ORIE 5355: Applied Data Science - Decision-making beyond Prediction

Lecture 4: Weighting + other topics in Data Collection

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Announcements

- HW1 due Tuesday 9/12
- Quiz 1 will also be that week
- No class on Monday (Labor day weekend)

Questions from last time?

Plan for today

- Weighting techniques
- 1 slide on quantifying uncertainty
- Other topics
  - Data collection case studies beyond polling
    Ratings + Recommendations
  - Other topics in data collection
    Differential privacy, Bias, Eliciting complex opinions, Modeling opinion dynamics
- Module summary + questions

Weighting

Stratification summary: change who you call

- Suppose you have L mutually exclusive demographic groups
- There are N^ℓ people in group ℓ in the population you care about
- Each group ℓ has group response rate A^ℓ
- Call number of people in each group proportional to N^ℓ / A^ℓ

This reduces bias if group response rates are different across groups

Always reduces variance caused by sample groups not matching population groups

Main idea for weighting

- In stratified sampling, we balanced out the groups according to their population percentage *before* we called people
- With weighting, we try to do the same thing, but *after* we call people and know how many from each group responded
- Why?
  - You might not know response rates per group
  - You might not know a person's demographics until you call them
  - Can run *sensitivity analyses:* "what would the estimate be if this demographic group only composes x% of the population instead of y%?"
- Comes at a cost: doesn't have the same variance reduction properties as does stratified sampling

Main idea, 2 steps:

Step 1: Use the responses to estimate the mean response for each group ℓ, i.e., get an estimate $\hat{y}^{\ell}$ of the true opinion $\bar{y}^{\ell}$

Step 2: Do a weighted average of $\hat{y}^{\ell}$; each group is given weight W^{ℓ}

$$\hat{y} = \sum_{\ell} W^{\ell} \, \hat{y}^{\ell}$$

If $W^{\ell} = P^{\ell}$ and $\hat{y}^{\ell} \to \bar{y}^{\ell}$, then $\hat{y} \to \bar{y}$

Details differ in how to construct estimate $\hat{y}^{\ell}$, how to calculate weight W^{ℓ}, and what groups ℓ to consider

Naïve Weighting

Step 1: Use the mean response for each group ℓ separately, i.e.

$$\hat{y}^{\ell} = \frac{\sum_{j \in \{j \mid A_j = 1, x = \ell\}} Y_j}{|\{j \mid A_j = 1,\ x = \ell\}|}$$

Step 2: Weight W^{ℓ} is our best guess of true population fraction P^{ℓ} for group ℓ

Complication: How many groups/which ones?

- If group too broad (e.g., group ℓ just gender), then break cardinal rule:

  Need: Opinion Y_j *is independent of whether they respond* A_j*, conditional on group* ℓ

- If group is too specific (*ethnicity* x *gender* x *education* x *age*), then:

  Problem 1: Estimate $\hat{y}^{\ell} = \frac{\sum_{j \in \{j \mid A_j = 1, x = \ell\}} Y_j}{|\{j \mid A_j = 1, x = \ell\}|}$ might be really bad

  Too few respondents in a group → high variance (1 person might determine entire average)

  Problem 2: We might not know population fraction P^{ℓ}

Tackling Problem 2: Population weights

- Suppose very specific group (*ethnicity* x *gender* x *education* x *age*)
- Naïve: try to figure out true population fraction (“joint distribution”)

  “W^ℓ = P^ℓ *fraction of pop is college educated white women age 35-44”*
- Easier: Use “marginal” distribution for each covariate

  “a fraction of population is women”

  “b fraction of population is college educated”

  “c fraction of population is white”

  “d fraction of population is age 35-44”

  $\Rightarrow$Pretend “W^ℓ = *abcd fraction of pop is college educated white women age 35-44”*
- *Not covered -- “raking”: match marginal distribution for each covariate without assuming that marginal distributions make up joint distribution*

The homework

- In the homework, first we define groups just based on a single covariate, for example gender, ethnicity/race, political party, etc.
  - (e.g., group ℓ just based on gender); we give you P^ℓ
- Then we define groups based on 2 covariates; we give you P^ℓ
- Then we define groups based on 2 covariates and ask you to construct P^ℓ based on marginal distributions

