

Checking Privacy Expectations on Personalized Ads and Ad Settings

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Web Browsing



LGBTQNATION™

WIKIPEDIA

Advertisements

ADS BY GOOGLE

Try the OfficeRunner

 navfox.com

Signs Of Alcoholism

Signs Of Alcoholism In Your City Alcohol Rehab Advice On NavFox!

of dementia.

activebeat.co/Dementia

 atlantisevents.com

All-Gay & Lesbian Cruises

New cruises on the world's best ships to the Caribbean & Europe




Get guaranteed lifetime income and reduced risks to retirees all here.

advisorworld.com/CompareAnnuities

Ads by Google

Ad Settings

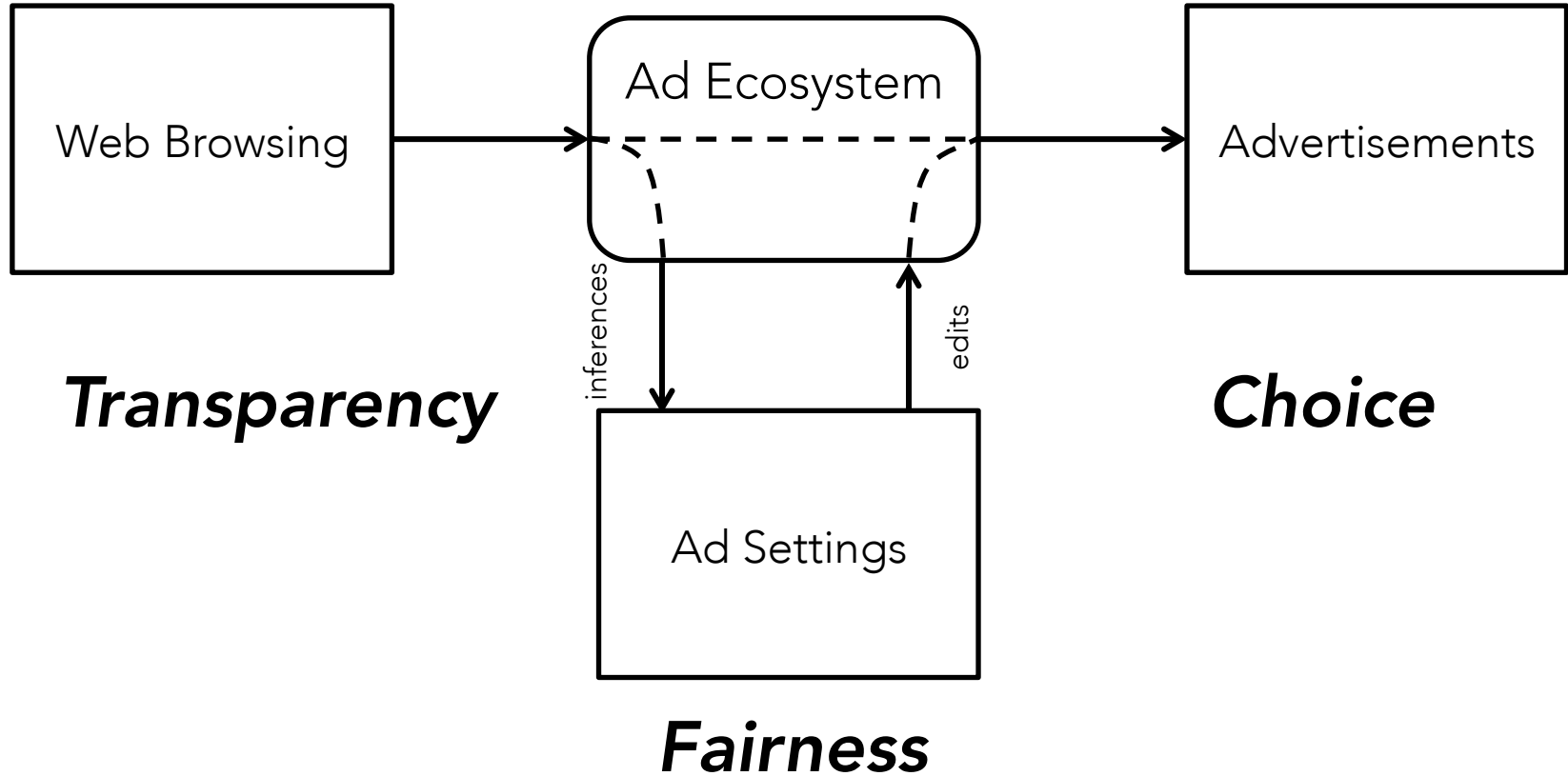
www.google.com/settings/ads

	Ads on Google	Google ads across the web [?]
	 Search	  Google ads across the web YouTube
Gender	N/A	Male Edit <small>Based on the websites you've visited</small>
Age	N/A	18-24 Edit <small>Based on the websites you've visited</small>
Languages	N/A	None Edit <small>Based on the websites you've visited</small>
Interests	N/A	Bike Helmets & Protective Gear, and 2 more Edit <small>Based on the websites you've visited</small>
Opt-out settings	Opt out of interest-based ads on Google	Opt out of interest-based Google ads across the web

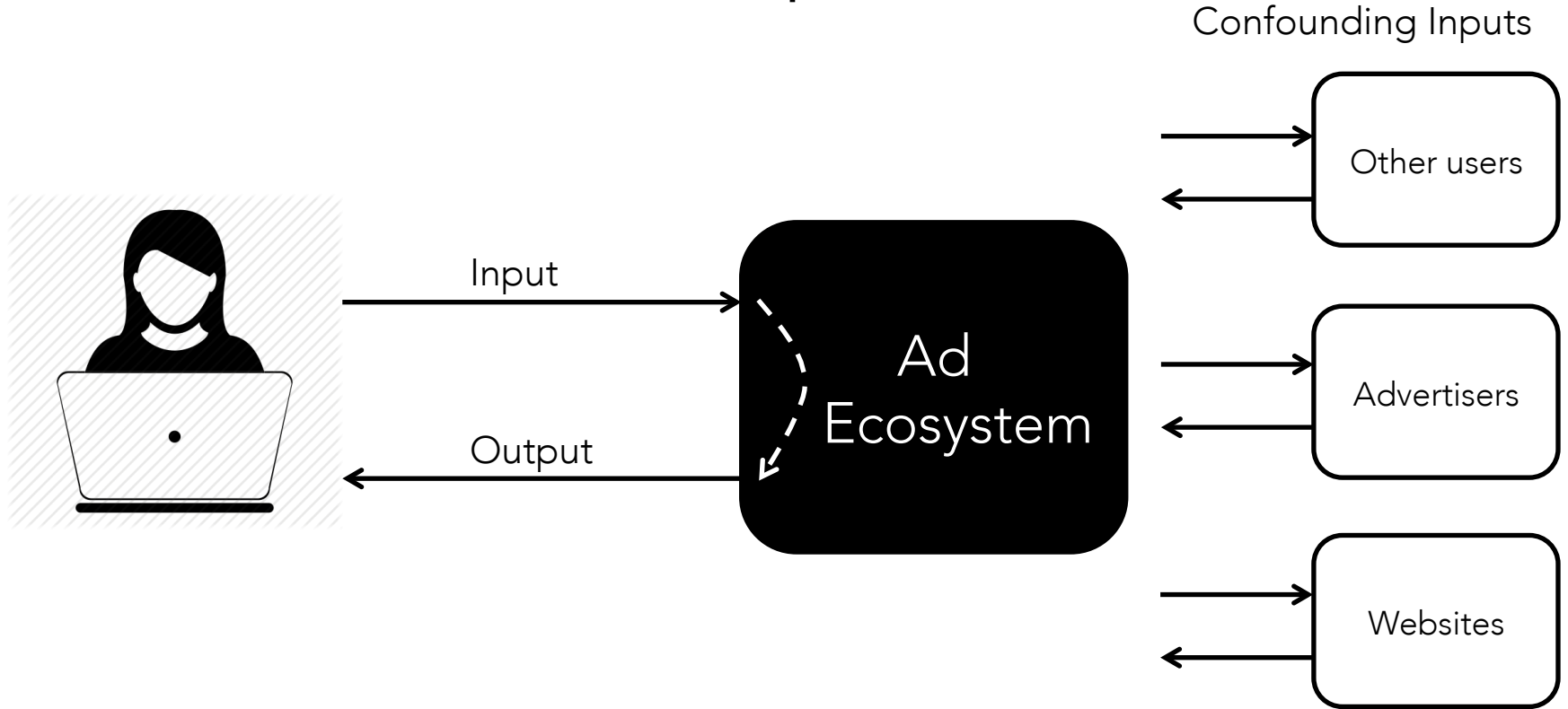
Research Questions

- Are ad settings **transparent**?
- Do ad settings provide users **choice**?
- Are personalized ads served in a **fair** manner?

Information Flow Experiments



Information Flow Experiments



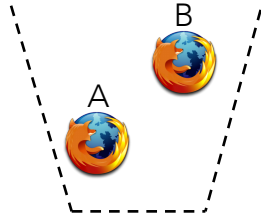
Contributions

- Methodology for information flow experiments
- Tool implementing our methodology
- Experimental findings

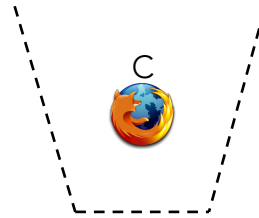
Outline

- Related Work
 - Pairwise Similarities
 - Correlations
 - Randomized Controlled Trials (RCTs)
- Our Methodology and Tool
- Experimental Findings

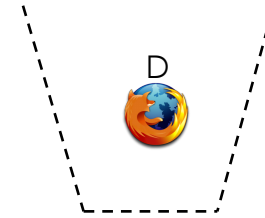
Pairwise Similarities [Guha'10]



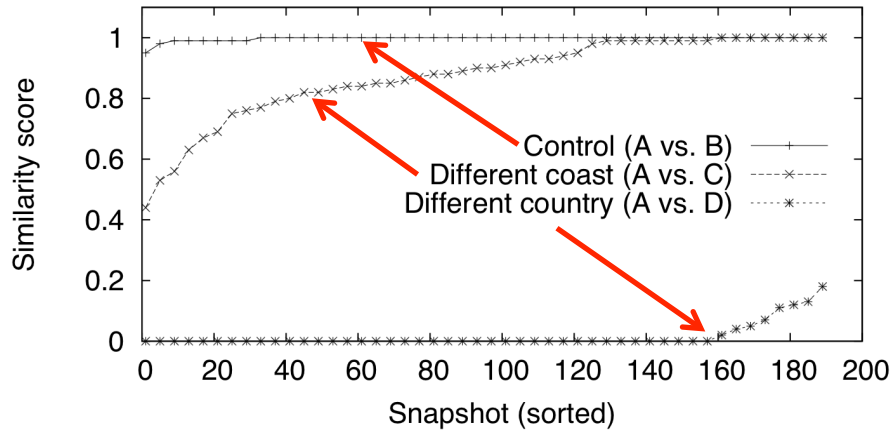
Control Browsers
(New York)



Experimental Browser 1
(San Francisco)



Experimental Browser 2
(Germany)



S. Guha, B. Cheng, and P. Francis.

Challenges in measuring online advertising systems. *IMC 2010*.

