

The Science of Product Development

Bringing Causal Inference to Conversion and Retention Metrics

David Robinson, Director of Data Science at Contentsquare
2024 NYR Conference



When a company designs a product, they want it to be easy to use

Some are designed better than others!

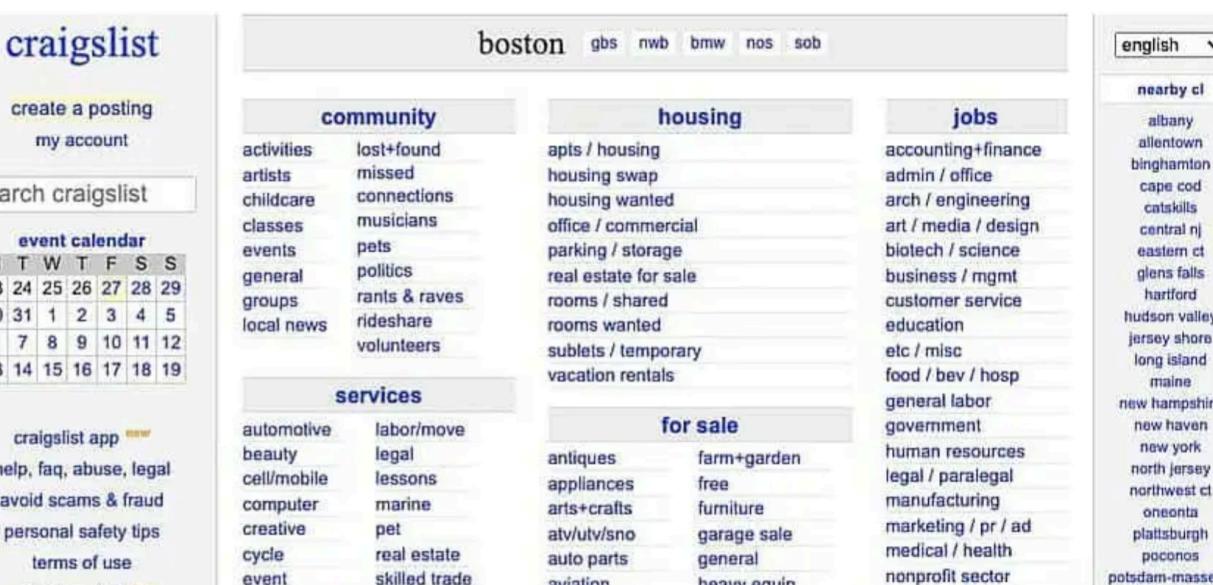
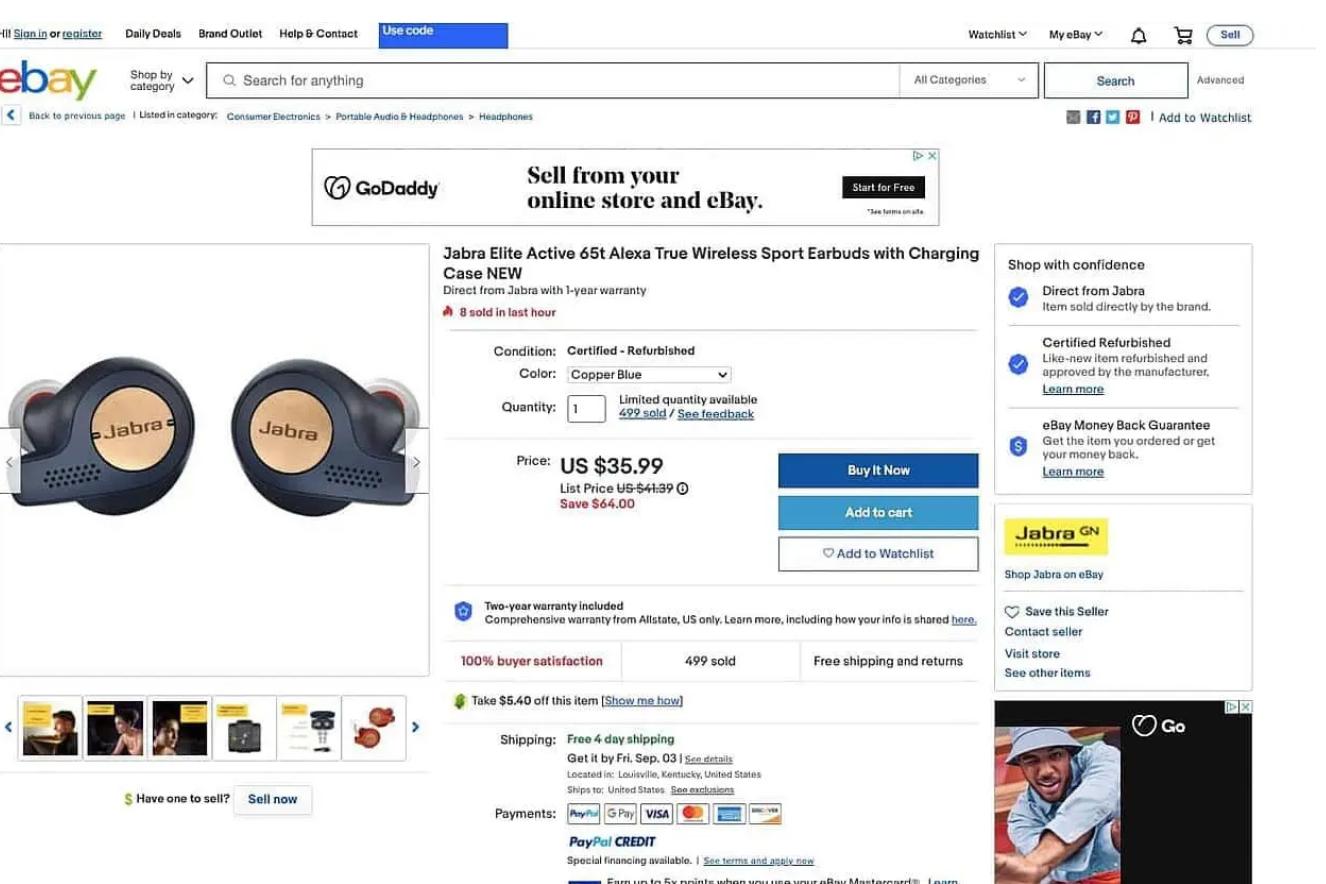
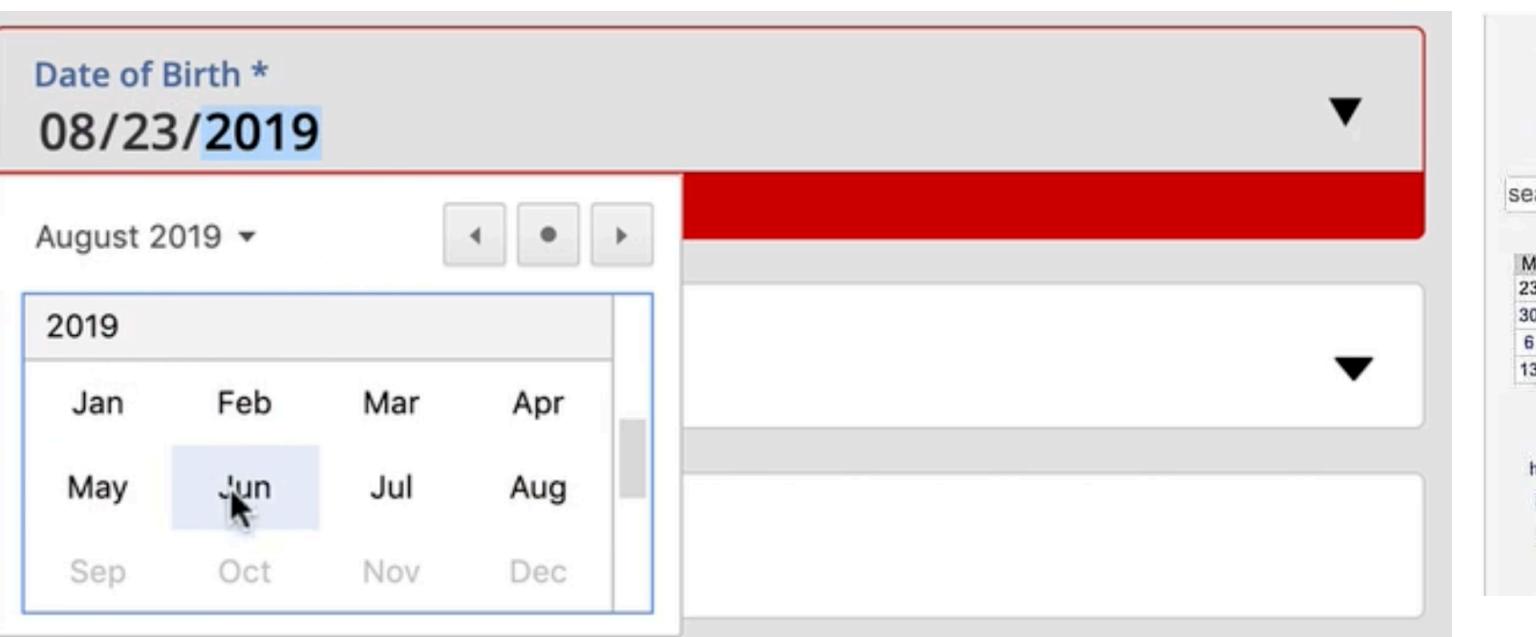
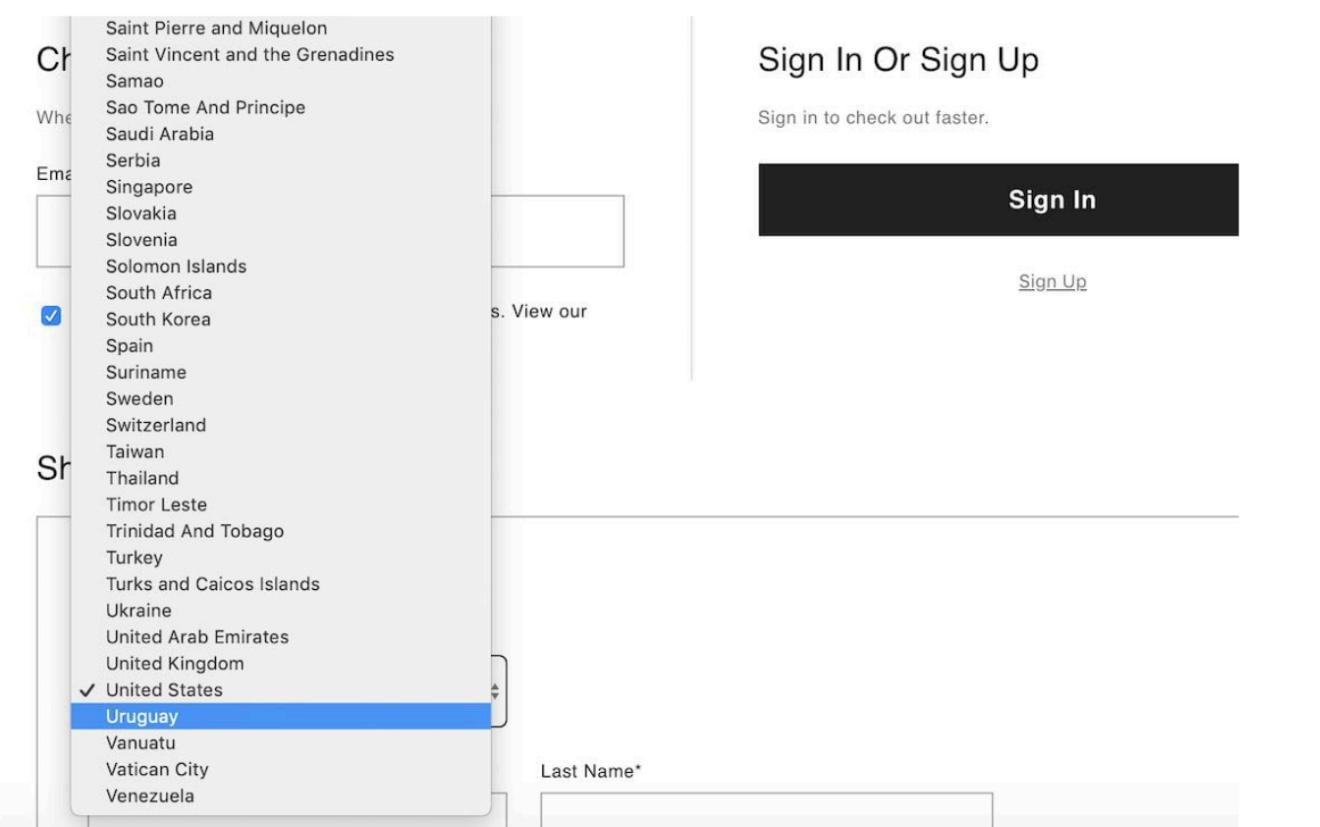
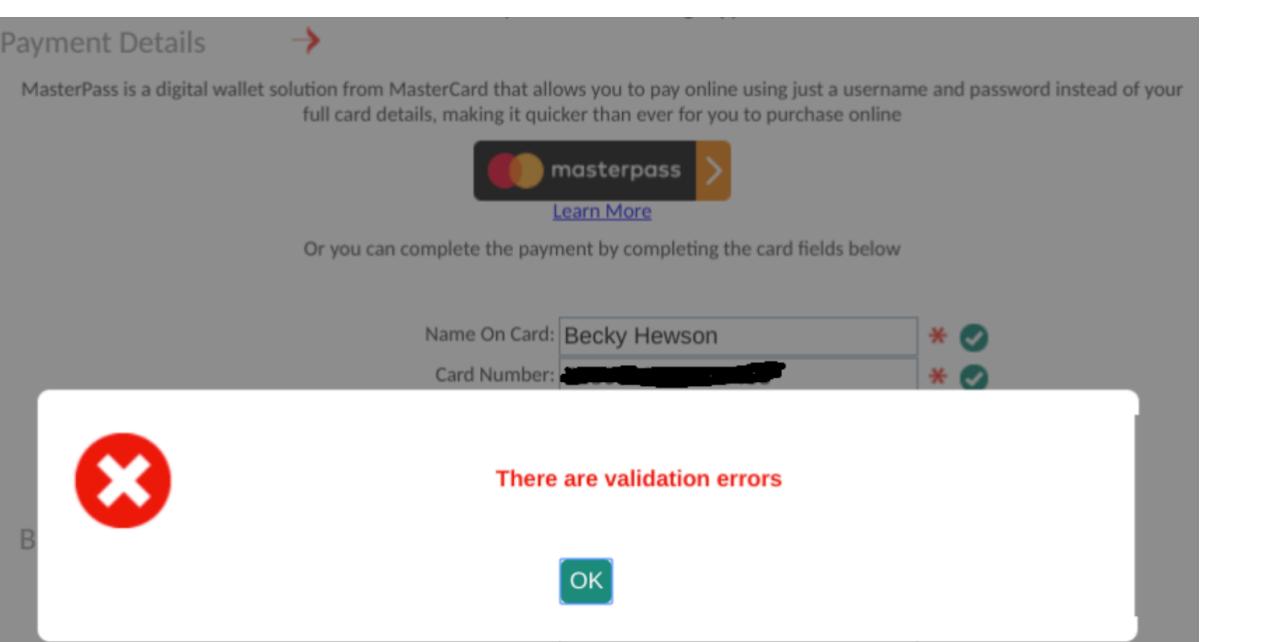
Digital products have an advantage that designers of physical products can only dream of

They can collect data on how every single customer is using the product: what they're viewing, what they're clicking, and where they're getting stuck.

Digital products have an advantage that designers of physical products can only dream of

They can collect data on how every single customer is using the product: what they're viewing, what they're clicking, and where they're getting stuck.

So what's their excuse?



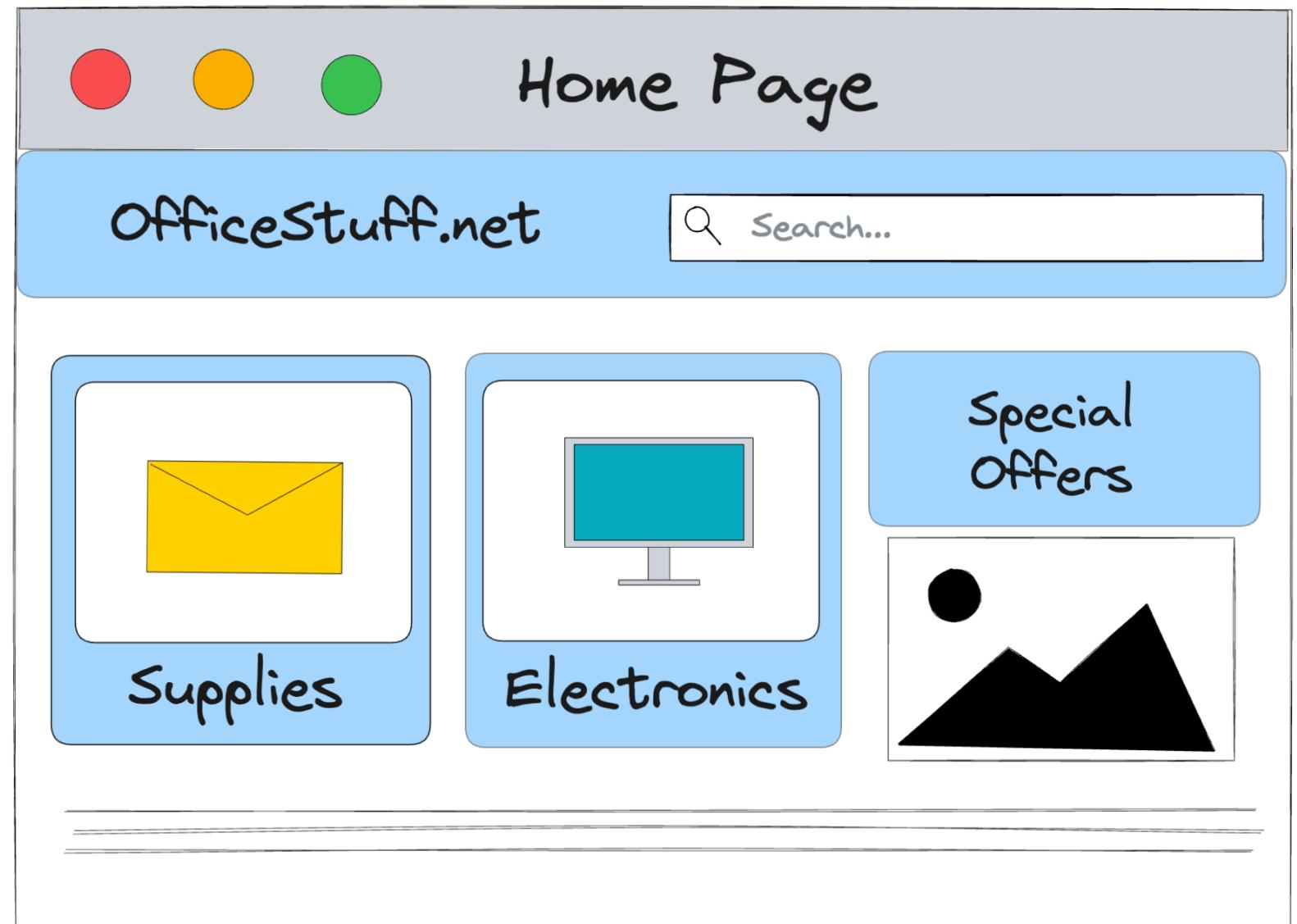
Land on /home
 Click "Special Offers"
 View /special-offers
 Click "Paperclips"
 View /paper-clips
 Click "Add to Cart"
 Click "Check Out"
 View /checkout
 Click "Save for Later"
Drop Off

Land on /home
 Click "Special Offers"
 View /special-offers
 Click Back
 Click "Search"
 Enter "Headphones"
 Click - Sort by Price
 Click - Sort by Category
Drop Off

Land on /promo
 Click "50% Off Special Offers"
 View /special-offers
 Click Back
 Click - Sign In
 Click "Search"
 Enter "Keyboard"
 Click - Sort by Price
 Click - Filter by Price
 Click - Mechanical Keyboard
 View /products/mechanical-keyboard
 Click - "Buy (One Click)"
Purchase

Land on /home
 Click "Browse"
 View /categories
 View /recent
 Click Back
Drop Off

View /home
 Click "Supplies"
 View /supplies
 Click "Paper"
 View /products/paper
 Click "Add to Cart"
 View /supplies
 Click "Scissors"
 View /products/scissors
 Click Back
 Click "Premium Scissors"
 View /products/scissors
 Click "Add to Cart"
 View - Checkout
 Click - Enter Name
 Click - Enter Credit Card
 Validation Error
 Click - Enter Credit Card
 Click - Check Terms & Conditions
Purchase

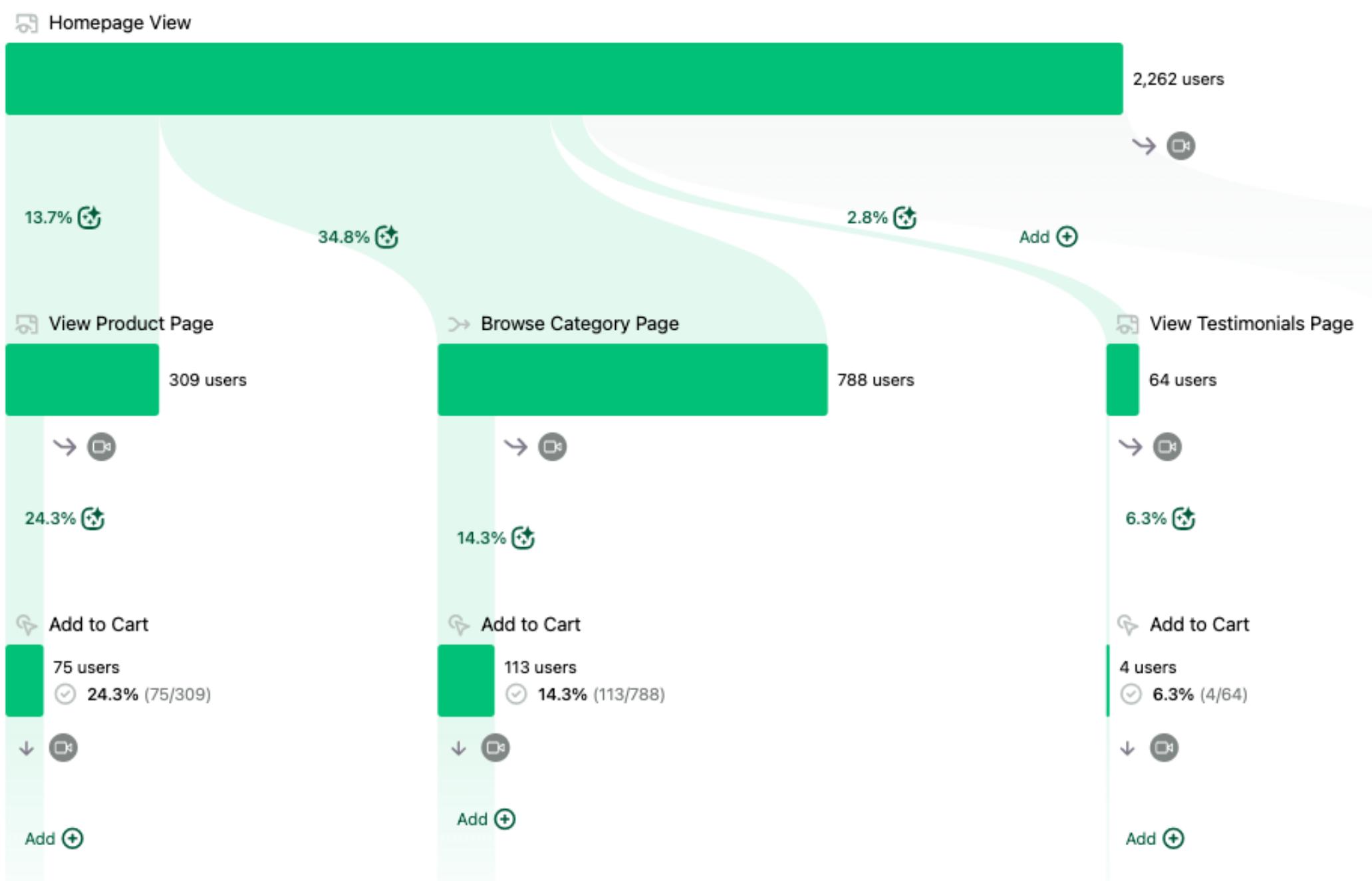


The Checkout page wireframe for OfficeStuff.net features a header with three colored circles (red, yellow, green) and the text "Checkout". Below the header are input fields for "Name" and "Address". A payment method selection section includes "Credit Card", "Apple Pay", and "Paypal" buttons. At the bottom is a checkbox labeled "I agree to the Terms & Conditions" and a "Purchase" button.

