Thoughts on Causation, Group Decision-making, and Uncertainty

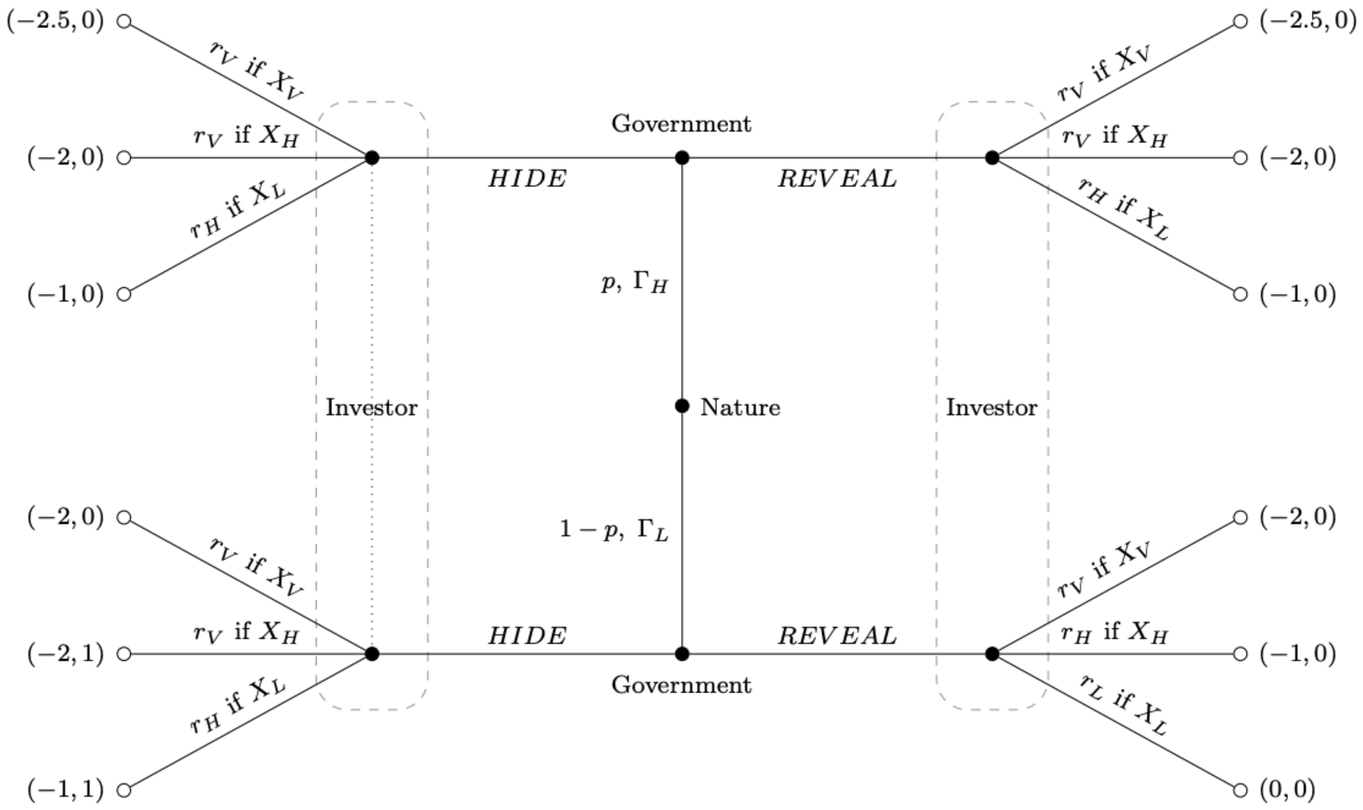
3 Stories from Industry

Christopher Gandrud, 2022-03-30

About me

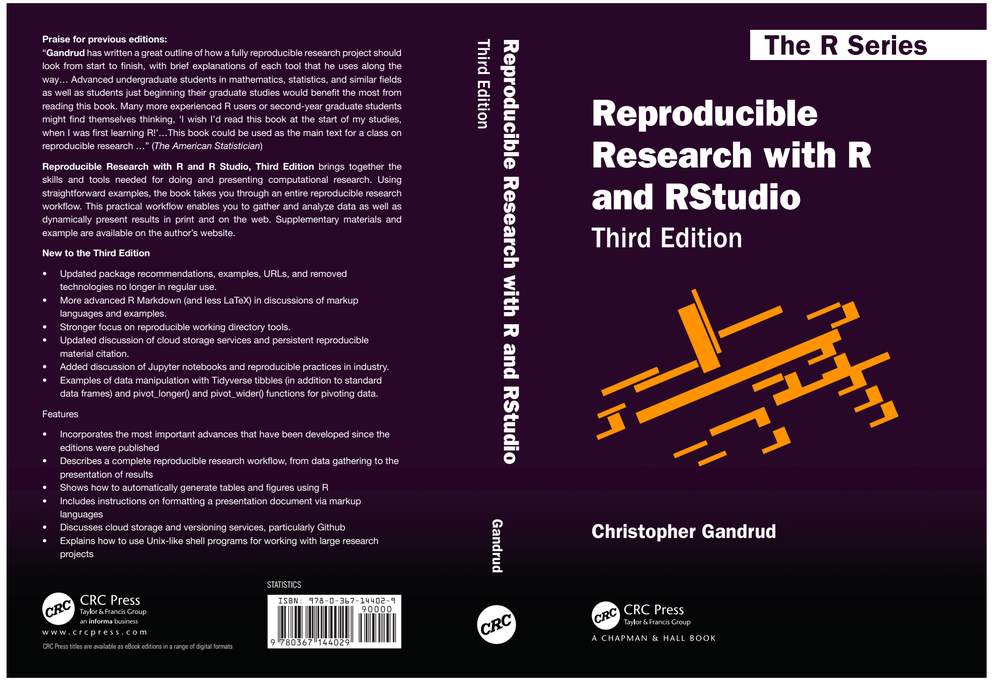
Academic

Figure 1: Reduced-form Game Tree of Financial Transparency and Sovereign Borrowing Costs with No Intrinsic Transparency Choice Costs



But, my side interest became my main interest:

How to scale research/ decision-making through software & processes



Praise for previous editions:
"**Gandrud** has written a great outline of how a fully reproducible research project should look from start to finish, with brief explanations of each tool that he uses along the way… Advanced undergraduate students in mathematics, statistics, and similar fields as well as students just beginning their graduate studies would benefit the most from reading this book. Many more experienced R users or second-year graduate students might find themselves thinking, 'I wish I'd read this book at the start of my studies, when I was first learning R!'…This book could be used as the main text for a class on reproducible research …" (*The American Statistician*)

Reproducible Research with R and R Studio, Third Edition brings together the skills and tools needed for doing and presenting computational research. Using straightforward examples, the book takes you through an entire reproducible research workflow. This practical workflow enables you to gather and analyze data as well as dynamically present results in print and on the web. Supplementary materials and example are available on the author's website.

New to the Third Edition

- Updated package recommendations, examples, URLs, and removed technologies no longer in regular use.
- More advanced R Markdown (and less LaTeX) in discussions of markup languages and examples.
- Stronger focus on reproducible working directory tools.
- Updated discussion of cloud storage services and persistent reproducible material citation.
- Added discussion of Jupyter notebooks and reproducible practices in industry.
- Examples of data manipulation with Tidyverse tibbles (in addition to standard data frames) and pivot_longer() and pivot_wider() functions for pivoting data.

Features

- Incorporates the most important advances that have been developed since the editions were published
- Describes a complete reproducible research workflow, from data gathering to the presentation of results
- Shows how to automatically generate tables and figures using R
- Includes instructions on formatting a presentation document via markup languages
- Discusses cloud storage and versioning services, particularly Github
- Explains how to use Unix-like shell programs for working with large research projects