Pairwise Similarities

- Key contributions
 - First methodology for studying ads
 - Google ads on non-Google websites are influenced by location
 - Facebook ads are based on user profiles
- Drawbacks
 - Sensitive to variations on a single browser agent
 - No statistical tests

Correlations [Lecuyer'14]



email1 --- ad1
email2 --- ad2
email3 --- ad3
email4 --- ad4
email5 --- ad5



email1 --- ad1
email3 --- ad2
email5 --- ad4



email1 --- ad1
email2 --- ad2
email4 --- ad3



email3 --- ad4
email5 --- ad4

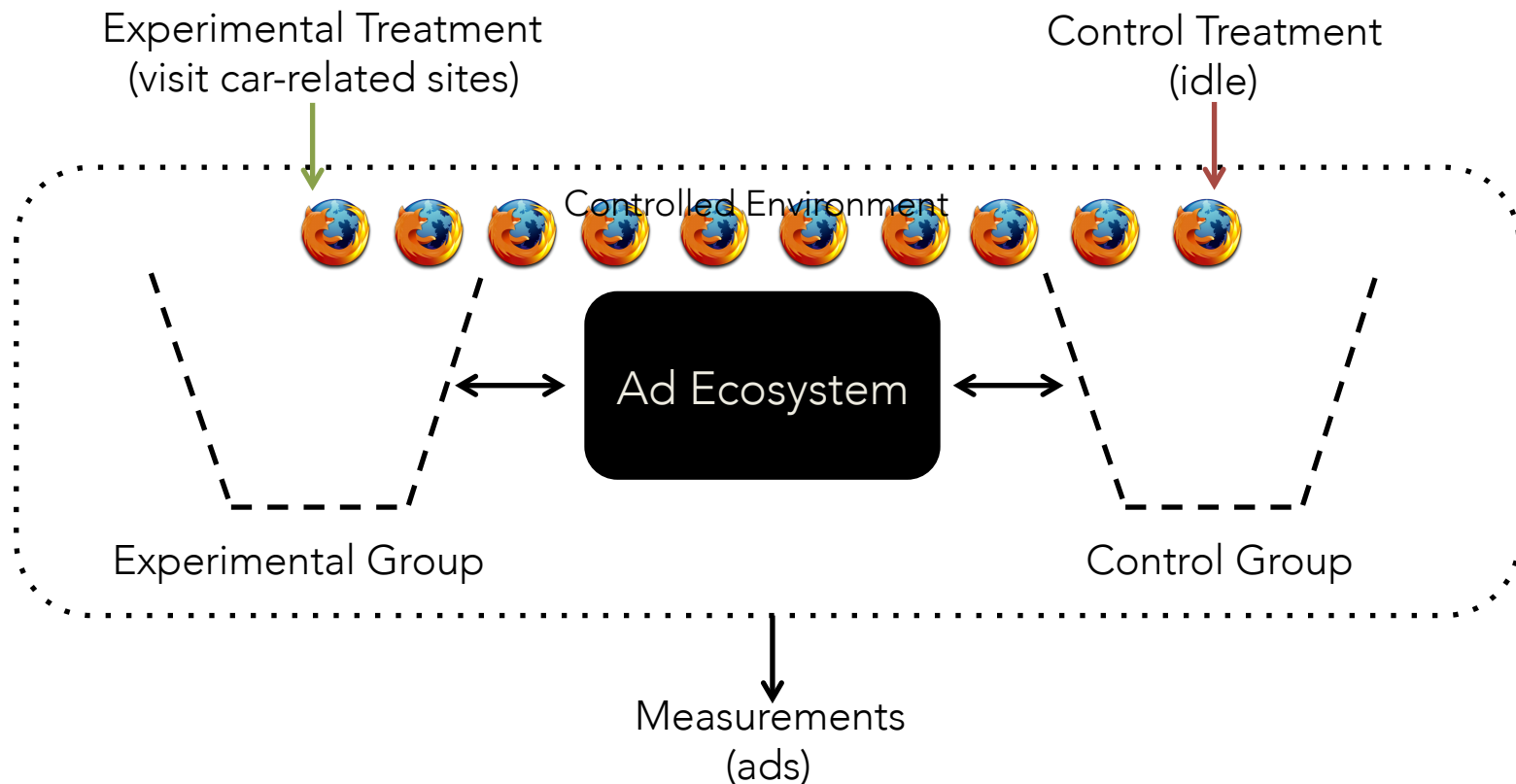


email2 --- ad3
email4 --- ad4
email5 --- ad4

Correlations

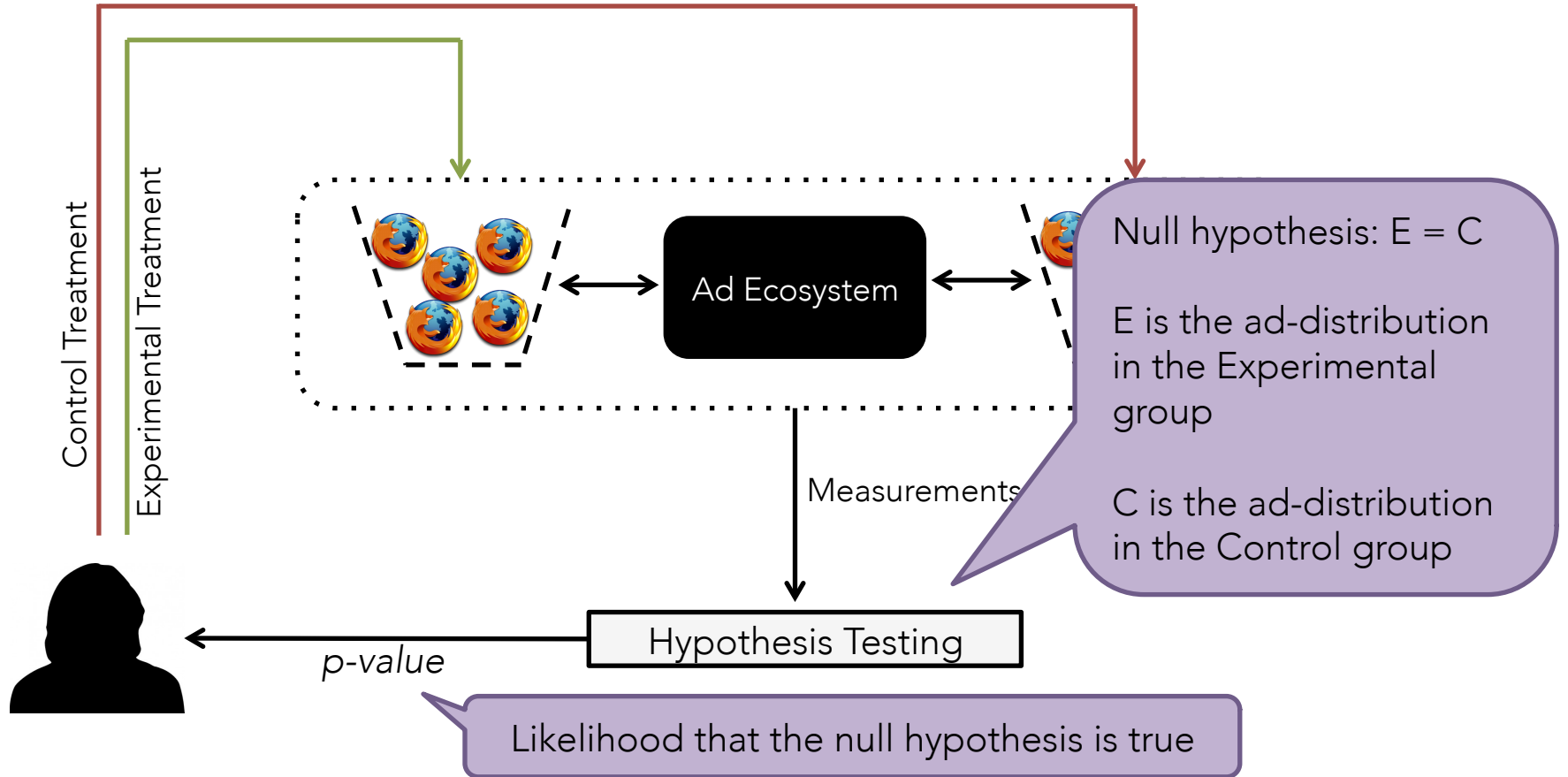
- Key contributions
 - Ads are targeted to emails on sensitive topics like depression, HIV
 - Showed that under certain assumptions, logarithmic number of shadow accounts are required
 - Extended Xray to Amazon and YouTube
- Drawbacks
 - Fairly strong assumptions
 - Correlations do not denote targeting

Randomized Controlled Trials



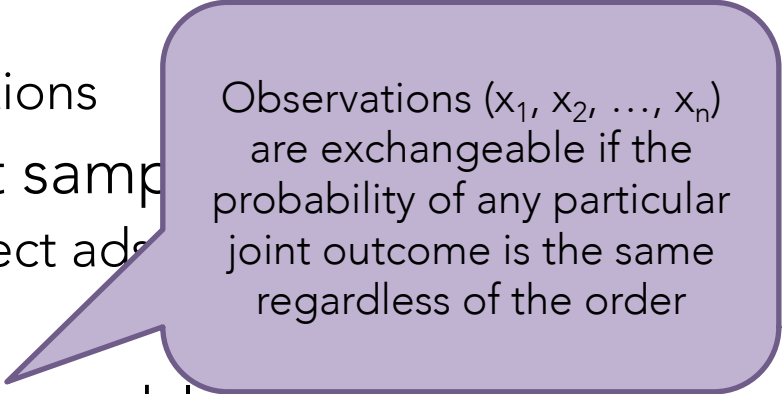
M. C. Tschantz, A. Datta, A. Datta, and J. M. Wing.
A methodology for information flow experiments. *CoRR*, [abs/1405.2376](https://arxiv.org/abs/1405.2376), 2014.

