Blocking

Ryan T. Moore

American University

The Lab @ DC

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What?

Motivation: A Causal Inference Question

"Would a canvassing policy increase enrollment in a health insurance program?"

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Precinct	Party	Canvass?	Enroll %
1	Dem		
2	Dem		
3	Rep		
4	Rep		

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Suppose we observationally measure

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1	Dem	Yes	60
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		Diff in Means: (Yes − No)	40

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Causal claims? Concerns?

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Seriously? Well, ...

```r
x <- sample(0:1, size = 10, replace = TRUE)
```

```r
x
```

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

Figure 1: Unlucky

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$$SE(\widehat{ATE}) = \sqrt{\frac{1}{N-1}\left[\frac{m\text{Var}(Y_i(0))}{N-m} + \frac{(N-m)\text{Var}(Y_i(1))}{m} + 2\text{Cov}(Y_i(0), Y_i(1))\right.}$$

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  - $10^{th} \rightarrow$ treated: $SE : \sqrt{\frac{6}{4} + \frac{4}{6}} = \sqrt{2.66}$
- If $\text{Var}(Y_i(0)) \neq \text{Var}(Y_i(1))$, allocate $\rightarrow$ higher-Variance condition

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Demonstration:

Unit	Y_0	Y_1 (+ cov)	Y_1 (− cov)
1	0	0	10
2	5	5	5
3	10	10	0
Means	5	5	5

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Means	5	5	5

Suppose assign 1 to Tr, 2 to Co.

$\widehat{ATE}_{+\text{cov}} = -7.5, 0, 7.5$

$\widehat{ATE}_{-\text{cov}} = 2.5, 0, -2.5$ (less variance!)

Example: Canvassing and Enrollment

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(Or, just Party $\rightarrow$ Enrollment?)

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What would have happened to "No" precincts if "Yes"?

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What do we really want to know?

Does canvassing actually <u>change</u> enrollment in precinct?
(Or, just Party $\rightarrow$ Enrollment?)

What <u>would have</u> happened to "No" precincts if "Yes"?

What would have happened under <u>other</u> conditions?

Example: Canvassing and Enrollment

Suppose we can know both potential outcomes ...

Precinct	Party	Canvass?	Enroll % if No Canvass	Enroll % if Canvass
1	Dem	_	20	60
2	Dem	_	30	70
3	Rep	_	20	30
4	Rep	_	30	40
		Means:	25	50

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$\text{ATE} = 50 - 25 = 25$

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$\text{ATE} = 50 - 25 = 25$

(True or an estimate?)

Example: Canvassing and Enrollment

Another way to think about same information:

Precinct	Party	Canvass?	Enroll % if No Canvass	Enroll % if Canvass	True Precinct Effect
1	Dem	_	20	60	40
2	Dem	_	30	70	40
3	Rep	_	20	30	10
4	Rep	_	30	40	10
		Means:	25	50	25

$$\text{ATE} = (40 + 40 + 10 + 10)/4 = 25$$

The "Fundamental Problem of Causal Inference' '

We can't observe both "Canvassed" and "Not Canvassed" for a precinct.

We can't observe both potential outcomes (counterfactuals).

So, how can we get a good causal estimate?

Example: Canvassing and Enrollment

Suppose we observe ...

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Estimated ATE $= 65 - 25 = 40$

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Estimated ATE $= 65 - 25 = 40$ ☹ (too big)

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		Means:	30	45

Estimated ATE $= 45 - 30 = 15$

Example: Canvassing and Enrollment

Or, we could have observed ...

Precinct	Party	Canvass?	Enroll % if No Canvass	Enroll % if Canvass
1	Dem	Yes		60
2	Dem	No	30	
3	Rep	Yes		30
4	Rep	No	30	
		Means:	30	45

Estimated ATE $= 45 - 30 = 15$ ☹ (too small; closer)

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In our random allocation, possible data were

Assignments	Est ATE
YYNN	40

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Two assignments (YYNN and NNYY) leave treatment perfectly confounded with party.

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Let's ensure X does not predict T.

A Solution

Blocking:

Creating pre-treatmnt groups that look same on predictors.

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(Then, randomize within groups.)

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2	Dem	N	30	
3	Rep	N	20	
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(Then, randomize within groups.)

Example: Canvassing and Enrollment

Blocking restricts possible data to

Assignments	Est TE
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Estimates have less variance, are closer to true ATE.

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Under random allocation, 5 possible estimates: 40, 15, 25, 35, 10. Blocking restricts to 3 best: 15, 25, 35.

