VIDEO QUALITY IMPACTS VIEWER BEHAVIOR:
INFERRING CAUSALITY USING QUASI-EXPERIMENTAL DESIGNS

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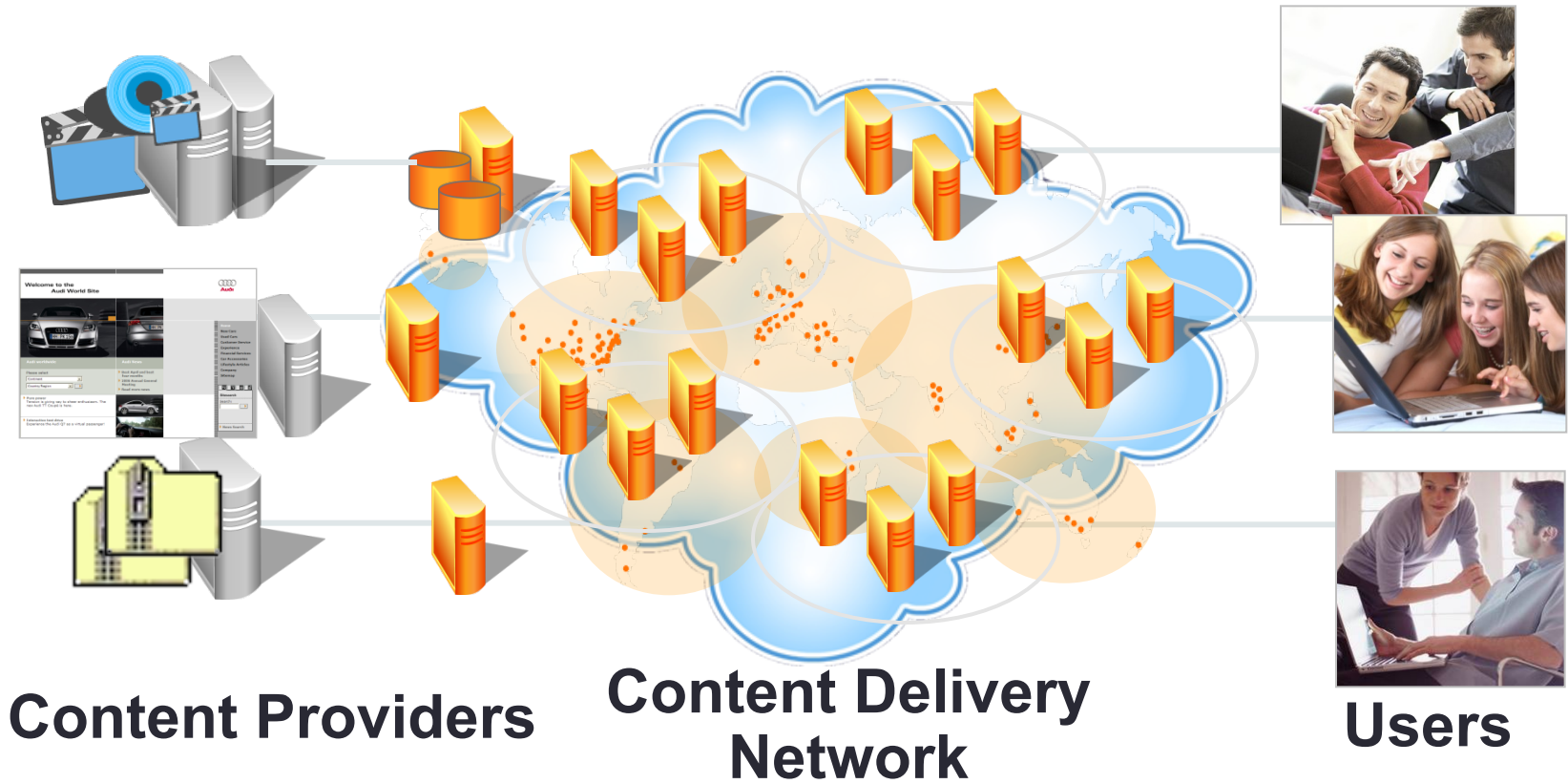UMass, Amherst & Akamai

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Joint work with S. Shunmuga Krishnan (Akamai).
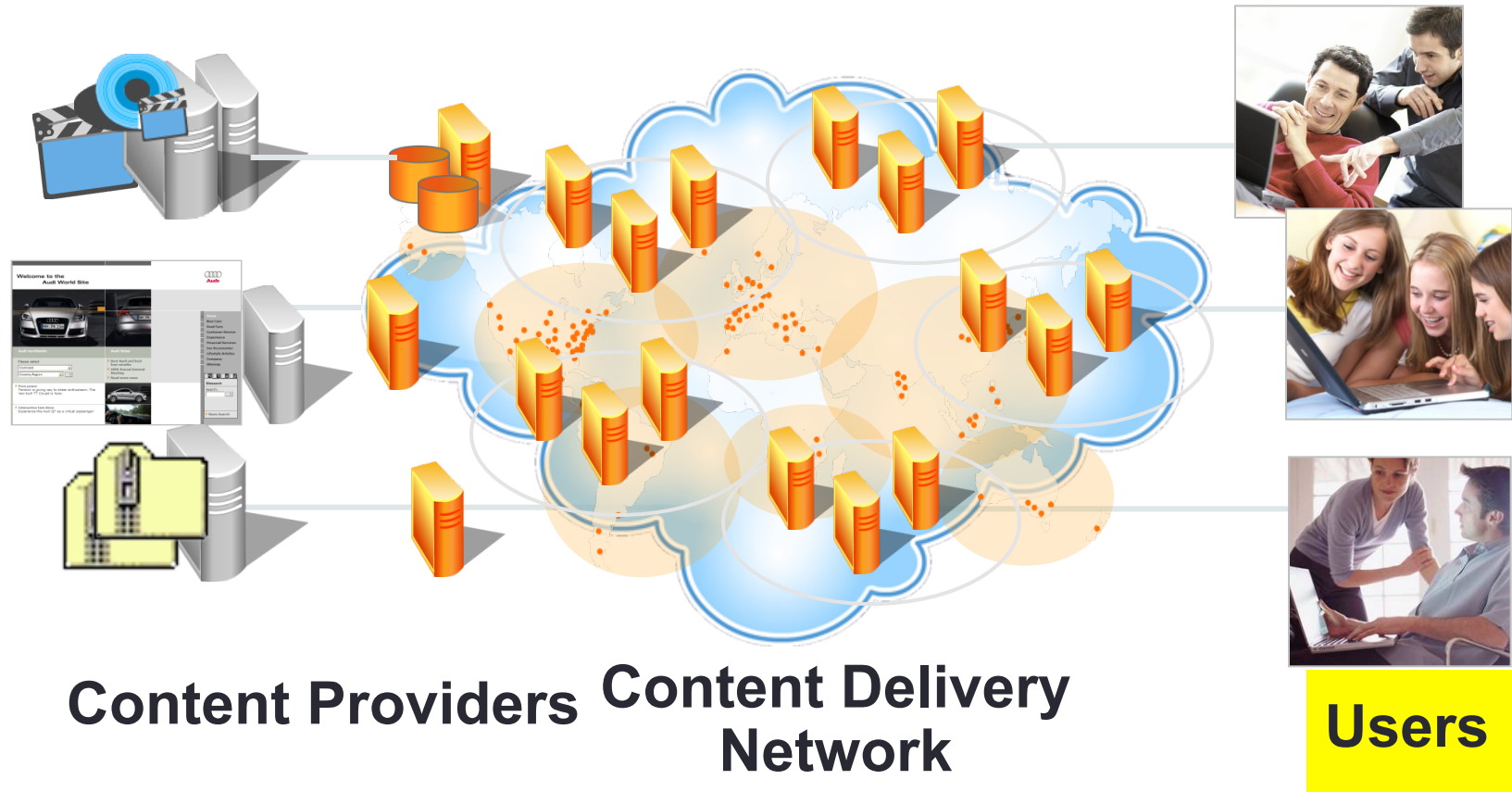
The Video Delivery Ecosystem

Content Providers

Content Delivery Network

Users

The Video Delivery Ecosystem

Content Providers   **Content Delivery Network**   **Users**

- Media Providers: News, Movies, Entertainment, Sports, Television, …

The Video Delivery Ecosystem

Content Providers

Content Delivery Network

Users

- Different devices (desktop, mobile,…)
- Different geographies
- Different connectivity (cellular, DSL, cable, fiber, …)

