Visualizing Logistic Regression:

Application of coloring book technique in a reproducible *ggplot2* system

Andriy Koval, Ph.D.

Power of Population Data Science webinar series

Population Data BC

2018-11-01

github.com/andkov/ipdln-2018-hackathon

About me

- Ph.D. in Quantitative Methods (2014)
- Reproducible research enthusiast since 2012
- Graph maker
- See work at github.com/andkov
- Follow @andkovpro

A. Graphing Technique

0.0 Data & Context : Mortality factors of Canadian immigrants at IPDLN-2018 hackathon
0.1 Modeling form: univariate logistic regression with categorical predictors
0.2 Graphical form: faceted scatterplot in ggplot2
0.3 Coloring book: Mapping informed expectations from predictors onto color

B. Workflow Highlights

1.0 "Let no one ignorant of geometry enter": (my) scripts were written to be read by humans
1.1 RAnalysisSkeleton by Will Beasley: basic starting point for reproducible projects
1.2 Autonomous phases: data cleaning, statistical modelling, graph production
1.3 Layers of Isolation: analysis vs presentation using .R (+ .Rmd) => .html (+ .pdf)
1.4 Two essential means of production: knitr::stitch() vs rmarkdown::render()

C. Live demonstration from github.com/andkov/IPDLN-2018 hackathon

D. Conclusions

2.0 Different than Notebooks: sacrifices simplicity for agility via layers of isolation
2.1 R (+ .Rmd) = .html (+ .pdf) : moving away from *data playing* towards *data science*
2.2 Reproducible projects: moving away from notebooks towards software

A. Graphing Technique

0.0 Data & Context : Mortality factors of Canadian immigrants at IPDLN-2018 hackathon by Statistics Canada in Banff

International Population Data Linkage Conference 2018
The LIDIC Hackathon: LInked Data Innovation Challenge

Information for Participants

Date and Time: September 11, 2018 afternoon

Sponsors: We are grateful for sponsorship of this workshop by Statistics Canada and IBM.

Description: Participants will engage in a team-based analysis of a complex, linked, synthesized dataset provided by Statistics Canada. This synthesized data base links socioeconomic and mortality data representing the Canadian population. The data based was derived from existing linked data available at Statistics Canada.

Objectives:

- To encourage innovative thinking about complex linked databases
- To stimulate interdisciplinary and inter-jurisdictional data collaborations
- To facilitate an environment for creative thinking about data
- To promote networking amongst participants

Number of records: 4,346,649
Number of variables: 34

A. Graphing Technique

0.0 Data & Context : Mortality factors of Canadian immigrants at IPDLN-2018 hackathon by Statistics Canada in Banff

```
ls_model$predicted_values %>% glimpse(50) # predicted values
```

```
Observations: 3,883
Variables: 9
$ PR          <fct> Alberta, Alberta, Alberta...
$ age_group   <fct> 65, 60, 30, 80, 55, 40, 6...
$ female      <fct> FALSE, FALSE, TRUE, FALSE...
$ educ3       <fct> high school, more than hi...
$ marital     <fct> mar_cohab, mar_cohab, mar...
$ poor_health <fct> FALSE, FALSE, FALSE, TRUE...
$ FOL         <fct> English only, English onl...
$ dv_hat      <dbl> 1.8628432, 2.3139500, 6.1...
$ dv_hat_p    <dbl> 0.8656280, 0.9100258, 0.9...
```

Originally:

Number of records: 4,346,649
Number of variables: 34

Data recreated from model parameters

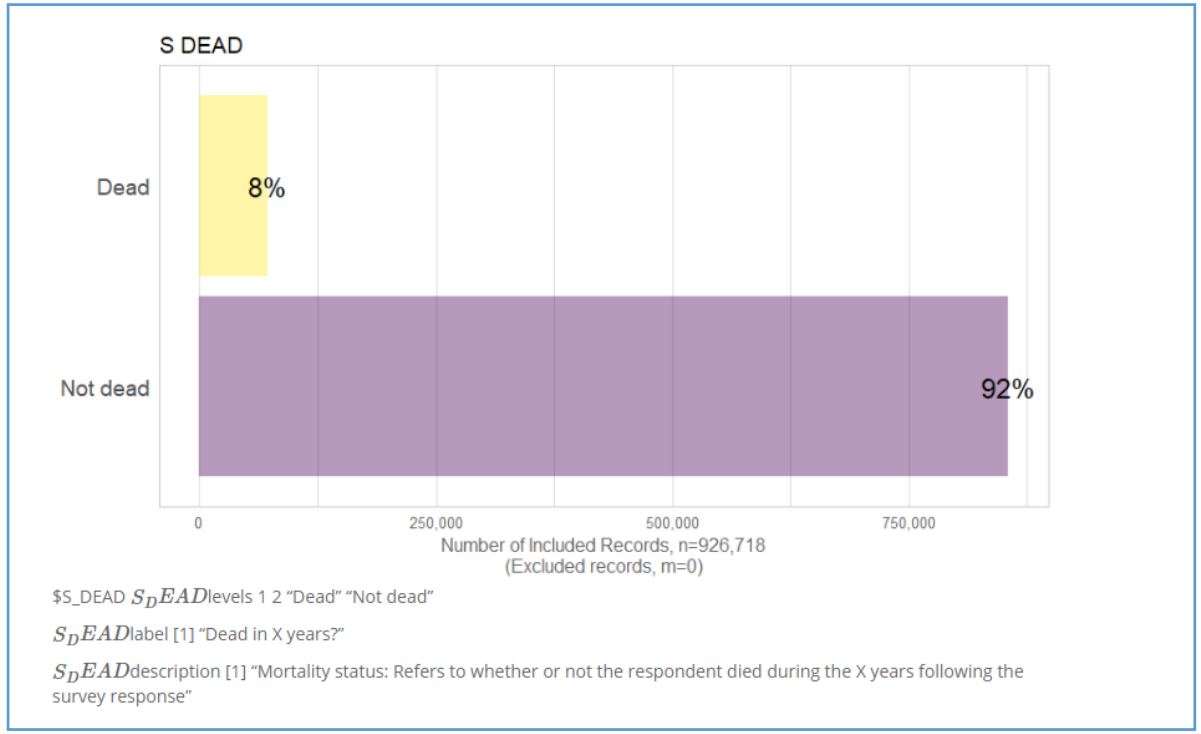
You can use this data to recreate the graphs from this talk with the script *./reports/graphing-phase-only/graphing-phase-only.R*

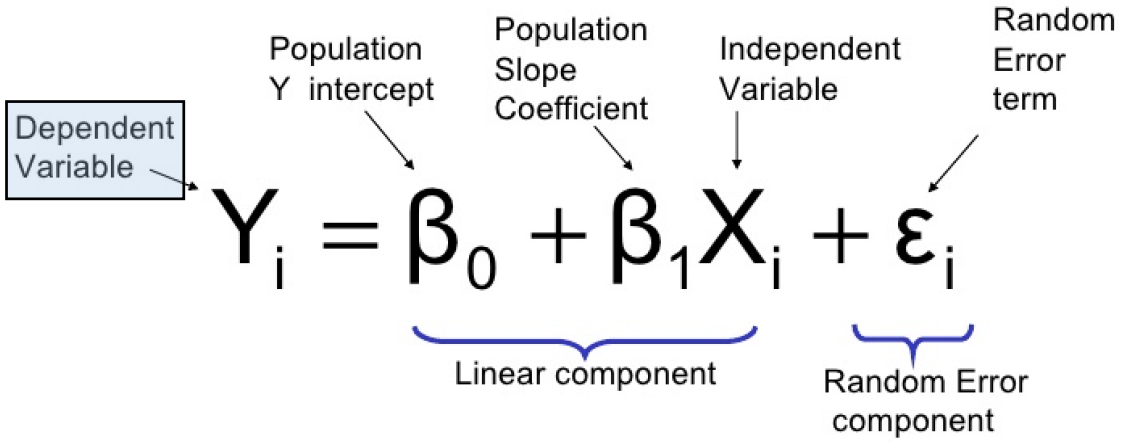
A. Graphing Technique

0.1 Modeling form

dv ~ -1 + PR + age_group + female + marital + educ3 + poor_health + FOL

Dead in X years





$$\ln\left(\frac{\hat{p}}{(1-\hat{p})}\right) = b_0 + b_1X_1 + b_2X_2 + \ldots + b_pX_p$$

Source: https://towardsdatascience.com/how-are-logistic-regression-ordinary-least-squares-regression-related-1deab32d79f5

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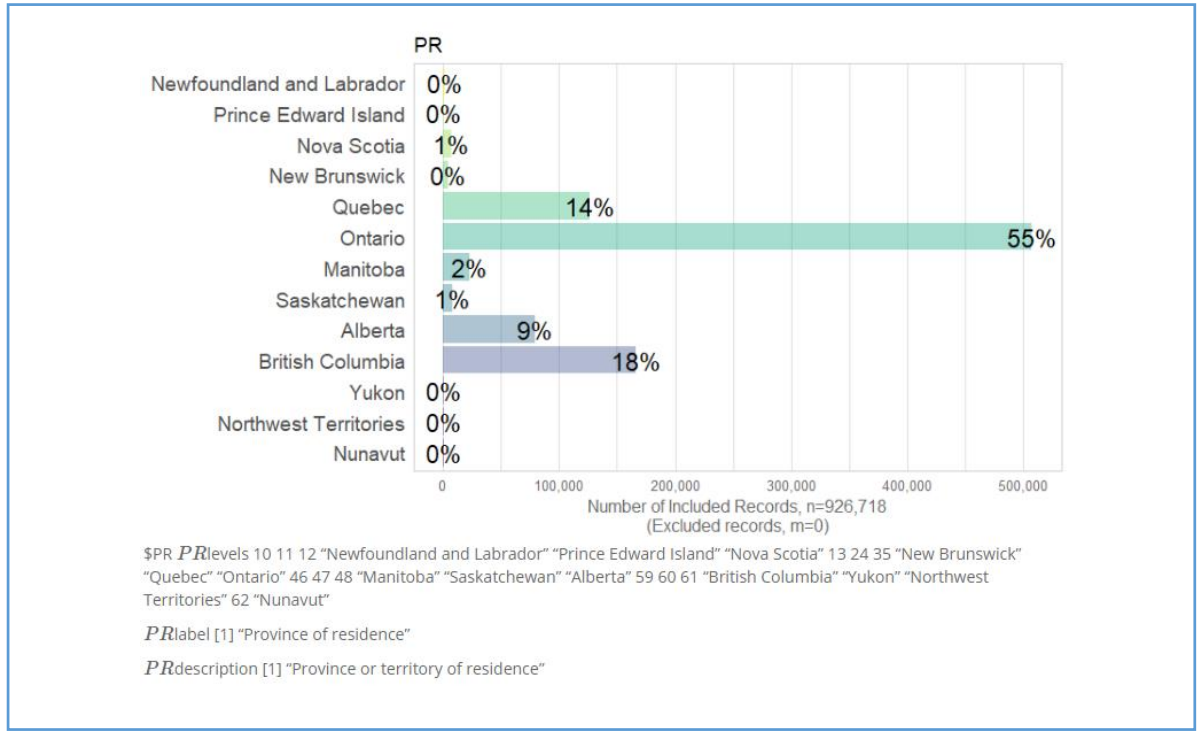
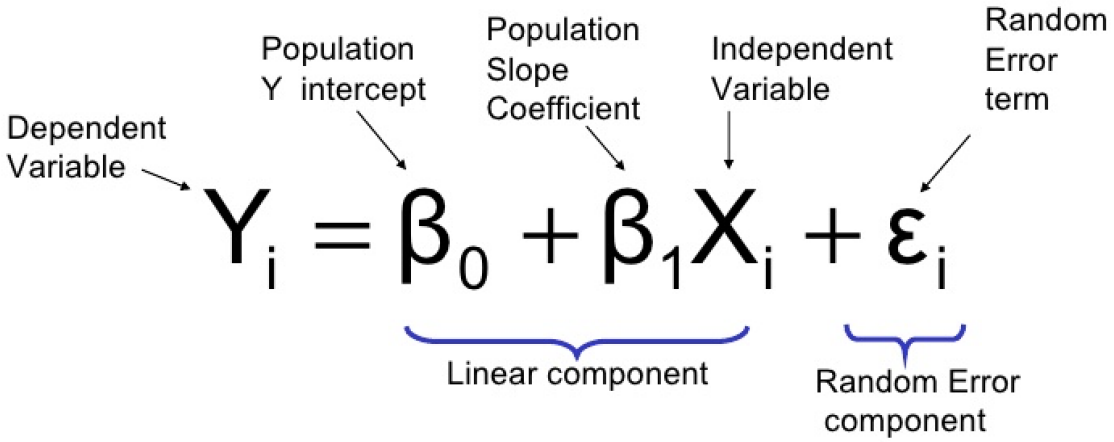
A. Graphing Technique

0.1 Modeling form

dv ~ -1 + PR + age_group + female + marital + educ3 + poor_health + FOL

Province of residence





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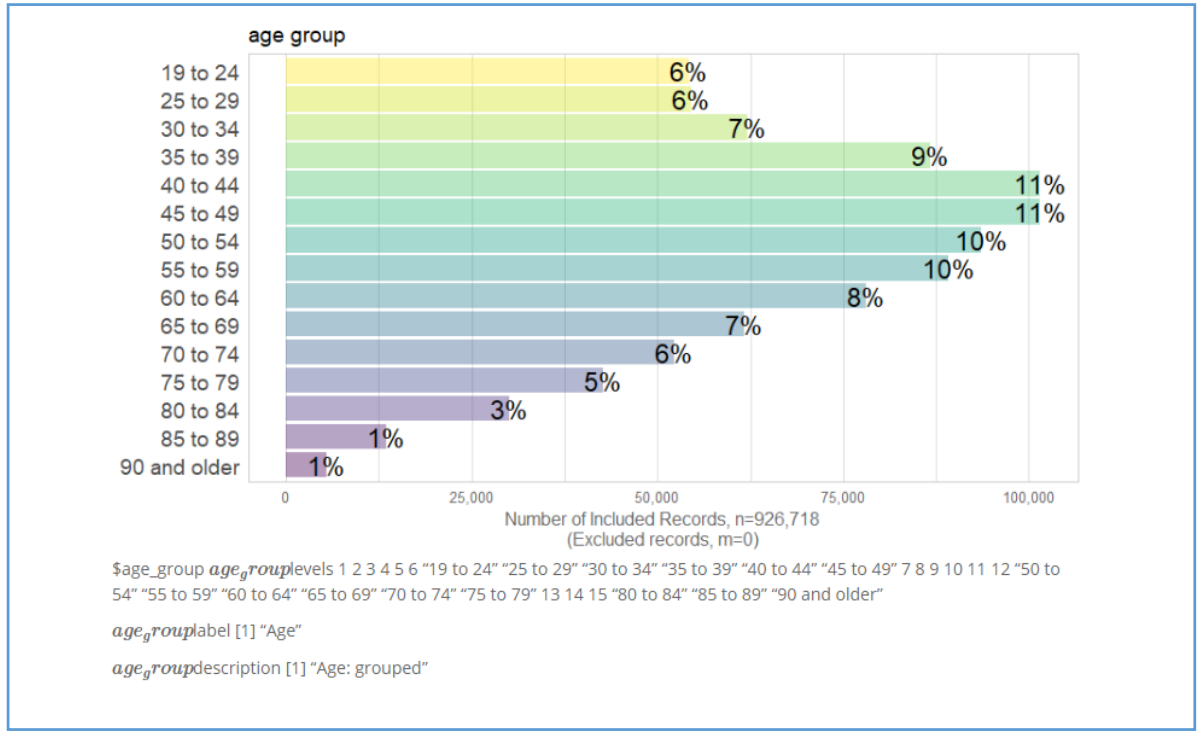
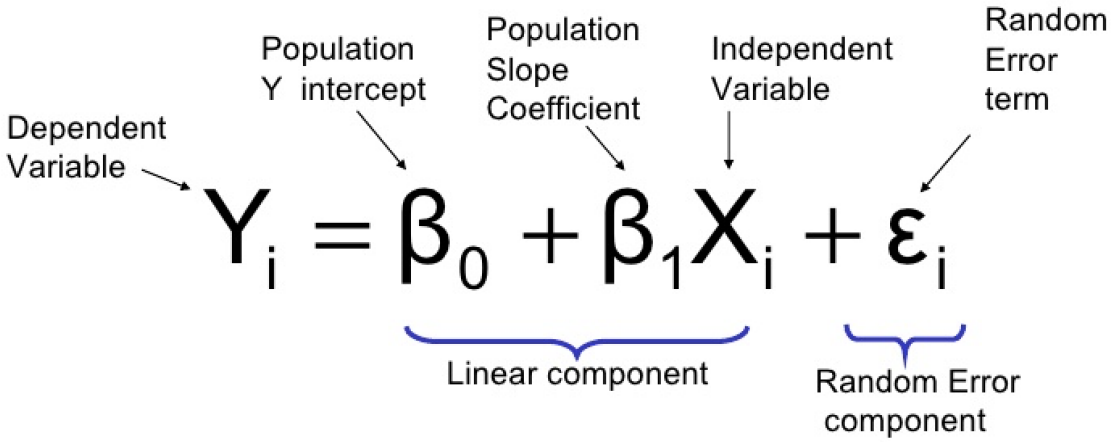
5-year age category