What statistical tools can turn sequences of events into **product insights and improvements?**

Date range Past 7 days within a single session [Update results](#) [Enter](#)

Description [Add description](#)

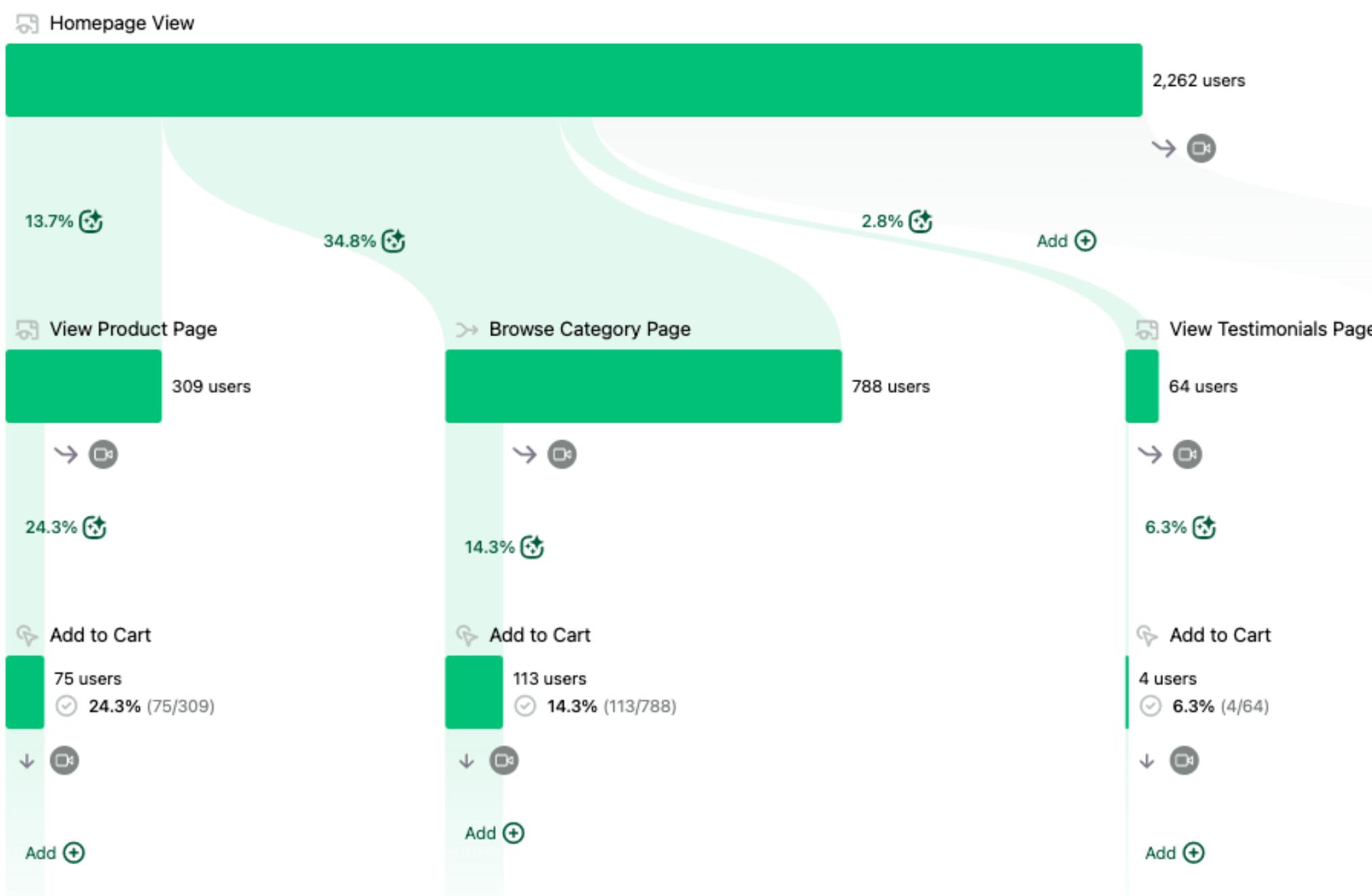


We developed these principles at
Heap to power the Journeys product
(launched 2022)



Date range Past 7 days within a single session

Description



Today, I'm focused more on the theory: on the “missing science” of analyzing and improving products



We developed these principles at Heap to power the Journeys product (launched 2022)



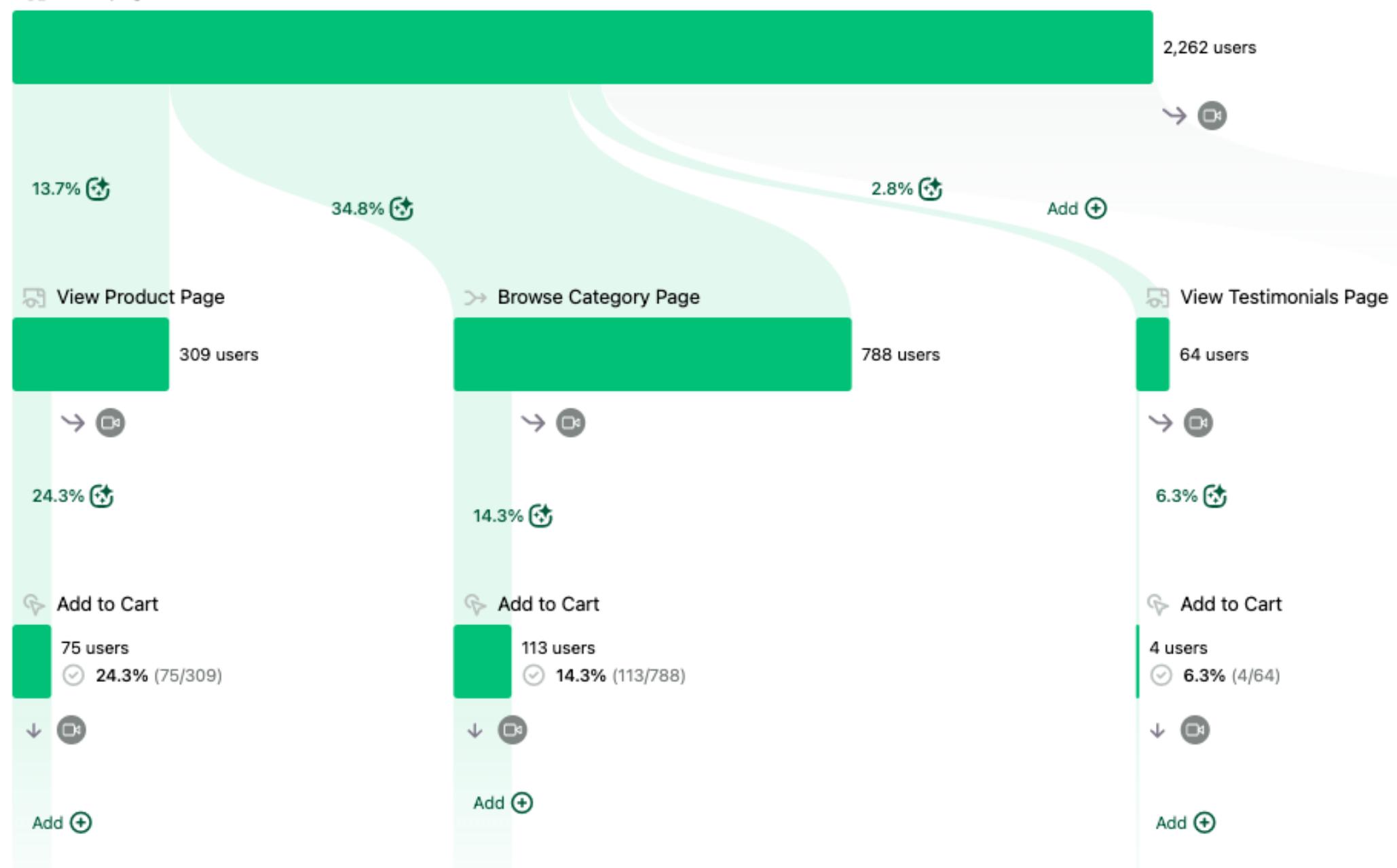
Date range Past 7 days within a single session

Update results

⌘ + Enter

Description Add description

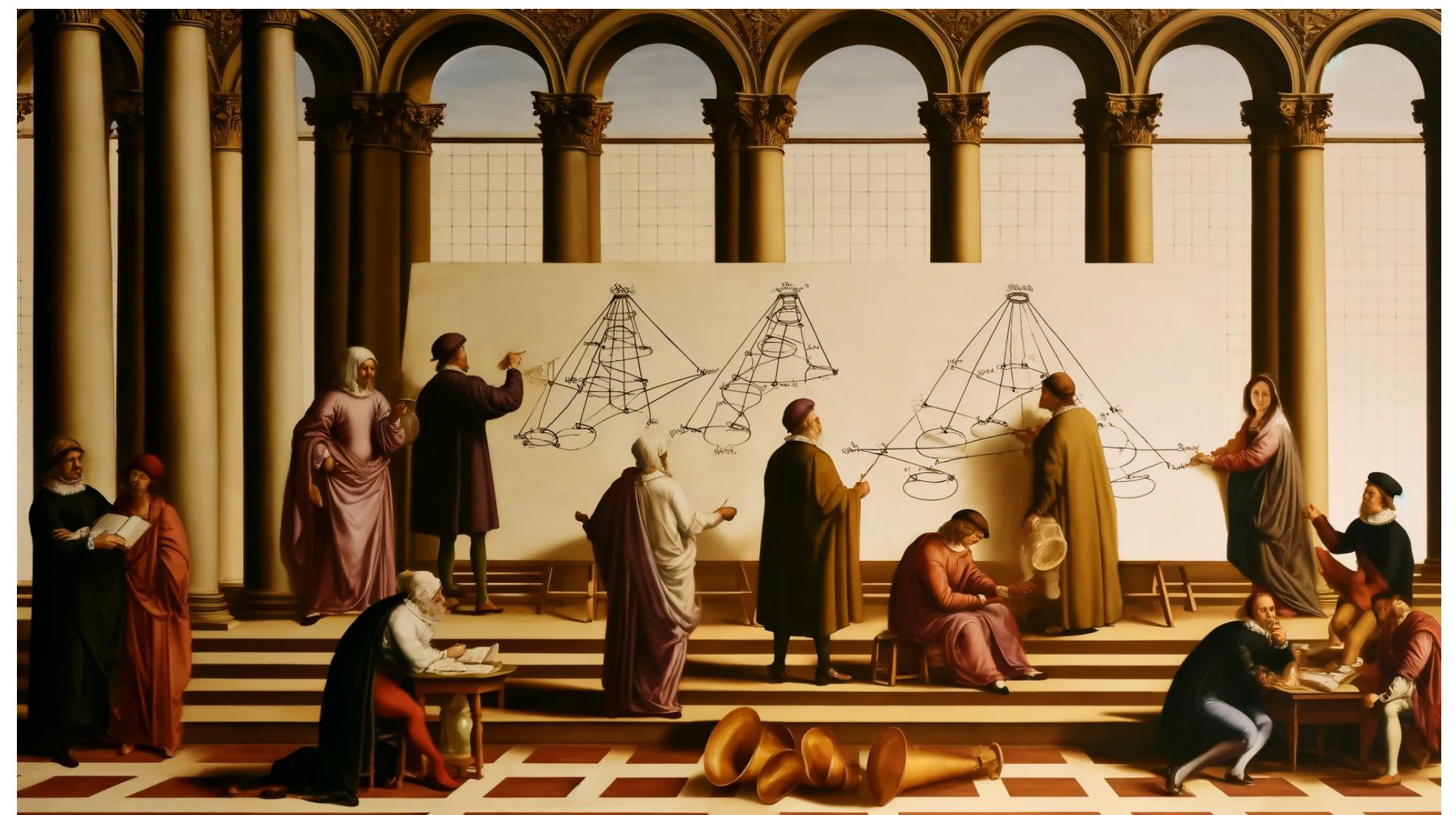
Homepage View



We developed these principles at Heap to power the Journeys product (launched 2022)

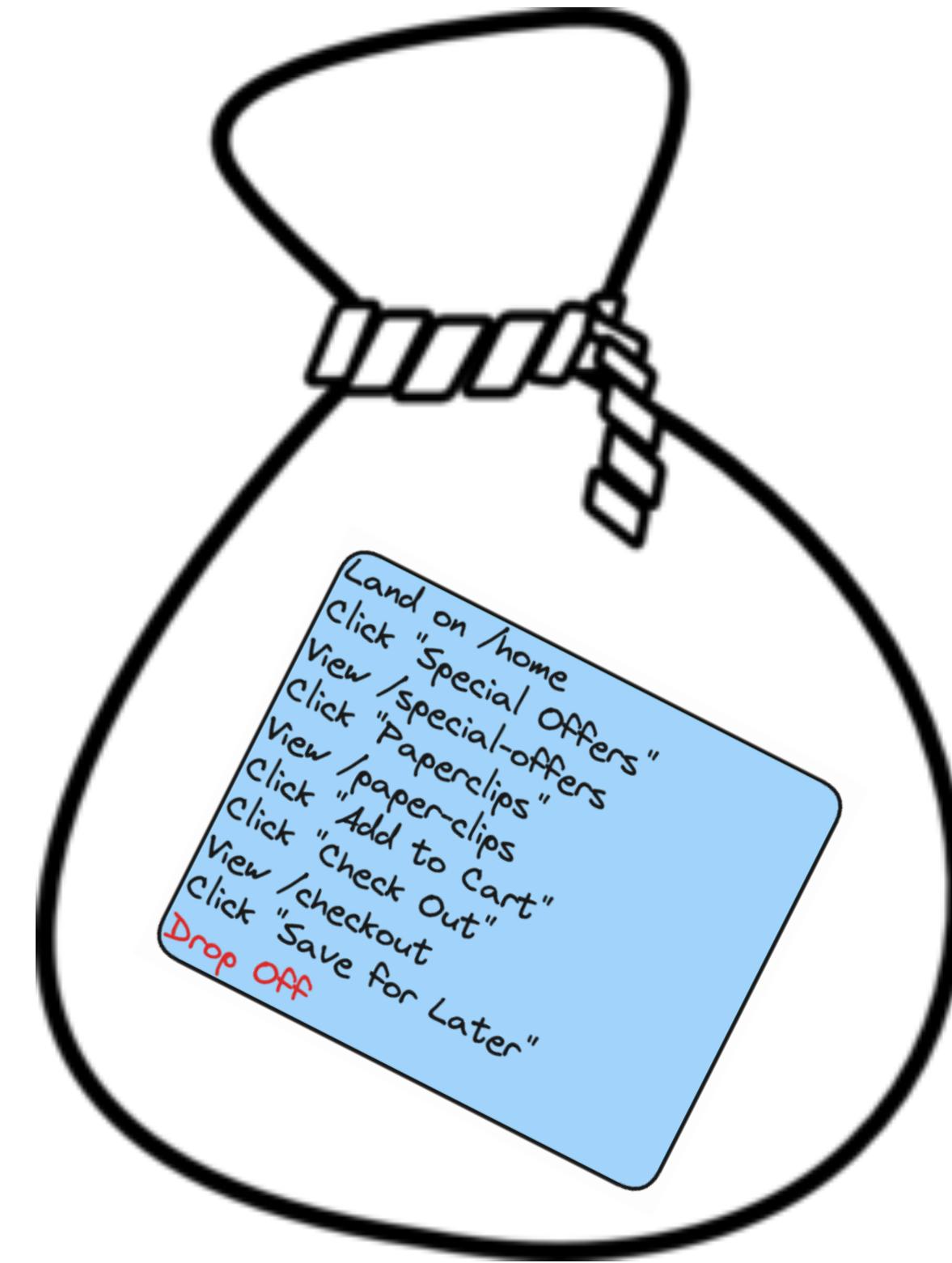


Today, I'm focused more on the theory: on the “missing science” of analyzing and improving products



Correlations

The “bag of clicks” model



The “bag of clicks” model

Land on /home
Click "Special Offers"
View /special-offers
Click "Paperclips"
View /paper-clips
Click "Add to Cart"
Click "Check Out"
View /checkout
Click "Save for Later"
Drop OFF

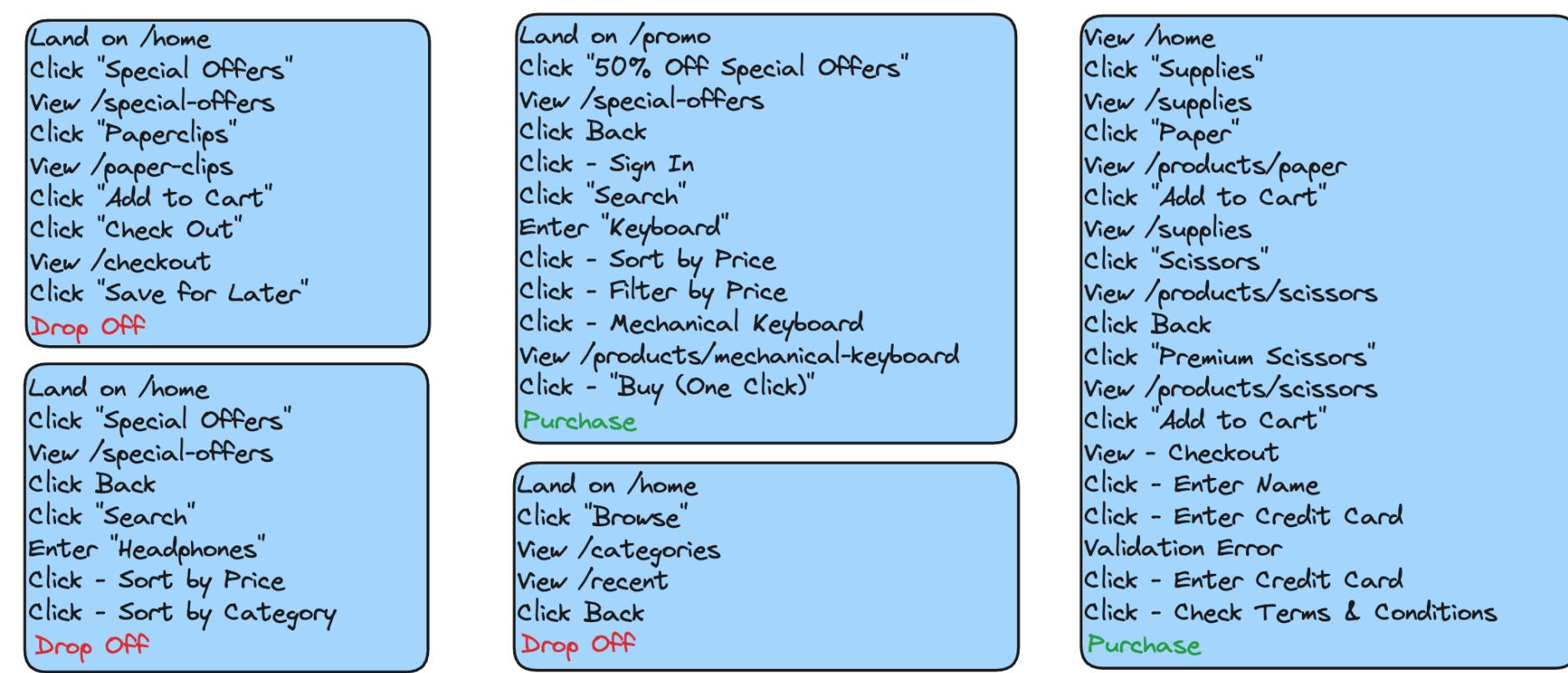
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Land on /promo
Click "50% Off Special Offers"
View /special-offers
Click Back
Click - Sign In
Click "Search"
Enter "Keyboard"
Click - Sort by Price
Click - Filter by Price
Click - Mechanical Keyboard
View /products/mechanical-keyboard
Click - "Buy (One Click)"
Purchase

Land on /home
Click "Browse"
View /categories
View /recent
Click Back
Drop OFF

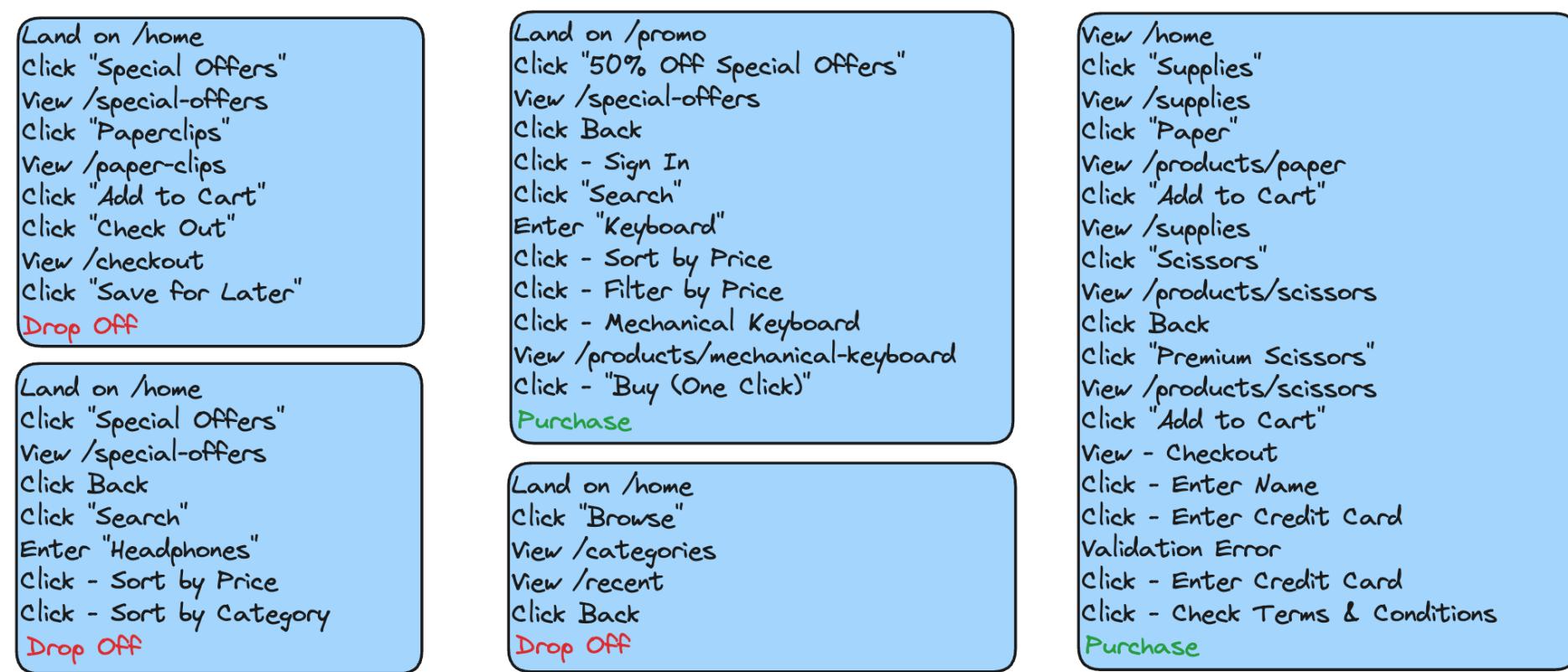
View /home
Click "Supplies"
View /supplies
Click "Paper"
View /products/paper
Click "Add to Cart"
View /supplies
Click "Scissors"
View /products/scissors
Click Back
Click "Premium Scissors"
View /products/scissors
Click "Add to Cart"
View - Checkout
Click - Enter Name
Click - Enter Credit Card
Validation Error
Click - Enter Credit Card
Click - Check Terms & Conditions
Purchase

The “bag of clicks” model



user_id	viewed_home	clicked_search	clicked_read_reviews	clicked_learn_more	...yada yada...	purchased
187180	0	1	1	0	...	1
662863	0	0	0	0	...	1
684172	1	1	1	0	0	0
261982	1	1	0	0	0	0
579325	1	1	1	1	1	0
829755	1	1	0	1	...	0
454574	1	1	0	0	0	0
216105	1	1	1	1	1	...
181215	0	1	0	0	0	0
996510	1	1	0	0	0	0
379967	1	1	0	0	0	0
511056	1	1	0	1	...	0
948165	1	1	1	0	0	0
575719	1	1	0	1	1	0
356383	1	1	1	0	0	0
582609	1	1	1	0	0	0
988781	1	0	0	1	1	0

The “bag of clicks” model



"Users viewed these pages and did these clicks..."

user_id	viewed_home	clicked_search	clicked_read_reviews	clicked_learn_more	...yada yada...	purchased
187180	0	1	1	0	...	1
662863	0	0	0	0	...	1
684172	1	1	1	0	0	0
261982	1	1	0	0	0	0
579325	1	1	1	1	1	0
829755	1	1	0	1	...	0
454574	1	1	0	0	0	0
216105	1	1	1	1	1	...
181215	0	1	0	0	0	0
996510	1	1	0	0	0	0
379967	1	1	0	0	0	0
511056	1	1	0	1	...	0
948165	1	1	1	0	0	0
575719	1	1	0	1	1	0
356383	1	1	1	0	0	0
582609	1	1	1	0	0	0
988781	1	0	0	1	1	0

"...which of those led to **purchases**?"

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187180	0	1	1	0	...	1
662863	0	0	0	0	...	1
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261982	1	1	0	0	...	0
579325	1	1	1	1	...	0
829755	1	1	0	1	...	0
454574	1	1	0	0	...	0
216105	1	1	1	1	...	1
181215	0	1	0	0	...	0
996510	1	1	0	0	...	0
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511056	1	1	0	1	...	0
948165	1	1	1	0	...	0
575719	1	1	0	1	...	0
356383	1	1	1	0	...	0
582609	1	1	1	0	...	0
988781	1	0	0	1	...	0
857058	1	1	0	0	...	0
498438	1	1	0	0	...	0
470140	1	0	1	0	...	0
714748	1	0	0	1	...	0
624947	1	1	1	1	...	0
524455	1	0	0	1	...	1

$$y_i = \beta_1 x_{i1} + \beta_2 x_{i2} + \cdots + \beta_p x_{ip} + \varepsilon_i$$

user_id	viewed_home	clicked_search	clicked_read_reviews	clicked_learn_more	...yada yada...	purchased
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216105	1	1		1	1 ...	1
181215	0	1		0	0 ...	0
996510	1	1		0	0 ...	0
379967	1	1		0	0 ...	0
511056	1	1		0	1 ...	0
948165	1	1		1	0 ...	0
575719	1	1		0	1 ...	0
356383	1	1		1	0 ...	0
582609	1	1		1	0 ...	0
988781	1	0		0	1 ...	0
857058	1	1		0	0 ...	0
498438	1	1		0	0 ...	0
470140	1	0		1	0 ...	0
714748	1	0		0	1 ...	0
624947	1	1		1	1 ...	0
524455	1	0		0	1 ...	1

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● ● ●

Checkout

I agree to Terms & Conditions

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$$y_i = \beta_1 x_{i1} + \beta_2 x_{i2} + \cdots + \beta_p x_{ip} + \varepsilon_i$$



Checkout

Name

Address

Credit Card
Apple Pay
Paypal

I agree to Terms & Conditions

Purchase

This click has a 100% correlation with purchasing!
 

user_id	viewed_home	clicked_search	clicked_read_reviews	clicked_learn_more	...yada yada...	purchased
187180	0	1		1	0 ...	1
662863	0	0		0	0 ...	1
684172	1	1		1	0 ...	0
261982	1	1		0	0 ...	0
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829755	1	1		0	1 ...	0
454574	1	1		0	0 ...	0
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181215	0	1		0	0 ...	0
996510	1	1		0	0 ...	0
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511056	1	1		0	1 ...	0
948165	1	1		1	0 ...	0
575719	1	1		0	1 ...	0
356383	1	1		1	0 ...	0
582609	1	1		1	0 ...	0
988781	1	0		0	1 ...	0
857058	1	1		0	0 ...	0
498438	1	1		0	0 ...	0
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● ● ●

Checkout

Credit Card
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I agree to Terms & Conditions

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575719	1	1		0	1 ...	0
356383	1	1		1	0 ...	0
582609	1	1		1	0 ...	0
988781	1	0		0	1 ...	0
857058	1	1		0	0 ...	0
498438	1	1		0	0 ...	0
470140	1	0		1	0 ...	0
714748	1	0		0	1 ...	0
624947	1	1		1	1 ...	0
524455	1	0		0	1 ...	1