Randomized Controlled Trials



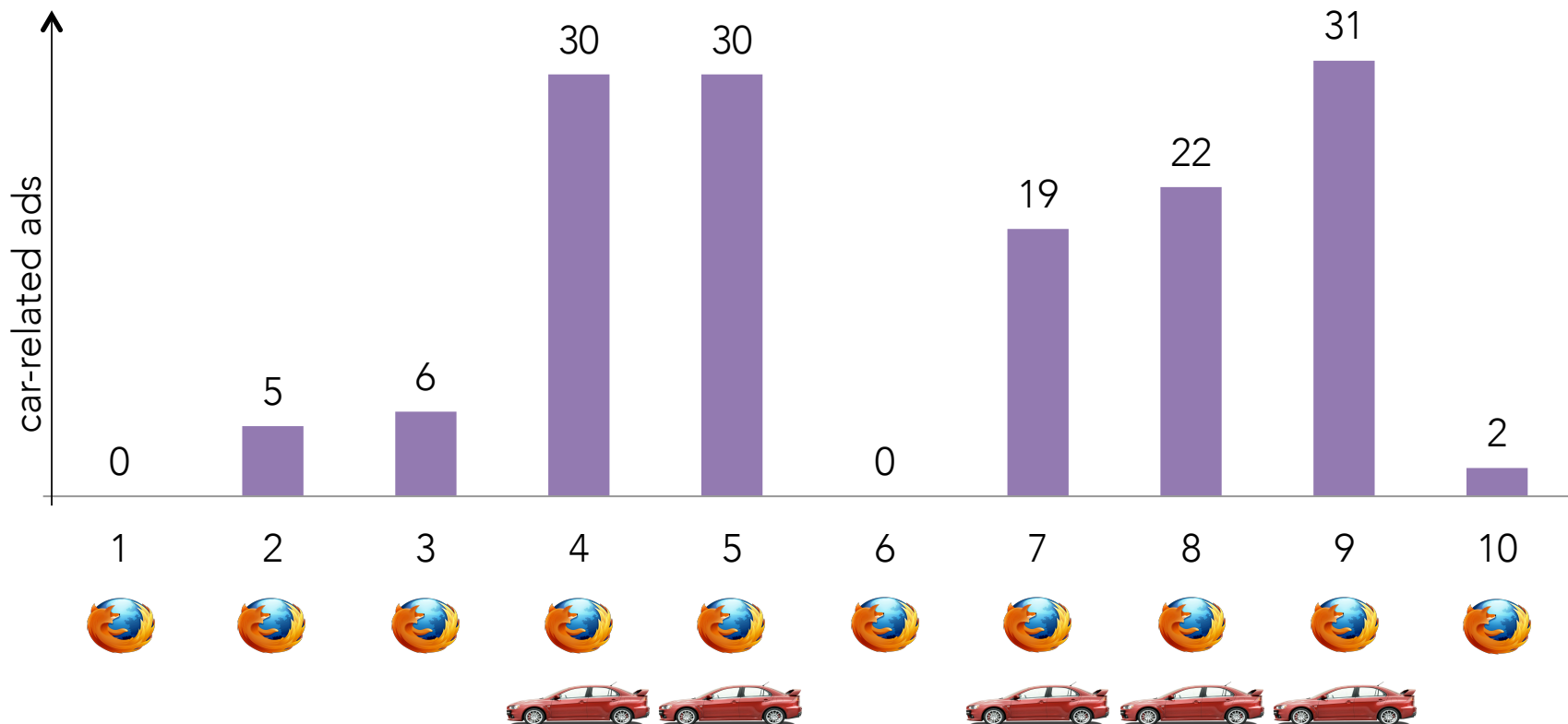
Permutation Test [Good'05]

- It is a non-parametric test
 - No assumptions about ad distributions
- It does not require independent samples
 - Ads served to one browser can affect ads served to another browser
- Assumption: Samples are exchangeable under the null hypothesis
- A statistic that discriminates between the null and alternate hypotheses

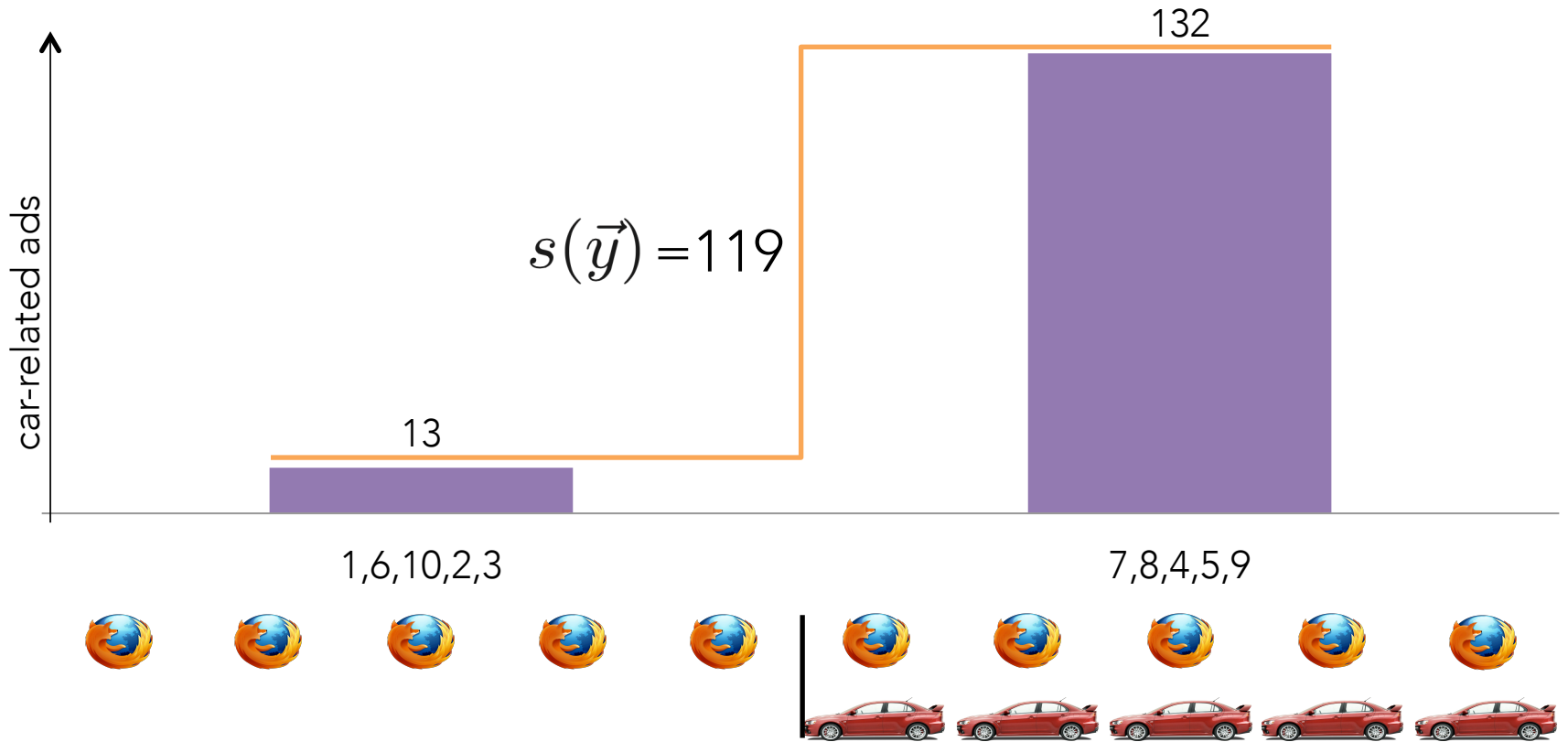


Observations (x_1, x_2, \dots, x_n) are exchangeable if the probability of any particular joint outcome is the same regardless of the order

Permutation Test: Example



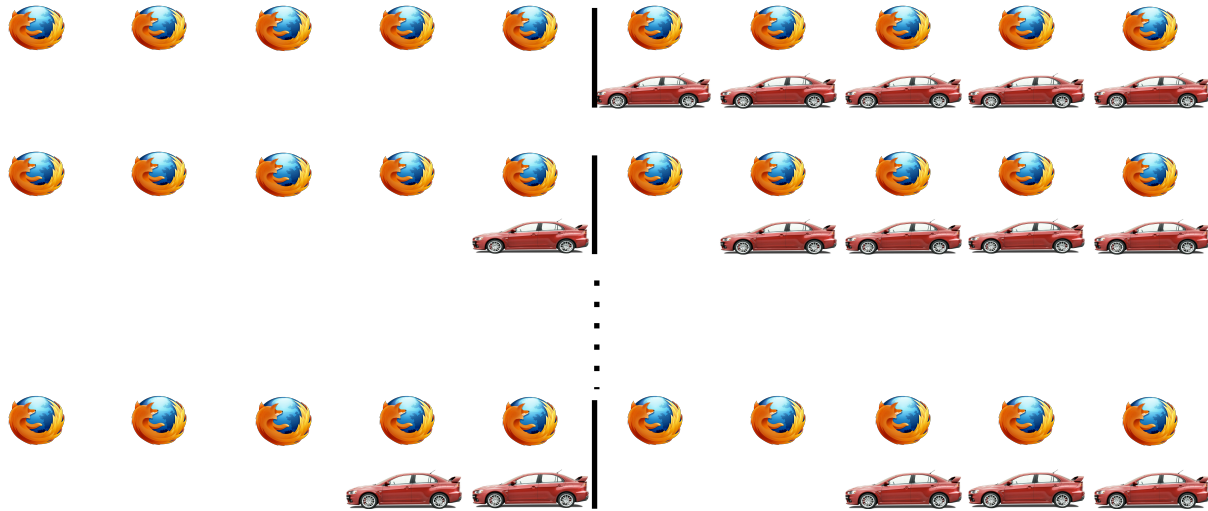
Permutation Test: Example



\vec{y} is the measurement vector

$s(\vec{y})$ is the statistic computed over \vec{y}

Permutation Test: Example



$$s(\pi(\vec{y})) = 119$$

$$s(\pi(\vec{y})) = 67$$

$$s(\pi(\vec{y})) = 7$$

$$s(\vec{y}) = 119$$

$$\text{p-value} = \frac{\text{count}[s(\vec{y}) \leq s(\pi(\vec{y}))]}{\text{number of permutations}} = \frac{1}{{}^{10}C_5} = 0.004$$

$\pi(\vec{y})$ is a permutation of \vec{y}

Reject null hypothesis

Randomized Controlled Trials

- Key contributions
 - Demonstrates information flow from web browsing to Google ads served on third-party news sites
 - Methodology uses reasonable assumptions
- Drawbacks
 - Few browser agents in an experiment
 - Manual selection of test statistic is difficult

