Causal Inference with group_by and summarise

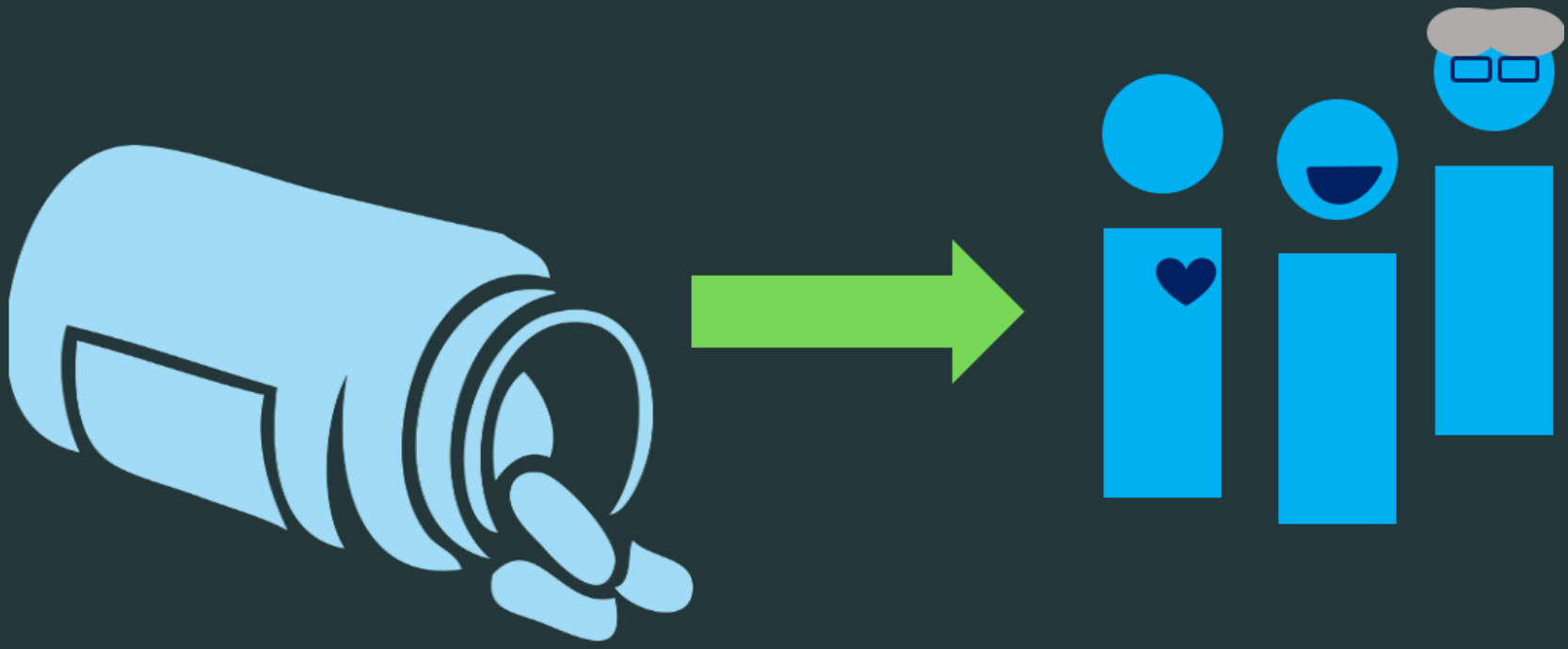
Lucy D'Agostino McGowan

Wake Forest University

2022-07-23 (updated: 2022-10-16)