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Checkout

Name

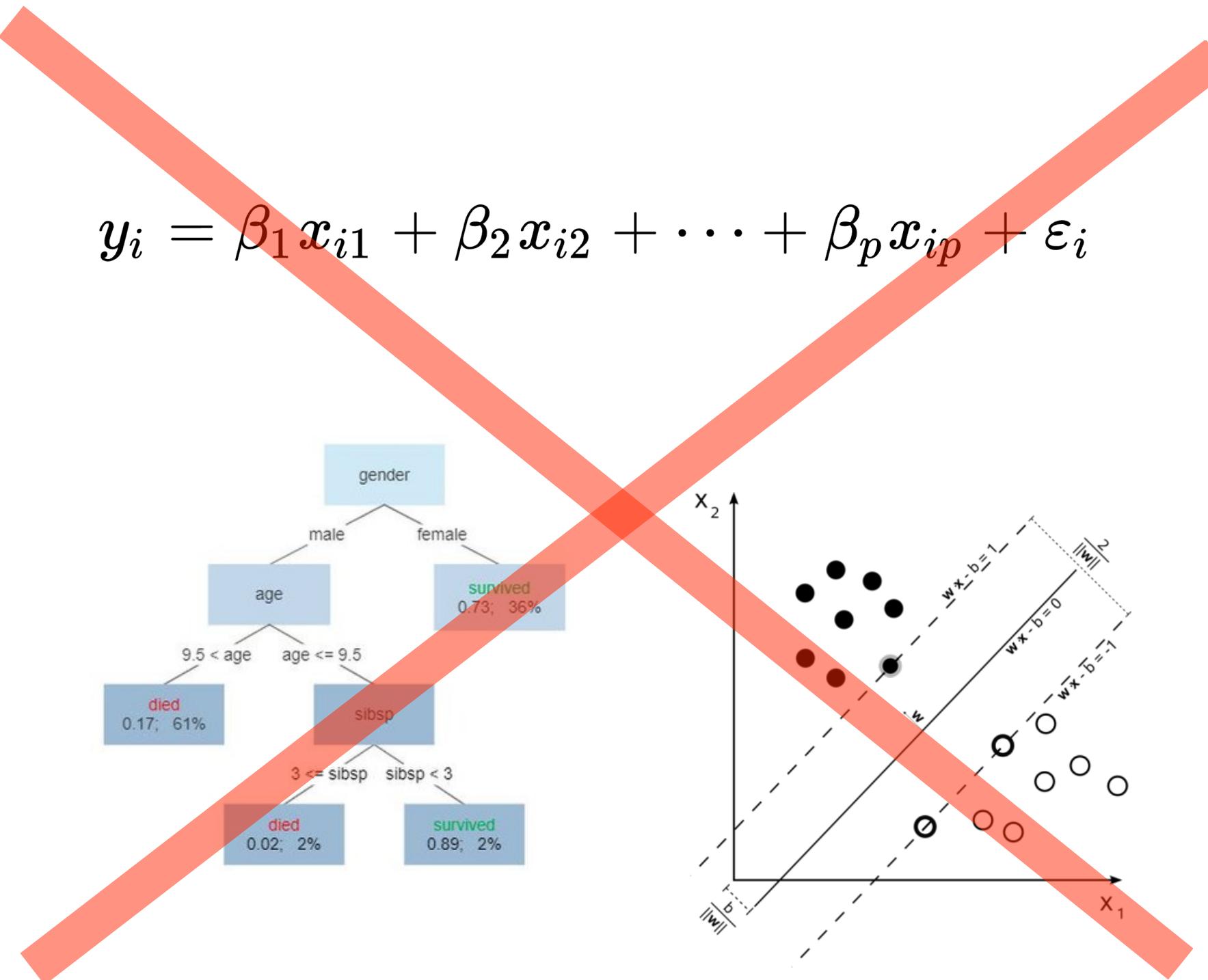
Address

Credit Card | Apple Pay | Paypal

This click has a 99% correlation with purchasing! → I agree to Terms & Conditions

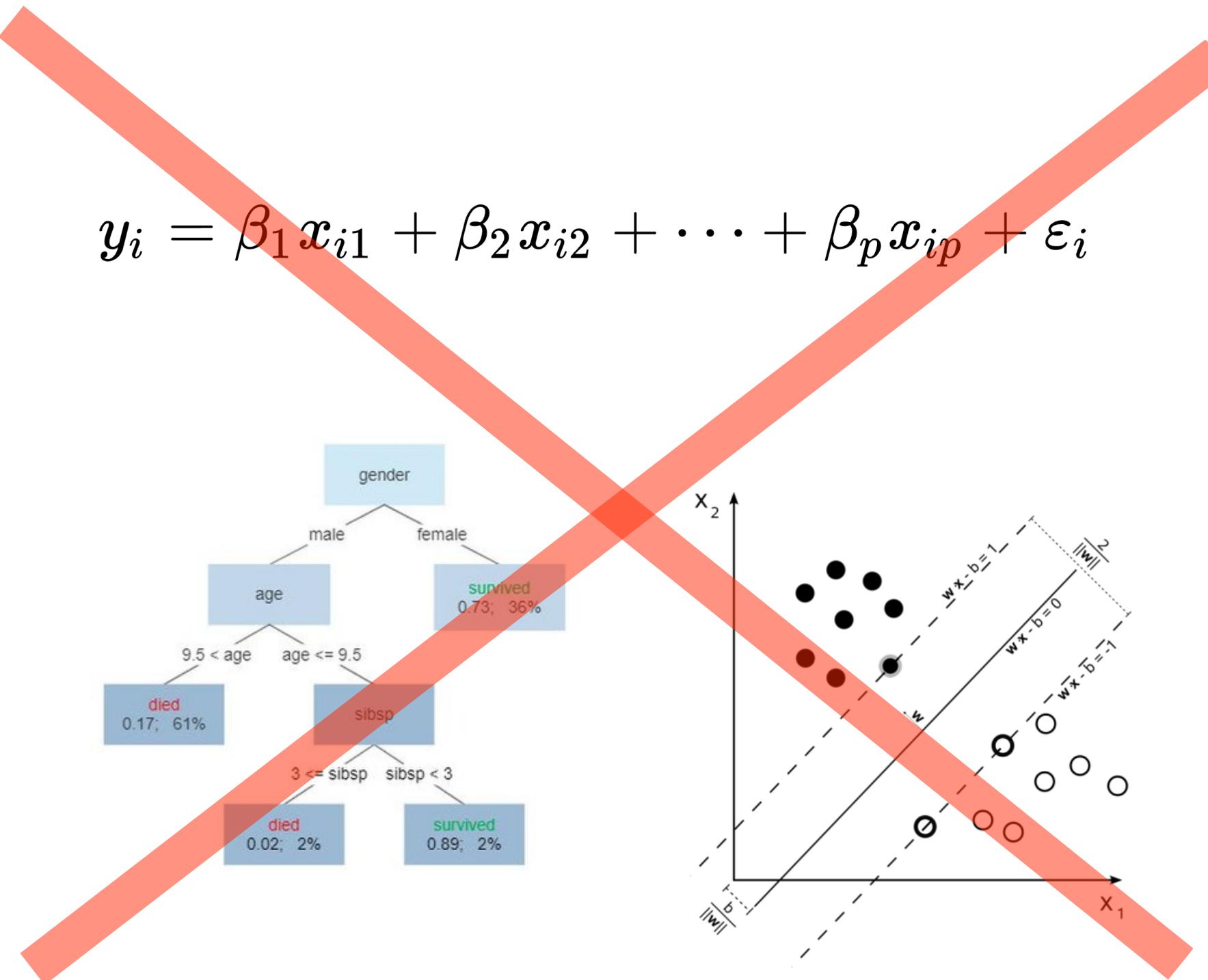
Purchase

The most important problems facing product builders
aren't predictive, they're **causal**

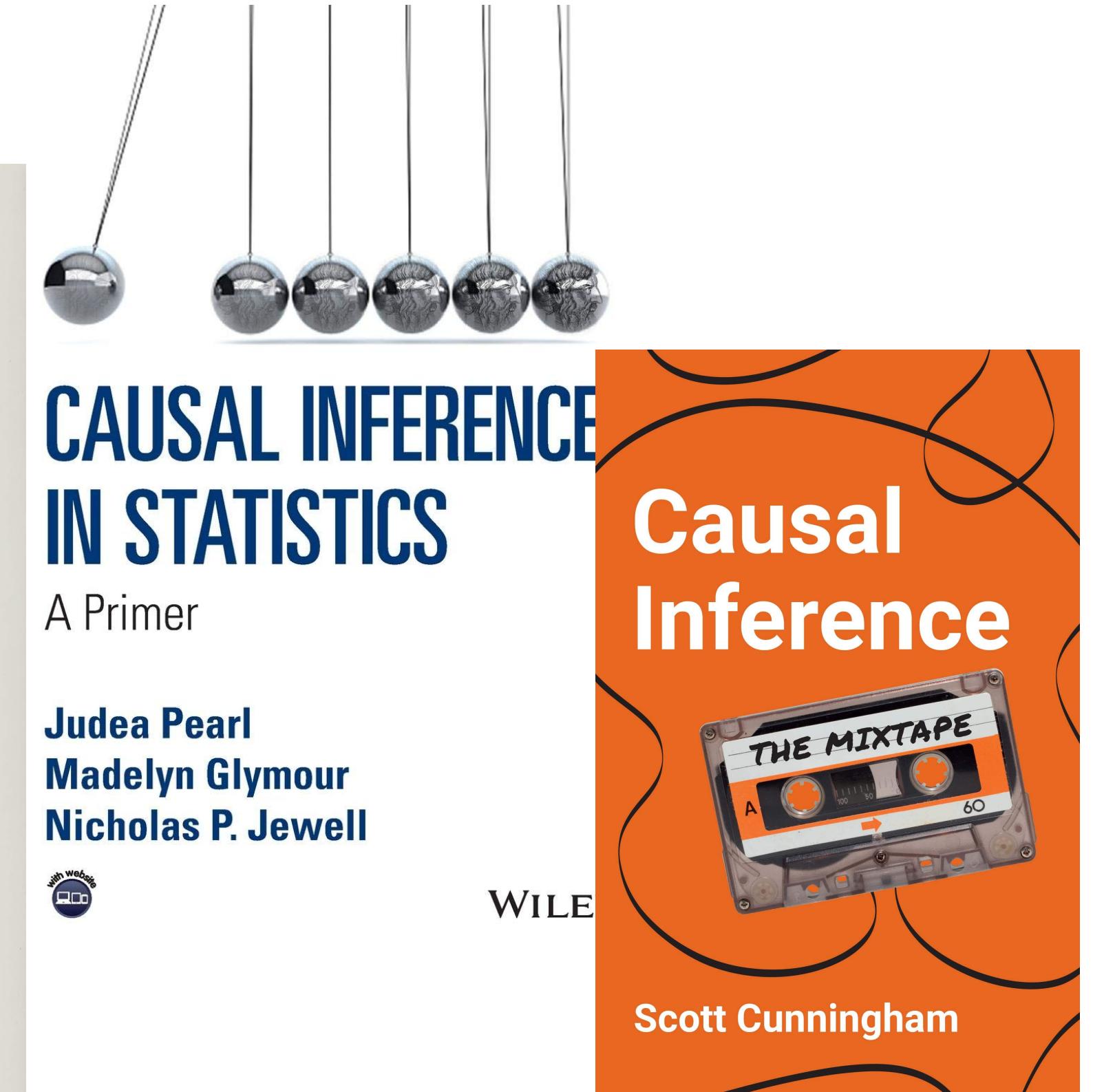
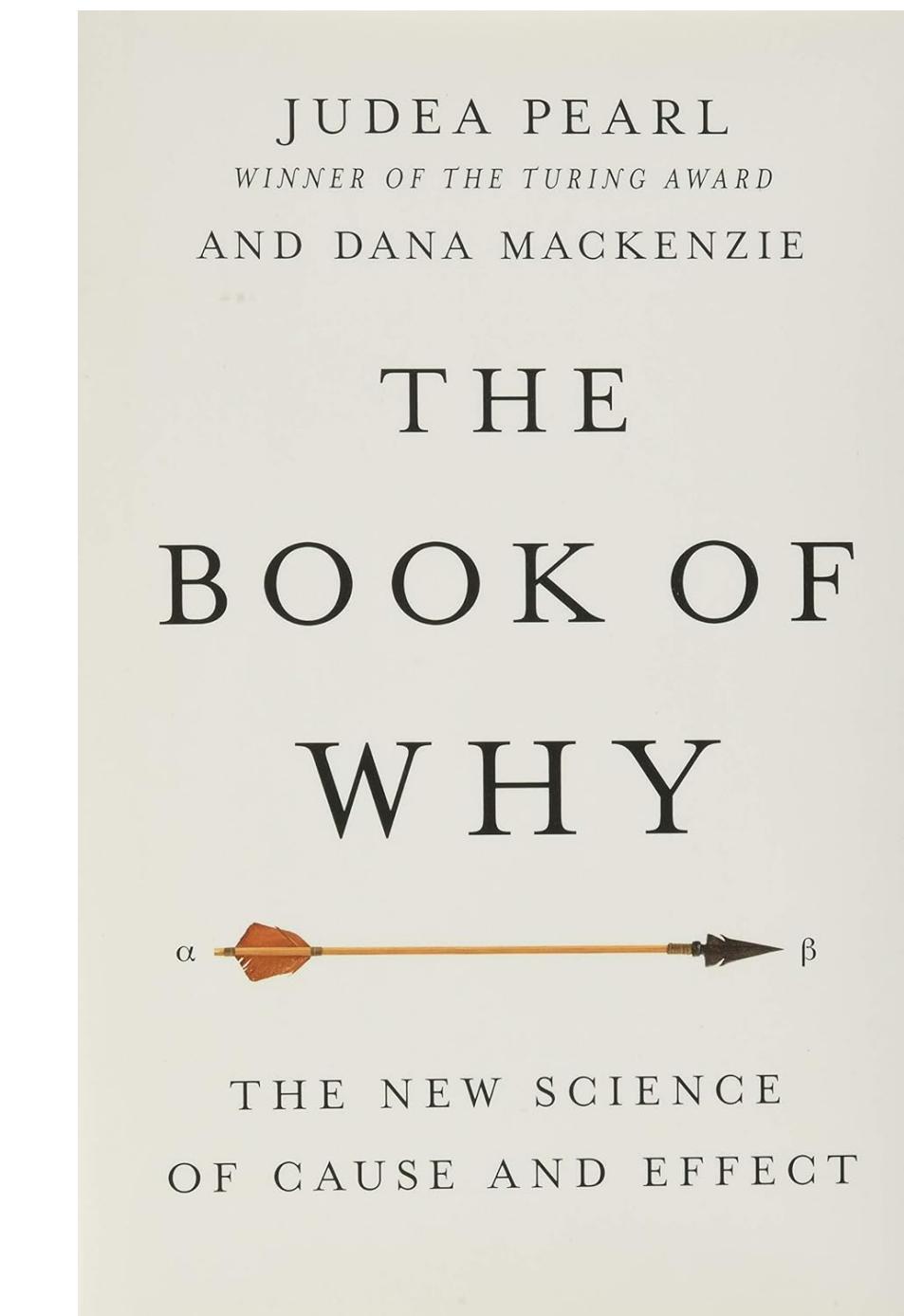


Prediction

The most important problems facing product builders
aren't predictive, they're **causal**



Prediction



Intervention

Maybe it *is* actually true that making the purchase button bigger would improve the conversion rate. How can we determine that?

Maybe it *is* actually true that making the purchase button bigger would improve the conversion rate. How can we determine that?

A/B Test!

Name

Address

Credit Card	Apple Pay	Paypal
-------------	-----------	--------

I agree to Terms & Conditions

Purchase

Control

Name

Address

Credit Card	Apple Pay	Paypal
-------------	-----------	--------

I agree to Terms & Conditions

Purchase

Experiment

A/B tests are the gold standard for determining the impact of an intervention

Name

Address

Credit Card Apple Pay Paypal

I agree to Terms & Conditions

Purchase

Control

Name

Address

Credit Card Apple Pay Paypal

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Purchase

Experiment

A/B tests are the gold standard for determining the impact of an intervention

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Experiment

- It's no surprise it works: they're randomized controlled trials (RCTs), which scientists have studied for a century!

A/B tests are the gold standard for determining the impact of an intervention

Name

Address

Credit Card Apple Pay Paypal

I agree to Terms & Conditions

Purchase

Control

Name

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Experiment

- It's no surprise it works: they're randomized controlled trials (RCTs), which scientists have studied for a century!
- But...

A/B tests are the gold standard for determining the impact of an intervention

Name

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- It's no surprise it works: they're randomized controlled trials (RCTs), which scientists have studied for a century!
- But...
 - they are **not** the only way to reason about causal effects

A/B tests are the gold standard for determining the impact of an intervention

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Purchase

Control

Name

Address

Credit Card Apple Pay Paypal

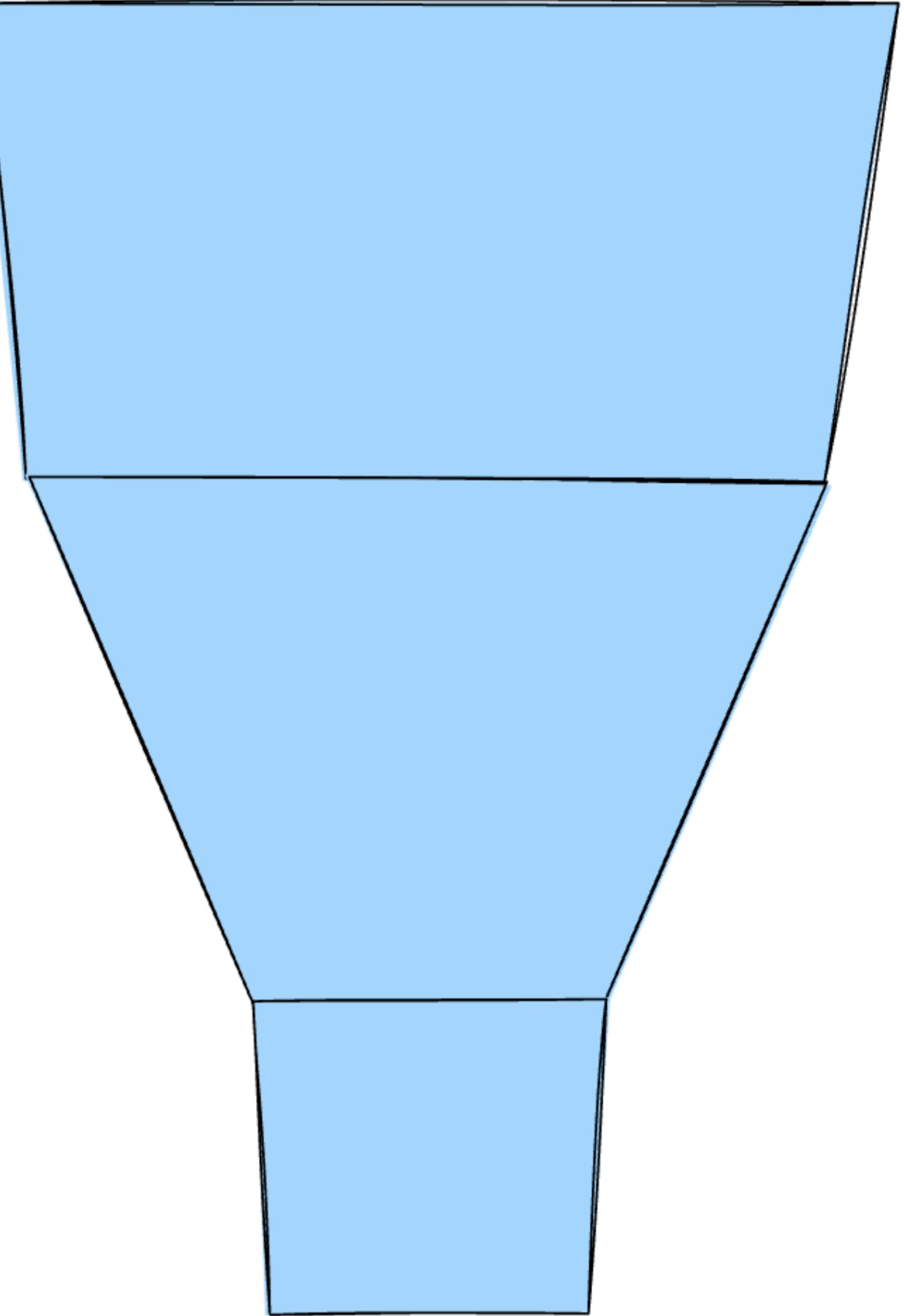
I agree to Terms & Conditions

Purchase

Experiment

- It's no surprise it works: they're randomized controlled trials (RCTs), which scientists have studied for a century!
- But...
 - they are **not** the only way to reason about causal effects
 - it does **not** mean that all observational data is useless