The Video Delivery Ecosystem
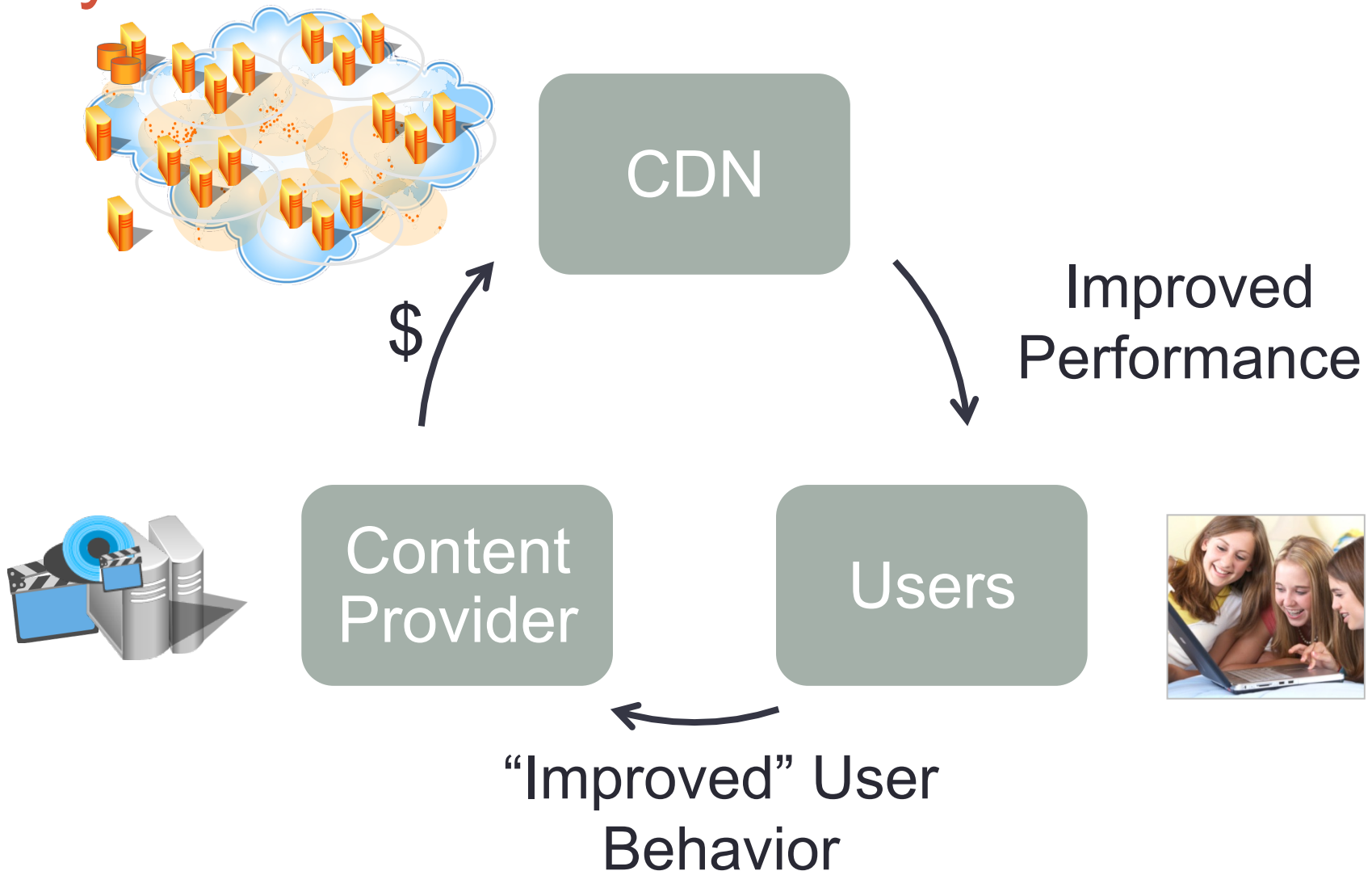

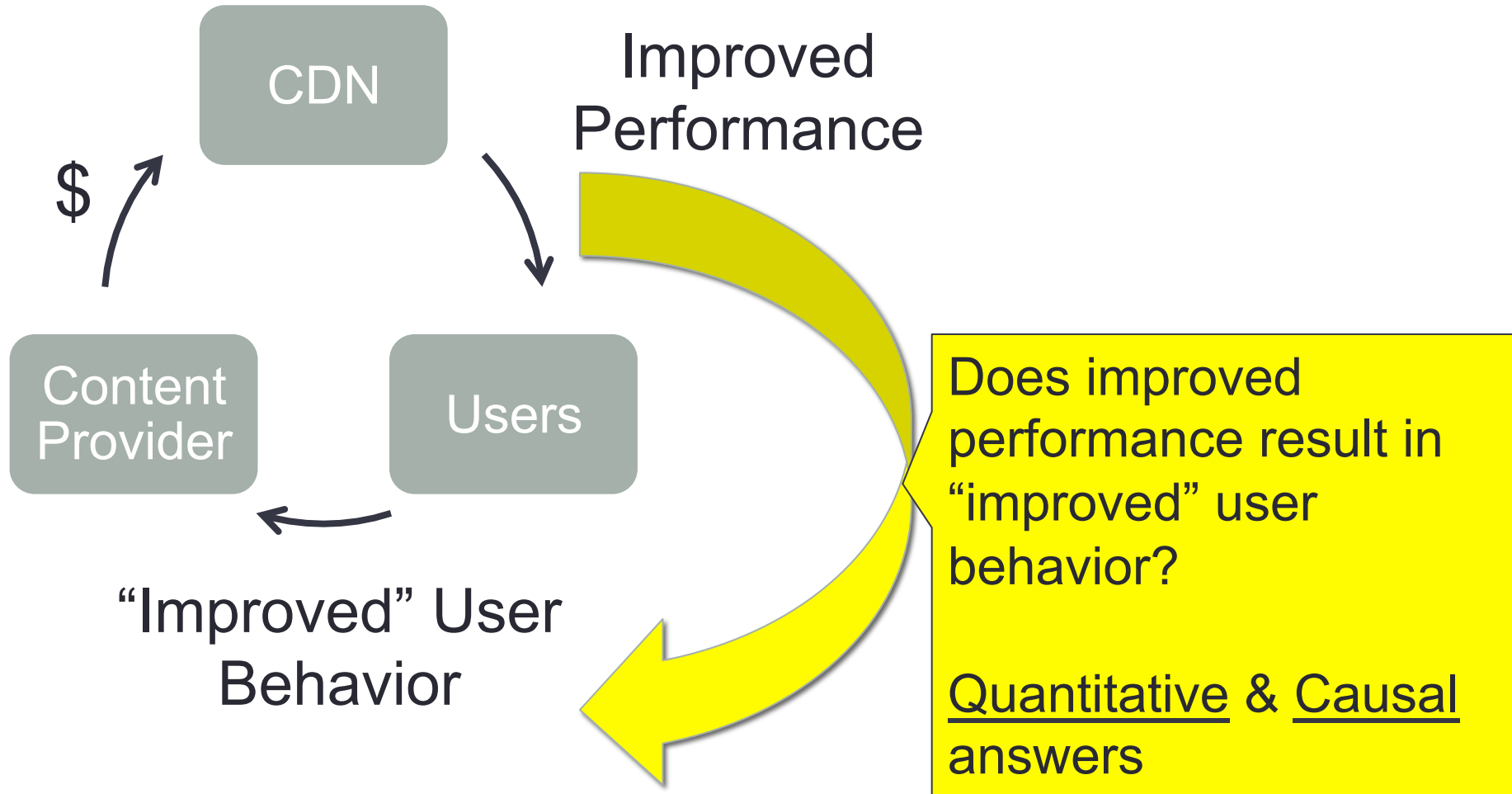**Content Providers**   **Content Delivery Network**   **Users**
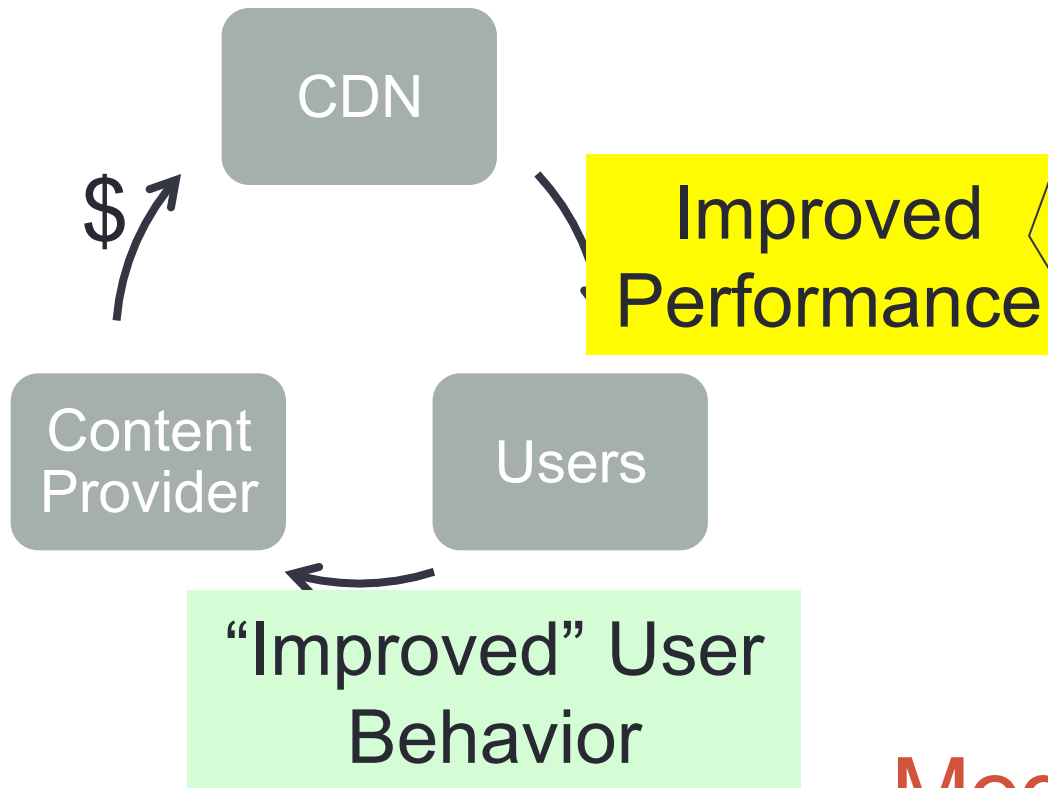
Example: Akamai Network
- 100,000+ servers in 1000+ clusters in 1000+ networks in 70+ countries serving trillions of requests a day.