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Third Edition

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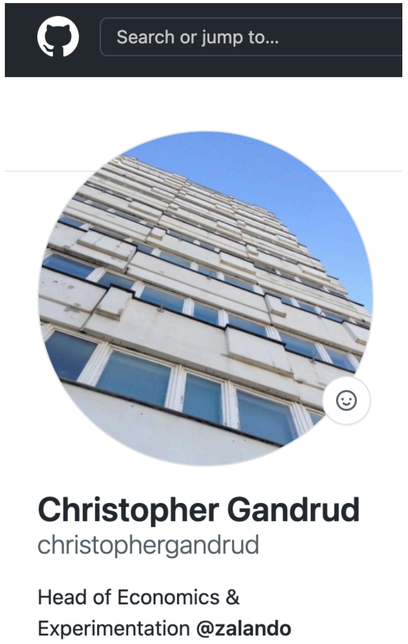
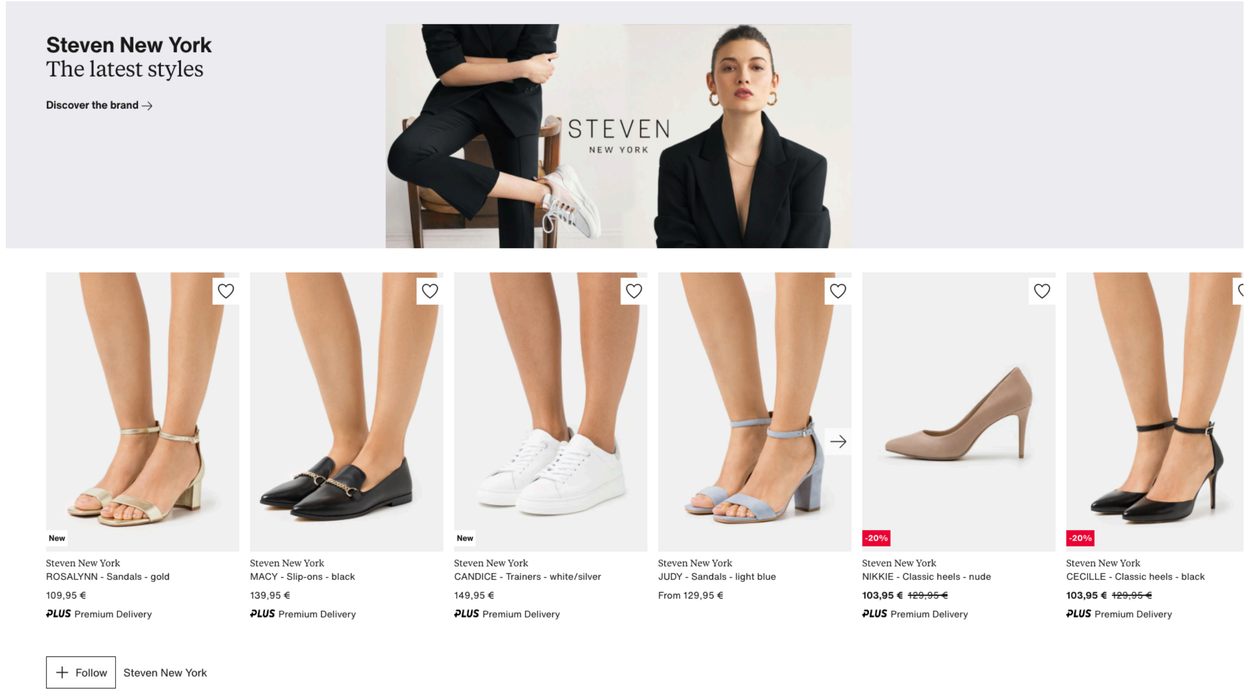
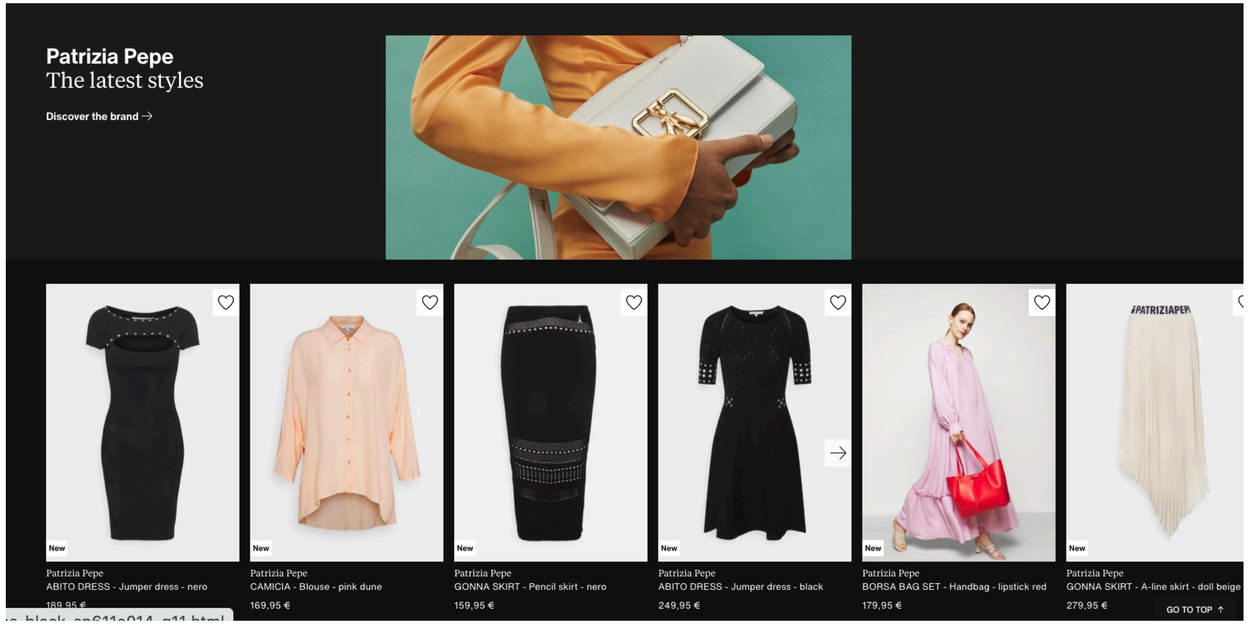


Created Economics Team at Zalando

First project was building real-time ad auction system





Expanded to become Economics & Experimentation . . .

. . . AKA the causal inference department

Why a department for causal inference?

Why a causal inference department?

. . . to help the company make better choices

Story 1

Causal Inference and Decision-making

Or

How to stop wasting money

Review for you

Interlude: Causation

It's not clear that $P(O_i \mid A = a)$ is quite what we want here. Strictly it might be better to work with

$$P(O^{A=a}) \qquad \text{a.k.a.} \qquad P(O_i \mid \mathrm{do}(a))$$

the distribution of O given that we *do* or *set* A to a, not just *see* $A = a$ (Pearl 2000)

An expected utility formulated this way gives us *causal decision theory*

Corporate Decision-making

There are many products/investments a company could make to achieve some objective

Decision-makers want to choose the ones that will <u>cause</u> the most positive change (net of their costs)

Corporate Decision-making

There are many products/investments a company could make to achieve some objective

Decision-makers want to choose the ones that will <u>cause</u> the most positive change (net of their costs)

Invest in things that <u>make a difference</u>

Counterfactual Prediction

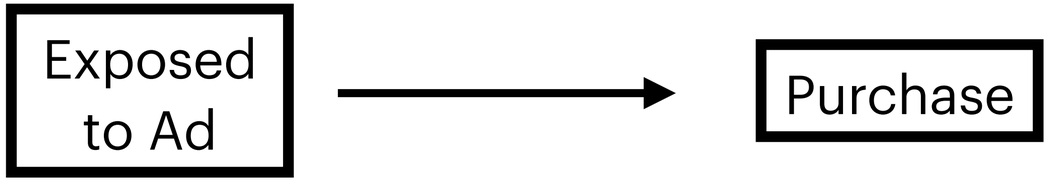
= world with product – world without product

A common mistake

Many companies optimise ad spend based on “last click attribution”

A common mistake

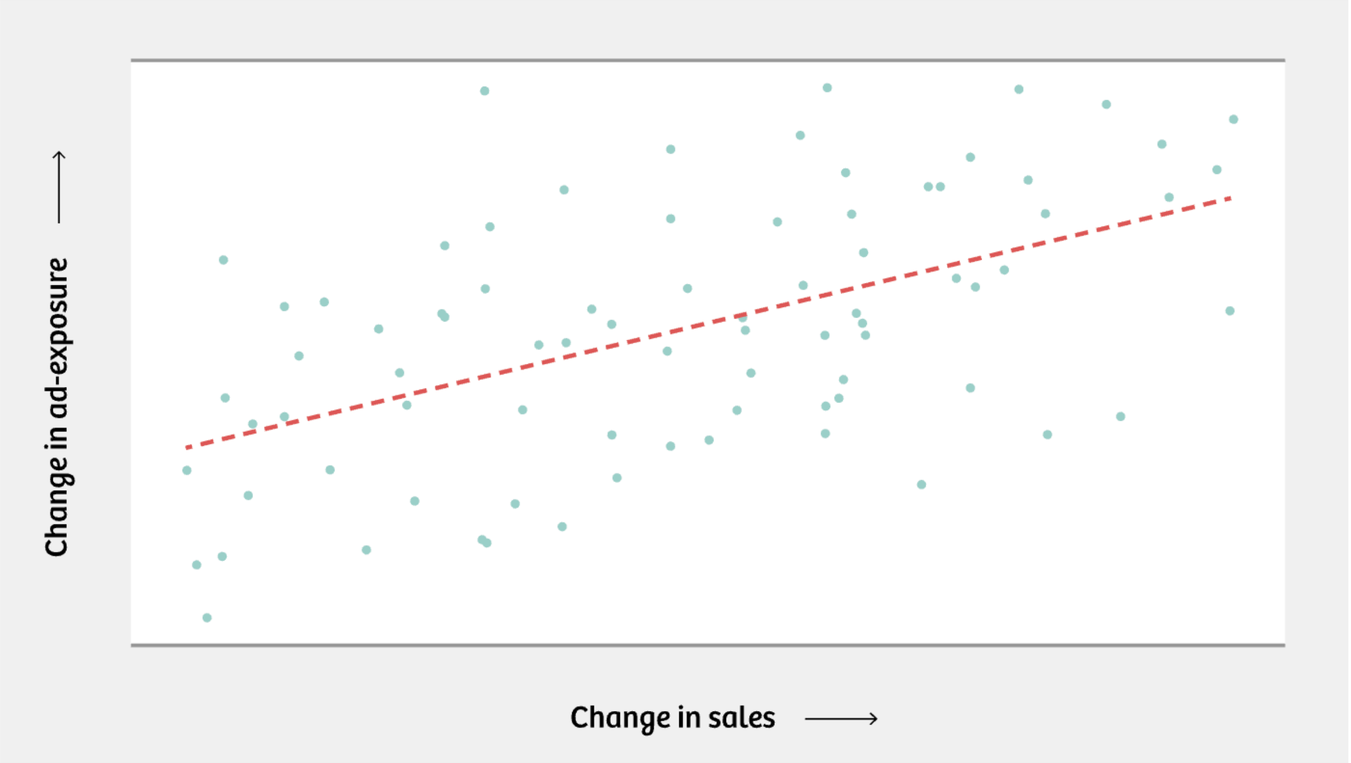
Many companies optimise ad spend based on “last click attribution”



