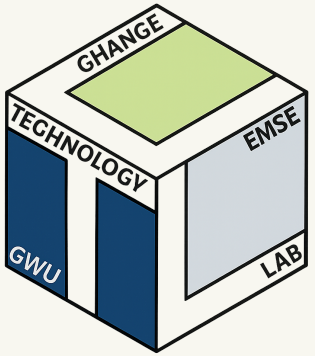
PhD Proposal Defense:

Electric Vehicle Smart Charging Adoption, Economic Implications for the Grid, and the surveydown Survey Platform

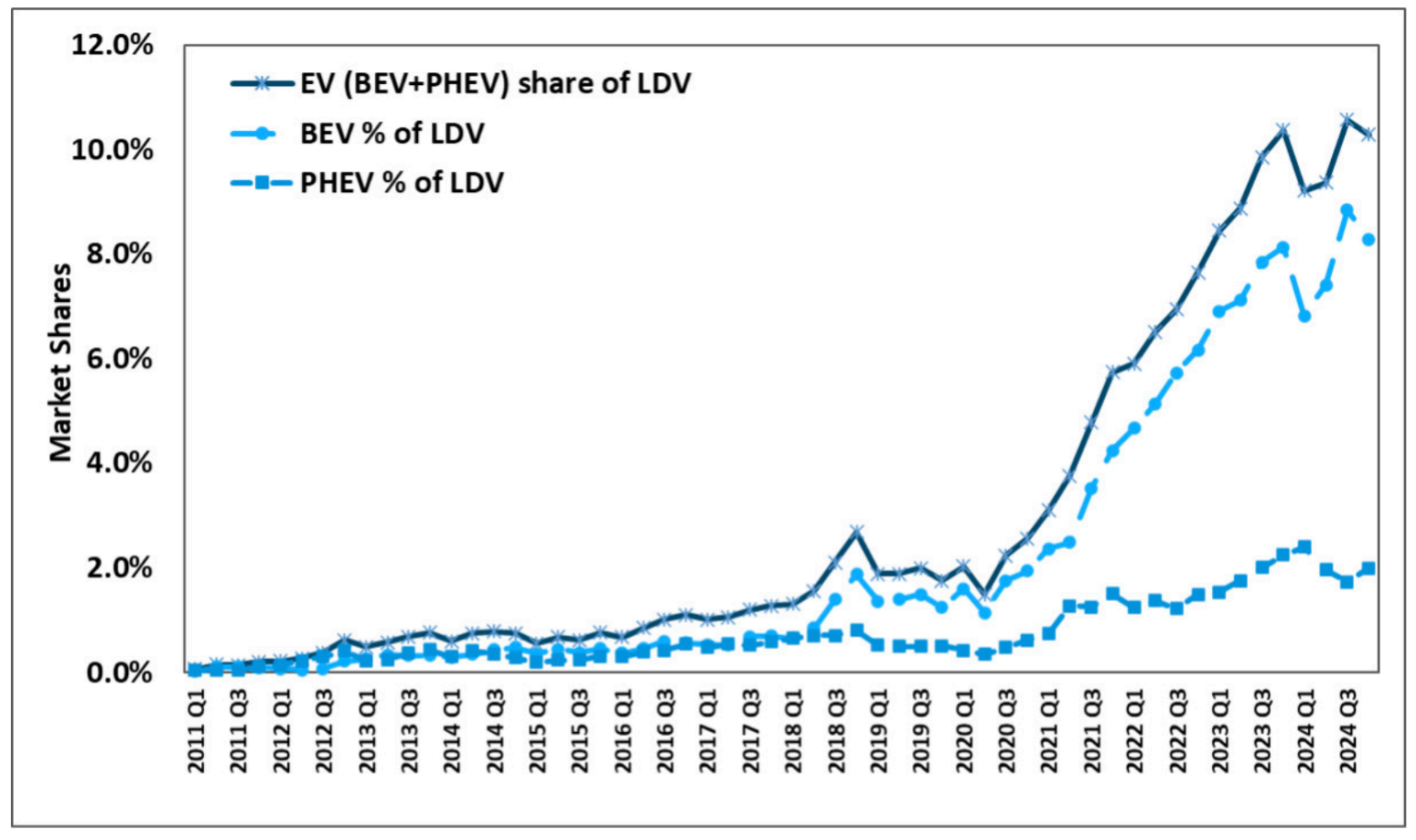


Pingfan Hu
George Washington University

Study 1

Electric Vehicle Smart Charging Adoption

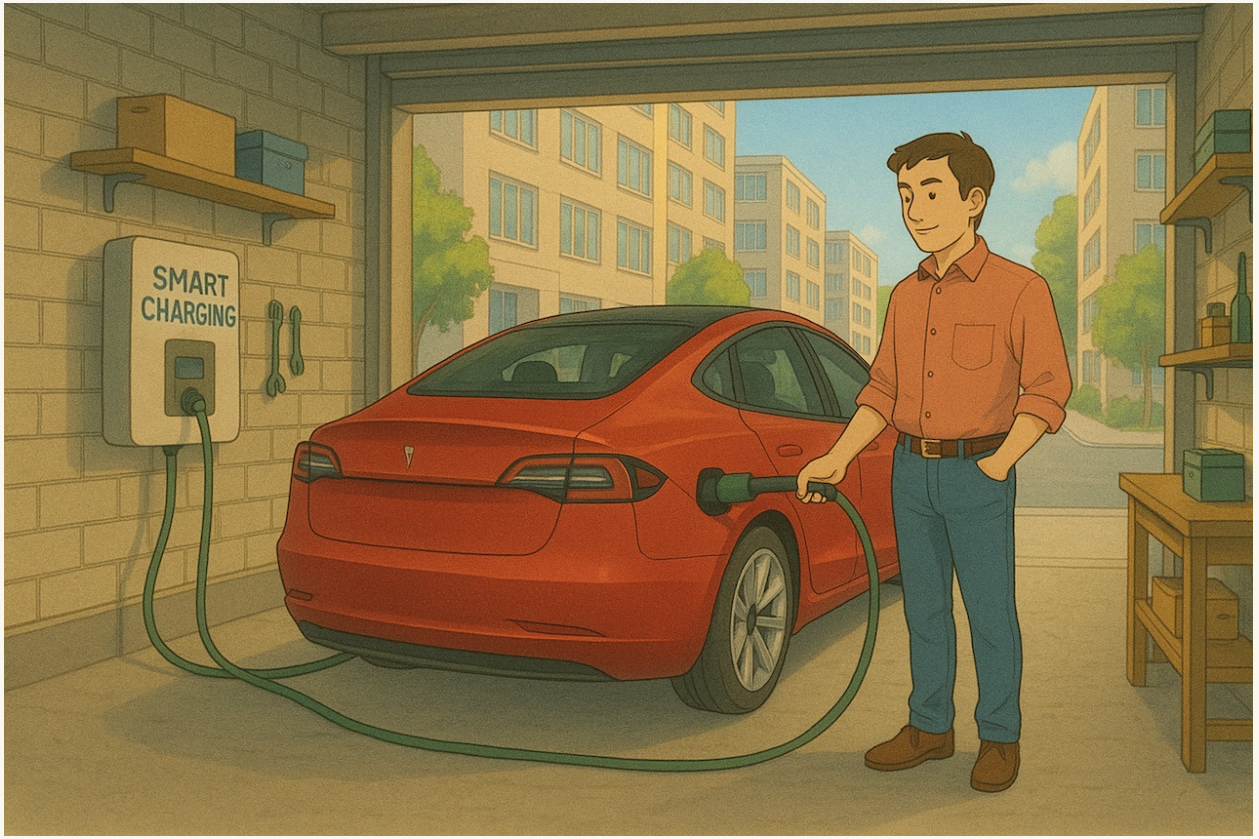
EV sales in US reaching ~10% of sales



Source: Argonne National Lab, www.anl.gov/ev-facts/model-sales

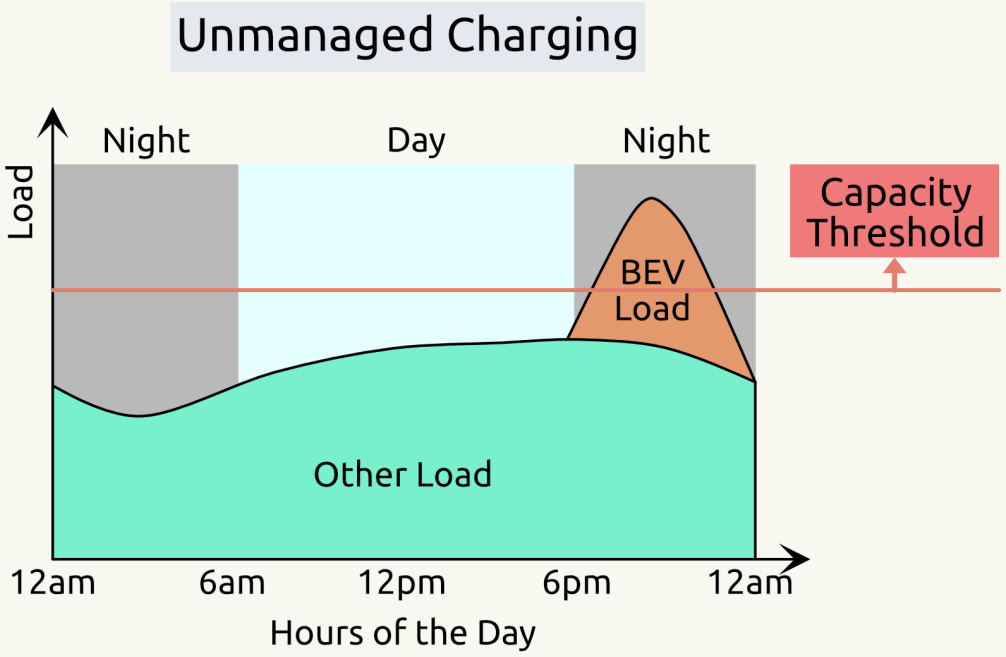
Introduction

- **Unmanaged** BEV charging is becoming a problem to the grid.
- **Managed** charging is cheaper and smoothes out the grid load.
- **Smart** charging: Supplier-Managed Charging (SMC) and Vehicle-to-Grid (V2G).



SMC - Supplier Managed Charging

- SMC smooths out overnight EV charging demand.
- Electricity demand is controlled below capacity threshold.
- It saves money and reduces pollution.



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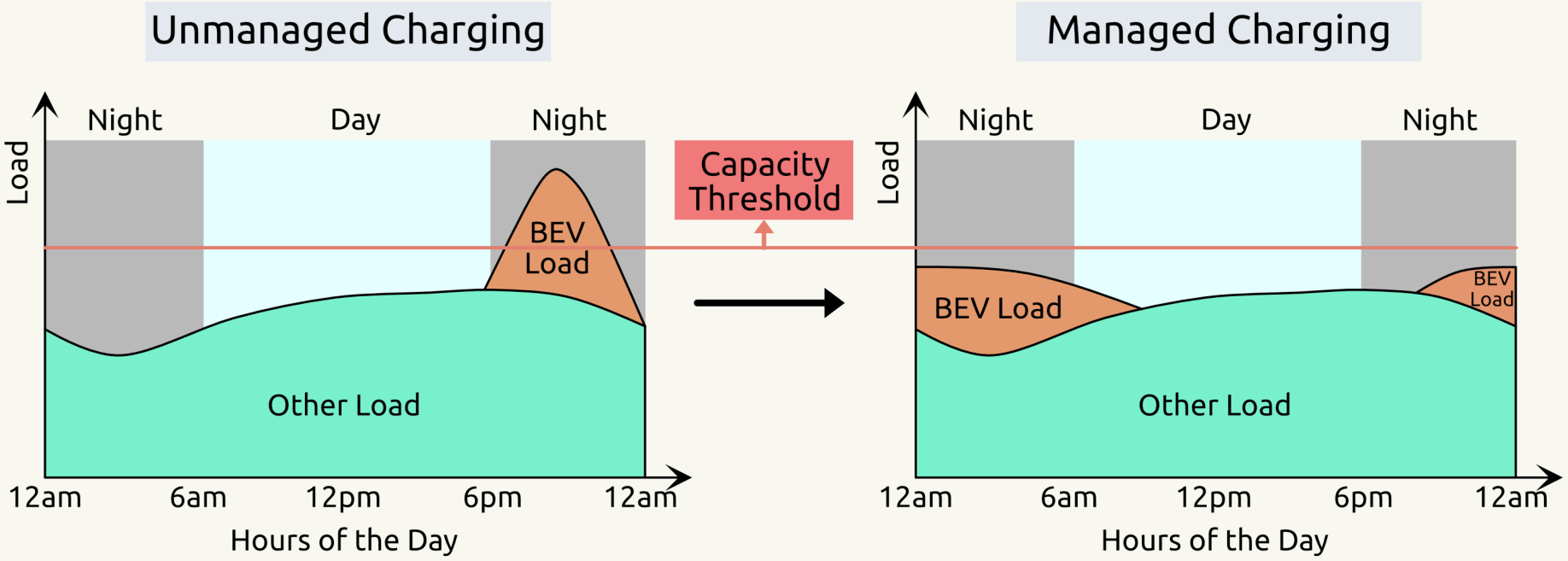


Managed charging avoids overload caused by BEV charging.

V2G - Vehicle-to-Grid

Non-V2G (Single Direction)

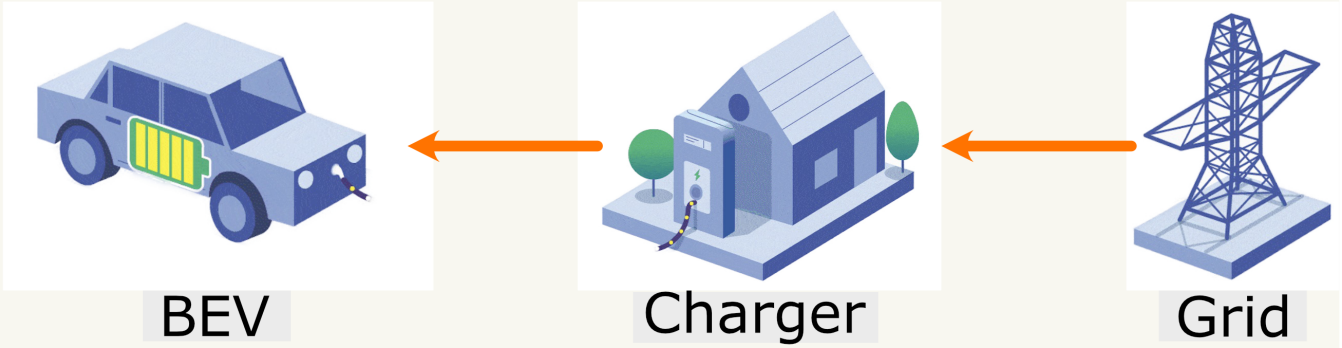
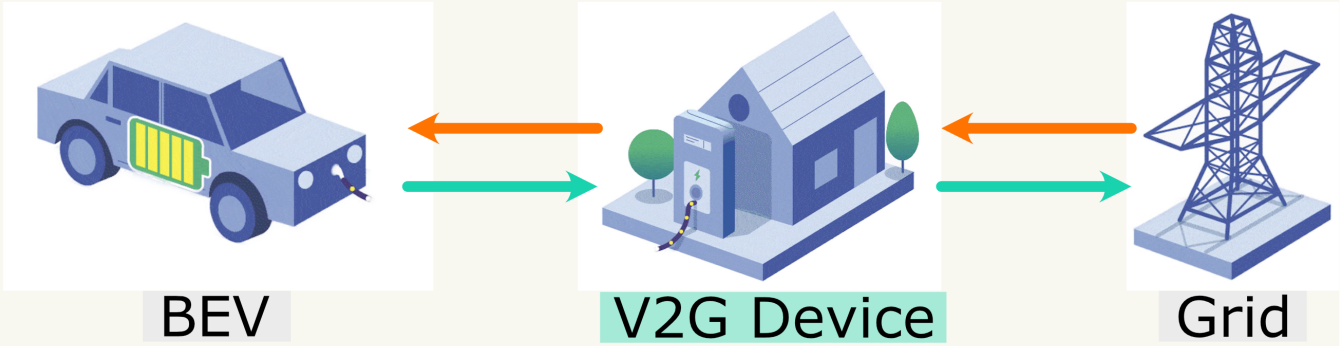


Figure Source: *wri.org*

V2G (Bi-direction)



In a V2G event, BEVs can charge the grid when necessary. BEVs are charged back eventually. Owners earn money.

Smart charging depends on enrollment.

Literature Review

1. A study by Wong et al. (2023) examined **incentives** affect the EV owners' acceptance, but EV ownership is only 19%.
2. A study by Philip and Whitehead (2024) found **range anxiety** matters, but EV ownership is only 1.28%.
3. Another study by Huang et al. (2021) indicates the importance of **fast charging**, but the sample size is only 157.

None of them have demographics data to study heterogeneity.

We need high EV ownership & large sample size, and consider heterogeneity.

Research Questions

1. **Sensitivity**: How do changes in smart charging program **features** influence BEV owners' willingness to opt in?
2. **Enrollment Rate**: Under what **combinations of features** will BEV owners be more willing to opt in to smart charging programs?

Conjoint survey to collect BEV owners' willingness.
Multinomial logit model for utility simulations.

Survey Design with `formr`

Conjoint Questions

1. Monetary Incentives
2. Charging Limitations
3. Flexibility

Demographic Questions

1. BEV Ownership
2. Personal Info
3. Household Info

Conjoint Question Explained

A Sample Conjoint Question

For example, if these were the only apples available, which would you choose? *

Option 1	Option 2	Option 3
		
Type: Fuji **Price**: $ 2 / lb **Freshness**: Average	**Type**: Pink Lady **Price**: $ 1.5 / lb **Freshness**: Excellent	**Type**: Honeycrisp **Price**: $ 2 / lb **Freshness**: Poor

1. Provide respondents with different **sets** of attributes.
2. Observe choices across random sets.
3. Estimate **utility** of each attribute.