Tackling Problem 1: MRP

Problem 1: Estimate $\hat{y}^{\ell} = \frac{\sum_{j \in \{j \mid A_j = 1, x = \ell\}} Y_j}{|\{j \mid A_j = 1, x = \ell\}|}$ might be really bad

Too few respondents in a group → high variance (1 person might determine entire average)

- Somehow this seems wrong: presumably, the estimate for a group should be very close to that of a "neighboring" group
- "Multi-level regression with post-stratification" (MRP)

Main idea: Train a (Bayesian) regression model to get estimate $\hat{y}^{\ell}$ for each set of covariates. Then, "post-stratify" by weighting $\hat{y}^{\ell}$ by population fraction P^{ℓ}

For groups with many samples, estimate $\hat{y}^{\ell}$ just based on that group; otherwise, based on "neighboring" groups

Parting thoughts on weighting

- Where do the population percentages come from? In political polling, you need to define a universe of “likely voters”
- Methods not covered here: *Inverse Propensity Scoring*, and *Matching*
- Note, can only weight when you observe the covariates for each respondent!
- What if sampling bias is correlated with a feature you don’t observe?
  - Next time!

Parting thoughts

Be purposeful! Does your numeric data capture what you want it to?

Be skeptical! Just because a poll was “random” doesn’t make it good

Unmeasured confounding and quantifying uncertainty

1 slide summary

Challenge

- Stratification and weighting help us when we have covariates that capture the selection bias and different opinions
  - Response rates correlates with education, and we know education level of respondents
- What if we don't have access to these covariates? This is called "unmeasured confounding"

What to do about it

- We can't hope to "correct" for unmeasured confounding
- However, we can *quantify the uncertainty* under *assumptions* on how bad the problem is
  - "If response rates were this different by group, and if this group has this magnitude of different opinion, here's how different by answer would be"

The challenge

- In the last lecture, weighting helped us deal with *measured* selection bias/differential non-response

  Response rates and political opinions both correlate with educational status;

  (1) Education status can be asked for during the poll
  (2) We can roughly guess at voter distribution by education status
  (3) Then use various *weighting* techniques
- What if response rates & opinions depend on a covariate that we don’t observe, or that we don’t know the population distribution of?
- Very little we can do to recover “point-estimate” of population opinion
- However, we can *quantify the uncertainty* under *assumptions* on how bad the problem is

Setup

- Suppose there is a (binary) covariate u_j that correlates with both the opinion of interest Y_j and whether people respond A_j.
- You don't observe u_j for any individual j
- u is the only unmeasured confounding: A_j is uncorrelated with true opinion Y_j given u_j -- but we don't have u_j
- You have an estimate $\hat{y}$ (raw average of responses)
- Idea: Make assumptions on "how bad" the unmeasured confounding can get to derive uncertainty regions for your estimate of interest.

How to quantify uncertainty

- If we assume like we did on the last slide: "Conditional on what group the respondent belongs to, their opinion does not correlate with whether they respond"
- Then, you can do some math where your error decomposes into the difference between groups in *whether they respond* and *true opinion differences*

$$\hat{y} - \bar{y} \to \left(\tilde{P}^1 - P^1\right)\left(E\left[Y_j \mid u_j = 1\right] - E\left[Y_j \mid u_j = 0\right]\right)$$

More detail: Notation and Insight

- True population fractions of u: $\mathrm{P}^1 = \Pr(u_j = 1), 1 - \mathrm{P}^1 = \Pr(u_j = 0)$
- Response fractions: $\tilde{\mathrm{P}}^\ell = \Pr(u_j = \ell \mid A_j = 1)$
- $\bar{y} \stackrel{\text{def}}{=} E[Y_j] = P^1 E[Y_j \mid u_j = 1] + (1 - P^1) E[Y_j \mid u_j = 0]$
- $\hat{y} \to E[Y_j \mid A_j = 1] = \tilde{\mathrm{P}}^1 E[Y_j \mid u_j = 1, A_j = 1] + (1 - \tilde{P}^1) E[Y_j \mid u_j = 0, A_j = 1]$
- Insight:

$$E[Y_j \mid u_j = \ell, A_j = 1] = E[Y_j \mid u_j = \ell]$$

"Conditional on what group the respondent belongs to, their opinion does not correlate with whether they respond" ← We assumed this on last slide!