A common mistake

Exposed to Ad → Purchase

Many companies optimised ad spend based on “last click attribution”



Source

A common mistake

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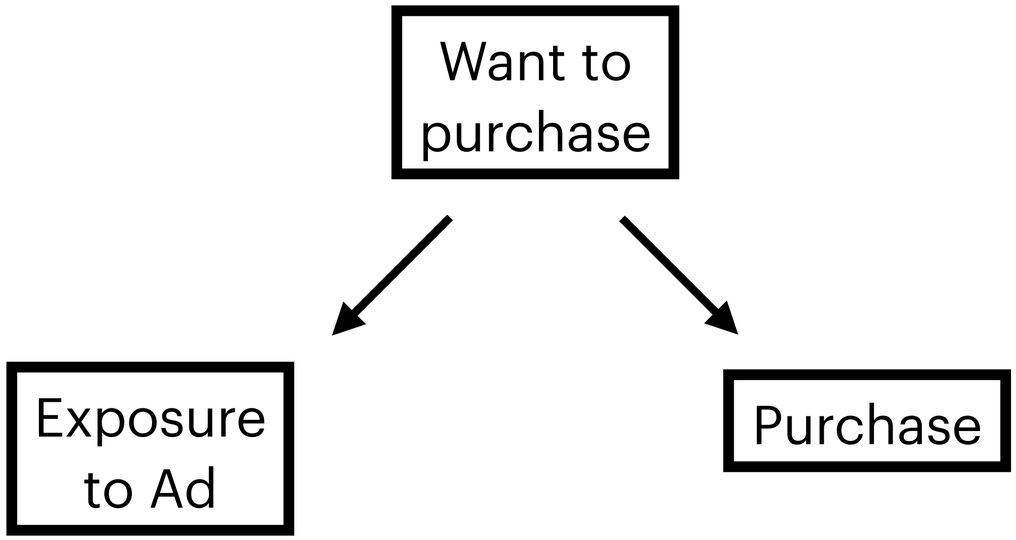
Confounded!

<u>But</u>, the best way to optimise last click attribution is to target customer with ads that were already going to buy the product → great “KPIs” (key performance indicators), huge waste of money



the Correspondent

Analysis

6 November 2019 • Reading time 21 - 26 minutes

In 2018 $273bn was spent on digital ads globally. We delve into the world of clicks, banners and keywords to find out if any of it is real. What do we really know about the effectiveness of digital advertising?

The new dot com bubble is here: it's called online advertising

Jesse **FREDERIK** + *Maurits* **MARTIJN**

link

Causal Inference

Causal inference methodological toolkit (A/B testing, diff-in-diff, DAGs, . . .) is crucial for making good investment decisions

We all know correlation doesn’t equal causation

We all know correlation doesn’t equal causation

But remember that correlation doesn’t even necessarily indicate the *sign* of the causal relationship!

We all know correlation doesn't equal causation

But remember that correlation doesn't even necessarily indicate the *sign* of the causal relationship!

Selection bias and other threats to causal inference are a big deal → hard work/skill needed to do causal inference → make good decisions

Is this correct?

Selection bias and other threats to **causal inference** are a big deal → hard work/skill needed to do causal inference → make **good decisions**

Are we missing important nuance?

Causal Decision Making and Causal Effect Estimation Are Not the Same... and Why It Matters

To appear in the inaugural issue of the INFORMS Journal of Data Science.

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Causal Effect Estimation (CEE)

(Going potential outcomes on you)

Treated

$$\tau(x) = E[Y(1) - Y(0) \mid X = x]$$

Treatment Effect

not Treated

Causal Decision Making (CDM)

$$a^*(x) = 1(\tau(x) > 0)$$

Treatment assignment
Maximizing Expected value given x

How good does the estimate need to be?

$$\tau(x)$$

How good does the estimate need to be?

Or how does the estimate need to be good?

$$\tau(x)$$

Implication 1
Choose the right objective function

Invest in learning the optimal treatment assignment more than just causal effect

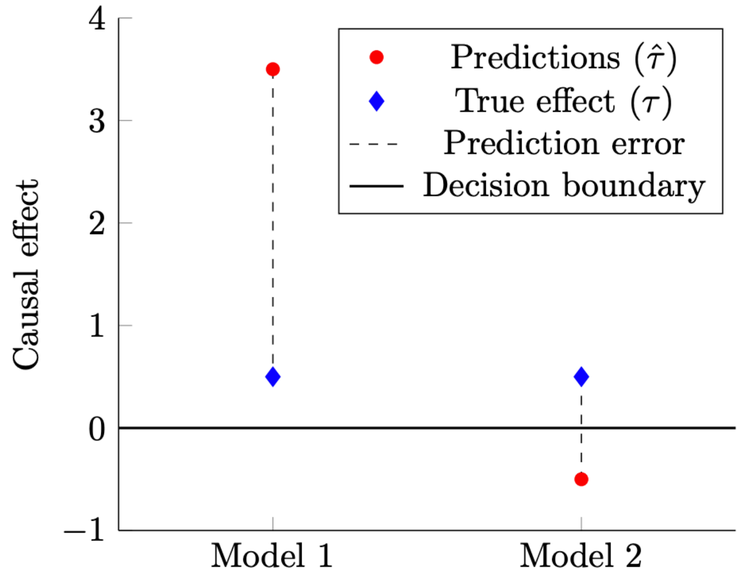
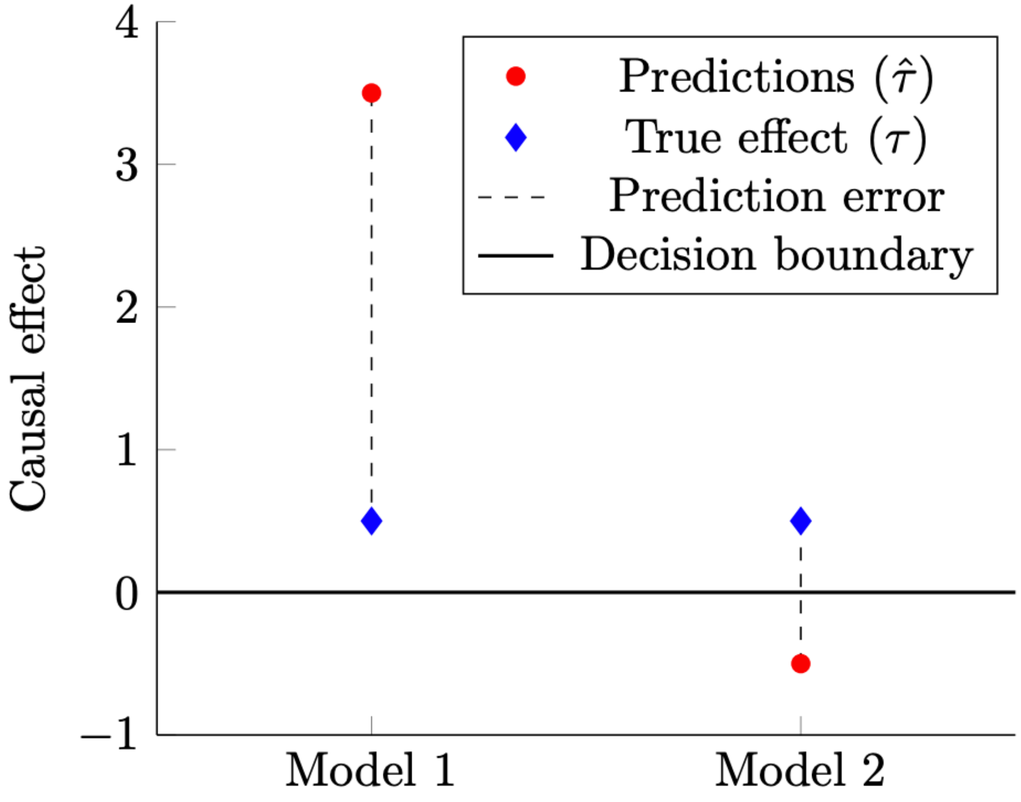
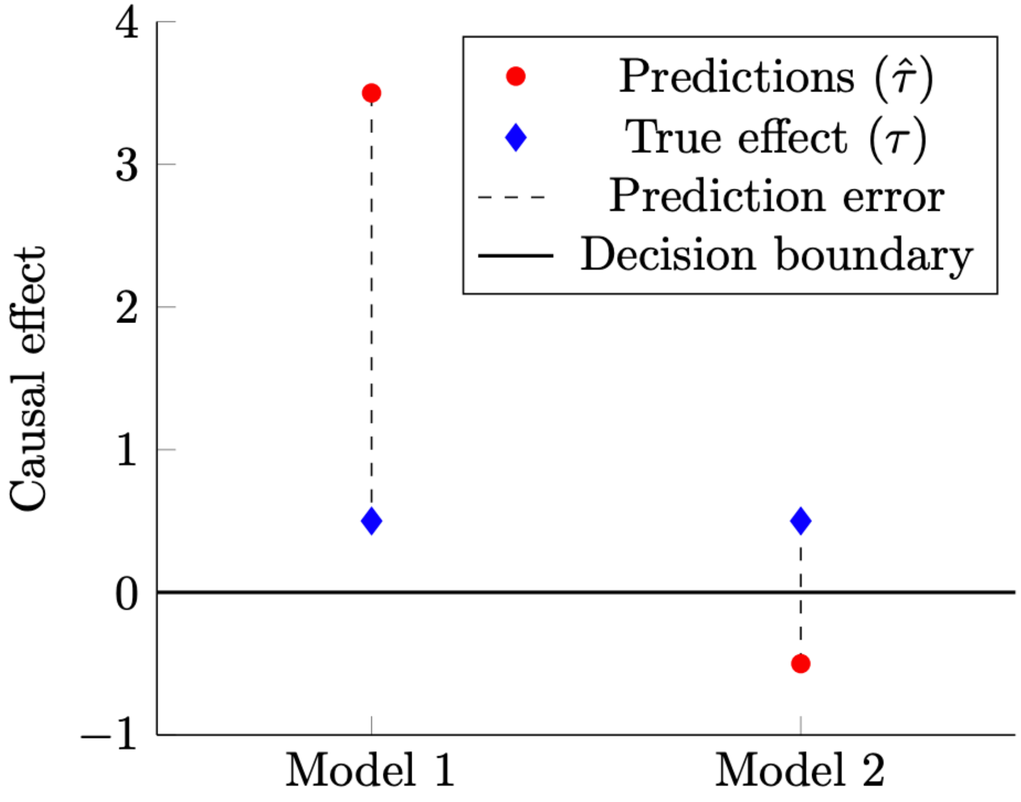