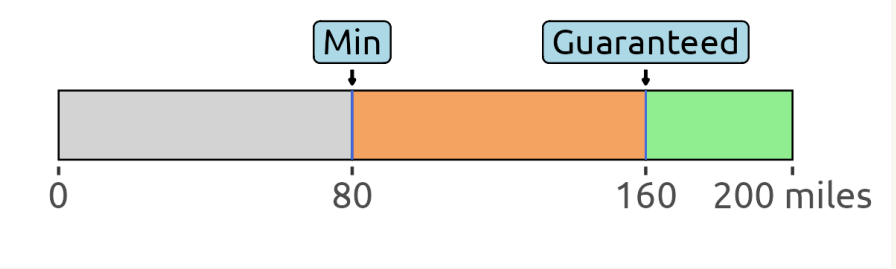
SMC Programs

Attributes

No.	Attributes	Range
1	Enrollment Cash	$50 to $300
2	Monthly Cash	$2 to $20
3	Monthly Override	0 to 5
4	Min Battery	20% to 40%
5	Guaranteed Battery	60% to 80%

Sample Program

Attributes	Values
Enrollment Cash	$300
Monthly Cash	$20
Monthly Override	5



(Range determined by stated vehicle they own)

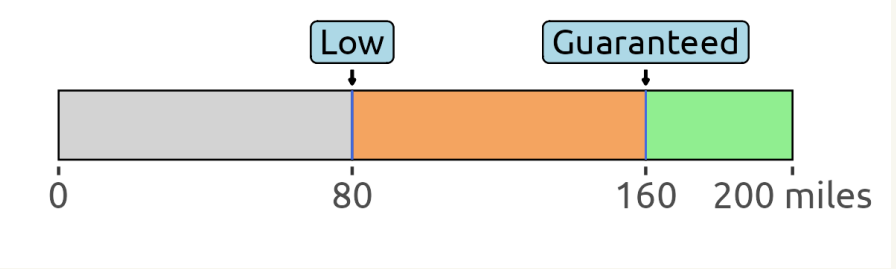
V2G Programs

Attributes

No.	Attributes	Range
1	Enrollment Cash	$50 to $300
2	Occurrence Cash	$2 to $20
3	Monthly Occurrence	1 to 4
4	Lower Bound	20% to 40%
5	Guaranteed Battery	60% to 80%

Sample Program

Attributes	Values
Enrollment Cash	$300
Occurrence Cash	$20
Monthly Occurrence	1

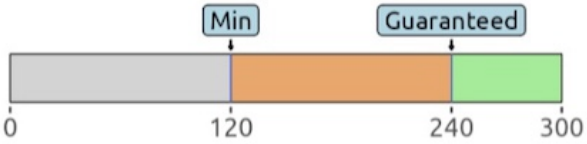


(Range determined by stated vehicle they own)

Sample SMC Question

(1 of 6) If your utility offers you these 2 SMC programs, which one do you prefer?
(Your BEV has maximum range of **300** miles.)

Access the SMC Attributes

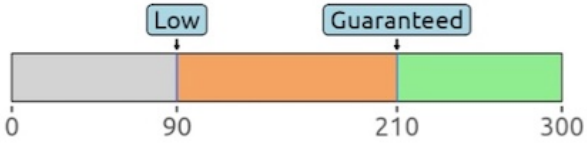
Option 1	Option 2	Option 3
Enrollment Cash: $100 Monthly Cash: $20 Override Allowance: 1 per Month	Enrollment Cash: $200 Monthly Cash: $10 Override Allowance: 1 per Month	Not Interested
Battery Thresholds (in Miles): 	Battery Thresholds (in Miles): 	

Sample V2G Question

(1 of 6) If your utility offers you these 2 V2G programs, which one do you prefer?
(Your BEV has maximum range of **300** miles.)

Access the V2G Attributes

Option 1	Option 2	Option 3
Enrollment Cash: $100 Occurrence Cash: $5 Monthly Occurrence: 2	Enrollment Cash: $100 Occurrence Cash: $20 Monthly Occurrence: 2	
Battery Thresholds (in Miles):	Battery Thresholds (in Miles):	Not Interested



Survey Fielding - 1356 in Total

Meta Ads: Voluntary participants

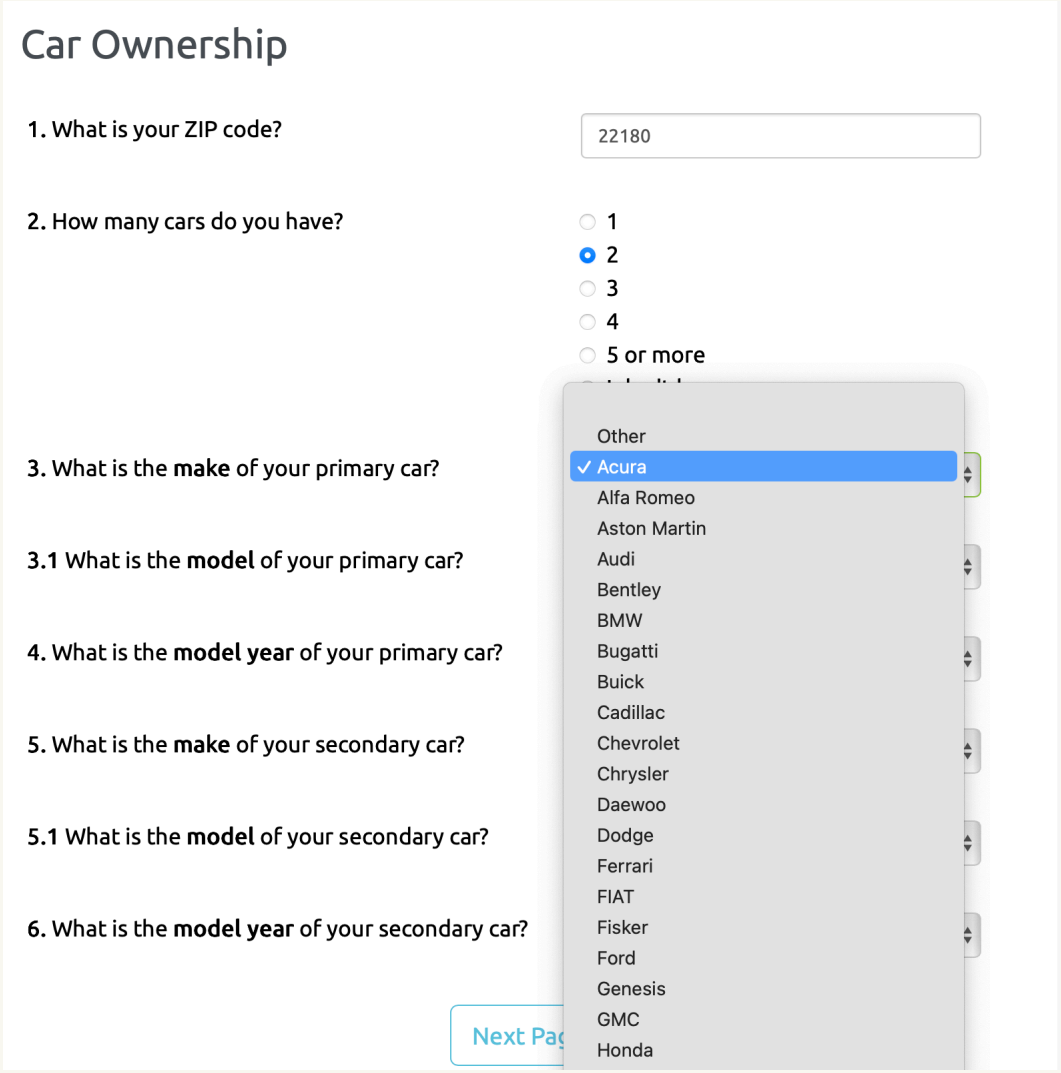
- **803** responses
- March to July in 2024

Dynata Recruitment: Paid survey

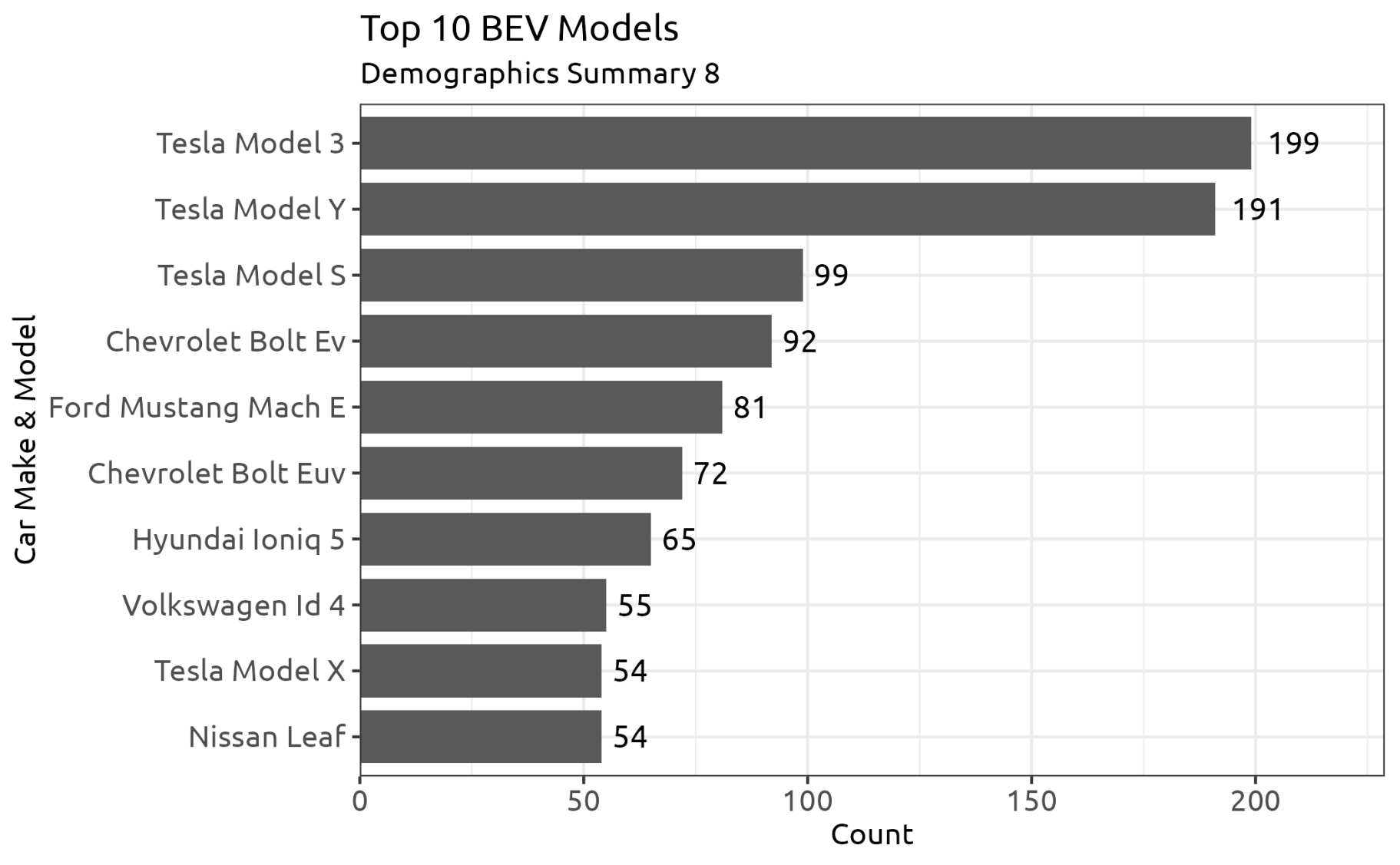
- **553** responses
- September to November in 2024

Facebook Messenger Instagram | dynata

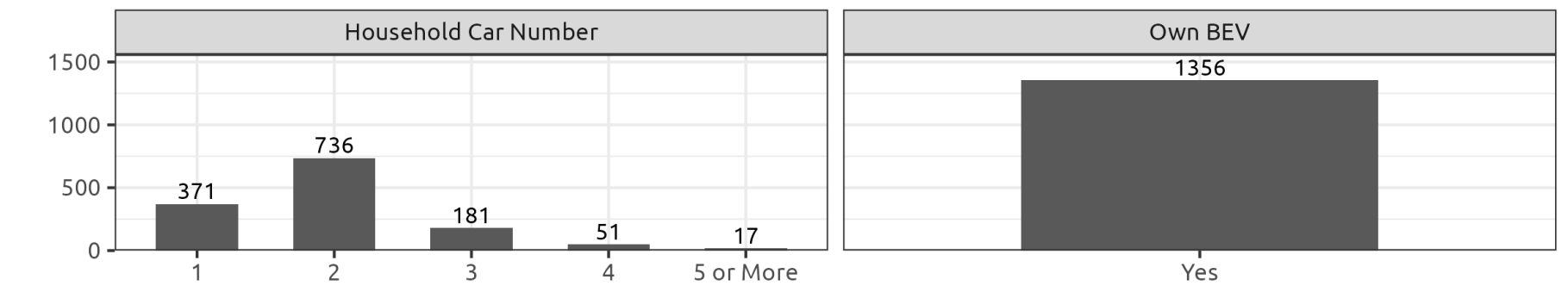
Survey Question - Car Ownership

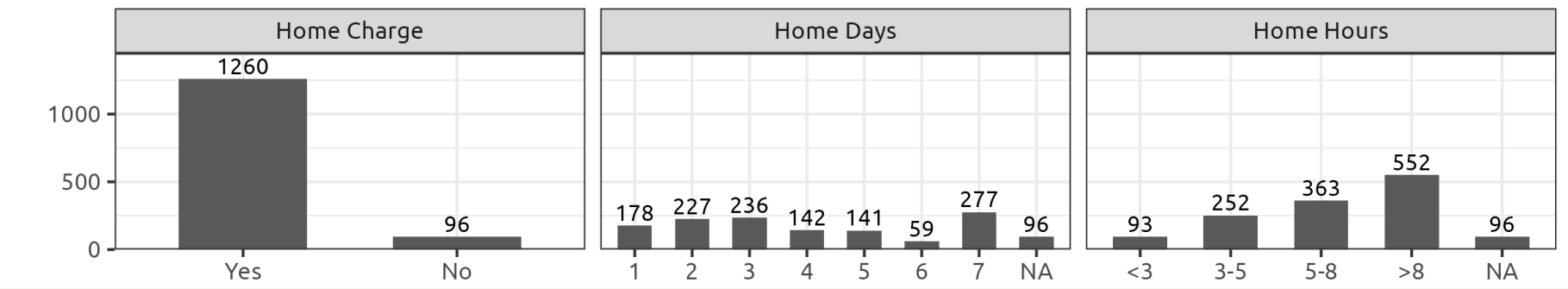


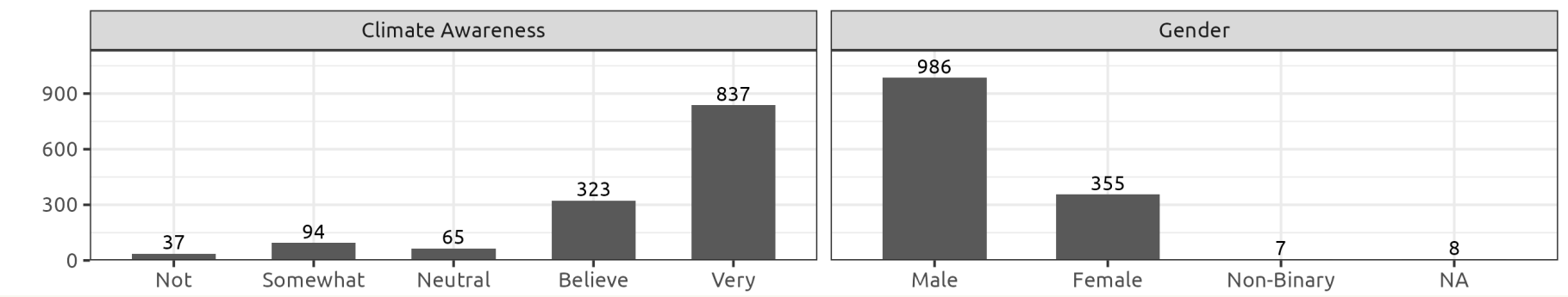
Survey Results - Top 10 BEV



Survey Results - Demographics







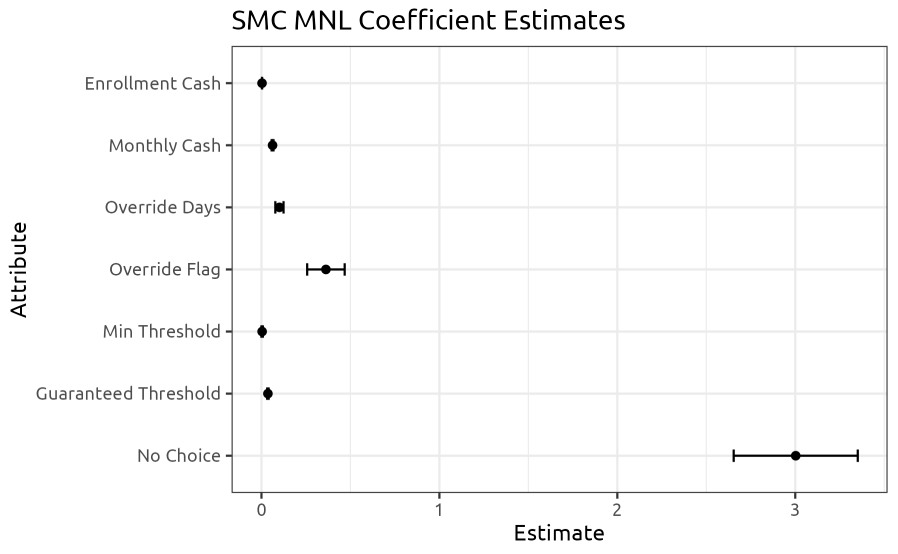
Survey Results - Willingness to Participate

Multinomial Logit Models

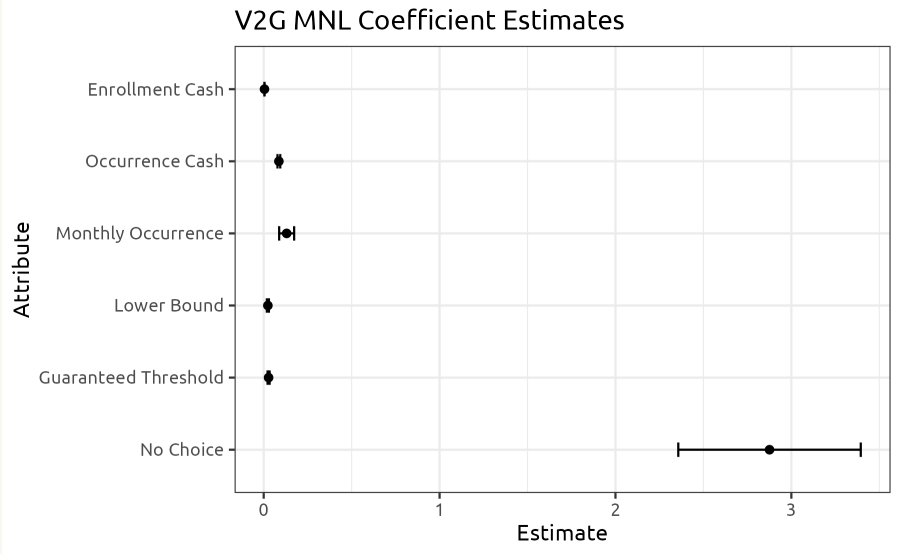
$$u_j = v_j + \epsilon_j = \beta' x + \epsilon_j \qquad P_j = \frac{e^{v_j}}{\sum_{k=1}^{J} e^{v_k}}$$

Utility esimated using maximum likelihood estimation (MLE).

SMC Estimates



V2G Estimates



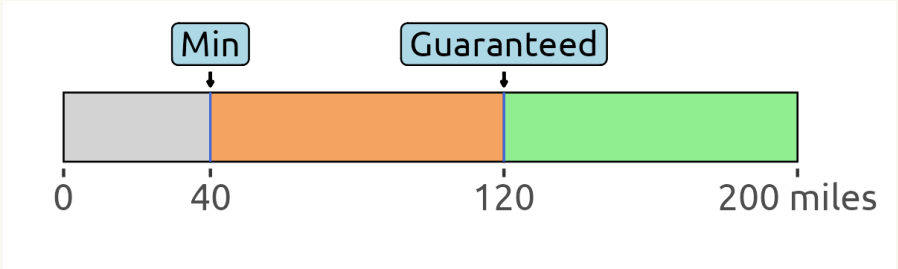
Without compensation, users will not participate.