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  $\rightsquigarrow$ different actors interested in different effects

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- Estimate **closer to truth**
- Increased **efficiency**
- Triply-robust estimates: block, randomize, adjust
- Block-level effects
  $\rightsquigarrow$ different actors interested in different effects
- Guidelines for limited/uncertain resources

Why Block: Balance

Simulation study: 100 units, $X_1 \sim N(0,1)$, $X_2 \sim \text{Unif}(0,1)$, $X_3 \sim \chi^2_2$; 1000 such experiments. Assg treatmnt in 3 ways.

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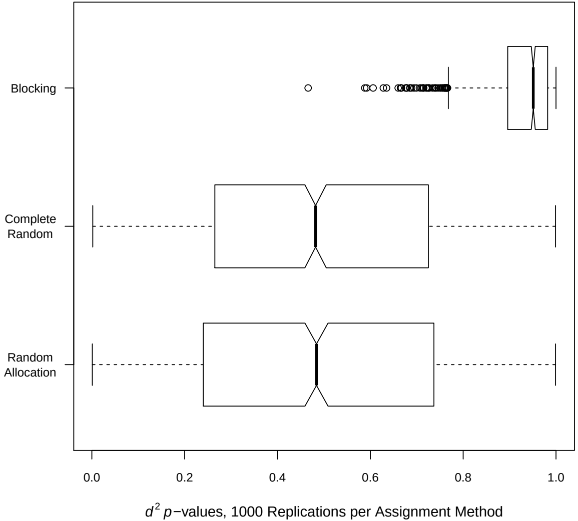
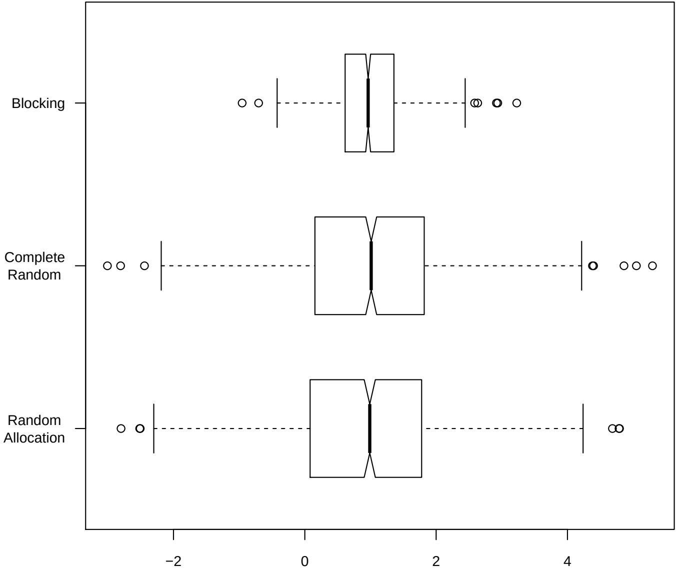


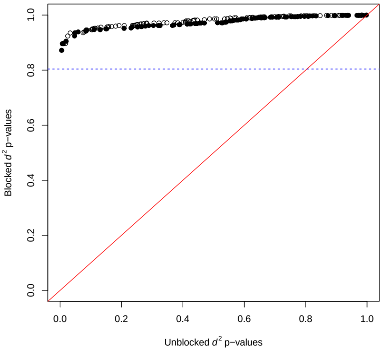
Why Block: Efficiency

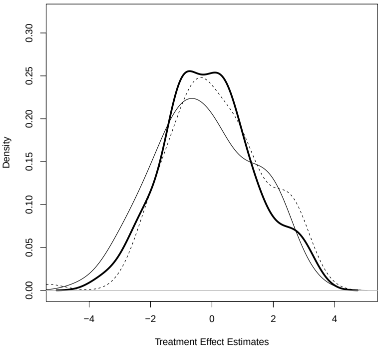


Blocking in Applications: Balance and Efficiency

Moore (2012): Perry Preschool Experiment

Left: QQ plot of balance (100 blocked vs. unblocked)
Right: Est TE under sharp null (100 blocked vs. unblocked)

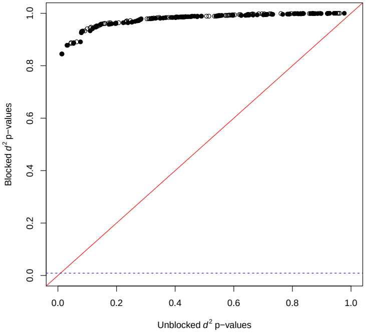


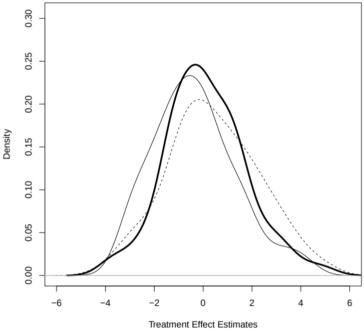


(SES, sex, IQ)

Balance in Applications: Balance and Efficiency

Considering more variables ...