More detail: Quantifying uncertainty in math

$$\bar{y} = P^1 E[Y_j \mid u_j = 1] + (1 - P^1) E[Y_j \mid u_j = 0]$$
$$\hat{y} \to \tilde{P}^1 E[Y_j \mid u_j = 1] + (1 - \tilde{P}^1) E[Y_j \mid u_j = 0]$$

Rearrange:

$$\hat{y} \to \bar{y} + \left(\tilde{P}^1 - P^1\right) E[Y_j \mid u_j = 1] + \left(P^1 - \tilde{P}^1\right) E[Y_j \mid u_j = 0]$$
$$= \bar{y} + \left(\tilde{P}^1 - P^1\right) \left(E[Y_j \mid u_j = 1] - E[Y_j \mid u_j = 0]\right)$$

Then, make assumptions on *whether respond* and *opinion* differences to quantify how far $\hat{y}$ can be from $\bar{y}$

If *either* response fractions or opinions between groups are similar, effect of unmeasured confounding is small!

Unmeasured confounding in ML

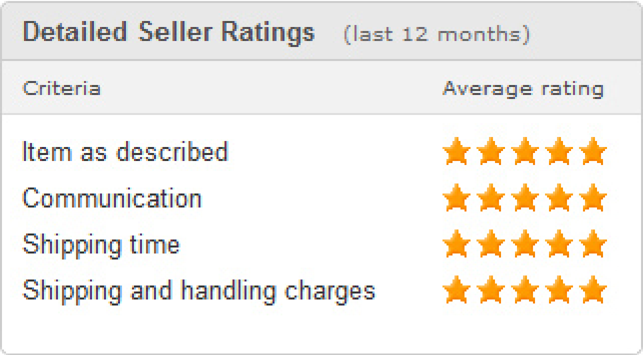
- In data science, we often care about *causal inference*
  - "What is the causal effect of going to a private high school on college success?"
  - Problem: In the US, private HS attendance correlated with parents' wealth
- Unmeasured confounding (you might not know parents' wealth) would mess up your *inference* of the relationship in a regression
- You can also quantify unmeasured confounding and range of effects in such cases