Enrollment Sensitivity

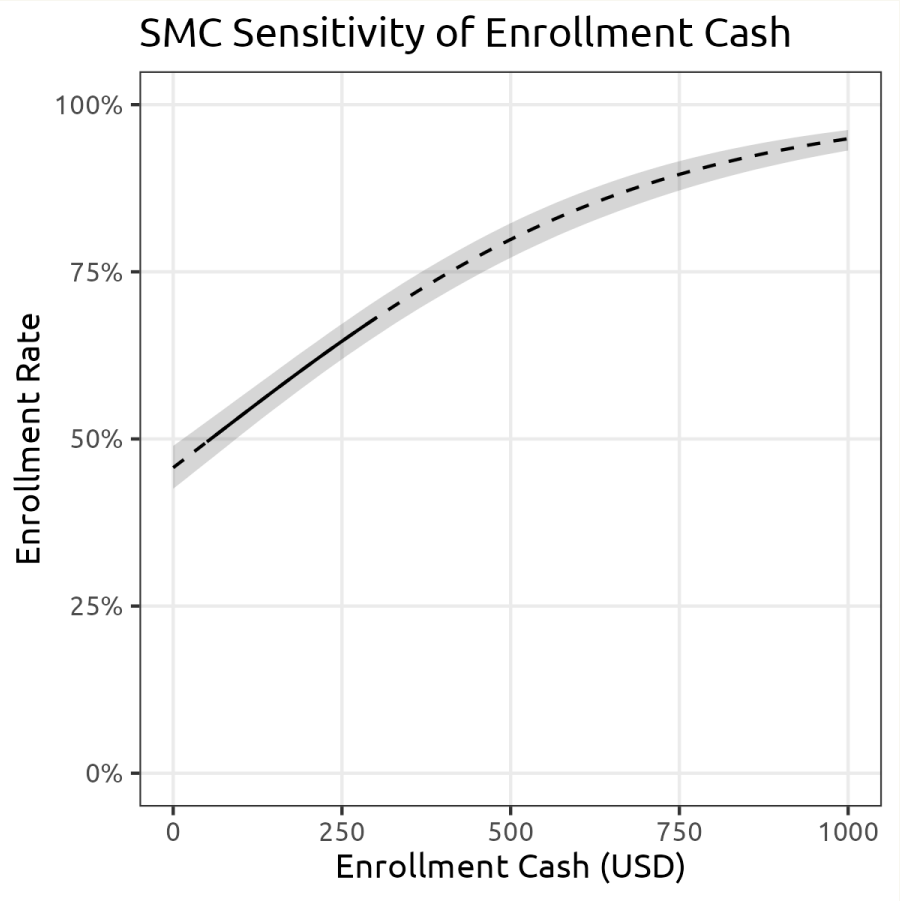
Baseline Simulation

Choice between "None" and this program:

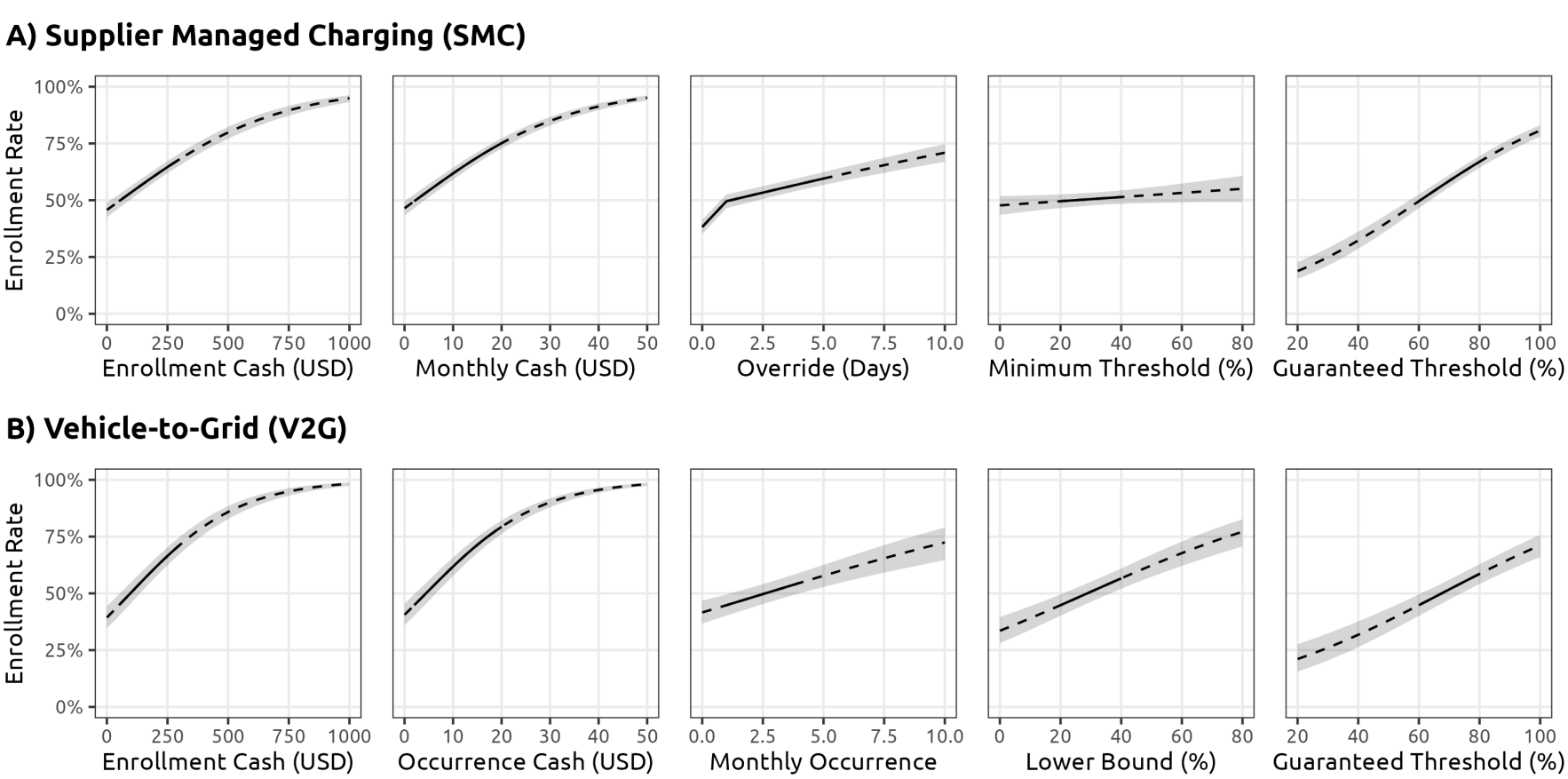
Attributes	Values
Enrollment Cash	**$0 - $1000**
Monthly Cash	$2
Monthly Override	1



Sensitivity Plot



Enrollment Sensitivity



1. Steeper slope indicates higher sensitivity.
2. Diminishing returns exist.

Equivalencies of 5% Enrollment Increase

SMC

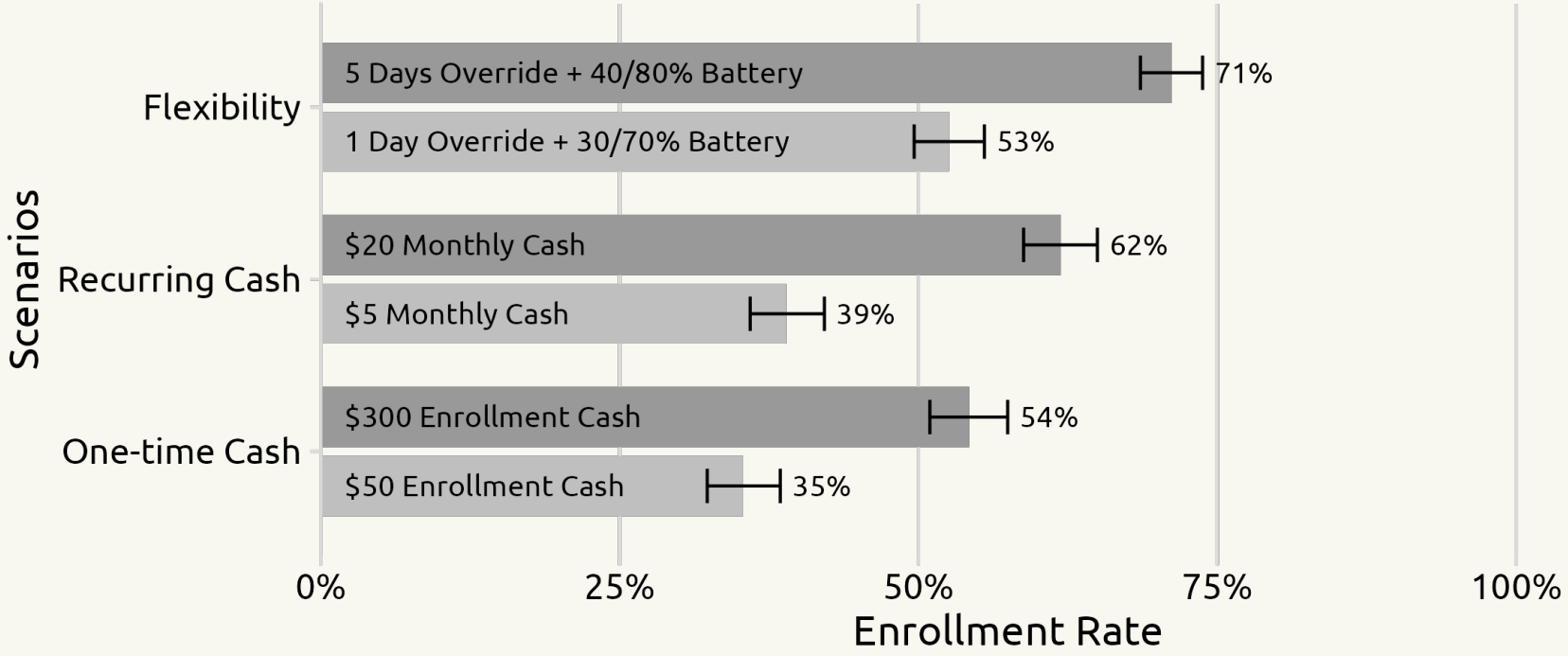
Attribute	Equivalence Value	Unit
Enrollment Cash	64.7	$
Monthly Cash	3.2	$
Override Days	2.0	Days
Minimum Threshold	54.8	%
Guaranteed Threshold	**5.5**	%

V2G

Attribute	Equivalence Value	Unit
Enrollment Cash	**45.0**	**$**
Occurrence Cash	**2.3**	**$**
Monthly Occurrence	1.5	Times
Lower Bound	8.5	%
Guaranteed Threshold	7.2	%

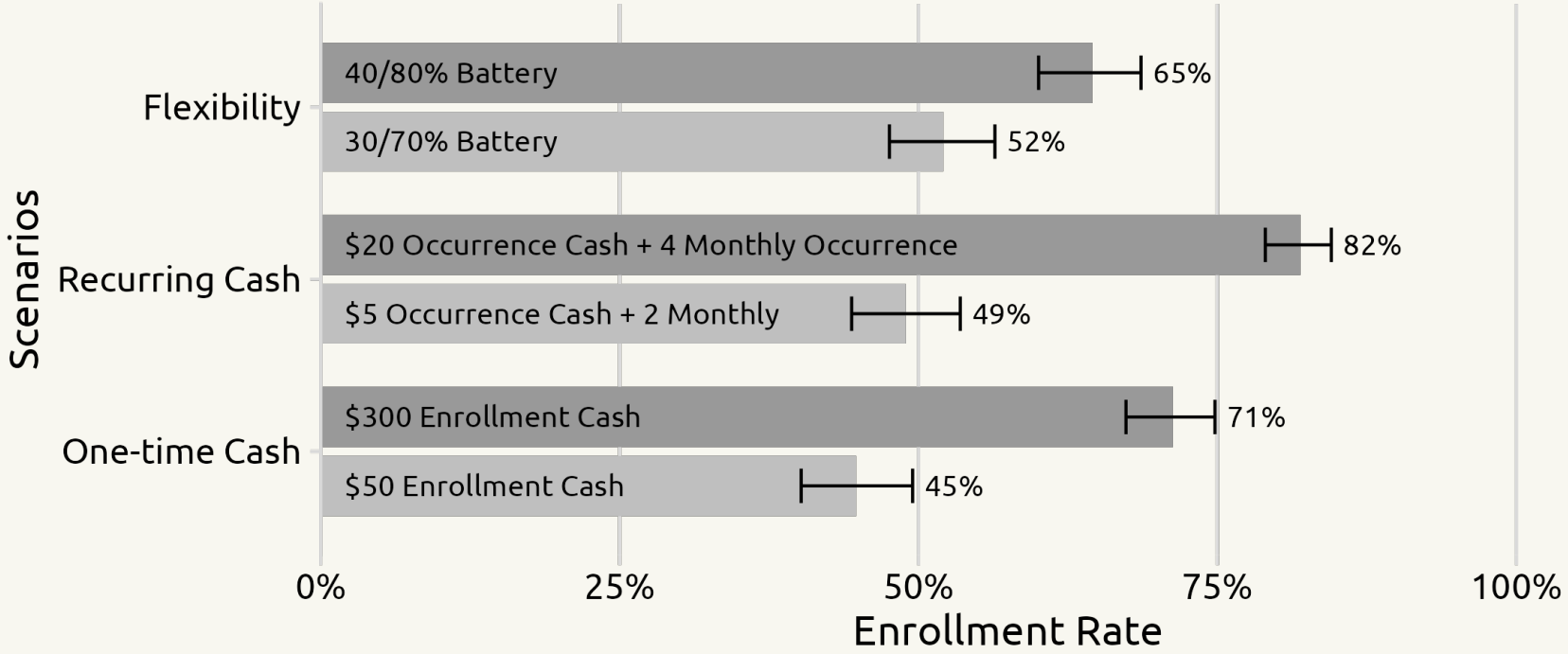
1. **Smaller** value indicates higher efficiency.
2. **Monetary** incentives are valued more in V2G than SMC.
3. **Guaranteed** threshold is more important in SMC than V2G, indicating range anxiety.
4. Attribute equivalencies can be used to inform incentive design.

SMC Scenario Analysis



1. **Flexibility** is highly valued.
2. **Recurring** incentives are more important than one-time.
3. Payment alone is not enough.

V2G Scenario Analysis



1. Still, **recurring** incentives are more important than one-time.
2. But **flexibility** is not as important compared with SMC.
3. Owners are willing to leverage BEV as a source of income.

Smart Charging Enrollment Simulator

Smart Charging Enrollment Simulator | About | SMC (Supplier-Managed Charging) | V2G (Vehicle-to-Grid)

SMC Attributes:

Enrollment Cash ($)

0

Monthly Cash ($)

0

Override Allowance per Month

0

Minimum Threshold (%)

0 20 100

0 10 20 30 40 50 60 70 80 90 100

Guaranteed Threshold (%)

0 60 100

0 10 20 30 40 50 60 70 80 90 100

Reset

Predicted SMC Enrollment Probability:

31.9%

About SMC:

- SMC (Supplier-Managed Charging) allows the utility to monitor, manage, and restrict BEV charging to optimize energy flow during night charging at home.
- By participating in SMC, your BEV will be mostly charged during off-peak periods.

SMC Attributes Explained:

Attribute	Description
Enrollment Cash	The one-time payment you'll receive if you stay for at least 3 months.
Monthly Cash	The recurring monthly payment you'll receive if you don't exceed override allowance.
Override Allowance	The monthly frequency of override to normal charging, effective for 24hrs. If you exceed the limit, no monthly cash for this month.
Minimum Threshold	SMC won't be triggered below this threshold. In the survey it's converted to miles.
Guaranteed Threshold	SMC will give you this much of range by the morning (8 hrs' charging). In the survey it's converted to miles.

Contributions

1. First **large N** study of BEV owners' preferences for smart charging programs.
2. Quantified the **sensitivity** of BEV owners' preferences for smart charging features.
3. Introduced the concept of attribute **equivalencies** to inform incentive design.

Appendix - SMC Logit Model

Attribute	Coef.	Est.	SE	Level	Unit
Enrollment Cash	β_1	0.0031	0.0002	50, 100, 200, 300	USD
Monthly Cash	β_2	0.0623	0.0027	2, 5, 10, 15, 20	USD
Override Days	β_3	0.1010	0.0118	0, 1, 3, 5	Days
Override Flag	β_4	0.3622	0.0538	Yes, No	-
Minimum Threshold	β_5	0.0037	0.0021	20, 30, 40	%
Guaranteed Threshold	β_6	0.0362	0.0021	60, 70, 80	%
No Choice	β_7	3.0026	0.1779	-	-

Appendix - V2G Logit Model

Attribute	Coef.	Est.	SE	Level	Unit
Enrollment Cash	β_1	0.0045	0.0026	50, 100, 200, 300	USD
Occurrence Cash	β_2	0.0863	0.0040	2, 5, 10, 15, 20	USD
Monthly Occurrence	β_3	0.1305	0.0217	1, 2, 3, 4	Times
Lower Threshold	β_4	0.0237	0.0030	20, 30, 40	%
Guaranteed Threshold	β_5	0.0278	0.0030	60, 70, 80	%
No Choice	β_6	2.8759	0.2647	-	-