Figure 1 Comparison of the causal effect predictions made by two models. Model 1 has a larger prediction error than Model 2, but a smaller decision-making error because it predicts the sign of the causal effect correctly.



Mode 2 has lower Mean Squared Error — better estimate of causal effect . . .

$$\mathrm{MSE}(\hat{\tau}) = E[((Y(1) - Y(0)) - \hat{\tau}(X))^2]$$

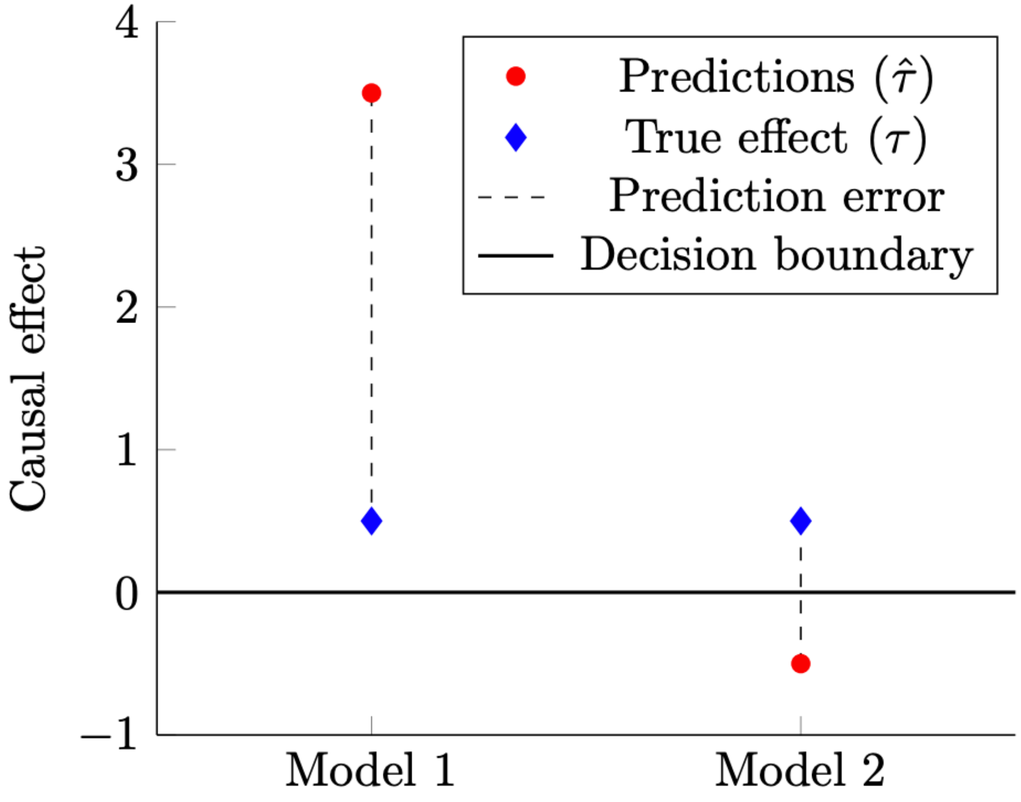


Mode 2 has lower Mean Squared Error — better estimate of causal effect . . .

$$\mathrm{MSE}(\hat{\tau}) = E[((Y(1) - Y(0)) - \hat{\tau}(X))^2]$$

. . . but higher regret. We chose the wrong treatment.

$$\mathrm{Regret}(\hat{a}) = E[Y(a^*(X)) - Y(\hat{a}(X))]$$



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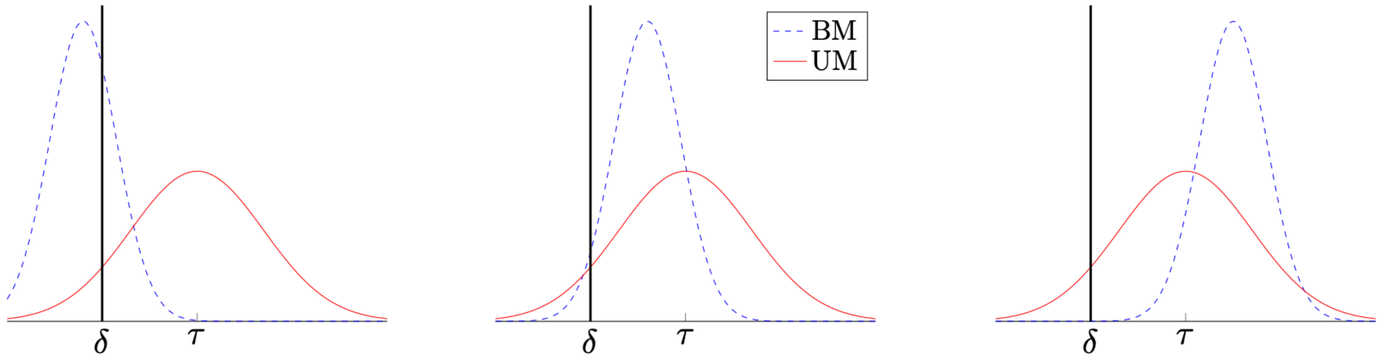
. . . but higher regret. We chose the wrong treatment.

$$\mathrm{Regret}(\hat{a}) = E[Y(a^*(X)) - Y(\hat{a}(X))]$$

More like a classification problem, then a regression problem.