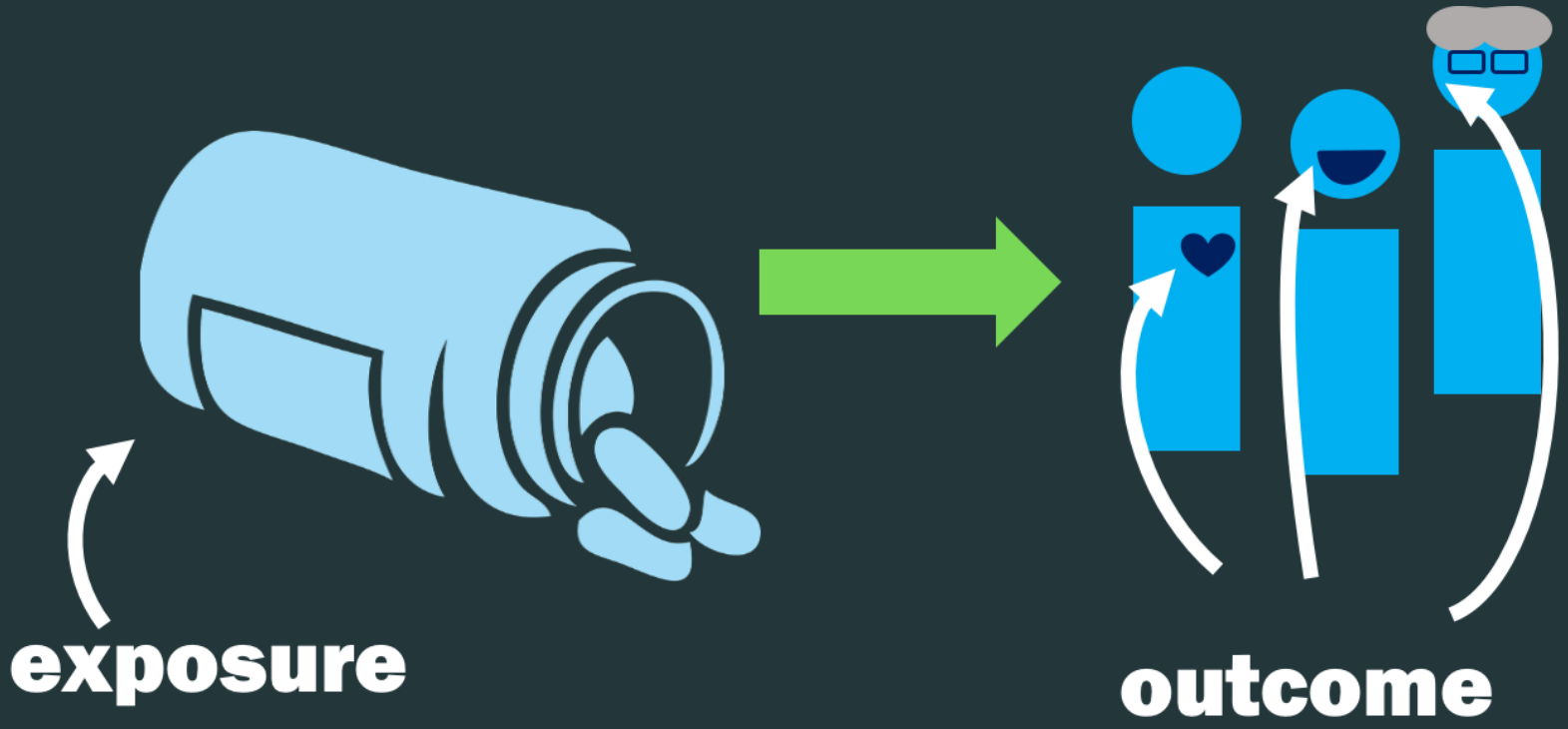
Observational Studies

Goal: To answer a research question



Observational Studies

Goal: To answer a research question

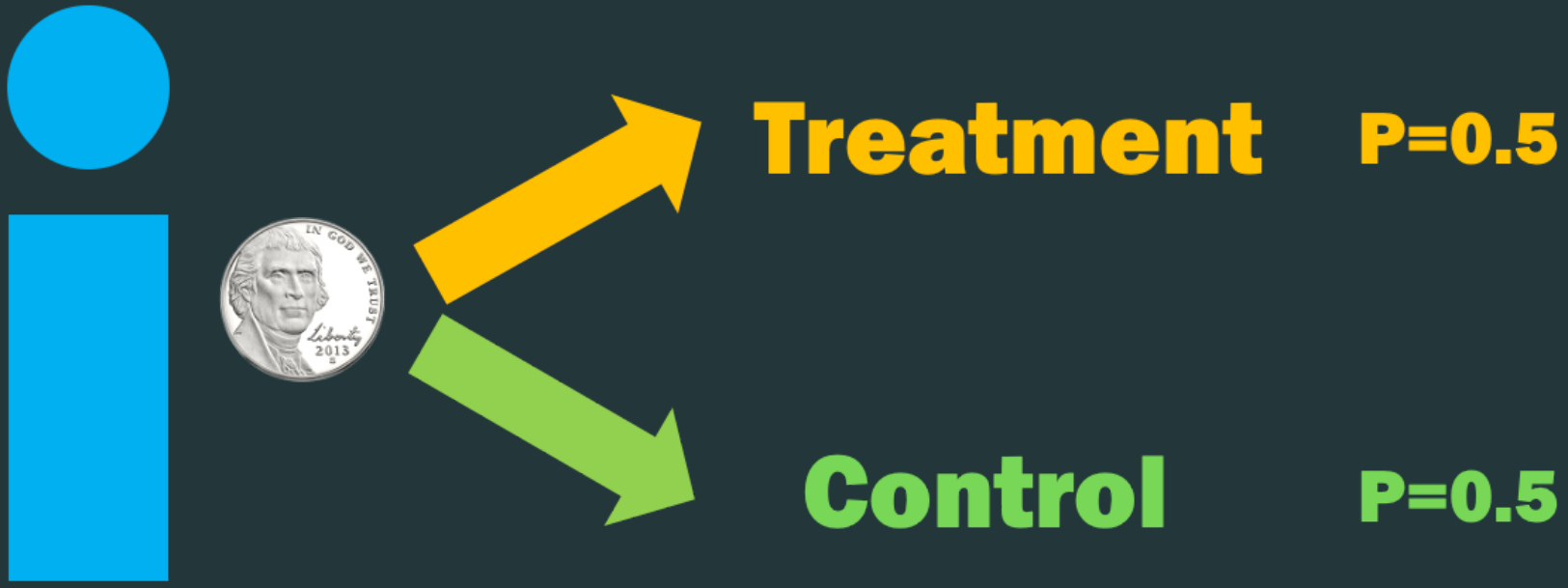


Observational Studies

Randomized Controlled Trial

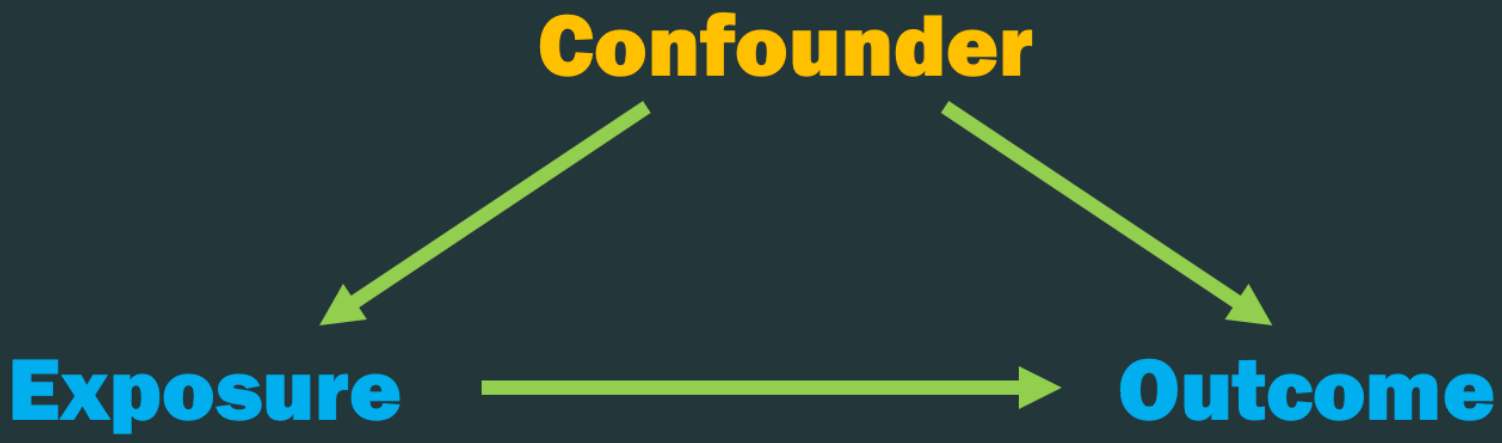
Observational Studies

Randomized Controlled Trial

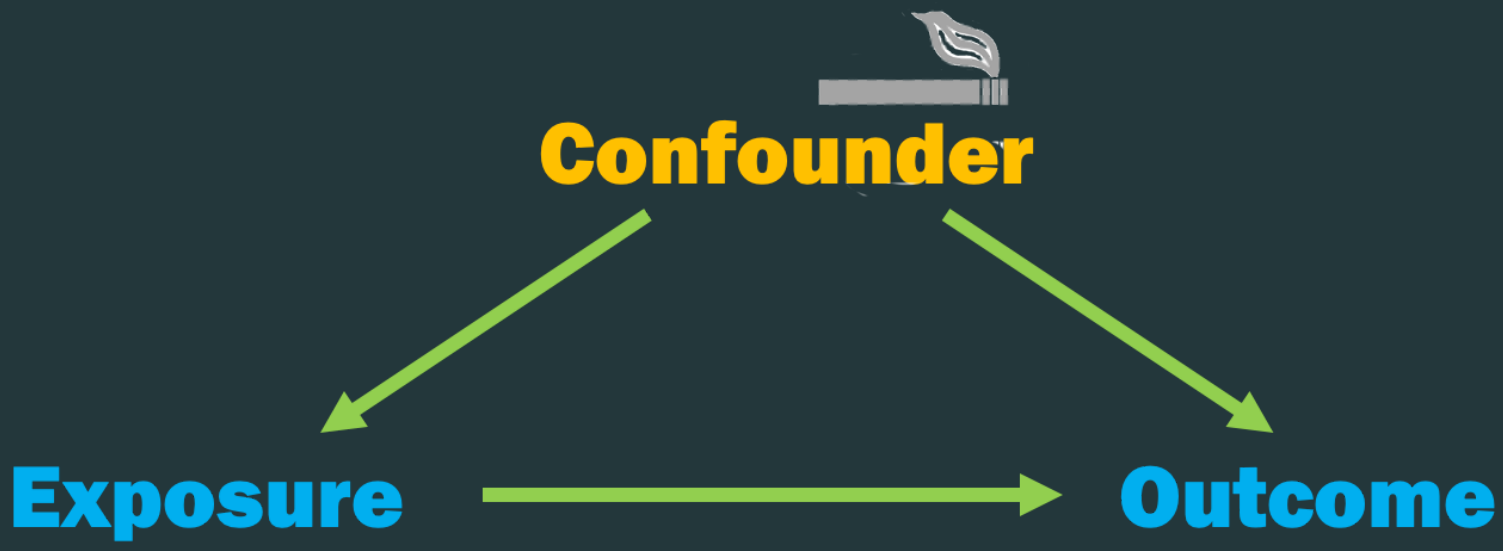


Observational Studies

Confounding



Confounding



One binary confounder

Simulation

```
n <- 1000
sim <- tibble(
  confounder = rbinom(n, 1, 0.5),
  p_exposure = case_when(
    confounder == 1 ~ 0.75,
    confounder == 0 ~ 0.25
  ),
  exposure = rbinom(n, 1, p_exposure),
  outcome = confounder + rnorm(n)
)
```

```
## # A tibble: 1,000 × 3
##    confounder exposure outcome
##         <int>    <int>   <dbl>
##  1          0        0  1.13
##  2          0        0  1.11
##  3          1        1  0.129
##  4          1        0  1.21
##  5          0        0  0.0694
##  6          1        1 -0.663
##  7          1        1  1.81
##  8          1        1 -0.912
##  9          1        0 -0.247
## 10          0        0  0.998
## # … with 990 more rows
```

