel Test

data:  vaccinatedF by
     messageF (message_6, message_7, message_8)
     stratified by date_sentF
chi-squared = 5.1, p-value = 0.08
```

So, since we have a marginal rejection, we do the other tests. The differences are still quite small.

```
test_msgs("message_6", "message_7")
```

```
[1] 0.5697
```

```
test_msgs("message_6", "message_8")
```

```
[1] 0.1693
```

```
test_msgs("message_7", "message_8")
```

```
[1] 0.0285
```

```
rq_5a_est <- difference_in_means(vaccinated ~ messageF, blocks = date_sent, data = wrkdat3, subset = wrkdat3$messageF %in% c("me
rq_5b_est <- difference_in_means(vaccinated ~ messageF, blocks = date_sent, data = wrkdat3, subset = wrkdat3$messageF %in% c("me
rq_5c_est <- difference_in_means(vaccinated ~ messageF, blocks = date_sent, data = wrkdat3, subset = wrkdat3$messageF %in% c("me

rq_5a_est
```

```
Design:  Blocked
                    Estimate Std. Error t value Pr(>|t|)  CI Lower CI Upper    DF
messageFmessage_7 -0.0002589   0.001726   -0.15   0.8807 -0.003642 0.003124 59395
```

```
rq_5b_est
```

```
Design:  Blocked
                   Estimate Std. Error t value Pr(>|t|)  CI Lower CI Upper    DF
messageFmessage_8 0.0009202   0.001569  0.5863   0.5577 -0.002156 0.003996 58466
```

```r
rq_5c_est
```

```
Design:  Blocked
                  Estimate Std. Error t value Pr(>|t|)  CI Lower CI Upper    DF
messageFmessage_8 0.004312   0.001919   2.247  0.02463 0.0005511 0.008073 23771
```

RQ6: Did adaptive randomization increase vaccinations over fixed randomization?

We also will report the effect of using adaptive randomization versus fixed randomization on total vaccinations — since we withheld 25% of each of the three weeks experimental pools for fixed randomization and adapted the other 100 – 25%. Our aim in this study was to (1) learn about which messages worked best but also (2) increase vaccination. The fixed randomization maximized statistical power to detect effects whereas the adaptive randomization increased the numbers of people exposed to more effective messages.

It looks like slightly more people were vaccinated in the non-adaptive arm of the study.

```r
with(wrkdat3, table(date_sent, is_chosen_from_uniform, exclude = c()))
```

```
            is_chosen_from_uniform
date_sent    FALSE  TRUE
  2021-05-25     0 10003
  2021-05-26     0  9999
  2021-05-27     0  9999
  2021-05-28     0  9999
  2021-06-02  5947  1994
  2021-06-03  5969  1972
  2021-06-04  5919  2029
  2021-06-07  5933  2009
  2021-06-08  5988  1949
  2021-06-09 10437  5245
  2021-06-10 10503  5176
  2021-06-11 10501  5178
  2021-06-14 10499  5180
```

```r
rq6_est <- difference_in_means(vaccinated ~ is_chosen_from_uniform, blocks = date_sentF, data = wrkdat3, subset = wrkdat3$date_s
rq6_est
```

```
Design:  Blocked
                        Estimate Std. Error t value Pr(>|t|)   CI Lower CI Upper     DF
is_chosen_from_uniform 0.0009958  0.0008211   1.213   0.2252 -0.0006135 0.002605 102410
```

```r
rq6_cmh_perm <- cmh_test(vaccinatedF ~ factor(is_chosen_from_uniform) | date_sentF, data = wrkdat3, subset = wrkdat3$date_sent >
rq6_cmh_perm
```

```
    Approximative Generalized Cochran-Mantel-Haenszel Test

data:  vaccinatedF by
     factor(is_chosen_from_uniform) (FALSE, TRUE)
     stratified by date_sentF
chi-squared = 1.5, p-value = 0.2
```

Exploratory Analyses Not Pre-registered

Effects on vaccination within a week

The experiment ran during a time of national campaigns in favor of vaccination. The control group in our experiment would have been exposed to this, and thus, might have gotten vaccinated for reasons other than a nudge from a text message.

No strong evidence that people were likely to be vaccinated within a week in "any message" versus control or versus any given message.