Video Delivery Economics: The Virtuous Cycle

The *Most* Important and *Least* Understood Link

CDN

$

Content Provider

Users

Improved Performance

"Improved" User Behavior

Does improved performance result in "improved" user behavior?

Quantitative & Causal answers

CDN

Content Provider

Users

$

Improved Performance

1. <u>Availability</u>: Viewers download video without failure.
2. <u>Startup Delay:</u> Video starts without much delay.
3. <u>Rebuffers:</u> Video plays without freezes.

"Improved" User Behavior

Media & Entertainment
(Ad-supported or Subscription)

1. <u>Abandonment</u>: Reduce viewers who abandon without viewing the video.
2. <u>Engagement</u>: Viewers watch videos longer.
3. <u>Repeat Viewership:</u> Viewers keep coming back to site to watch more videos.
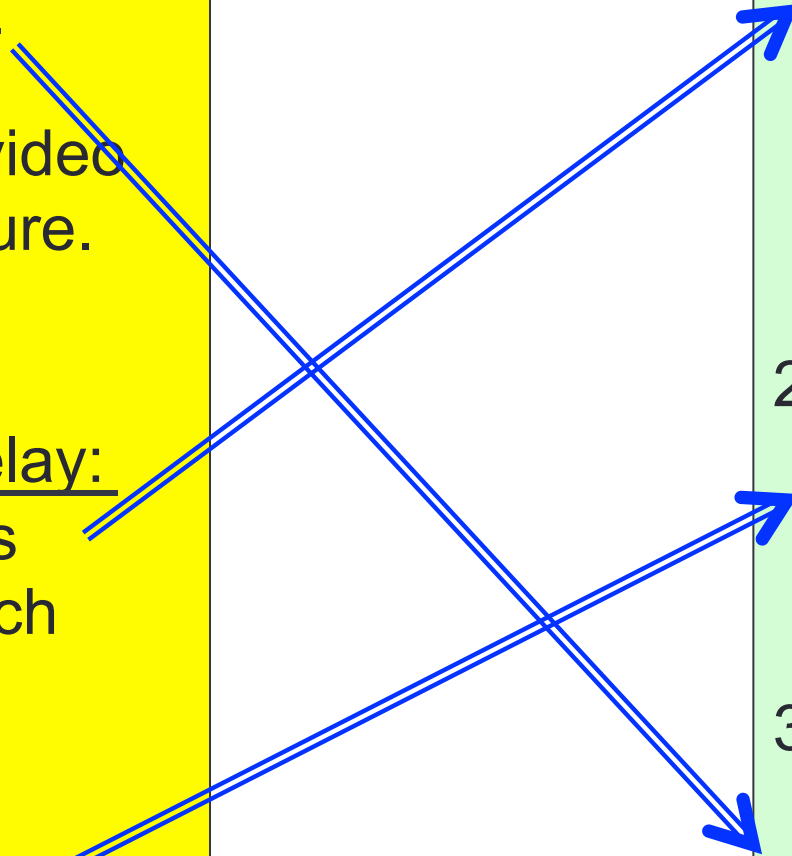
VIDEO PERFORMANCE

1. <u>Availability:</u> Viewers download video without failure.

2.   <u>Startup Delay:</u> Video starts without much delay.

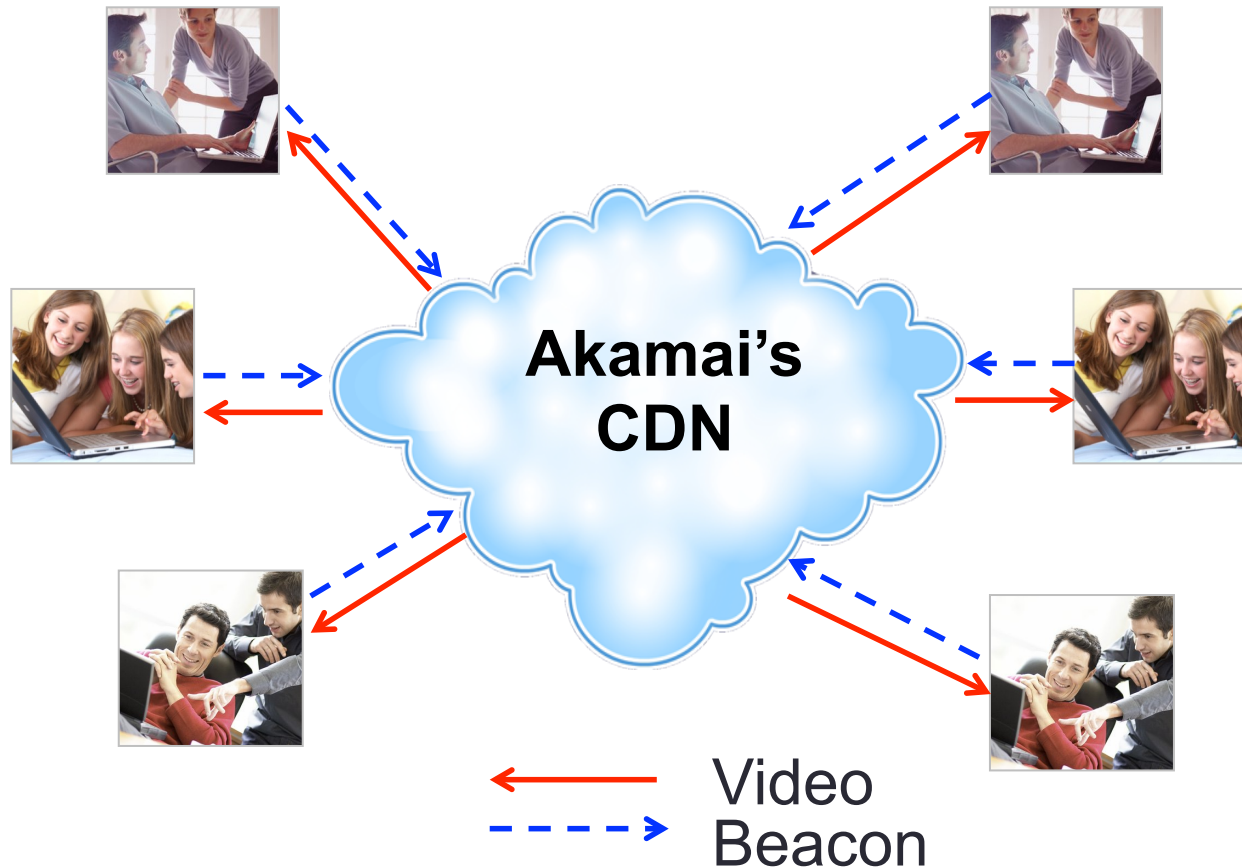3. <u>Rebuffers:</u> Video plays without freezes.