Simulation

```r
n <- 1000
sim <- tibble(
  confounder = rbinom(n, 1, 0.5),
  p_exposure = case_when(
    confounder == 1 ~ 0.75,
    confounder == 0 ~ 0.25
  ),
  exposure = rbinom(n, 1, p_exposure),
  outcome = confounder + rnorm(n)
)
```

```
## # A tibble: 1,000 × 3
##    confounder exposure outcome
##         <int>    <int>   <dbl>
##  1          0        0  1.13
##  2          0        0  1.11
##  3          1        1  0.129
##  4          1        0  1.21
##  5          0        0  0.0694
##  6          1        1 -0.663
##  7          1        1  1.81
##  8          1        1 -0.912
##  9          1        0 -0.247
## 10          0        0  0.998
## # … with 990 more rows
```

Simulation

```r
n <- 1000
sim <- tibble(
  confounder = rbinom(n, 1, 0.5),
  p_exposure = case_when(
    confounder == 1 ~ 0.75,
    confounder == 0 ~ 0.25
  ),
  exposure = rbinom(n, 1, p_exposure),
  outcome = confounder + rnorm(n)
)
```

```
## # A tibble: 1,000 × 3
##    confounder exposure outcome
##         <int>    <int>   <dbl>
##  1          0        0  1.13
##  2          0        0  1.11
##  3          1        1  0.129
##  4          1        0  1.21
##  5          0        0  0.0694
##  6          1        1 -0.663
##  7          1        1  1.81
##  8          1        1 -0.912
##  9          1        0 -0.247
## 10          0        0  0.998
## # … with 990 more rows
```

Simulation

```
n <- 1000
sim <- tibble(
  confounder = rbinom(n, 1, 0.5),
  p_exposure = case_when(
    confounder == 1 ~ 0.75,
    confounder == 0 ~ 0.25
  ),
  exposure = rbinom(n, 1, p_exposure),
  outcome = confounder + rnorm(n)
)
```

```
## # A tibble: 1,000 × 3
##    confounder exposure outcome
##         <int>    <int>   <dbl>
##  1          0        0  1.13
##  2          0        0  1.11
##  3          1        1  0.129
##  4          1        0  1.21
##  5          0        0  0.0694
##  6          1        1 -0.663
##  7          1        1  1.81
##  8          1        1 -0.912
##  9          1        0 -0.247
## 10          0        0  0.998
## # … with 990 more rows
```

Simulation

```r
n <- 1000
sim <- tibble(
  confounder = rbinom(n, 1, 0.5),
  p_exposure = case_when(
    confounder == 1 ~ 0.75,
    confounder == 0 ~ 0.25
  ),
  exposure = rbinom(n, 1, p_exposure),
  outcome = confounder + rnorm(n)
)
```

```
## # A tibble: 1,000 × 3
##    confounder exposure outcome
##         <int>    <int>   <dbl>
##  1          0        0  1.13
##  2          0        0  1.11
##  3          1        1  0.129
##  4          1        0  1.21
##  5          0        0  0.0694
##  6          1        1 -0.663
##  7          1        1  1.81
##  8          1        1 -0.912
##  9          1        0 -0.247
## 10          0        0  0.998
## # … with 990 more rows
```

Simulation

```
lm(outcome ~ exposure, data = sim)
```

```
##
## Call:
## lm(formula = outcome ~ exposure, data = sim)
##
## Coefficients:
## (Intercept)     exposure
##      0.2688       0.4070
```