Implication 2
Confounded data *might* not be that bad



(a) Large opposite bias (b) Small opposite bias (c) Reinforcing bias

Unbiased models with low confoundedness can be hard to estimate/gather data for

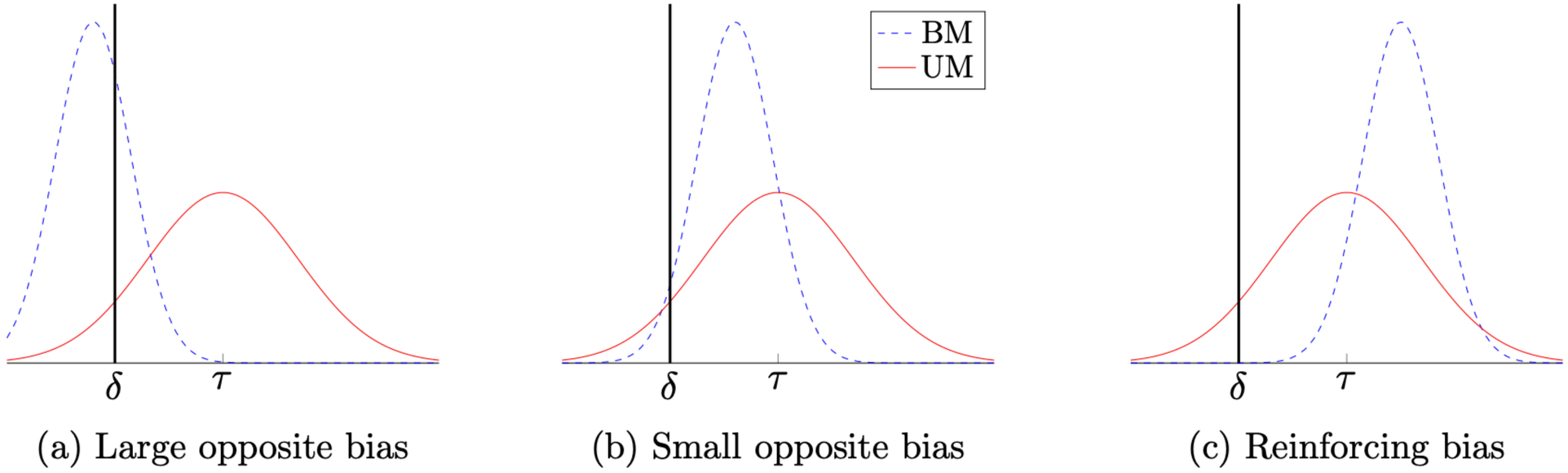


Figure 2 Sampling distributions of the causal effect estimate of a biased model (BM) and an unbiased model (UM). In this example (see details in the text), the correct decision is made when a model's estimate of τ is larger than δ. For decision making, a BM can be either worse (a), about the same (b), or even better (c) than a UM.

Confounded data may be bad for causal effect estimation, but enable optimal treatment assignment

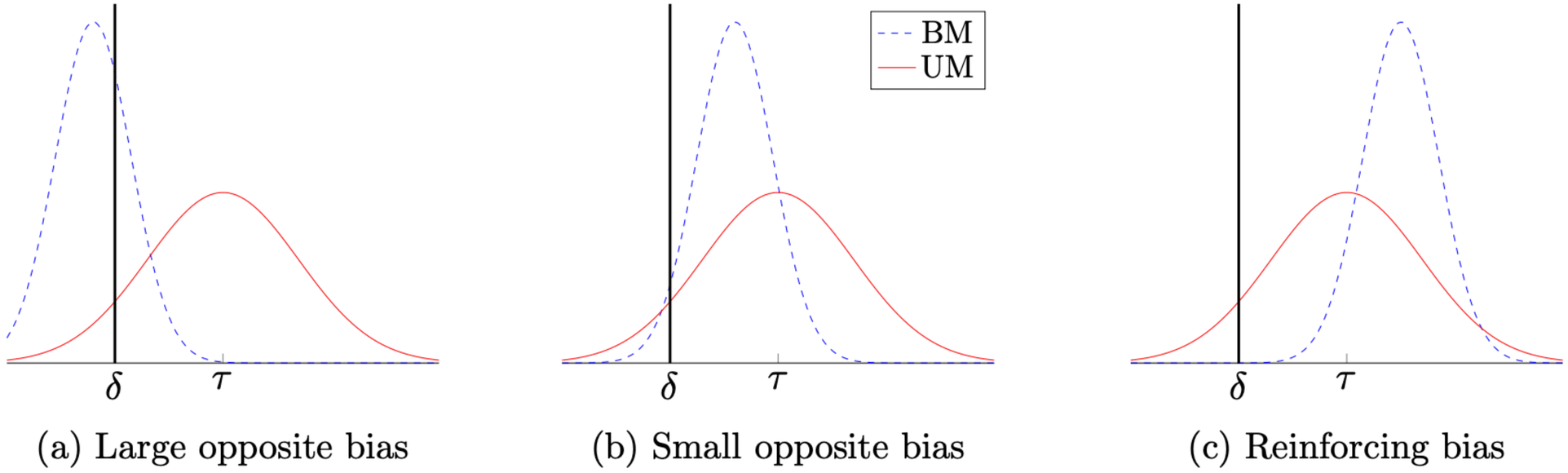
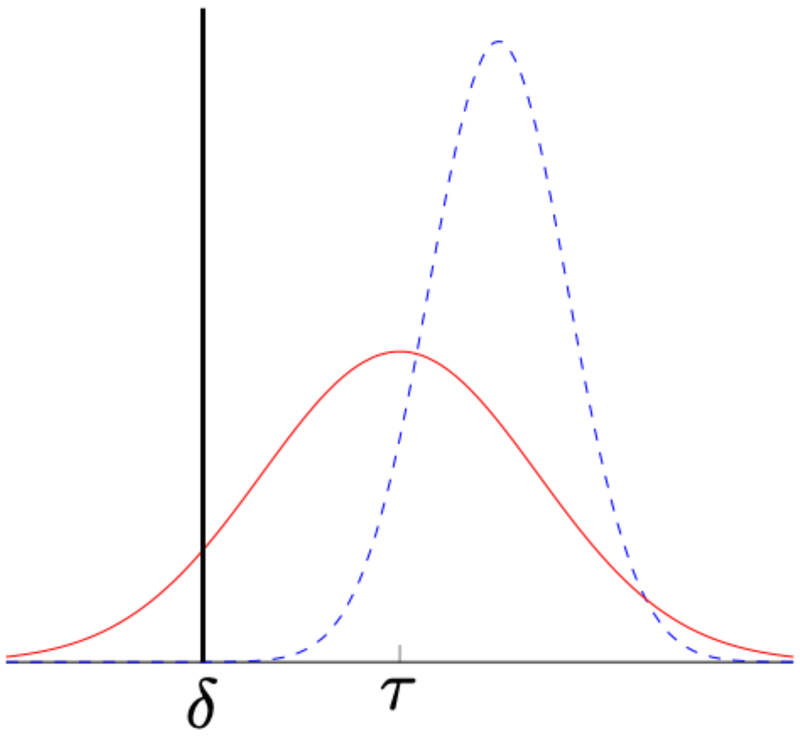


Figure 2 Sampling distributions of the causal effect estimate of a biased model (BM) and an unbiased model (UM). In this example (see details in the text), the correct decision is made when a model's estimate of τ is larger than δ. For decision making, a BM can be either worse (a), about the same (b), or even better (c) than a UM.

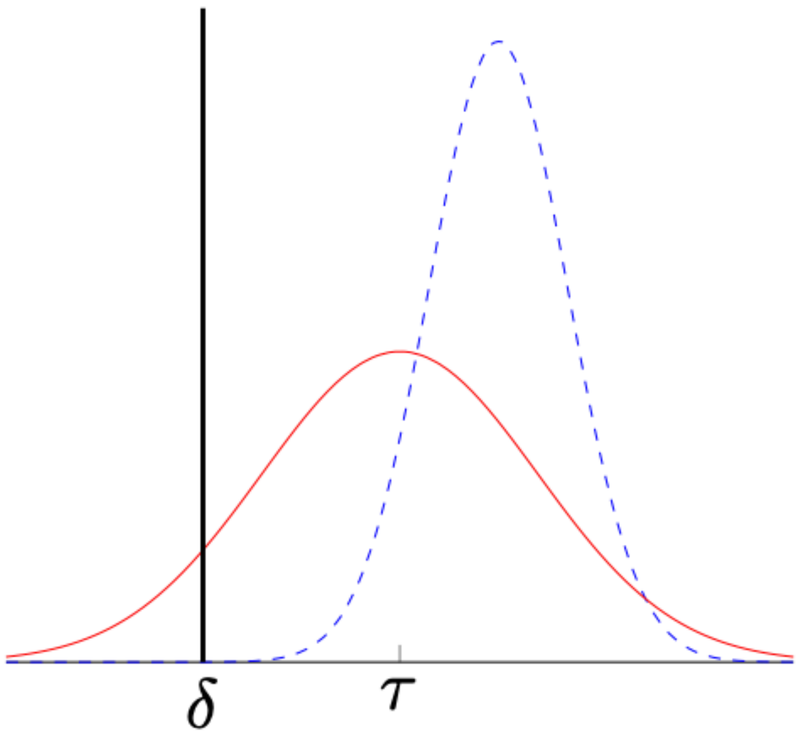
When might this happen?