Study 2

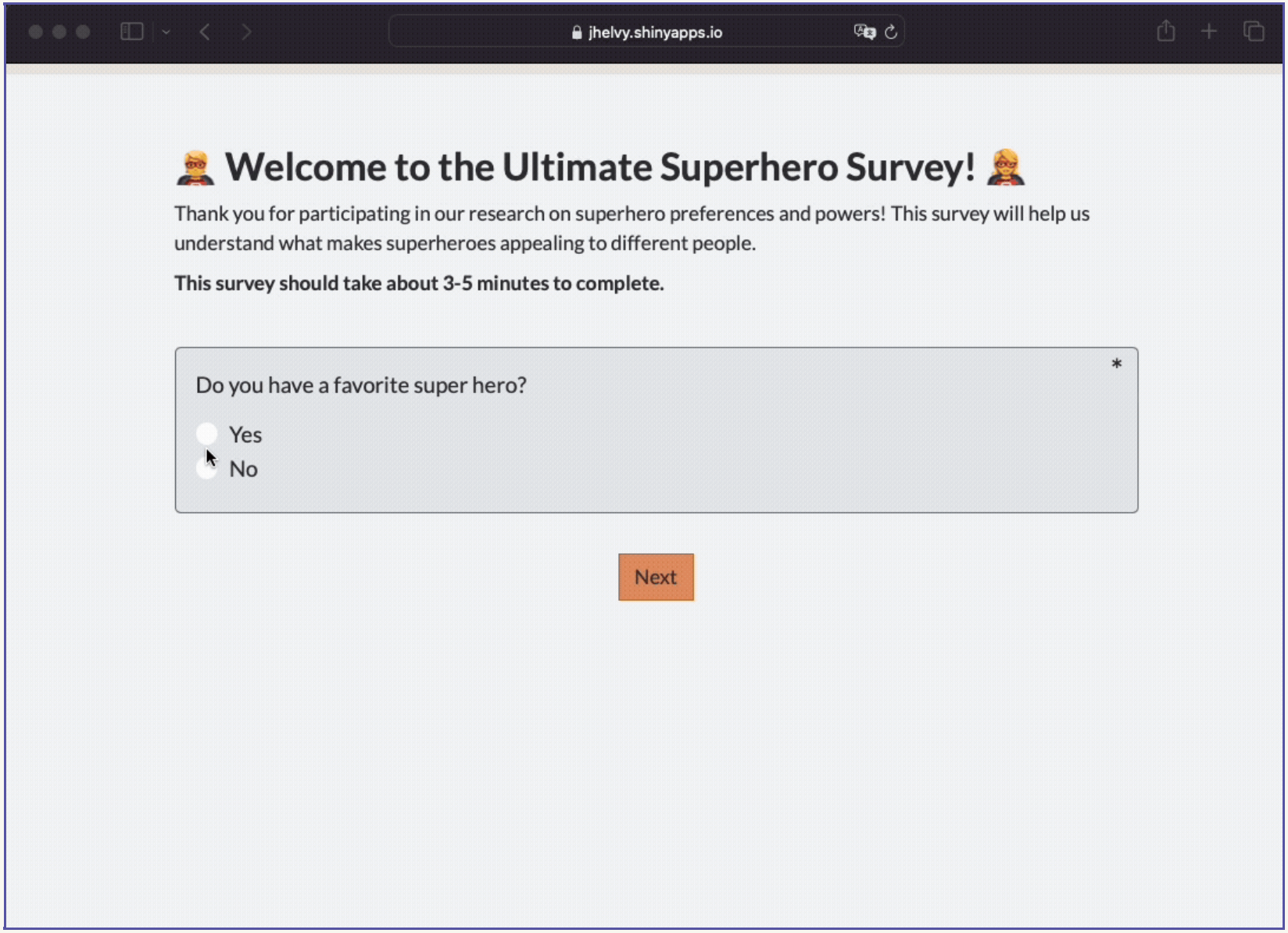
Smart Charging Economy

Study 3

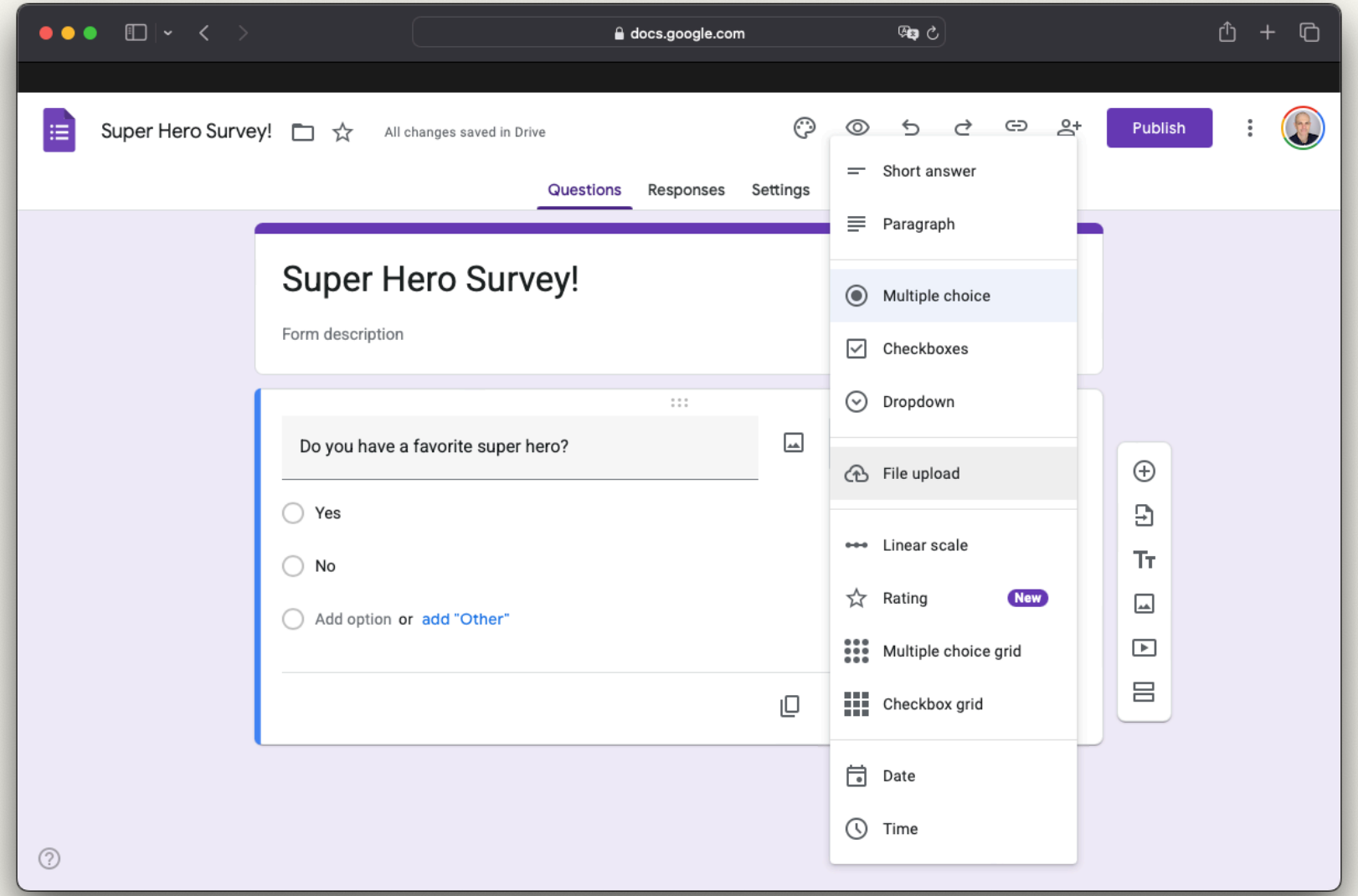
The surveydown Survey Platform

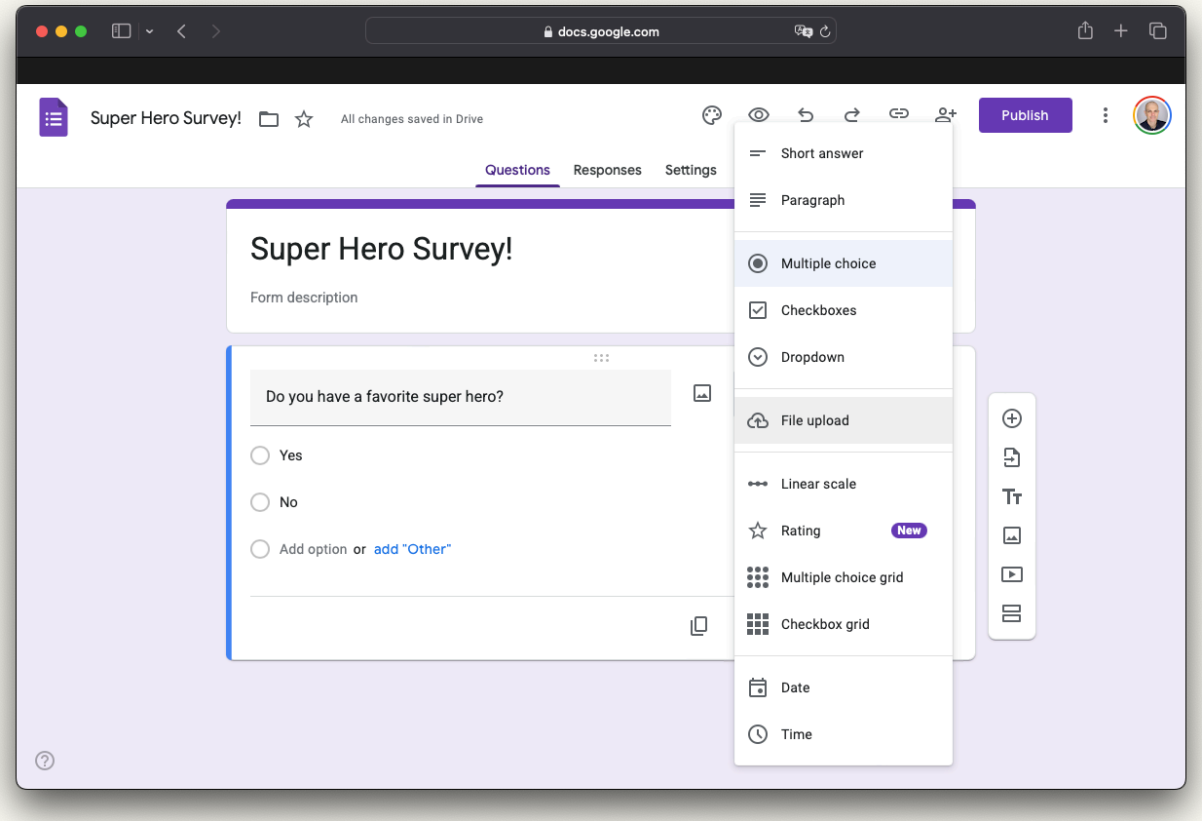
I try to figure out what people want…

Prof. John Helveston


jhelvy.shinyapps.io
🦸 Welcome to the Ultimate Superhero Survey! 🦸
Thank you for participating in our research on superhero preferences and powers! This survey will help us understand what makes superheroes appealing to different people.
This survey should take about 3-5 minutes to complete.
Do you have a favorite super hero? *
Yes
No
Next

WYSIWYG Interface

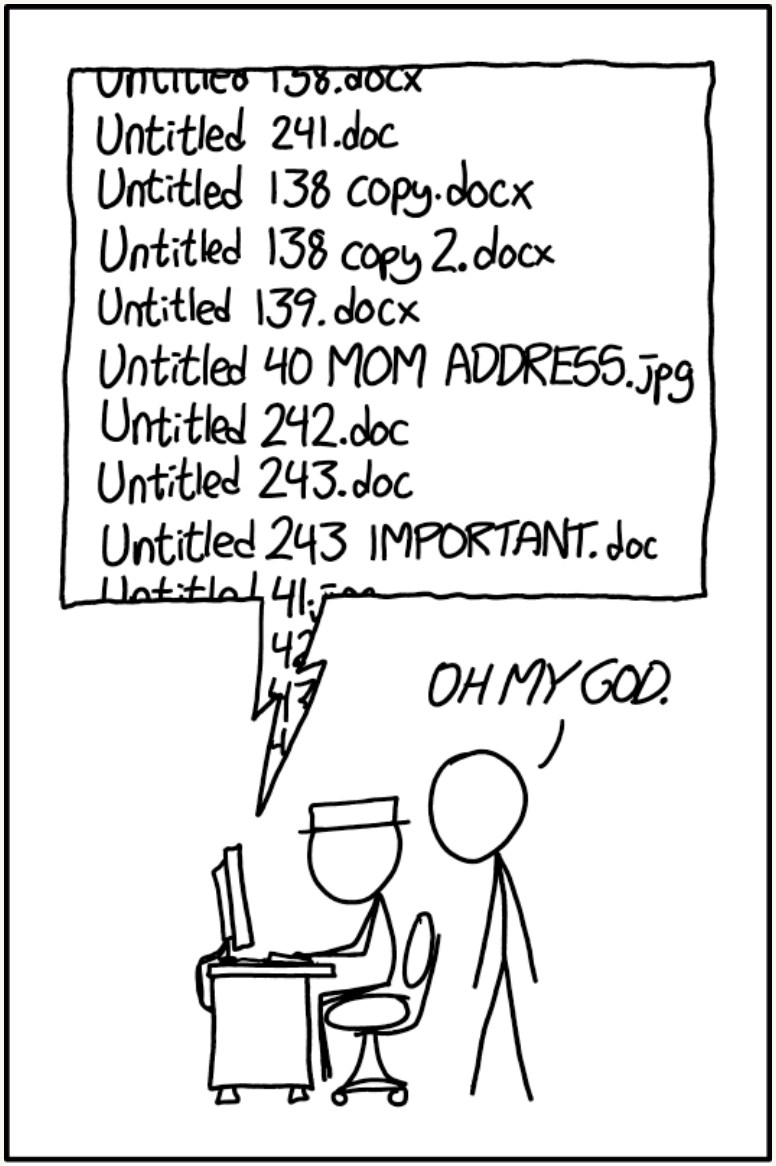


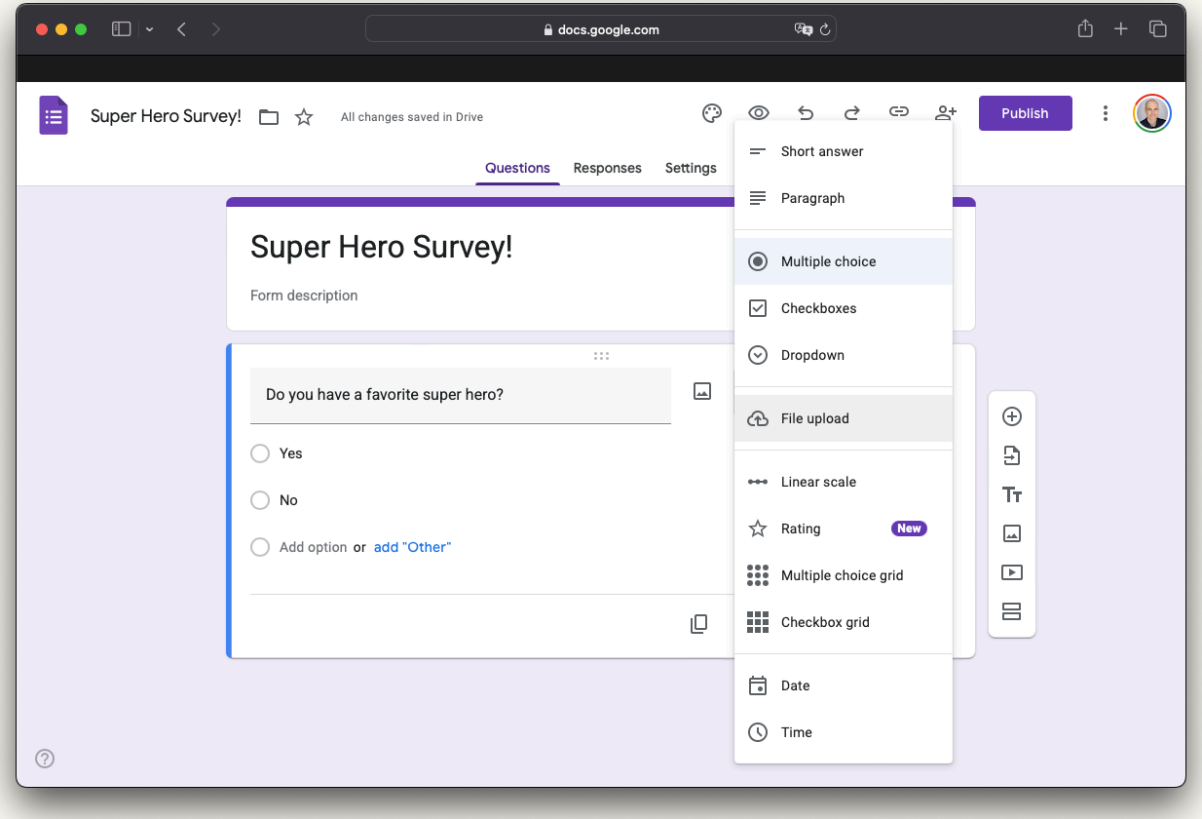


Limitations

❌ Reproduciblity

❌ Version control


Untitled 158.docx
Untitled 241.doc
Untitled 138 copy.docx
Untitled 138 copy 2.docx
Untitled 139.docx
Untitled 40 MOM ADDRESS.jpg
Untitled 242.doc
Untitled 243.doc
Untitled 243 IMPORTANT.doc
OH MY GOD.



Limitations

- ❌ Reproduciblity
- ❌ Version control
- ❌ Limited features
- ❌ Open source

Why not make surveys from code?

~~**Limitations**~~

Features

- ✅ Reproducibility
- ✅ Version control
- ✅ Lots of features
- ✅ Open source

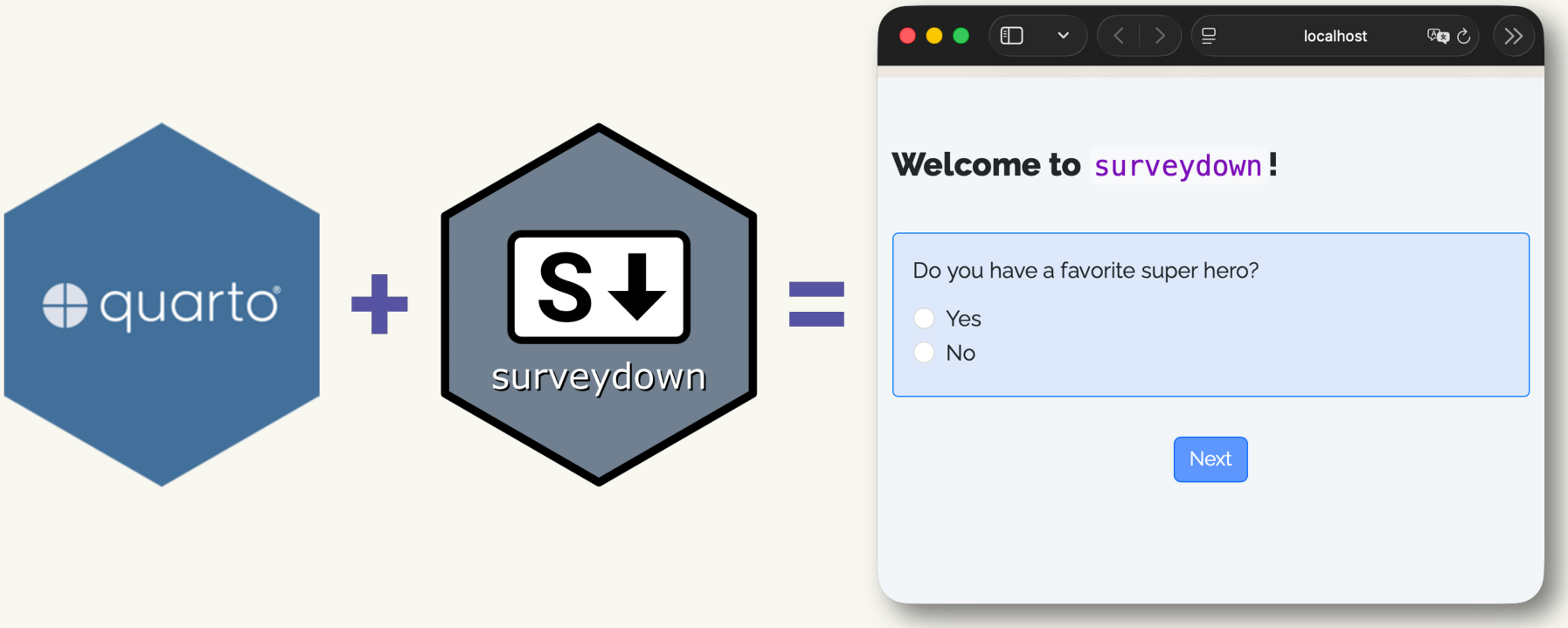
Introducing surveydown!