Simulation

```
sim %>%
  group_by(exposure) %>%
  summarise(avg_y = mean(outcome))
```

```
## # A tibble: 2 × 2
##   exposure avg_y
##      <int> <dbl>
## 1        0 0.269
## 2        1 0.676
```

Simulation

```
sim %>%
  group_by(exposure) %>%
  summarise(avg_y = mean(outcome))
```

```
## # A tibble: 2 × 2
##   exposure avg_y
##      <int> <dbl>
## 1        0 0.269
## 2        1 0.676
```

Simulation

```
sim %>%
  group_by(exposure) %>%
  summarise(avg_y = mean(outcome))
```

```
## # A tibble: 2 × 2
##   exposure avg_y
##      <int> <dbl>
## 1        0 0.269
## 2        1 0.676
```

Simulation

```
sim %>%
  group_by(exposure) %>%
  summarise(avg_y = mean(outcome)) %>%
  pivot_wider(names_from = exposure,
              values_from = avg_y,
              names_prefix = "x_") %>%
  summarise(estimate = x_1 - x_0)
```

```
## # A tibble: 1 × 1
##   estimate
##      <dbl>
## 1    0.407
```

Simulation

```
sim %>%
  group_by(confounder, exposure) %>%
  summarise(avg_y = mean(outcome))
```

```
## # A tibble: 4 × 3
## # Groups:   confounder [2]
##   confounder exposure    avg_y
##        <int>    <int>    <dbl>
## 1          0        0 -0.00907
## 2          0        1 -0.0166
## 3          1        0  1.09
## 4          1        1  0.936
```

Simulation

```
sim %>%
  group_by(confounder, exposure) %>%
  summarise(avg_y = mean(outcome)) %>%
  pivot_wider(names_from = exposure,
              values_from = avg_y,
              names_prefix = "x_") %>%
  summarise(estimate = x_1 - x_0)
```

```
## # A tibble: 2 × 2
##   confounder estimate
##        <int>    <dbl>
## 1          0 -0.00752
## 2          1 -0.151
```

Two binary confounders

Simulation

```
n <- 1000
sim2 <- tibble(
  confounder_1 = rbinom(n, 1, 0.5),
  confounder_2 = rbinom(n, 1, 0.5),

  p_exposure = case_when(
    confounder_1 == 1 & confounder_2 == 1 ~ 0.
    confounder_1 == 0 & confounder_2 == 1 ~ 0.
    confounder_1 == 1 & confounder_2 == 0 ~ 0.
    confounder_1 == 0 & confounder_2 == 0 ~ 0.
  ),
  exposure = rbinom(n, 1, p_exposure),
  outcome = confounder_1 + confounder_2 + rnor
)
```

```
## # A tibble: 1,000 × 4
##    confounder_1 confounder_2 exposure outcome
##           <int>        <int>    <int>   <dbl>
##  1            0            0        0   0.521
##  2            1            0        0   1.38
##  3            0            0        0  -0.624
##  4            0            1        1   0.427
##  5            1            0        1   1.31
##  6            0            0        0  -0.707
##  7            1            1        1   2.52
##  8            1            0        0   1.45
##  9            0            0        0  -0.505
## 10            0            1        1   0.793
## # … with 990 more rows
```

Simulation

```
lm(outcome ~ exposure, data = sim2)
```

```
##
## Call:
## lm(formula = outcome ~ exposure, data = sim2)
##
## Coefficients:
## (Intercept)     exposure
##      0.6395       0.6951
```

Simulation

```
sim2 %>%
  group_by(confounder_1, confounder_2, exposure) %>%
  summarise(avg_y = mean(outcome)) %>%
  pivot_wider(names_from = exposure,
              values_from = avg_y,
              names_prefix = "x_") %>%
  summarise(estimate = x_1 - x_0)
```

```
## # A tibble: 4 × 3
## # Groups:   confounder_1 [2]
##   confounder_1 confounder_2 estimate
##          <int>        <int>    <dbl>
## 1            0            0 -0.309
## 2            0            1  0.0466
## 3            1            0 -0.0271
## 4            1            1 -0.00275
```

