

Finding Words Associated with DIF

Predicting and Describing Differential Item Functioning using Large Language Models

Hotaka Maeda - Smarter Balanced

Yikai (EK) Lu - University of Notre Dame

DIF Analysis

- ▶ Differential item functioning (DIF) - correct item response probabilities that depend on examinee demographic background, after conditioning on ability
- ▶ Psychometrician + Item content developer/SME

Purpose

1. Predict DIF from the item text by training (fine-tune) an encoder transformer language model
2. Then, use “explainable AI” (XAI) methods to identify words associated with DIF

► Impact

- Avoid sample size issue
- Provide immediate item writing/revision feedback (3 years in advance for SB)
- Understand how DIF manifests qualitatively

METHODS

Item Data

- ▶ 42,176 English language arts & math items that have been field-tested
 - Multiple choice
 - Multiple select
 - Short answer
 - Essay
 - Hot-text
- ▶ DIF results for gender, race/ethnicity, SES, English language learner, disability
- ▶ Grades 3 to 11

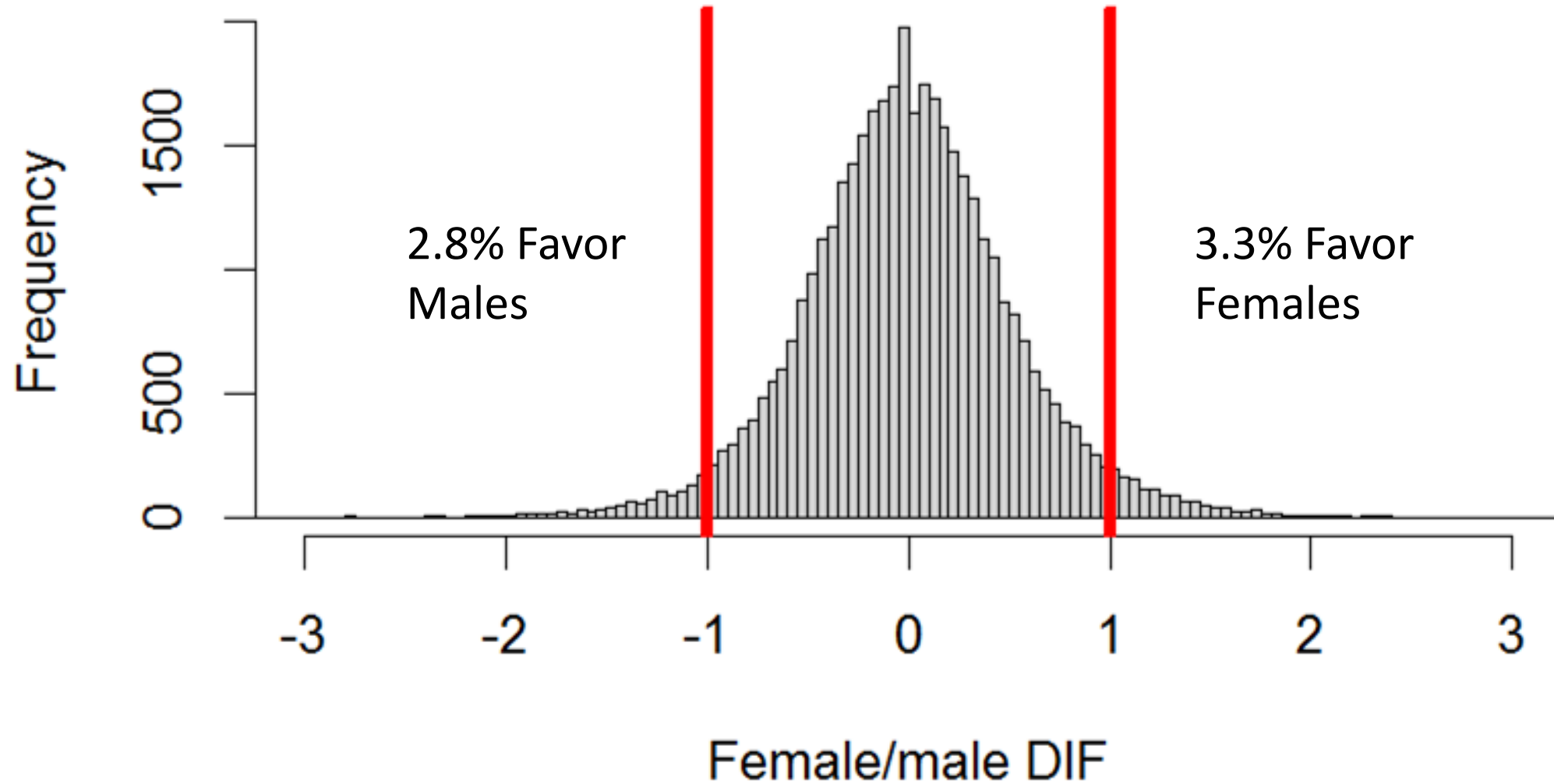
DIF Data

- ▶ Mantel-Haenszel delta difference (MH)
 - ≤ -1 favors male students
 - ≥ 1 favors female students
- ▶ Standardized mean difference effect size (ES)
 - ≤ -0.17 favors male students
 - ≥ 0.17 favors female students
- ▶ ES was divided by 0.17 and treated like MH
- ▶ $N \geq 100$ female and ≥ 100 male examinees per item

DIF Prediction

- ▶ Fine-tune DeBERTa V3-large transformer encoder LLM with DIF statistic as target and concatenated item text as input
- ▶ 80% training, 10% evaluation, 10% testing data
- ▶ DIF statistic options
 - Continuous – treat DIF as a continuous/numerical value
 - 2 category – binary DIF >0 or <0
 - 3 category – 3 bins: ≤ -1 , -1 to 1 , and ≥ 1

Gender DIF Statistic Histogram



3 Category – Prediction Method

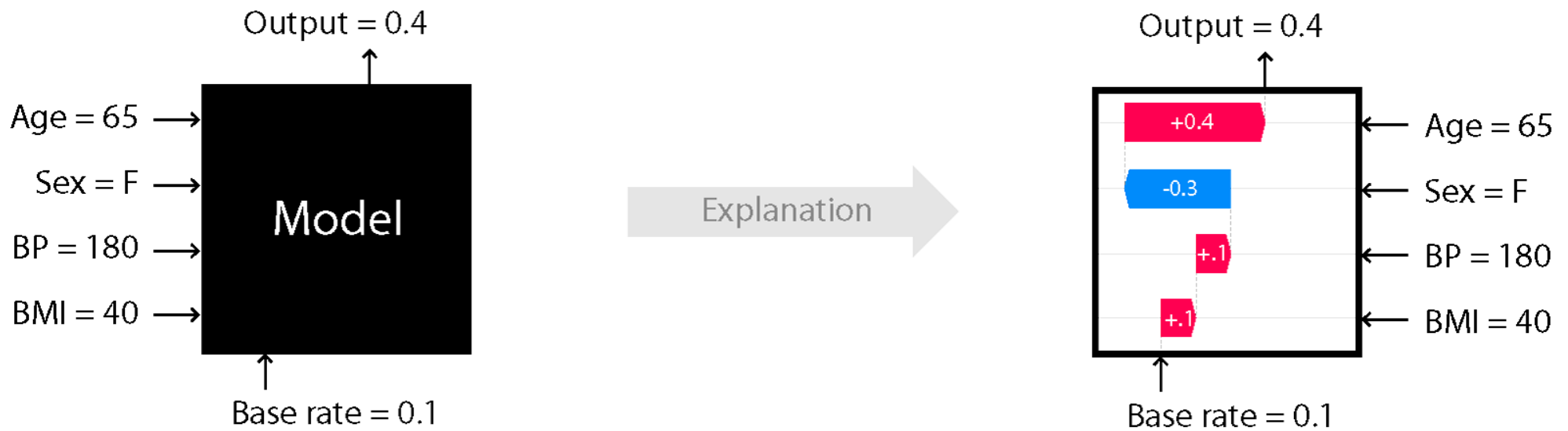
Get probabilities using DIF SE, then predict them



item_id	DIF	favor_male	no_DIF	favor_female
1	-0.8	.33	.66	.01
2

DIF Model “Explainer”