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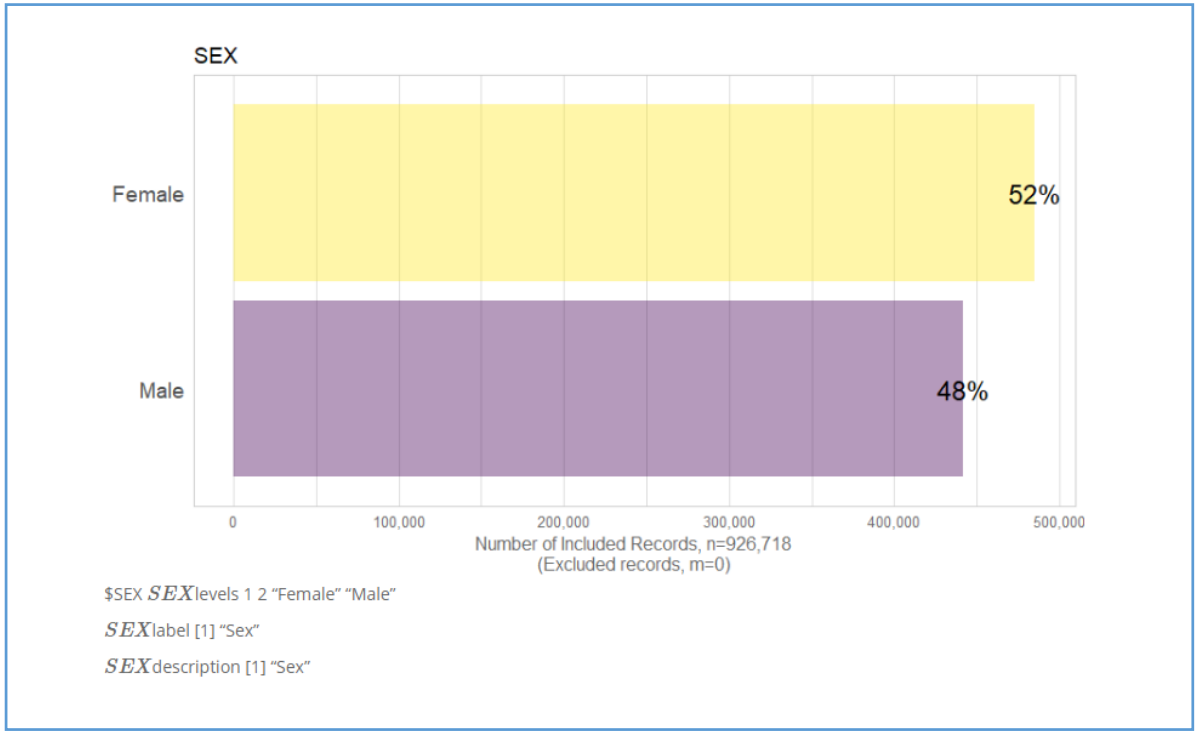
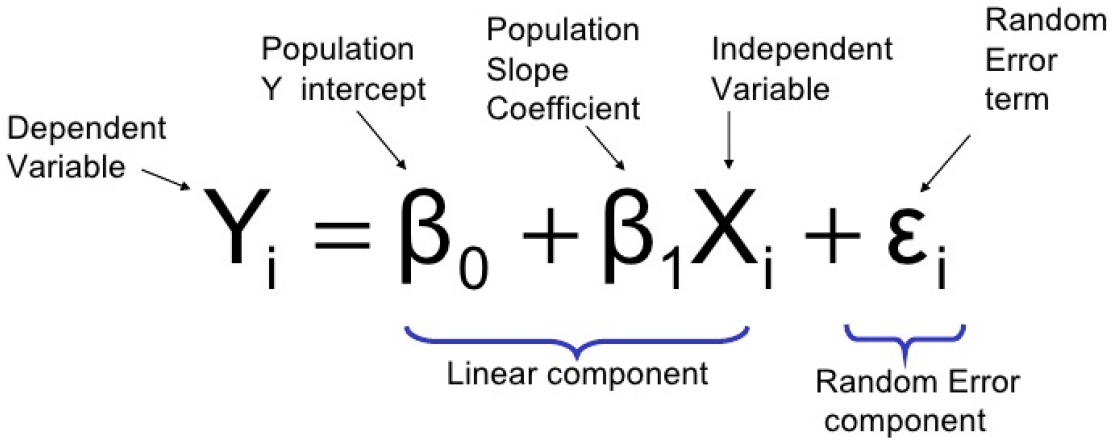
Sex





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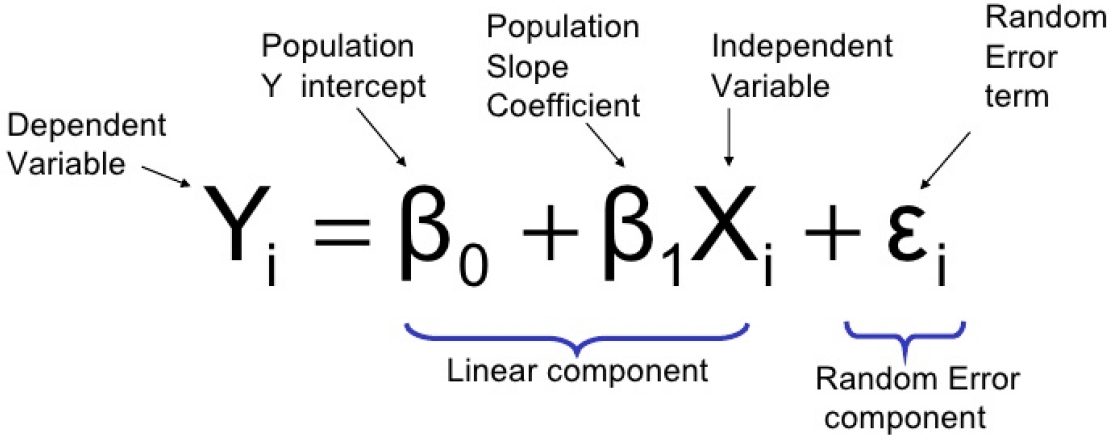
Marital Status

```
# because `still legaly married` is more legal than human
,marital = car::recode(
  MARST, "
  'Divorced'                              = 'sep_divorced'
  ;'Legally married (and not separated)'   = 'mar_cohab'
  ;'Separated, but still legally married'  = 'sep_divorced'
  ;'Never legally married (single)'        = 'single'
  ;'Widowed'                               = 'widowed'
  ")
,marital = factor(marital, levels = c(
  "sep_divorced","widowed","single","mar_cohab"))
```



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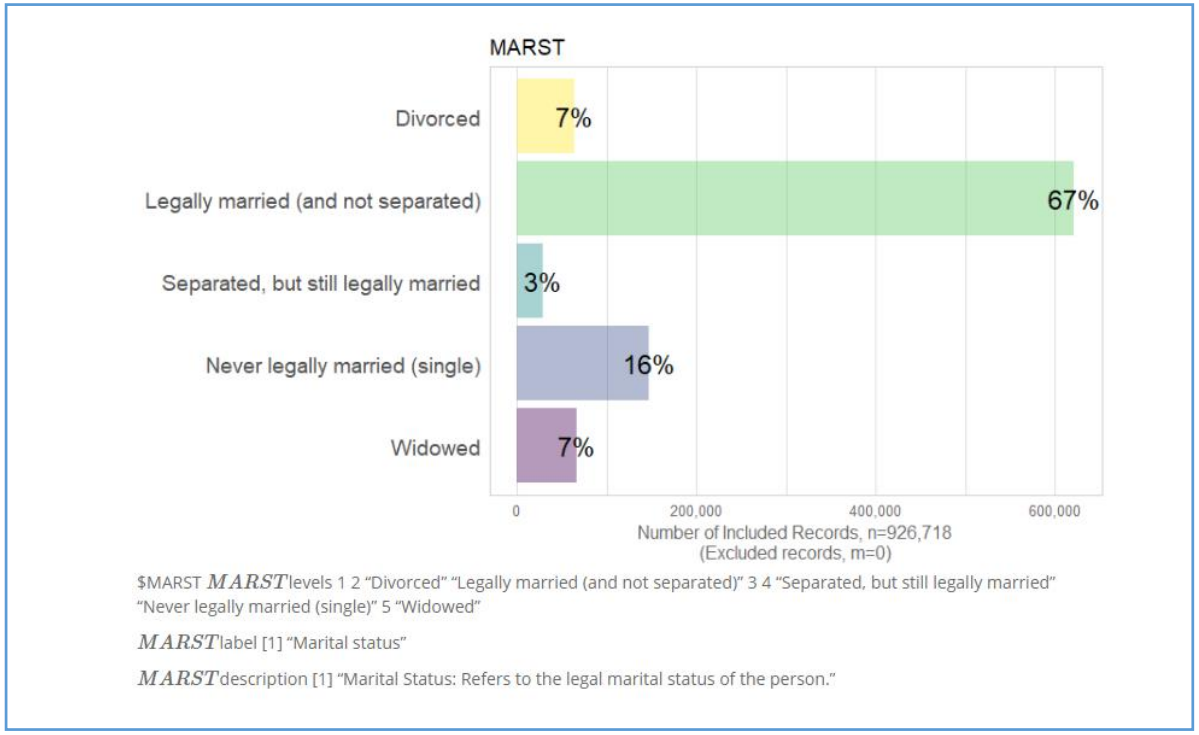

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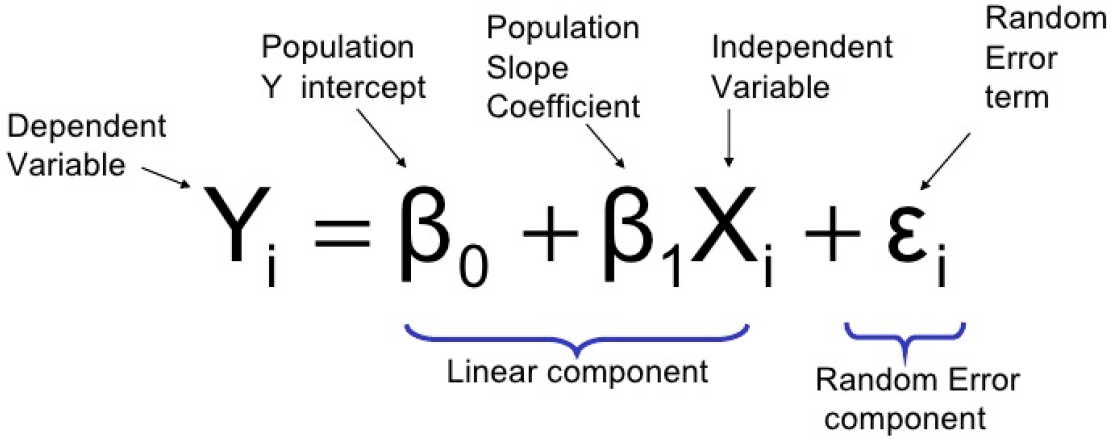
Highest Degree

```
# because even only 5 may be too granular for our purposes
,educ3 = car::recode(
  HCDD, "
  'None'                                                                                                  = 'less than high school'
  ;'High school graduation certificate or equivalency certificate'                                        = 'high school'
  ;'Other trades certificate or diploma'                                                                  = 'high school'
  ;'Registered apprenticeship certificate'                                                                = 'more than high school'
  ;'College, CEGEP or other non-university certificate or diploma from a program of 3 months to less than 1 year' = 'more than high school'
  ;'College, CEGEP or other non-university certificate or diploma from a program of 1 year to 2 years'    = 'more than high school'
  ;'College, CEGEP or other non-university certificate or diploma from a program of more than 2 years'    = 'more than high school'
  ;'University certificate or diploma below bachelor level'                                               = 'more than high school'
  ;'Bachelors degree'                                                                                      = 'more than high school'
  ;'University certificate or diploma above bachelor level'                                               = 'more than high school'
  ;'Degree in medicine, dentistry, veterinary medicine or optometry'                                       = 'more than high school'
  ;'Masters degree'                                                                                        = 'more than high school'
  ;'Earned doctorate degree'                                                                               = 'more than high school'
  ")
,educ3 = factor(educ3, levels = c(
  "less than high school"
  , "high school"
  , "more than high school"
)
)
```

```
# # because we want/need to inspect newly created variables
ds1 %>% group_by(educ3) %>% summarize(n = n())
```

```
# A tibble: 3 x 2
  educ3                    n
  <fct>                <int>
1 less than high school  902326
2 high school           1403807
3 more than high school 2040516
```



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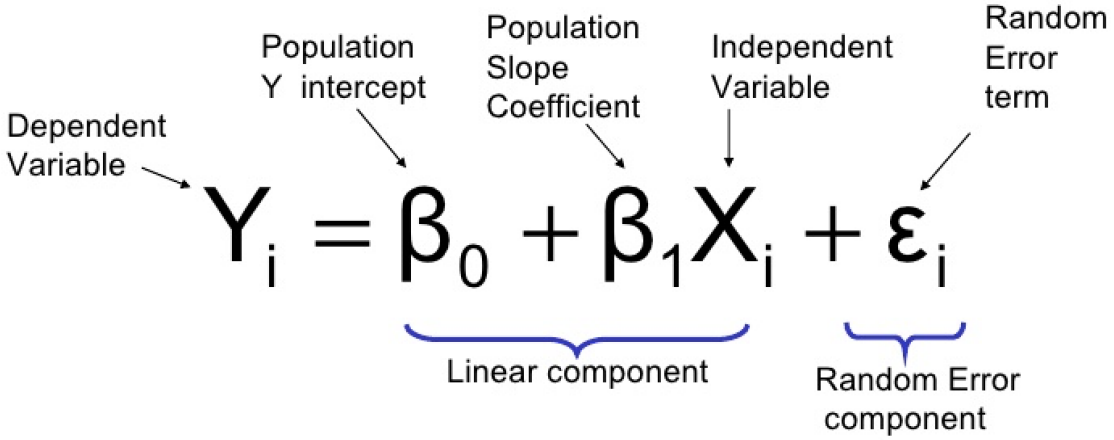
A. Graphing Technique