Funnels



Name

Address

Credit Card

Apple Pay

Paypal



I agree to Terms & Conditions

Purchase



Name

Address

Credit Card

Apple Pay

Paypal

I agree to Terms & Conditions

Purchase

1000 users
start the form

Name

Address

Credit Card

Apple Pay

Paypal

600 users
check the box

I agree to Terms & Conditions

594 users
purchase

Purchase

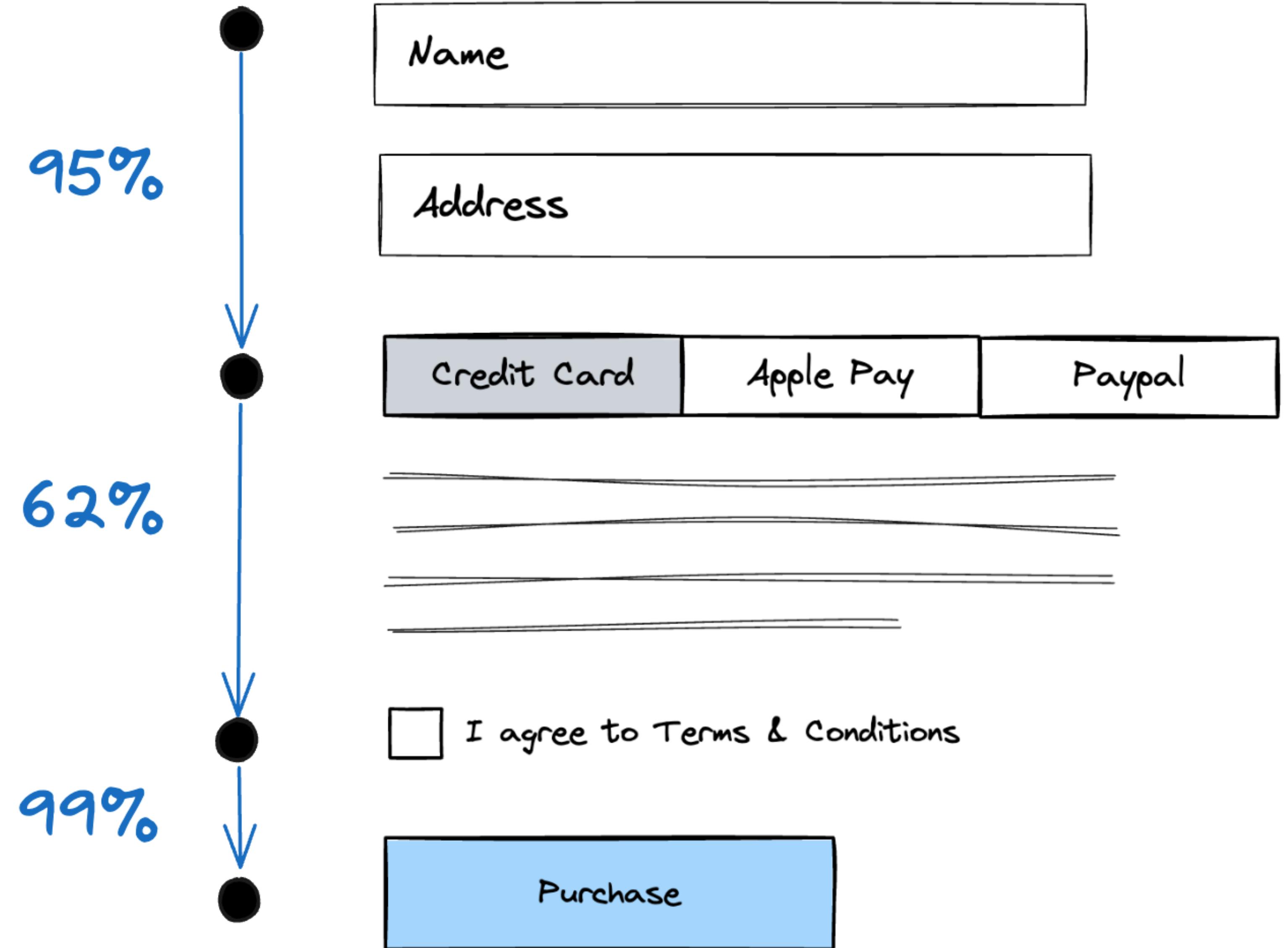
Name

Address

Credit Card Apple Pay Paypal

I agree to Terms & Conditions

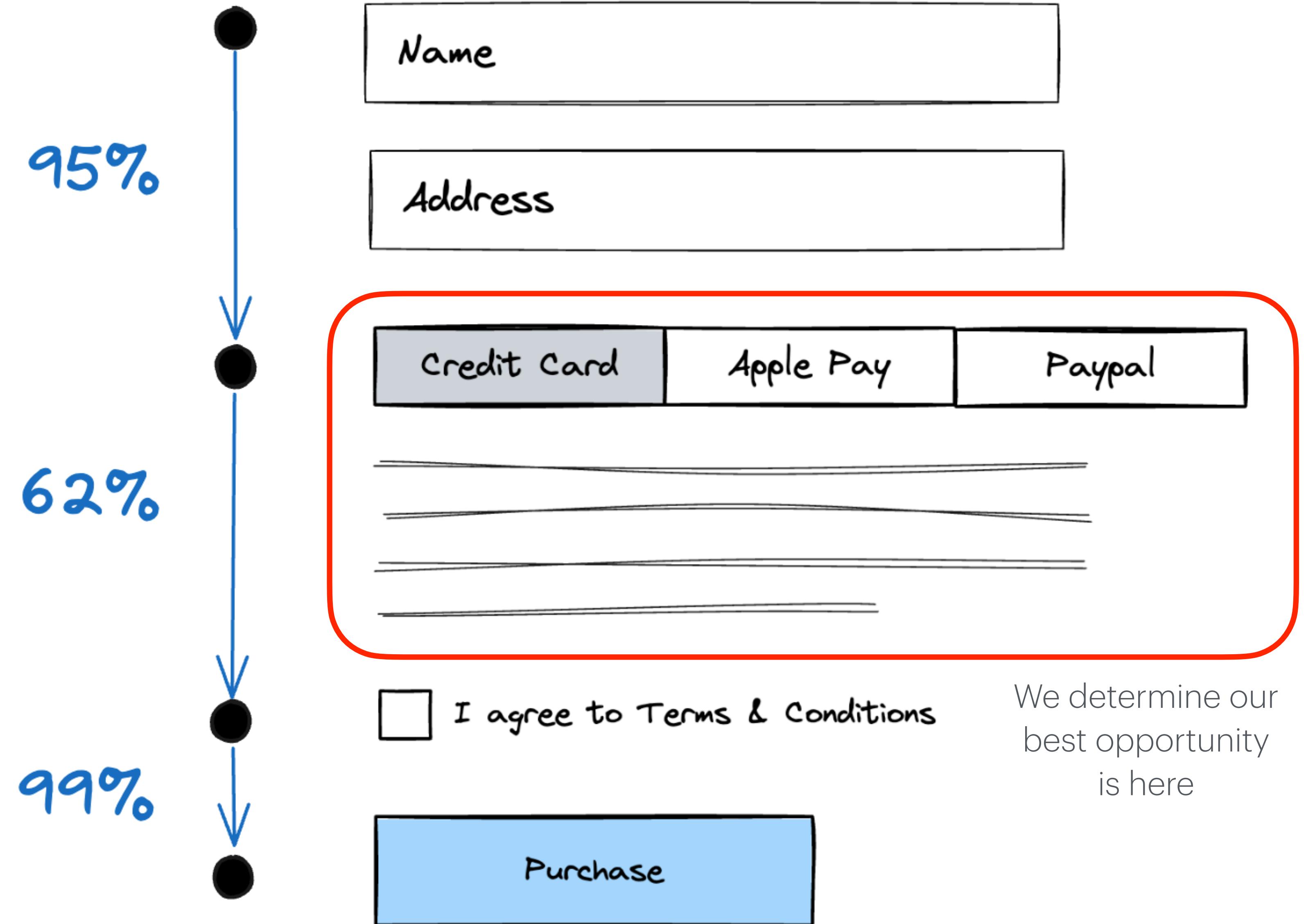
Purchase

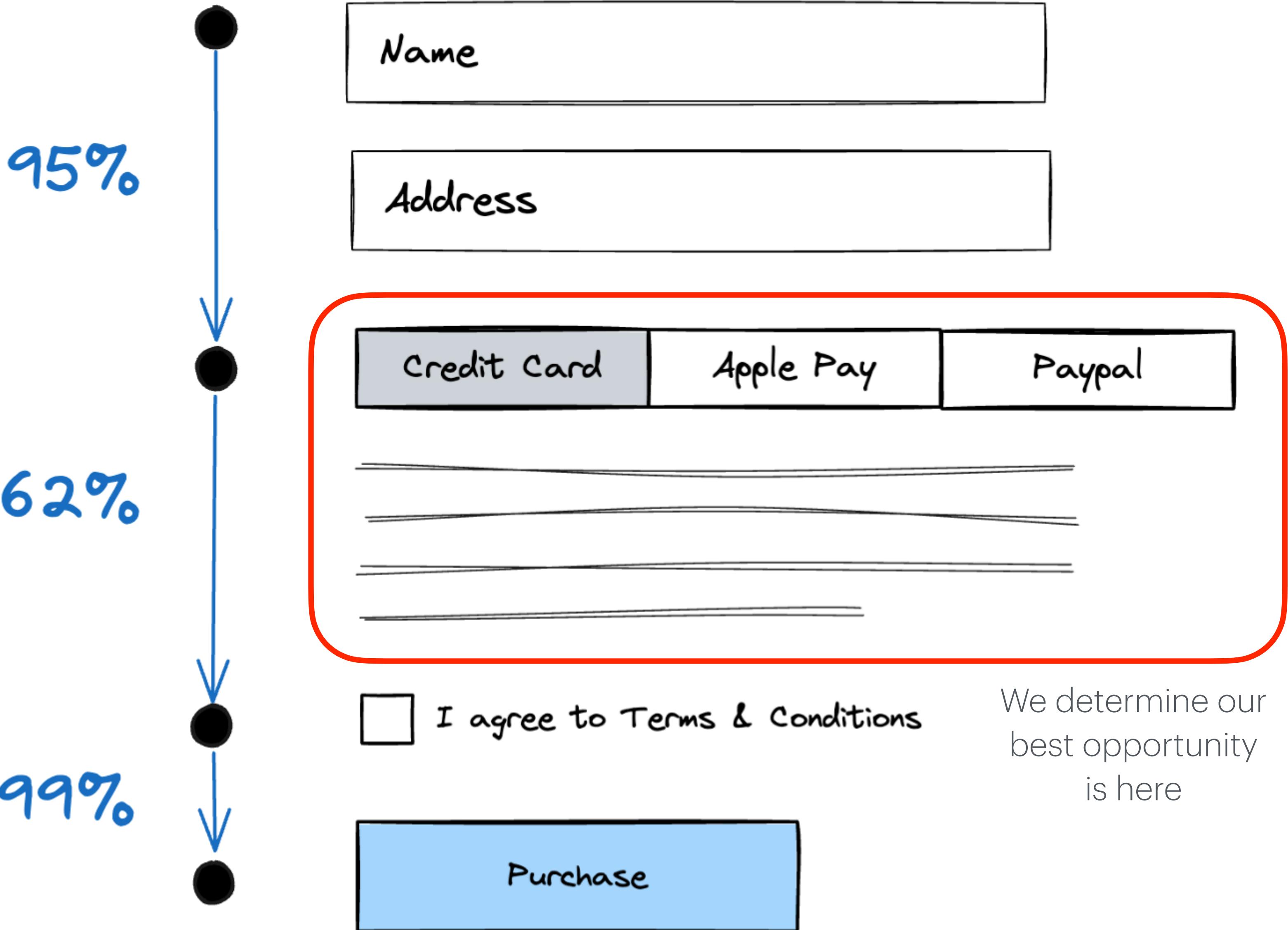
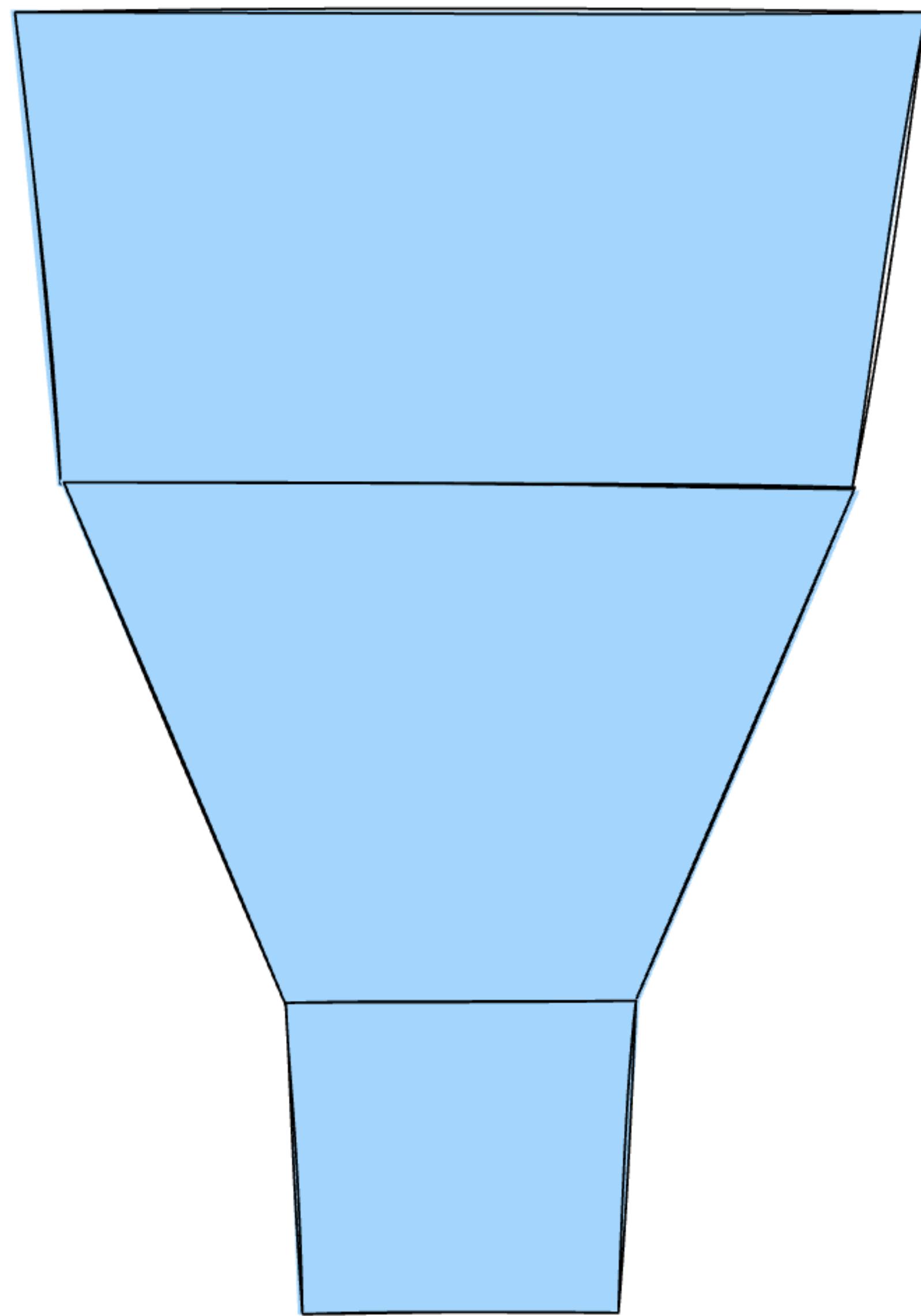


95%

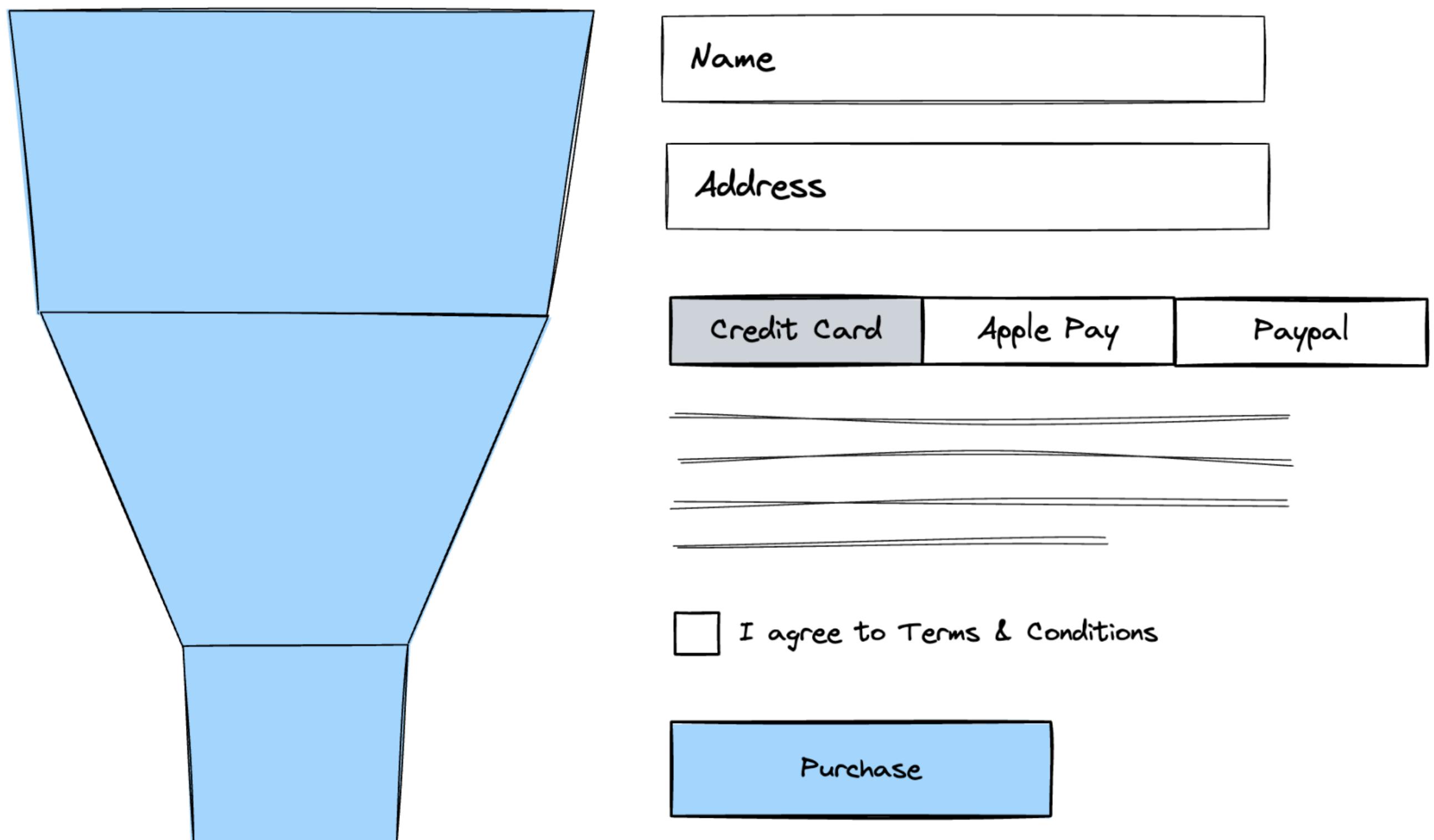
62%

99%



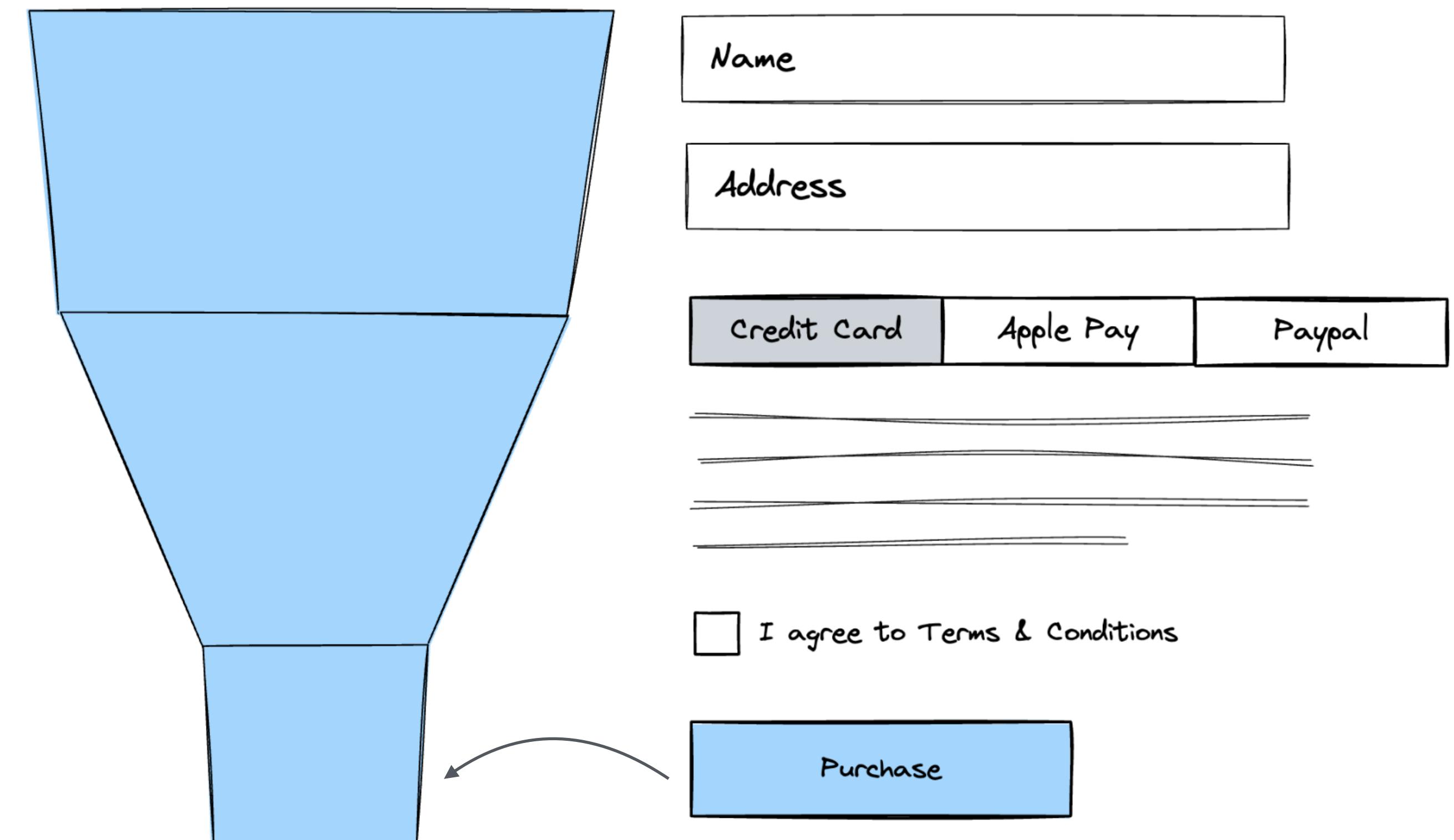


Why are we able to do causal reasoning with funnels?



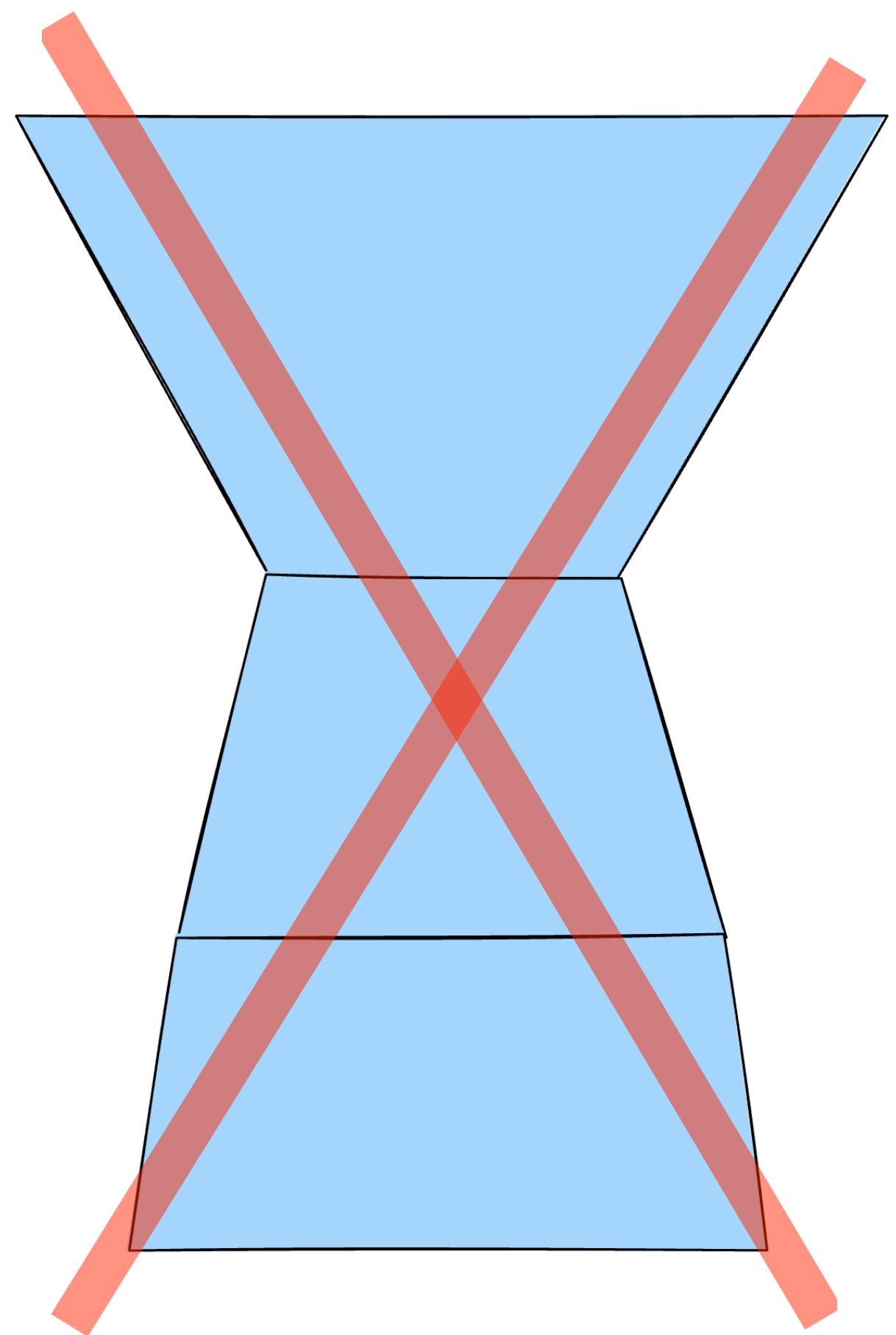
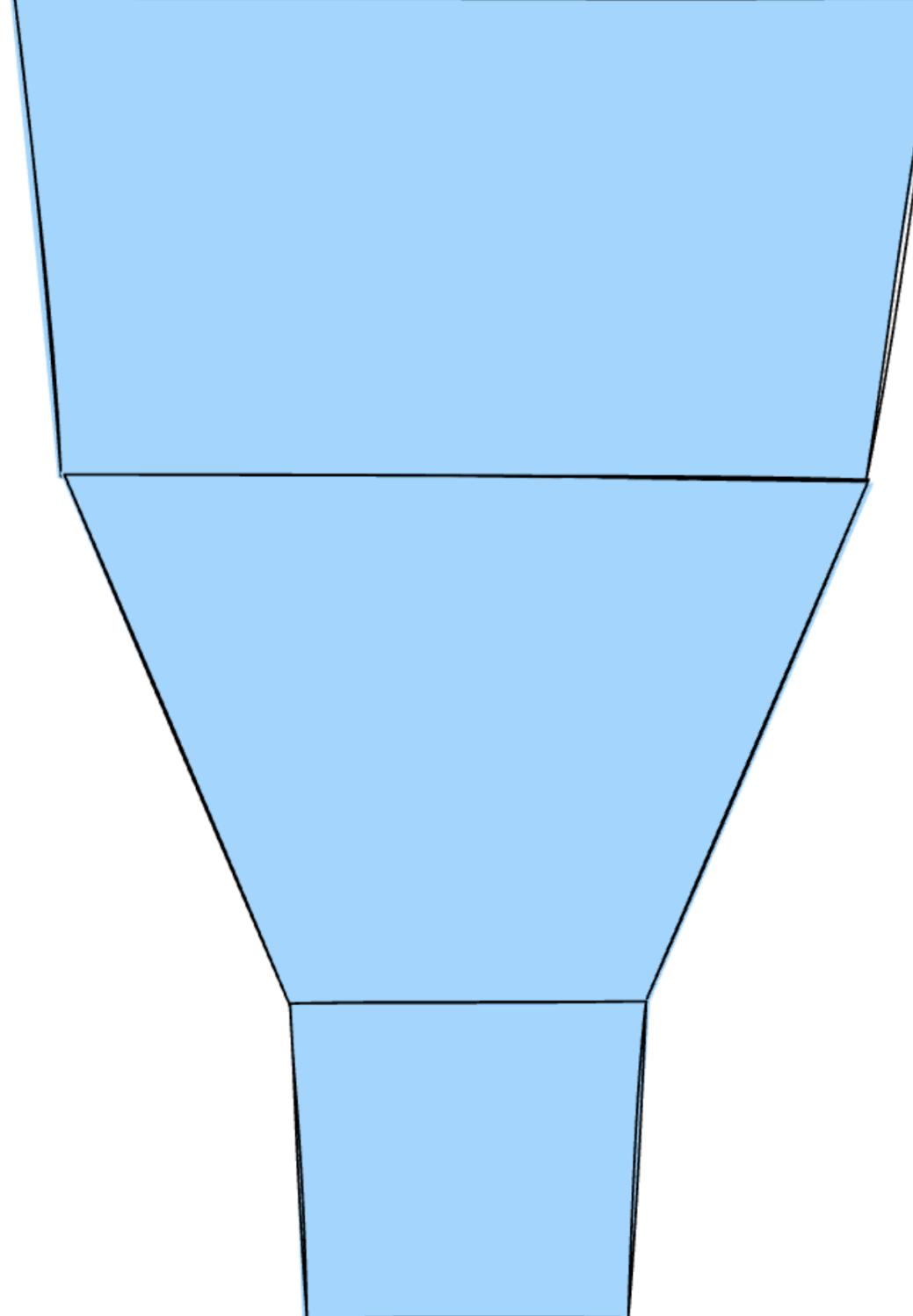
Why are we able to do causal reasoning with funnels?

- **Locality:** We assume modifications to one part of a flow affect only that step in the funnel

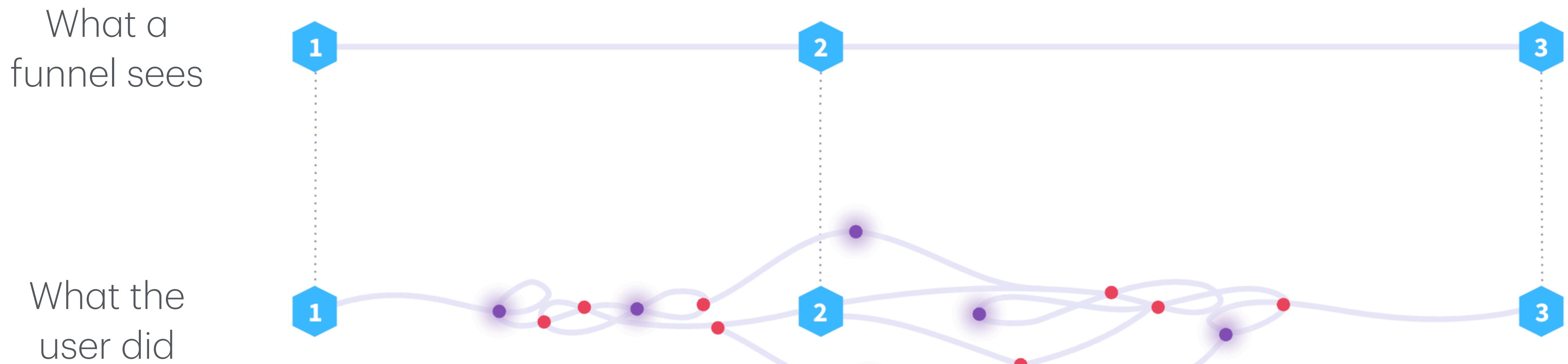


Why are we able to do causal reasoning with funnels?