(+ siblings, AFDC, mom empl, educ, father, ...)

How: `blockTools`

Blocking with blockTools

Start with some sample data:

```
library(blockTools)
data(x100)

x100 |> head()
```

```
    id id2  b1  b2 g  ig
1 1001 101 156 795 b 729
2 1002 102 813 469 a 627
3 1003 103 950 978 a 959
4 1004 104 991 781 a 661
5 1005 105 613 759 a 819
6 1006 106 654 838 b 643
```

(Moore 2012; Moore and Schnakenberg 2023)

Blocking with blockTools

```r
b <- block(x100, id.vars = "id",
           block.vars = c("b1", "b2"))
```

```r
bl <- b$blocks$`1`

bl |> head()
```

```
  Unit 1 Unit 2   Distance
1   1043   1040 0.01240000
2   1100   1020 0.02259275
3   1065   1027 0.02912651
4   1085   1081 0.03498815
5   1088   1061 0.04789253
6   1064   1014 0.07985116
```

Blocking with `blockTools`

Why all this?

```r
bl <- b$blocks$`1`
```

We are extracting just the blocked pairs themselves.

- Why `b$blocks`? Since `b` has 3 components:

```r
names(b)
```

```
[1] "blocks"    "level.two" "call"
```

- Why `blocks$`1‘? Since this is (default-named) first (and only) “group”:

```r
names(b$blocks)
```

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

Blocking with blockTools

What else could we do?

```
b_3groups_3conditions <- block(
  x100,
  groups = "g",                  # (Factor variable in data)
  n.tr = 3,
  id.vars = "id",
  block.vars = c("b1", "b2"),
  distance = "mve"
)
```

```
b_3groups_3conditions$blocks
```

```
$a
   Unit 1 Unit 2 Unit 3 Max Distance
1    1076   1039   1056    0.2509889
2    1065   1061   1002    0.4335040
3    1084   1058   1017    0.4373315
4    1059   1046   1081    0.4524767
```

Blocking with blockTools

Some rows from each "group":

```
rows_a <- b_3groups_3conditions$blocks$a |> slice(1:2) |> mutate
rows_b <- b_3groups_3conditions$blocks$b |> slice(1:2) |> mutate
rows_c <- b_3groups_3conditions$blocks$c |> slice(1:2) |> mutate
bind_rows(rows_a, rows_b, rows_c)
```

```
  Unit 1 Unit 2 Unit 3 Max Distance group
1   1076   1039   1056    0.2509889     a
2   1065   1061   1002    0.4335040     a
3   1043   1040   1019    0.1664608     b
4   1048   1031   1062    0.2288718     b
5   1095   1092   1049    0.3778655     c
6   1045   1015   1082    0.3808569     c
```

Blocking with `blockTools`

Other arguments to `block()`

- `vcov.data`
- `groups`: for exact-blocks
- `n.tr`
- `id.vars`
- `block.vars`
- `algorithm`: `optGreedy`, `optimal`, `naiveGreedy`, `randGreedy`, `sortGreedy`
- `distance`: `mahalanobis`, `mcd`, `mve`, `euclidean`, $k \times k$ matx
- `weight`
- `level.two`: block states by most similar cities
- `valid.var`, `valid.range`: Goldilocks
- `seed.dist`: (for `mcd` and `mve`)

Assign

```r
a <- assignment(b, seed = 71573706)
a
```

```
Assignments:

     Treatment 1   Treatment 2   Distance
1    1040          1043          0.01240000
2    1100          1020          0.02259275
3    1065          1027          0.02912651
4    1081          1085          0.03498815
5    1088          1061          0.04789253
6    1014          1064          0.07985116
7    1032          1070          0.08279625
8    1097          1098          0.08882421
9    1038          1018          0.09316331
10   1031          1048          0.10391953
11   1084          1058          0.10835825
```