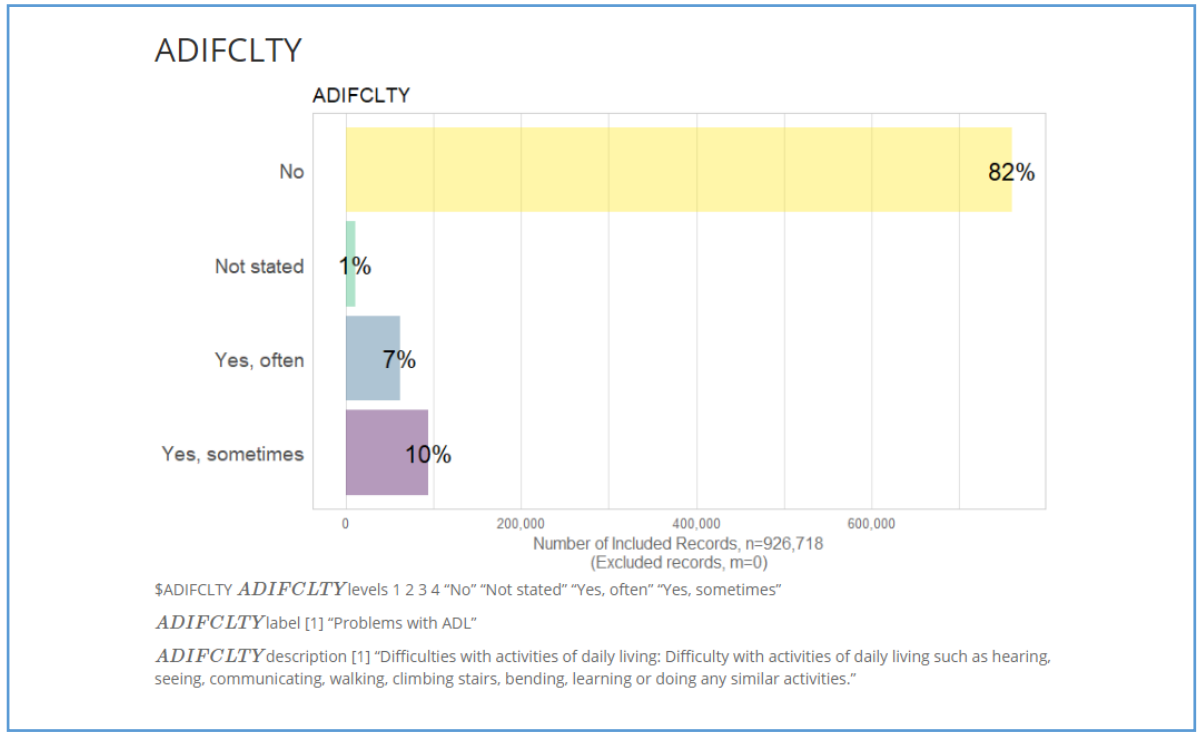
0.1 Modeling form

dv ~ -1 + PR + age_group + female + marital + educ3 + poor_health + FOL

Activities of Daily Living

```
# ADIFCLTY                "Problems with ADL" (physical & cognitive)
# DISABFL                 "Problems with ADL" (physical & social)
# because this is what counts practically
,poor_health = ifelse(ADIFCLTY %in% c("Yes, often","Yes, sometimes")
                      &
                        DISABFL %in% c("Yes, often","Yes, sometimes"),
                      TRUE, FALSE
)
,poor_health = factor(poor_health, levels = c("TRUE","FALSE"))
```





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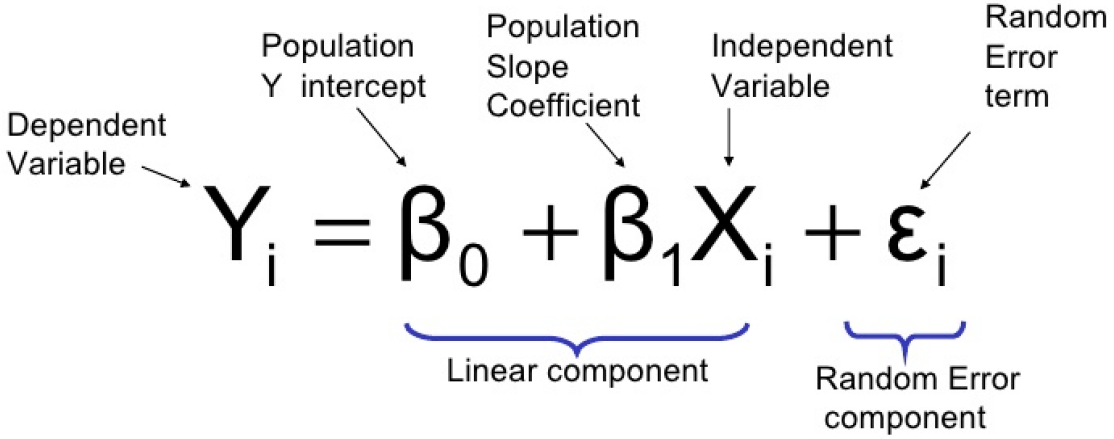

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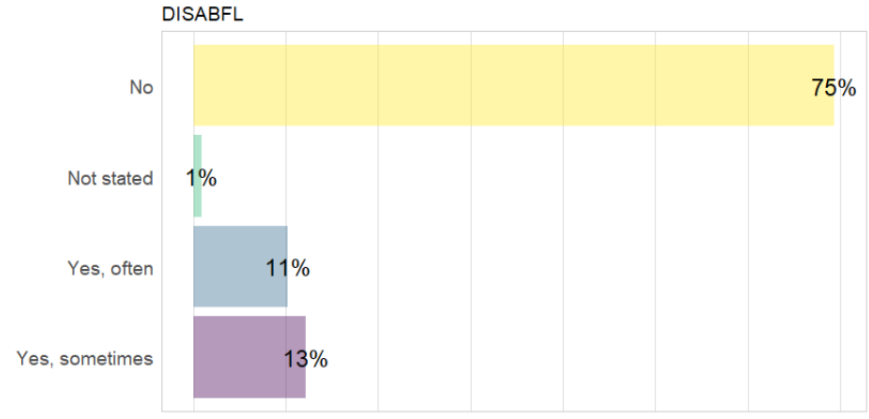
DISABFL



$DISABFL *DISABFL* levels 1 2 3 4 "No" "Not stated" "Yes, often" "Yes, sometimes"

DISABFL label [1] "Problems with ADL"

DISABFL description [1] "Difficulties with activities of daily living: Refers to difficulty with daily activities and/or a physical condition or mental condition or health problem that reduces the amount or kind of activity that a person can do at home, at work or school or in other activities (e.g., transportation, leisure)."

$$\ln\left(\frac{\hat{p}}{(1-\hat{p})}\right) = b_0 + b_1X_1 + b_2X_2 + \ldots + b_pX_p$$

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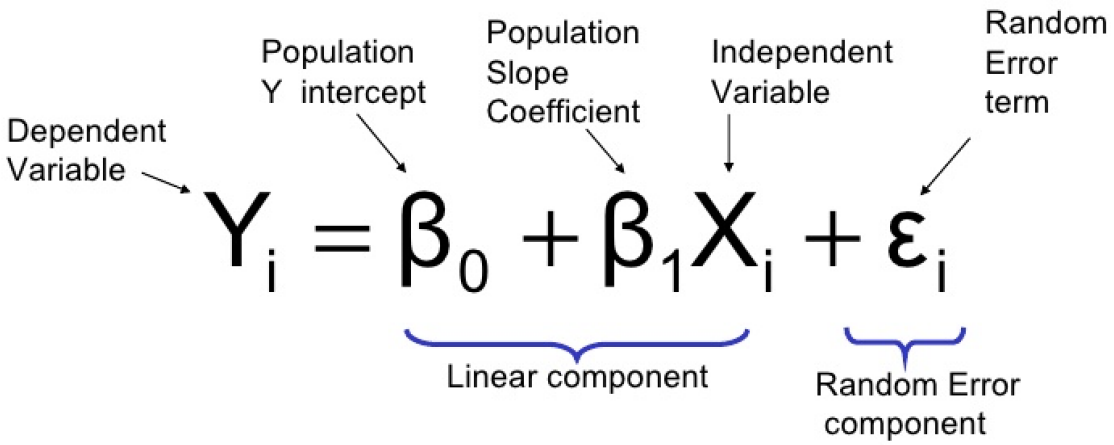
A. Graphing Technique

0.1 Modeling form

dv ~ -1 + PR + age_group + female + marital + educ3 + poor_health + FOL

First Official Language



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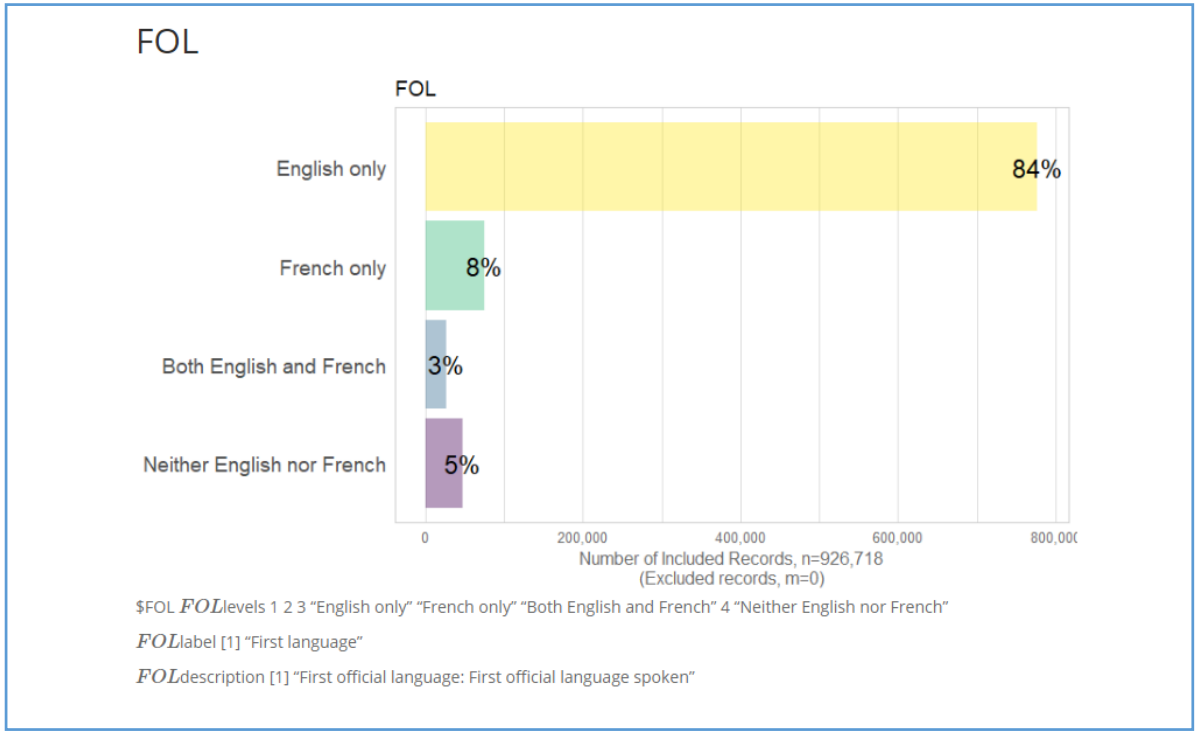

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A. Graphing Technique

dv ~ -1 + PR + age_group + female + marital + educ3 + poor_health + FOL

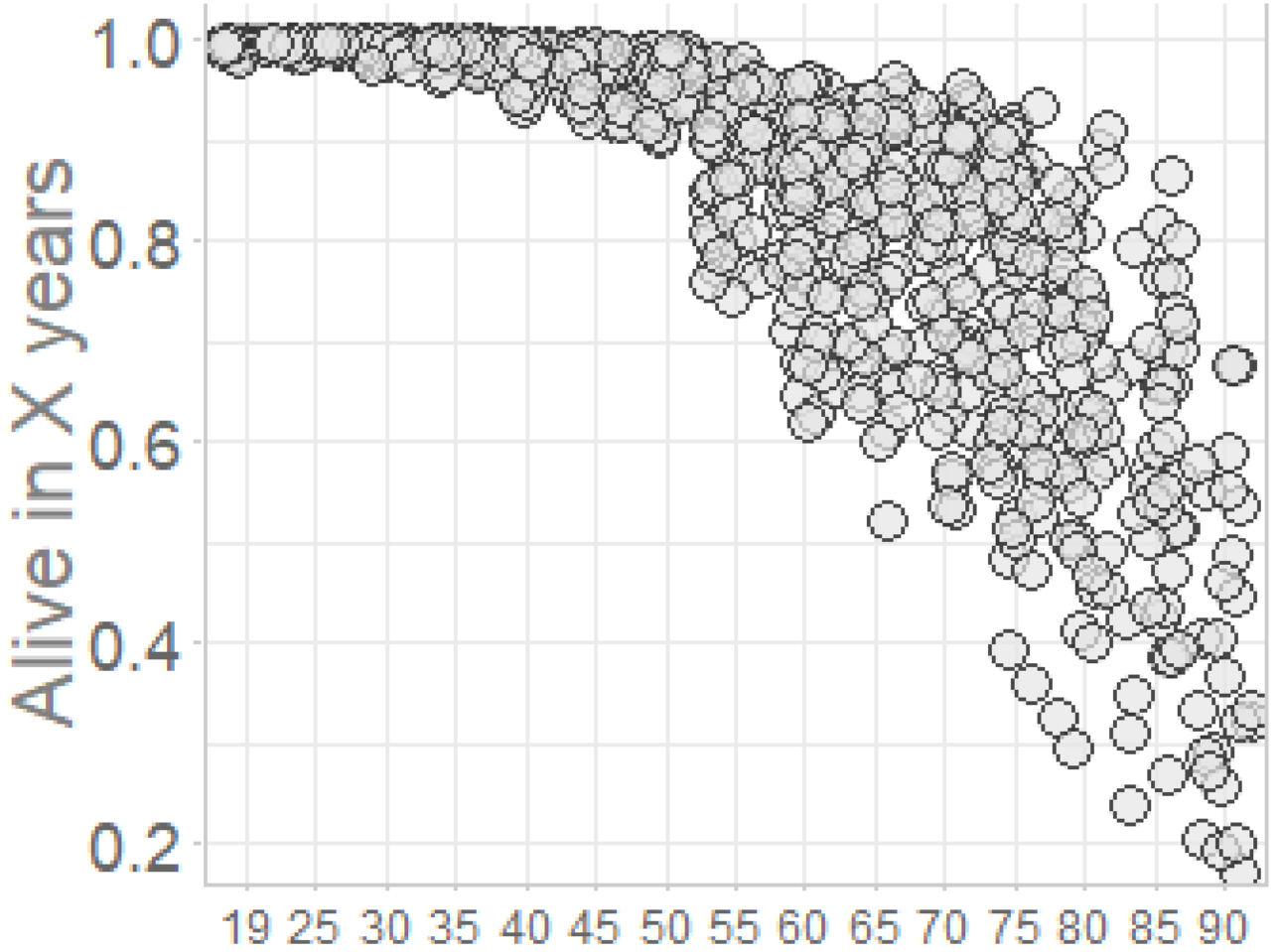
0.2 Graphical form

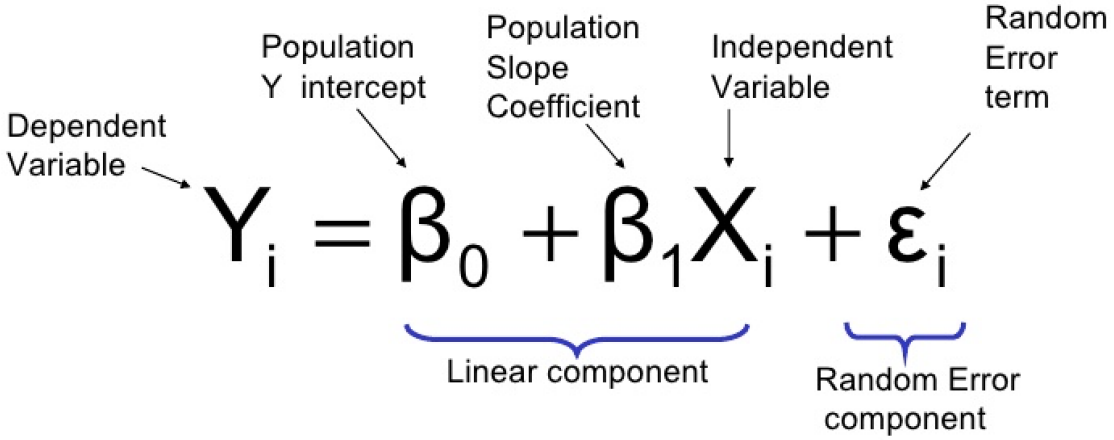
LEGEND

point = person
Y-axis = probability R is dead in X years
X-axis = age group (floor of 5-year category)