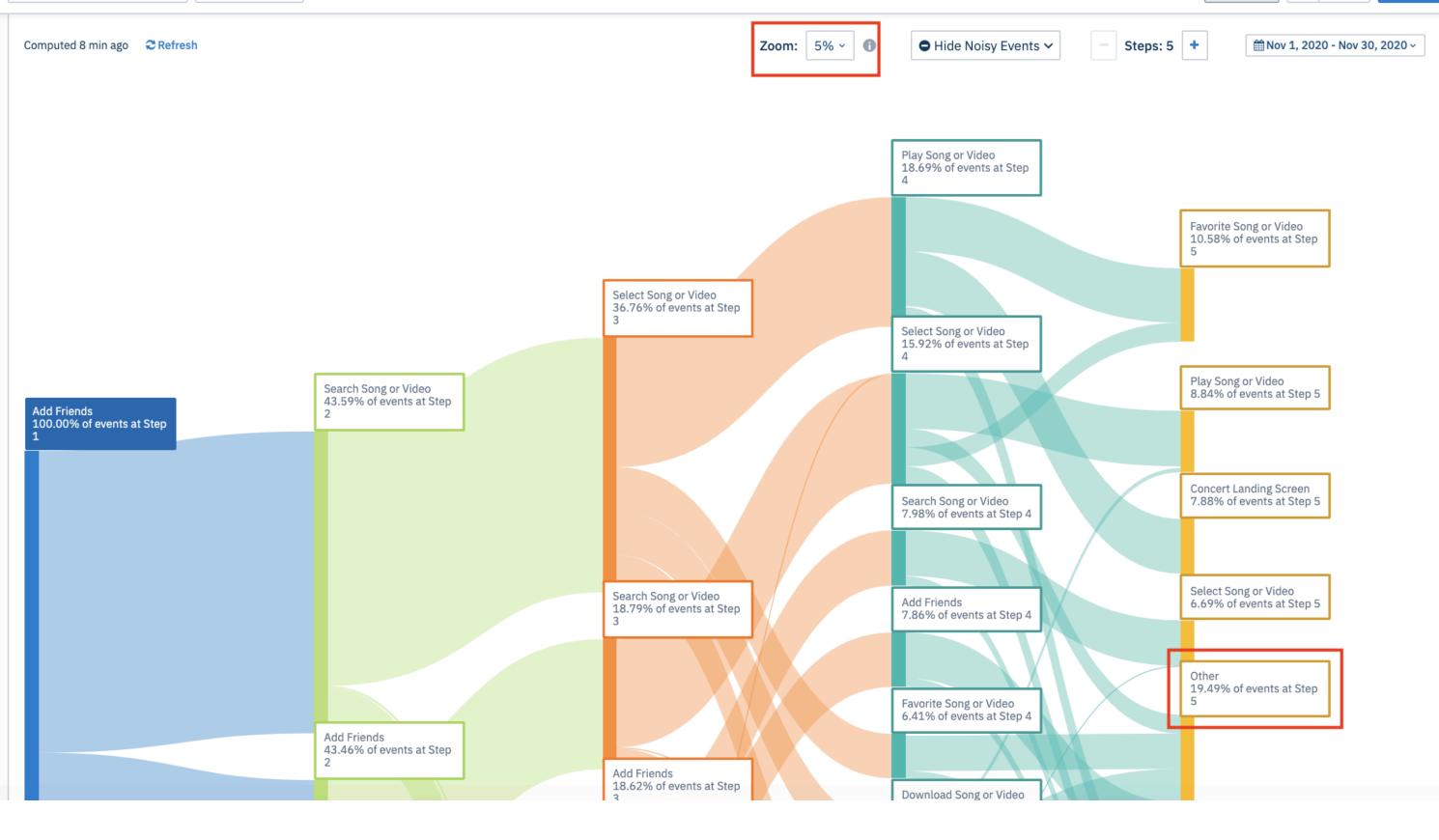
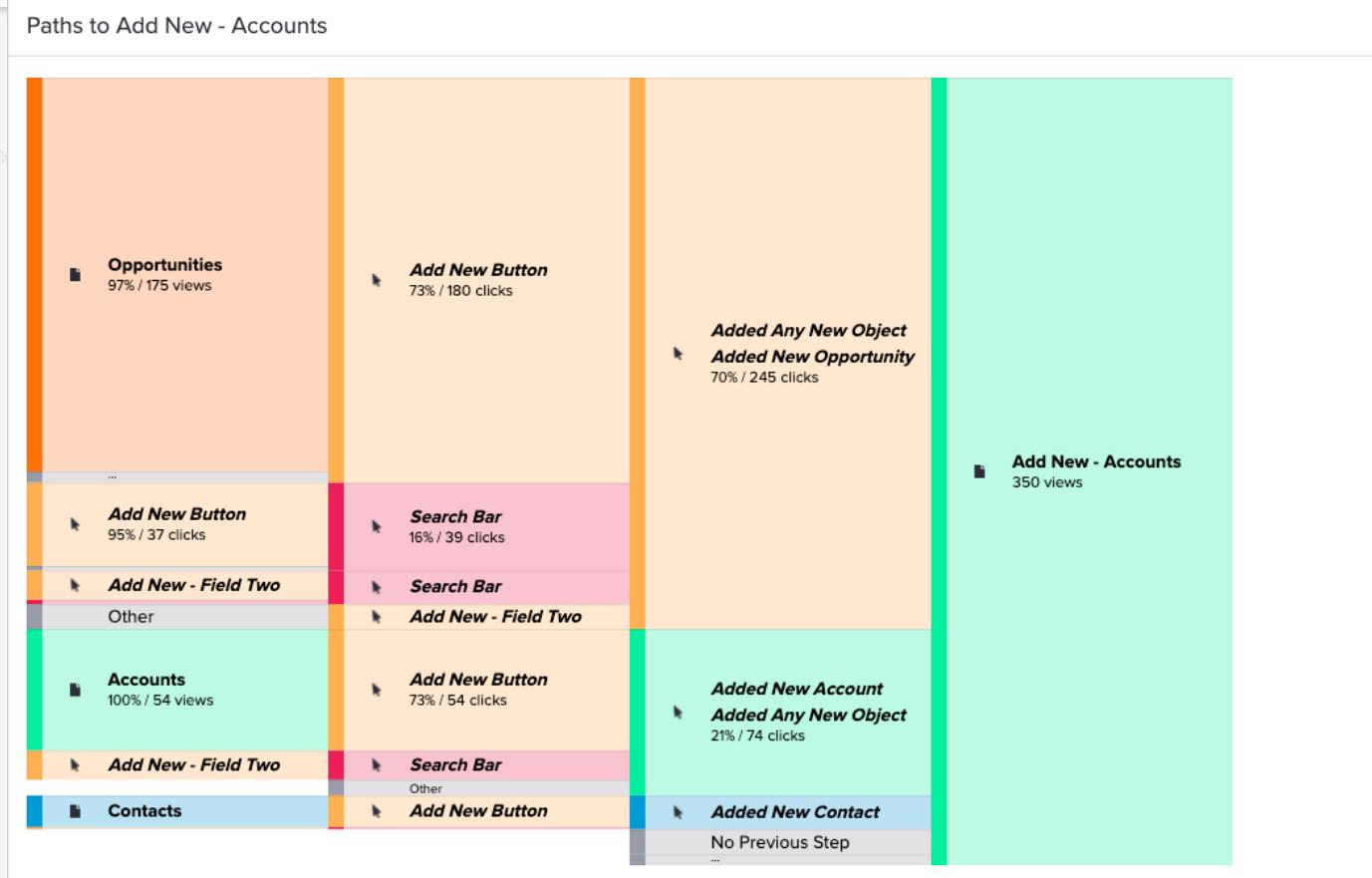
- **Locality:** We expect modifications to one part of a flow to affect only that step in the funnel
- **Chronology:** Users are measured as they progress forward in the funnel; not if they skip steps



The weakness of a funnel is that it's **linear**



Previous tools for measuring nonlinear sequences count consecutive actions

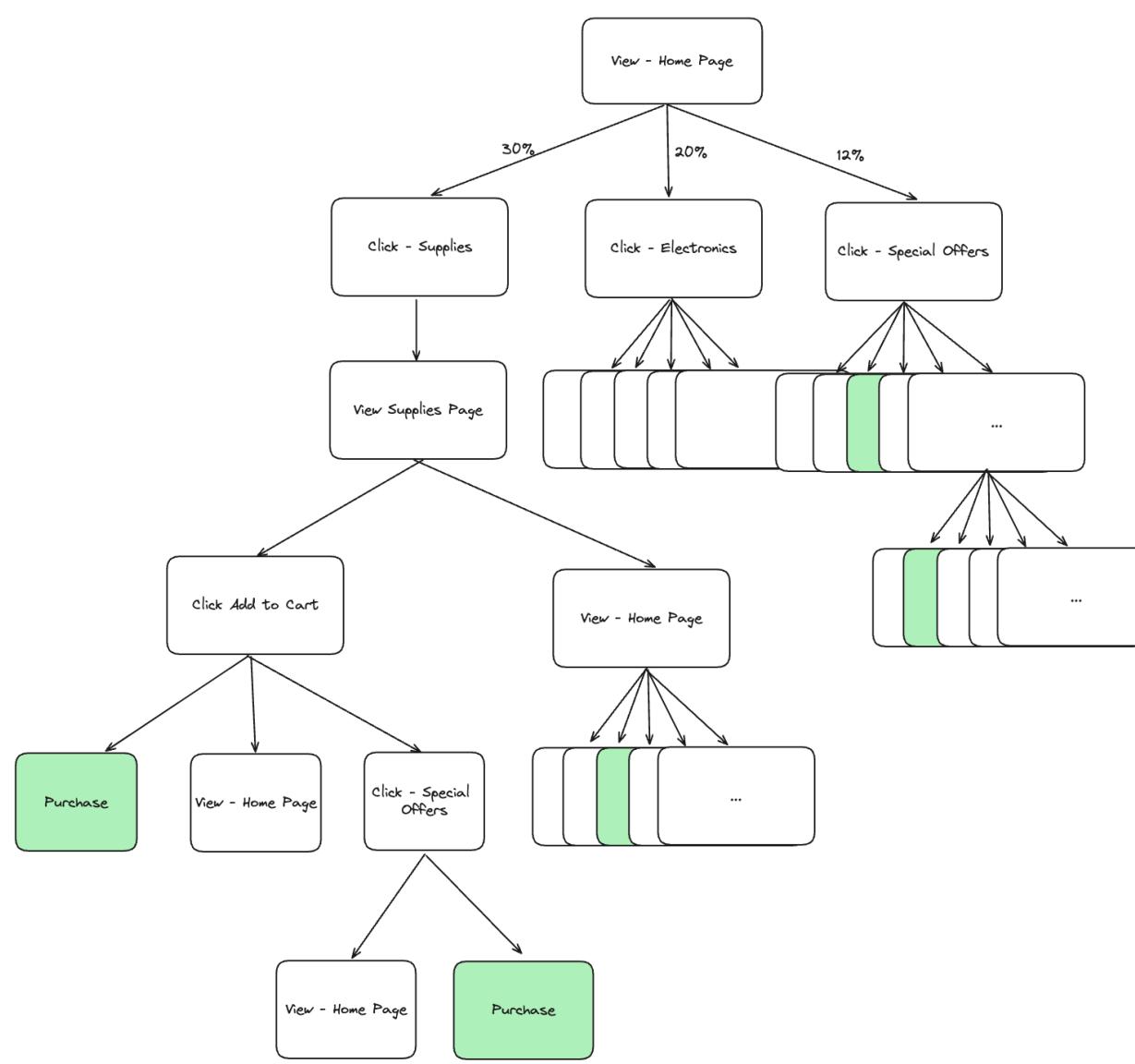


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Click "Search"
Enter "Keyboard"
View /checkout
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Drop OFF

Land on /home
click "Special Offers"
View /special-offers
click Back
Click "Search"
Enter "Headphones"
Click - Sort by Price
View /recent
Click - Sort by Category
Drop OFF

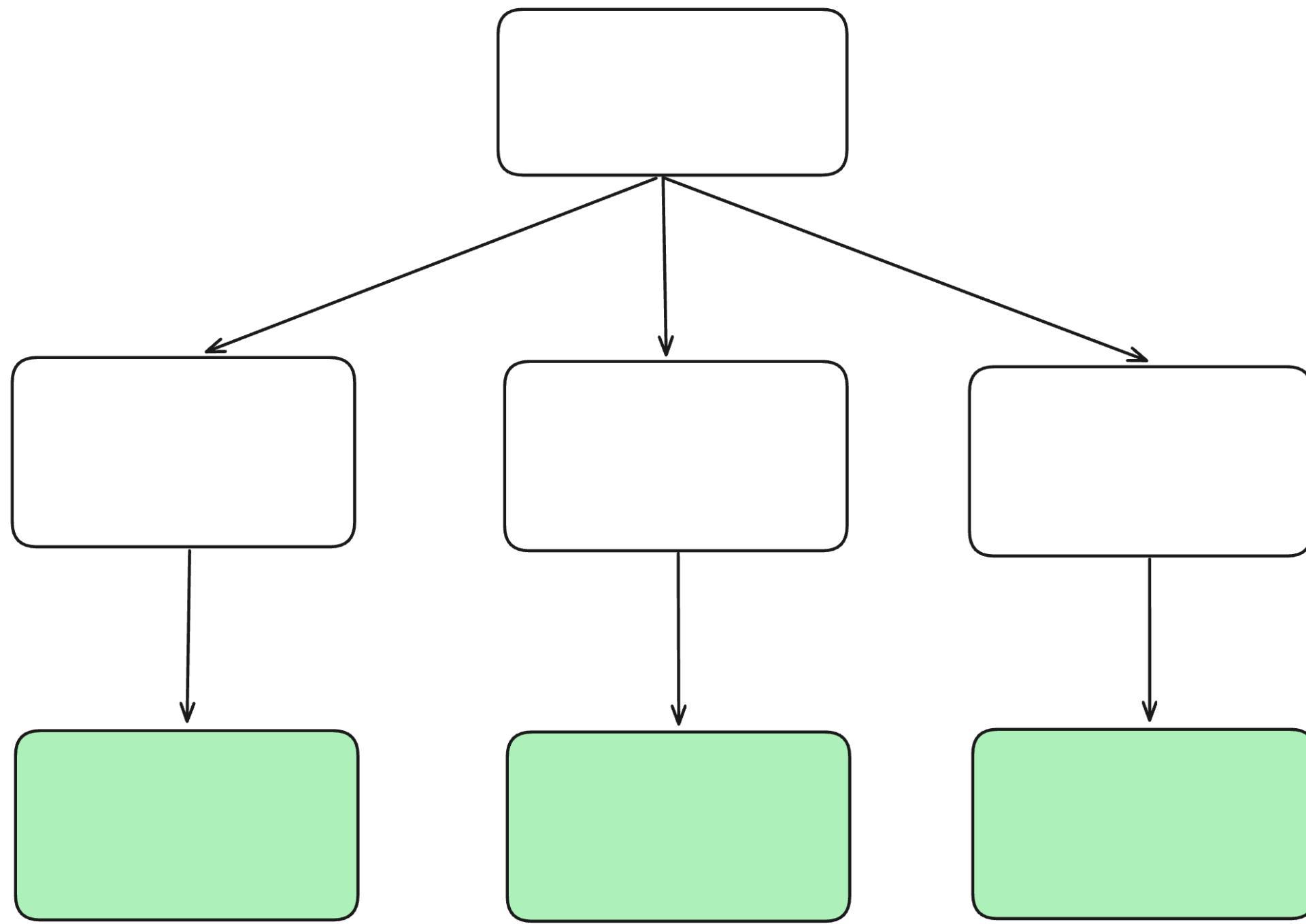
Land on /promo
click "50% OFF Special Offers"
View /special-offers
Click Back
Click "Sign In"
Click "Search"
Enter "Keyboard"
View /supplies
Click "Add to Cart"
View /products/paper
Click "Scissors"
View /products/scissors
Click Back
Click "Premium Scissors"
View /products/scissors
Click "Add to Cart"
View - Checkout
Click - Enter Name
Click - Enter Credit Card
Validation Error
Click - Enter Credit Card
Click - Check Terms & Conditions
Purchase

Land on /home
Click "Supplies"
View /supplies
Click "Paper"
View /products/paper
Click "Scissors"
View /products/scissors
Click Back
Click "Premium Scissors"
View /products/scissors
Click "Add to Cart"
View - Checkout
Click - Enter Name
Click - Enter Credit Card
Validation Error
Click - Enter Credit Card
Click - Check Terms & Conditions
Purchase



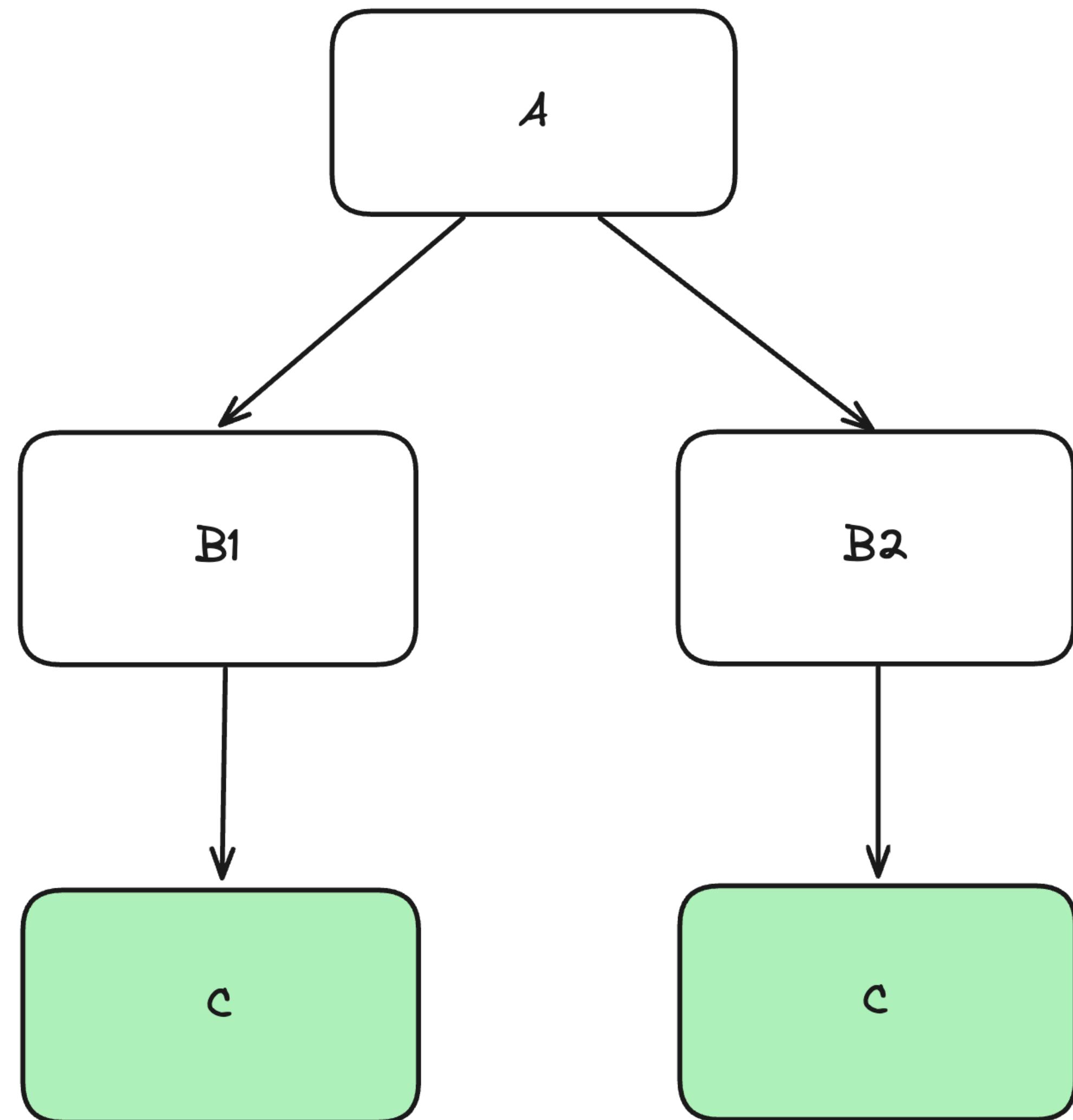
This leads to an explosion in state space: very difficult to draw conclusions

Journeygrams



Journeygrams are a calculus that uses a directed rooted tree to quantify sequences of events

We **specify** the tree based on the causal hypotheses we're considering



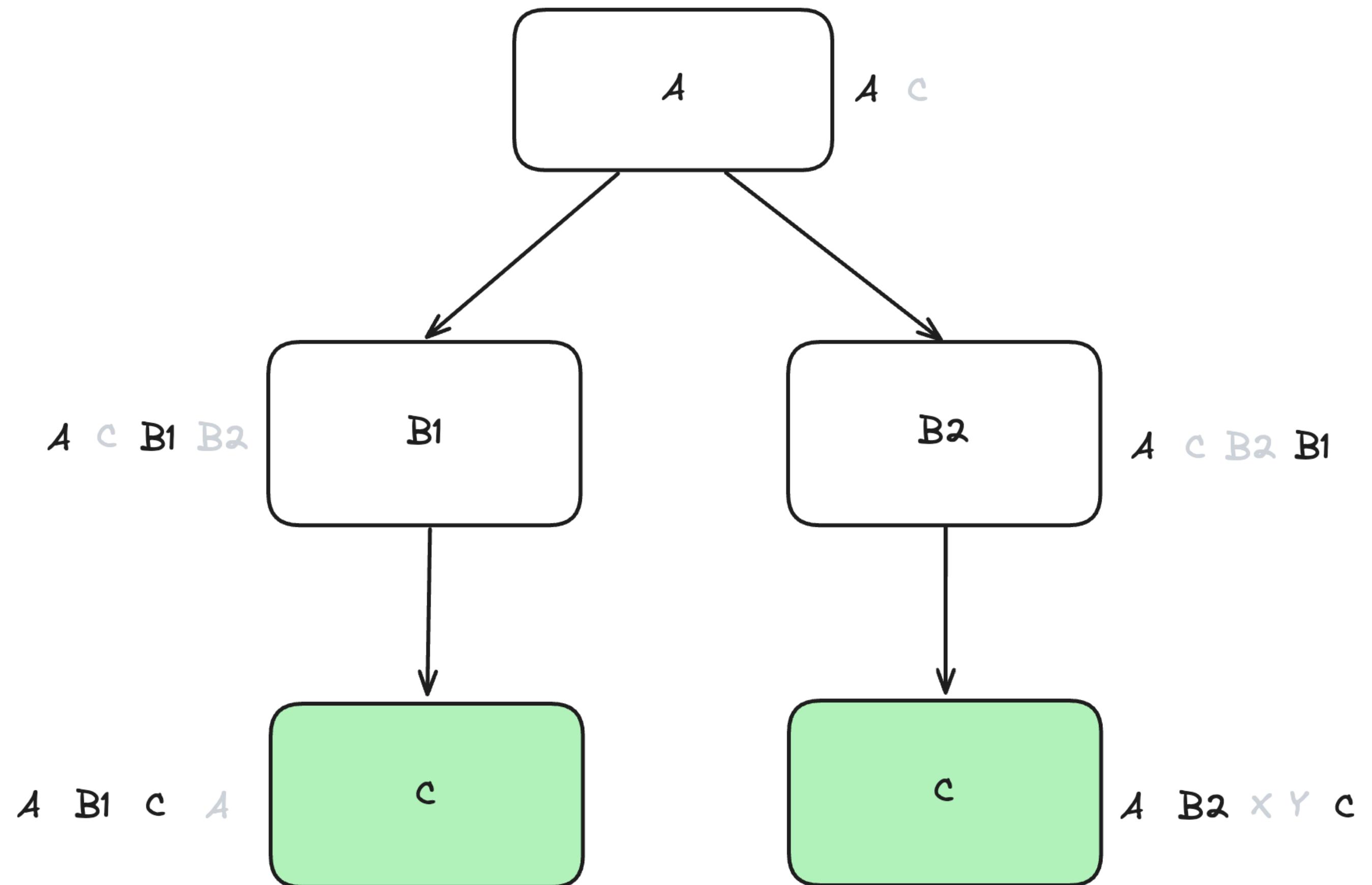
How Journeygrams Work

Sequences **walk** the tree, transitioning to the next step when they see an event

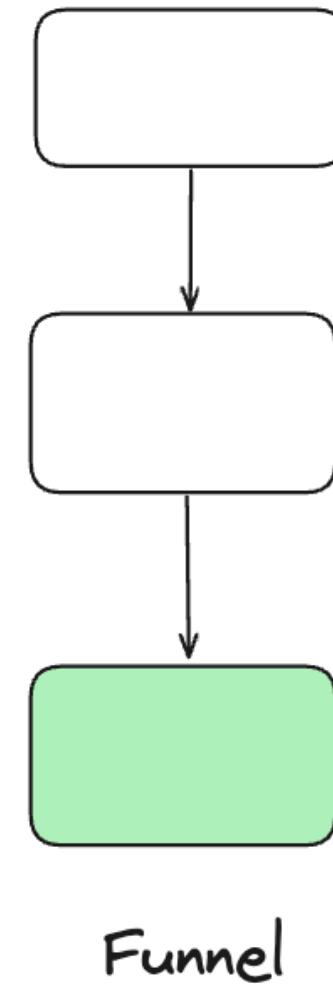
When there's a fork, it follows the one that happens **first**

They **can't skip** steps

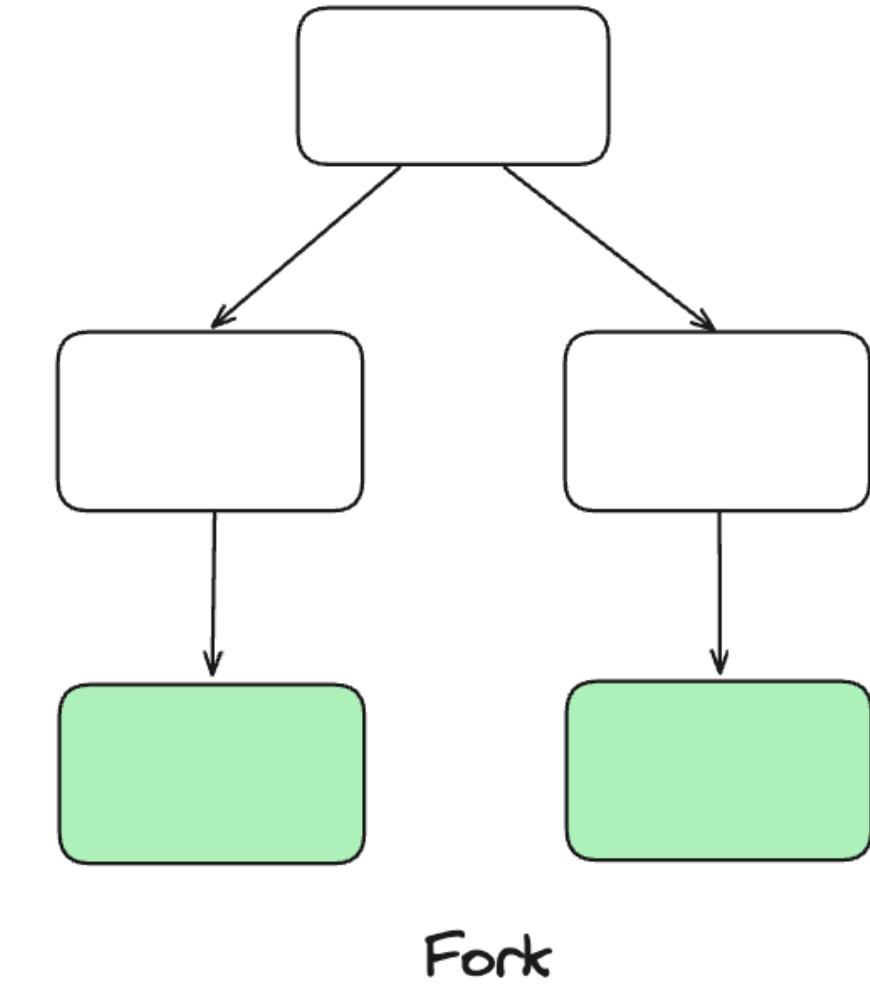
It **ignores** events other than the ones it is waiting for