- ▶ SHAP – XAI method
- ▶ Breaks down a complex black-box model into something interpretable
 - Shows association of each word with predicted DIF value (“word attributions”)



RESULTS

DIF - Prediction

- ▶ Continuous DIF model

- $R^2 = .31$

- ▶ 3 Category DIF model

- Cross entropy loss = 0.11 (hard to interpret)

- Multiple regression predicting DIF from 3 predicted probabilities: $R^2 = .31$
(including interactions)

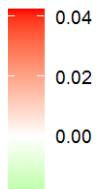
Example Item – Continuous Model

Observed DIF = 1.0

Predicted DIF = 0.99

A student is writing an argumentative essay for the school newspaper about taking a "gap year" before starting college. Read the draft of the essay and complete the task that follows. By the end of their high school careers, many students look forward to the new experiences and challenges that college will bring. They feel excited about starting school, leaving home, and making new friends. For some, however, the thought of spending another four years in a classroom seems overwhelming. After working so hard for so long, some students need time away from the rigors of academia. That is why many students across the United States are now taking a gap year before entering the world of higher education. Although the practice has been popular in the United Kingdom and Australia for decades, most Americans are unfamiliar with the concept of a gap year. Essentially, a gap year is a yearlong break from study that allows students to pursue interests outside the classroom. There are many reasons students decide to delay college. Some are exhausted after years of studying, while others are unsure of what they want to do with the rest of their lives. Some students want to see the world, and others want to find ways to help people. During their gap year, students might work for a volunteer organization, complete an internship, or travel around the globe. Critics argue that taking a gap year will cause students to fall behind their peers, but some college admissions officers feel that students who take a year off return to the classroom more focused and ready to work. This may be why some of the nation's top universities actually endorse the idea of delaying enrollment. Harvard University, one of the best schools in the country, encourages newly admitted students to take a year off before starting college. According to the university's website, about 50 to 70 percent of students take advantage of this opportunity to defer. Princeton, another prestigious university, encourages students to apply to its Bridge Year Program, which allows a select group of new students to defer admission for a year while they volunteer in other countries. Despite all this, there are still people who feel that a gap year does more harm than good. They worry that students who decide to take a year off without knowing how they want to spend their time will lose motivation and specific academic skills they worked so hard to build over the years. These people are often working under the misguided notion that a gap year is nothing more than an excuse for students to do nothing for a year, which is not the intention of the gap year. This essay is missing a conclusion. Write a conclusion that follows from the argument.

Favors
Female
Students



Favors
Male
Students

Example Item – 3 Category Model

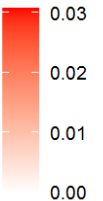
Observed DIF = 1.0

Predicted Female DIF $p = 0.46$

Predicted Male DIF $p = 0.01$

A student is writing an argumentative essay for the school newspaper about taking a "gap year" before starting college. Read the draft of the essay and complete the task that follows. By the end of their high school careers, many students look forward to the new experiences and challenges that college will bring. They feel excited about starting school, leaving home, and making new friends. For some, however, the thought of spending another four years in a classroom seems overwhelming. After working so hard for so long, some students need time away from the rigors of academia. That is why many students across the United States are now taking a gap year before entering the world of higher education. Although the practice has been popular in the United Kingdom and Australia for decades, most Americans are unfamiliar with the concept of a gap year. Essentially, a gap year is a yearlong break from study that allows students to pursue interests outside the classroom. There are many reasons students decide to delay college. Some are exhausted after years of studying, while others are unsure of what they want to do with the rest of their lives. Some students want to see the world, and others want to find ways to help people. During their gap year, students might work for a volunteer organization, complete an internship, or travel around the globe. Critics argue that taking a gap year will cause students to fall behind their peers, but some college admissions officers feel that students who take a year off return to the classroom more focused and ready to work. This may be why some of the nation's top universities actually endorse the idea of delaying enrollment. Harvard University, one of the best schools in the country, encourages newly admitted students to take a year off before starting college. According to the university's website, about 50 to 70 percent of students take advantage of this opportunity to defer. Princeton, another prestigious university, encourages students to apply to its Bridge Year Program, which allows a select group of new students to defer admission for a year while they volunteer in other countries. Despite all this, there are still people who feel that a gap year does more harm than good. They worry that students who decide to take a year off without knowing how they want to spend their time will lose motivation and specific academic skills they worked so hard to build over the years. These people are often working under the misguided notion that a gap year is nothing more than an excuse for students to do nothing for a year, which is not the intention of the gap year. This essay is missing a conclusion. Write a conclusion that follows from the argument.