```
rq7_test <- cmh_test(vac_in_weekF ~ not_controlF | date_sentF, data = wrkdat3)
rq7_test
```

```
    Asymptotic Generalized Cochran-Mantel-Haenszel Test

data:  vac_in_weekF by not_controlF (0, 1)
     stratified by date_sentF
chi-squared = 0.00041, df = 1, p-value = 1
```

```
rq7a_test <- cmh_test(vac_in_weekF ~ messageF | date_sentF, data = wrkdat3)
rq7a_test
```

```
    Asymptotic Generalized Cochran-Mantel-Haenszel Test

data:  vac_in_weekF by
     messageF (message_0, message_1, message_2, message_3, message_4, message_5, message_6, message_7, message_8)
     stratified by date_sentF
chi-squared = 8.7, df = 8, p-value = 0.4
```

```
rq7a_est <- lm_robust(vac_in_week ~ messageF, weights = IPW_weight_multarm, data = wrkdat3)
rq7a_est
```

```
                      Estimate Std. Error   t value  Pr(>|t|)   CI Lower CI Upper     DF
(Intercept)        0.009127748  0.0009266  9.851260 6.884e-23  0.0073117 0.010944 142419
messageFmessage_1  0.000124368  0.0013438  0.092548 9.263e-01 -0.0025095 0.002758 142419
messageFmessage_2  0.000262444  0.0013718  0.191314 8.483e-01 -0.0024263 0.002951 142419
messageFmessage_3  0.002280338  0.0014842  1.536381 1.244e-01 -0.0006287 0.005189 142419
messageFmessage_4 -0.001289688  0.0012946 -0.996239 3.191e-01 -0.0038270 0.001248 142419
messageFmessage_5 -0.000005737  0.0013428 -0.004273 9.966e-01 -0.0026376 0.002626 142419
messageFmessage_6 -0.000254321  0.0011945 -0.212902 8.314e-01 -0.0025956 0.002087 142419
messageFmessage_7 -0.000963766  0.0013199 -0.730162 4.653e-01 -0.0035508 0.001623 142419
messageFmessage_8  0.000933308  0.0013295  0.702014 4.827e-01 -0.0016724 0.003539 142419
```

```
rq7plot_dat <- tidy(rq7a_est)

rq7plot_dat$term <- c("Control", paste("M", 1:8, " v Ctrl", sep = ""))

rq7plot_dat$mtype <- c("Control", "Ownership", "Safety", "Preventing bad outcomes", "Epistemic humility+no bad outcomes", "Acces

rq7plot_dat <- rq7plot_dat %>% filter(term != "Control")
rq7plot_dat$termF <- factor(rq7plot_dat$term, levels = rq2plot_dat$term)
with(rq7plot_dat, table(term, termF, exclude = c()))
```

```
           termF
term         M7 v Ctrl M6 v Ctrl M4 v Ctrl M1 v Ctrl M8 v Ctrl M2 v Ctrl M5 v Ctrl M3 v Ctrl
  M1 v Ctrl          0         0         0         1         0         0         0         0
  M2 v Ctrl          0         0         0         0         0         1         0         0
  M3 v Ctrl          0         0         0         0         0         0         0         1
  M4 v Ctrl          0         0         1         0         0         0         0         0
  M5 v Ctrl          0         0         0         0         0         0         1         0
  M6 v Ctrl          0         1         0         0         0         0         0         0
  M7 v Ctrl          1         0         0         0         0         0         0         0
  M8 v Ctrl          0         0         0         0         1         0         0         0
```

```
rq7plot <- ggplot(rq7plot_dat, aes(x = estimate, y = termF)) +
  geom_vline(aes(xintercept = 0), color = "grey") +
  geom_point() +
```

```r
  geom_errorbarh(mapping = aes(xmin = conf.low, xmax = conf.high), height = .2) +
  xlab("Difference in Vaccination Proportion vs No Message within a Week (95% CI)") +
  geom_text(aes(label = mtype), check_overlap = TRUE, nudge_y = .2, family = "Open Sans", size = 4.5) +
  ylab("") +
  theme_classic(base_family = "Open Sans") +
  xlim(rq2xlim) +
  theme(
    text = element_text(size = 13),
    axis.line.y = element_blank(),
    axis.text.y = element_blank(),
    axis.ticks.y = element_blank(),
    axis.text.x = element_text(angle = 0, hjust = 1)
  )

# print(rq7plot)
```

```r
ggsave(file = "rq7plot.pdf", path = OUTPUT_DIR, plot = rq7plot, device = cairo_pdf)
ggsave(file = "rq7plot.png", path = OUTPUT_DIR, plot = rq7plot, type = "cairo-png", dpi = 300)
```