VIEWER BEHAVIOR

1. <u>Abandonment:</u> Reduce viewers who abandon without viewing the video.

2. <u>Engagement:</u> Viewers watch videos longer.

3. <u>Repeat Viewership:</u> Viewers keep coming back to site to watch more videos.

The Data

Akamai's Client-side Player Plugin

Video
Beacon

Globally-deployed Akamai plugin that runs inside the media player and reports viewer actions and performance metrics via ``beacons'' from millions of actual end-users around the world.
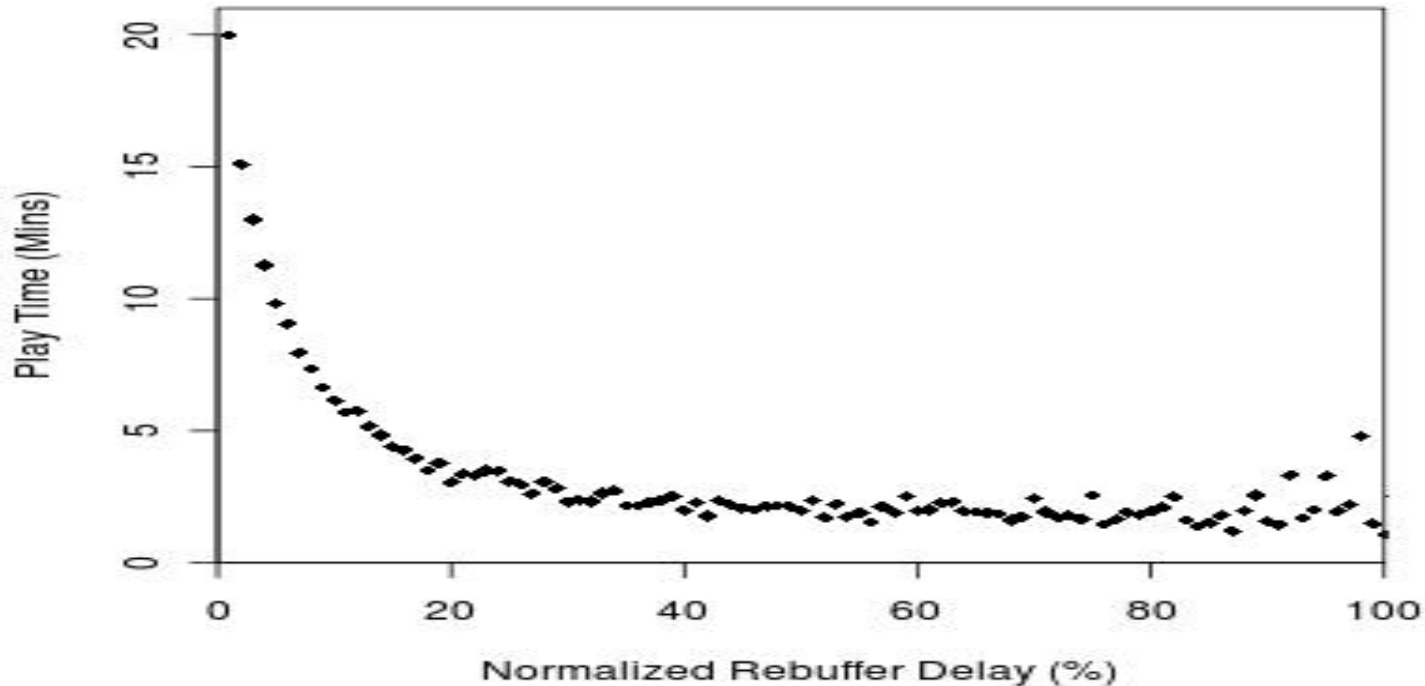
Our Data Set

One of the most extensive data sets *ever* analyzed for this purpose.

Analyzed data from the widely-deployed Akamai's client-side plug-in.

- 6.7 million unique viewers
- 23 million views
- 216 million minutes of video played
- 102 thousand unique videos
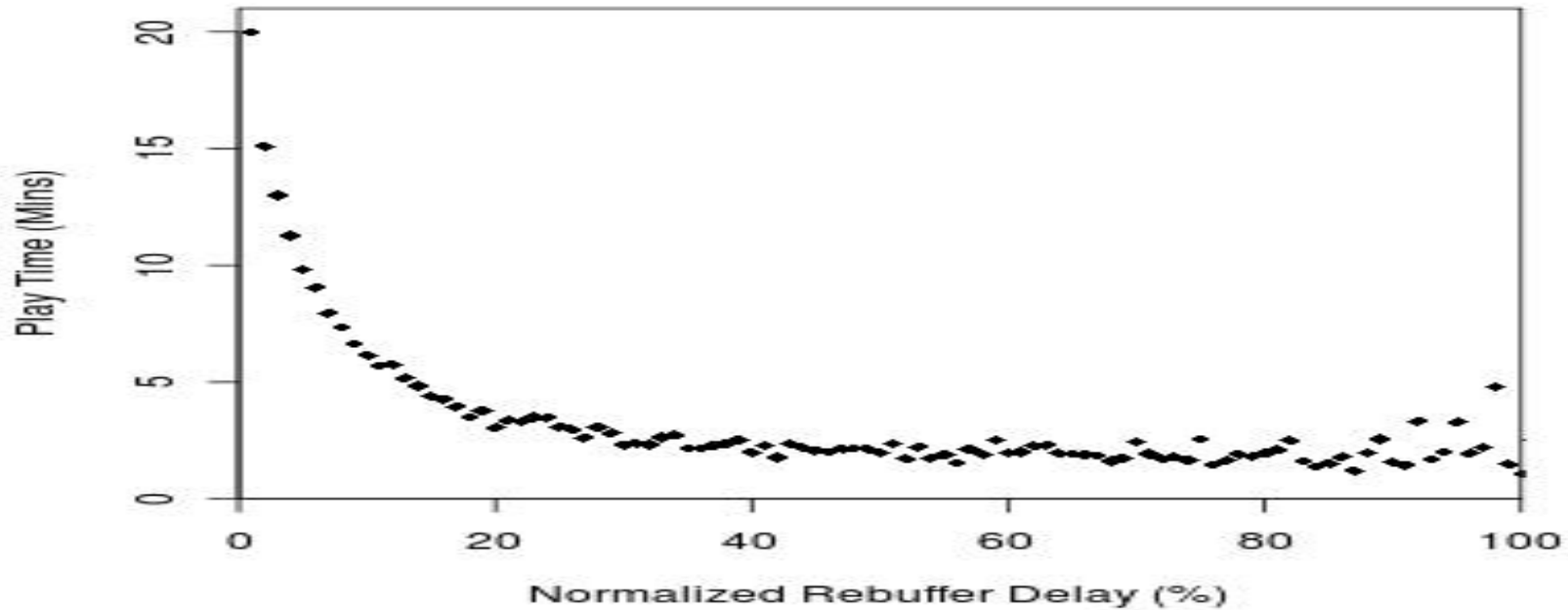- Viewers in three continents (NA, Europe, and Asia)

The Techniques

Correlation

Hypothesis: Video rebuffering causes viewers to watch less.

Strong negative rank correlation. Kendall correlation = -0.421.

Correlation

Threat to causality: Users who are better off can afford better network connectivity, resulting in less rebuffering. They can also afford access to more interesting content.

Correlation ≠ Causality

<u>Correlation:</u> A and B "move together".

versus

<u>Causality:</u> A causes B to occur.