(c) Reinforcing bias

When confounding is stronger for people that have larger effects.

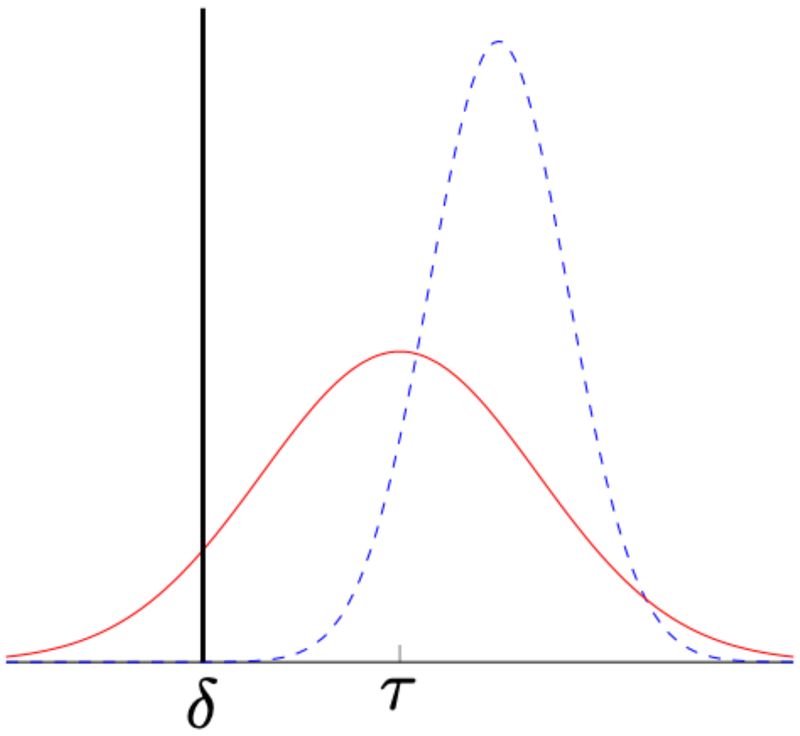
For example, when customers with bigger causal effects are also more strongly influenced by the treatment



(c) Reinforcing bias

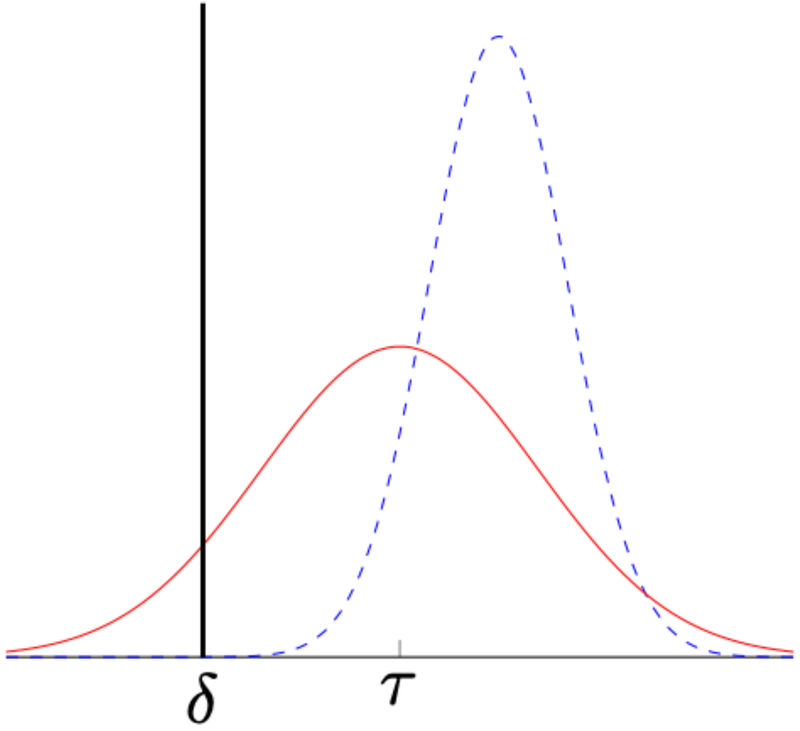
For example, when customers with bigger causal effects are also more strongly influenced by the treatment

I've seen this a lot.



(c) Reinforcing bias

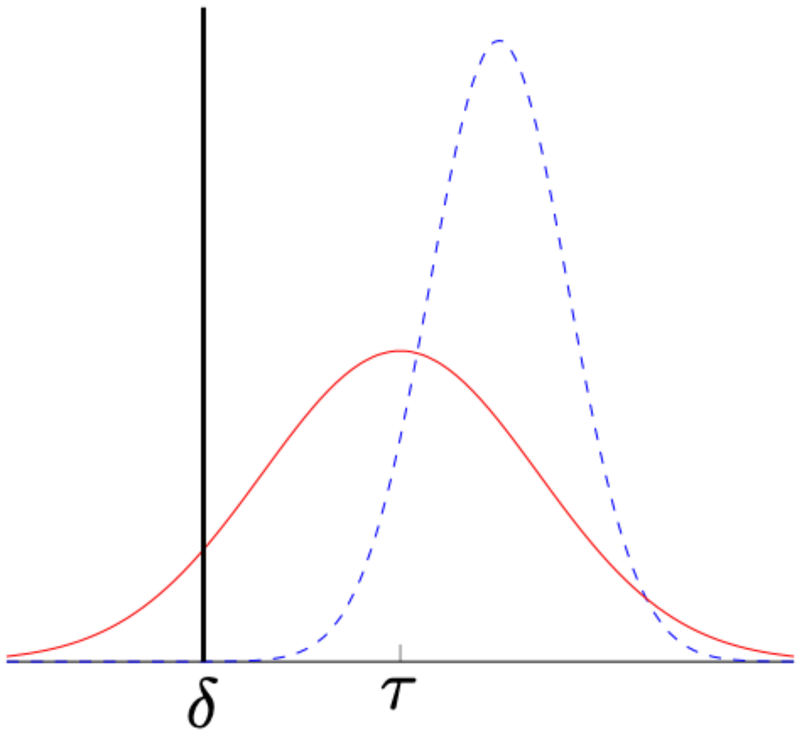
Biased, but lower variance can lead to better decisions than less biased but higher variance.



(c) Reinforcing bias

Gathering uncounfounded data/ adjusting for confounding can be **very expensive/time consuming**, but depending on the **nature of the confounding** and effectiveness of treatment can be a **sub-optimal use of time** compared to alternatives.

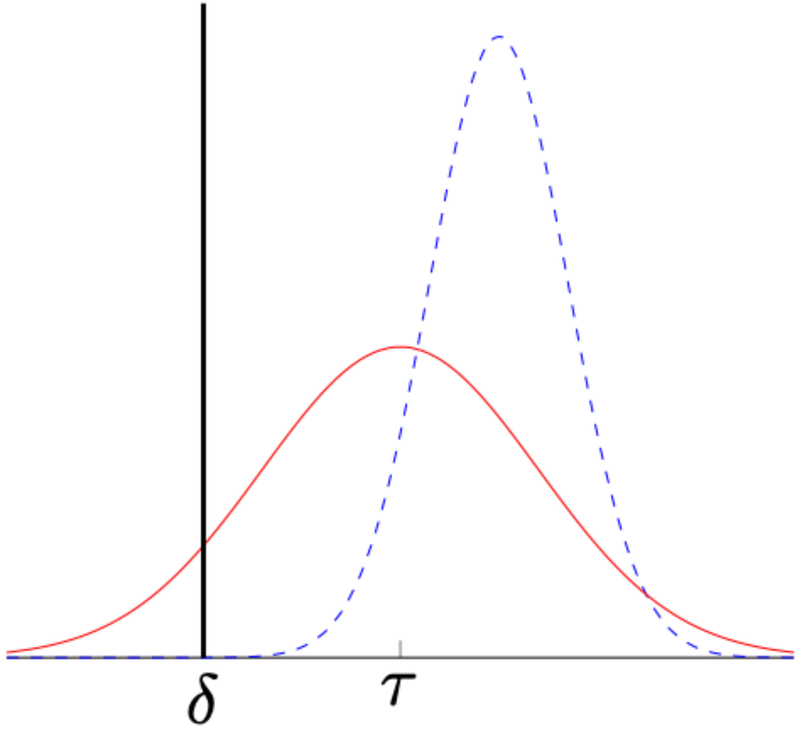
Implication 3
Use alternative (proxy) target variables