In this talk, we will cover:

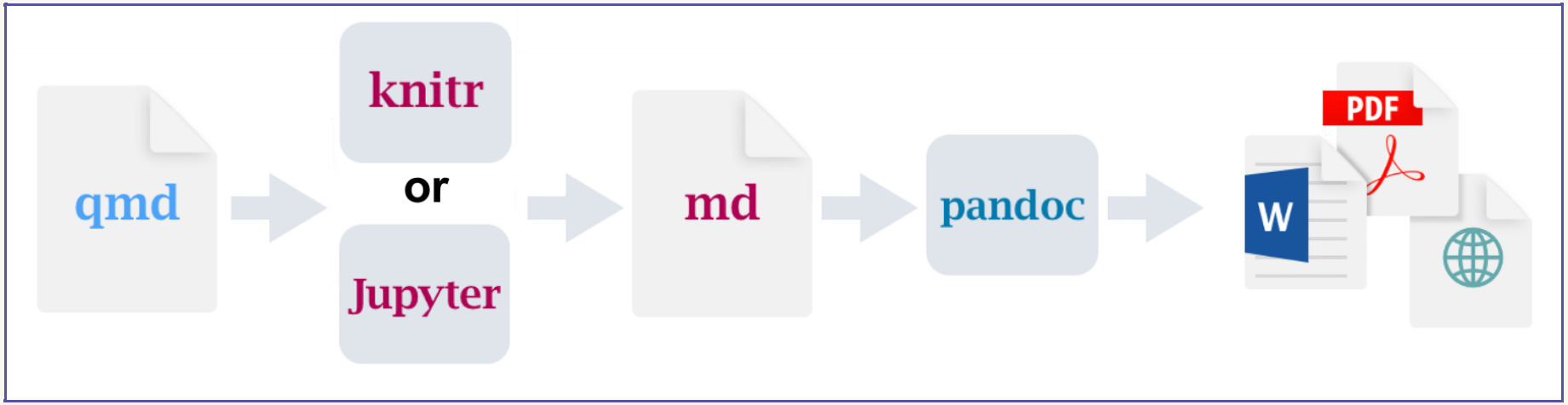
- What is `surveydown`?
- How does it work?
- What can I do with it?
- What's next?

What is surveydown?

R package that renders Quarto files into surveys



Quarto is a publishing system



Original qmd file

Markdown + R code chunks

````
---
format: html
title: "HTML Page with R Code"
---

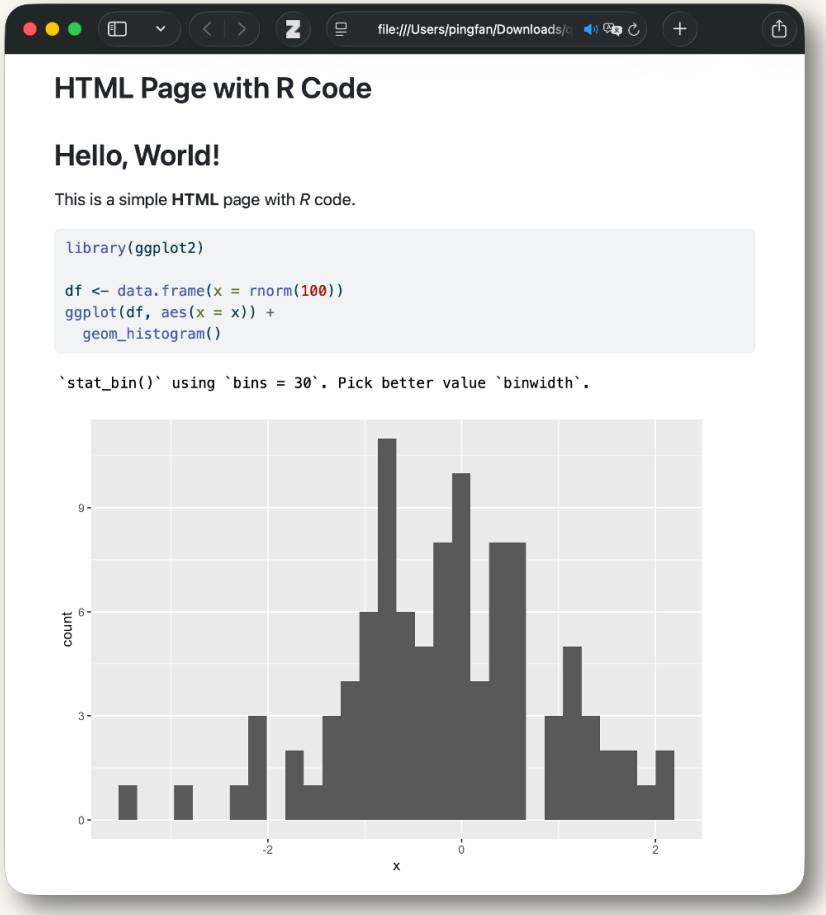
# Hello, World!

This is a simple **HTML** page with *R* code.

```{r}
library(ggplot2)

df <- data.frame(x = rnorm(100))
ggplot(df, aes(x = x)) +
  geom_histogram()
```
````

Rendered HTML



Original qmd file

Markdown + Python code chunks

```
---
format: pdf
title: "PDF File with Python Code"
---

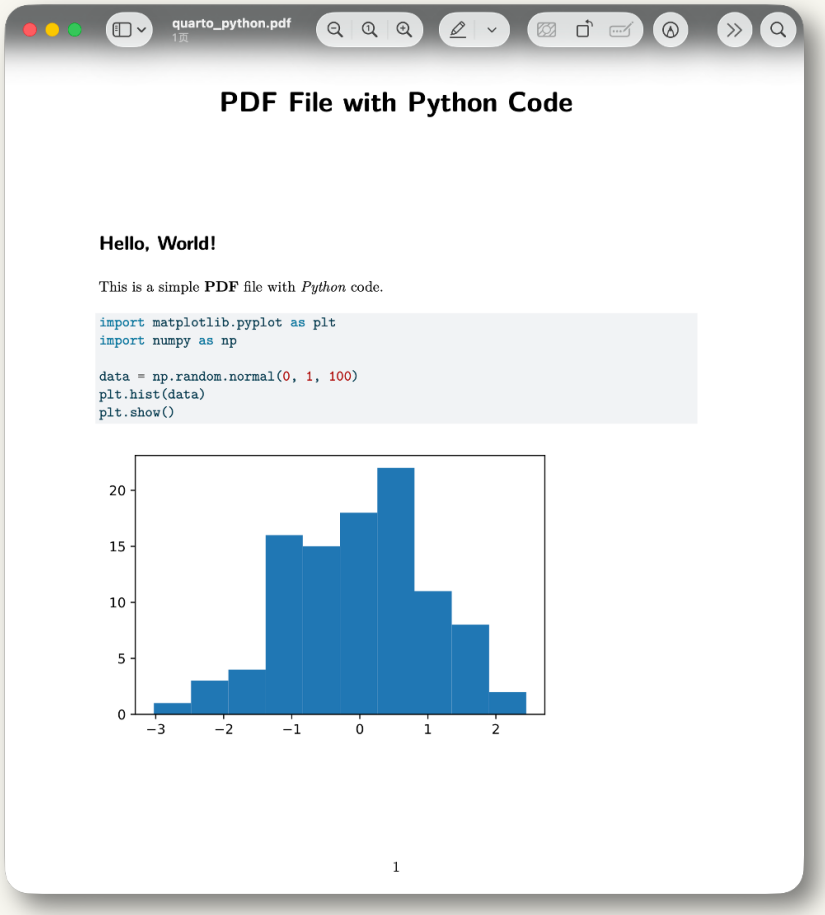
# Hello, World!

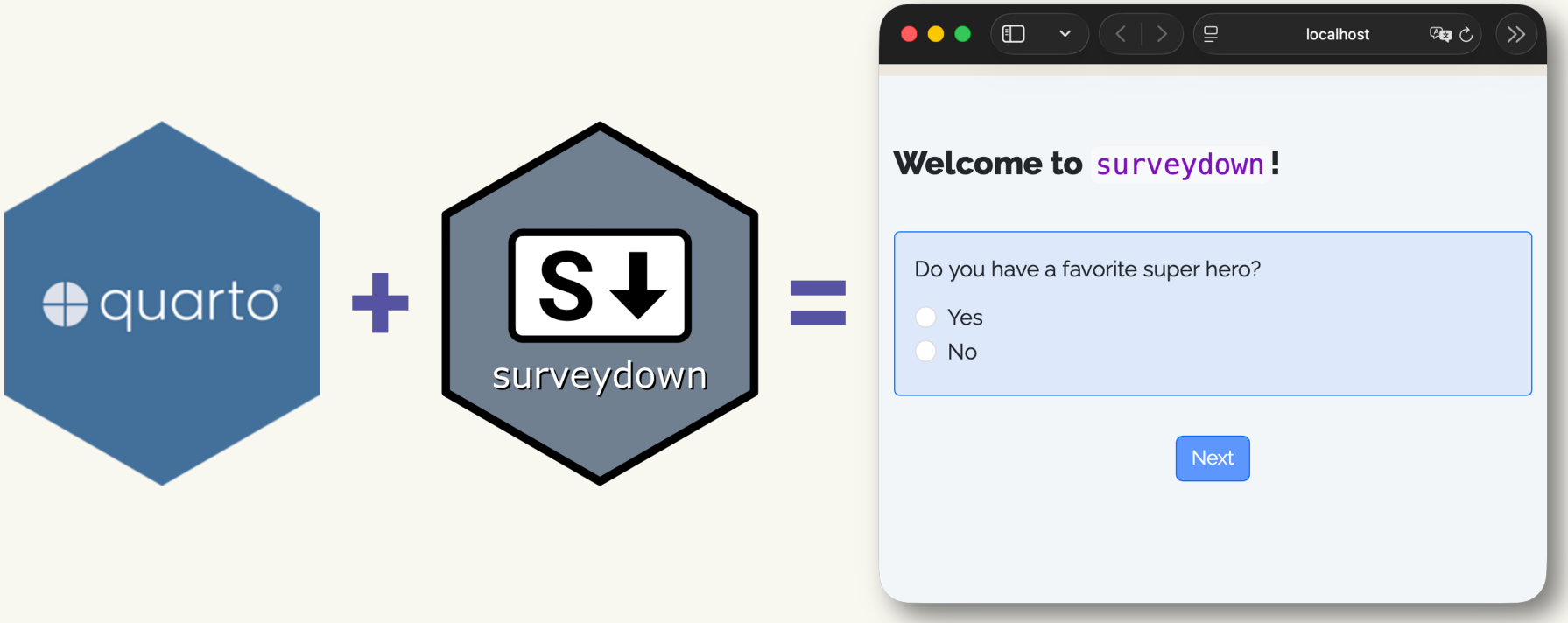
This is a simple **PDF** file with *Python* code.

```{python}
import matplotlib.pyplot as plt
import numpy as np

data = np.random.normal(0, 1, 100)
plt.hist(data)
plt.show()
```
```

Rendered PDF




quarto
surveydown
localhost
Welcome to surveydown!
Do you have a favorite super hero?
Yes
No
Next

survey.qmd

````
---
format: html
echo: false
warning: false
---

```{r}
library(surveydown)
```

::: {#welcome .sd-page}

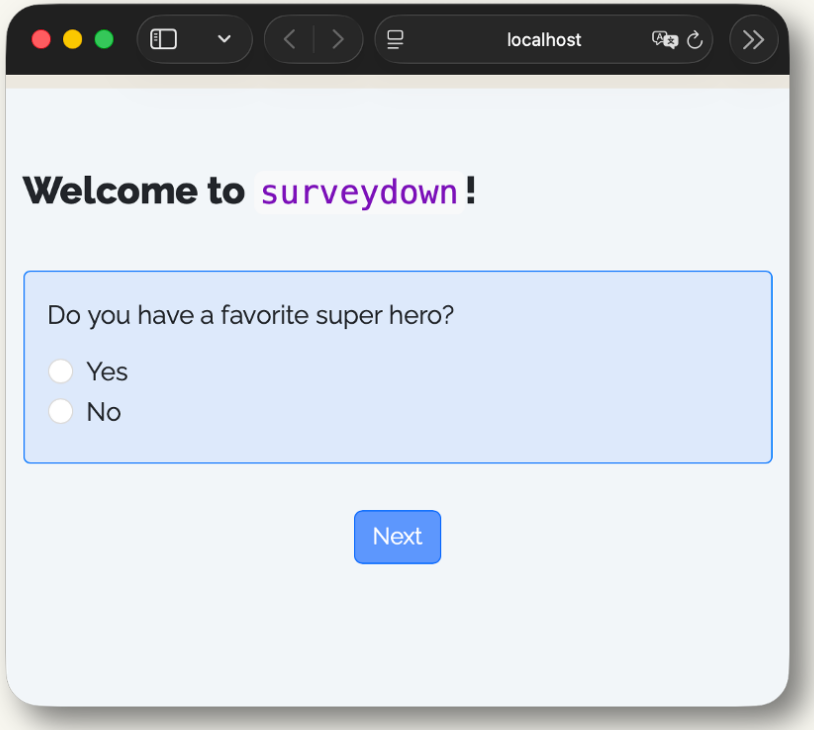
# Welcome to `surveydown`!

```{r}
sd_question(
  type  = "mc",
  id    = "has_fav_hero",
  label = "Do you have a favorite super hero?",
  option = c(
    "Yes" = "yes",
    "No"  = "no"
  )
)

sd_next()
```

:::
````

Rendered Survey



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    "Yes" = "yes",
    "No"  = "no"
  )
)

sd_next()
```

:::
````

YAML header for a “clean” output

survey.qmd

````
---
format: html
echo: false
warning: false
---

```{r}
library(surveydown)
```

::: {#welcome .sd-page}

# Welcome to `surveydown`!

```{r}
sd_question(
  type  = "mc",
  id    = "has_fav_hero",
  label = "Do you have a favorite super hero?",
  option = c(
    "Yes" = "yes",
    "No"  = "no"
  )
)

sd_next()
```

:::
````

Load the surveydown Package

survey.qmd

````
---
format: html
echo: false
warning: false
---

```{r}
library(surveydown)
```

::: {#welcome .sd-page}

# Welcome to `surveydown`!

```{r}
sd_question(
  type  = "mc",
  id    = "has_fav_hero",
  label = "Do you have a favorite super hero?",
  option = c(
    "Yes" = "yes",
    "No"  = "no"
  )
)

sd_next()
```

:::
````

Use Quarto fences (`:::`) to define survey pages

survey.qmd

````
---
format: html
echo: false
warning: false
---

```{r}
library(surveydown)
```

::: {#welcome .sd-page}

# Welcome to `surveydown`!

```{r}
sd_question(
  type  = "mc",
  id    = "has_fav_hero",
  label = "Do you have a favorite super hero?",
  option = c(
    "Yes" = "yes",
    "No"  = "no"
  )
)

sd_next()
```

:::
````

Page content

- Markdown for texts, images, etc.
- `sd_question()` for survey questions
- `sd_next()` for page navigation

survey.qmd

````
---
format: html
echo: false
warning: false
---

```{r}
library(surveydown)
```

::: {#welcome .sd-page}

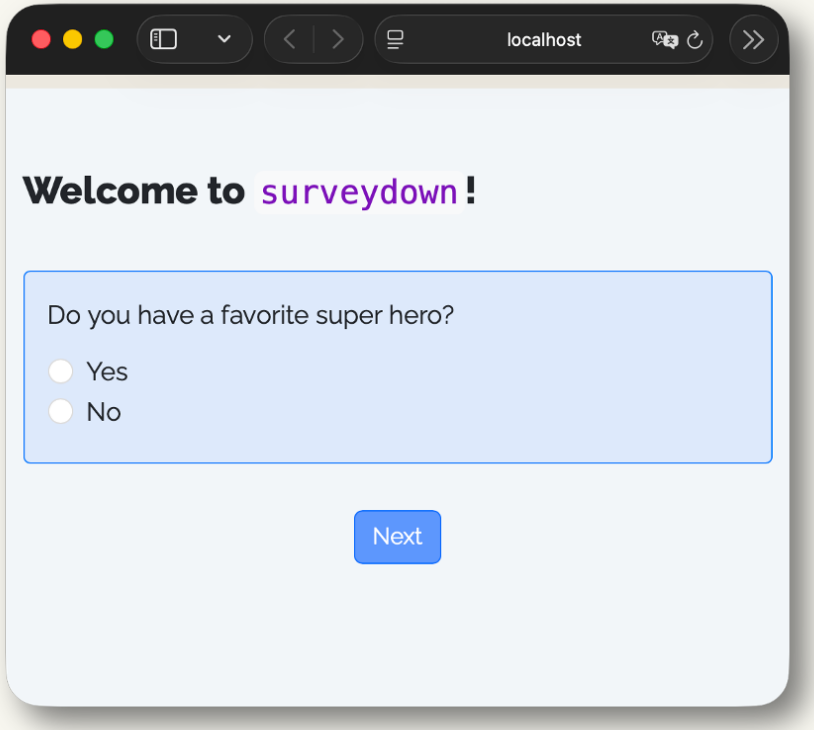
# Welcome to `surveydown`!

```{r}
sd_question(
  type  = "mc",
  id    = "has_fav_hero",
  label = "Do you have a favorite super hero?",
  option = c(
    "Yes" = "yes",
    "No"  = "no"
  )
)

sd_next()
```

:::
````

Rendered Survey



survey.qmd

```
---
format: html
echo: false
warning: false
---

```{r}
library(surveydown)
```

::: {#welcome .sd-page}

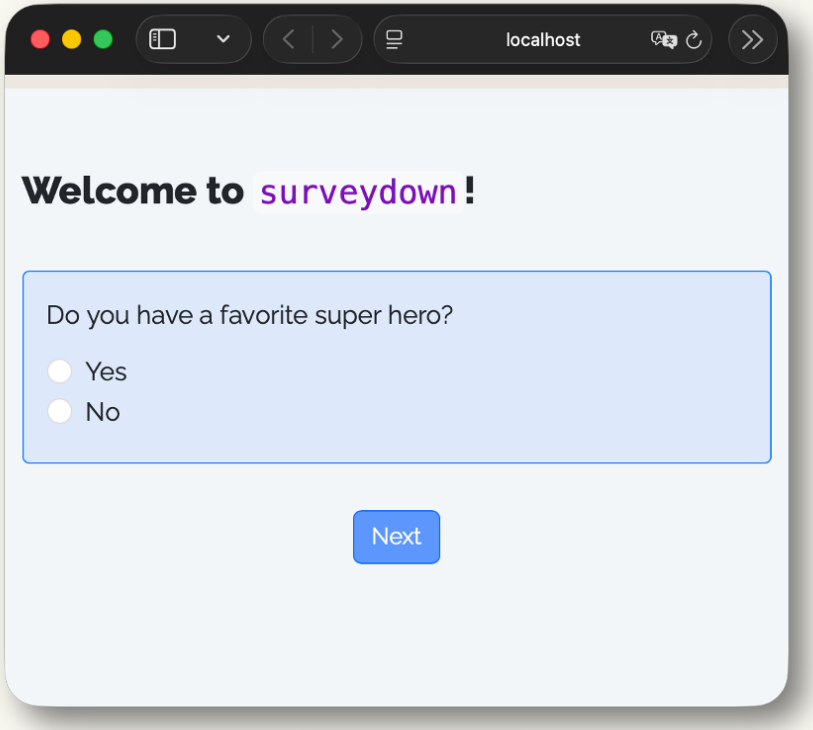
Welcome to `surveydown`!