Funnels are a **special case** of
journeygram

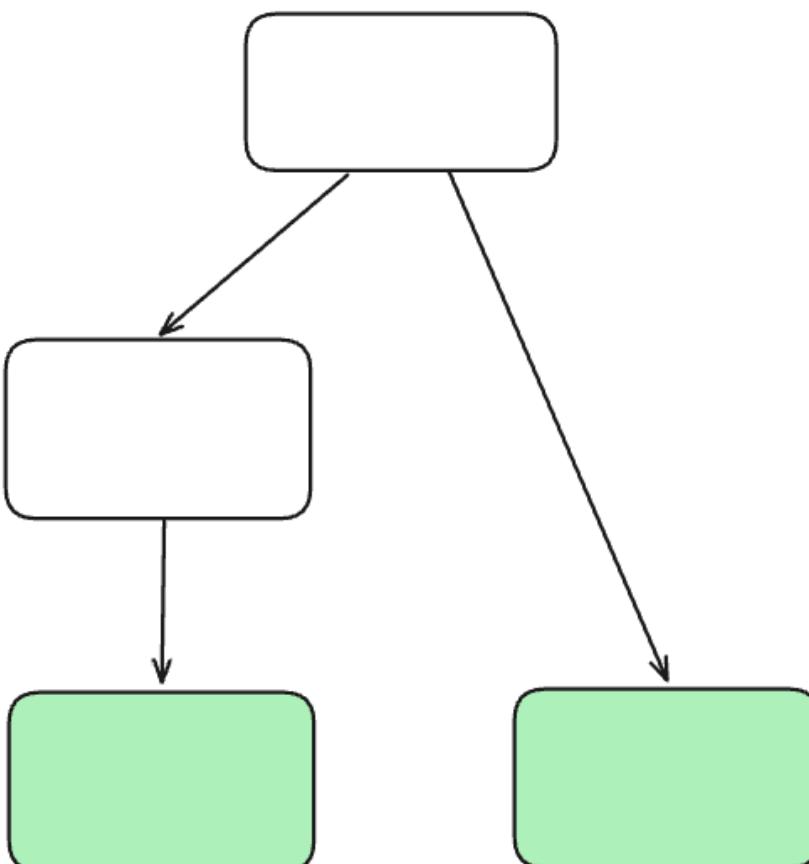


Funnel

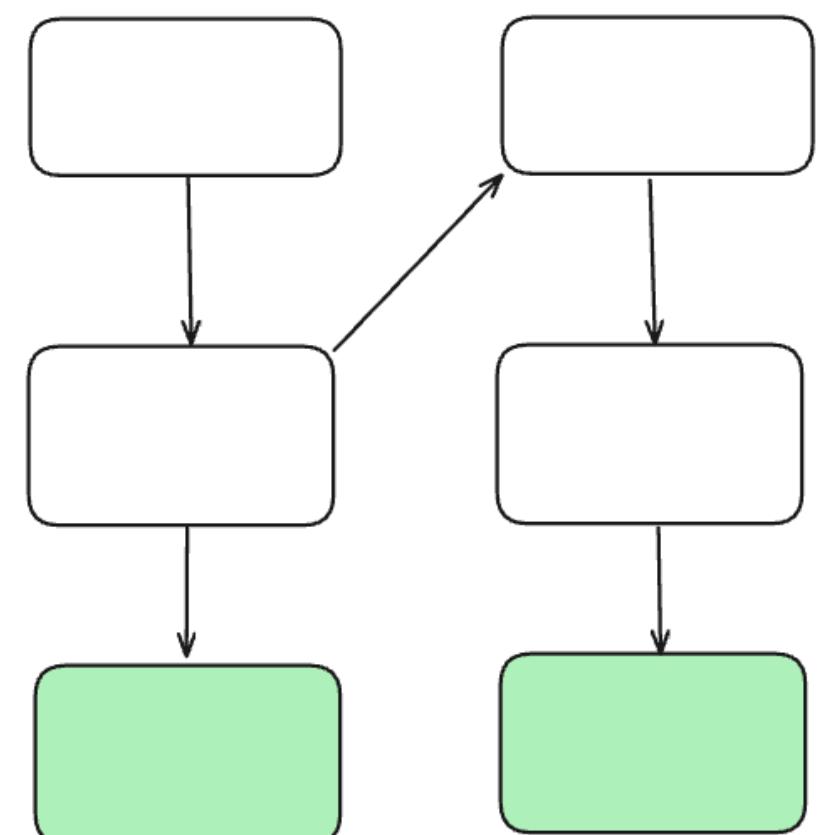


Fork

Other shapes let us extend the kinds of causal conclusions we intuitively draw from funnels



Skippable Steps



Backtracking

If clicks happen at the same point in a journey, we can compare them

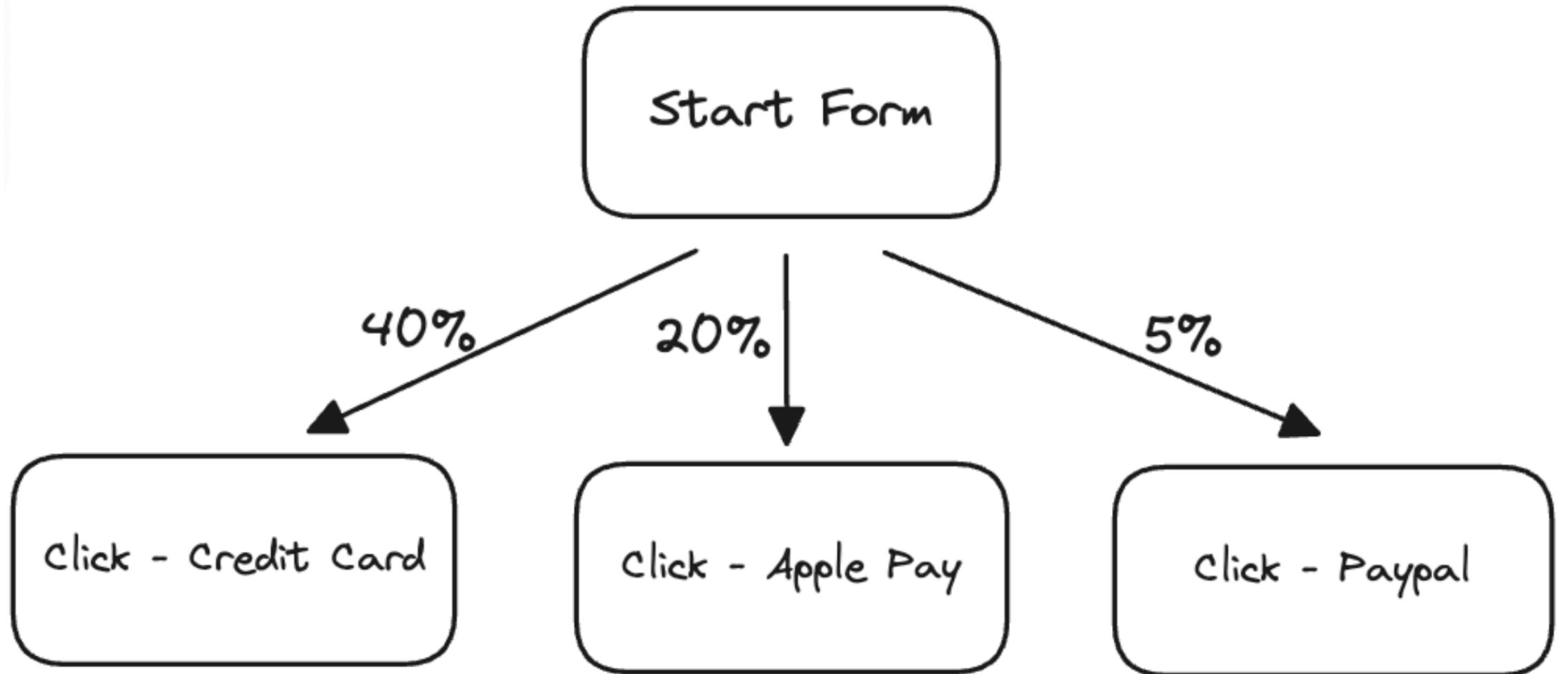
Name

Address

Credit Card	Apple Pay	Paypal
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I agree to Terms & Conditions



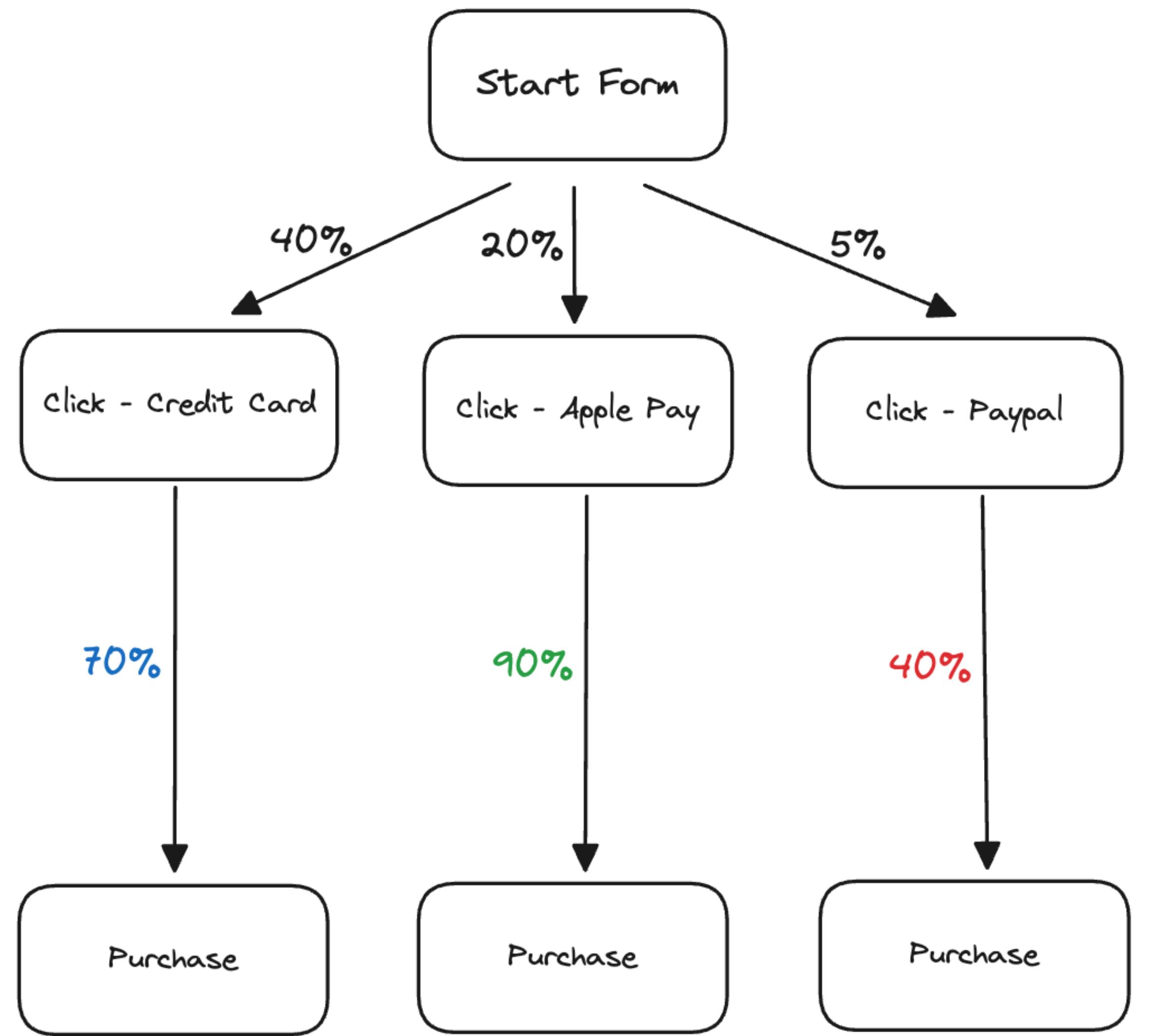
Name

Address

Credit Card Apple Pay Paypal

I agree to Terms & Conditions

Purchase



Name

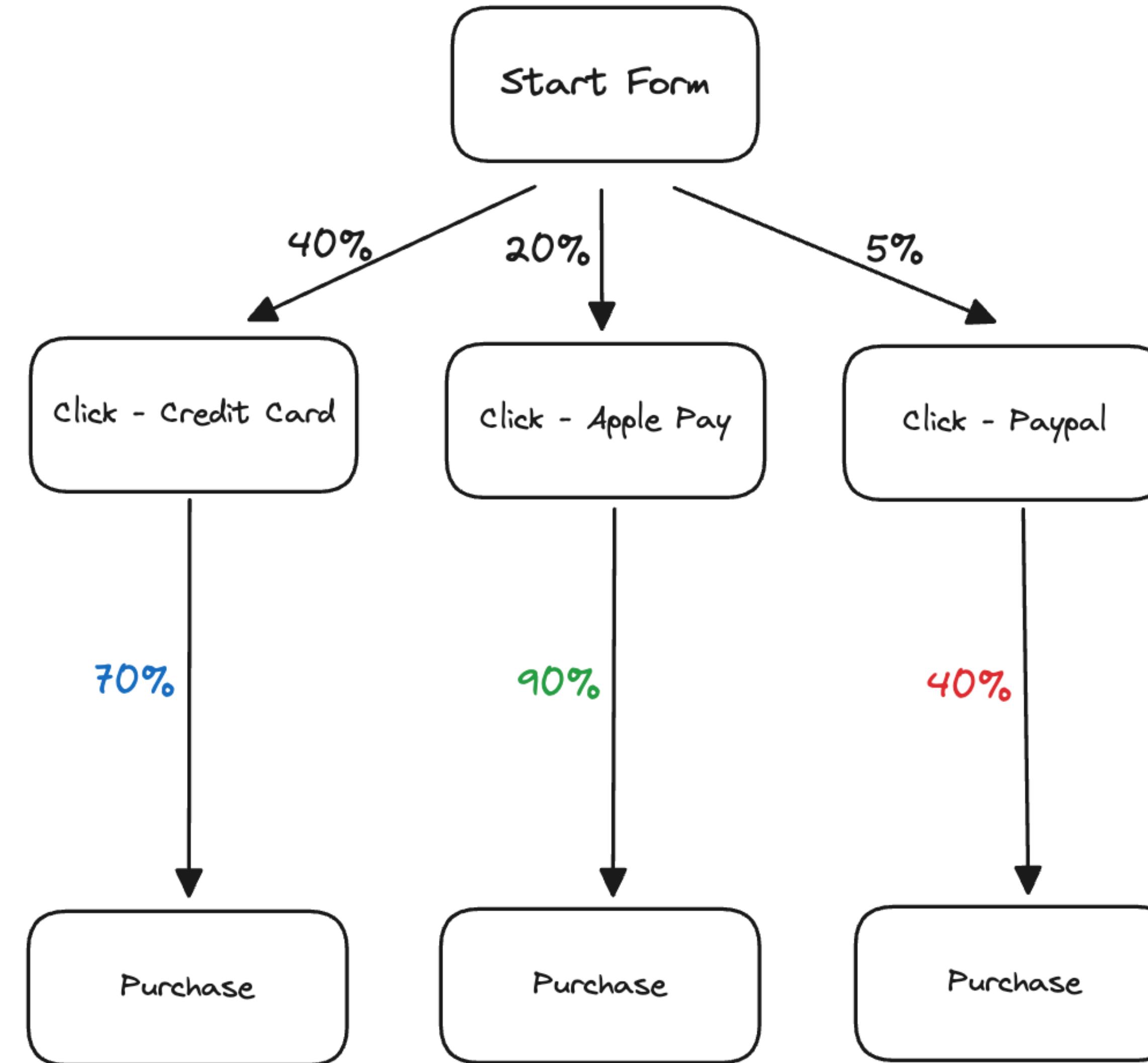
Address

Credit Card Apple Pay Paypal

I agree to Terms & Conditions

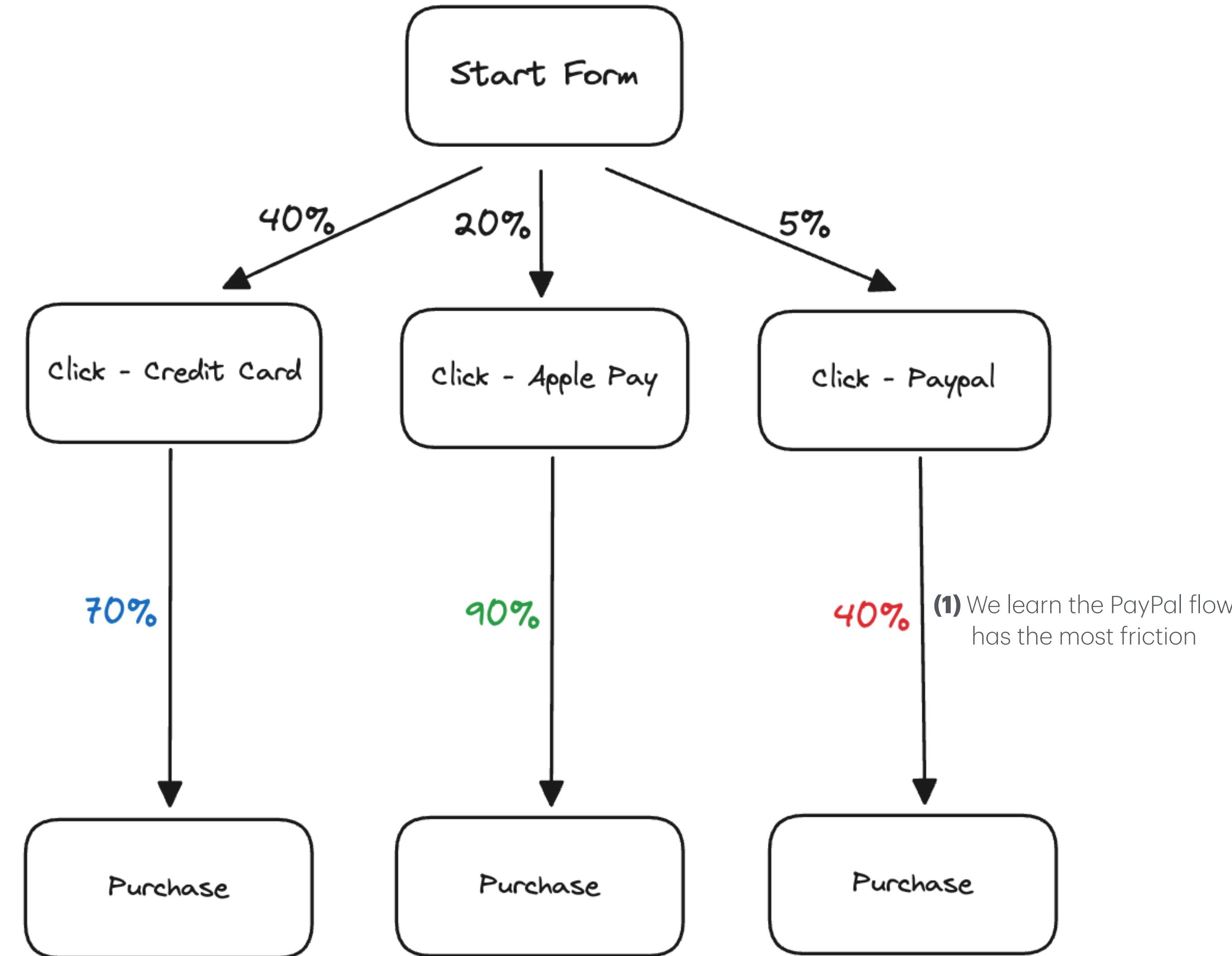
Purchase

In causal inference terms, we're matching



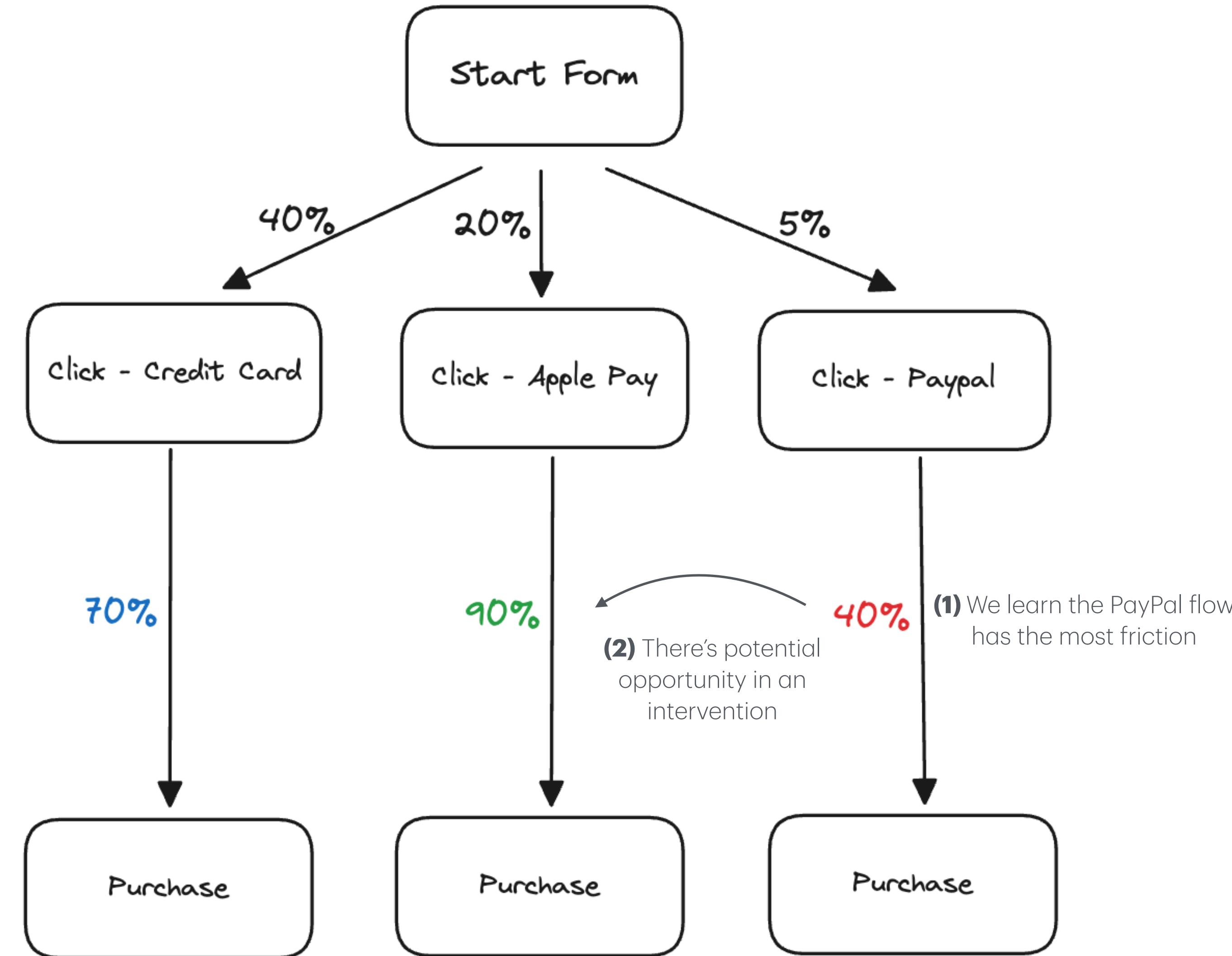
How do we use a journey to reason about causal effects?

In causal inference terms, we're matching



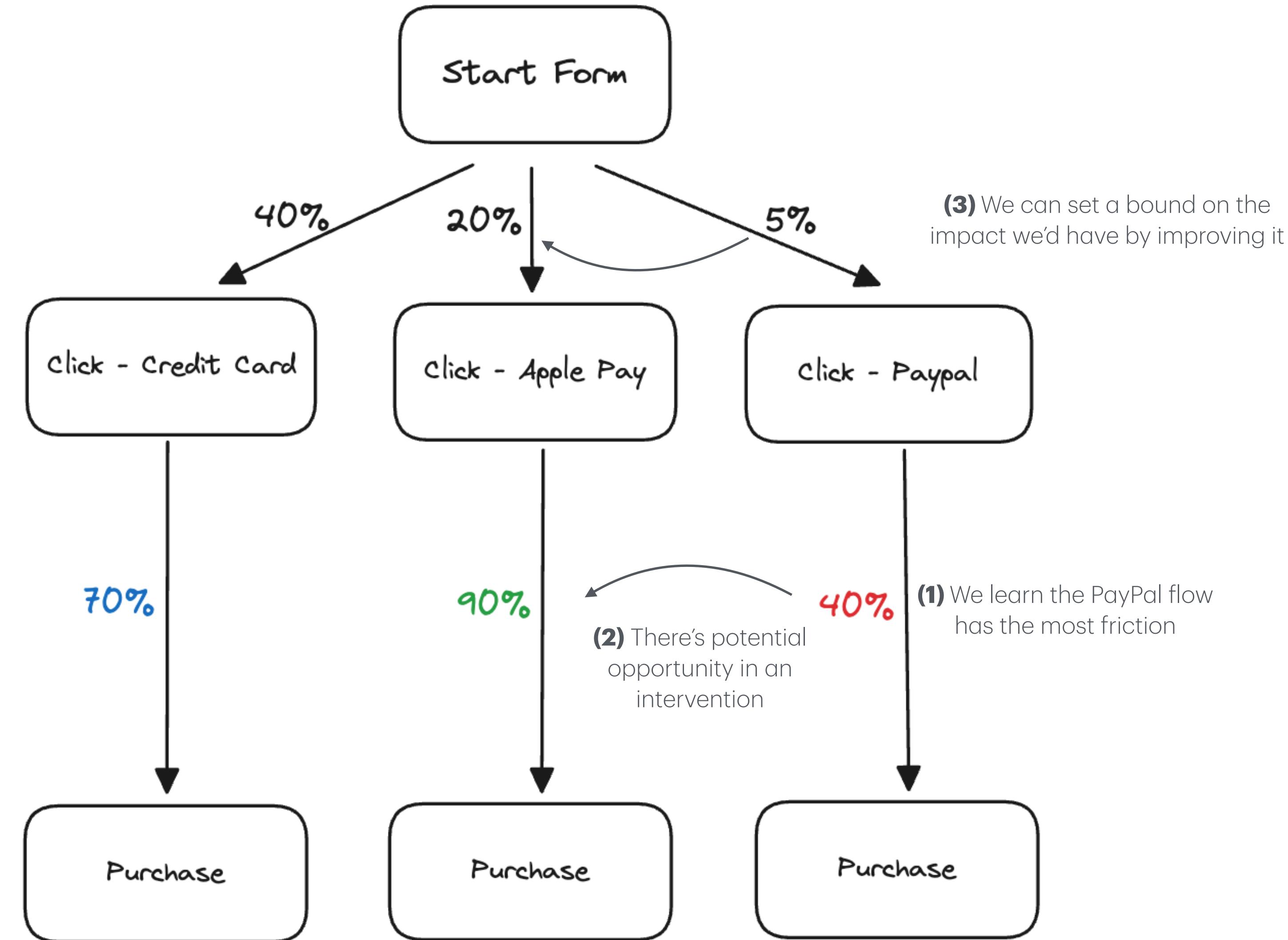
How do we use a journey to reason about causal effects?