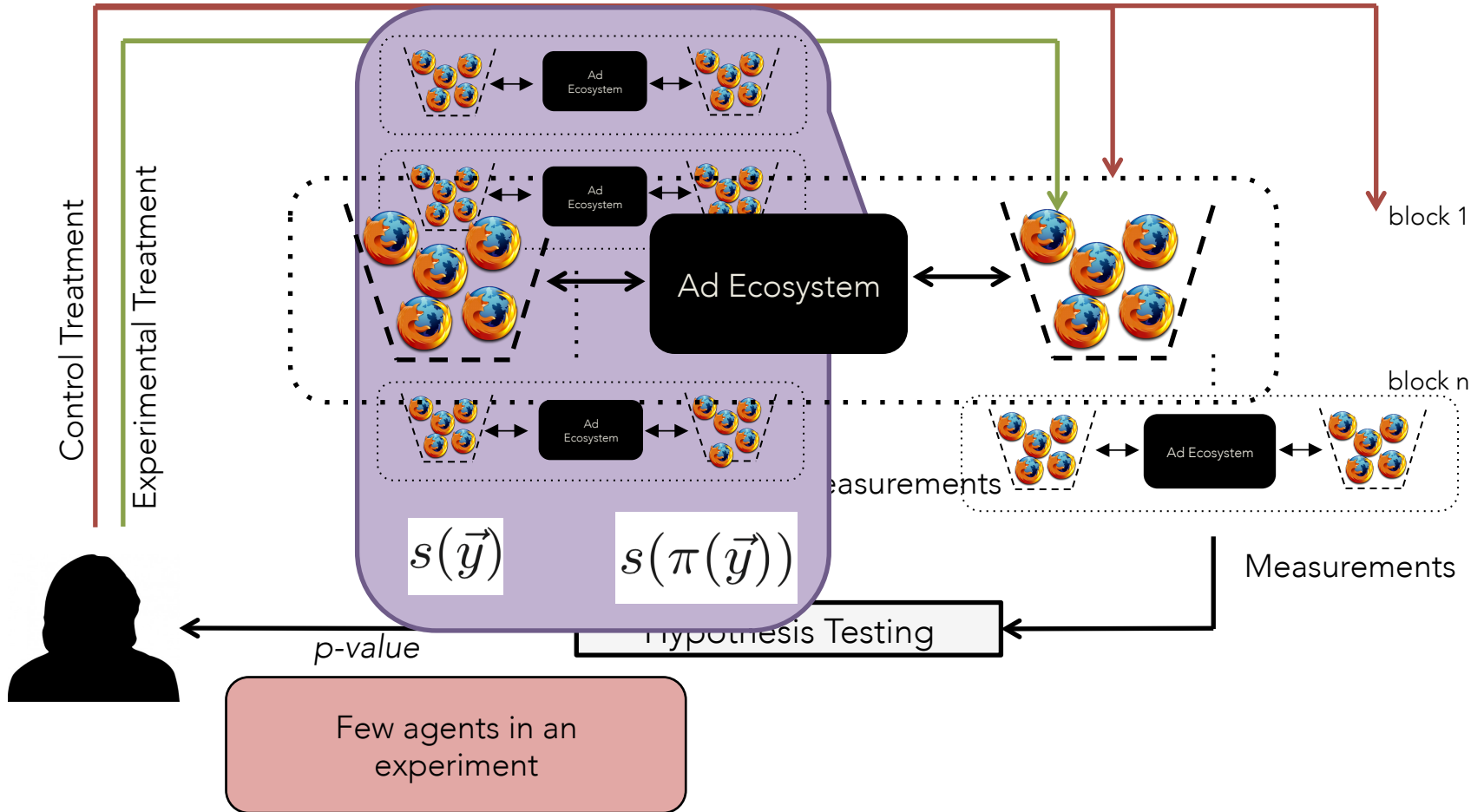
Comparison

	RCTs	Pairwise Similarities	Correlations
Statistical Significance	yes	no	no
Information Flow	yes	no	no
Reasonable assumptions about the Ad Ecosystem	yes	yes	no

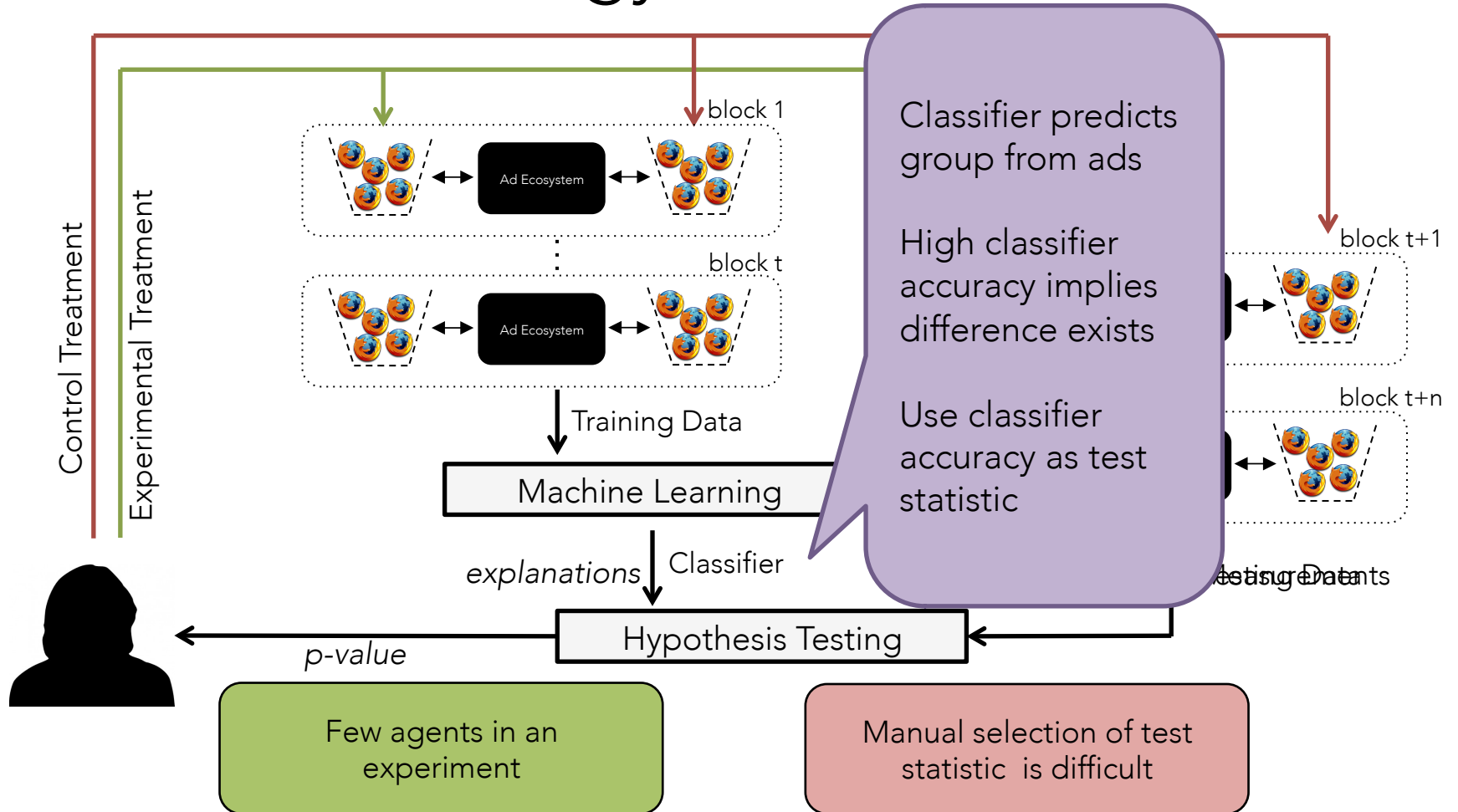
Outline

- Related Work
- Our Methodology and Tool
 - Increasing samples in RCTs
 - Automating statistic selection
 - Providing explanations
- Experimental Findings