```{r}
sd_question(
  type  = "mc",
  id    = "has_fav_hero",
  label = "Do you have a favorite super hero?",
  option = c(
    "Yes" = "yes",
    "No"  = "no"
  )
)

sd_next()
```

:::
```

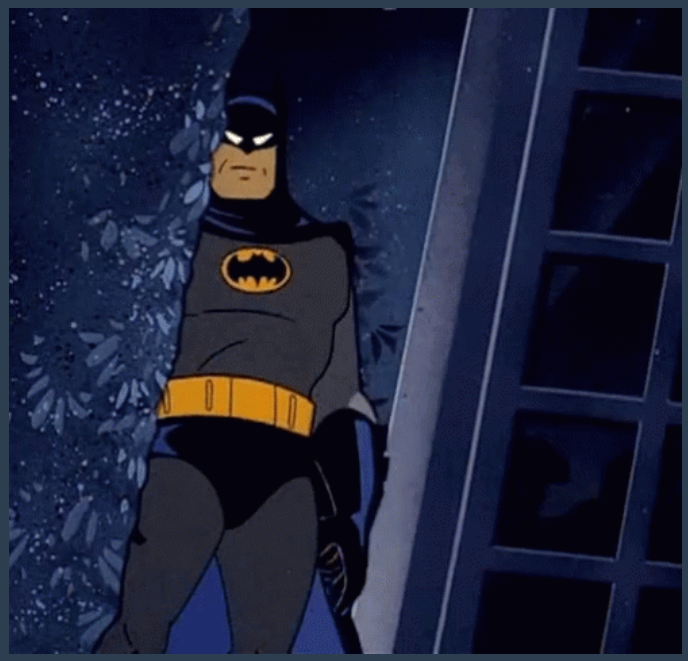
Rendered Survey

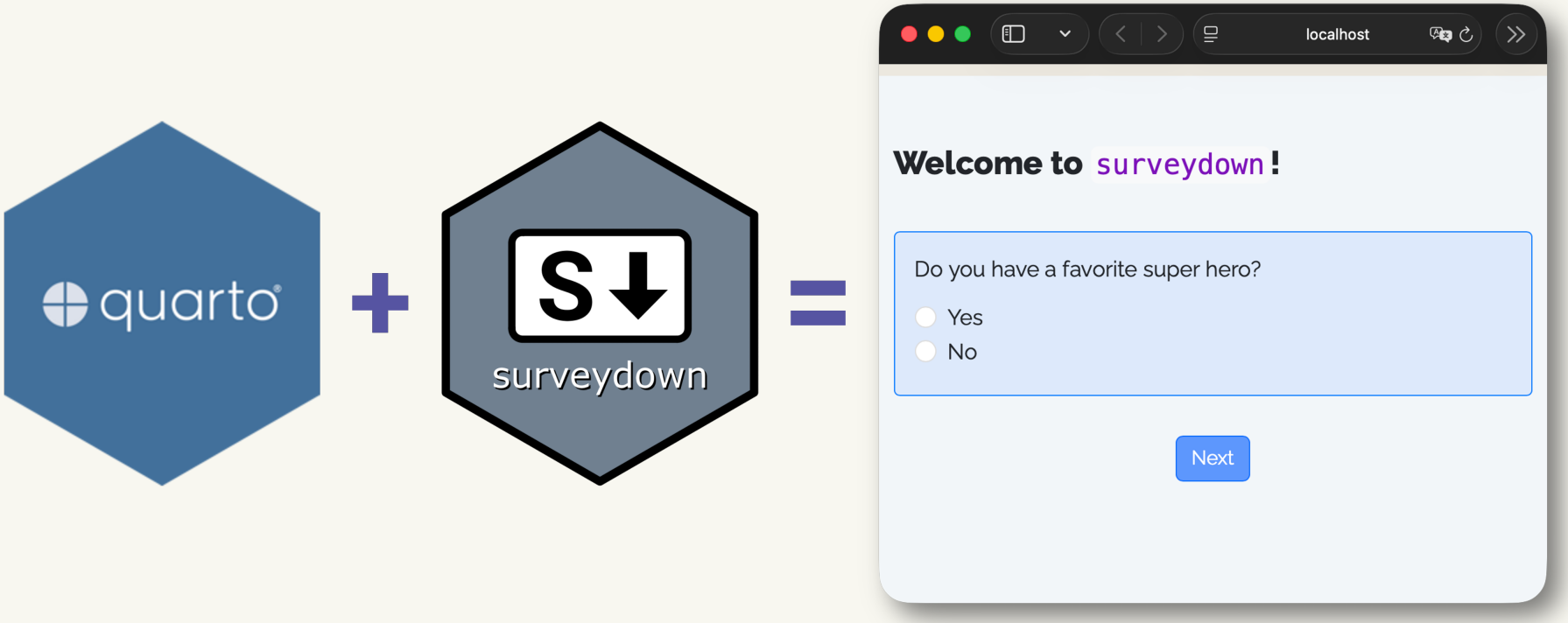


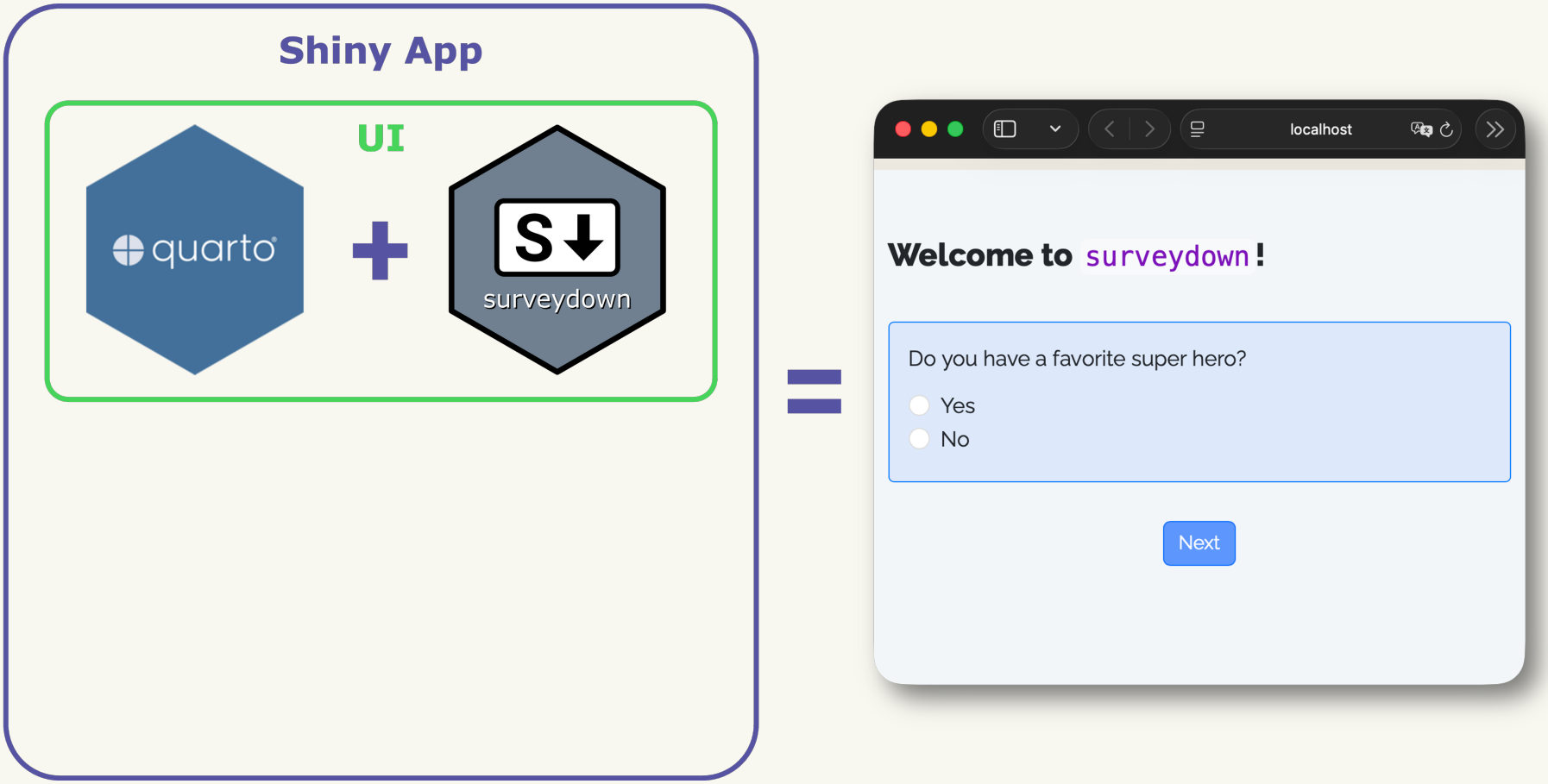
has_fav_hero
yes
no
no
yes

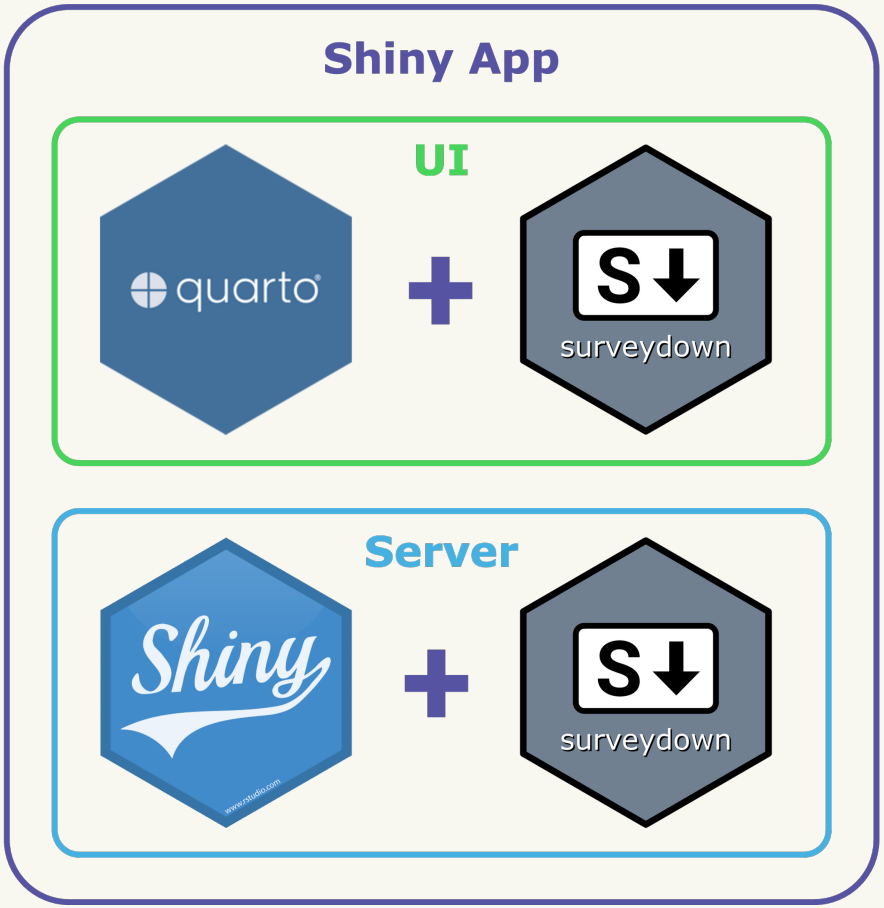
Wait a minute…
Quarto renders to static html pages, right?

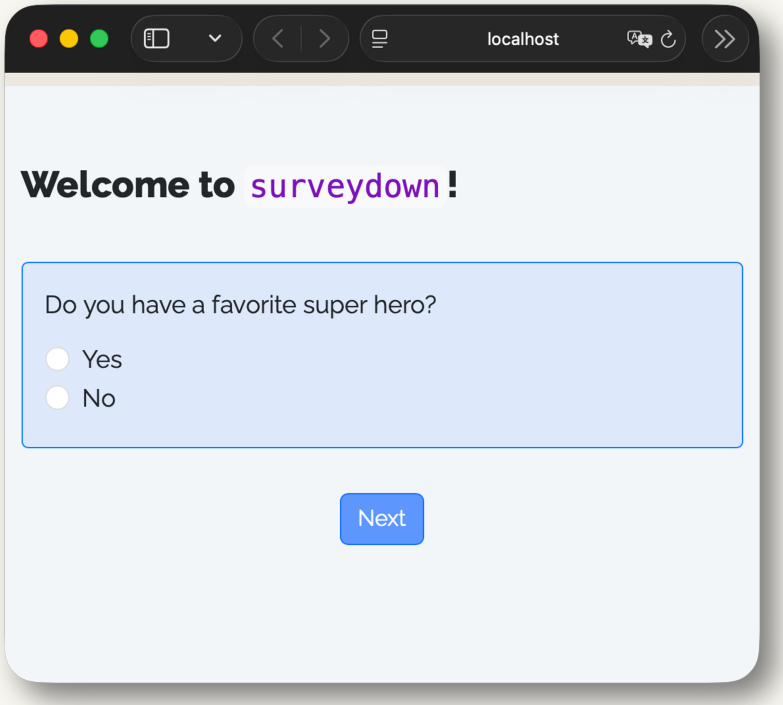
Shiny to the rescue!




quarto
surveydown
localhost
Welcome to surveydown!
Do you have a favorite super hero?
Yes
No
Next


Shiny App
UI
quarto
surveydown
localhost
Welcome to surveydown!
Do you have a favorite super hero?
Yes
No
Next


Shiny App
UI
quarto
surveydown
Server
Shiny
surveydown


localhost
Welcome to surveydown!
Do you have a favorite super hero?
Yes
No
Next

A complete surveydown survey

`survey.qmd`

A **Quarto doc** defining the survey content (pages, texts, images, questions, etc).

`app.R`

An **R script** defining the survey Shiny app.

Don’t panic!

app.R

```
library(surveydown)

ui <- sd_ui()

server <- function(input, output, session) {

  sd_server()

}

shiny::shinyApp(ui = ui, server = server)
```

app.R

```
1  library(surveydown)
2
3  ui <- sd_ui()
4
5  server <- function(input, output, session) {
6
7    sd_server()
8
9  }
10
11 shiny::shinyApp(ui = ui, server = server)
```

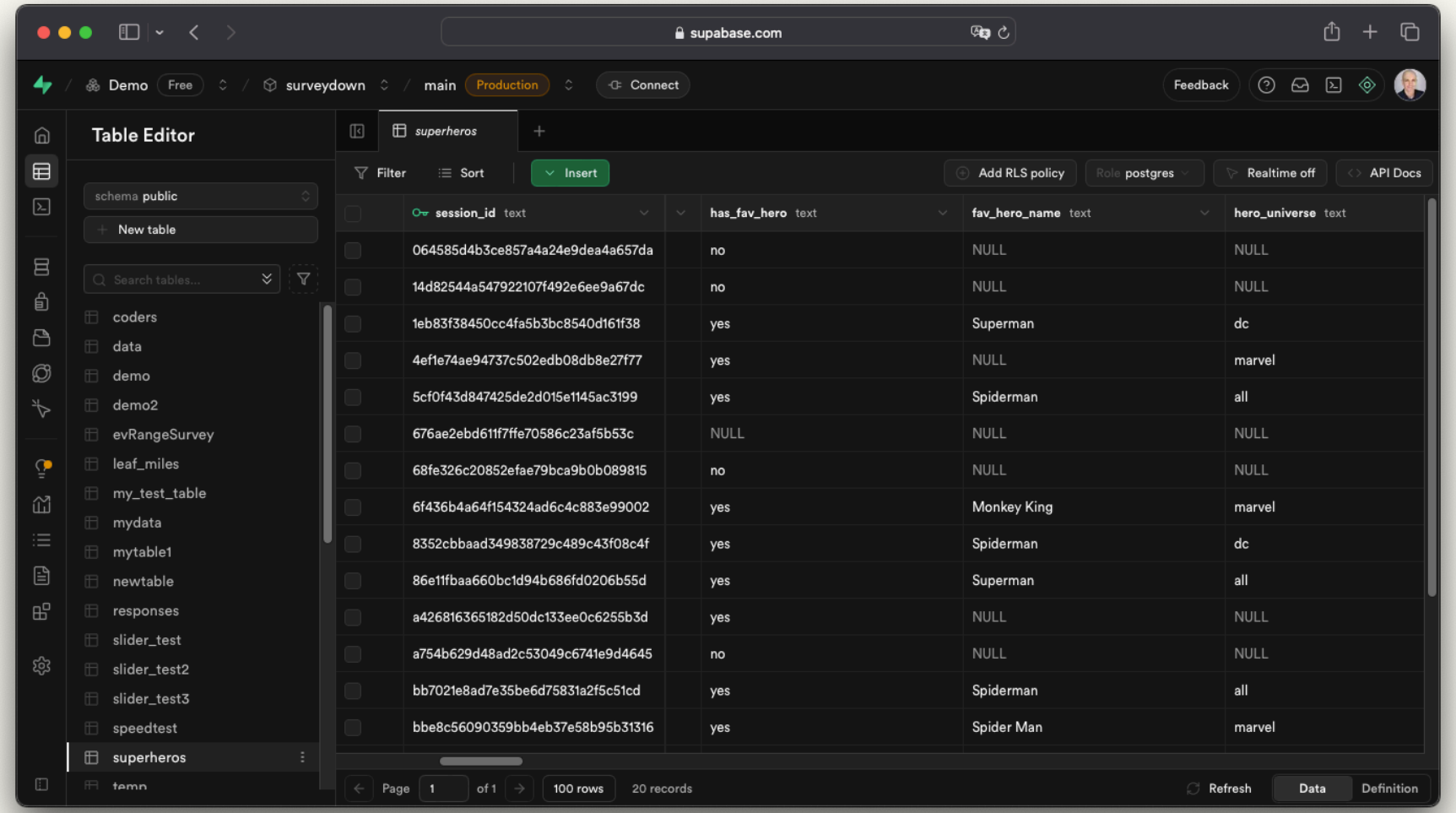
Render `survey.qmd` as UI

Run the `surveydown` server

Wait a minute…
How do you store the response data?