(c) Reinforcing bias

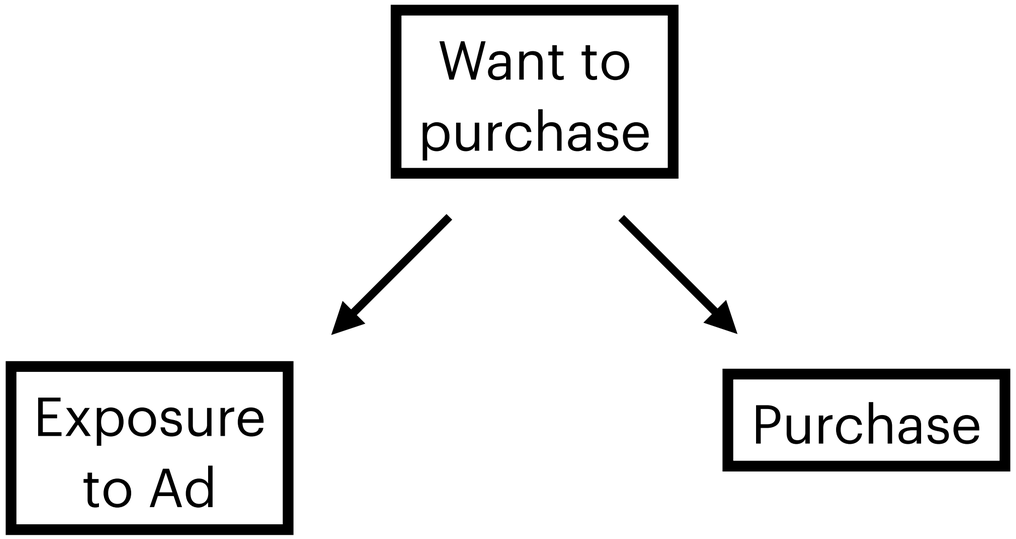
Proxy variable

Variable that is easy to measure/ predict and correlated with the treatment, such that it allows for correct treatment decisions.



(c) Reinforcing bias

But proceed with caution!



Modeling outcome prediction works best when

1. Outcomes and effects are correlated. For instance, Radcliffe and Surry (2011) find that marketing interventions often have the most positive effect on high-spending customers, and as a result, modeling causal effects does not benefit decision making as much in retail environments.

2. Outcomes are easier to estimate than causal effects, which may occur when data for one or more treatment conditions are limited (e.g., due to experimentation costs) or the signal-to-noise ratio is much larger for outcomes than for effects (as in our example).

3. Predictions are used to rank individuals. For example, if the goal is to intervene on the top-percent individuals with the largest effects, we only need to score and rank the individuals; whether the scores represent effect estimates is irrelevant.

Big take away 1

Know your objective function and gather costly information accordingly

Big takeaway 2

Causal effect estimation is needed to evaluate treatment policy regime, but not every treatment decision

Story 2

Induced structured utilities

or

How to get stuff done and waste less time in meetings

Review for you

Being a rational group and making rational group decisions may be harder than you think

Lots of possibilities for making it easier

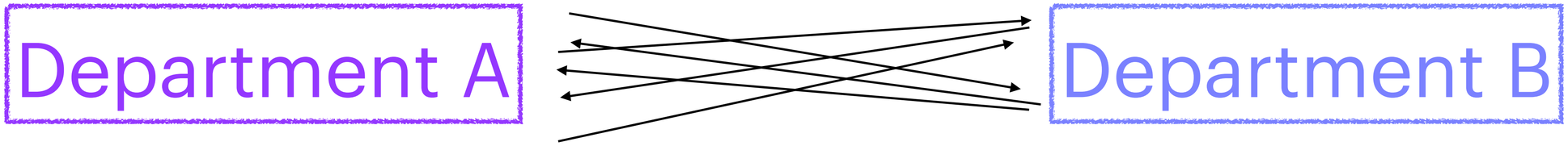
- → Restrict the choice domain: dictators, committees, departments, runoffs
- → Induce structured utilities, e.g. elite leadership, psychological heuristic

Early in my time in industry

Early in my time in industry

Constant conflict,
Constant meetings →
No delivery

My naive proposed solution



Some complicated system with
voting rules and auctions

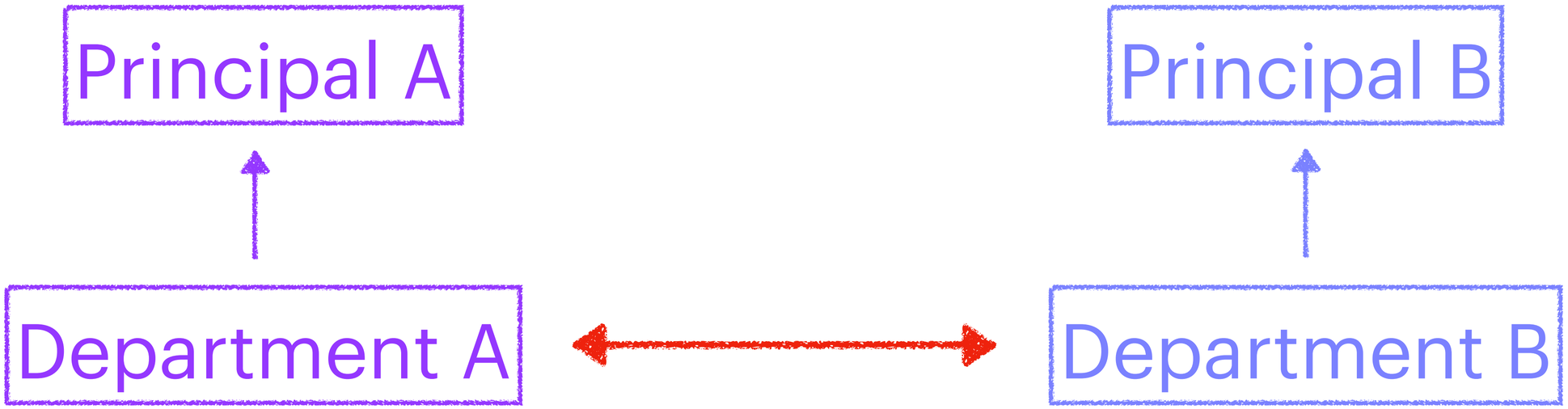
“What the hell are you doing?”

— feedback to me from a senior mentor

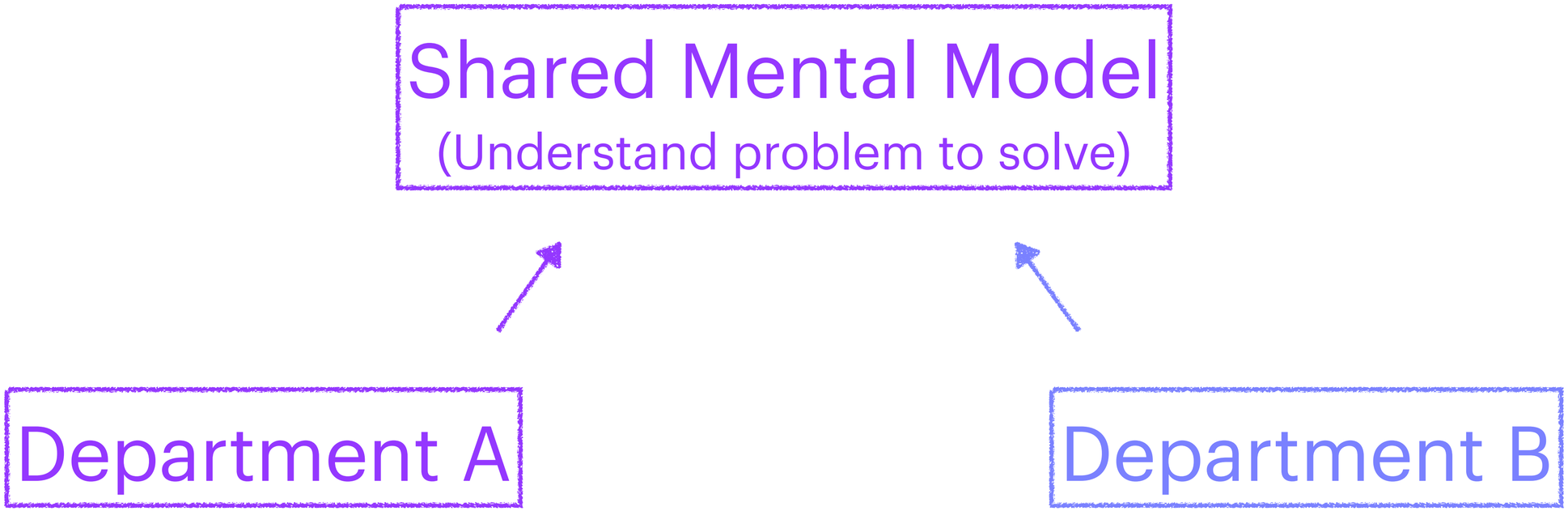
The problem isn’t that they don’t have a good voting system,

it’s that they <u>don’t share a common understanding</u> of the problem they are trying to solve.