```r
rq2_rq7_plot <- ggarrange(rq2plot, rq7plot, nrow = 1)
```

```
Warning in grid.Call(C_stringMetric, as.graphicsAnnot(x$label)): font family 'Open Sans' not found in PostScript font database

Warning in grid.Call(C_stringMetric, as.graphicsAnnot(x$label)): font family 'Open Sans' not found in PostScript font database

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Warning in grid.Call(C_stringMetric, as.graphicsAnnot(x$label)): font family 'Open Sans' not found in PostScript font database

Warning in grid.Call(C_stringMetric, as.graphicsAnnot(x$label)): font family 'Open Sans' not found in PostScript font database

Warning in grid.Call(C_stringMetric, as.graphicsAnnot(x$label)): font family 'Open Sans' not found in PostScript font database

Warning in grid.Call(C_stringMetric, as.graphicsAnnot(x$label)): font family 'Open Sans' not found in PostScript font database
```

```
Warning in grid.Call(C_stringMetric, as.graphicsAnnot(x$label)): font family 'Open Sans' not found in PostScript font database

Warning in grid.Call(C_stringMetric, as.graphicsAnnot(x$label)): font family 'Open Sans' not found in PostScript font database

Warning in grid.Call(C_stringMetric, as.graphicsAnnot(x$label)): font family 'Open Sans' not found in PostScript font database

Warning in grid.Call(C_stringMetric, as.graphicsAnnot(x$label)): font family 'Open Sans' not found in PostScript font database
```

```
# print(rq2_rq7_plot)

ggsave(file = "rq2_rq7_plot.pdf", path = OUTPUT_DIR, plot = rq2_rq7_plot, device = cairo_pdf, width = 12, height = 6)
ggsave(file = "rq2_rq7_plot.png", path = OUTPUT_DIR, plot = rq2_rq7_plot, type = "cairo-png", dpi = 300, width = 12, height = 6)
```

Each iteration separately

We looked at both overall vaccination and vaccination within a week (only available for those assigned in the first week). The following table shows that we have no strong arguments against the claim that our messages were the same as control in regards either outcome. (Not adjusting p-values here because this is exploratory work and because we have so few small p-values).

```
test_msgs2 <- function(msg1, msg2, the_iteration, thefmla = vaccinatedF ~ messageF | date_sentF) {
  ## msg1 and msg2 are strings indicating message assignment in messageF
  effect_test <- cmh_test(thefmla,
    data = wrkdat3,
    subset = wrkdat3$messageF %in% c(msg1, msg2) & wrkdat3$iteration == the_iteration,
    distribution = asymptotic() # approximate(nresample = 10000, parallel = "multicore", ncpu = 6)
  )
  return(pvalue(effect_test)[1])
}

msg_by_iteration <- as_tibble(expand.grid(iteration = 1:3, messageF = levels(wrkdat3$messageF)[-1], stringsAsFactors = FALSE))

test_msgs2(msg1 = "message_0", msg2 = msg_by_iteration$messageF[1], the_iteration = 3)
```

```
[1] 0.5406
```

```
set.seed(12345)
msg_by_iteration <- msg_by_iteration %>%
  rowwise() %>%
  mutate(p_vs_ctrl = test_msgs2("message_0", messageF, iteration)) %>%
  arrange(iteration, messageF)

msg_by_iteration <- msg_by_iteration %>%
  rowwise() %>%
  mutate(p_vac_week_vs_ctrl = test_msgs2("message_0", messageF, iteration, thefmla = vac_in_weekF ~ messageF | date_sentF))

msg_by_iteration <- msg_by_iteration %>% mutate(p_vac_week_vs_ctrl = ifelse(p_vac_week_vs_ctrl == p_vs_ctrl, NA, p_vac_week_vs_c
print(msg_by_iteration, n = 100)
```

```
# A tibble: 24 x 4
# Rowwise:
   iteration messageF  p_vs_ctrl p_vac_week_vs_ctrl
       <int> <chr>         <dbl>              <dbl>
 1         1 message_1   0.414              0.624
 2         1 message_2   0.777              0.776
 3         1 message_3   0.485              0.554
 4         1 message_4   0.0950             0.151
 5         1 message_5   0.432              0.999
 6         1 message_6   0.174              0.368
 7         1 message_7   0.00849            0.185
 8         1 message_8   0.911              0.458
 9         2 message_1   0.601              0.188
10         2 message_2   0.685              0.655
11         2 message_3   0.870              0.127
```