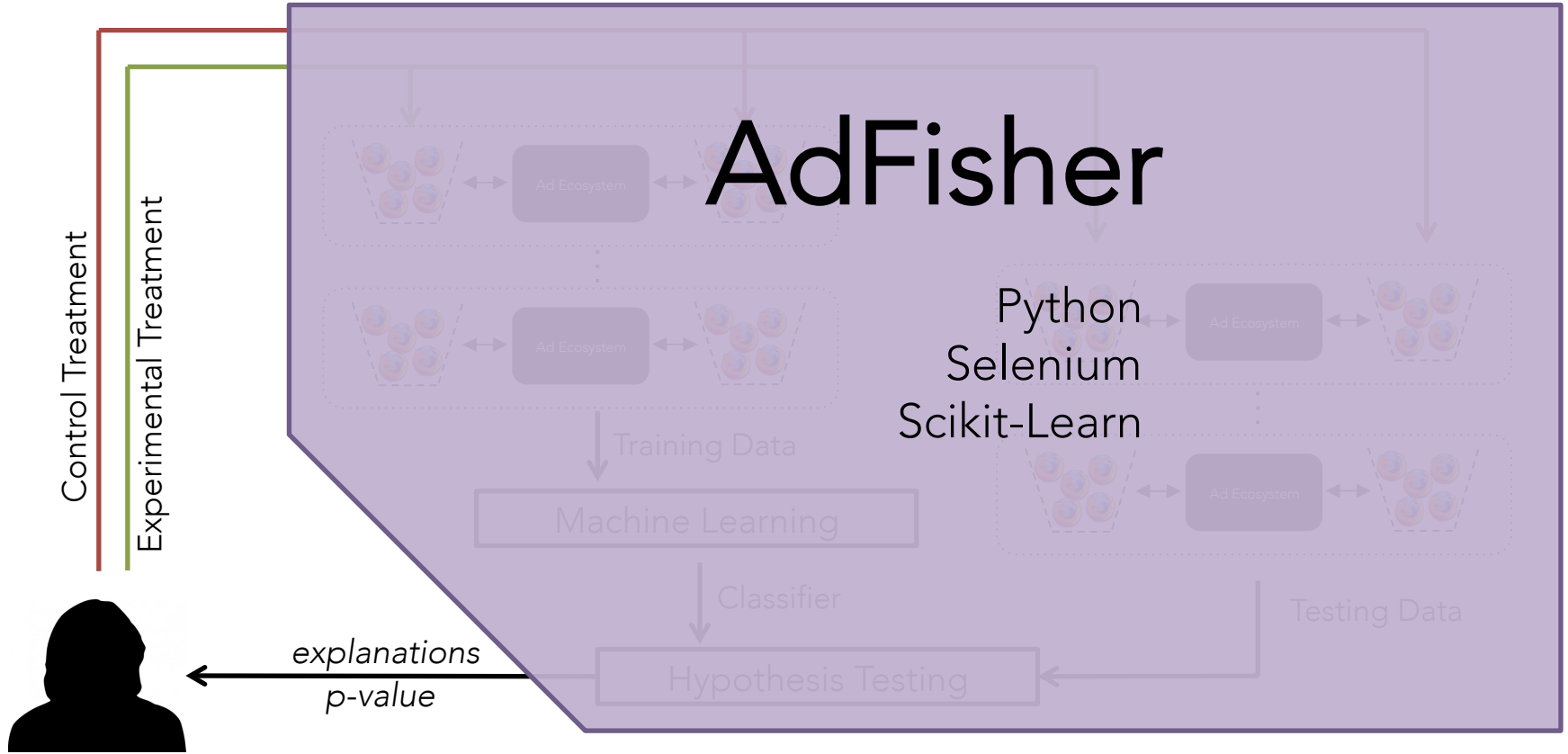
Our Methodology



Our Methodology



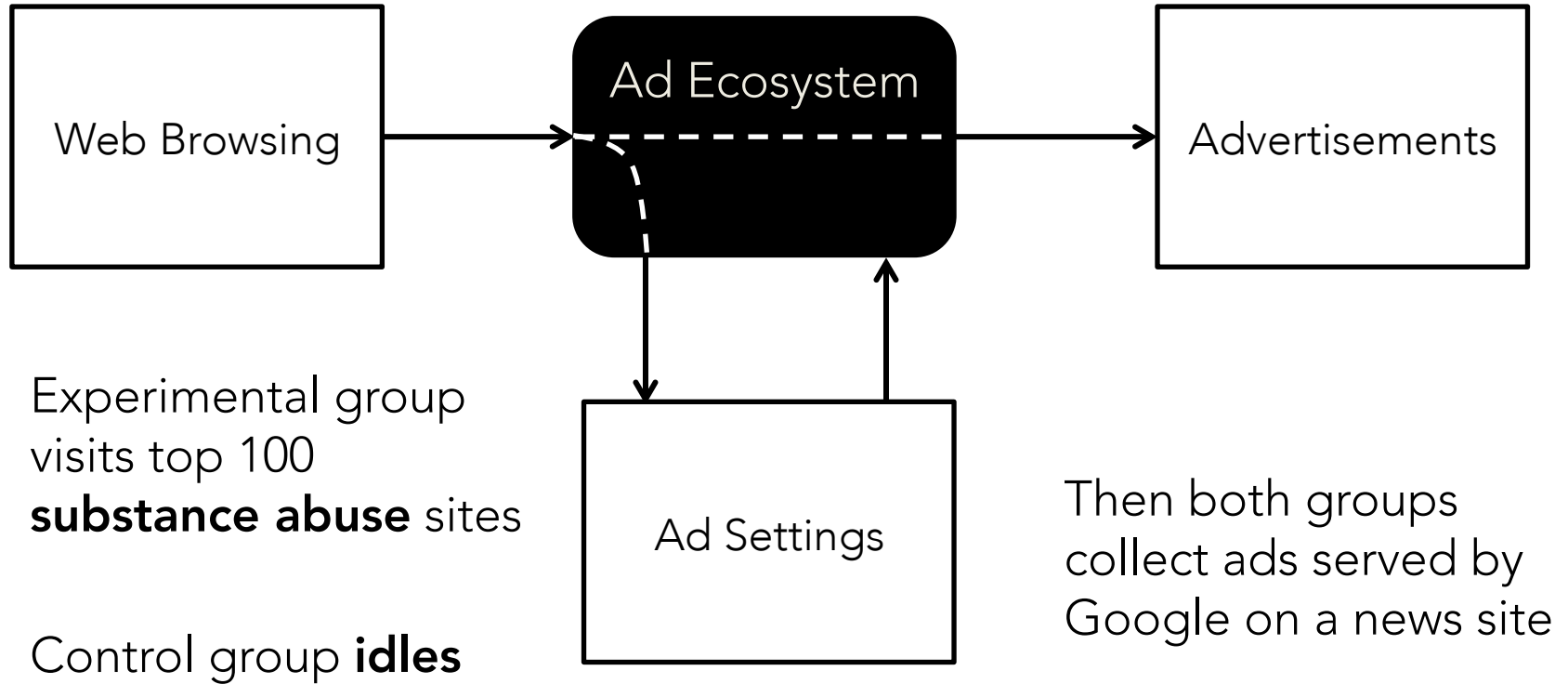
Our Methodology and Tool



Outline

- Related Work
- Our Methodology and Tool
- Experimental Findings
 - Transparency
 - Choice
 - Fairness

Experiment 1: Transparency



Experiment 1: Transparency

Explanations

p-value = 0.0000053

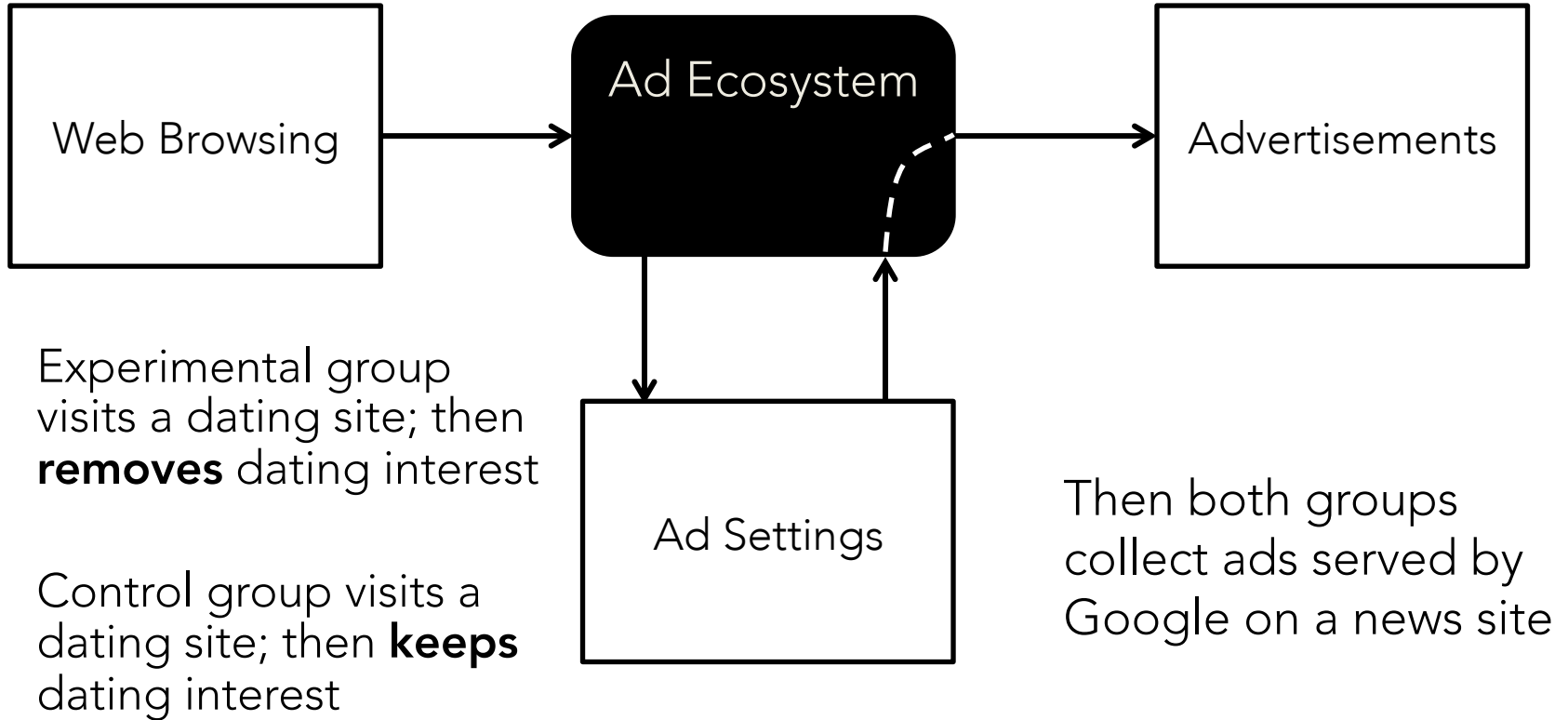
Top ads for group visiting substance abuse webpages	
The Watershed Rehab	www.thewatershed.com/Help
Watershed Rehab	www.thewatershed.com/Rehab
The Watershed Rehab	Ads by Google

The Watershed Rehab
www.thewatershed.com/Help - Drug & Alcohol Rehabilitation Call Today For Help Now!
Ads by Google

Significant effect
on ads,
no effect on ad
settings

Top ads for control group	
Alluria Alert	www.bestbeautybrand.com
Best Dividend Stocks	dividends.wyattresearch.com
10 Stocks to Hold Forever	www.streetauthority.com
Delivery Drivers Wanted	get.lyft.com/drive
VA Home Loans Start Here	www.vamortgagecenter.com

Experiment 2: Choice



Experiment 2: Choice

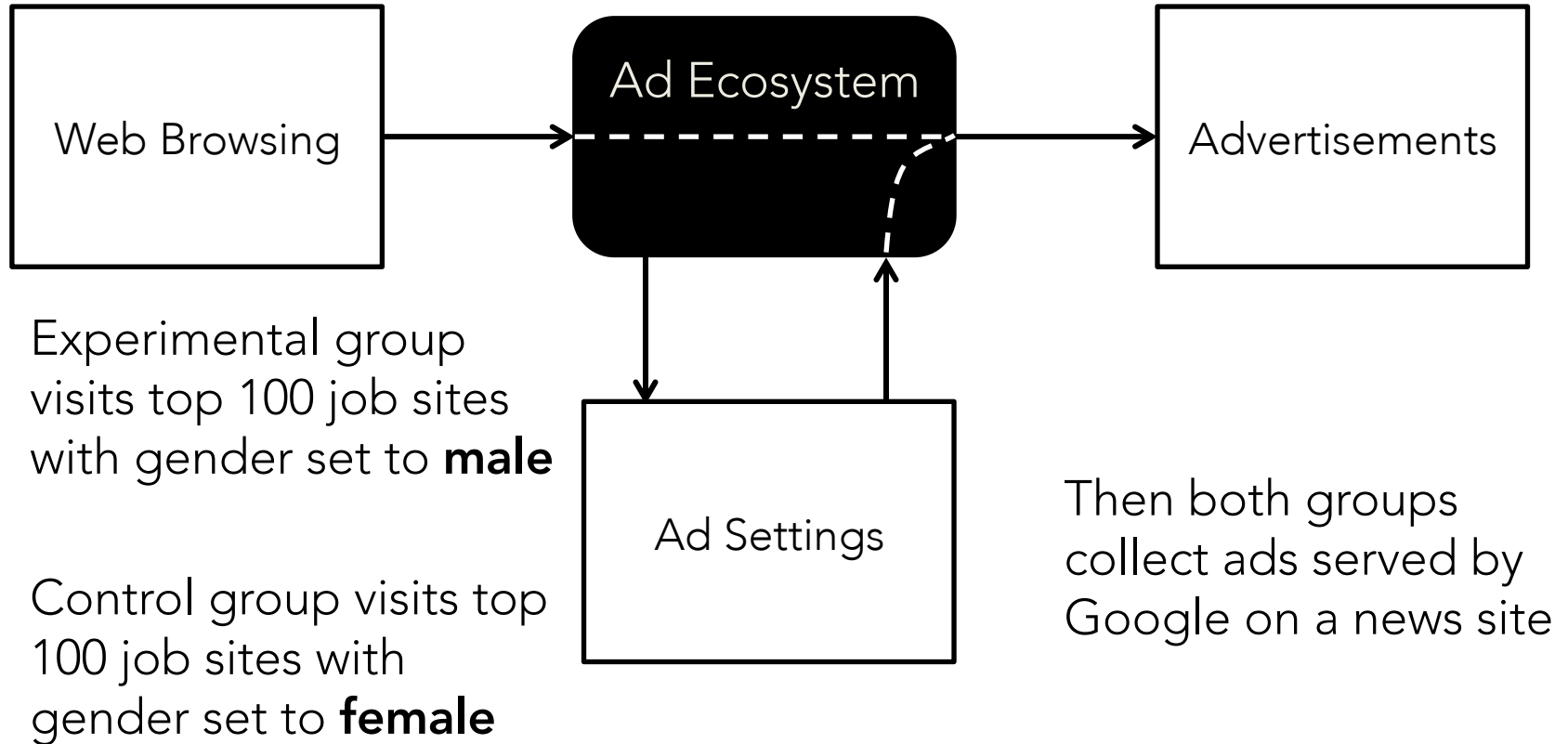
Explanations

p-value = 0.0000053

Significant effect
on ads

Top ads for group keeping dating interest	
Are You Single?	www.zoosk.com/Dating
Top 5 Online Dating Sites	www.consumer-rankings.com/Dating
Why can't I find a date?	www.gk2gk.com
Latest Breaking News	www.onlineinsider.com
Gorgeous Russian Ladies	anastasiadate.com
Top ads for group removing dating interest	
Car Loans w/ Bad Credit	www.car.com/Bad-Credit-Car-Loan
Individual Health Plans	www.individualhealthquotes.com
Crazy New Obama Tax	www.endofamerica.com
Atrial Fibrillation Guide	www.johnshopkinshealthalerts.com
Free \$5 - \$25 Gift Cards	swagbucks.com