Favors
Female
Students



Example Item with No DIF

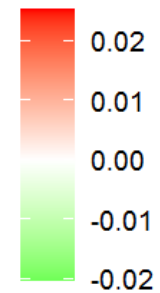
Continuous Model

This question has two parts. First, answer part A. Then, answer part B. Part A Click on the statement that best describes what the use of the bee/petunia study shows about the results of the fake flower study.

3 Category Model

This question has two parts. First, answer part A. Then, answer part B. Part A Click on the statement that best describes what the use of the bee/petunia study shows about the results of the fake flower study.

Favors Female Students



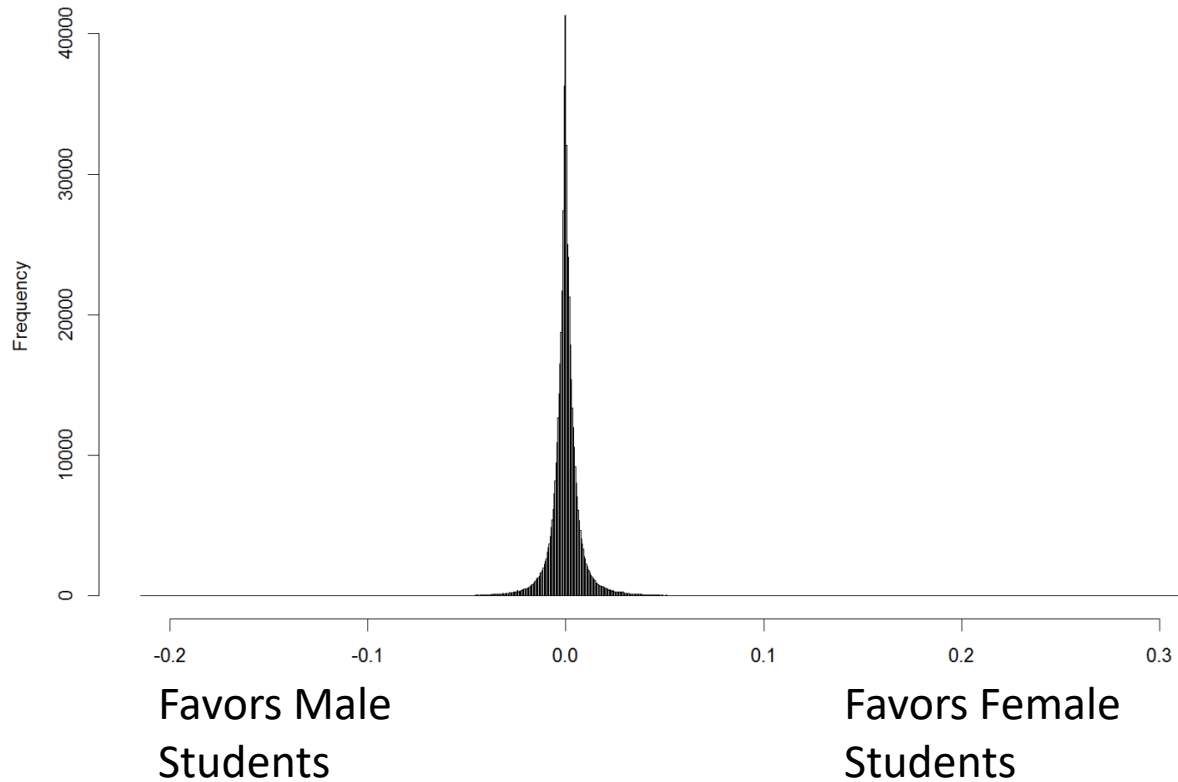
Favors Male Students

```
Combined_attribution = ifelse(m_attribution >0, yes = -m_attribution, no = 0) +  
ifelse(f_attribution >0, yes = f_attribution, no = 0)
```