```
12         2 message_4   0.510               0.215
13         2 message_5   0.369               0.357
14         2 message_6   0.741               0.250
15         2 message_7   0.732               0.298
16         2 message_8   0.289               0.0548
17         3 message_1   0.541               0.731
18         3 message_2   0.988               0.893
19         3 message_3   0.0394              0.127
20         3 message_4   0.321               0.203
21         3 message_5   0.944               0.680
22         3 message_6   0.318               0.517
23         3 message_7   0.567               0.523
24         3 message_8   0.405               0.469
```

Nor is there strong evidence that "any message" was better than control, even when we assess the relationships for each iteration separately:

```r
rq8_iteration1_test <- cmh_test(vaccinatedF ~ not_controlF | date_sentF, data = wrkdat3, subset = wrkdat3$iteration == 1)
rq8_iteration1_test
```

```

    Asymptotic Generalized Cochran-Mantel-Haenszel Test

data:  vaccinatedF by not_controlF (0, 1)
     stratified by date_sentF
chi-squared = 1, df = 1, p-value = 0.3
```

```r
rq8_iteration2_test <- cmh_test(vaccinatedF ~ not_controlF | date_sentF, data = wrkdat3, subset = wrkdat3$iteration == 2)
rq8_iteration2_test
```

```

    Asymptotic Generalized Cochran-Mantel-Haenszel Test

data:  vaccinatedF by not_controlF (0, 1)
     stratified by date_sentF
chi-squared = 0.0055, df = 1, p-value = 0.9
```

```r
rq8_iteration3_test <- cmh_test(vaccinatedF ~ not_controlF | date_sentF, data = wrkdat3, subset = wrkdat3$iteration == 3)
rq8_iteration3_test
```

```

    Asymptotic Generalized Cochran-Mantel-Haenszel Test

data:  vaccinatedF by not_controlF (0, 1)
     stratified by date_sentF
chi-squared = 0.57, df = 1, p-value = 0.5
```

```r
## Also looking at vaccinations within a week for the first iteration
rq9_iteration1_test <- cmh_test(vac_in_weekF ~ not_controlF | date_sentF, data = wrkdat3, subset = wrkdat3$iteration == 1)
rq9_iteration1_test
```

```

    Asymptotic Generalized Cochran-Mantel-Haenszel Test

data:  vac_in_weekF by not_controlF (0, 1)
     stratified by date_sentF
chi-squared = 0.36, df = 1, p-value = 0.6
```

```r
rq9_iteration2_test <- cmh_test(vac_in_weekF ~ not_controlF | date_sentF, data = wrkdat3, subset = wrkdat3$iteration == 2)
rq9_iteration2_test
```

```

    Asymptotic Generalized Cochran-Mantel-Haenszel Test

data:  vac_in_weekF by not_controlF (0, 1)
     stratified by date_sentF
chi-squared = 1.9, df = 1, p-value = 0.2
```

```r
rq9_iteration3_test <- cmh_test(vac_in_weekF ~ not_controlF | date_sentF, data = wrkdat3, subset = wrkdat3$iteration == 3)
rq9_iteration3_test
```

```

    Asymptotic Generalized Cochran-Mantel-Haenszel Test

data:  vac_in_weekF by not_controlF (0, 1)
     stratified by date_sentF
```

```
chi-squared = 0.34, df = 1, p-value = 0.6
```

Exploratory Analyses Pre-registered

These analysis all compare effects of messages as they might vary for people who live in different kinds of places (using ZCTA as the place).

EQ1: Do explicit appeals to the safety of vaccines increase responses in areas with higher proportions of Black or Latinx people? Message 2 vs. control

We cannot detect any simple linear differential effect of pct black or latinx on the message 2 versus control comparison.

```r
wrkdat3_eq1 <- wrkdat3 %>%
  filter(messageF %in% c("message_0", "message_2") & zcta != "00000") %>%
  droplevels()
dim(wrkdat3_eq1)
```

```
[1] 23249    44
```

```r
table(wrkdat3_eq1$date_sent, wrkdat3_eq1$messageF, exclude = c())
```

```
             message_0 message_2
  2021-05-25      1089      1087
  2021-05-26      1095      1099
  2021-05-27      1087      1087
  2021-05-28      1092      1088
  2021-06-02       688      1108
  2021-06-03       677      1107
  2021-06-04       675      1109
  2021-06-07       679      1095
  2021-06-08       686      1105
  2021-06-09       830       572
  2021-06-10       823       576
  2021-06-11       831       570
  2021-06-14       819       575
```