The higher the dot = the higher the chance to be alive in X years

Visualizing probability instead of log-odds because it is more intuitive





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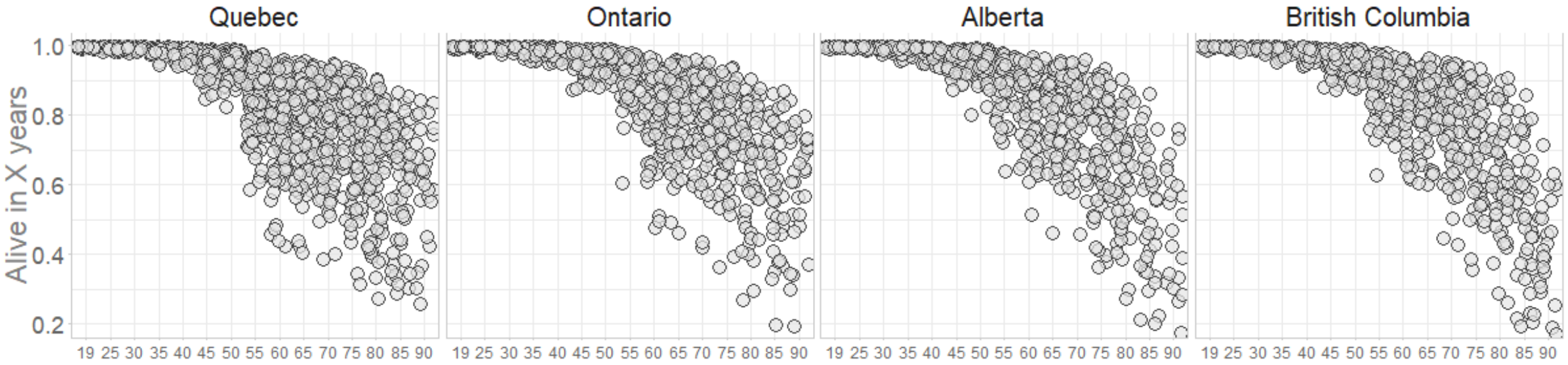
A. Graphing Technique

dv ~ -1 + PR + age_group + female + marital + educ3 + poor_health + FOL

0.2 Graphical form



LEGEND

Facet = Province of residence

A. Graphing Technique

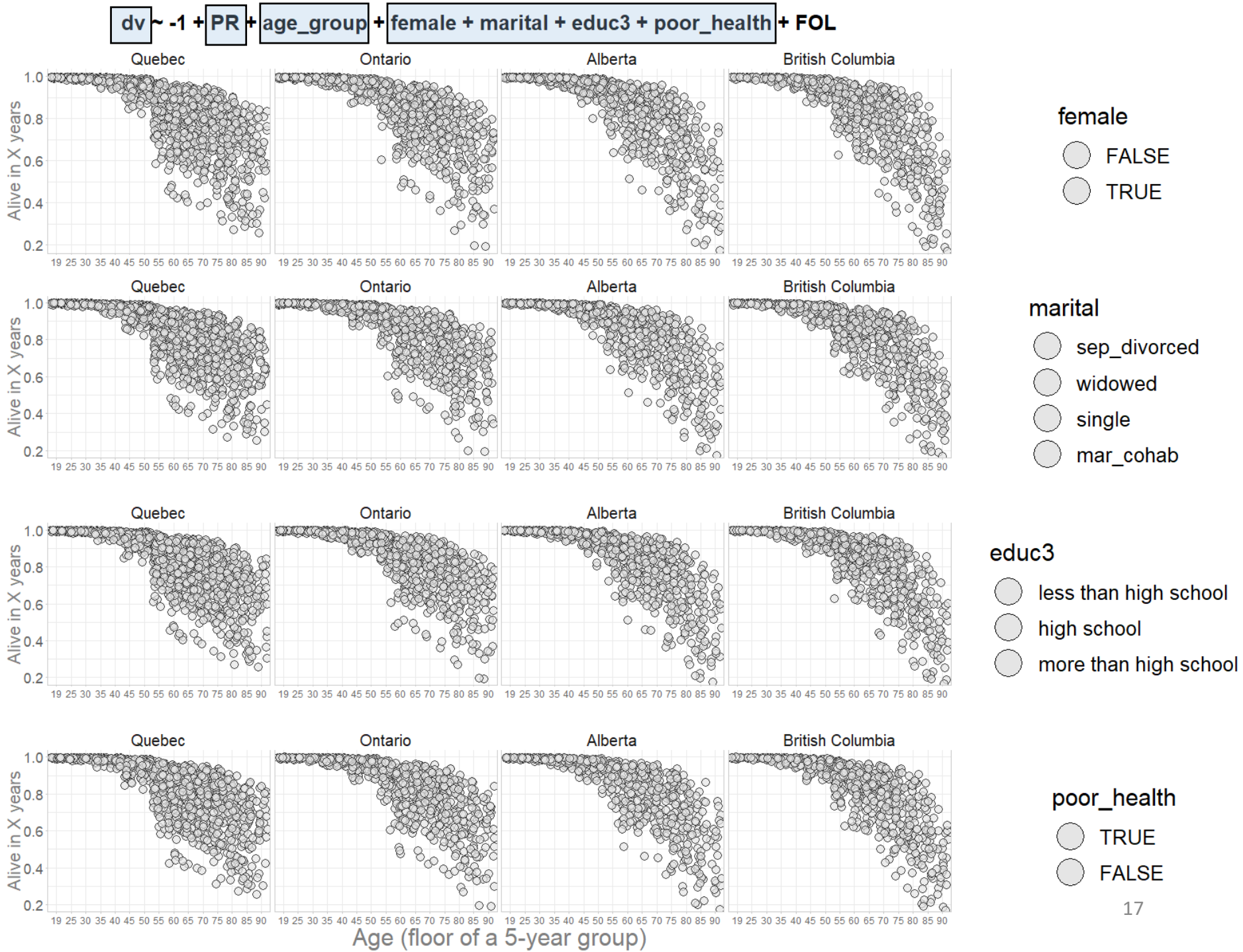
0.2 Graphical form

LEGEND

Rows = duplicate of each other (for now).

Notice that FOL is not displayed

The book is ready for coloring



A. Graphing Technique

0.3 Coloring book

dv ~ -1 + PR + age_group + female + marital + educ3 + poor_health + FOL

QUESTION

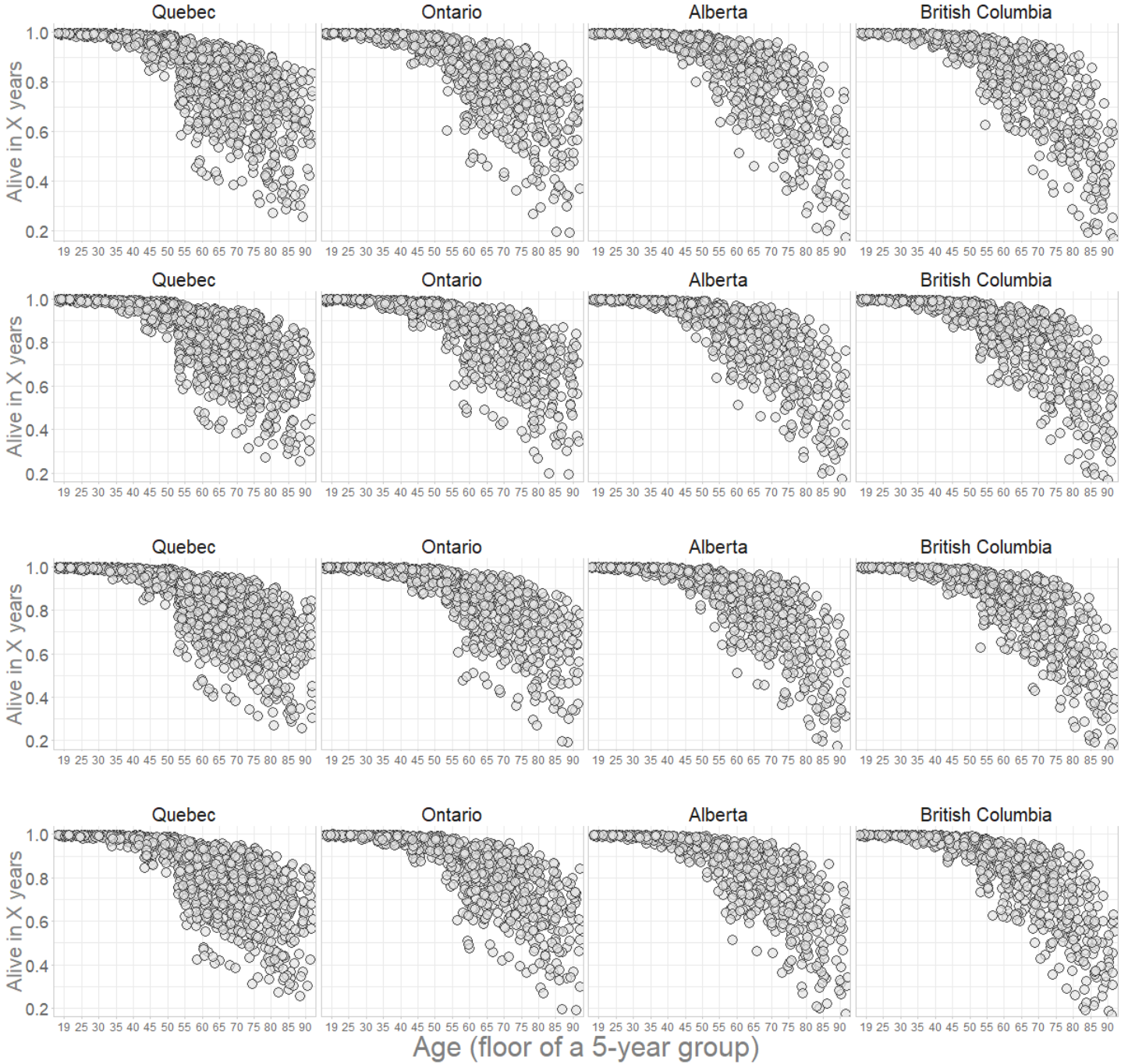
What should the "reference group" be for each predictor?

What do we expect based on existing research?

Informed expectation

Reference group

?



female
- FALSE
- TRUE

marital
- sep_divorced
- widowed
- single
- mar_cohab

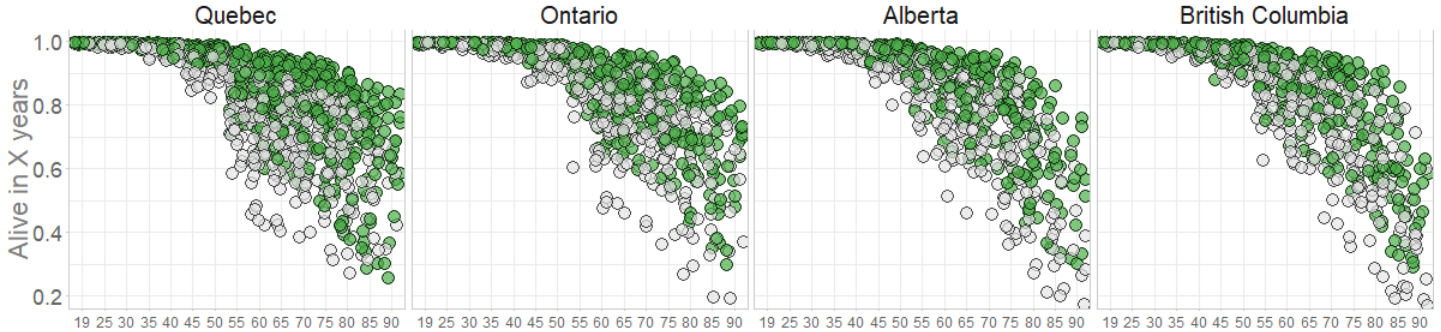
educ3
- less than high school
- high school
- more than high school