Experiment 3: Fairness



Experiment 3: Fairness

Explanations

p-value = 0.0000053

Significant effect
on ads

Top ads for female group	
Jobs (Hiring Now)	www.jobsinyourarea.co
4Runner Parts Service	www.westernpatoyotaservice.com
Criminal Justice Program	www3.mc3.edu/Criminal+Justice
Goodwill - Hiring	goodwill.careerboutique.com
UMUC Cyber Training	www.umuc.edu/cybersecuritytraining
Top ads for male group	
\$200k+ Jobs - Execs Only	careerchange.com
Find Next \$200k+ Job	careerchange.com
Become a Youth Counselor	www.youthcounseling.degreeleap.com
CDL-A OTR Trucking Jobs	www.tadrivers.com/OTRJobs
Free Resume Templates	resume-templates.resume-now.com

Conclusions

- Are ad settings **transparent**?
No - Web browsing affects ads, not settings
- Do ad settings provide users **choice**?
Yes - Removing interests affects ads
- Are personalized ads served in a **fair** manner?
Probably not - Gender affects job-related ads

Contributions

- Methodology for information flow experiments
- Tool implementing our methodology
- Experimental findings

Future Work

- Extensions of AdFisher



- Assign blame for violations

Checking Privacy Expectations on Personalized Ads and Ad Settings

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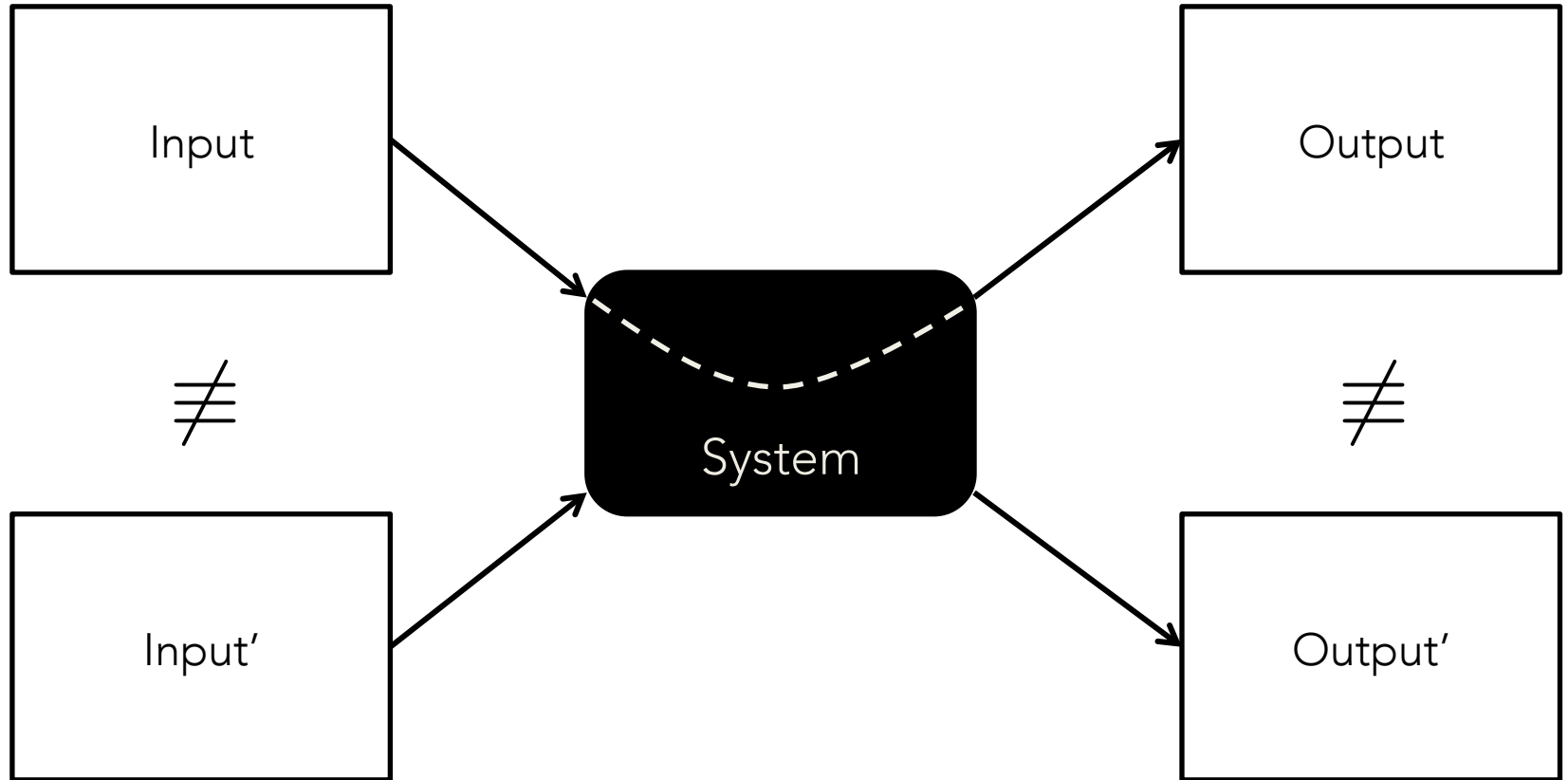
Department of Electrical and Computer Engineering
Carnegie Mellon University

Privacy Policy

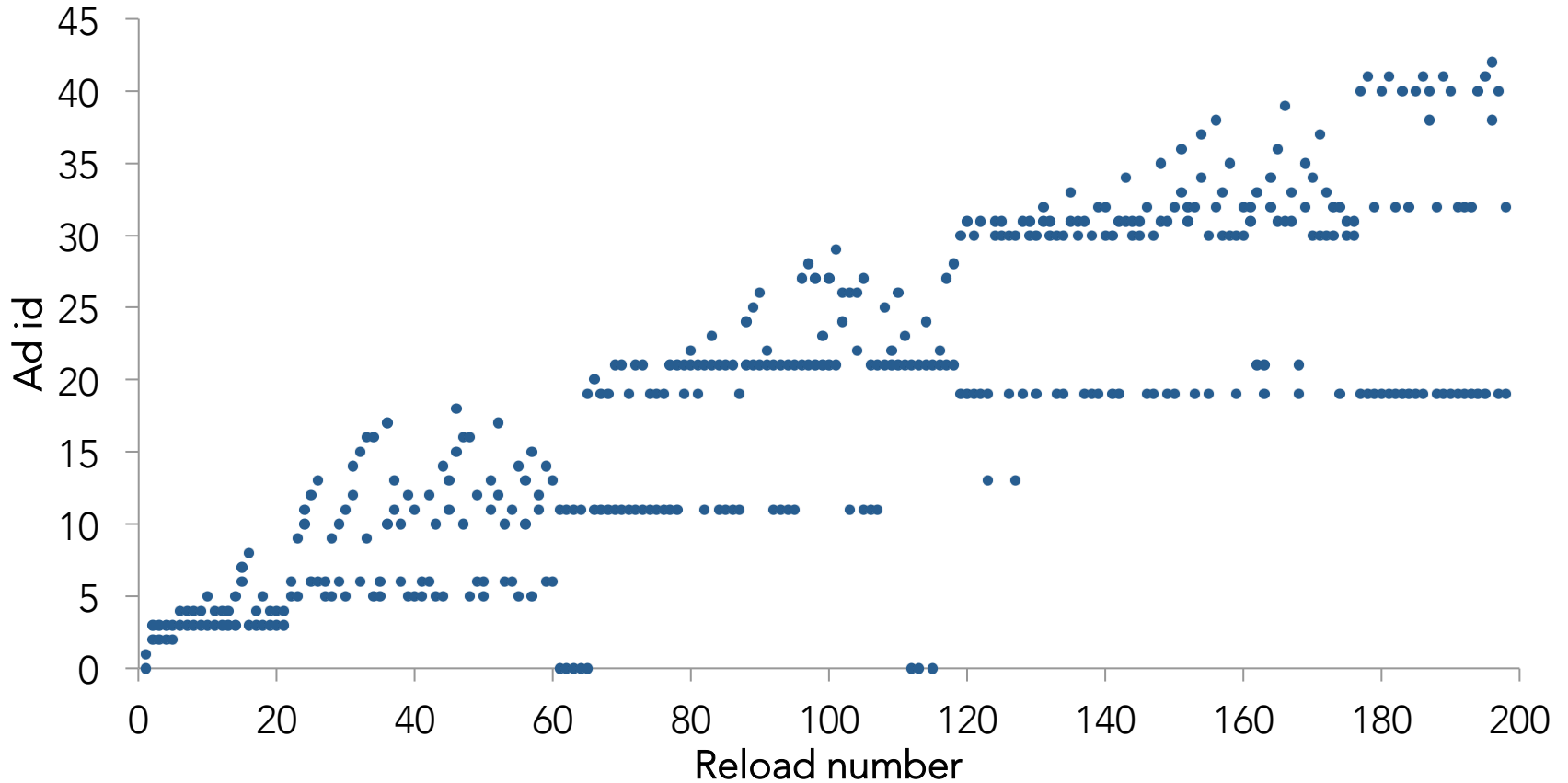
www.google.com/policies/privacy/

When showing you tailored ads, we will not associate a cookie or anonymous identifier with sensitive categories, such as those based on **race, religion, sexual orientation or health.**