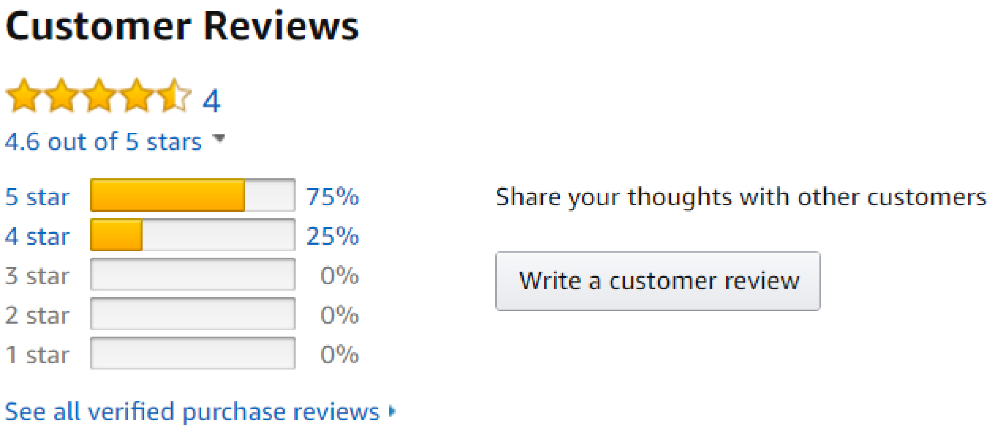
Case study: Ratings and recommendations

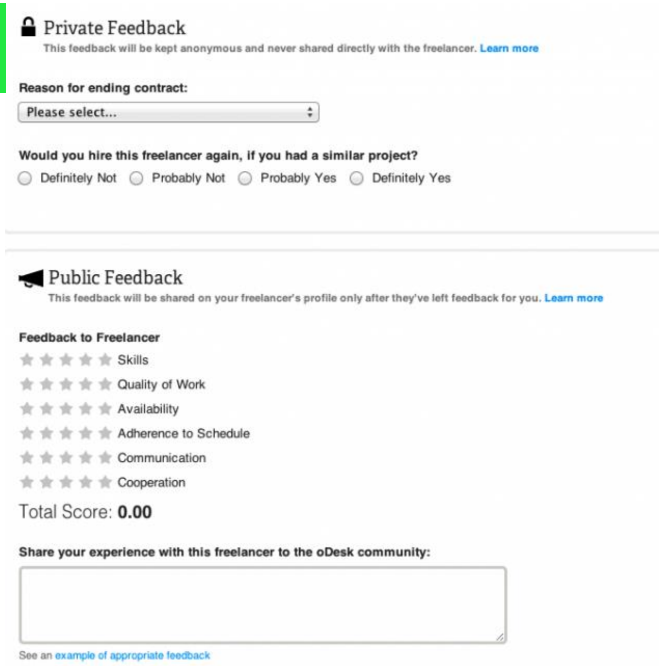
Overview

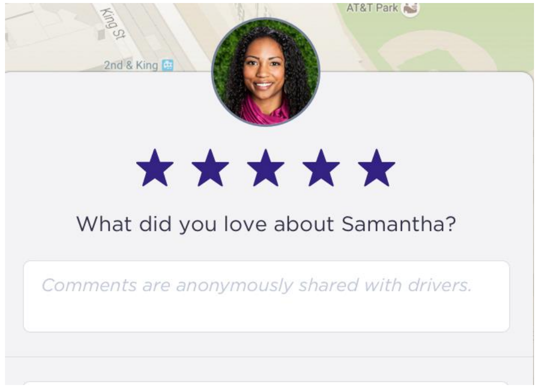
- So far, we’ve talked about explicit opinion collection in polling
- The same challenges apply in other settings
- Some differences
  - Often we don’t care about “absolute” opinion but “relative” opinions