In causal inference terms, we're matching

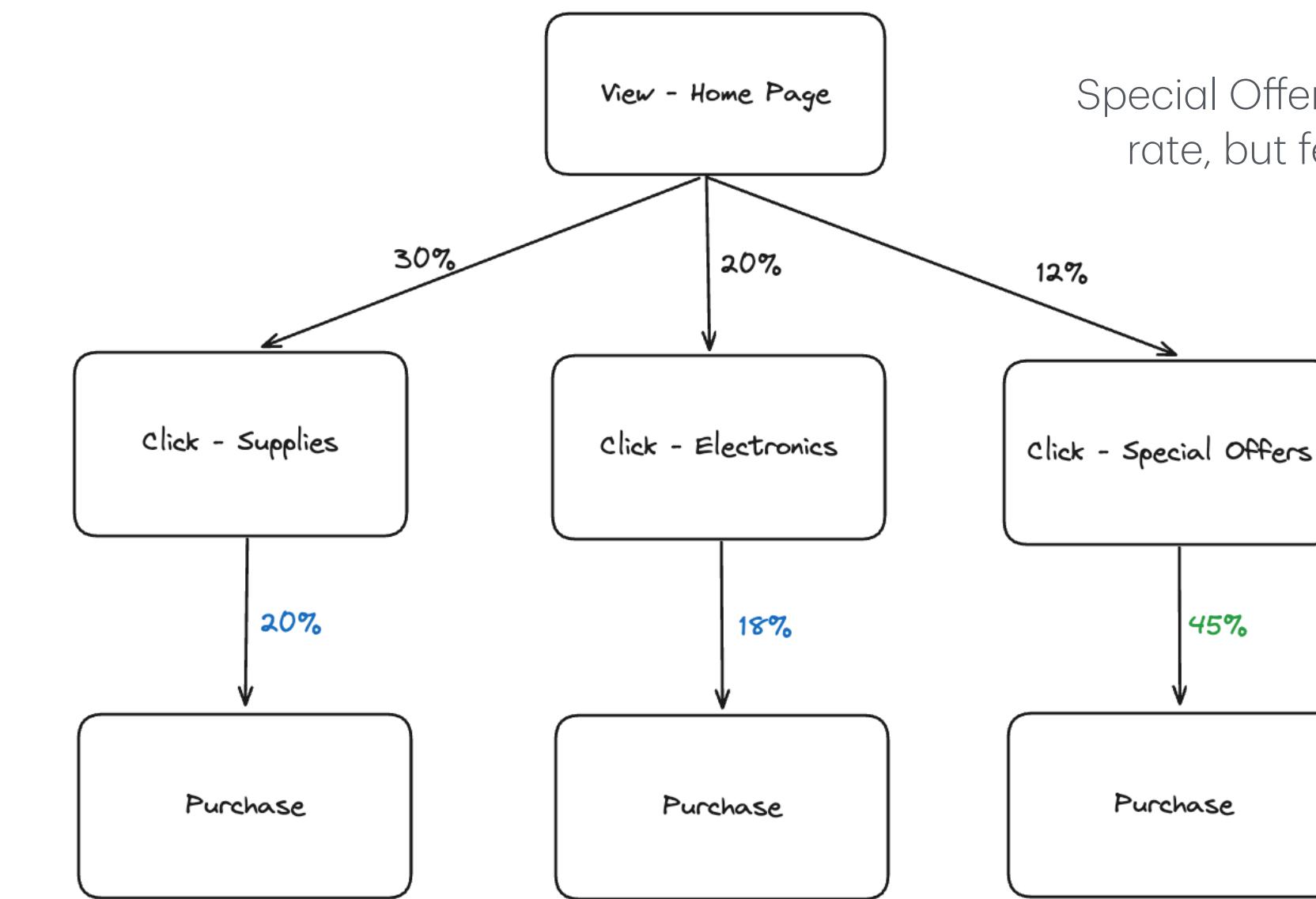
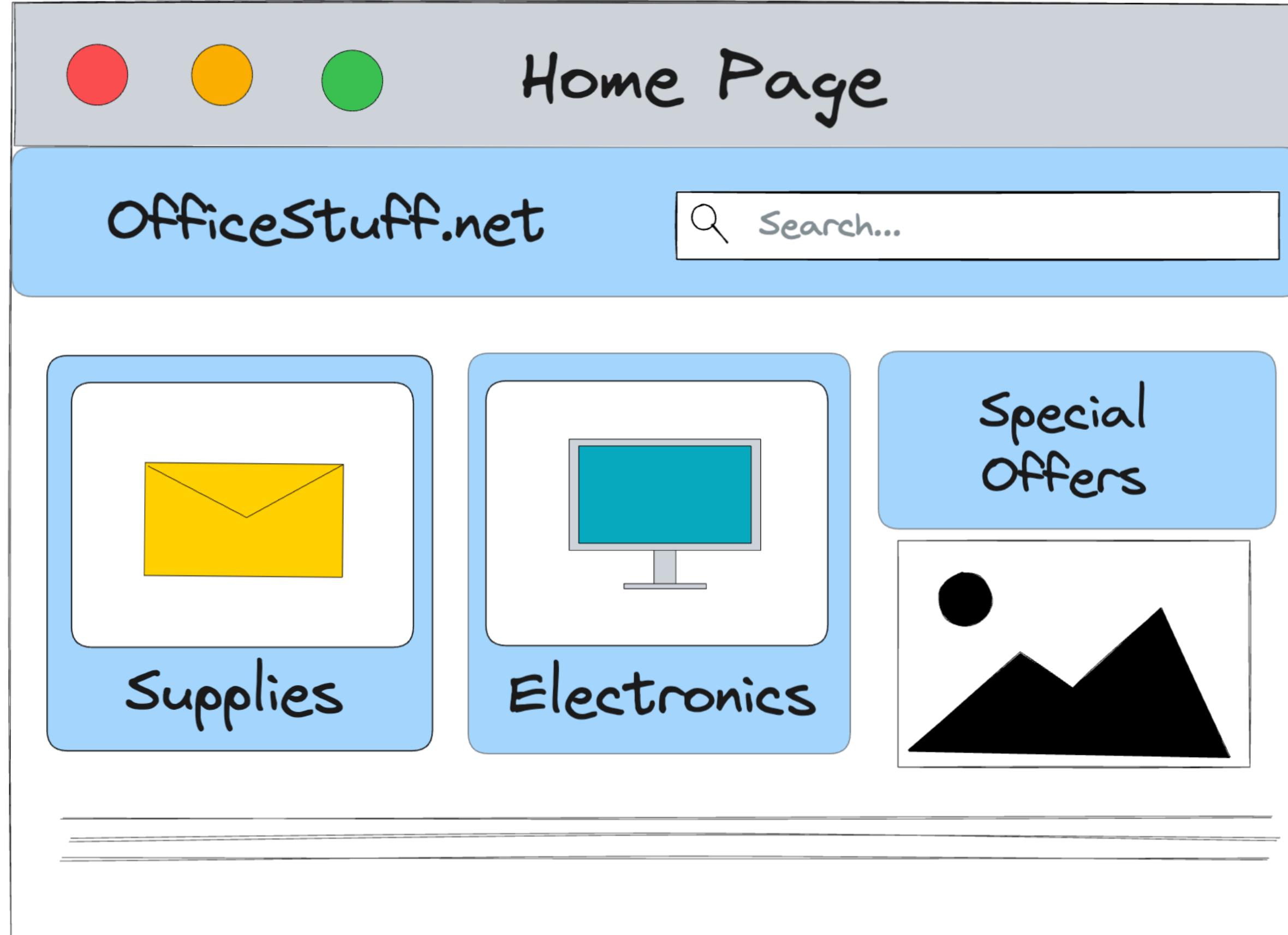


How do we use a journey to reason about causal effects?

In causal inference terms, we're matching



How do we use a journey to reason about causal effects?



Forks can measure larger goals, not just the UX within one page

Journeys: Skippable Steps

Name

Address

Credit Card

Apple Pay

Paypal

YES! Sign me up for hourly emails

YES! Donate \$1 to "Save the Octopi"

YES! I agree to Terms & Conditions

Bad UI can cause users
to miss important steps

Purchase

Name

Address

Credit Card

Apple Pay

Paypal

YES! Sign me up for hourly emails

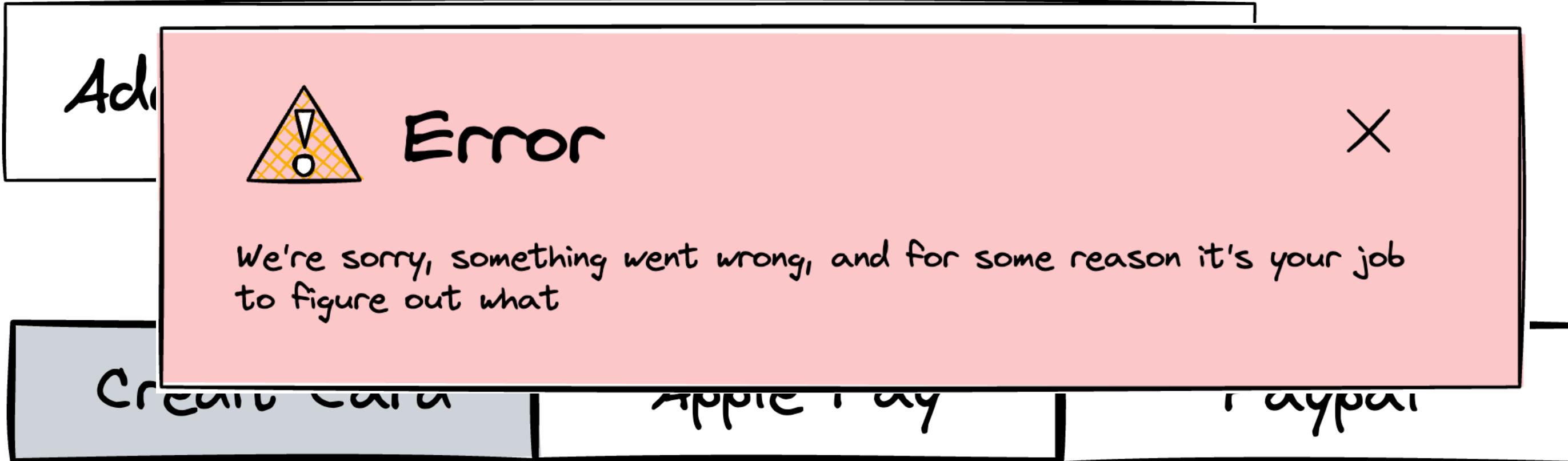
YES! Donate \$1 to "Save the Octopi"

YES! I agree to Terms & Conditions

Bad UI can cause users
to miss important steps

Purchase

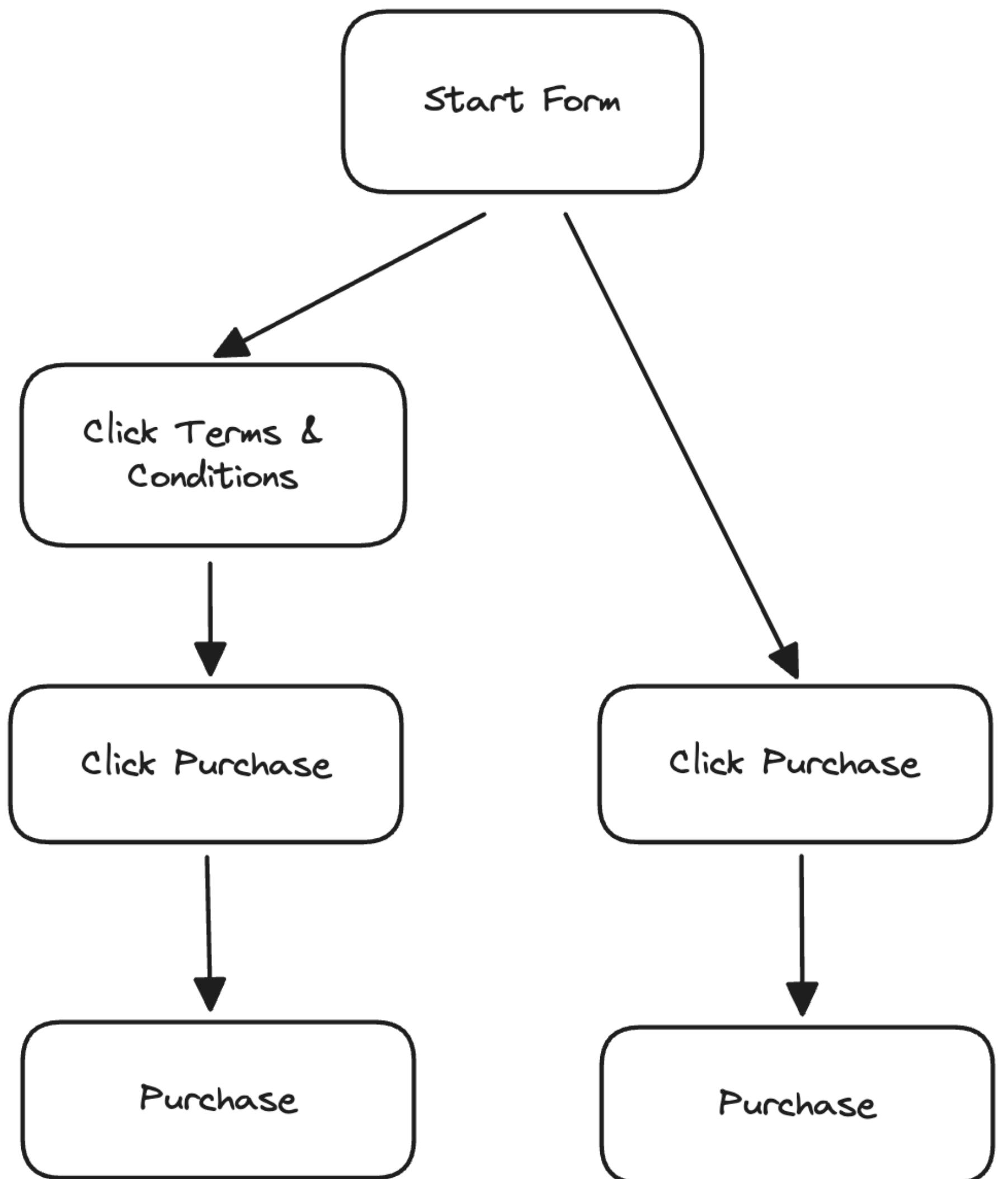
Name



- YES! Sign me up for hourly emails
- YES! Donate \$1 to "Save the Octopus"
- YES! I agree to Terms & Conditions

Bad UI can cause users to miss important steps





Name

Address

Credit Card Apple Pay Paypal

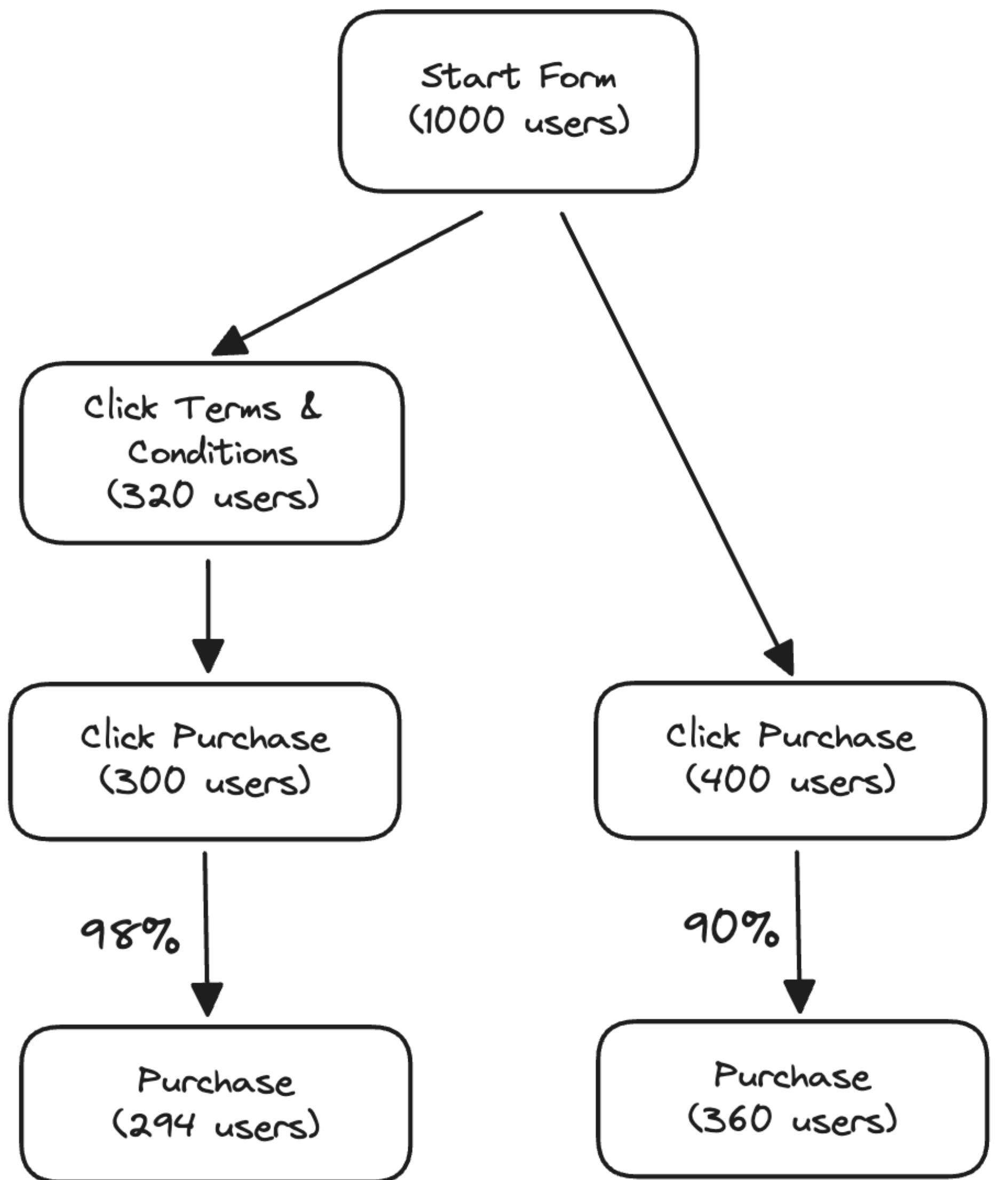
YES! Sign me up for hourly emails

YES! Donate \$1 to "Save the Octopi"

YES! I agree to Terms & Conditions

Purchase

This section displays various form fields and options. It includes input fields for 'Name' and 'Address', a payment method selector with 'Credit Card', 'Apple Pay', and 'Paypal' options, and three checkboxes for additional user preferences. A large blue 'Purchase' button is positioned at the bottom.



Name

Address

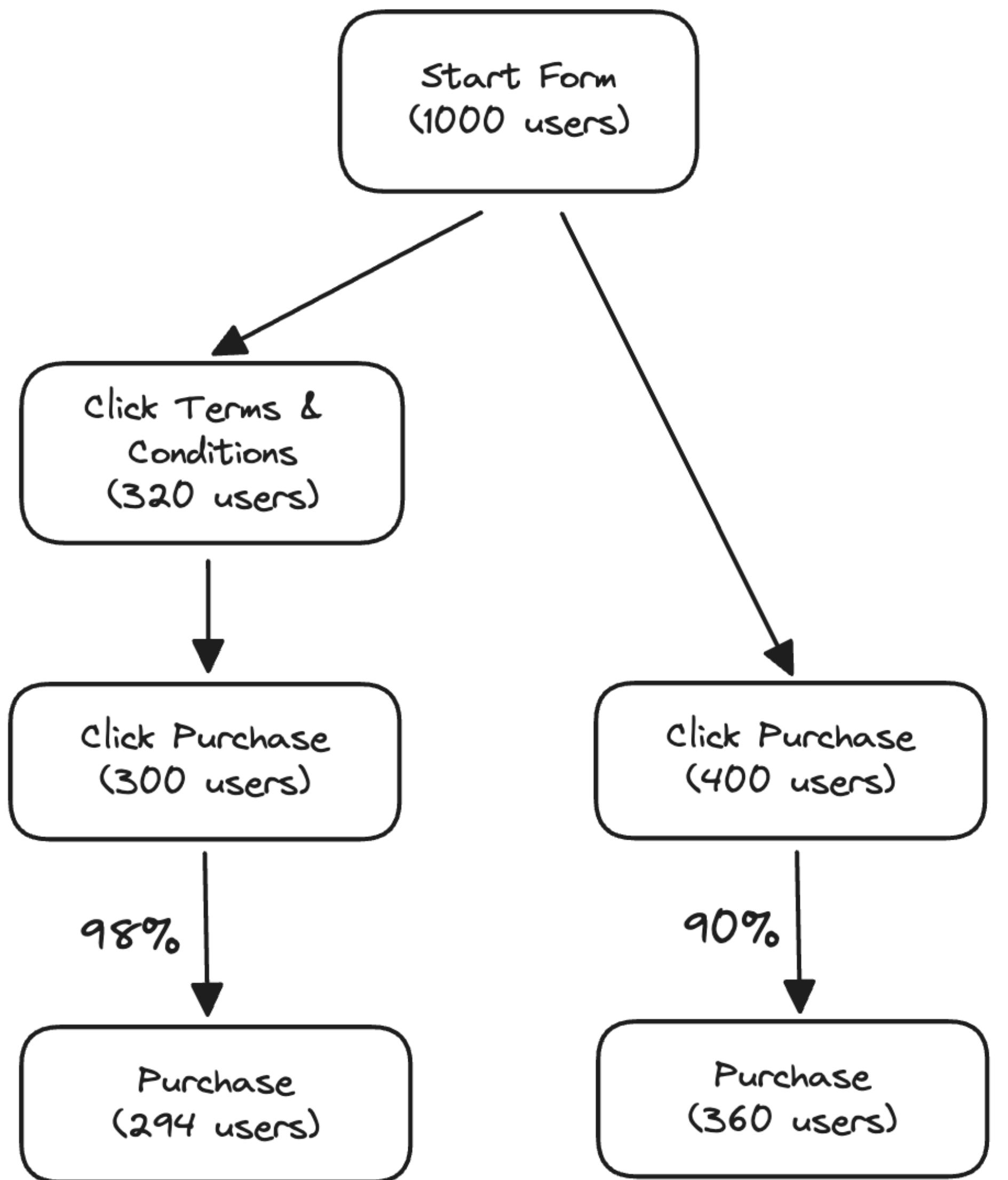
Credit Card Apple Pay Paypal

YES! Sign me up for hourly emails

YES! Donate \$1 to "Save the Octopi"

YES! I agree to Terms & Conditions

Purchase

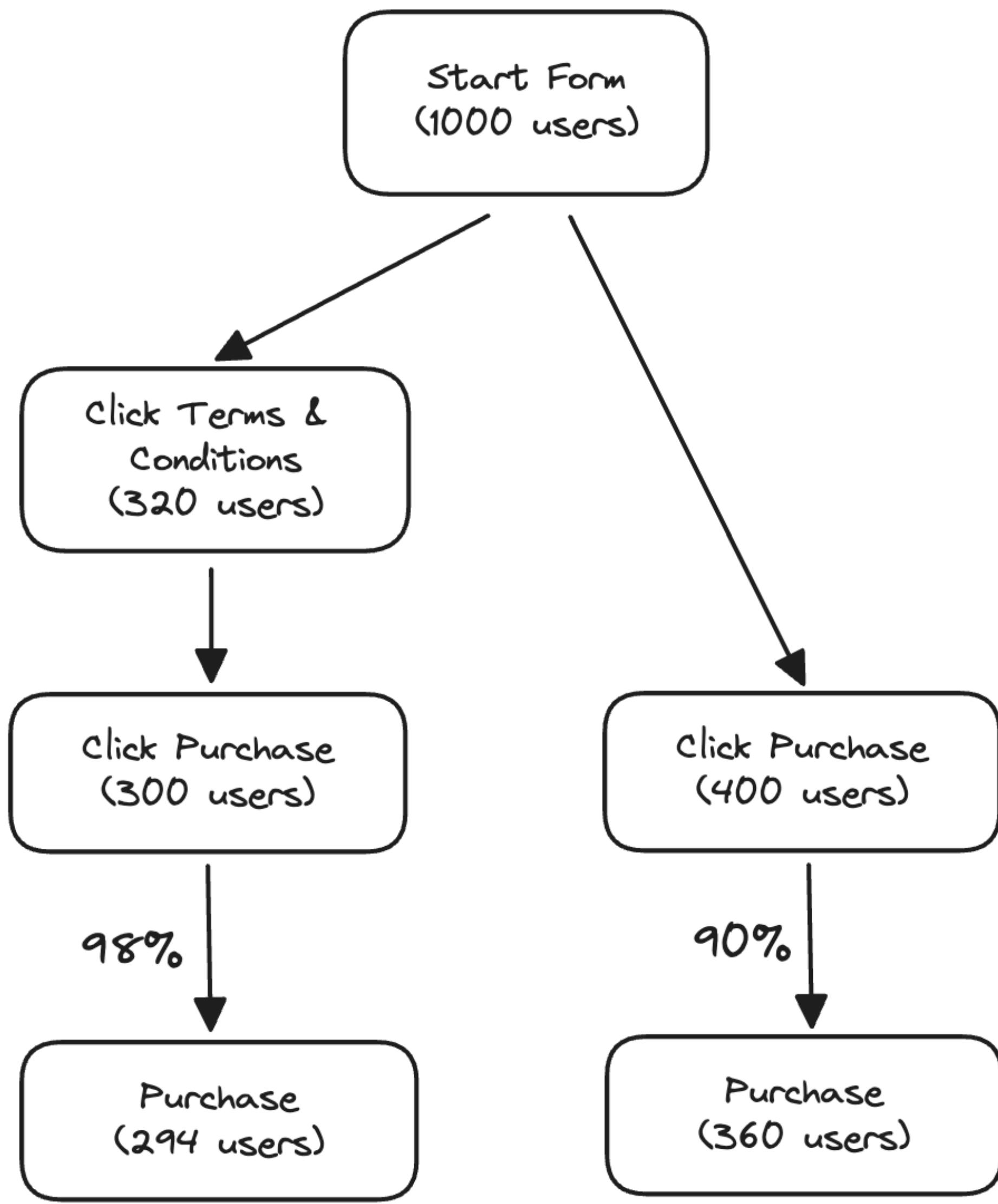


Opportunity
Size

$$400 * (.98 - .9) = 32 \text{ users}$$

The right side shows a user interface snippet with the following components:

- Name:** An input field for entering a name.
- Address:** An input field for entering an address.
- Payment Methods:** A row of three buttons: "Credit Card", "Apple Pay", and "Paypal".
- Checkboxes:** Three checkboxes on the right:
 - YES! Sign me up for hourly emails
 - YES! Donate \$1 to "Save the Octopi"
 - YES! I agree to Terms & Conditions
- Purchase Button:** A large blue button labeled "Purchase".