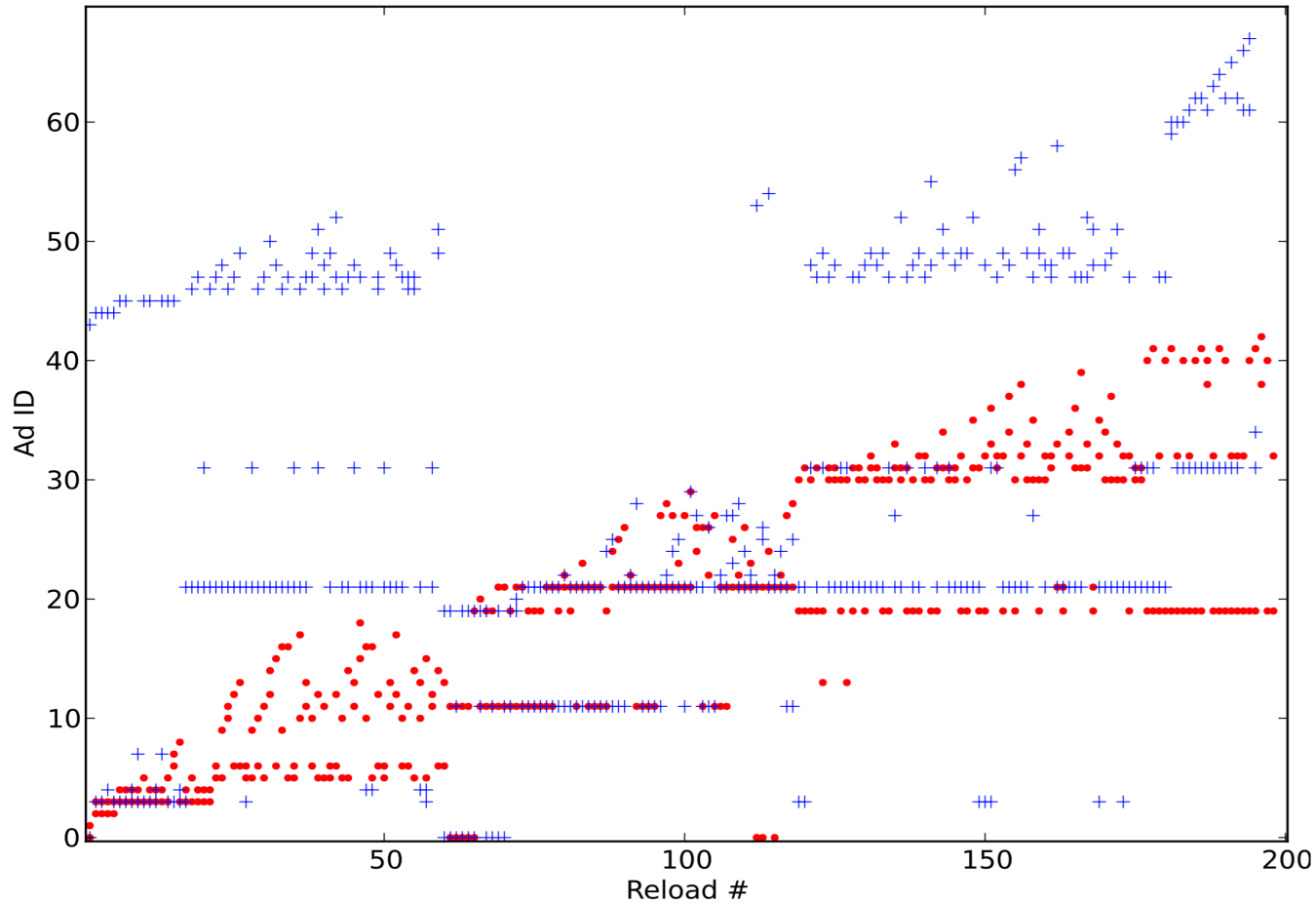
Information Flow Experiments



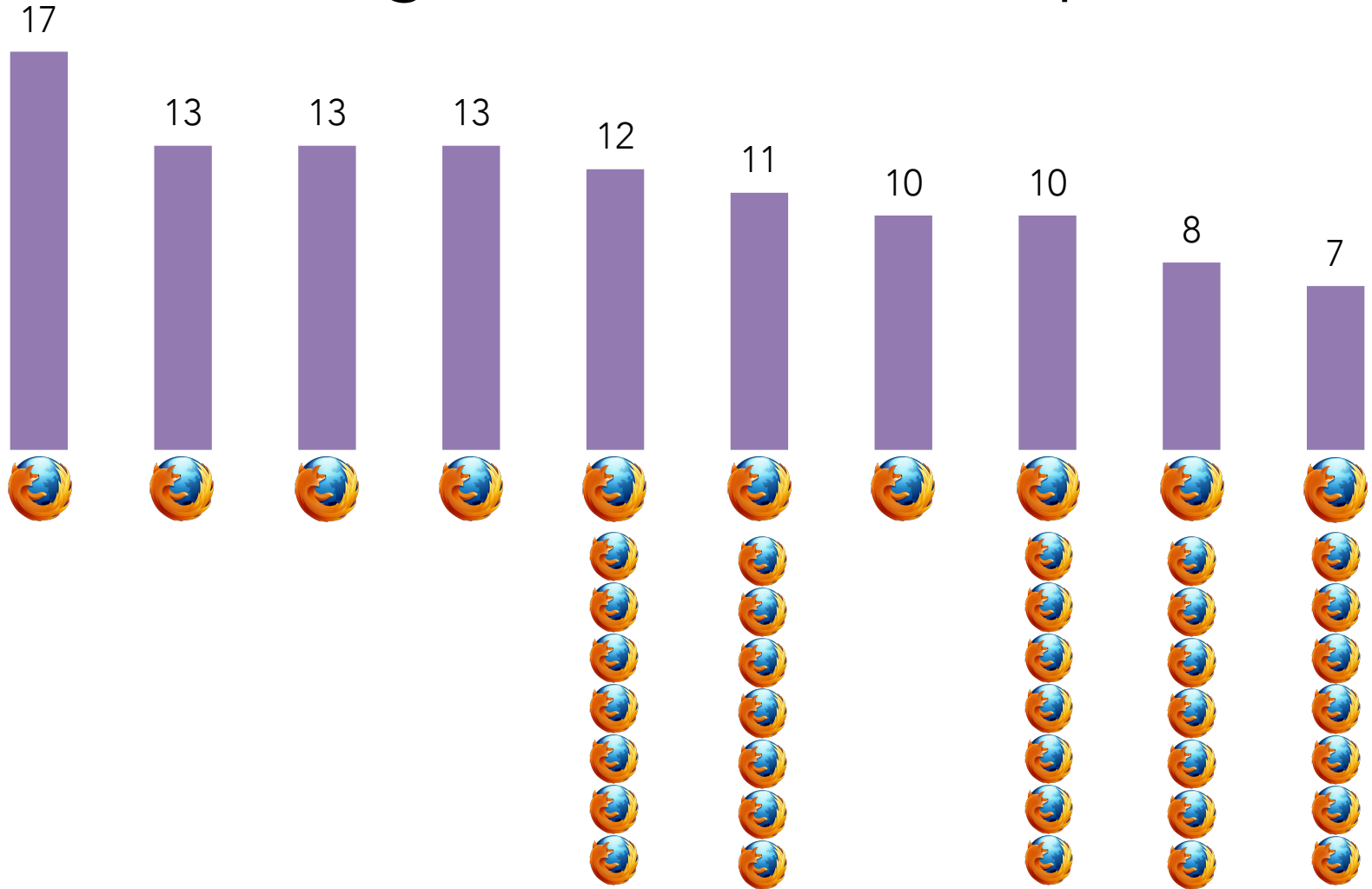
Ads vary over time



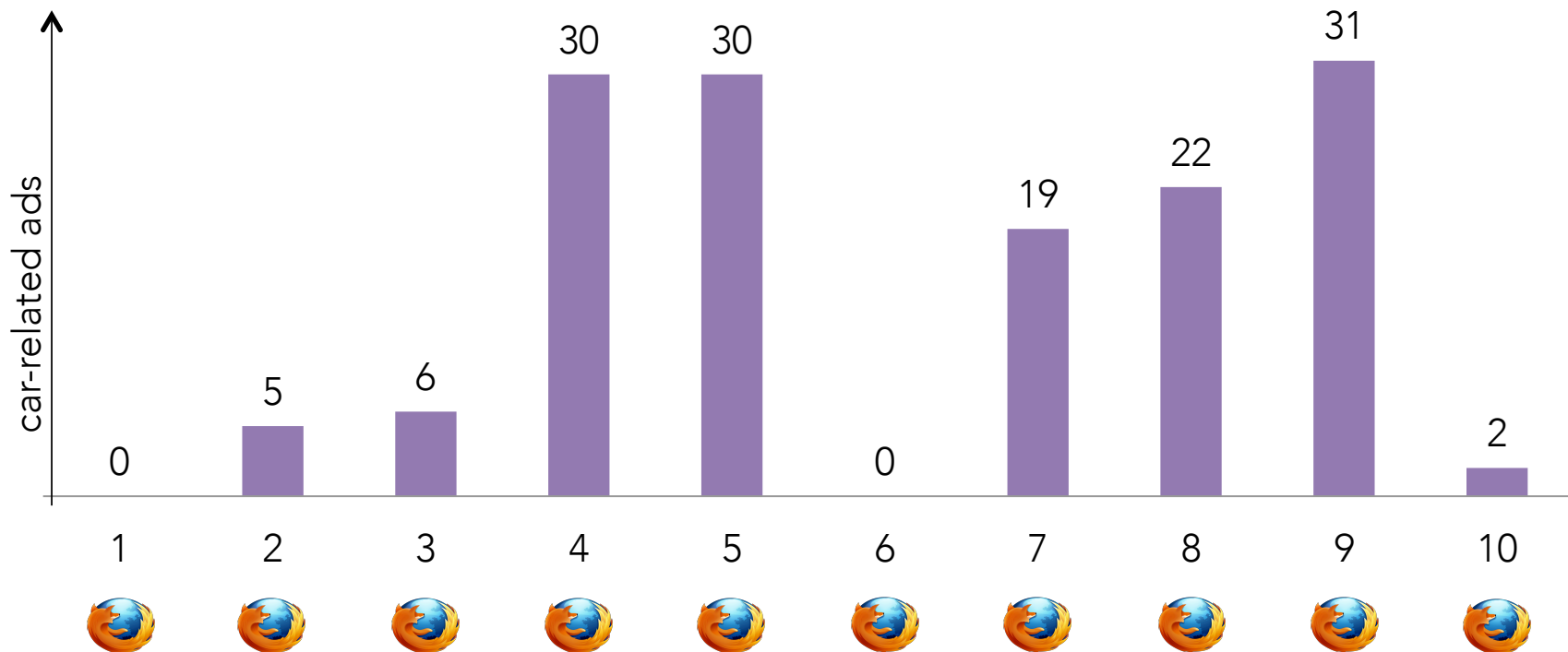
Ads differ on agents on the same machine



Browser Agents are not Independent



Permutation Test: Example



"BMW buy", "Audi purchase",
"new cars", "local car dealers",
"autos and vehicles", "cadillac
prices", and "best limousines"



'bmw', 'audi', 'car', 'vehicle', 'automobile', 'cadillac', 'limo'

P value

- Probability of obtaining a result at least as extreme as the one observed, assuming that the null hypothesis is true

- $$\text{p-value} = \frac{1}{|\vec{y}|!} \sum_{\pi \in \Pi(|\vec{y}|)} I[s(\vec{y}) \leq s(\pi(\vec{y}))]$$

I is the indicator function $s(\vec{y})$ is the statistic computed over \vec{y}

\vec{y} is the measurement vector $\pi(\vec{y})$ is a permutation of \vec{y}

$$p_{\text{ub}} = 1 - \text{BetaInv}\left(\frac{\alpha}{2}, n - k, k + 1\right)$$

$$p_{\text{lb}} = 1 - \text{BetaInv}\left(1 - \frac{\alpha}{2}, n - k + 1, k\right)$$