<u>Threats to Causality:</u> Confounding variables that could account for both A and B.

<u>Typical confounding variables:</u> Connectivity, Content, Geography.

Randomized Experiments

Idea: Equalize the impact of confounding variables using random ~~(Fisher 1937)~~

1. Randomly assign ~~a group to~~ receive "treatment" A.
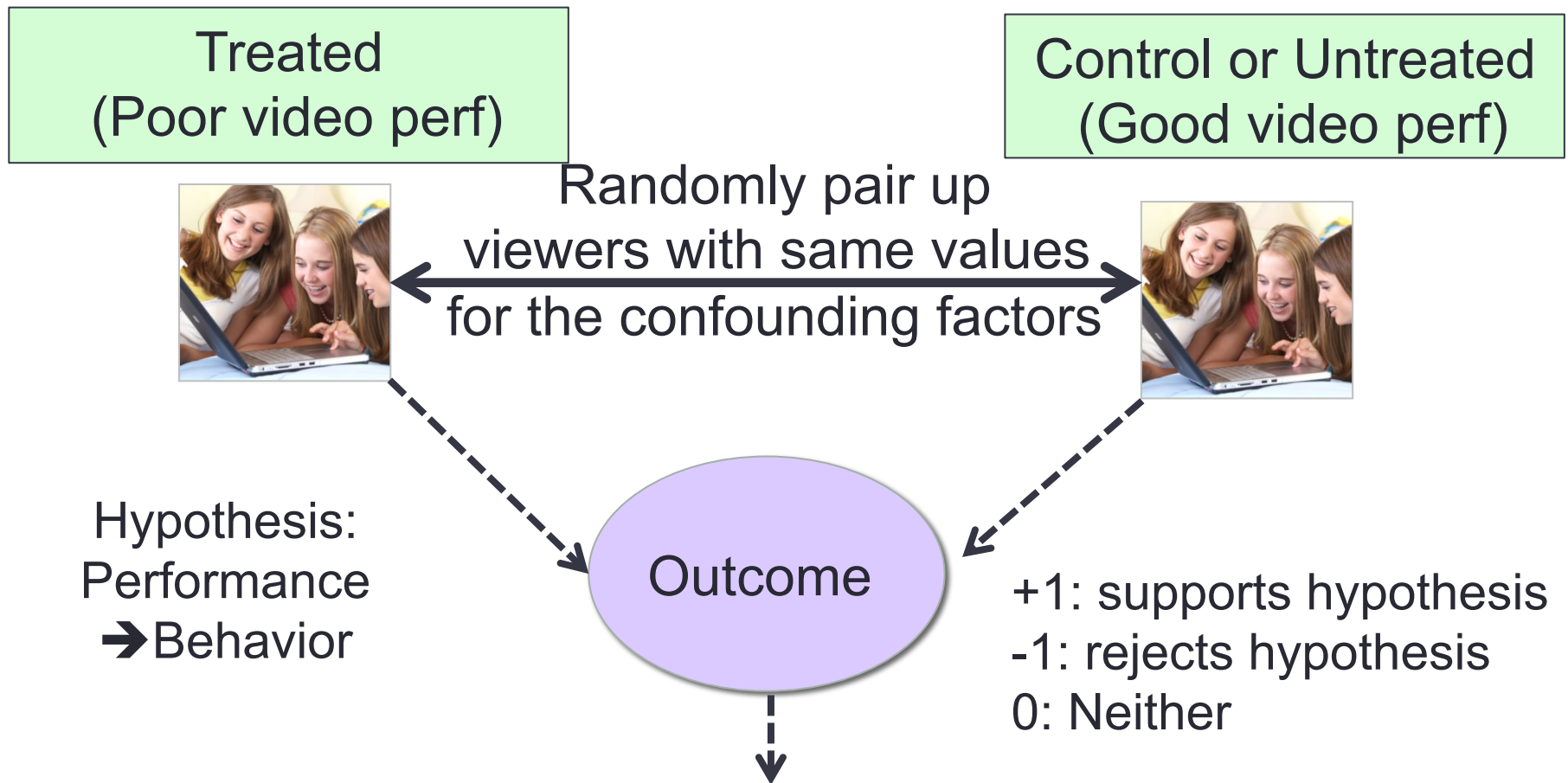2. Compare outcomes of the treatment versus the "untreated" control group.

Treatment = Degradation in Video Performance

Hard to do:

Operationally
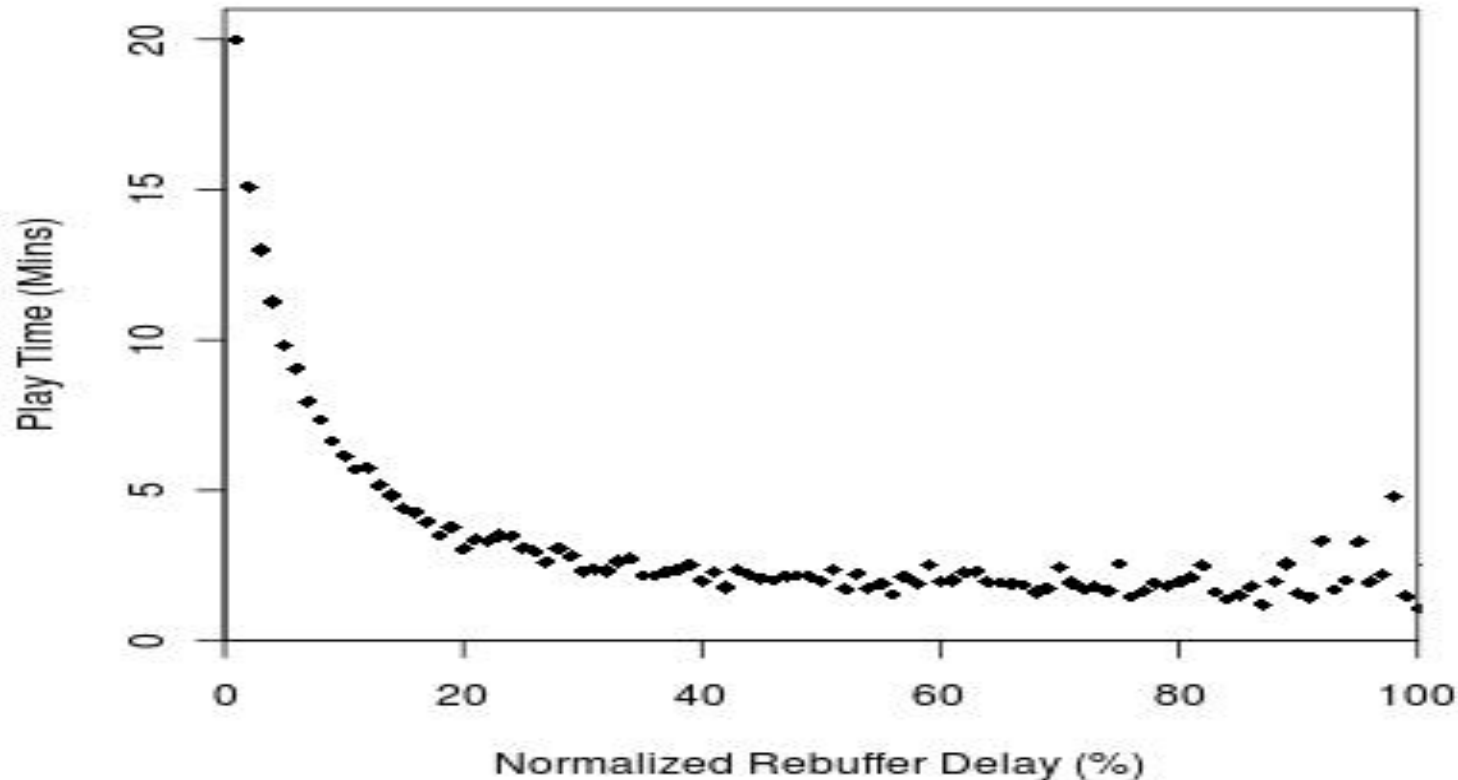Cost Effectively
Legally
Ethically

Our Approach: Quasi-Experiments

Idea: Equalize confounding factors by *experimental design.*
Example, Matched design (Levy et al 1985 nutrition study)

Treated
(Poor video perf)

Control or Untreated
(Good video perf)