Opportunity
Size

$$400 * (.98 - .9) = 32 \text{ users}$$

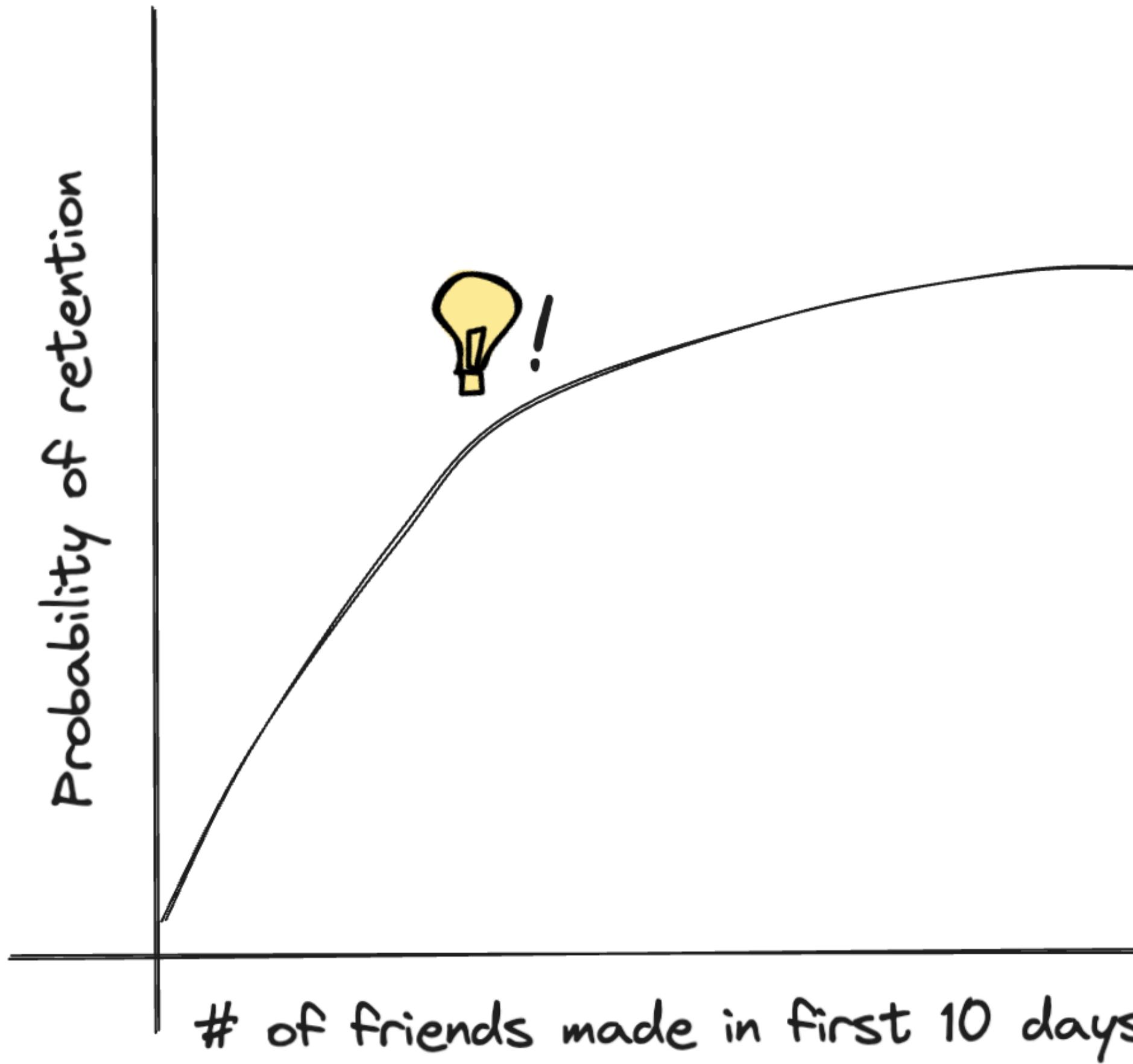
This information is lost in a bag-of-clicks approach

A screenshot of a database table illustrating user interactions and purchase status. The columns include user_id, viewed_home, clicked_search, clicked_read_reviews, clicked_learn_more, ...yada yada..., and purchased. A large red X is drawn across the entire table, indicating that this detailed interaction history is lost in a 'bag-of-clicks' approach.

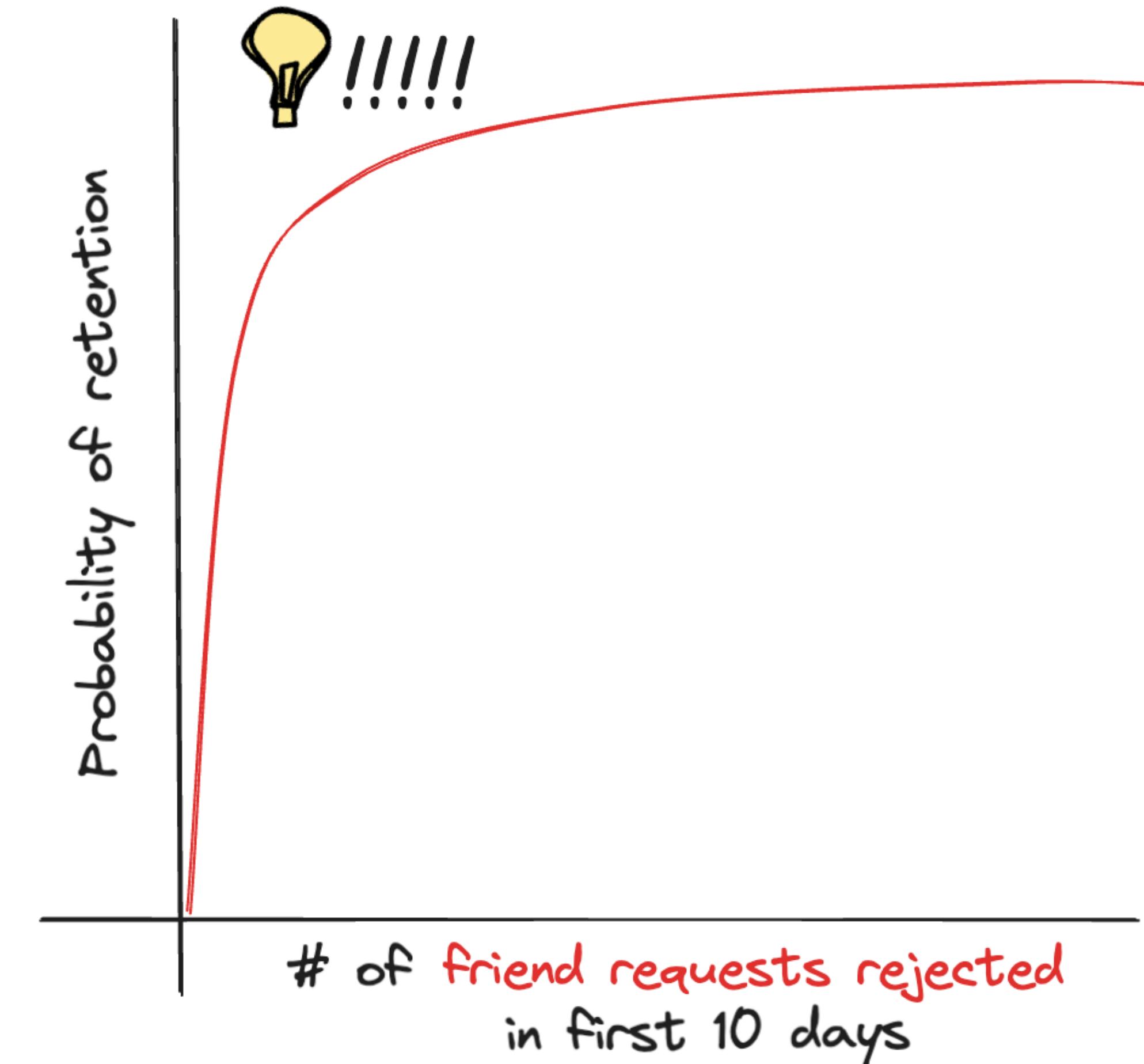
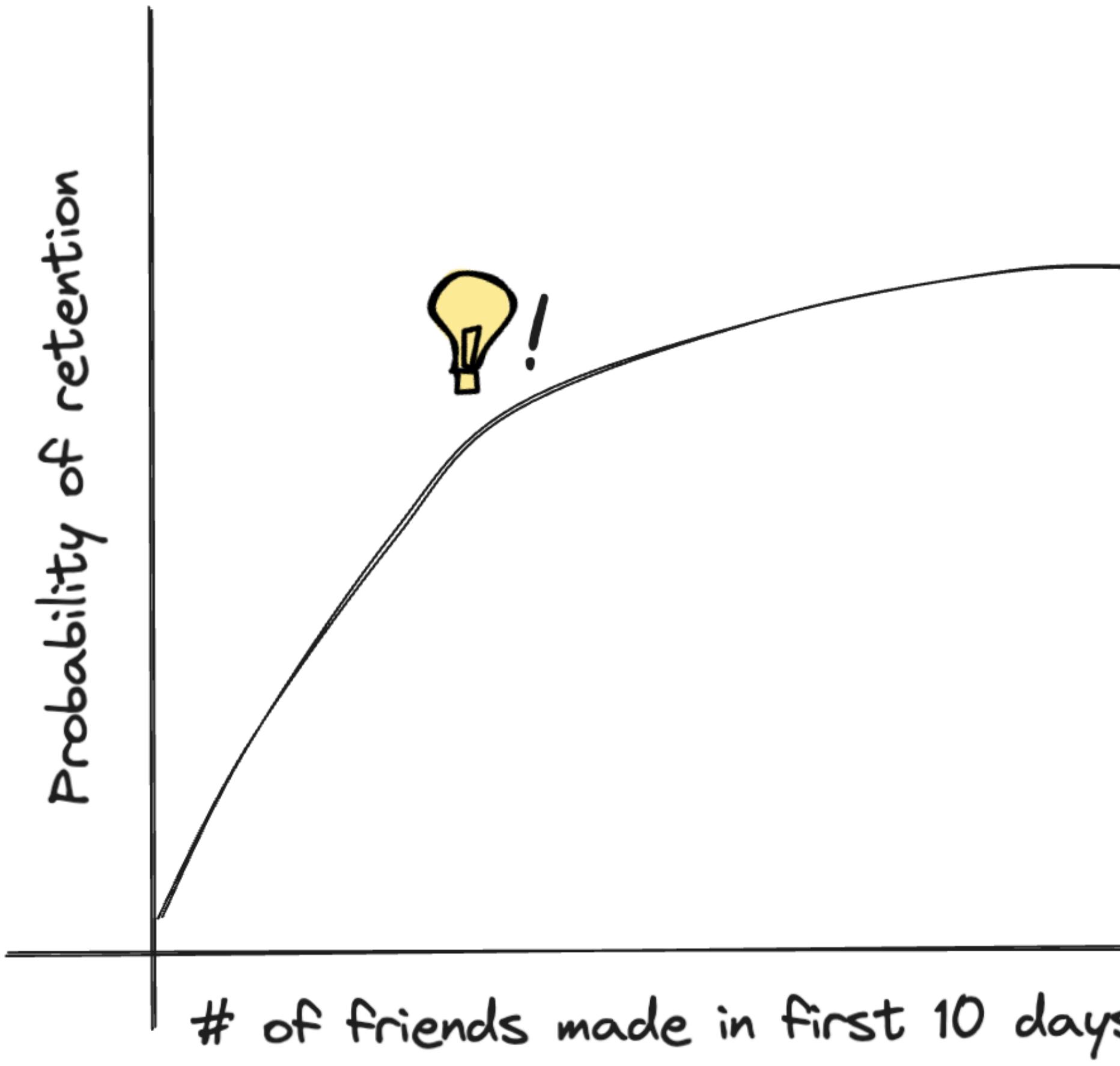
user_id	viewed_home	clicked_search	clicked_read_reviews	clicked_learn_more	...yada yada...	purchased
187180	0	1		1	0	1
662863	0	0		0	0	1
684172	1	1		1	0	0
261982	1	1		0	0	0
579325	1	1		1	1	0
829755	1	1		0	1	0
454574	1	1		0	0	0
216105	1	1		1	1	1
181215	0	1		0	0	0
996510	1	1		0	0	0
379967	1	1		0	0	0
511056	1	1		0	1	0
948165	1	1		1	0	0
575719	1	1		0	1	0
356383	1	1		1	0	0
582609	1	1		1	0	0
988781	1	0		0	1	0
857058	1	1		0	0	0
498438	1	1		0	0	0
470140	1	0		1	0	0
714748	1	0		0	1	0
624947	1	1		1	1	0
524455	1	0		0	1	1

Retention

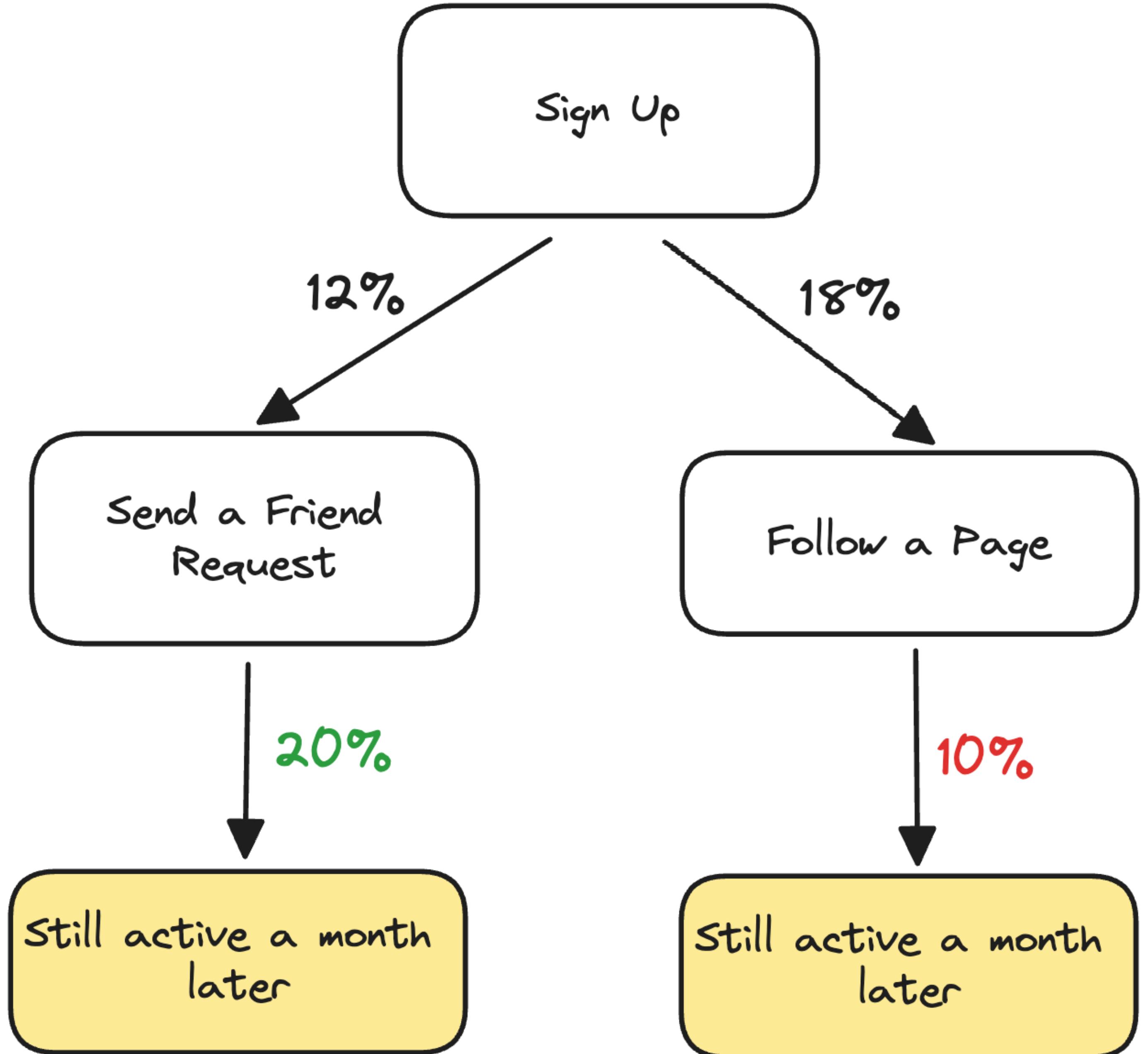
Facebook's “aha” moment



Facebook's “aha” moment?



What I'd rather see- find two actions that represent the same moment in a journey, and compare them



Conclusion



"After growing wildly for years, the field of computing appears to be reaching its infancy."

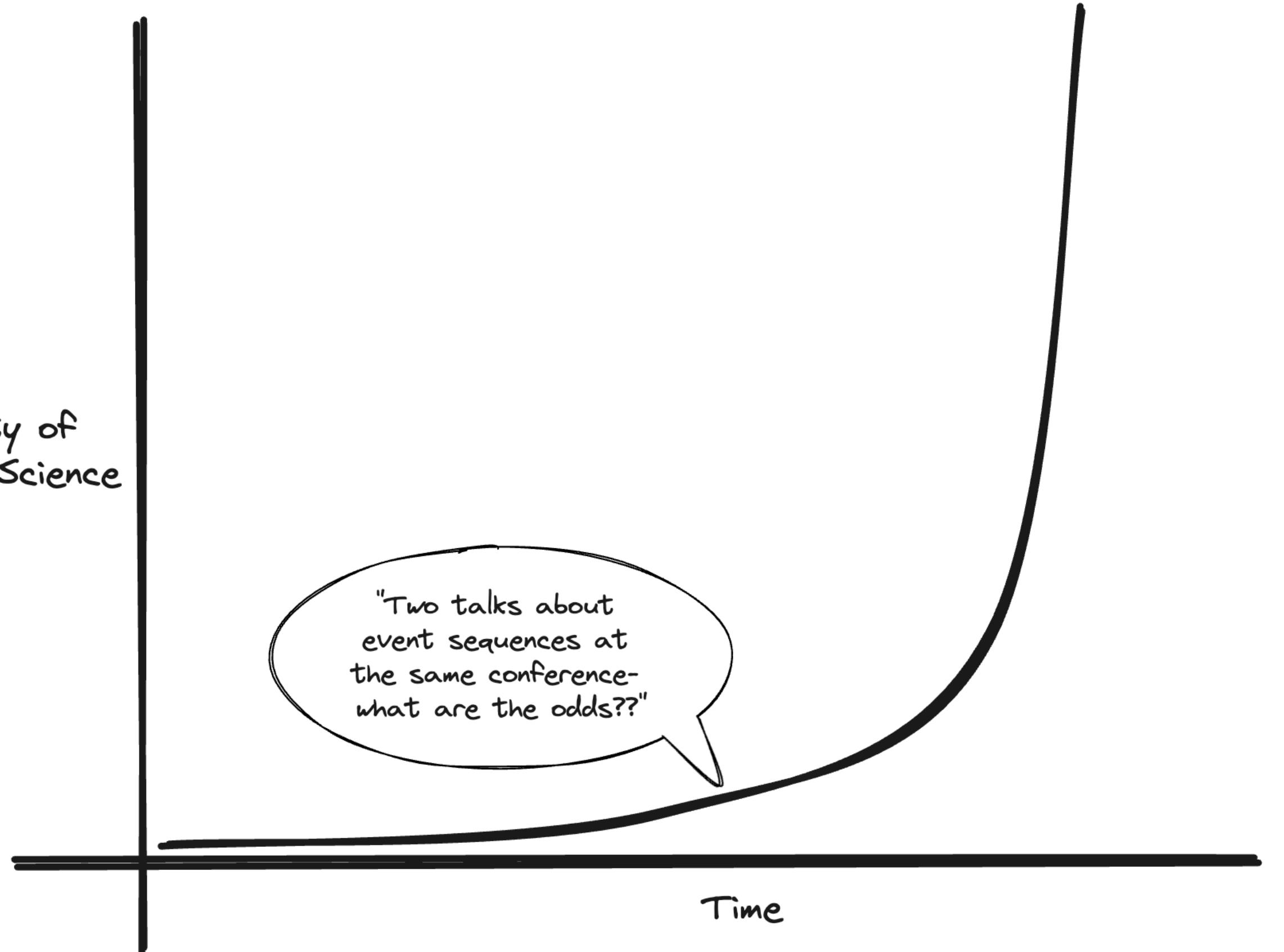
John Pierce, Bell Labs



"After growing wildly for years, the field of computing appears to be reaching its infancy."

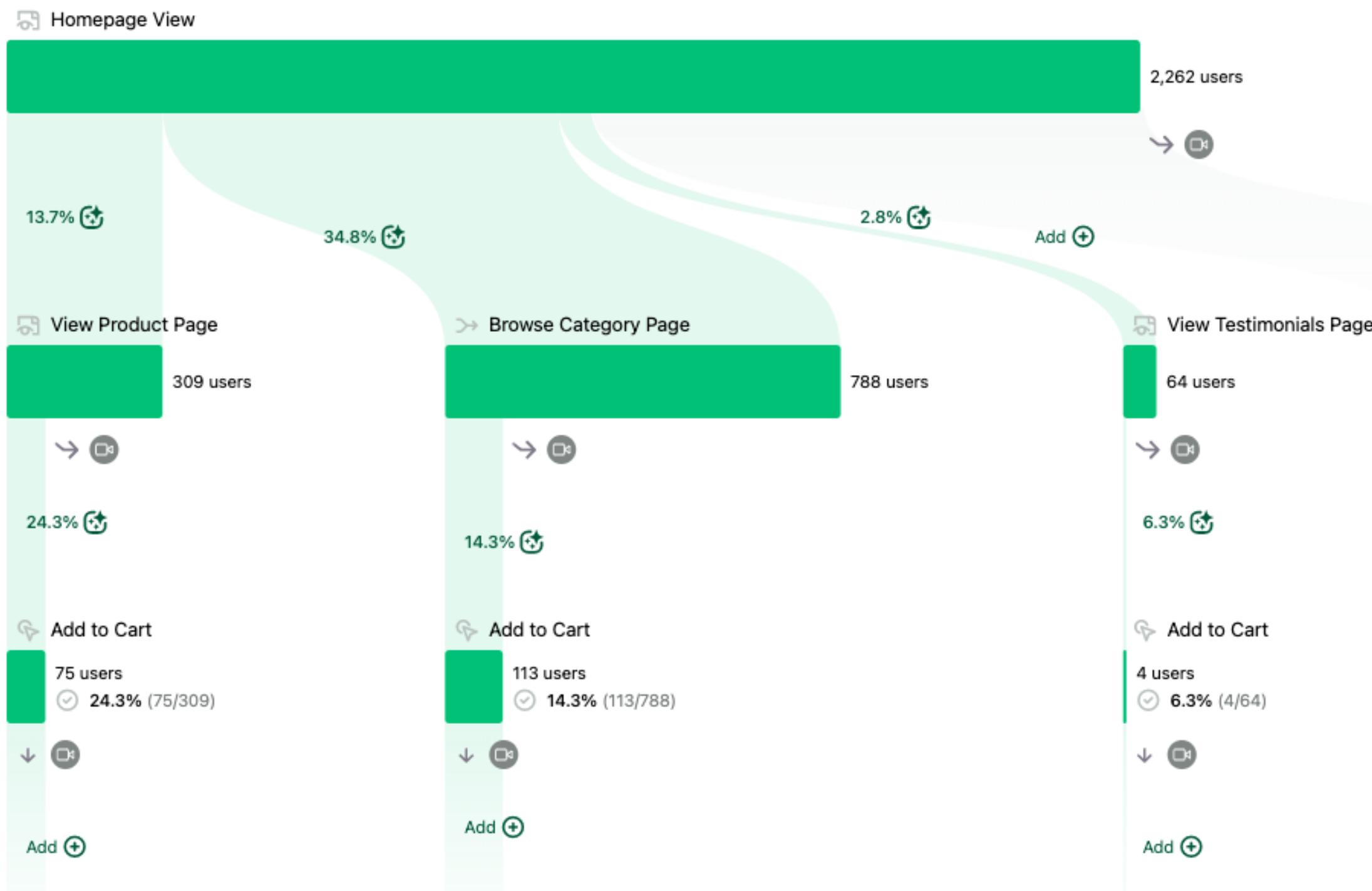
John Pierce, Bell Labs

Maturity of
Product Science



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at Heap, works in R.

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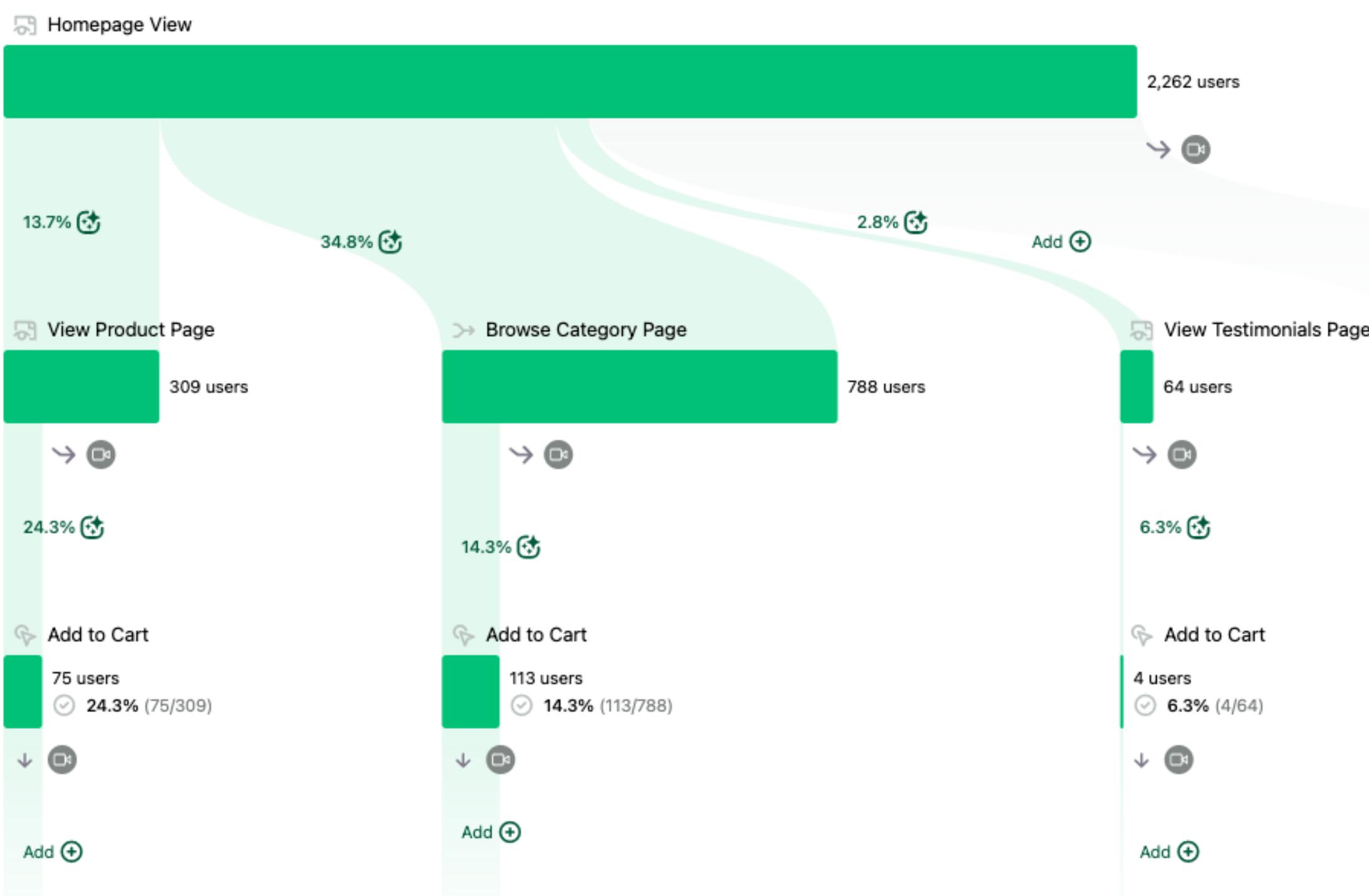
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Thank you!

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