Computational Personalization: Data science methods for personalized health

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"Providing the right treatment to the right patient, at the right dose at the right time"

Outline:

- Defining personalized healthcare
- Analysis of the Randomized Controlled Trial (RCT)
- A computational approach to personalization

Defining personalized healthcare

$$\{\text{patient}, \text{time}, \text{treatment}, \text{dose}\} \xrightarrow{f} \text{outcome}.$$

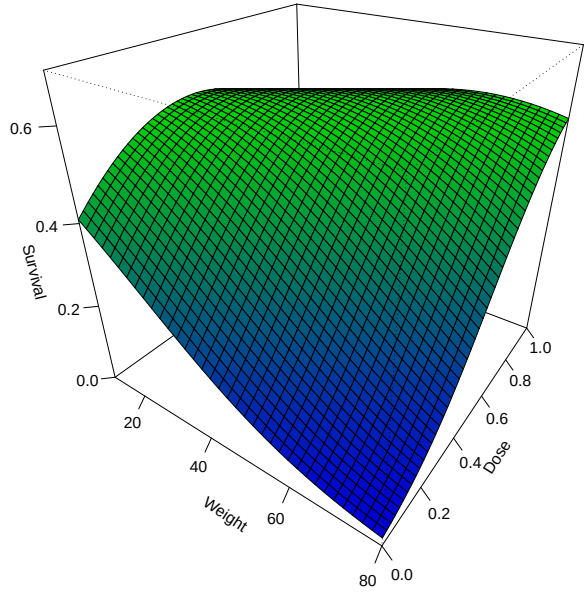
$$
\begin{aligned}
\text{outcome} &\overset{f}{\leftarrow} \{\text{patient}, \text{time}, \text{treatment}, \text{dose}\} \\
r &\overset{f}{\leftarrow} \{\text{patient}, \text{time}, \text{treatment}, \text{dose}\} \\
r &\overset{f}{\leftarrow} \{x, a\} \\
r &= f(x, a; \theta),
\end{aligned}
$$

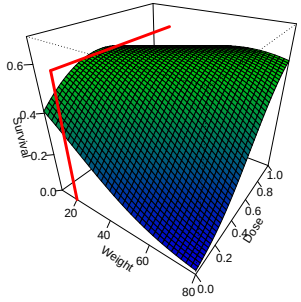
The reward, r, is a function of the context, x, (the characteristics of the patient), and the actions, a, (the treatment).

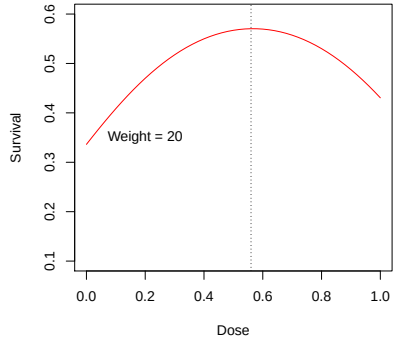
$$\arg\max_{a} f(x, a)$$

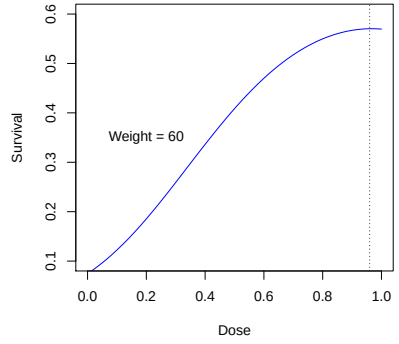
$$\sum_{t=1}^{T} \arg\max_{a_t} f(x_t, a_t),$$

We choose the treatments such that we maximize the reward over all treatments.


Survival
0.0
0.2
0.4
0.6
Weight
20
40
60
80
Dose
0.0
0.2
0.4
0.6
0.8
1.0


Survival
0.0
0.2
0.4
0.6
Weight
20
40
60
80
Dose
0.0
0.2
0.4
0.6
0.8
1.0


Weight = 20
Survival
0.1
0.2
0.3
0.4
0.5
0.6
Dose
0.0
0.2
0.4
0.6
0.8
1.0


Weight = 60
Survival
0.1
0.2
0.3
0.4
0.5
0.6
Dose
0.0
0.2
0.4
0.6
0.8
1.0

Why is this difficult?