  - We care a lot about “heterogeneous” opinions
  - We often have other “implicit” data on people’s opinions
- Briefly discuss some of these challenges in context of ratings and recommendations

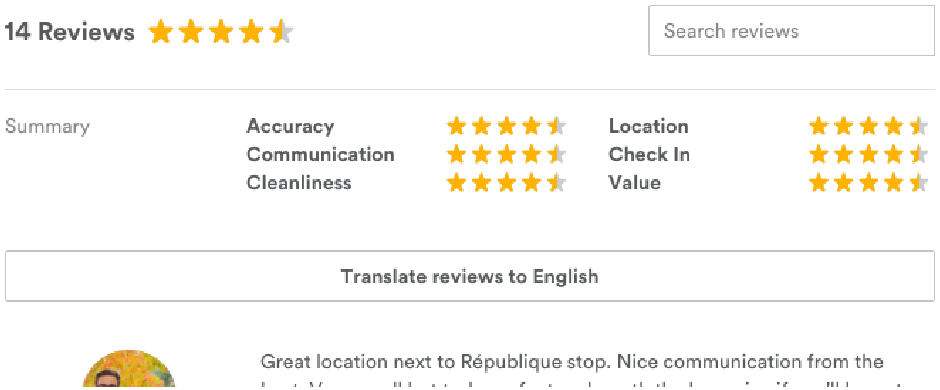
Rating systems











Measurement error: Ratings Inflation

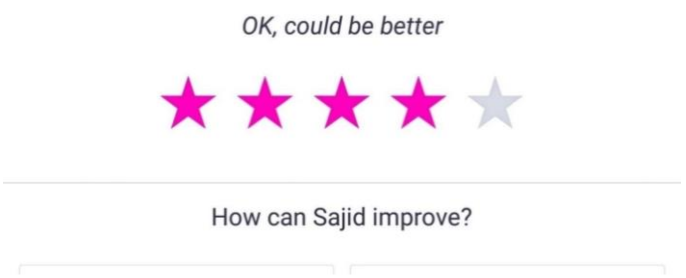
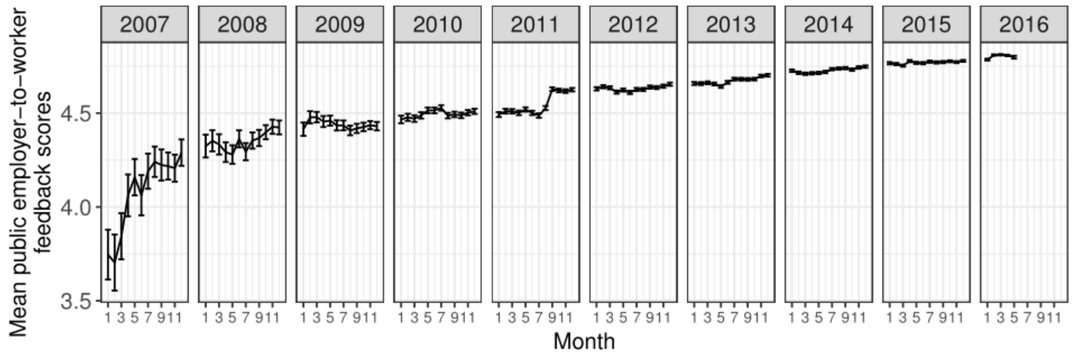