poor_health
- TRUE
- FALSE

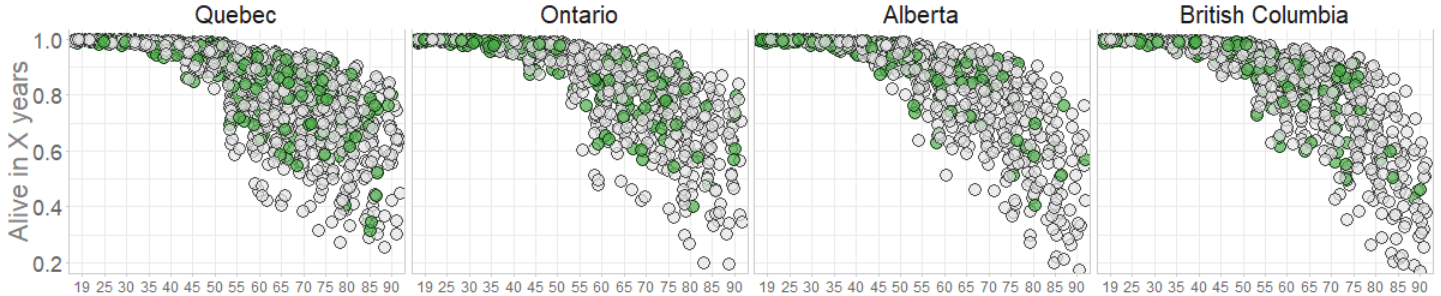
A. Graphing Technique

0.3 Coloring book

dv ~ -1 + PR + age_group + female + marital + educ3 + poor_health + FOL

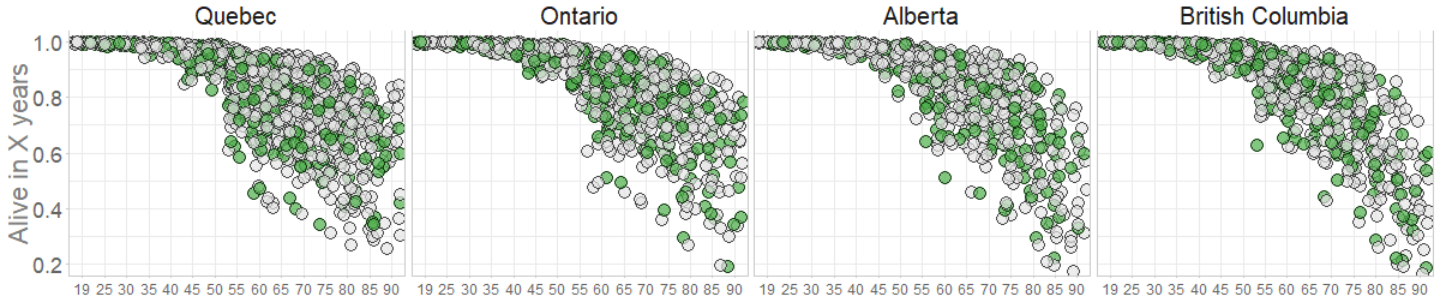


female
- FALSE
- TRUE



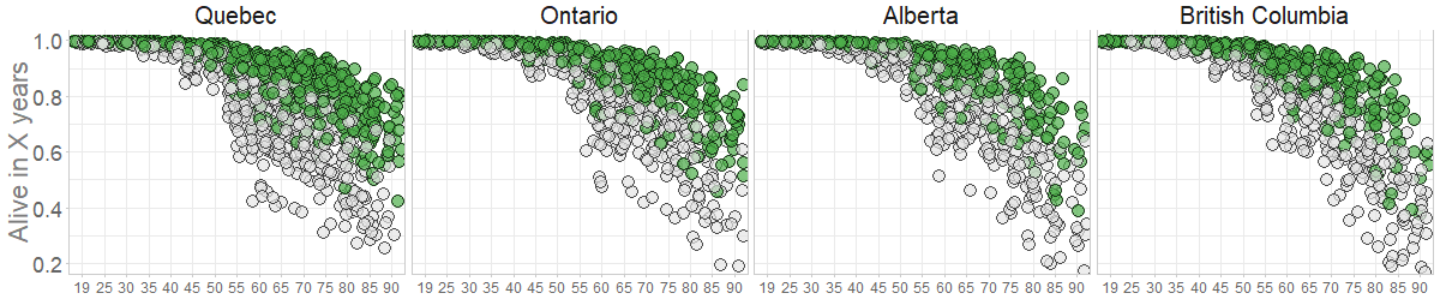
marital
- sep_divorced
- widowed
- single
- mar_cohab

Informed expectation



educ3
- less than high school
- high school
- more than high school

Reference group



poor_health
- TRUE
- FALSE

A. Graphing Technique

0.3 Coloring book

dv ~ -1 + PR + age_group + female + marital + educ3 + poor_health + FOL

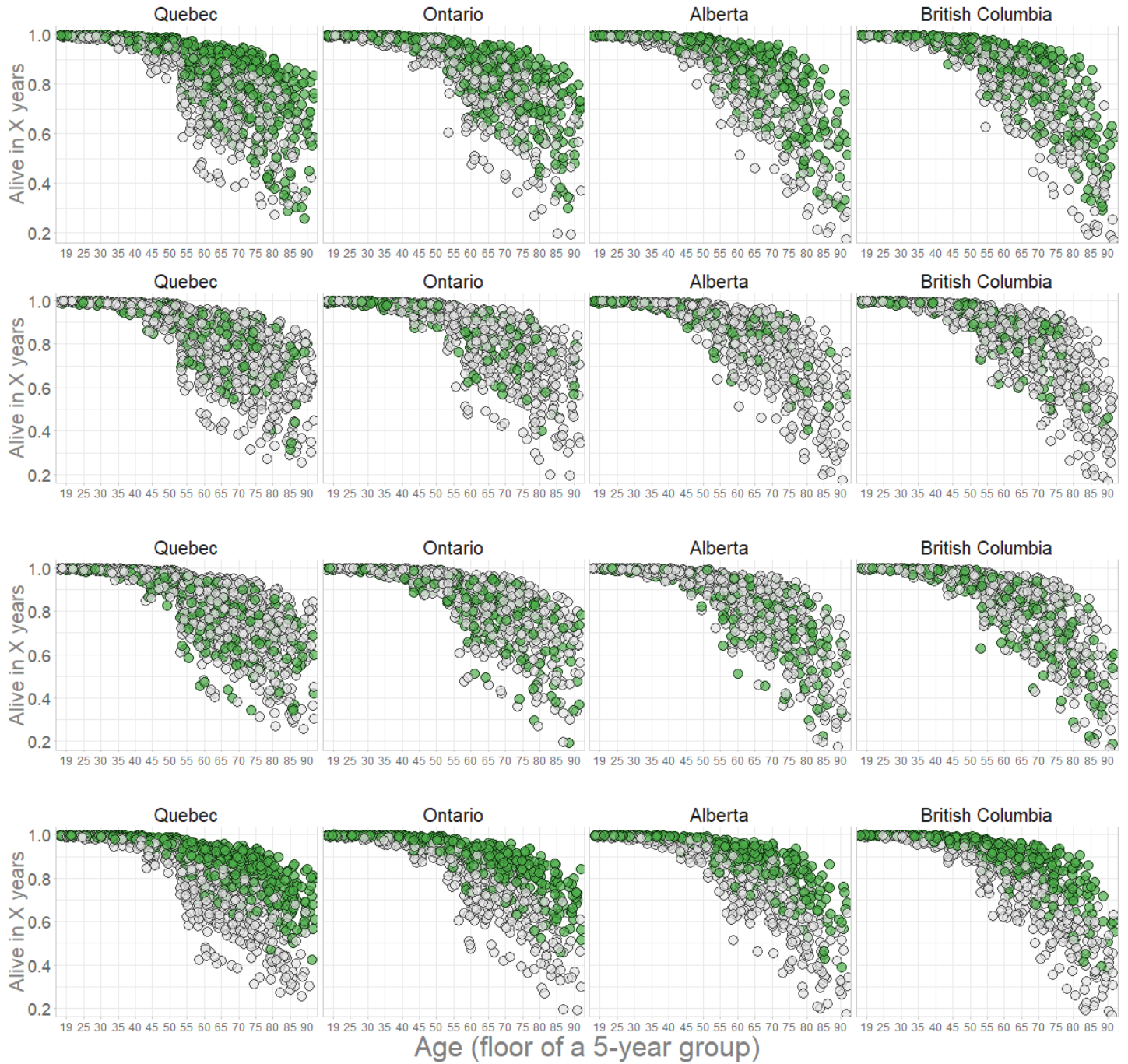
QUESTION

Compared to reference group, what levels of predictors are expected to **increase** the mortality risk?

Informed expectation

Moderately increased risk ?

Reference group



female
FALSE
TRUE

marital
sep_divorced
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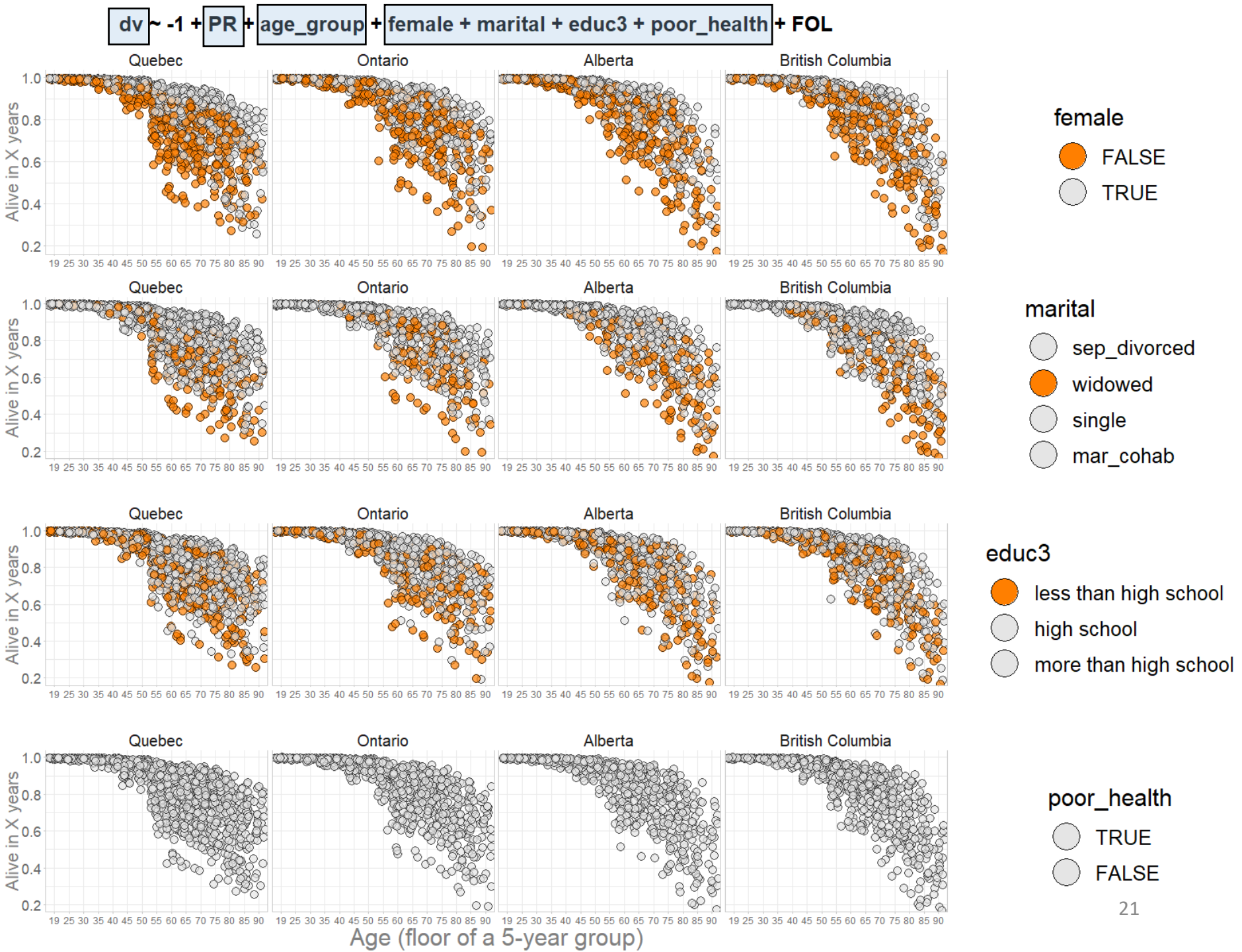
educ3
less than high school
high school
more than high school

poor_health
TRUE
FALSE

A. Graphing Technique

0.3 Coloring book



Informed expectation

Moderately increased risk

Reference group

A. Graphing Technique

0.3 Coloring book

QUESTION

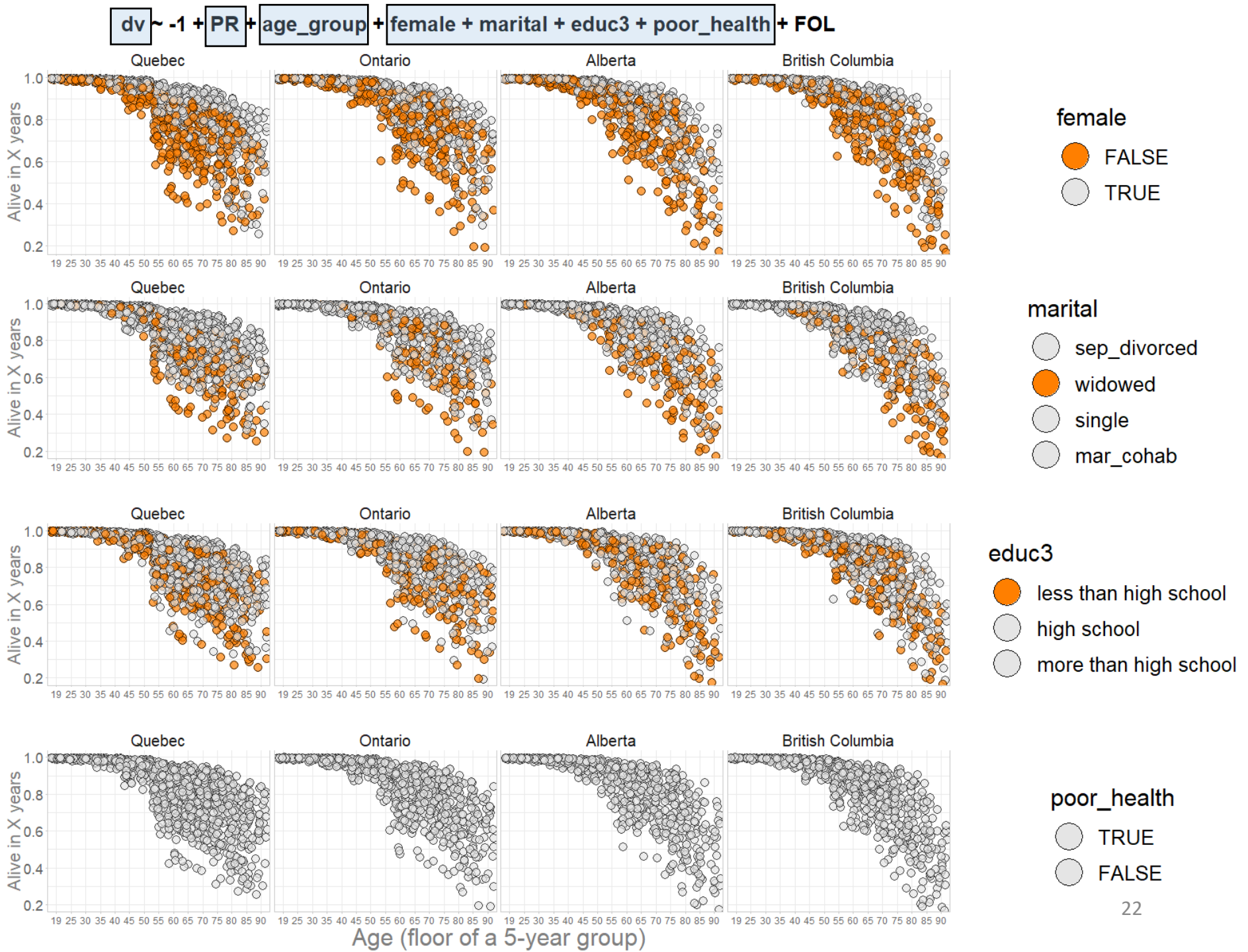
Compared to reference group, what levels of predictors are expected to **decrease** the mortality risk?