```r
make_weights <- function(dat) {
  block_m_each <- with(dat, table(date_sentF, messageF, exclude = c()))
  block_prob_each <- block_m_each / rowSums(block_m_each)
  declared_randomization <- declare_ra(blocks = dat$date_sentF, block_m_each = block_m_each, conditions = sort(unique(dat$messag
  IPW_weight <- 1 / obtain_condition_probabilities(declaration = declared_randomization, assignment = dat$messageF)
  stopifnot(all.equal(sort(unique(1 / IPW_weight)), sort(unique(block_prob_each))))
  return(IPW_weight)
}

wrkdat3_eq1$IPW_eq1 <- make_weights(wrkdat3_eq1)
## So, good that I didn't use the multi-arm weights.
with(wrkdat3_eq1, cor(IPW_eq1, IPW_weight_multarm))
```

```
[1] 0.352
```

```r
eq1_blk_estA <- lm_robust(vaccinated ~ messageF * pct_any_blk, data = wrkdat3_eq1, weights = IPW_eq1)
## Just including Fixed Effects for curiosity. We will report estA
eq1_blk_estB <- lm_robust(vaccinated ~ messageF * pct_any_blk, data = wrkdat3_eq1, fixed_effects = ~date_sentF)

eq1_blk_estA
```

```
                              Estimate Std. Error   t value  Pr(>|t|)  CI Lower CI Upper    DF
(Intercept)                  0.0188928   0.002016  9.370867 7.829e-21  0.014941 0.022845 23245
messageFmessage_2           -0.0002165   0.002783 -0.077775 9.380e-01 -0.005672 0.005239 23245
pct_any_blk                  0.0538385   0.018998  2.833943 4.602e-03  0.016602 0.091075 23245
messageFmessage_2:pct_any_blk -0.0002156   0.026120 -0.008253 9.934e-01 -0.051413 0.050982 23245
```

```
eq1_blk_estB
```

```
                              Estimate Std. Error  t value Pr(>|t|)  CI Lower CI Upper    DF
messageFmessage_2           -0.0002700   0.002751 -0.09816 0.921810 -0.005662 0.005122 23233
pct_any_blk                  0.0553735   0.018627  2.97276 0.002954  0.018863 0.091884 23233
messageFmessage_2:pct_any_blk  0.0004877   0.025627  0.01903 0.984818 -0.049744 0.050719 23233
```

```
eq1_lat_estA <- lm_robust(vaccinated ~ messageF * pct_hisp, data = wrkdat3_eq1, weights = IPW_eq1)
## Just including Fixed Effects for curiosity. We will report estA
eq1_lat_estB <- lm_robust(vaccinated ~ messageF * pct_hisp, data = wrkdat3_eq1, fixed_effects = ~date_sentF)

eq1_lat_estA
```

```
                           Estimate Std. Error t value  Pr(>|t|)  CI Lower CI Upper    DF
(Intercept)                0.018012   0.001849  9.7392 2.264e-22  0.014387 0.021637 23245
messageFmessage_2          0.001080   0.002534  0.4262 6.700e-01 -0.003887 0.006048 23245
pct_hisp                   0.034689   0.009438  3.6756 2.378e-04  0.016191 0.053187 23245
messageFmessage_2:pct_hisp -0.007924   0.012534 -0.6322 5.272e-01 -0.032492 0.016643 23245
```

```
eq1_lat_estB
```

```
                           Estimate Std. Error t value  Pr(>|t|)  CI Lower CI Upper    DF
messageFmessage_2          0.000861   0.002514  0.3424 0.7320161 -0.004067 0.005789 23233
pct_hisp                   0.033746   0.009169  3.6804 0.0002334  0.015774 0.051717 23233
messageFmessage_2:pct_hisp -0.006495   0.012236 -0.5309 0.5955128 -0.030478 0.017487 23233
```

EQ2: Does the implication of choice through emphasis on a conspicuous advantage increase responses in areas with higher proportions of Republican people? Message 3 vs. control

No detectable difference in effects.