Figure 2: Monthly average public feedback scores assigned to workers by employers on completed projects.



[Filippas, Horton, Golden 2017]

When 4.3 Stars Is Average: The Internet's Grade-Inflation Problem

The Wall Street Journal April 5, 2017

https://xkcd.com/1098/

Why ratings inflation & what to do about it?

- Many hypotheses for why ratings inflate
    - Explicit pressure from sellers – worry about retaliation
    - Implicit pressure – don't want to hurt people's livelihoods

    → Either misreport, or selection – less likely to report after bad experience
- Inflation is a type of measurement error:
    - The "quality" scale doesn't match well to the "rating" scale
    - Inflation over time – mapping from quality to rating changes over time
    - Why does it matter? We ask you this in the homework
- What to do about it:
    - Try to reduce some of the pressure
    - Weighting to tackle selection: paper in the homework: [Nosko & Tadelis]
    - Change the rating scale: [Garg and Johari]

Experiment Description

Status quo: Clients hire freelancers, rate them at contract end

Form includes a numeric rating from 0 to 10, with avg >8/10

Challenge: Can we induce different (non-inflated) ratings by changing the question we ask on the rating form?

Experiment design

- Add additional question to private portion of the form (6 treatments)

  Randomization at the *client* level
- Observe ratings for 3 months (180k jobs, 60k clients, 80k freelancers)

Treatment groups

Treatment	Question Phrasing	Answer choices
Numeric	How would you rate this freelancer overall?	0 – 5

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Numeric	How would you rate this freelancer overall?	0 – 5
Adjectives	How would you rate this freelancer overall?	Terrible Mediocre Good Great Phenomenal Best possible freelancer!

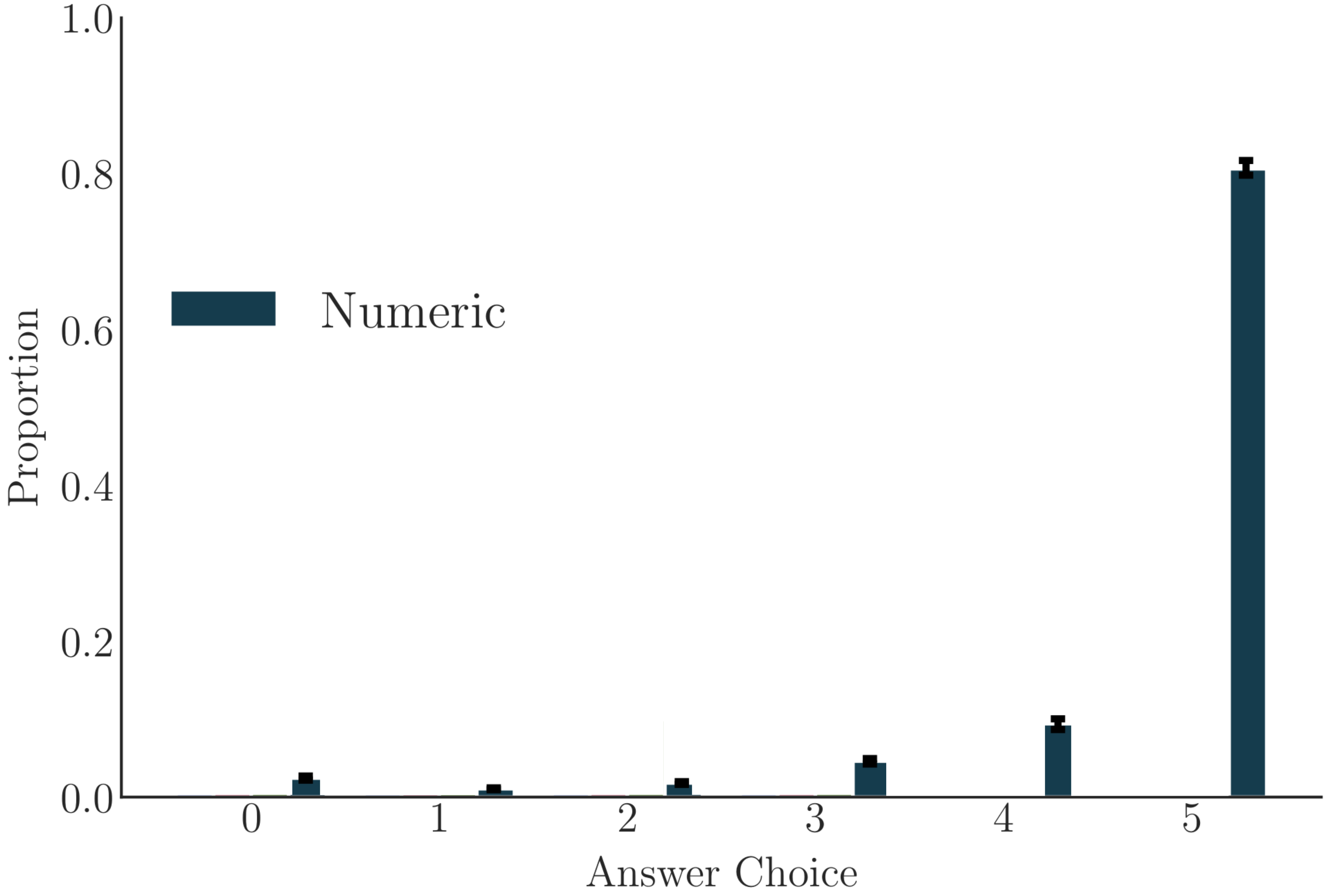
“Designing Informative Rating Systems: Evidence from an Online Labor Market” Nikhil Garg and Ramesh Johari