Informed expectation

Moderately increased risk

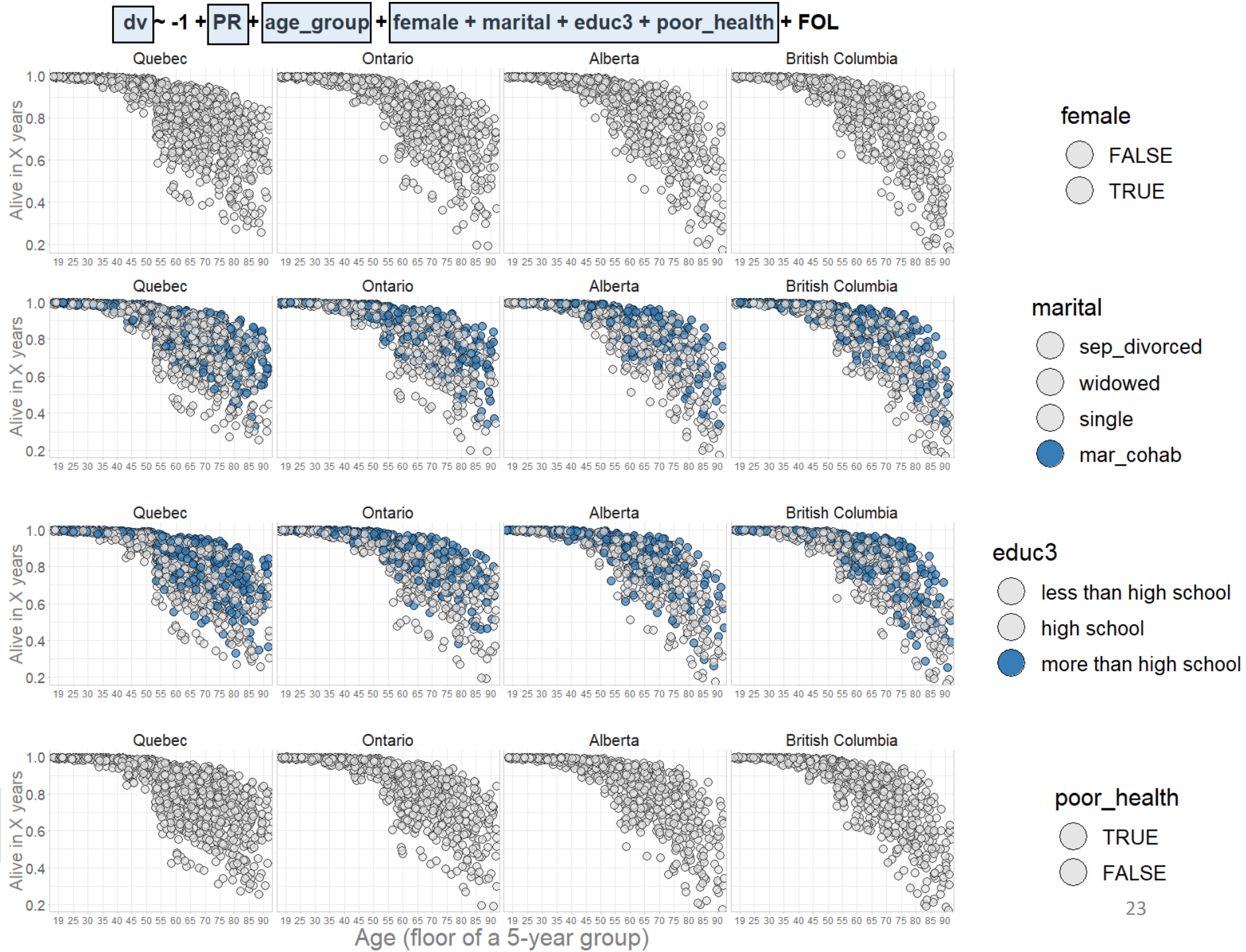
Reference group

Moderately decreased risk ?



A. Graphing Technique

0.3 Coloring book



Informed expectation

Moderately increased risk

Reference group

Moderately decreased risk

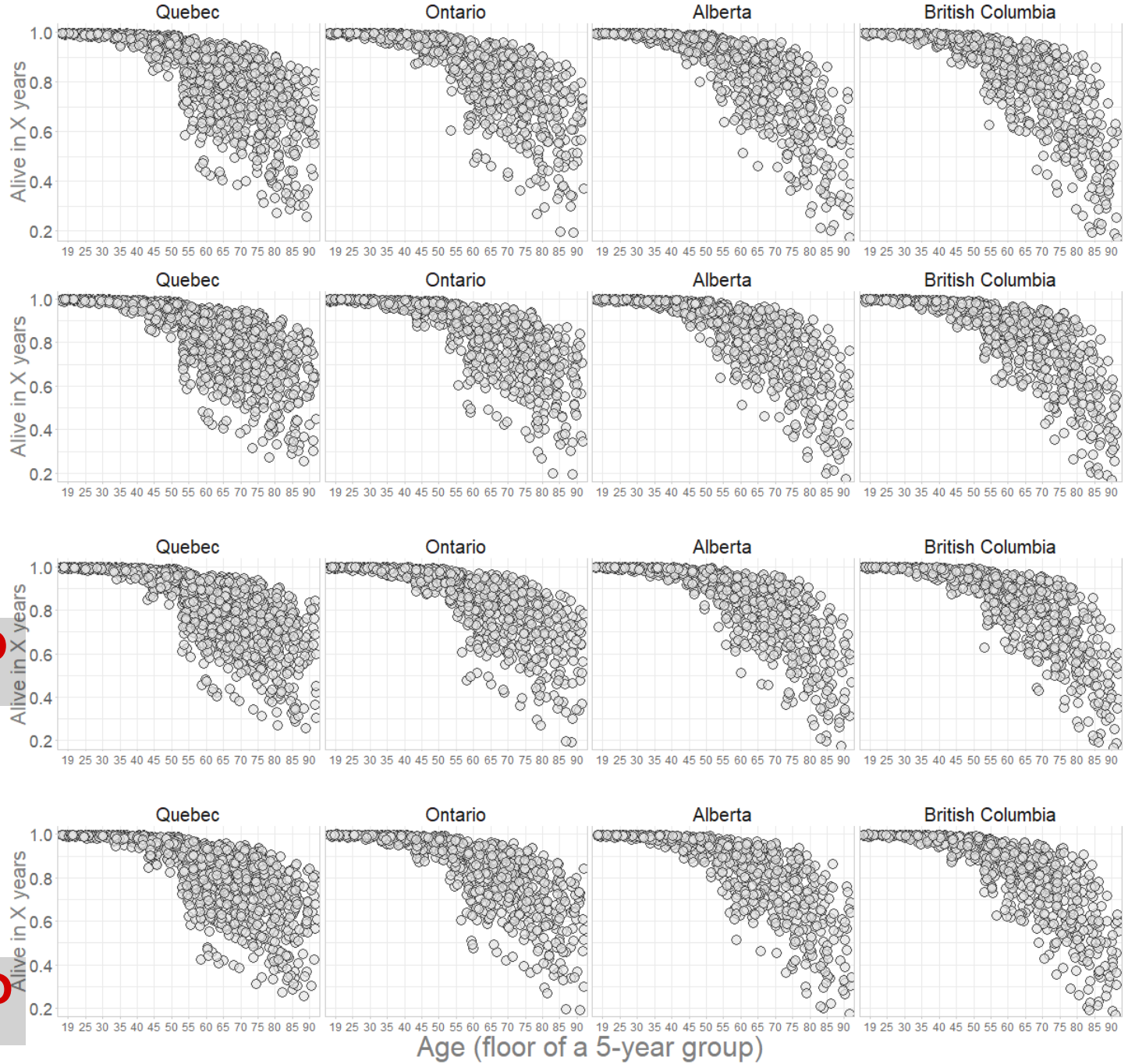
A. Graphing Technique

0.3 Coloring book

dv ~ -1 + PR + age_group + female + marital + educ3 + poor_health + FOL

QUESTION

What levels of predictors are expected to affect mortality risk drastically?



female
- FALSE
- TRUE

marital
- sep_divorced
- widowed
- single
- mar_cohab

educ3
- less than high school
- high school
- more than high school

poor_health
- TRUE
- FALSE

Informed expectation

- Substantially increased risk ?
- Moderately increased risk
- Reference group
- Moderately decreased risk
- Substantially decreased risk ?

A. Graphing Technique

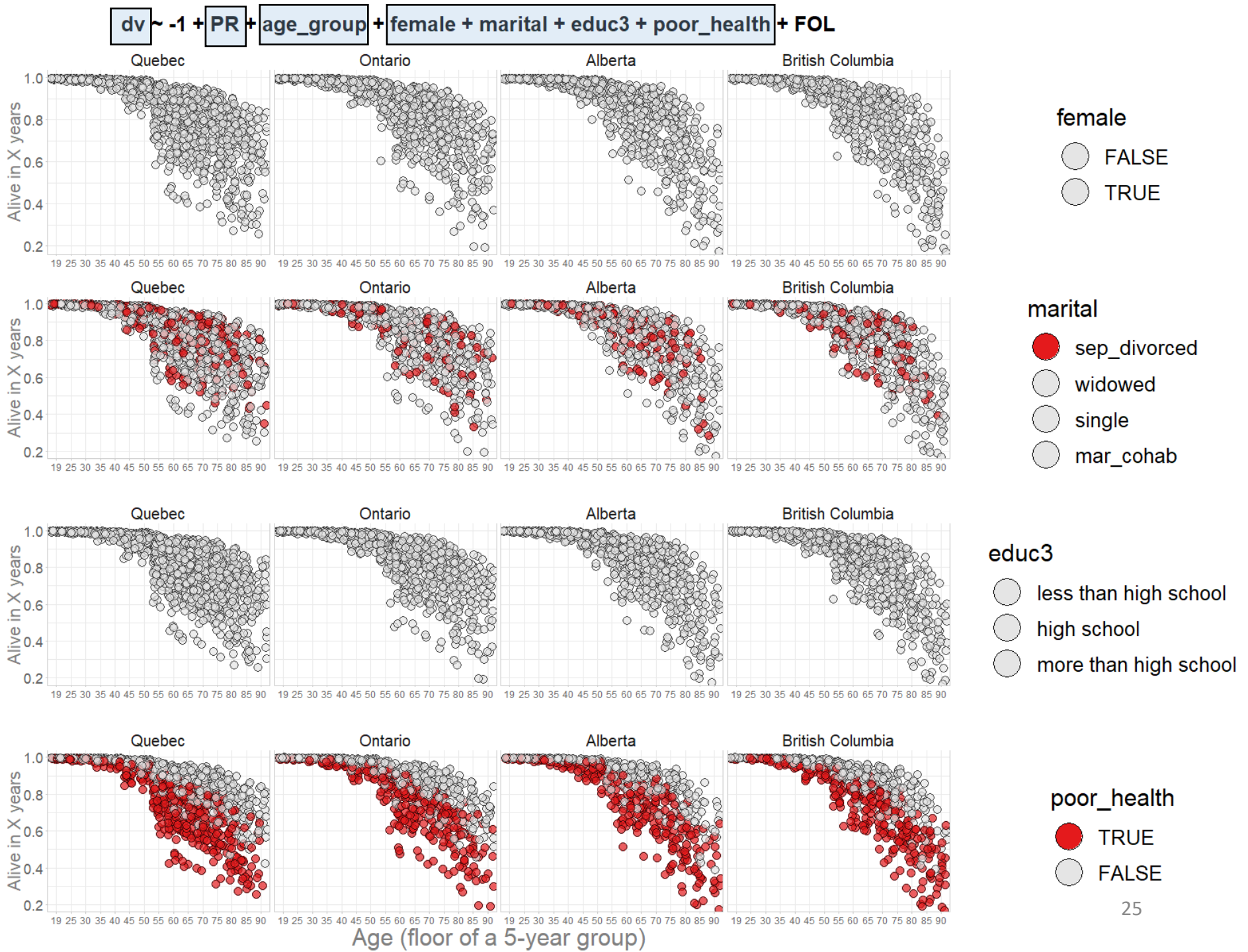
0.3 Coloring book

QUESTION

What levels of predictors are expected to affect mortality risk drastically?

Informed expectation

- Substantially increased risk
- Moderately increased risk
- Reference group
- Moderately decreased risk
- Substantially decreased risk



A. Graphing Technique

0.3 Coloring book

dv ~ -1 + PR + age_group + female + marital + educ3 + poor_health + FOL

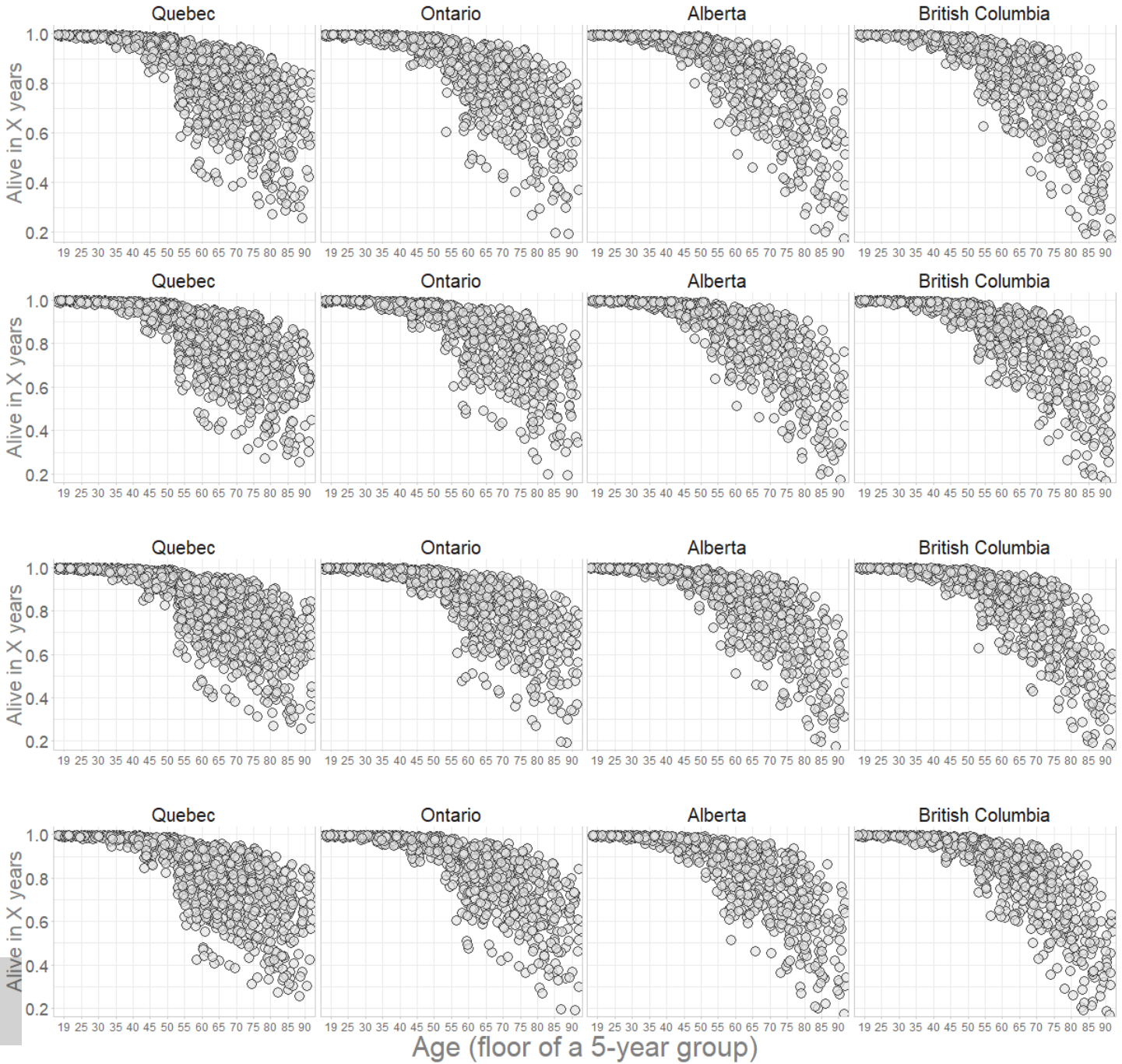
QUESTION

What levels of predictors are expected to affect mortality risk drastically?