PostgreSQL to the rescue!

supabase.com

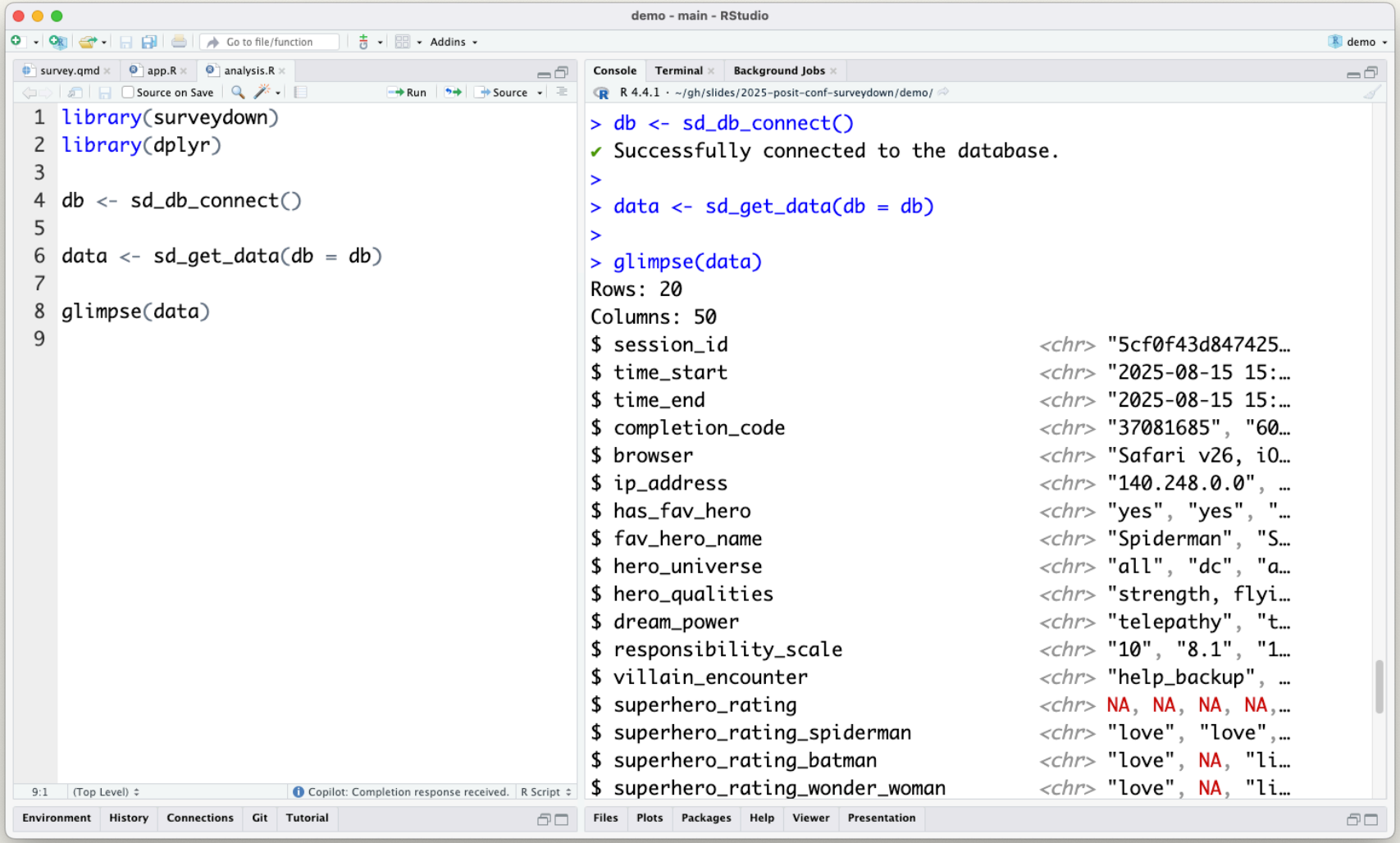


app.R

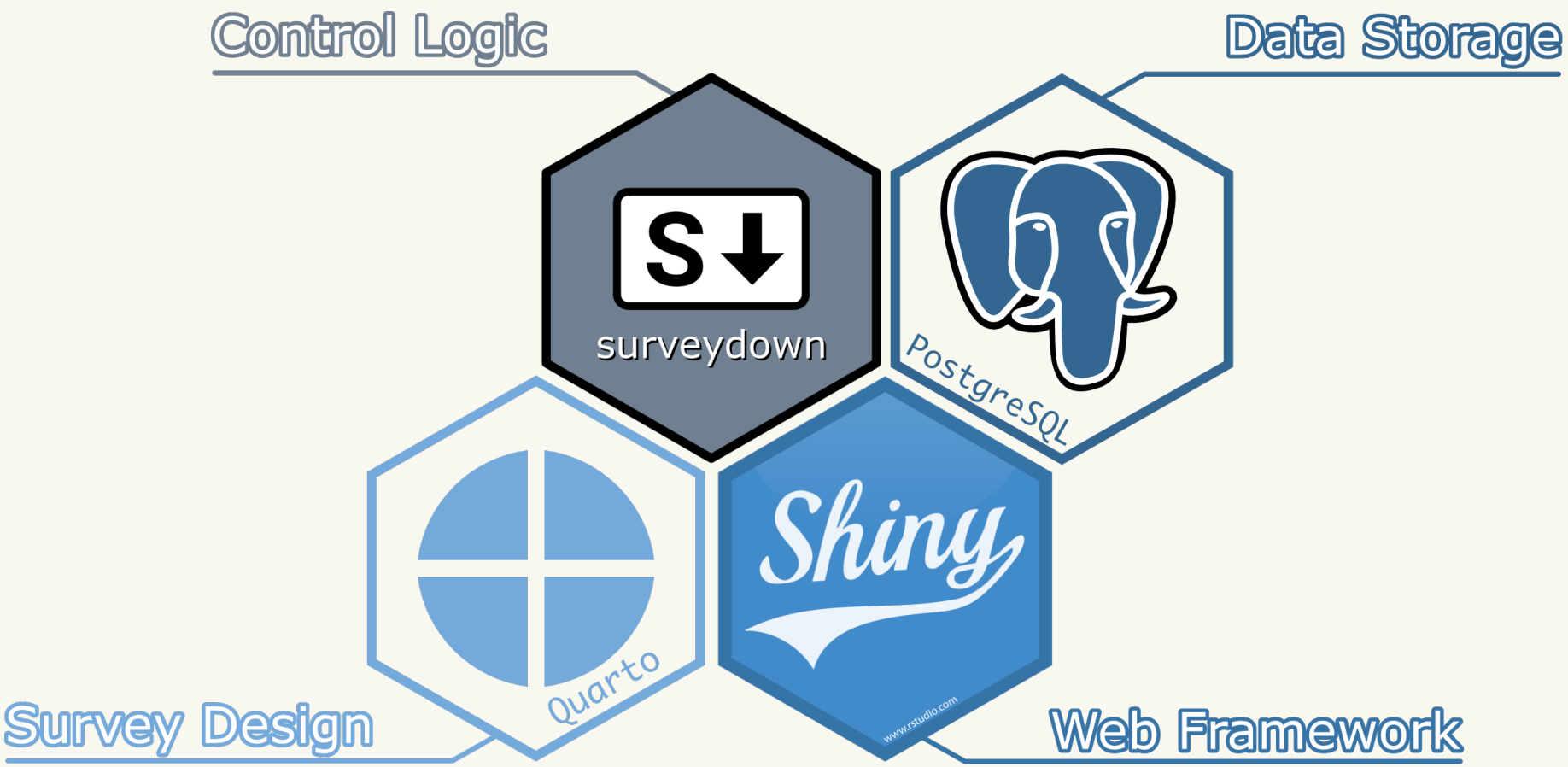
```
1  library(surveydown)
2
3  # sd_db_config()
4  db <- sd_db_connect()
5
6  ui <- sd_ui()
7
8  server <- function(input, output, session) {
9
10   sd_server(db)
11
12 }
13
14 shiny::shinyApp(ui = ui, server = server)
```

Store credentials
Connect to the database

Pass connection to `sd_server()`

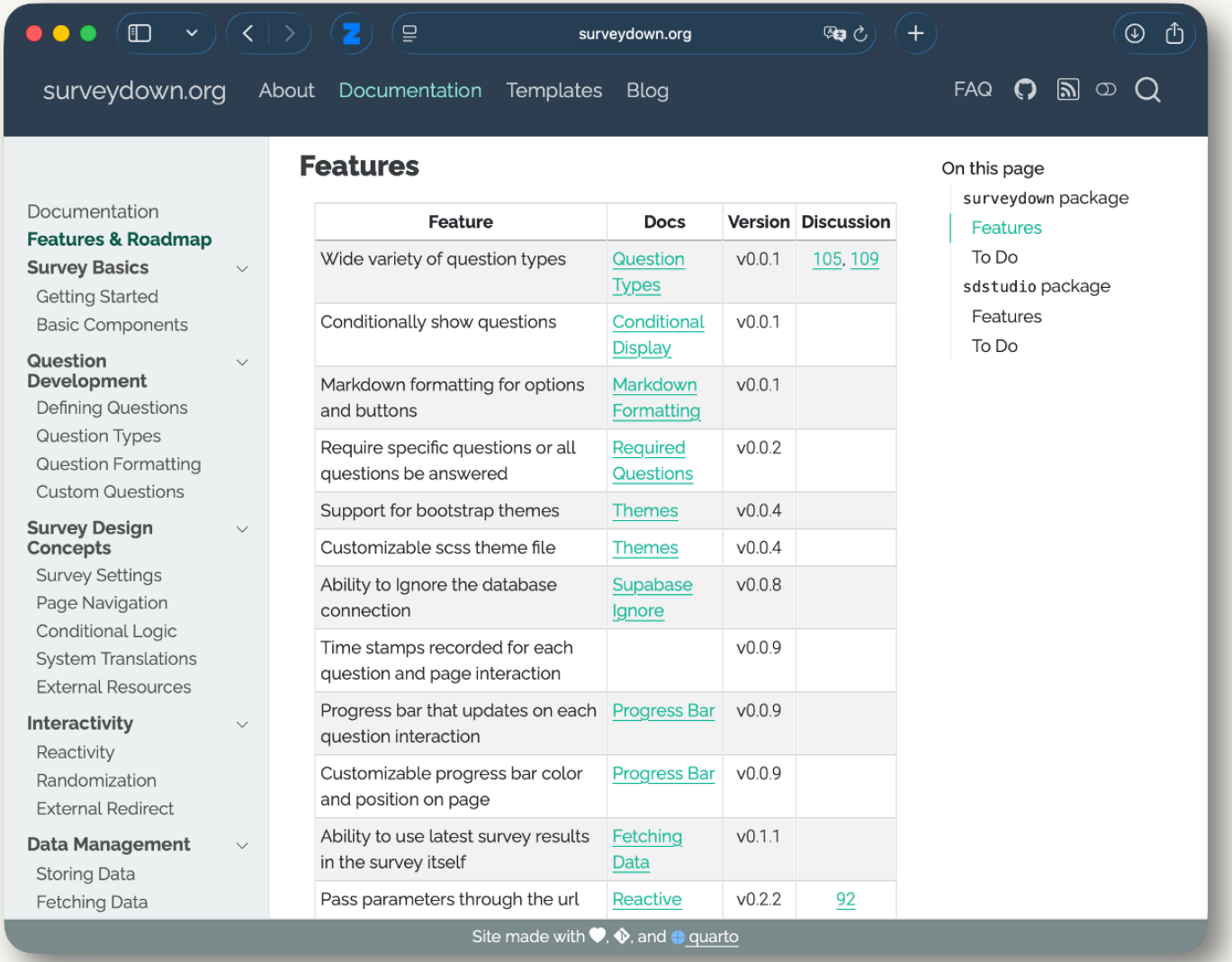

demo - main - RStudio
Go to file/function
Addins
demo
survey.qmd
app.R
analysis.R
Source on Save
Run
Source
1 library(surveydown)
2 library(dplyr)
3
4 db <- sd_db_connect()
5
6 data <- sd_get_data(db = db)
7
8 glimpse(data)
9
9:1
(Top Level)
Copilot: Completion response received.
R Script
Environment
History
Connections
Git
Tutorial
Console
Terminal
Background Jobs
R 4.4.1 · ~/gh/slides/2025-posit-conf-surveydown/demo/
> db <- sd_db_connect()
✔ Successfully connected to the database.
>
> data <- sd_get_data(db = db)
>
> glimpse(data)
Rows: 20
Columns: 50
$ session_id <chr> "5cf0f43d847425…
$ time_start <chr> "2025-08-15 15:…
$ time_end <chr> "2025-08-15 15:…
$ completion_code <chr> "37081685", "60…
$ browser <chr> "Safari v26, iO…
$ ip_address <chr> "140.248.0.0", …
$ has_fav_hero <chr> "yes", "yes", "…
$ fav_hero_name <chr> "Spiderman", "S…
$ hero_universe <chr> "all", "dc", "a…
$ hero_qualities <chr> "strength, flyi…
$ dream_power <chr> "telepathy", "t…
$ responsibility_scale <chr> "10", "8.1", "1…
$ villain_encounter <chr> "help_backup", …
$ superhero_rating <chr> NA, NA, NA, NA,…
$ superhero_rating_spiderman <chr> "love", "love",…
$ superhero_rating_batman <chr> "love", NA, "li…
$ superhero_rating_wonder_woman <chr> "love", NA, "li…
Files
Plots
Packages
Help
Viewer
Presentation

What is surveydown?


Control Logic
Data Storage
surveydown
PostgreSQL
Quarto
Shiny
www.rstudio.com
Survey Design
Web Framework

What can surveydown do?

surveydown is feature-packed!



Feature Highlights

Question types

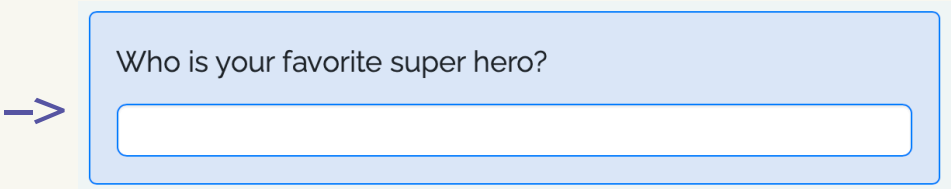
Conditional logic

12 Built-in Question Types

`text`	`textarea`	`numeric`	`mc`
`mc_multiple`	`mc_buttons`	`mc_multiple_buttons`	`select`
`slider`	`slider_numeric`	`date`	`daterange`

Question Type: `text`

```
sd_question(
  type  = "text",
  id    = "fav_hero_name",
  label = "Who is your favorite super hero?"
)
```



Question Type: `mc_buttons`

```
sd_question(
  type  = "mc_buttons",
  id    = "dream_power",
  label = "If you could have ONE superpower?",
  option = c(
    "🕸️ Web-slinging"   = "webslinging",
    "🛡️ Super Strength" = "strength",
    "✈️ Flight"         = "flight",
    "🧠 Telepathy"      = "telepathy",
    "⚡ Super Speed"    = "speed"
  ),
  direction = "vertical"
)
```

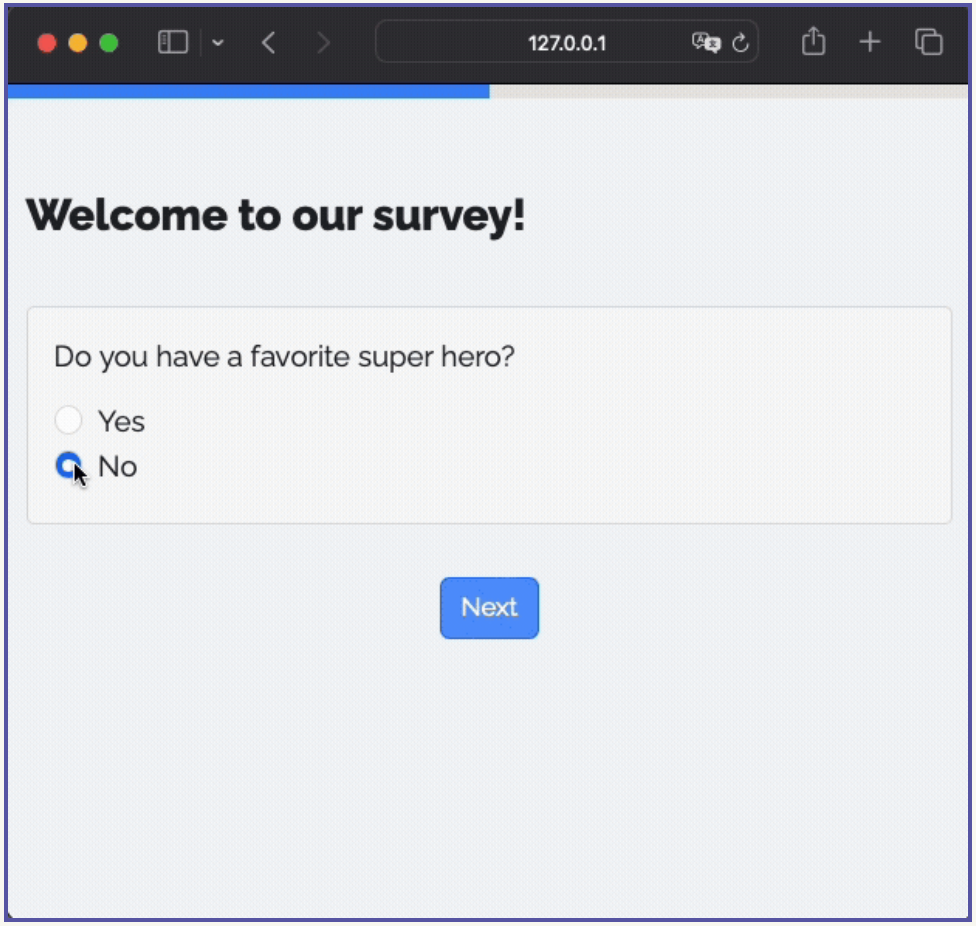
Conditional logic

Conditional showing

Conditional skipping

Conditional stopping

Conditional showing - `sd_show_if()`



Conditional showing - `sd_show_if()`

`survey.qmd`

```
# Conditional Question
sd_question(
  type  = "mc",
  id    = "has_fav_hero",
  label = "Do you have a favorite hero?",
  option = c("Yes" = "yes", "No" = "no")
)

# Target Question
sd_question(
  type  = "text",
  id    = "fav_hero",
  label = "Who is your favorite super hero?"
)
```

`app.R`

```
# Inside server
sd_show_if(
  input$has_fav_hero == "yes" ~ "fav_hero"
)
```

Condition ~ Target

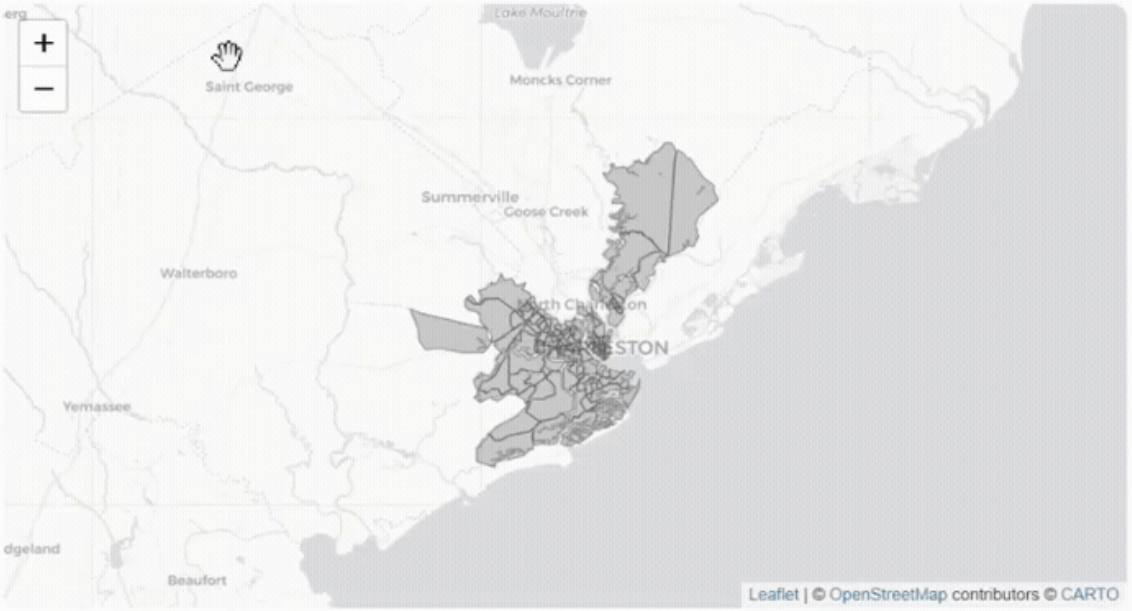
"If {condition}, then show {target}"

If it works in Shiny,
it works in surveydown.