Treatment groups

Treatment	Question Phrasing	Answer choices
Numeric	How would you rate this freelancer overall?	0 – 5
Adjectives	How would you rate this freelancer overall?	Terrible Mediocre Good Great Phenomenal Best possible freelancer!
Expectations	How did this freelancer compare to your expectations?	Much worse than I expected … Beyond what I could have expected
Average	How does this freelancer compare to others you have hired?	Worst Freelancer I’ve Hired Below Average Average Above Average Well Above Average Best Freelancer I’ve hired
Average, random order		
Average, not affect score	How does this freelancer compare to others you have hired? (This will not impact the freelancer’s score)	

“Designing Informative Rating Systems: Evidence from an Online Labor Market” Nikhil Garg and Ramesh Johari

Result: marginal rating distributions



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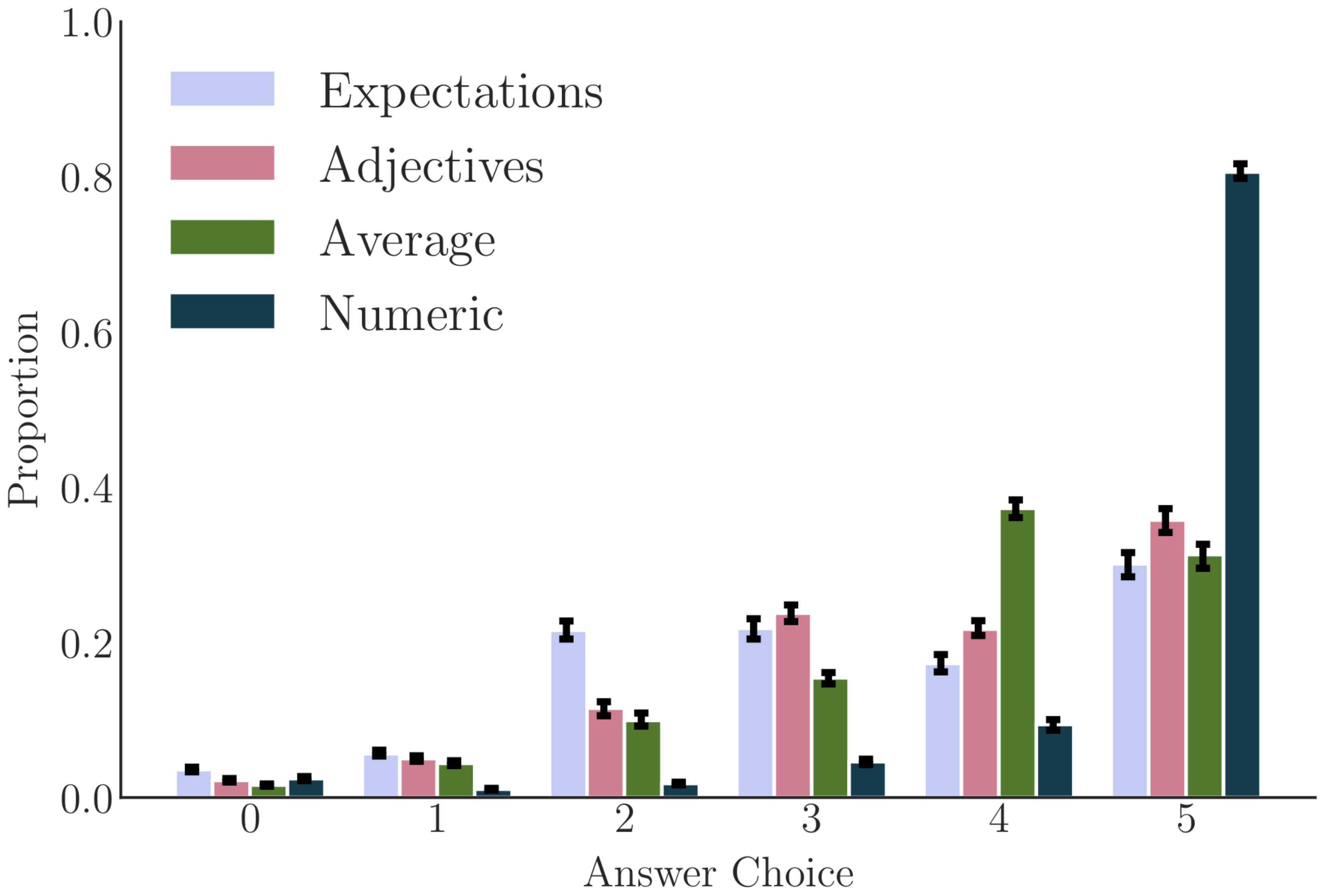

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Ratings heterogeneity

- There is much ratings “heterogeneity”
  - Different people have different opinions on the same item
  - Different ‘categories’ of items might have different average ratings
- Why does this matter?
  - You want to give each person a personalized “rating” or recommendation
  - You want to compare items across categories
- What to do about it?
  - Personalized recommendations → starting next time
  - “Standardize” ratings across categories
  - Communicate to customers – e.g., “relative” ratings instead of “absolute” ones

Implicit data collection in recommendations

- You have many implicit signals about people's opinions
  - Do they finish watching the show, or start watching the next episode?
  - Do they keep coming back and buying other things
  - Did they browse other items instead of putting something in their cart?
  - Do they re-hire the same freelancer/work with the same client again?
- These give *different* information than do explicit ratings
  - From a different population of users
  - Often more numerous, but harder to analyze
  - "revealed preference" – might be more predictive of future behavior
- Using such data
  - Train models to predict different future behavior, using various signals
  - Might take away "user agency" – what if they want to change their behavior?

Miscellaneous topics in data and data collection

(Differential) Privacy

- What if you're asking about a sensitive attribute?

  For example, an insurance company wants to estimate the percentage of their policy holders who smoke

- Goal: collect data in a way such that you learn very little about any individual person, but you are accurate across population
- How? Add noise to each response
- Example: Tell each person, "roll a 6-sided dice. If it's 1 or 2, lie about whether you smoke. Otherwise, tell the truth." If fraction Y people tell you that they smoke, then we know that the truth X satisfies:

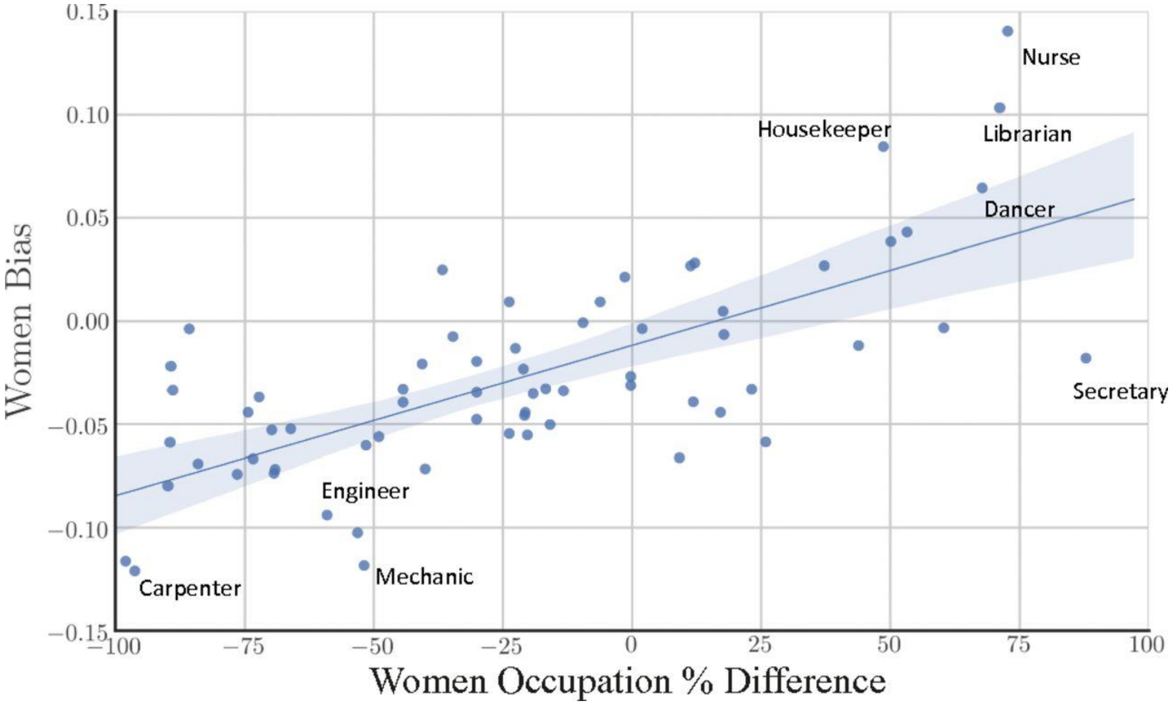
$$Y = \frac{4}{6}X + \frac{2}{6}(1 - X)$$

- Similar ideas used to collect and share data at Apple and the US Census

Using biased data

- The world is full of historic inequities
  - Some neighborhoods are over-policed compared to others → data will have more "crimes there"
  - Every possible opinion expressed on forums like Reddit
  - Who succeeded at a university
- Models trained using this data will *reflect* and *amplify* these biases
- Many techniques to audit and mitigate such biases in models

Bias in word embeddings



"Word Embeddings Quantify 100 Years of Gender and Ethnic Stereotypes" by Nikhil Garg, Londa Schiebinger, Dan Jurafsky, and James Zou

Eliciting complex opinions

- So far, we’ve talked about soliciting “low-dimensional” opinions
  - Binary opinions, or one of a small number of options
- What if we want to solicit opinions on complicated things?
  - How your town should spend $2M budget across parks, sports teams, art festivals, etc.
  - When should we schedule these five events over 10 time slots?
- You can’t ask people to rank every option
- Several standard techniques
  - Participatory budgeting
  - Pairwise comparisons
- More generally, many cool techniques in crowdsourcing

Data dynamics

- The world is not static
  - Opinions change with external events
  - Your startup is growing and attracting new kinds of customers
  - Weekends are different than weekdays, except on holidays…
- Similar problem as “Problem 1” in survey weighting – if you don’t share data across time, then you don’t have enough data. But if you do share data, then suddenly your dataset differs from what you care about
- Techniques to model opinion dynamics – “smooth” over time
- Some related challenges covered in pricing module

Module Summary

- Measurement error: The construct you care about is never perfectly captured by the data that you have
- Selection effects/differential non-response happens everywhere you're collecting opinions from people
- You can use stratification and weighting to mitigate selection effects *on known covariates*
- On unknown covariates, quantify uncertainty!

Never take opinion data at face value. Always ask:

(1) What did I measure, versus what did I care to measure?

(2) Who answered versus what's the population of interest

(3) What am I going to *do* with the data, and how does that affect data collection?

Will show up in the rest of the course!

Questions?