```
wrkdat3_eq2 <- wrkdat3 %>%
  filter(messageF %in% c("message_0", "message_3") & zcta != "00000") %>%
  droplevels()
dim(wrkdat3_eq2)
```

```
[1] 22772    44
```

```
table(wrkdat3_eq2$date_sent, wrkdat3_eq2$messageF, exclude = c())
```

```

             message_0 message_3
  2021-05-25      1089      1080
  2021-05-26      1095      1096
  2021-05-27      1087      1091
  2021-05-28      1092      1084
  2021-06-02       688       986
  2021-06-03       677       980
  2021-06-04       675       989
  2021-06-07       679       996
  2021-06-08       686       995
  2021-06-09       830       603
  2021-06-10       823       599
  2021-06-11       831       602
  2021-06-14       819       600
```

```
wrkdat3_eq2$IPW_eq2 <- make_weights(wrkdat3_eq2)

eq2_gop_estA <- lm_robust(vaccinated ~ messageF * pct_gop, data = wrkdat3_eq2, weights = IPW_eq2)
## Just including Fixed Effects for curiosity. We will report estA
eq2_gop_estB <- lm_robust(vaccinated ~ messageF * pct_gop, data = wrkdat3_eq2, fixed_effects = ~date_sentF)

eq2_gop_estA
```

```
                          Estimate Std. Error t value  Pr(>|t|) CI Lower  CI Upper    DF
(Intercept)               0.033399    0.00480  6.9582 3.541e-12  0.02399  0.042808 22768
```

```
messageFmessage_3         -0.002249    0.00661 -0.3402 7.337e-01 -0.01520  0.010707 22768
pct_gop                   -0.027623    0.01238 -2.2321 2.562e-02 -0.05188 -0.003366 22768
messageFmessage_3:pct_gop  0.009509    0.01705  0.5576 5.771e-01 -0.02392  0.042935 22768
```

```
eq2_gop_estB
```

```
                           Estimate Std. Error t value Pr(>|t|) CI Lower   CI Upper    DF
messageFmessage_3         -0.001908   0.006526 -0.2924  0.76996 -0.01470  0.0108826 22756
pct_gop                   -0.024921   0.012234 -2.0370  0.04166 -0.04890 -0.0009412 22756
messageFmessage_3:pct_gop  0.008442   0.016846  0.5012  0.61627 -0.02458  0.0414618 22756
```

EQ3: Do explicit appeals to ease of access increase responses in areas with higher proportions of Black or Latinx people? Message 5 vs. control

No detectable differences. Magnitude of moderation is large-ish given this phenomenon (on order of 1 or 2 pts, but negative).

```
wrkdat3_eq3 <- wrkdat3 %>%
  filter(messageF %in% c("message_0", "message_5") & zcta != "00000") %>%
  droplevels()
dim(wrkdat3_eq3)
```

```
[1] 25934    44
```

```
table(wrkdat3_eq3$date_sent, wrkdat3_eq3$messageF, exclude = c())
```

```
             message_0 message_5
  2021-05-25      1089      1084
  2021-05-26      1095      1086
  2021-05-27      1087      1088
  2021-05-28      1092      1091
  2021-06-02       688      1655
  2021-06-03       677      1645
  2021-06-04       675      1653
  2021-06-07       679      1665
  2021-06-08       686      1656
  2021-06-09       830       559
  2021-06-10       823       566
  2021-06-11       831       558
  2021-06-14       819       557
```

```
wrkdat3_eq3$IPW_eq3 <- make_weights(wrkdat3_eq3)

eq3_blk_estA <- lm_robust(vaccinated ~ messageF * pct_any_blk, data = wrkdat3_eq3, weights = IPW_eq3)
## Just including Fixed Effects for curiosity. We will report estA
eq3_blk_estB <- lm_robust(vaccinated ~ messageF * pct_any_blk, data = wrkdat3_eq3, fixed_effects = ~date_sentF)
eq3_blk_estA
```

```
                               Estimate Std. Error t value  Pr(>|t|) CI Lower CI Upper    DF
(Intercept)                    0.018567   0.002043  9.0861 1.098e-19  0.01456 0.022572 25930
messageFmessage_5              0.001946   0.002743  0.7095 4.780e-01 -0.00343 0.007322 25930
pct_any_blk                    0.051307   0.019179  2.6752 7.473e-03  0.01372 0.088898 25930
messageFmessage_5:pct_any_blk -0.026276   0.025041 -1.0493 2.940e-01 -0.07536 0.022805 25930
```