Randomly pair up
viewers with same values
for the confounding factors

Hypothesis:
Performance
➔Behavior

Outcome

+1: supports hypothesis
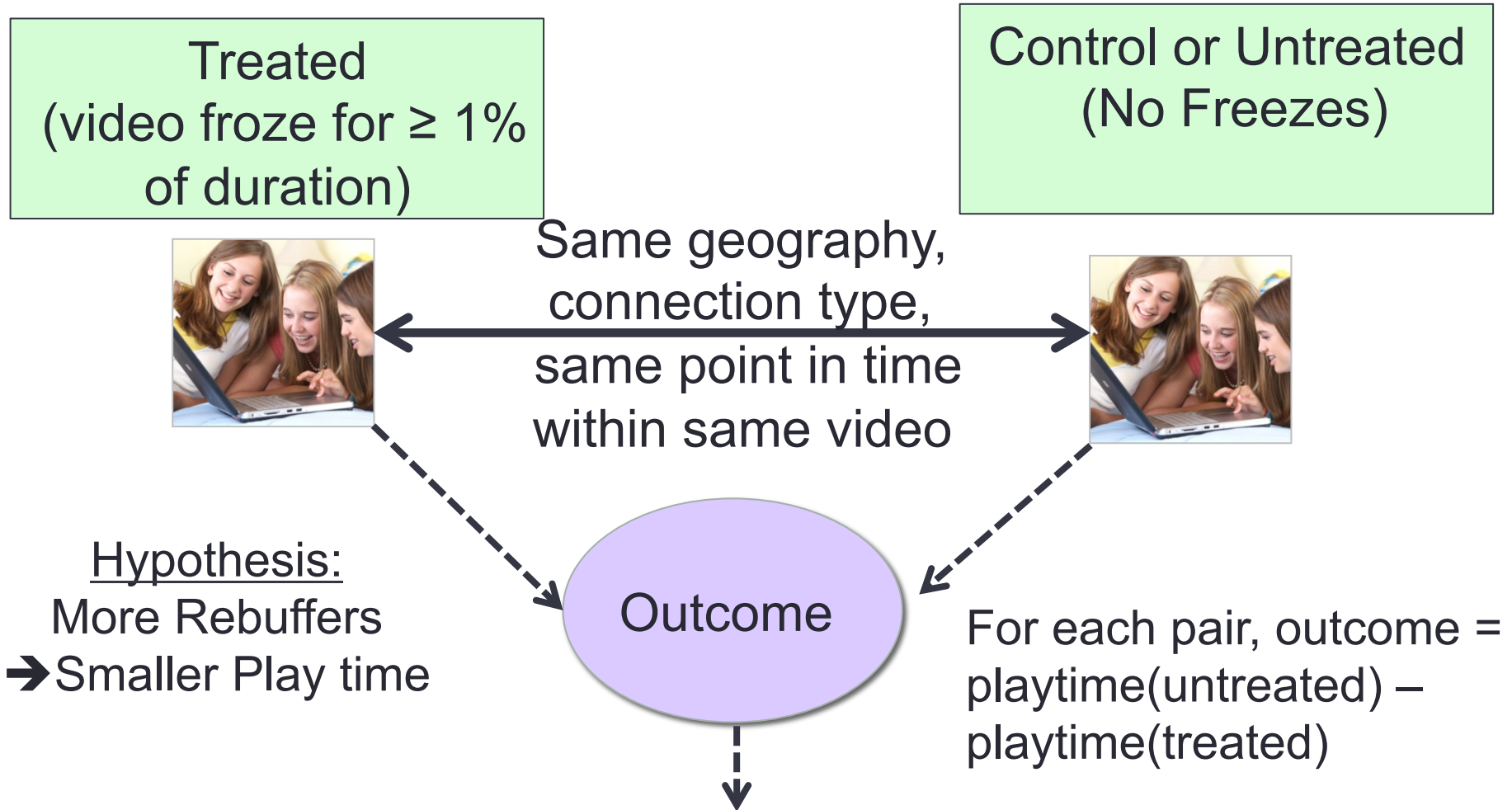-1: rejects hypothesis
0: Neither

Viewer Engagement

Does rebuffering reduce the average time a viewer plays a video?

Strong negative correlation (-0.421): increased normalized rebuffer delay correlates with decreased play time.

Quasi-Experiment for Viewer Engagement

Treated
(video froze for ≥ 1% of duration)

Control or Untreated (No Freezes)

Same geography, connection type, same point in time within same video

Hypothesis:
More Rebuffers
➔ Smaller Play time

Outcome

For each pair, outcome = playtime(untreated) – playtime(treated)

Results of Quasi-Experiment

Normalized Rebuffer Delay ($\gamma\%$)	Net Outcome
1	5.0%
2	5.5%
3	5.7%
4	6.7%
5	6.3%
6	7.4%
7	7.5%

A viewer experiencing rebuffering for 1% of the video duration watched 5% less of the video compared to an identical viewer who experienced no rebuffering.

Viewer Abandonment

How long will viewers wait for a video to startup?
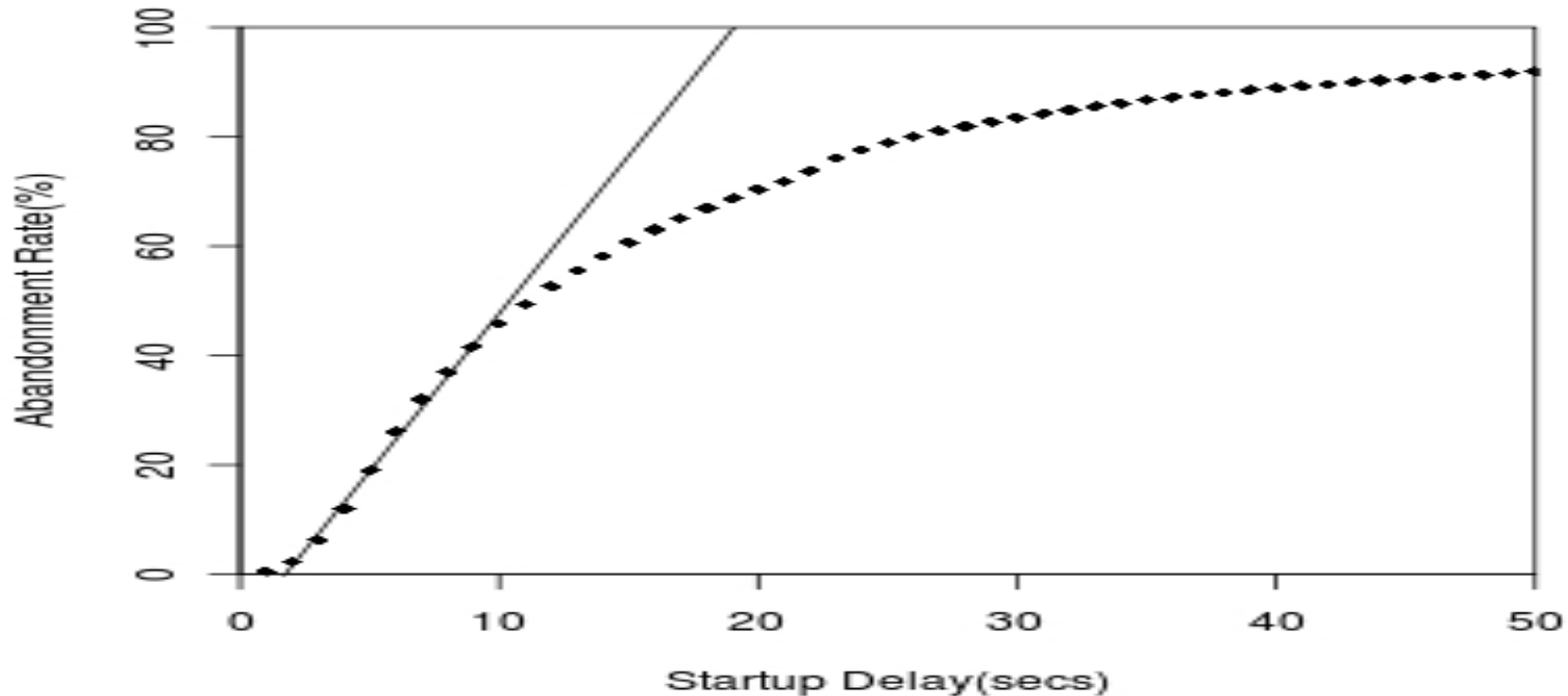
AbandonRate(x) = % of views abandoned if startup delay is z =100 X (Impatient(x)/(Impatient(x) + Patient(x)).