Word Attribution Histograms

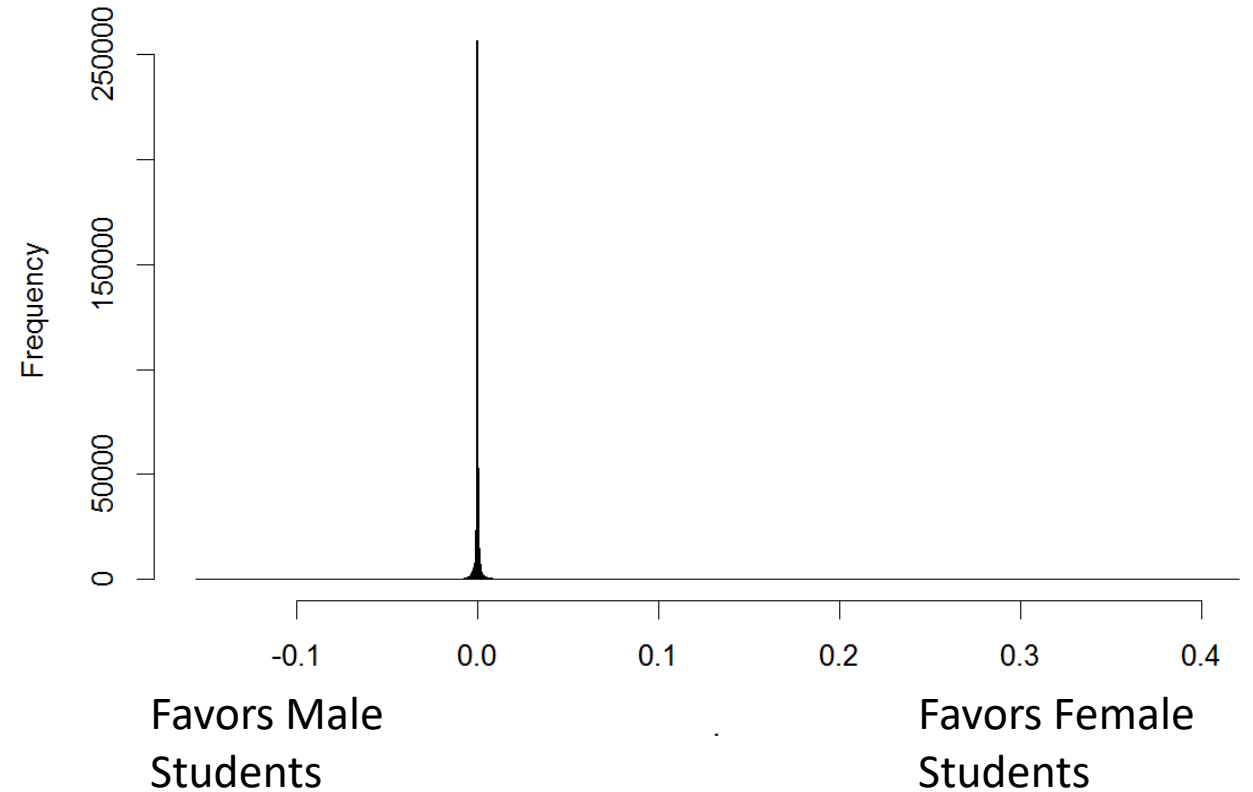
Continuous Model

Kurtosis = 69.4



3 Category Model

Kurtosis = 733.2



3 Category - Top words from 4,000 items

Favor female students	Favor male students
[Com]posting	destroyed
Narrative	predictive
Com[posting]	exposed
Argumentative	massive
Support	fought
[Re]cycling	Joni
Write	baseless
Summarize	clever
Performance	automated
intend	tame

Discussions

- ▶ 3-category was much easier to interpret
- ▶ (I think) we are the first to use NLP to predict DIF and identify words associated with DIF
- ▶ Eventually skip DIF analysis altogether?
- ▶ Prior to NCME presentation:
 - Preprint & Journal submission
 - Other XAI methods (LIME, integrated gradients)
 - DIF for other groups (race/ethnicity, SES, English language learner, disability)

Hotaka's LinkedIn Page

Finding Words Associated with DIF

Hotaka Maeda

Yikai Lu

hotaka.maeda@smarterbalanced.org