```
eq3_blk_estB
```

```
                               Estimate Std. Error t value Pr(>|t|) CI Lower CI Upper    DF
messageFmessage_5              0.002159   0.002699  0.8001 0.423633 -0.00313 0.007449 25918
pct_any_blk                    0.055429   0.018619  2.9771 0.002913  0.01894 0.091922 25918
messageFmessage_5:pct_any_blk -0.026560   0.024224 -1.0964 0.272898 -0.07404 0.020921 25918
```

```
eq3_lat_estA <- lm_robust(vaccinated ~ messageF * pct_hisp, data = wrkdat3_eq3, weights = IPW_eq3)
## Just including Fixed Effects for curiosity. We will report estA
eq3_lat_estB <- lm_robust(vaccinated ~ messageF * pct_hisp, data = wrkdat3_eq3, fixed_effects = ~date_sentF)
eq3_lat_estA
```

```
                            Estimate Std. Error t value  Pr(>|t|)  CI Lower CI Upper    DF
```

```
(Intercept)                 0.017433   0.001874  9.3041 1.455e-20  0.013760  0.02111 25930
messageFmessage_5           0.001536   0.002512  0.6114 5.410e-01 -0.003388  0.00646 25930
pct_hisp                    0.034860   0.009734  3.5814 3.424e-04  0.015782  0.05394 25930
messageFmessage_5:pct_hisp -0.011863   0.012585 -0.9426 3.459e-01 -0.036531  0.01280 25930
```

```r
eq3_lat_estB
```

```
                            Estimate Std. Error t value  Pr(>|t|)  CI Lower CI Upper    DF
messageFmessage_5           0.001597   0.002468  0.6474 0.5173976 -0.003239 0.006434 25918
pct_hisp                    0.033723   0.009157  3.6828 0.0002311  0.015775 0.051671 25918
messageFmessage_5:pct_hisp -0.011048   0.011843 -0.9328 0.3509152 -0.034261 0.012166 25918
```

EQ4: Does epistemic humility increase responses in areas with higher proportions of either Black or Latinx people or Republican people? Message 4 versus 3

No detectable differences in effect.

```r
wrkdat3_eq4 <- wrkdat3 %>%
  filter(messageF %in% c("message_3", "message_4") & zcta != "00000") %>%
  droplevels()
dim(wrkdat3_eq4)
```

```
[1] 21577    44
```

```r
table(wrkdat3_eq4$date_sent, wrkdat3_eq4$messageF, exclude = c())
```

```
             message_3 message_4
  2021-05-25      1080      1081
  2021-05-26      1096      1090
  2021-05-27      1091      1084
  2021-05-28      1084      1089
  2021-06-02       986       475
  2021-06-03       980       471
  2021-06-04       989       475
  2021-06-07       996       471
  2021-06-08       995       464
  2021-06-09       603       786
  2021-06-10       599       799
  2021-06-11       602       794
  2021-06-14       600       797
```

```r
wrkdat3_eq4$IPW_eq4 <- make_weights(wrkdat3_eq4)

eq4_gop_estA <- lm_robust(vaccinated ~ messageF * pct_gop, data = wrkdat3_eq4, weights = IPW_eq4)
## Just including Fixed Effects for curiosity. We will report estA
eq4_gop_estB <- lm_robust(vaccinated ~ messageF * pct_gop, data = wrkdat3_eq4, fixed_effects = ~date_sentF)
eq4_gop_estA
```

```
                           Estimate Std. Error t value  Pr(>|t|) CI Lower CI Upper    DF
(Intercept)                0.031424   0.004622  6.7992 1.079e-11  0.02237 0.040483 21573
messageFmessage_4         -0.002244   0.006677 -0.3360 7.369e-01 -0.01533 0.010844 21573
pct_gop                   -0.018053   0.011944 -1.5115 1.307e-01 -0.04146 0.005358 21573
messageFmessage_4:pct_gop -0.003277   0.017226 -0.1902 8.491e-01 -0.03704 0.030487 21573
```

```r
eq4_gop_estB
```

```
                           Estimate Std. Error t value Pr(>|t|) CI Lower CI Upper    DF
messageFmessage_4         -0.002618   0.006497 -0.4030   0.6870 -0.01535 0.010116 21561
pct_gop                   -0.016735   0.011589 -1.4440   0.1488 -0.03945 0.005981 21561
messageFmessage_4:pct_gop -0.002784   0.016703 -0.1667   0.8676 -0.03552 0.029954 21561
```