Square of Despair



Solution


Shared Mental Model
(Understand problem to solve)
Department A
Department B

AKA

Being a rational group and making rational group decisions may be harder than you think

I originally focused here

ssibilities for making it easier

- → Restrict the choice domain: dictators, committees, departments, runoffs
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But there is a lot more leverage here

Proposition

Mental Model > Org Structure/Rewards/Process

evp

Our Europe – our Strength For Security, Peace and Prosperity.

Short Manifesto for the European Elections

CDU CSU

evp

Our Europe – our Strength For Security, Peace and Prosperity.

Short Manifesto for the European Elections

CDU CSU

Real change in our relationship with the European Union

Our commitment to you:

For too long, your voice has been ignored on Europe. We will:

- *give you a say over whether we should stay in or leave the EU, with* ***an in-out referendum by the end of 2017***
- *commit to keeping the pound and* ***staying out of the Eurozone***
- ***reform the workings of the EU****, which is too big, too bossy and too bureaucratic*
- ***reclaim power from Brussels*** *on your behalf and* ***safeguard British interests*** *in the Single Market*
- *back businesses to create jobs in Britain by* ***completing ambitious trade deals and reducing red tape****.*

Proposition

Mental Model > Org Structure/Rewards/Process

Requires a lot of work

Reinforce effective mental models

Proposition

Mental Model > Org Structure/Rewards/Process

Requires a lot of work

Story 3

Utility elicitation

or

How you develop a shared understanding matters

Review for you

(Utility elicitation may be as hard as probability elicitation)

Digression: many of the most important problems are Wicked Hard Problems (Rittle and Weber 1973)

Lots of definitions, but wicked hard problems include having:

- Innumerable causes
- Time constraints
- Shifting conditions
- Tough to even describe
- Don’t have a right answer

A mental model about creating mental models

Rule of Thumb 1:

Stay humble, the real problem is rarely the problem you think it is

Rule of Thumb 2

People are more likely to adopt a mental model if they feel involved/understand/trust the process for developing it

Two products from two teams

Team A

Team B

Overlapping problem & solutions

Two products from two teams

Team A

Team B

Each team was focused on delivering some goals for roadmaps they had made separately

Dictatorial

Team A

Team B

"Just work together!”

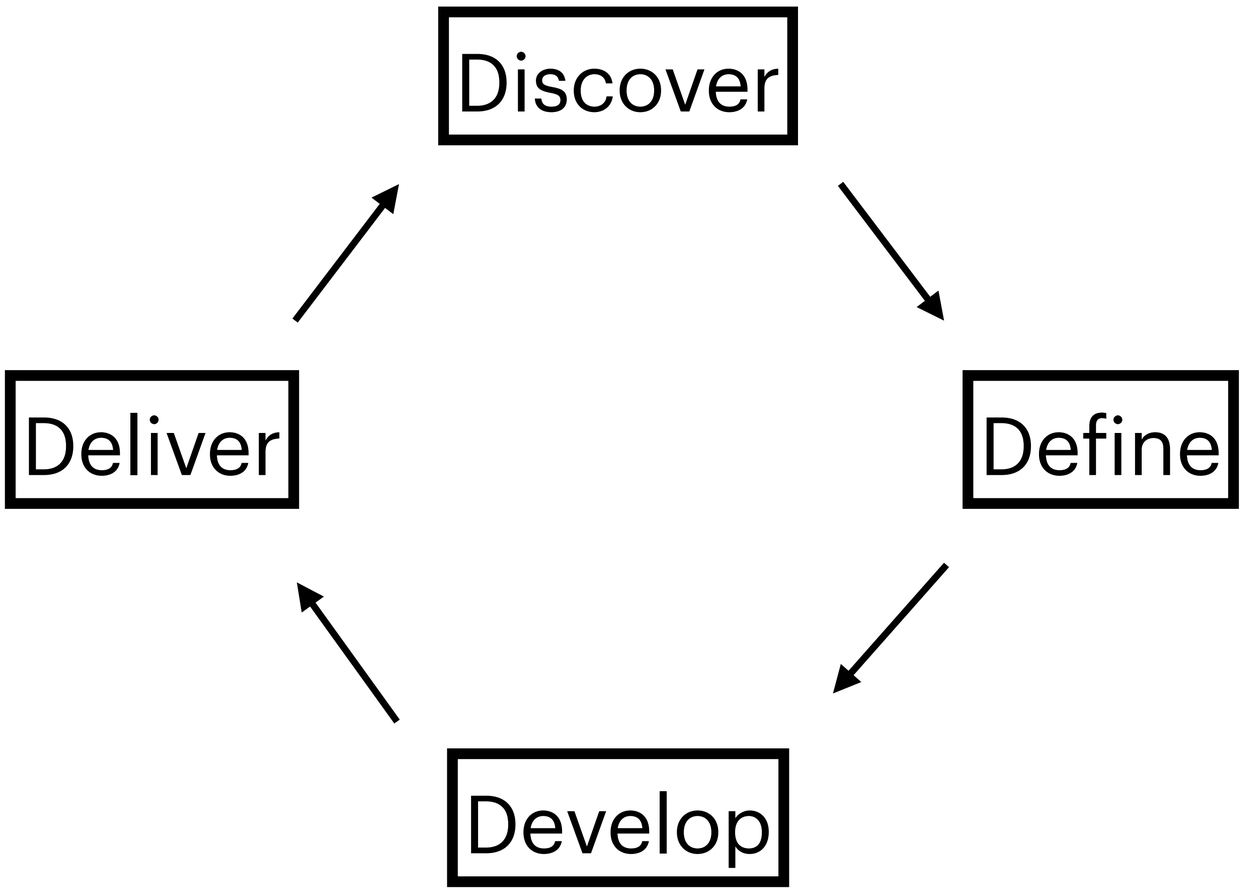
Alternative: Develop a shared understanding

Team A

Team B

"Each person take 10 minutes. Identify what problem you are trying to solve."

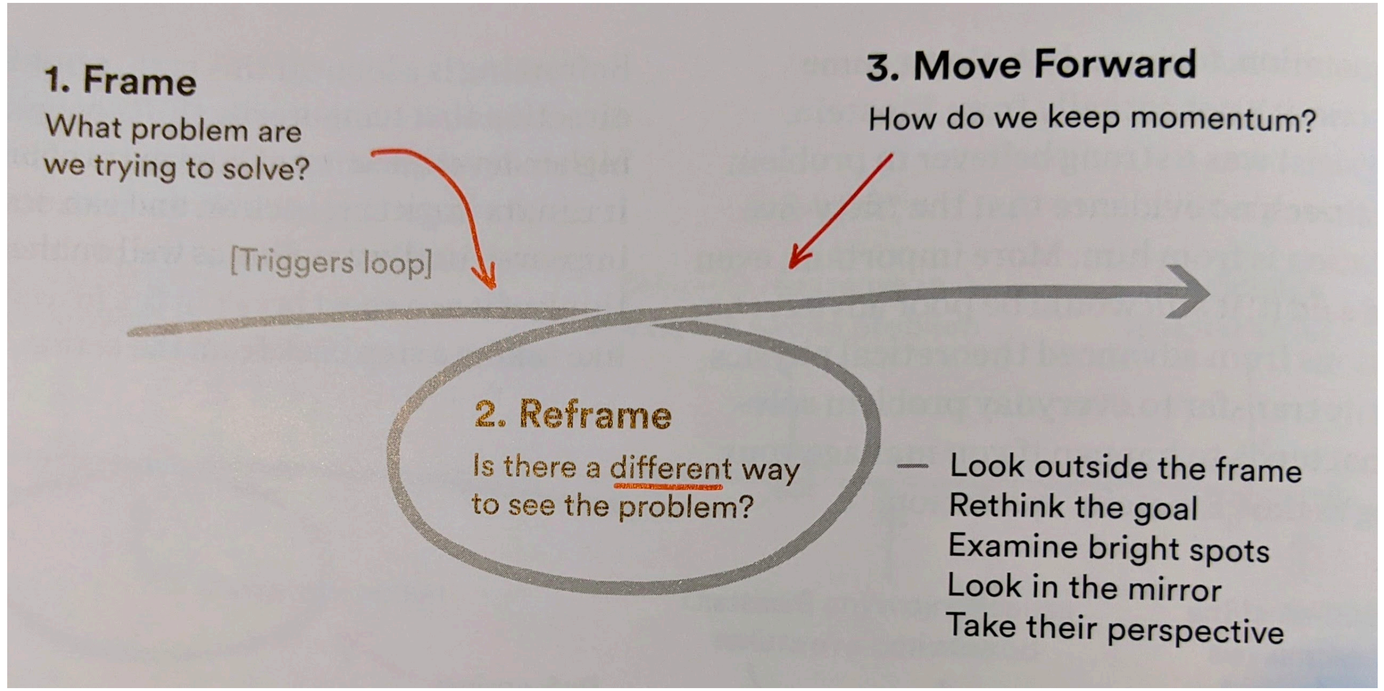
Design Process



Brown and IDEO

What do we want to achieve?

What problem are we solving?



Edell-Wedellsborg (2020)

Q&A