No “very bad” and it’s ok.

Informed expectation

- Substantially increased risk
- Moderately increased risk
- Reference group
- Moderately decreased risk
- Substantially decreased risk



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A. Graphing Technique

0.3 Coloring book

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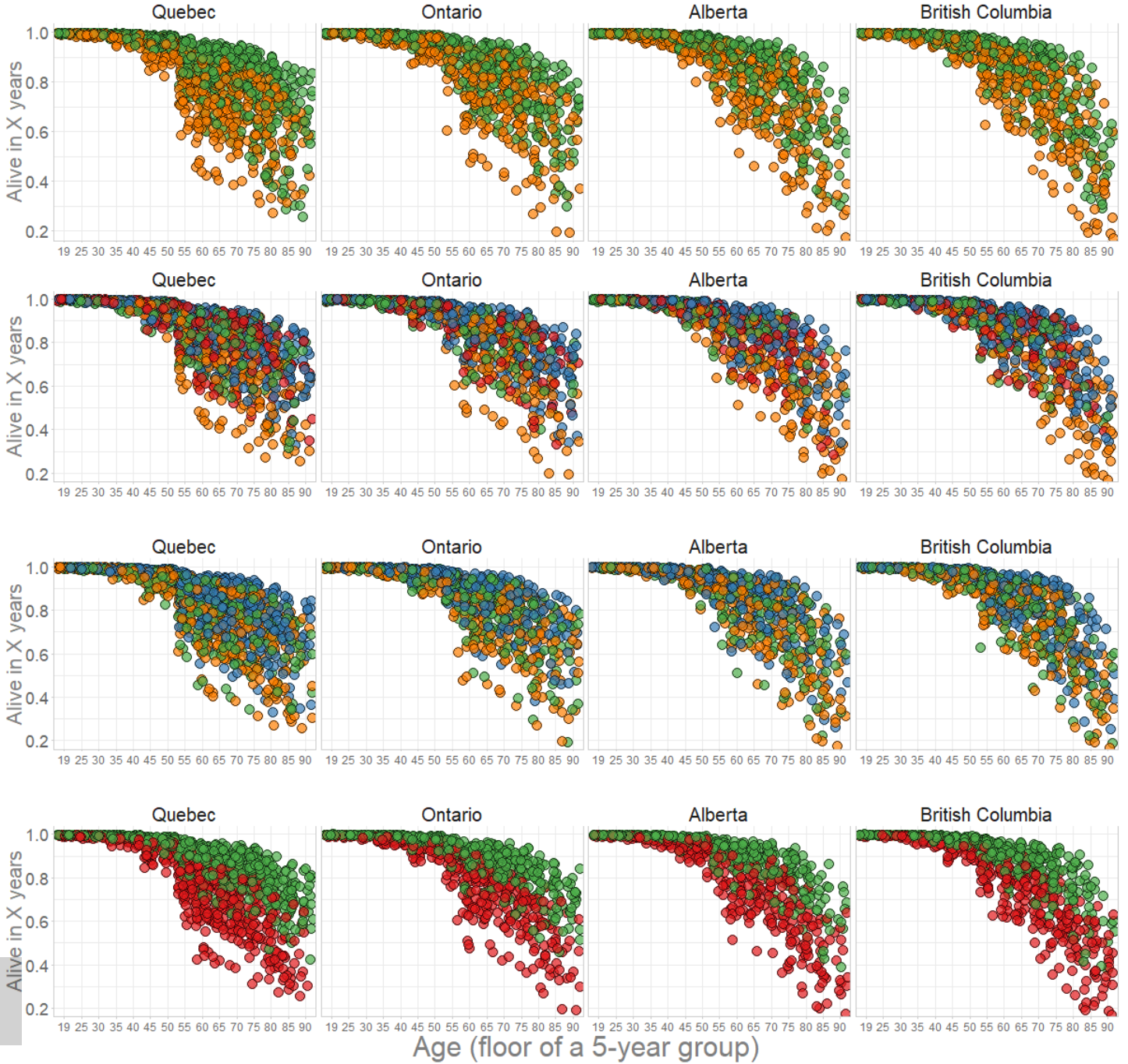

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- high school
- more than high school

poor_health
- TRUE
- FALSE

NOTICE

Plotting all colors at once may not be as informative as one would expect

May require too much tweaking to make useful

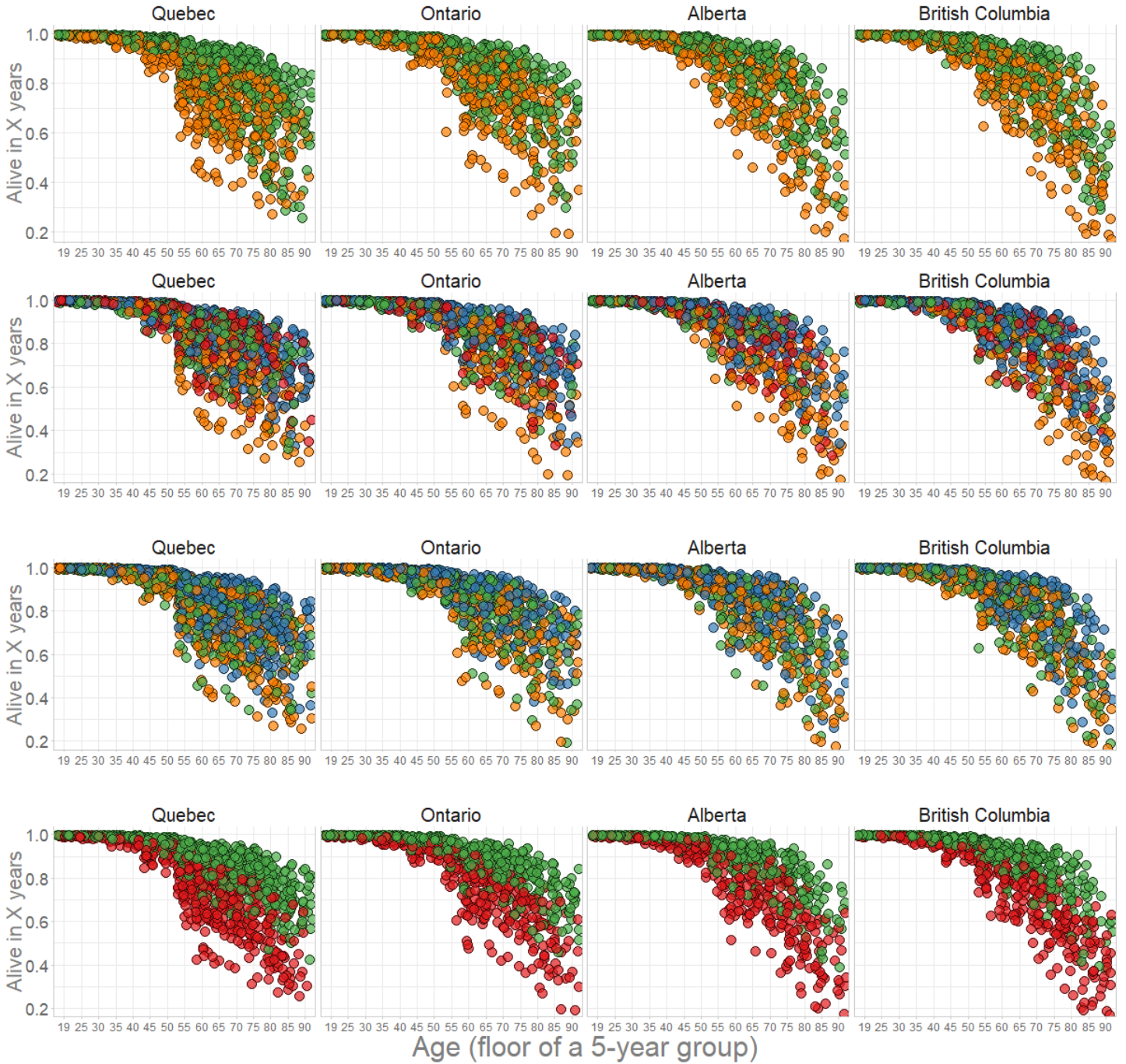
Informed expectation

- Substantially increased risk
- Moderately increased risk
- Reference group
- Moderately decreased risk
- Substantially decreased risk

A. Graphing Technique

0.3 Coloring book

dv ~ -1 + PR + age_group + female + marital + educ3 + poor_health + FOL



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poor_health
- TRUE
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NOTICE

Note all predictors are worth visualizing, some are there for control.

We can adjust what is being displayed

Informed expectation

- Substantially increased risk
- Moderately increased risk
- Reference group
- Moderately decreased risk
- Substantially decreased risk

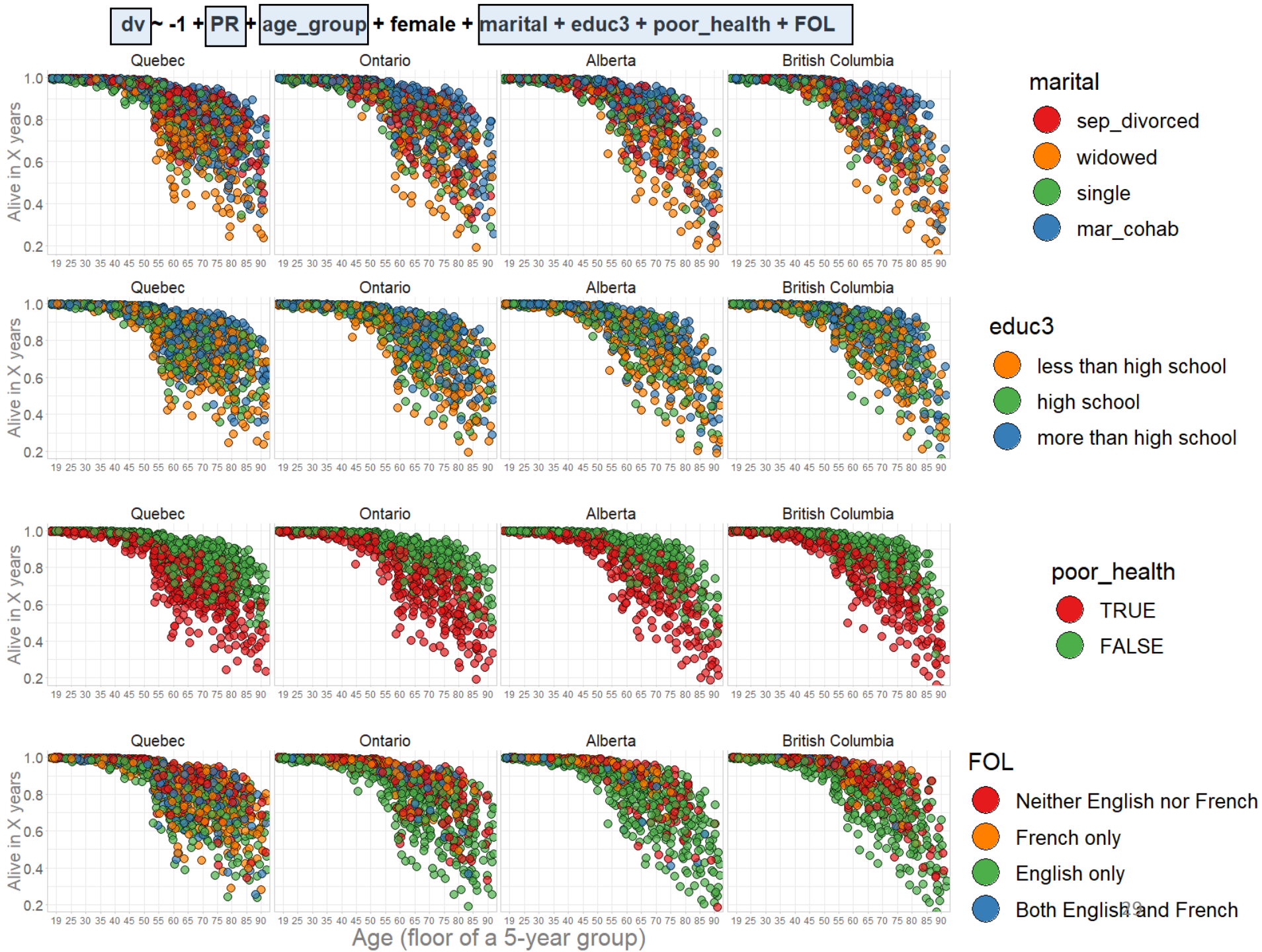
A. Graphing Technique

0.3 Coloring book

NOTICE

Note all predictors are worth visualizing, some are there for control.

We can adjust what is being displayed



Informed expectation

- Substantially increased risk
- Moderately increased risk
- Reference group
- Moderately decreased risk
- Substantially decreased risk

Let us try to reproduce these graphs!

Ideas to keep in mind as we begin live demonstration

B. Workflow Highlights

1.0 “Let no one ignorant of geometry enter”: (my) scripts were written to be read by humans
1.1 RAnalysisSkeleton by Will Beasley: basic starting point for reproducible projects
1.2 Autonomous phases: data cleaning, statistical modelling, graph production
1.3 Layers of Isolation: analysis vs presentation using .R (+ .Rmd) => .html (+ .pdf)
1.4 Two essential means of production: knitr::stitch() vs rmarkdown::render()

We will find these ideas implemented in this project

B. Workflow Highlights

1.0 “Let no one ignorant of geometry enter”: (my) scripts were written to be read by humans

Donald Knuth. "Literate Programming (1984)" in Literate Programming. CSLI, 1992, pg. 99.

I believe that the time is ripe for significantly better documentation of programs, and that we can best achieve this by considering programs to be works of literature. Hence, my title: "Literate Programming."

Let us change our traditional attitude to the construction of programs: Instead of imagining that our main task is to instruct a computer what to do, let us concentrate rather on explaining to human beings what we want a computer to do.

Source: http://www.literateprogramming.com/

Let’s open the main README and start the reproduction

.R
stores analysis
(what really happens)

.Rmd
stores presentation
(how you tell about it)

.R + .Rmd = .html

A. Graphing Technique

0.0 Data & Context : Mortality factors of Canadian immigrants at IPDLN-2018 hackathon
0.1 Modeling form: univariate logistic regression with categorical predictors
0.2 Graphical form: faceted scatterplot in ggplot2
0.3 Coloring book: Mapping informed expectations from predictors onto color

B. Workflow Highlights

1.0 "Let no one ignorant of geometry enter": (my) scripts were written to be read by humans
1.1 RAnalysisSkeleton by Will Beasley: basic starting point for reproducible projects
1.2 Autonomous phases: data cleaning, statistical modelling, graph production
1.3 Layers of Isolation: analysis vs presentation using .R (+ .Rmd) => .html (+ .pdf)
1.4 Two essential means of production: knitr::stitch() vs rmarkdown::render()

C. Live demonstration from github.com/andkov/IPDLN-2018 hackathon

D. Conclusions

2.0 Different than Notebooks: sacrifices simplicity for agility via layers of isolation
2.1 R (+ .Rmd) = .html (+ .pdf) : moving away from *data playing* towards *data science*
2.2 Reproducible projects: moving away from notebooks towards software

Questions? Comments?