Confidence Intervals

$$p_{\text{ub}} = 1 - \text{BetaInv}\left(\frac{\alpha}{2}, n - k, k + 1\right)$$

$$p_{\text{lb}} = 1 - \text{BetaInv}\left(1 - \frac{\alpha}{2}, n - k + 1, k\right)$$

Probabilistic Noninterference and Causal Effect

Definition 2 (Probabilistic Noninterference). *A system Q has probabilistic noninterference from L to H iff for all input sequences \vec{v}_1 and \vec{v}_2 ,*

$$[\vec{v}_1 \downarrow L] = [\vec{v}_2 \downarrow L] \text{ implies } [Q(\vec{v}_1) \downarrow L] = [Q(\vec{v}_2) \downarrow L]$$

Definition 3 (Effect). *The experimental factor X has an effect on Y given $Z := z$ iff there exists x_1 and x_2 such that the probability distribution of Y in $M[X:=x_1][Z:=z]$ is not equal to its distribution in $M[X:=x_2][Z:=z]$.*

Theorem 3. *Q has probabilistic interference iff there exists low inputs ℓ of length t such that \vec{V}_{hi}^t has an effect on \vec{V}_{lo}^t given $V_{\text{ii}}^t := \ell$.*

Xray

Theorem 1 *Under §4.2 assumptions, for any $\varepsilon > 0$ there exists an algorithm that requires $C \times \ln(N)$ accounts to correctly identify the inputs of a targeted ad with probability $(1 - \varepsilon)$. The constant C depends on ε and the maximum size of combinations r ($O(r2^r \log(\frac{1}{\varepsilon}))$).*

$$\begin{aligned}\mathbb{P} [\vec{x} | D_i] &= (p_{\text{in}})^{|A_i \cap A_k|} (1 - p_{\text{in}})^{|A_i \cap \bar{A}_k|} \\ &\quad \times (p_{\text{out}})^{|\bar{A}_i \cap A_k|} (1 - p_{\text{out}})^{|\bar{A}_i \cap \bar{A}_k|}, \\ \mathbb{P} [\vec{x} | D_\emptyset] &= (p_\emptyset)^{|A_k|} (1 - p_\emptyset)^{|\bar{A}_k|},\end{aligned}$$

Comparison

	RCTs	Guha et al.	XRay
Statistical Significance	yes	no	no
Information Flow	yes	no	no
Multiple Treatments/Inputs	no	yes	yes
Reasonable Assumptions	yes	yes	no

Machine Learning Algorithms

Algorithm	Parameter Space	
Logistic Regression	$C = \{2^{-5}, 2^{-4} \dots, 2^{15}\}$	penalty = $\{L_1, L_2\}$
SVM with poly kernel	$C = \{2^{-5}, 2^{-4} \dots, 2^{15}\}$	degree = $\{1, 2, 3, 4\}$
SVM with RBF kernel	$C = \{2^{-5}, 2^{-4} \dots, 2^{15}\}$	$\gamma = \{2^{-15}, 2^{-14} \dots, 2^3\}$
k nearest neighbors	$k = \{1, 3, \dots, 19\}$	$p = \{1, 2, 3\}$

p in kNN stands for L_p distance

Summary of Transparency Experiments

Treatment	Addl. Actions	Measurement	p-value	Finding
Substance Abuse	-	TOI, May	0.0000053	Violation
Substance Abuse	-	TOI, July	0.0000053	Violation
Substance Abuse	-	Guardian, July	0.0076	Violation
Substance Abuse	Top 10	TOI, July	0.0000053	Violation
Disability	-	TOI, May	0.0000053	Violation
Mental Disorder	-	TOI, May	0.053	Inconclusive
Infertility	-	TOI, May	0.11	Inconclusive
Adult Websites	-	TOI, May	0.42	Inconclusive

www.alex.com/topsites/category/Top/Health/Addictions/Substance_Abuse

www.alex.com/topsites/category/Top/Society/Disabled

Details of Transparency Experiment

Treatment	Other visits	measurement	date	blocks	# ads (# unique ads)			accuracy	p-value	computation times	
					experimental	control	total			training	testing
Substance abuse		TOI	May	100	20,420 (427)	22,204 (530)	42,624 (673)	81%	0.000005298	18s	3m19s
Substance abuse		TOI	July	100	16,206 (653)	18,202 (814)	34,408 (1045)	98%	0.000005298	21s	3m29s
Substance abuse		Guardian	July	100	8,359 (242)	11,489 (319)	19,848 (387)	62%	0.007551	11s	3m26s
Substance abuse	top 10	TOI	July	100	15,713 (603)	16,828 (679)	32,541 (905)	65%	0.000005298	19s	3m19s
Disability		TOI	May	100	19,787 (546)	23,349 (684)	43,136 (954)	75%	0.000005298	21s	3m18s
Mental disorder		TOI	May	100	22,303 (407)	22,257 (465)	44,560 (600)	59%	0.0529655	31s	3m19s
Infertility		TOI	May	100	22,438 (605)	22,544 (625)	44,982 (856)	57%	0.113977	39s	3m23s
Adult websites		TOI	May	100	17,670 (602)	17,760 (580)	35,430 (850)	52%	0.416935	33s	3m28s

Details of Transparency Experiments

Title	URL	Coefficient	appears in agents		total appearances	
			control	experi.	control	experi.
Top ads for identifying agents in the experimental group (visited websites associated with substance abuse)						
The Watershed Rehab	www.thewatershed.com/Help	-0.888	0	280	0	2276
Watershed Rehab	www.thewatershed.com/Rehab	-0.670	0	51	0	362
The Watershed Rehab	Ads by Google	-0.463	0	258	0	771
Veteran Home Loans	www.vamortgagecenter.com	-0.414	13	15	22	33
CAD Paper Rolls	paper-roll.net/Cad-Paper	-0.405	0	4	0	21
Top ads for identifying agents in control group						
Alluria Alert	www.bestbeautybrand.com	0.489	2	0	9	0
Best Dividend Stocks	dividends.wyattresearch.com	0.431	20	10	54	24
10 Stocks to Hold Forever	www.streetauthority.com	0.428	51	44	118	76
Delivery Drivers Wanted	get.lyft.com/drive	0.362	22	6	54	14
VA Home Loans Start Here	www.vamortgagecenter.com	0.354	23	6	41	9

Summary of Choice Experiments

Treatment	Measurement	p-value	Finding
Opting out	TOI, May	0.0000053	Compliance
Dating	TOI, May	0.0000053	Compliance
Dating	TOI, July	0.070	Inconclusive
Weight Loss	TOI, May	0.041	Compliance
Weight Loss	TOI, July	0.42	Inconclusive

Details of Choice Experiment

Title	URL	Coefficient	appears in agents		total appearances	
			kept	removed	kept	removed
Top ads for identifying the group that kept dating interests						
Are You Single?	www.zoosk.com/Dating	1.583	367	33	2433	78
Top 5 Online Dating Sites	www.consumer-rankings.com/Dating	1.109	116	10	408	13
Why can't I find a date?	www.gk2gk.com	0.935	18	3	51	5
Latest Breaking News	www.onlineinsider.com	0.624	2	1	6	1
Gorgeous Russian Ladies	anastasiadate.com	0.620	11	0	21	0
Top ads for identifying agents in the group that removed dating interests						
Car Loans w/ Bad Credit	www.car.com/Bad-Credit-Car-Loan	-1.113	5	13	8	37
Individual Health Plans	www.individualhealthquotes.com	-0.831	7	9	21	46
Crazy New Obama Tax	www.endofamerica.com	-0.722	19	31	22	51
Atrial Fibrillation Guide	www.johnshopkinshealthalerts.com	-0.641	0	6	0	25
Free \$5 - \$25 Gift Cards	swagbucks.com	-0.614	4	11	5	32

Summary of Fairness Experiments

Treatment	Addl. Actions	Measurement	p-value	Finding
Gender	-	TOI, May	0.77	Inconclusive
Gender	Jobs	TOI, May	0.0000053	Violation
Gender	Jobs	TOI, July	0.20	Inconclusive
Gender	Jobs	Guardian, July	0.12	Inconclusive
Gender	Jobs, Top 10	TOI, May	0.14	Inconclusive

Details of Fairness Experiment

Title	URL	Coefficient	appears in agents		total appearances	
			female	male	female	male
Top ads for identifying the simulated female group						
Jobs (Hiring Now)	www.jobsinyourarea.co	0.34	6	3	45	8
4Runner Parts Service	www.westernpatoyotaservice.com	0.281	6	2	36	5
Criminal Justice Program	www3.mc3.edu/Criminal+Justice	0.247	5	1	29	1
Goodwill - Hiring	goodwill.careerboutique.com	0.22	45	15	121	39
UMUC Cyber Training	www.umuc.edu/cybersecuritytraining	0.199	19	17	38	30
Top ads for identifying agents in the simulated male group						
\$200k+ Jobs - Execs Only	careerchange.com	-0.704	60	402	311	1816
Find Next \$200k+ Job	careerchange.com	-0.262	2	11	7	36
Become a Youth Counselor	www.youthcounseling.degreeleap.com	-0.253	0	45	0	310
CDL-A OTR Trucking Jobs	www.tadrivers.com/OTRJobs	-0.149	0	1	0	8
Free Resume Templates	resume-templates.resume-now.com	-0.149	3	1	8	10

Details of Choice and Fairness Experiments

Experiment	blocks	# ads (# unique ads)			accuracy	p-value	computation times	
		removed/opt-out	keep/opt-in	total			training	testing
Opting out	54	9,029 (139)	9,056 (293)	18,085 (366)	83%	0.000005298	4s	2m10s
Dating (May)	100	17,975 (518)	17,762 (457)	35,737 (669)	74%	0.000005298	13s	3m27s
Dating (July)	90	11,657 (727)	11,256 (706)	22,913 (1,014)	59%	0.07042	24s	3m20s
Weight Loss	83	15,826 (367)	15,449 (427)	31,275 (548)	60%	0.040948	16s	3m04s

Treatment	other visits	measurement	date	blocks	# ads (# unique ads)			accuracy	p-value	computation times	
					female	male	total			training	testing
Gender		TOI	May	100	20,137 (603)	20,263 (630)	40,400 (843)	48%	0.7714	25s	3m 22s
Gender	jobs	TOI	May	100	21,766 (545)	21,627 (533)	43,393 (736)	93%	0.000005298	23s	3m 26s
Gender	jobs	TOI	July	100	17,019 (673)	18,013 (690)	35,032 (954)	55%	0.2000	31s	3m 29s
Gender	jobs	Guardian	July	100	11,366 (410)	11,230 (408)	22,596 (581)	57%	0.1173	19s	3m 29s
Gender	jobs & top 10	TOI	July	100	14,507 (461)	14,231 (518)	28,738 (711)	56%	0.1448	23s	3m 24s