•Viewers start to abandon if startup delay exceeds 2 seconds.
•Beyond 2 seconds, a 1-second increase in delay results in roughly a 5.8% increase in abandonment rate.
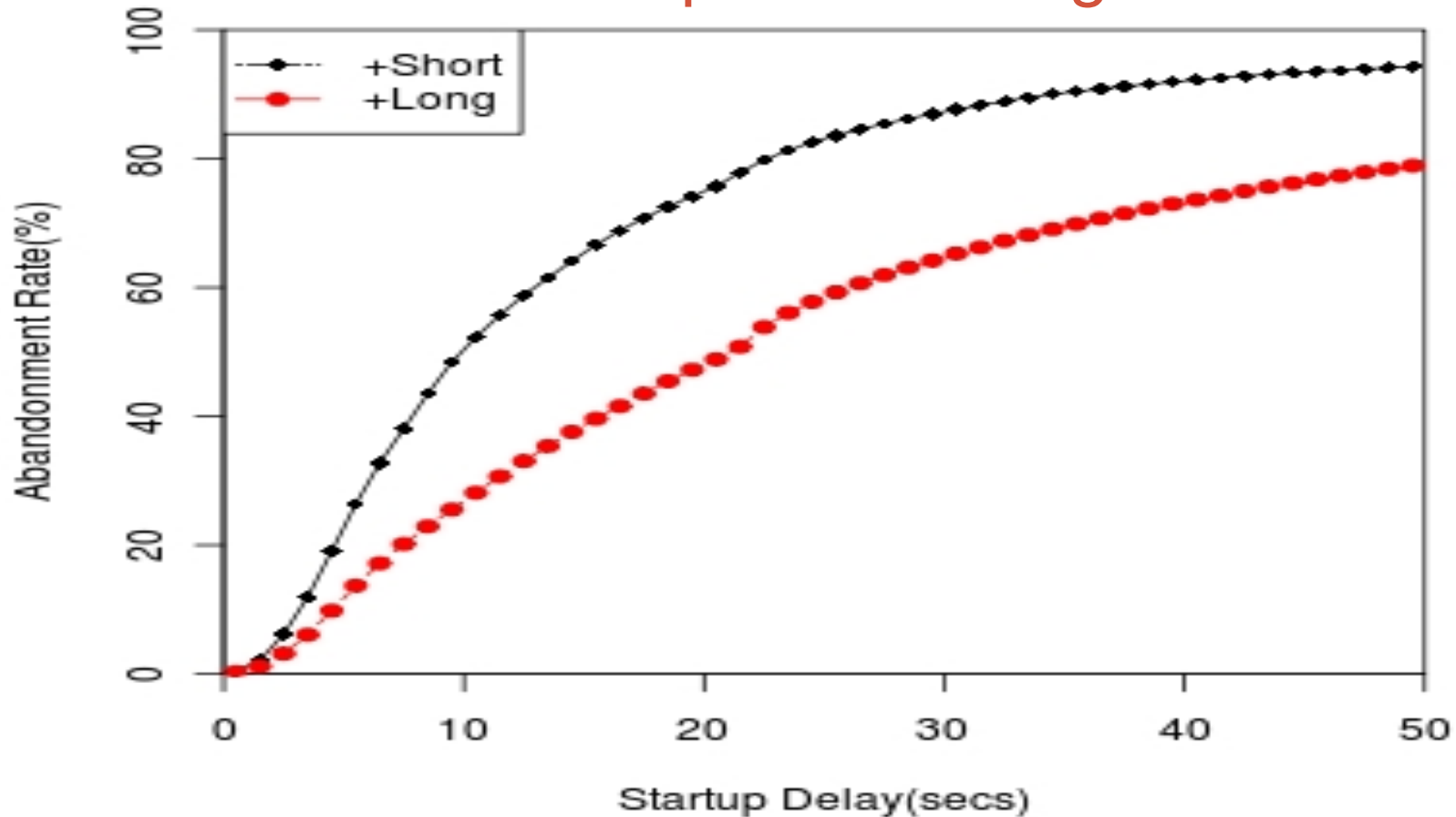
What is more frustrating?

Waiting 30 minutes for a long plane ride?

Waiting 30 minutes for a short cab ride?

# Viewers are less tolerant of startup delay for short videos in comparison to longer videos

Short: < 30 mins (e,g, news clip). Median Duration: 1.8 mins
Long: ≥ 30 mins(e.g, movie). Median Duration: 43.2 mins
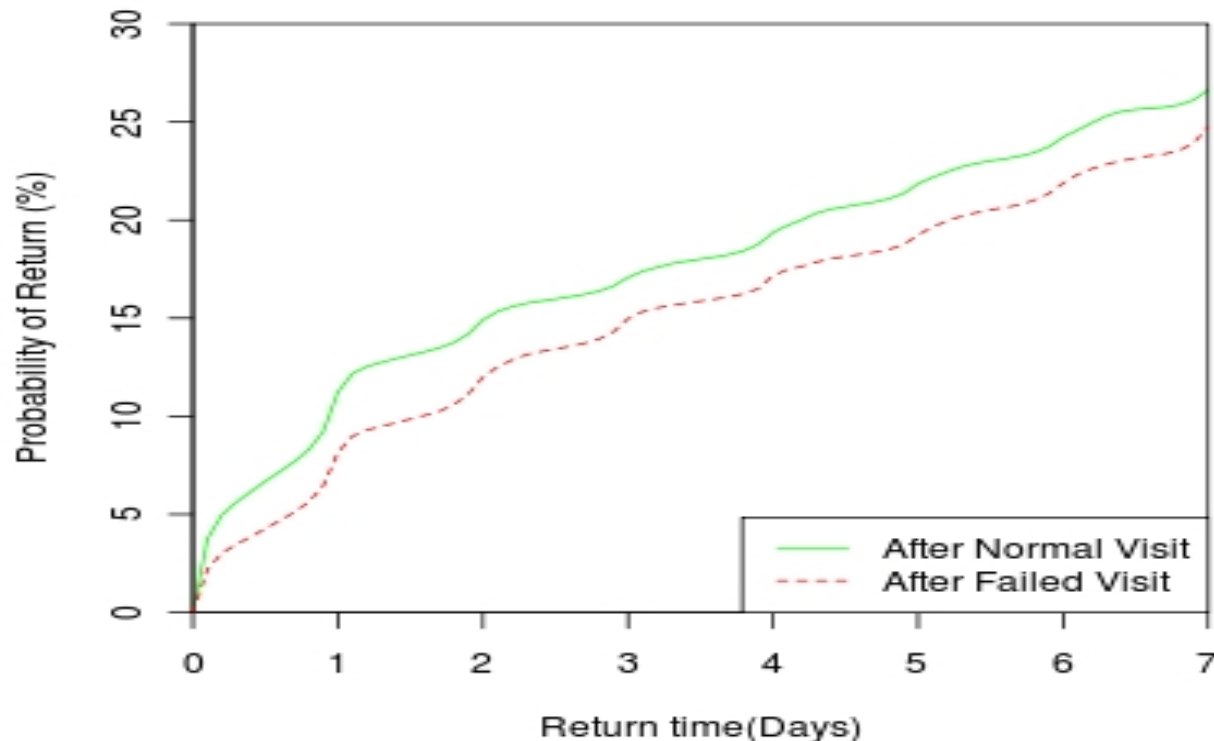
Anyone for the *Lightning* Express?

"Express train crosses the nation in 83 hours."
New York Times, June 4th 1876.