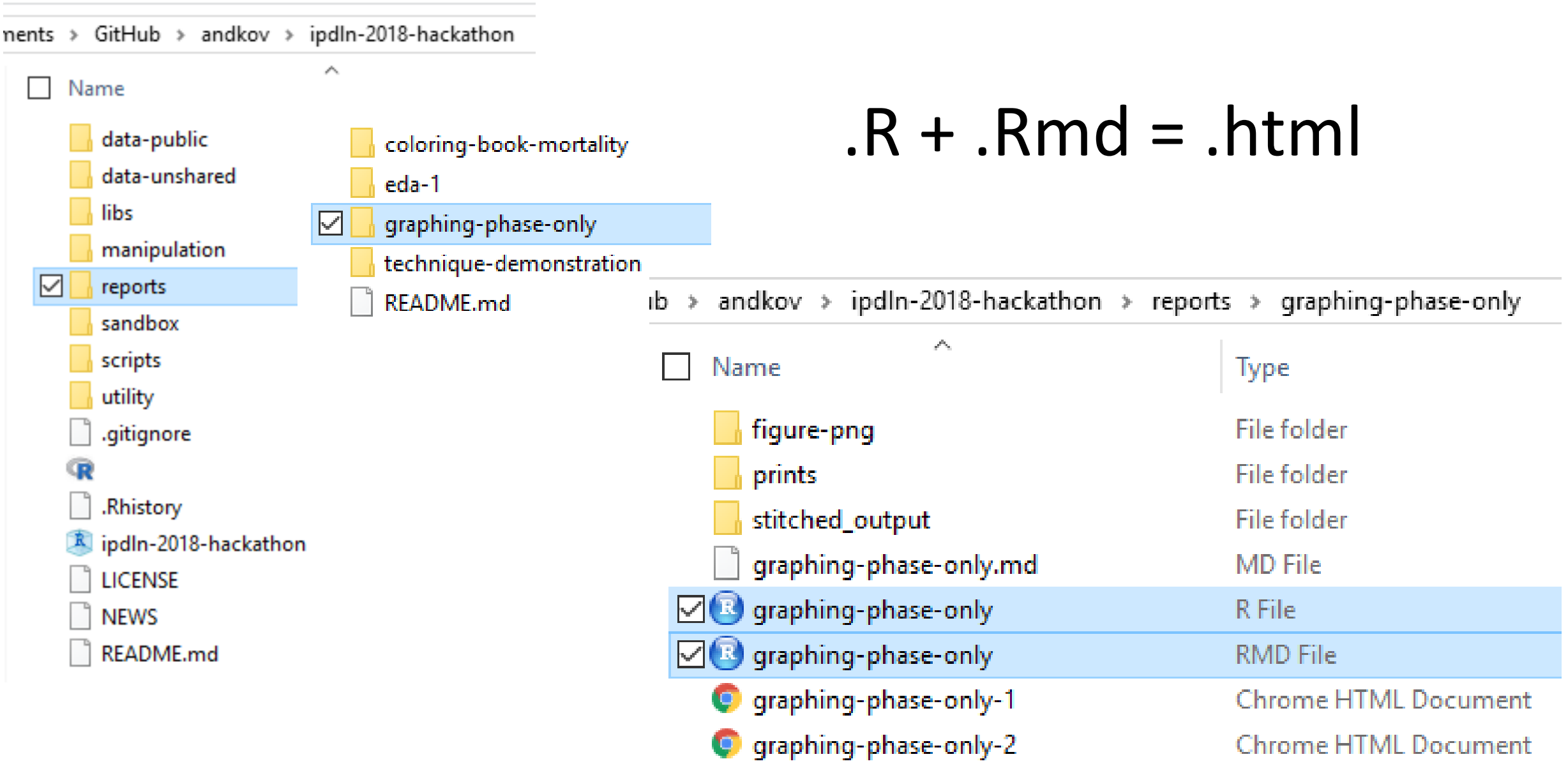
Andriy Koval

https://github.com/andkov

@andkovpro

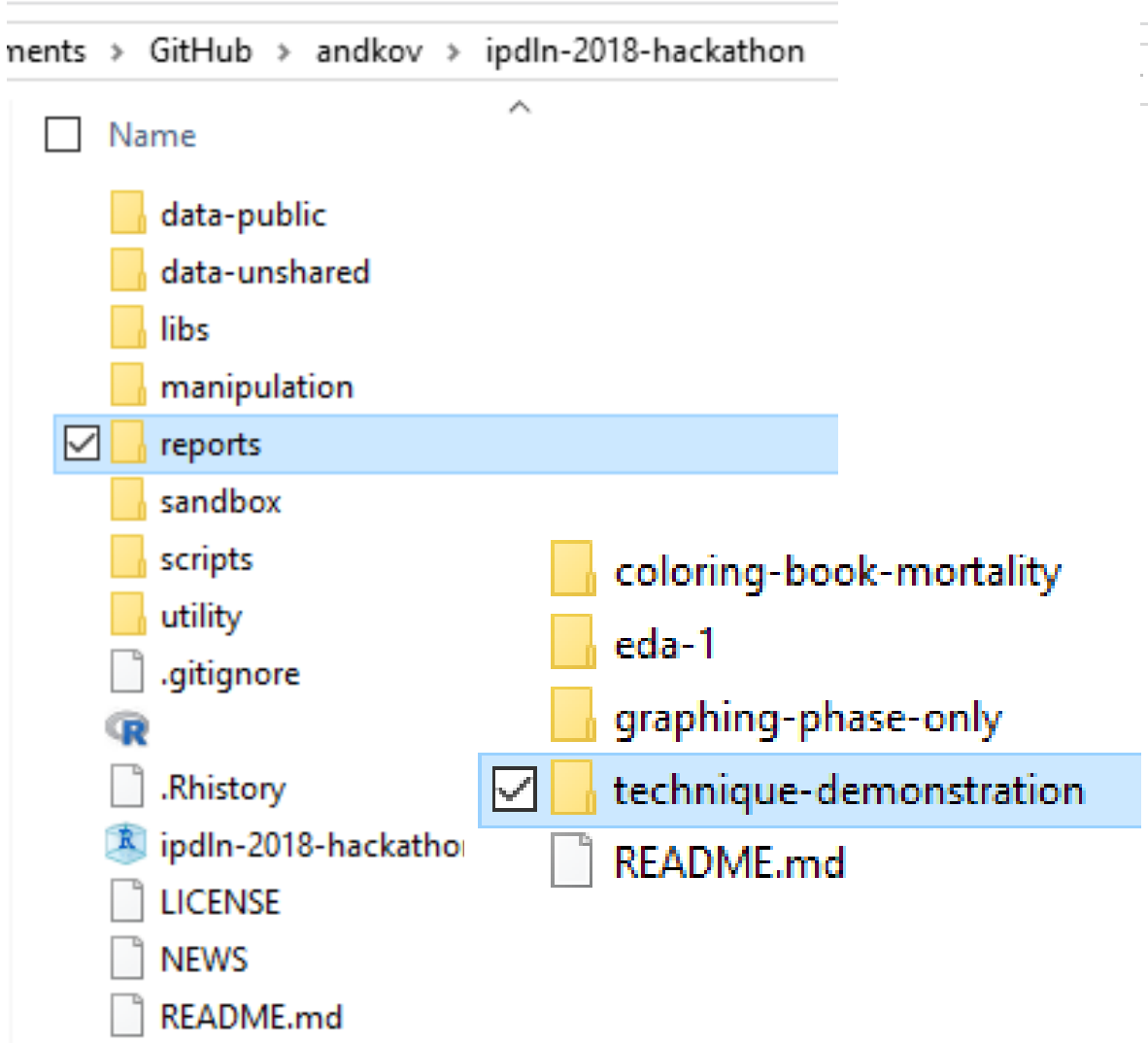
B. Workflow Highlights

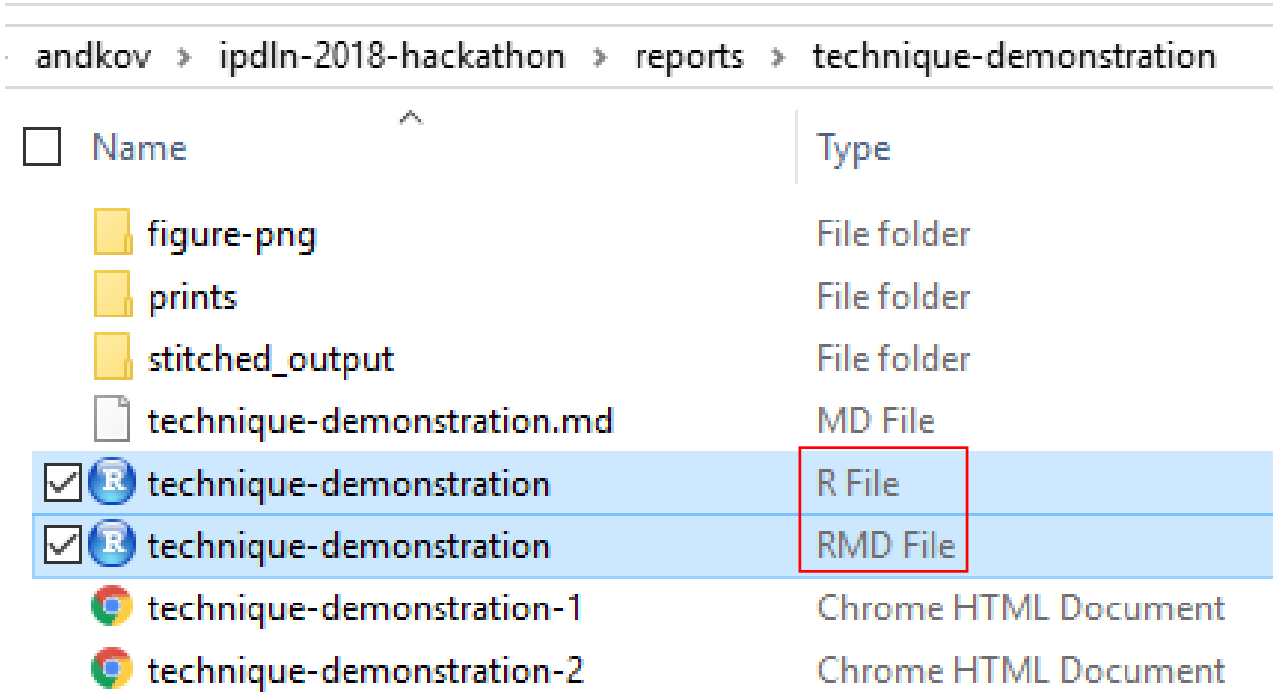
1.3 Layers of Isolation: analysis vs presentation

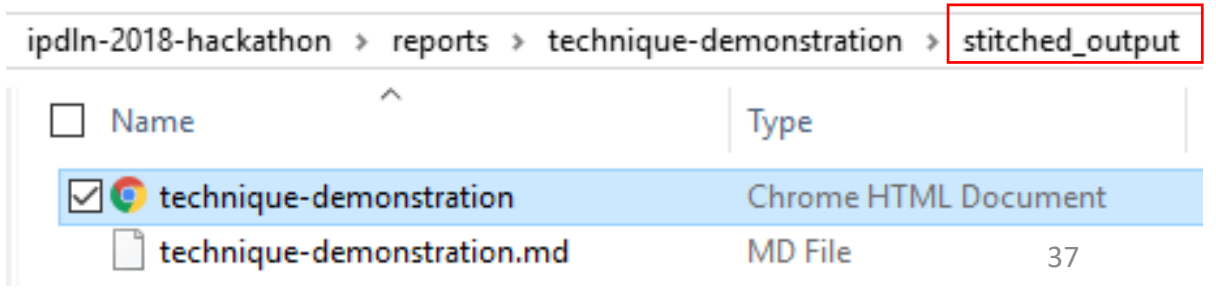


rmarkdown::render(.R + .Rmd) = .html

knitr::stitch(.R) = .html

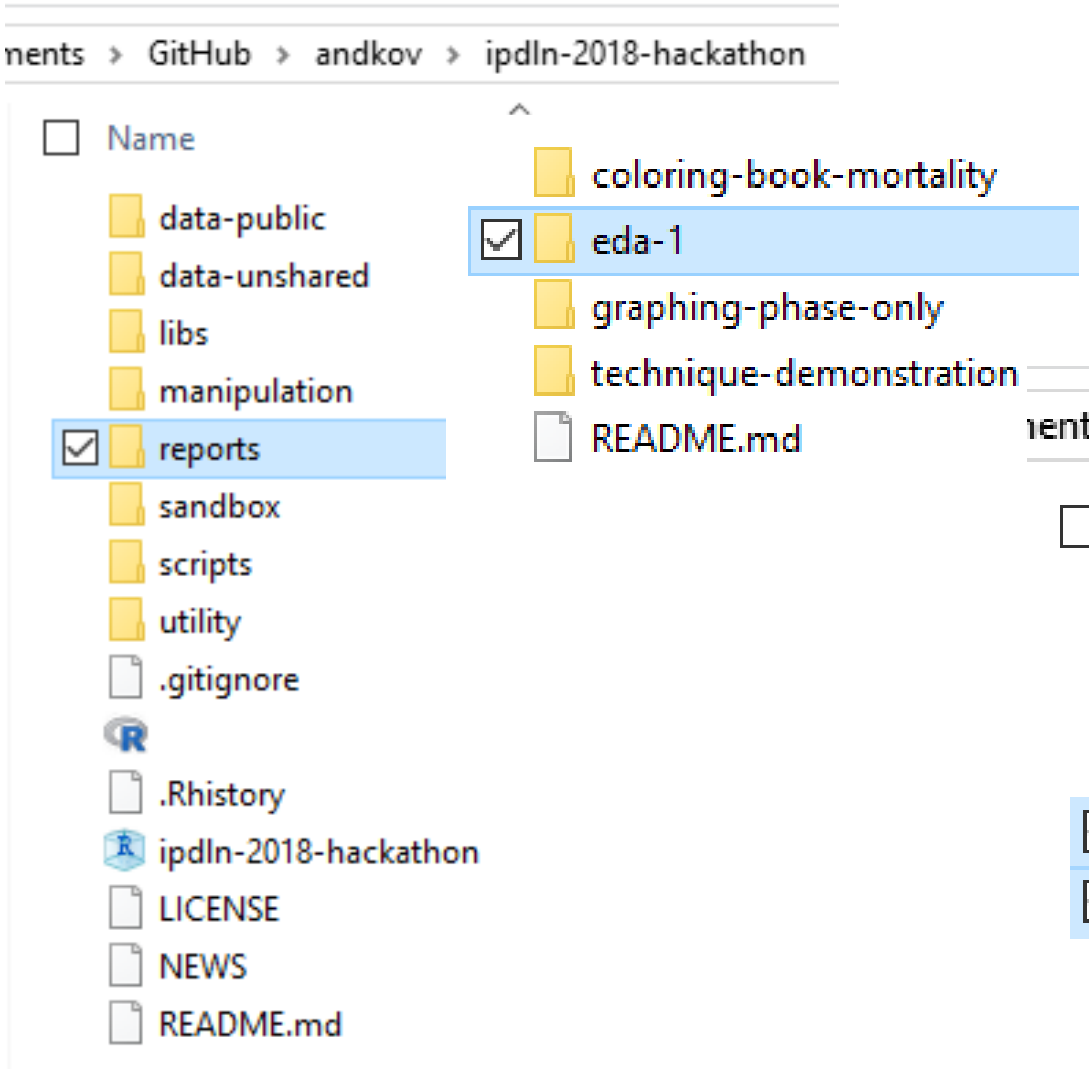






B. Workflow Highlights

1.3 Layers of Isolation: analysis vs presentation



$$.R + .Rmd_1 = .html_1$$

$$.R + .Rmd_2 = .html_2$$