```r
eq4_blk_estA <- lm_robust(vaccinated ~ messageF * pct_any_blk, data = wrkdat3_eq4, weights = IPW_eq4)
## Just including Fixed Effects for curiosity. We will report estA
eq4_blk_estB <- lm_robust(vaccinated ~ messageF * pct_any_blk, data = wrkdat3_eq4, fixed_effects = ~date_sentF)
eq4_blk_estA
```

```
                             Estimate Std. Error  t value  Pr(>|t|)  CI Lower CI Upper    DF
(Intercept)                  0.019125   0.002084  9.17906 4.730e-20  0.015041  0.02321 21573
messageFmessage_4           -0.003302   0.002909 -1.13507 2.564e-01 -0.009003  0.00240 21573
pct_any_blk                  0.067888   0.020681  3.28267 1.030e-03  0.027352  0.10842 21573
messageFmessage_4:pct_any_blk -0.001599  0.028836 -0.05547 9.558e-01 -0.058120  0.05492 21573
```

```r
eq4_blk_estB
```

```
                              Estimate Std. Error   t value Pr(>|t|)  CI Lower CI Upper    DF
messageFmessage_4           -0.0036235   0.002836 -1.277497 0.201440 -0.009183 0.001936 21561
pct_any_blk                  0.0613615   0.019686  3.117026 0.001829  0.022776 0.099947 21561
messageFmessage_4:pct_any_blk -0.0001924  0.027278 -0.007054 0.994371 -0.053659 0.053274 21561
```

```r
eq4_lat_estA <- lm_robust(vaccinated ~ messageF * pct_hisp, data = wrkdat3_eq4, weights = IPW_eq4)
## Just including Fixed Effects for curiosity. We will report estA
eq4_lat_estB <- lm_robust(vaccinated ~ messageF * pct_hisp, data = wrkdat3_eq4, fixed_effects = ~date_sentF)
eq4_lat_estA
```

```
                          Estimate Std. Error t value  Pr(>|t|)  CI Lower CI Upper    DF
(Intercept)               0.018922   0.001878 10.0774 7.851e-24  0.015242 0.022603 21573
messageFmessage_4        -0.002755   0.002664 -1.0345 3.009e-01 -0.007976 0.002465 21573
pct_hisp                  0.038470   0.009790  3.9294 8.542e-05  0.019280 0.057660 21573
messageFmessage_4:pct_hisp -0.004235   0.013966 -0.3032 7.617e-01 -0.031610 0.023140 21573
```

```r
eq4_lat_estB
```

```
                          Estimate Std. Error t value  Pr(>|t|)  CI Lower CI Upper    DF
messageFmessage_4        -0.002767   0.002619 -1.0565 0.2907542 -0.007901 0.002367 21561
pct_hisp                  0.036447   0.009411  3.8729 0.0001079  0.018001 0.054893 21561
messageFmessage_4:pct_hisp -0.005410   0.013201 -0.4098 0.6819606 -0.031284 0.020465 21561
```

EQ5: Is there a day-of-week effect? Proportions of vaccinations collapsed across all messages by day.

Since the randomization to message occurred **within day** and we have relatively few weeks, it is difficult to disentangle day of week effects from date effects. So, we only present descriptive information here.

```r
summary(wrkdat3$date_sent)
```

```
        Min.      1st Qu.       Median         Mean      3rd Qu.         Max.
"2021-05-25" "2021-05-28" "2021-06-07" "2021-06-04" "2021-06-10" "2021-06-14"
```

```r
table(weekdays(wrkdat3$date_sent))
```

```
   Friday    Monday  Thursday   Tuesday Wednesday
    33626     23621     33619     17940     33622
```

```r
wrkdat3$weekday_sent <- weekdays(wrkdat3$date_sent)

wrkdat3_weekday <- wrkdat3 %>%
  group_by(weekday_sent) %>%
  summarize(
    prop_vac = mean(vaccinated),
    prop_vac_in_week = mean(vac_in_week), nweek = n()
  )

wrkdat3_weekday
```

```
# A tibble: 5 x 4
  weekday_sent prop_vac prop_vac_in_week nweek
  <chr>           <dbl>            <dbl> <int>
1 Friday         0.0181          0.00803 33626
2 Monday         0.00923         0.00703 23621
3 Thursday       0.0195          0.00943 33619
4 Tuesday        0.0294          0.0109  17940
5 Wednesday      0.0218          0.0102  33622
```

EQ6: Is there an iteration effect? Some people were randomly assigned to have 3 weeks to schedule a vaccination and others only 1 week before the study ended. We explore whether there is a difference here.

We addressed this analysis above in our analysis by day of week and iteration.