Viewers with better connectivity have less patience for startup delay and abandon sooner.
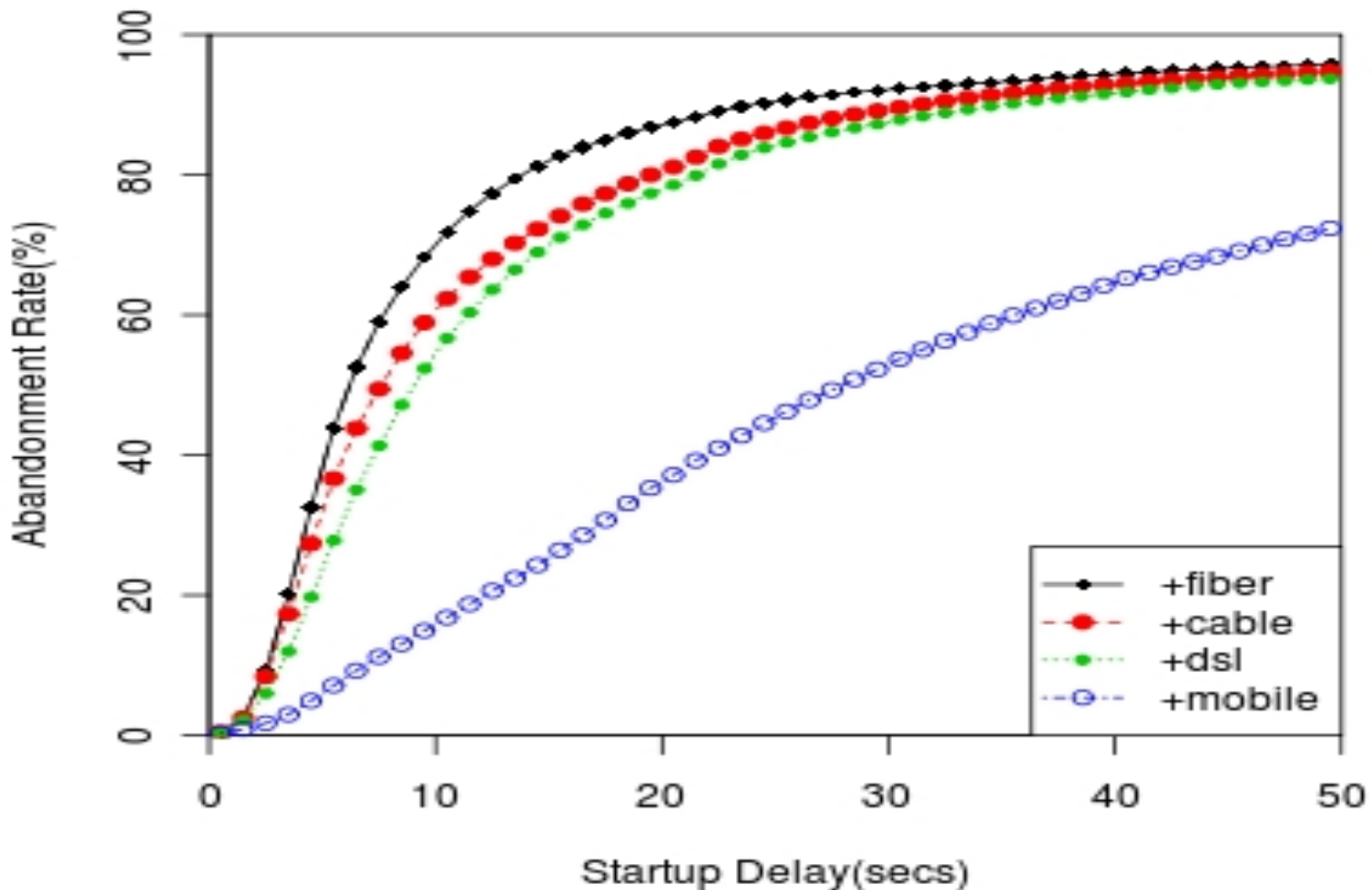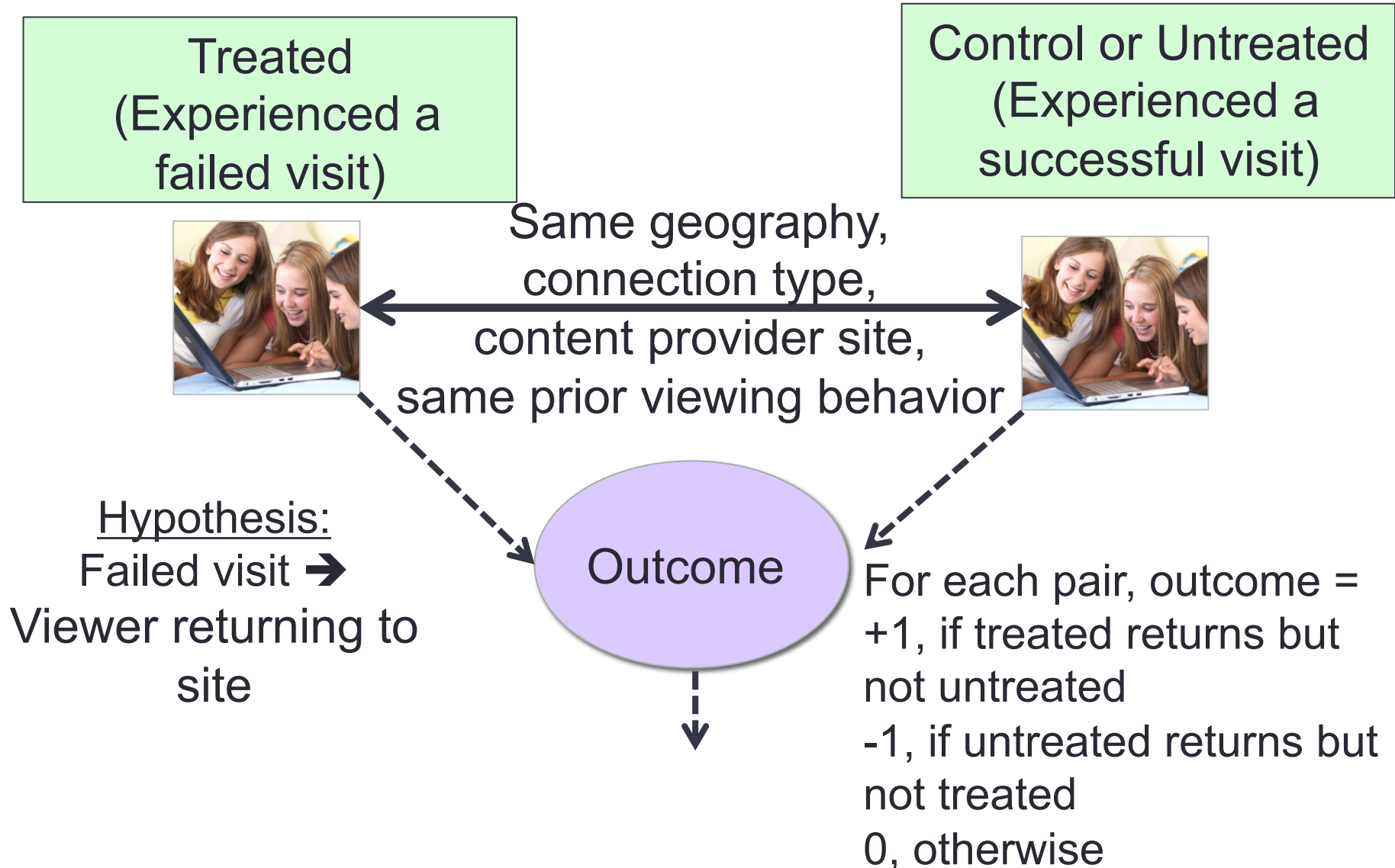
Repeat Viewership

Do failures reduce the likelihood that a user will return to the same content provider's site?

Failed Visit= The viewer fails to play a video and leaves the site ending the visit.
The probability of a viewer returning to a content provider's site within a specified time is distinctly smaller after a failed visit than after a normal visit.

Quasi-Experiment for Repeat Viewership

Treated
(Experienced a
failed visit)

Control or Untreated
(Experienced a
successful visit)

Same geography,
connection type,
content provider site,
same prior viewing behavior

Hypothesis:
Failed visit ➜
Viewer returning to
site

Outcome

For each pair, outcome =
+1, if treated returns but
not untreated
-1, if untreated returns but
not treated
0, otherwise

Results from Quasi-Experiment

A viewer experiencing a failed visit is 2.32% less likely to return to the same content provider's site within a week than a similar viewer that had a successful visit.

Our Contributions

First large-scale quantitative study of the causal link between video performance and viewer behavior.
- Prior work: correlational study of viewer engagement (Dobrian et al 2011).

Deeper and better understanding of
- how to architect delivery networks (for architects)
- user behavior and video monetization (for content providers)

New Quasi-Experimental Design (QED) techniques for causal inference in network measurement.
- Prior work: QED in social and medical sciences but not in our domain.

Questions?