- High dimensional learning from noisy data

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- Learning causal relationships

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- Learning causal relationships
- Balancing learning and earning

The Randomized Controlled Trial

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  1. Transparent and understandable
  2. Causal effects through randomization
  3. Practically appealing

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  1. Transparent and understandable
  2. Causal effects through randomization
  3. Practically appealing
- Disadvantages:
  1. Examines a very small number of options
  2. Poor balancing of earning and learning
  3. Inability to (re-)use data after trial

A computational approach

Disadvantages:

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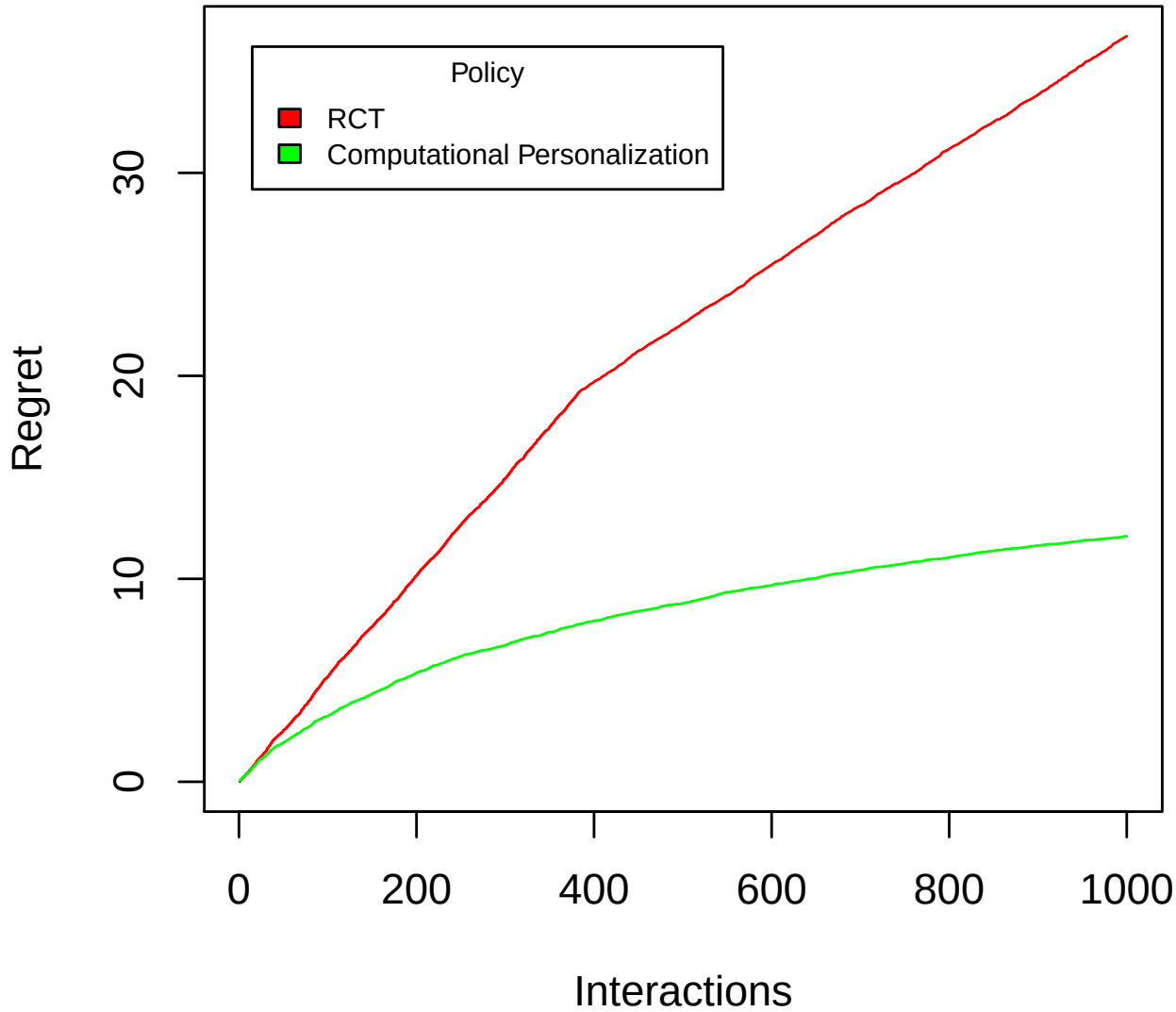
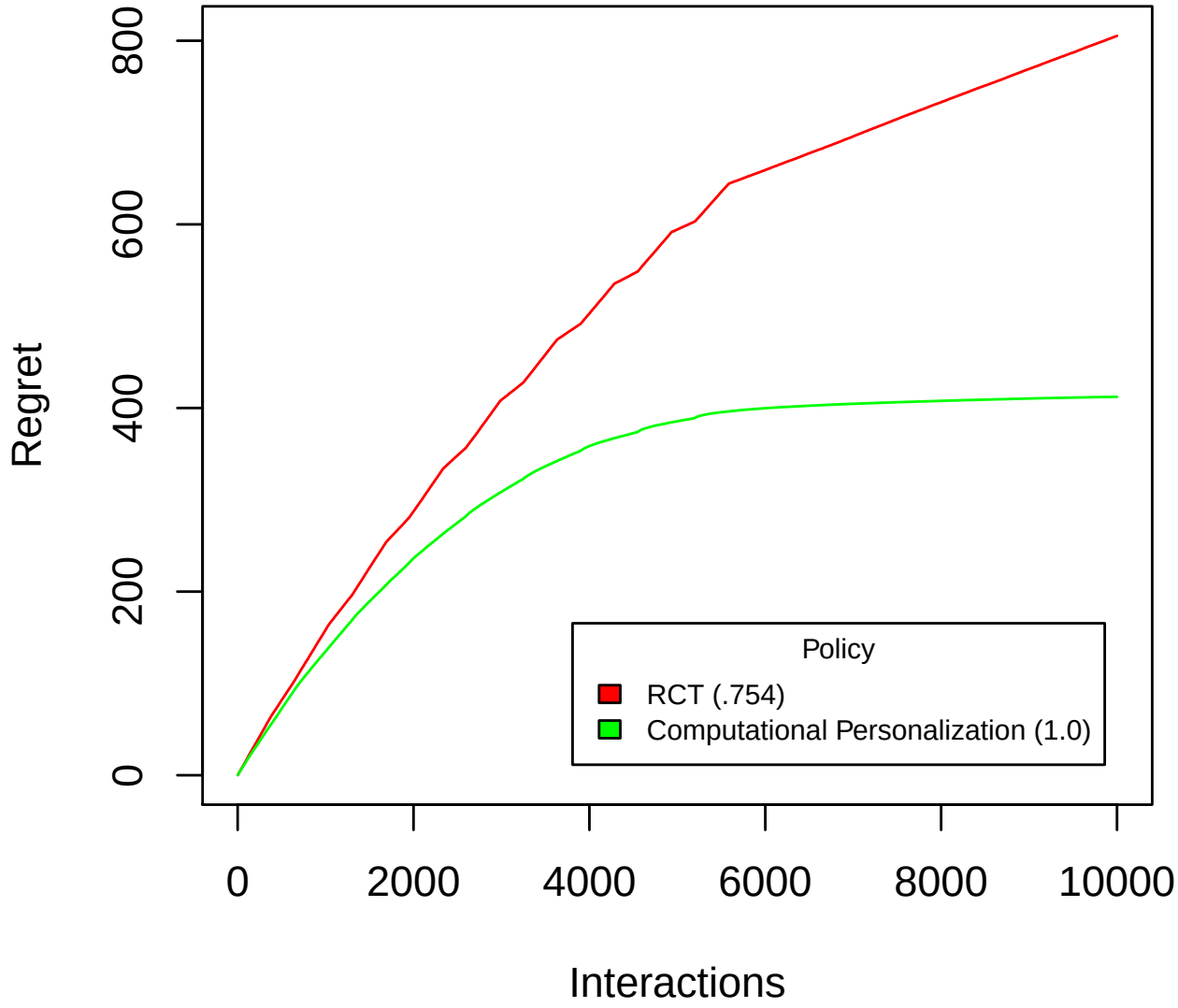
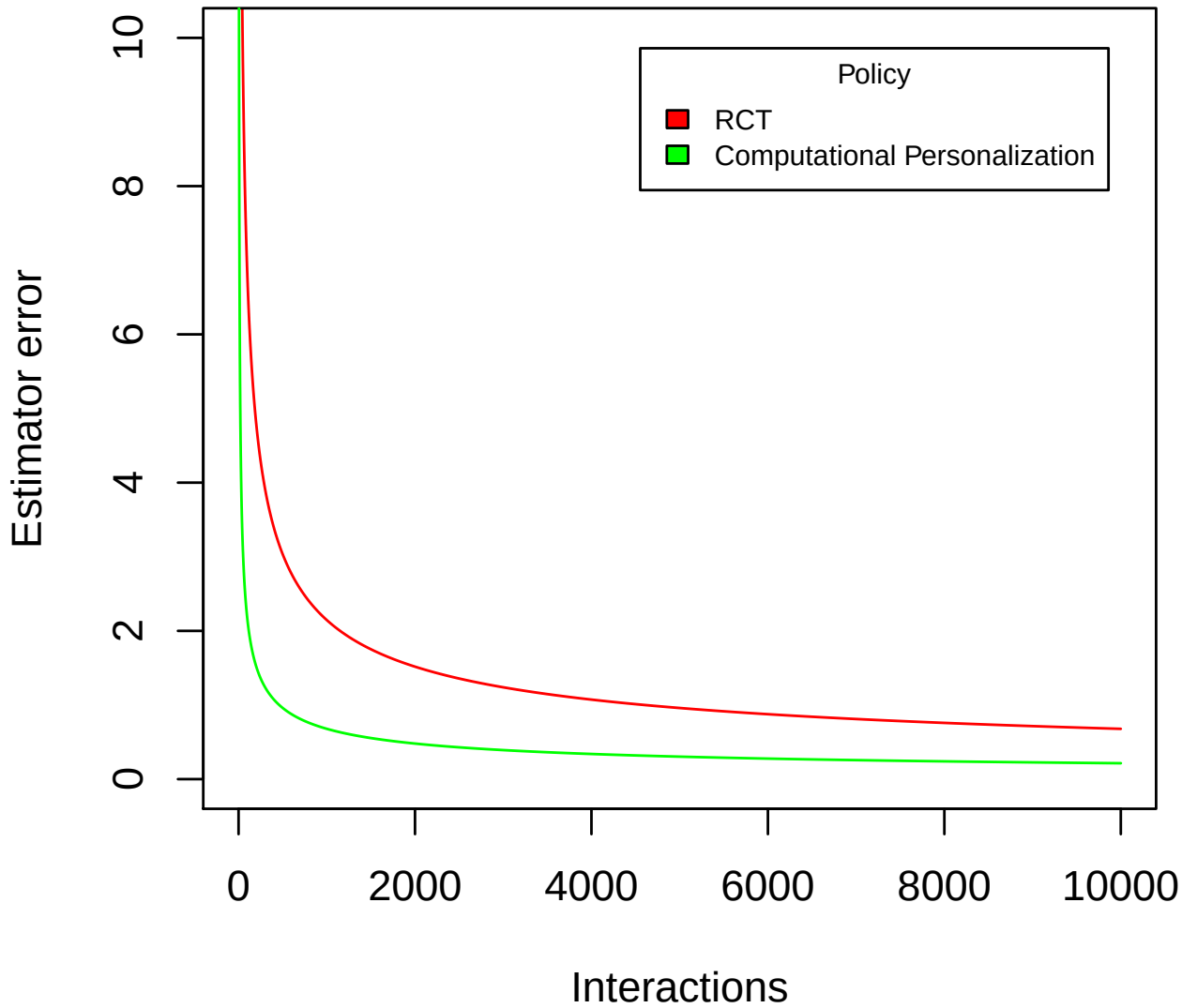
1. Loss of transparency: black-box
2. Practical challenges: no deterministic choices
3. Causal effects not guaranteed: need additional analysis
4. Computationally challenging

Why would we want this?


Policy
RCT
Computational Personalization
Regret
0
10
20
30
0
200
400
600
800
1000
Interactions


Regret
0
200
400
600
800
0
2000
4000
6000
8000
10000
Interactions
Policy
RCT (.754)
Computational Personalization (1.0)


Policy
RCT
Computational Personalization
Estimator error
0
2
4
6
8
10
0
2000
4000
6000
8000
10000
Interactions

Conclusion