Get Assignments

```r
a |> extract_conditions(x100, id.var = "id")
```

```
  [1] 2 1 2 2 2 2 1 2 2 1 1 1 1 1 1 1 2 2 1 2 2 2 1 2 1 1
 [38] 1 1 1 2 2 2 2 2 2 1 2 1 2 2 2 2 1 1 2 1 2 1 1 2 2 1
 [75] 1 2 2 2 1 2 1 1 1 1 2 1 2 1 1 2 1 2 1 1 2 2 1 2 1 1
```

```r
x100 |> mutate(
  condition = extract_conditions(a, x100, id.var = "id"))
```

```
     id id2  b1   b2 g  ig condition
1  1001 101 156  795 b 729         2
2  1002 102 813  469 a 627         1
3  1003 103 950  978 a 959         2
4  1004 104 991  781 a 661         2
5  1005 105 613  759 a 819         2
6  1006 106 654  838 b 643         2
7  1007 107 640  645 c  12         1
8  1008 108 681  404 a 221         2
```

Assign 3 Conditions, within Groups

```
a3 <- assignment(b_3groups_3conditions, seed = 979677744)
a3
```

```
Assignments:

Group: a
    Treatment 1  Treatment 2  Treatment 3  Max Distance
1   1056         1076         1039         0.2509889
2   1002         1061         1065         0.4335040
3   1058         1084         1017         0.4373315
4   1046         1081         1059         0.4524767
5   1073         1098         1029         0.4599752
6   1060         1067         1004         0.5921446
7   1089         1024         1032         0.7554402
8   1052         1054         1030         0.8848444
9   1093         1026         1068         0.8975495
10  1036         1008         1091         1.3586913
```

How: `randomizr`

Blocking with `randomizr::block_ra()`

```r
library(randomizr)

tr <- block_ra(x100$g)

# Better:

x100 |> mutate(tr = block_ra(x100$g))
```

```
       id id2  b1   b2 g  ig tr
1    1001 101 156  795 b 729  1
2    1002 102 813  469 a 627  1
3    1003 103 950  978 a 959  1
4    1004 104 991  781 a 661  1
5    1005 105 613  759 a 819  0
6    1006 106 654  838 b 643  1
7    1007 107 640  645 c  12  1
8    1008 108 681  404 a 221  0
9    1009 109 530  823 b 321  1
```

Then what?

`blockTools`: diagnose, get block IDs, check balance

Diagnose:

```
diagnose(a, data = x100, id.vars = "id",
         suspect.var = "b1", suspect.range = c(0, 5))
```

blockTools: diagnose, get block IDs, check balance

Diagnose:

```
diagnose(a, data = x100, id.vars = "id",
         suspect.var = "b1", suspect.range = c(0, 5))
```

Get block IDs

```
createBlockIDs(a, data = x100, id.var = "id")
```

`blockTools`: diagnose, get block IDs, check balance

Diagnose:

```
diagnose(a, data = x100, id.vars = "id",
         suspect.var = "b1", suspect.range = c(0, 5))
```

Get block IDs

```
createBlockIDs(a, data = x100, id.var = "id")
```

Get balance:

```
assg2xBalance(a, x100, id.var = "id",
              bal.vars = c("b1", "b2"))
```

Analysis

- Generally, use Lin or Blocked Diff-in-Means

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- LSDV (block indicators) weights w/in block TE's by

$$p_j(1 - p_j)n_j$$

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where

- p_j = share of block j treated
- n_j = size of block j
- (I.e., $p_j(1 - p_j) = \text{var}(TE)$ in block j)

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- Generally, use Lin or Blocked Diff-in-Means
- LSDV (block indicators) weights w/in block TE's by

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where

- p_j = share of block j treated
- n_j = size of block j
- (I.e., $p_j(1 - p_j) = \text{var}(TE)$ in block j)

Safer when

- p_j constant across blocks j
- n_j constant across blocks j

Analysis

```
library(estimatr)

df <- x100 |> mutate(tr = block_ra(x100$g))

lm_lin(b1 ~ tr, covariates = ~ g, data = df)
```

```
               Estimate Std. Error     t value     Pr(>|t|
(Intercept)  492.800000   39.08723 12.60769882 6.405020e-2
tr           -50.760000   51.70890 -0.98164922 3.287925e-0
gb_c          -4.673611  100.16089 -0.04666104 9.628824e-0
gc_c          -4.111111   92.84835 -0.04427770 9.647770e-0
tr:gb_c     -190.763889  129.80730 -1.46959290 1.450111e-0
tr:gc_c     -112.826389  128.65776 -0.87694974 3.827497e-0
            DF
(Intercept) 94
tr          94
gb_c        94
gc_c        94
```

Analysis

Can I just ignore blocks and pool?

Analysis

Can I just ignore blocks and pool?

- If p_j varies, no

Thanks!

rtm@american.edu
www.ryantmoore.org

References I

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