Simulation

```
n <- 100000
sim2 <- tibble(
  confounder_1 = rbinom(n, 1, 0.5),
  confounder_2 = rbinom(n, 1, 0.5),

  p_exposure = case_when(
    confounder_1 == 1 & confounder_2 == 1 ~ 0.
    confounder_1 == 0 & confounder_2 == 1 ~ 0.
    confounder_1 == 1 & confounder_2 == 0 ~ 0.
    confounder_1 == 0 & confounder_2 == 0 ~ 0.
  ),
  exposure = rbinom(n, 1, p_exposure),
  outcome = confounder_1 + confounder_2 + rnor
)
```

```
## # A tibble: 100,000 × 4
##    confounder_1 confounder_2 exposure outcome
##           <int>        <int>    <int>   <dbl>
##  1            1            1        1   2.35
##  2            1            1        0   3.71
##  3            0            0        0   2.08
##  4            0            1        1   0.516
##  5            0            0        0  -0.166
##  6            1            1        1   1.58
##  7            0            0        0   0.472
##  8            1            0        0   3.22
##  9            0            1        1   0.929
## 10            0            1        1   1.41
## # … with 99,990 more rows
```

Simulation

```
lm(outcome ~ exposure, data = sim2)
```

```
##
## Call:
## lm(formula = outcome ~ exposure, data = sim2)
##
## Coefficients:
## (Intercept)     exposure
##      0.6782       0.6561
```

Simulation

```
sim2 %>%
  group_by(confounder_1, confounder_2, exposure) %>%
  summarise(avg_y = mean(outcome)) %>%
  pivot_wider(names_from = exposure,
              values_from = avg_y,
              names_prefix = "x_") %>%
  summarise(estimate = x_1 - x_0)
```

```
## # A tibble: 4 × 3
## # Groups:   confounder_1 [2]
##   confounder_1 confounder_2 estimate
##          <int>        <int>    <dbl>
## 1            0            0  0.00565
## 2            0            1  0.0466
## 3            1            0  0.0185
## 4            1            1  0.00388
```

Continuous confounder?

Simulation

```
n <- 10000
sim3 <- tibble(
  confounder = rnorm(n),
  p_exposure = exp(confounder) / (1 + exp(conf
  exposure = rbinom(n, 1, p_exposure),
  outcome = confounder + rnorm(n)
)
```

```
## # A tibble: 10,000 × 3
##    confounder exposure outcome
##         <dbl>    <int>   <dbl>
##  1     -0.167        0  -0.560
##  2      0.252        1   0.628
##  3     -0.321        1  -0.608
##  4      0.621        0   1.58
##  5     -0.619        1   0.358
##  6     -0.897        0  -1.95
##  7     -2.01         0  -2.50
##  8      0.296        0  -1.10
##  9     -0.504        1  -0.316
## 10     -0.536        1   1.12
## # … with 9,990 more rows
```

Simulation

```
lm(outcome ~ exposure, data = sim3)
```

```
##
## Call:
## lm(formula = outcome ~ exposure, data = sim3)
##
## Coefficients:
## (Intercept)     exposure
##     -0.4036       0.8152
```

Simulation

```
sim3 %>%
  mutate(confounder_q = ntile(confounder, 5)) %>%
  group_by(confounder_q, exposure) %>%
  summarise(avg_y = mean(outcome)) %>%
  pivot_wider(names_from = exposure,
              values_from = avg_y,
              names_prefix = "x_") %>%
  summarise(estimate = x_1 - x_0)
```

```
## # A tibble: 5 × 2
##   confounder_q estimate
##          <int>    <dbl>
## 1            1   0.104
## 2            2  -0.0293
## 3            3   0.0201
## 4            4   0.0674
## 5            5   0.201
```

What if we could come up with a **summary score** of all confounders?