Embedding an interactive map with `leaflet`:

Question 1: Social Vulnerability is how likely people are to face greater harm or impact on their lives after disruptive hazard events like flooding based on social or economic conditions like income or transportation access.

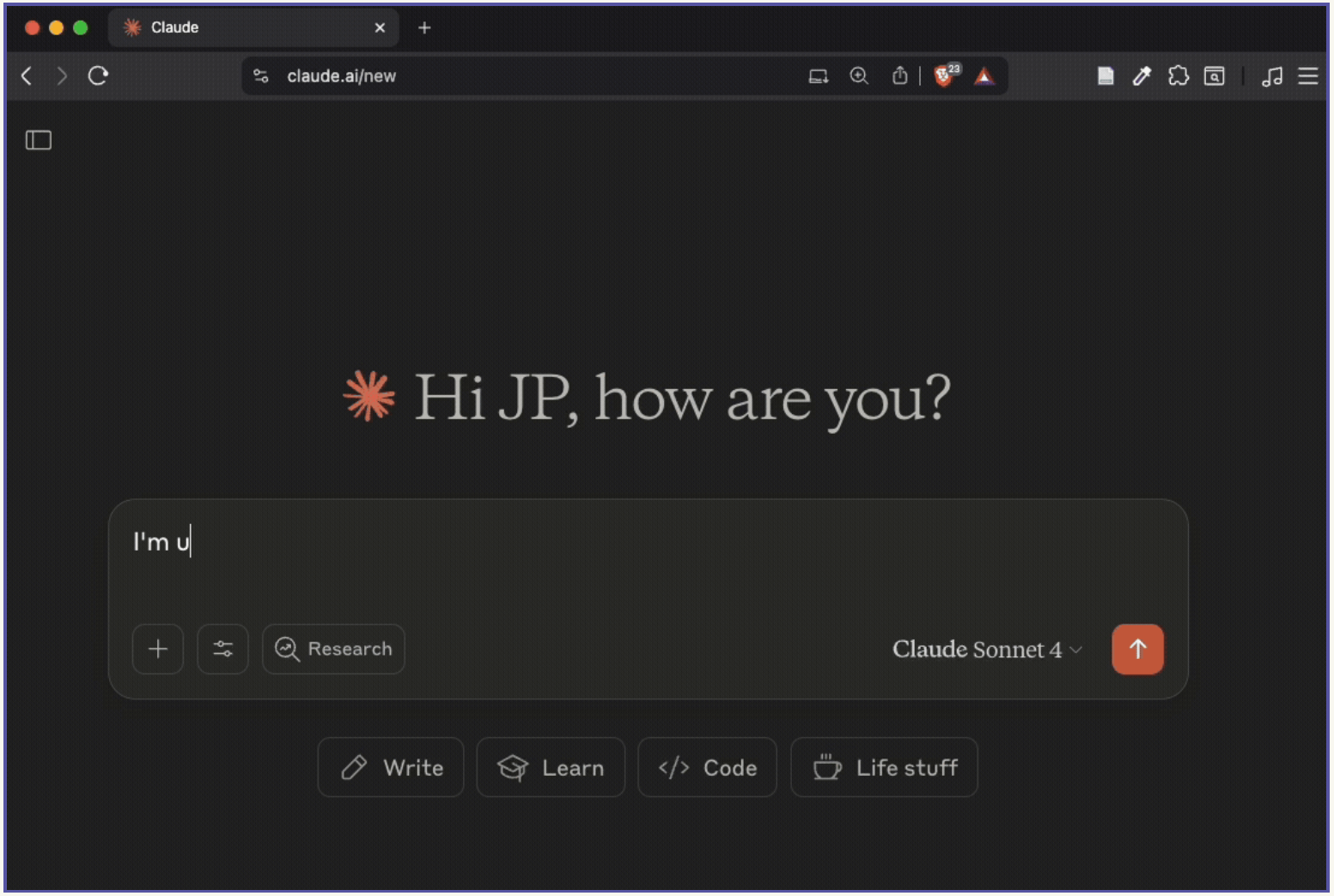
Please review the map of the City of Charleston, South Carolina, and select the areas you believe are more socially vulnerable to the impacts of hazardous events.



Next Question

`surveydown` + LLMs
is pretty cool

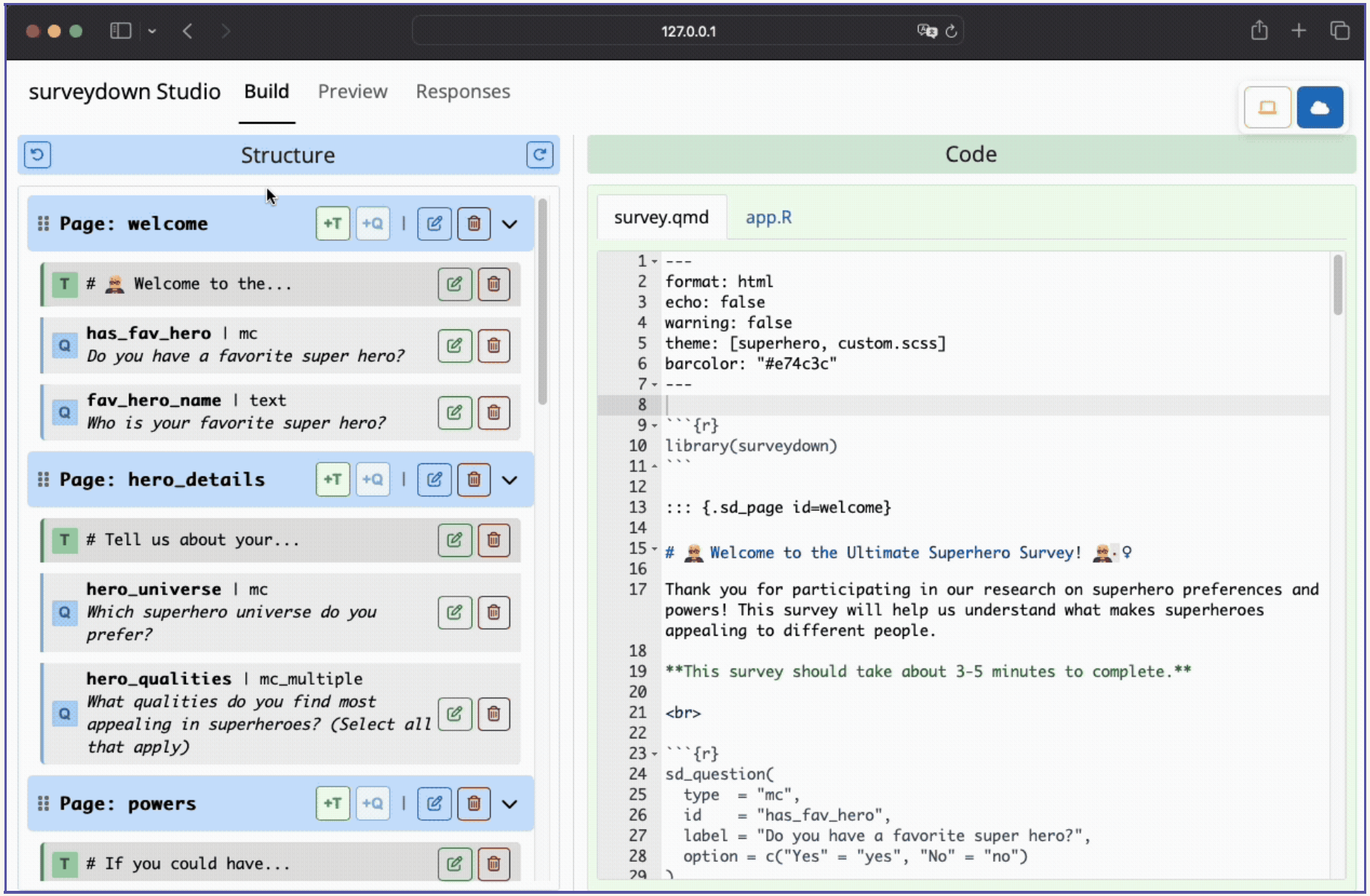
Generate surveys with LLMs!

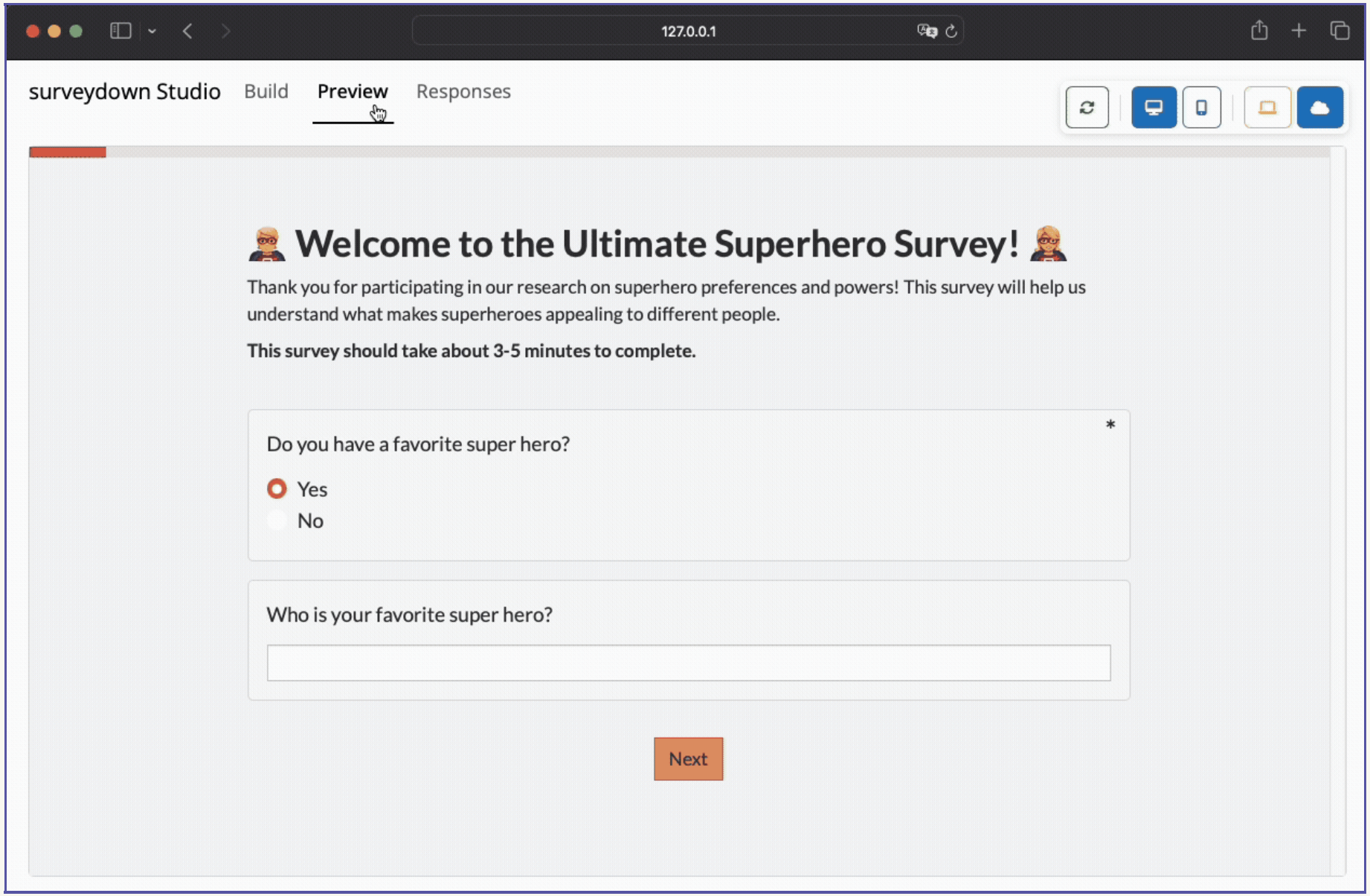


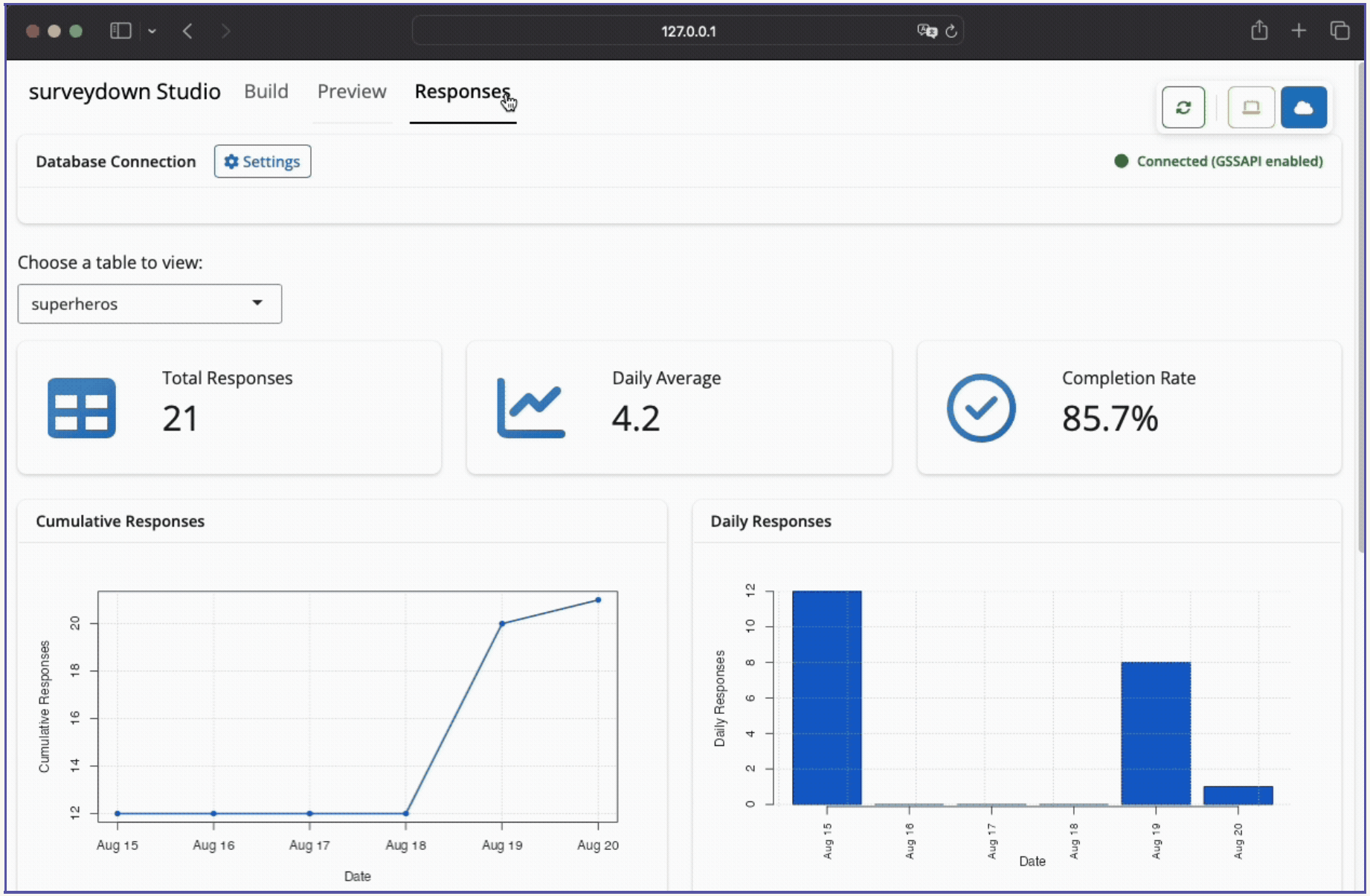
What's next?

Try out the companion `sdstudio` package:

```
sdstudio::launch()
```


127.0.0.1
surveydown Studio
Build
Preview
Responses
Structure
Page: welcome
+T
+Q
T # Welcome to the...
Q has_fav_hero | mc
Do you have a favorite super hero?
Q fav_hero_name | text
Who is your favorite super hero?
Page: hero_details
T # Tell us about your...
Q hero_universe | mc
Which superhero universe do you prefer?
Q hero_qualities | mc_multiple
What qualities do you find most appealing in superheroes? (Select all that apply)
Page: powers
T # If you could have...
Code
survey.qmd
app.R
1 ---
2 format: html
3 echo: false
4 warning: false
5 theme: [superhero, custom.scss]
6 barcolor: "#e74c3c"
7 ---
8
9 ```{r}
10 library(surveydown)
11 ```
12
13 ::: {.sd_page id=welcome}
14
15 # Welcome to the Ultimate Superhero Survey!
16
17 Thank you for participating in our research on superhero preferences and powers! This survey will help us understand what makes superheroes appealing to different people.
18
19 **This survey should take about 3-5 minutes to complete.**
20
21
22
23 ```{r}
24 sd_question(
25 type = "mc",
26 id = "has_fav_hero",
27 label = "Do you have a favorite super hero?",
28 option = c("Yes" = "yes", "No" = "no")
29)


127.0.0.1
surveydown Studio
Build
Preview
Responses
🦸 Welcome to the Ultimate Superhero Survey! 🦸
Thank you for participating in our research on superhero preferences and powers! This survey will help us understand what makes superheroes appealing to different people.
This survey should take about 3-5 minutes to complete.
Do you have a favorite super hero? *
Yes
No
Who is your favorite super hero?
Next


127.0.0.1
surveydown Studio
Build
Preview
Responses
Database Connection
Settings
Connected (GSSAPI enabled)
Choose a table to view:
superheros
Total Responses
21
Daily Average
4.2
Completion Rate
85.7%
Cumulative Responses
Cumulative Responses
12
14
16
18
20
Aug 15
Aug 16
Aug 17
Aug 18
Aug 19
Aug 20
Date
Daily Responses
Daily Responses
0
2
4
6
8
10
12
Aug 15
Aug 16
Aug 17
Aug 18
Aug 19
Aug 20
Date

With great power comes great responsibility.

Ways to help:

github.com/surveydown-dev/surveydown/

- Try it out!
- Give it a ⭐
- Post an issue
- Join the GitHub discussion
- Contribute a template

Meet the team!

surveydown.org

John Helveston, Ph.D.

Pingfan Hu

Bogdan Bunea

Reference List

Huang, Bing, Aart Gerard Meijssen, Jan Anne Annema, and Zofia Lukszo. 2021. "Are Electric Vehicle Drivers Willing to Participate in Vehicle-to-Grid Contracts? A Context-Dependent Stated Choice Experiment." *Energy Policy* 156 (September): 112410. https://doi.org/10.1016/j.enpol.2021.112410.

Philip, Thara, and Jake Whitehead. 2024. "Consumer Preferences Towards Electric Vehicle Smart Charging Program Attributes: A Stated Preference Study." Rochester, NY. https://doi.org/10.2139/ssrn.4812923.

Wong, Stephen D., Susan A. Shaheen, Elliot Martin, and Robert Uyeki. 2023. "Do Incentives Make a Difference? Understanding Smart Charging Program Adoption for Electric Vehicles." *Transportation Research Part C: Emerging Technologies* 151 (June): 104123. https://doi.org/10.1016/j.trc.2023.104123.