# BEHRT - Transformer for Electronic Health Records

Nova Search Reading Group

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# Context

Electronic Health Records

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Data:

1. Diagnostics
2. Procedures
3. Lab results
4. Medication
5. Medical notes

# Context - Research Tasks in EHRs

**General tasks:**

1. Medical Concept Extraction
2. Patient Trajectory Modeling
3. Disease Inference

**Tasks in Clinical Notes:**

1. Single concept extraction (e.g. tagging)
2. Temporal Event Extraction
3. Relation Extraction
4. Abbreviation Expansion

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# BEHRT - Introduction

Let each diagnose be a word, each visit a sentence, and a patient’s entire medical history a document.

# BEHRT - Data Prep

Data Source: Clinical Practice Research Datalink (CPRD)

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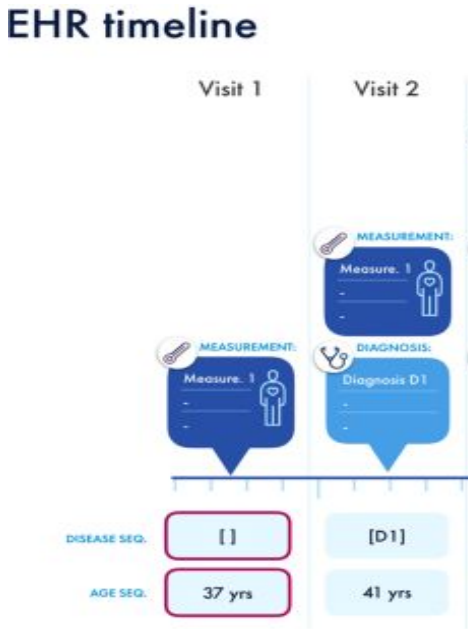

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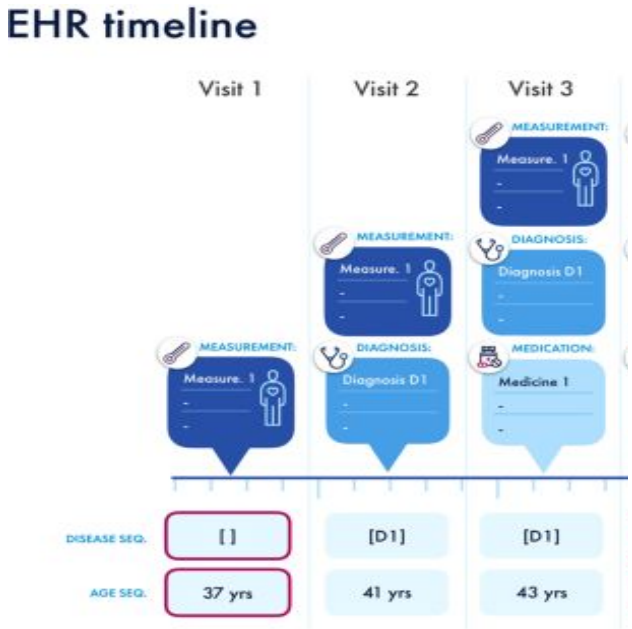

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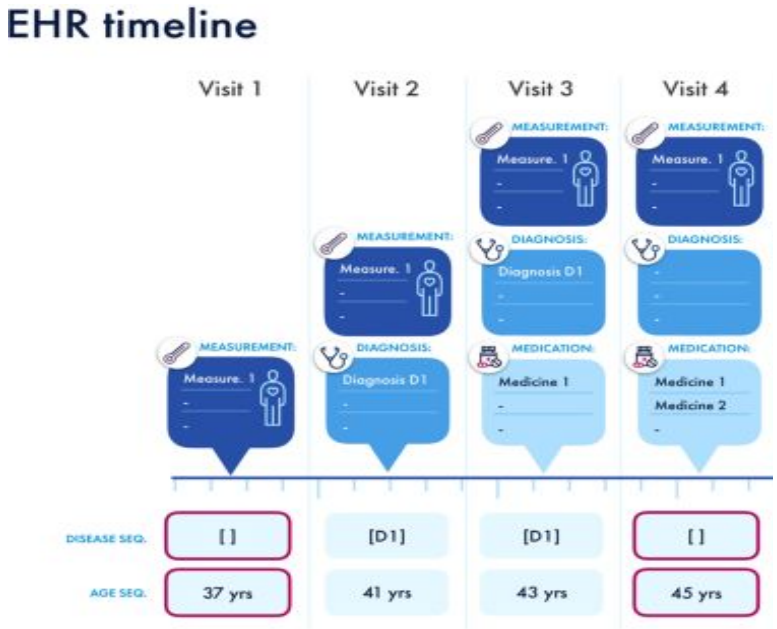

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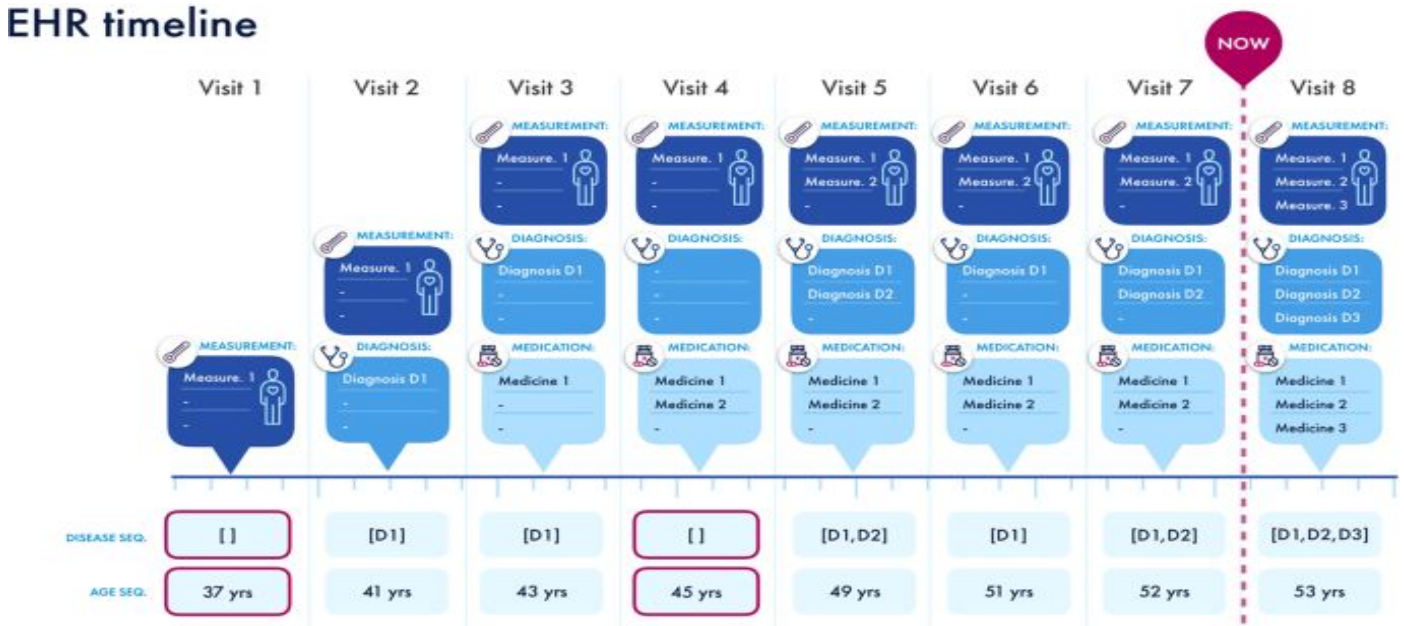

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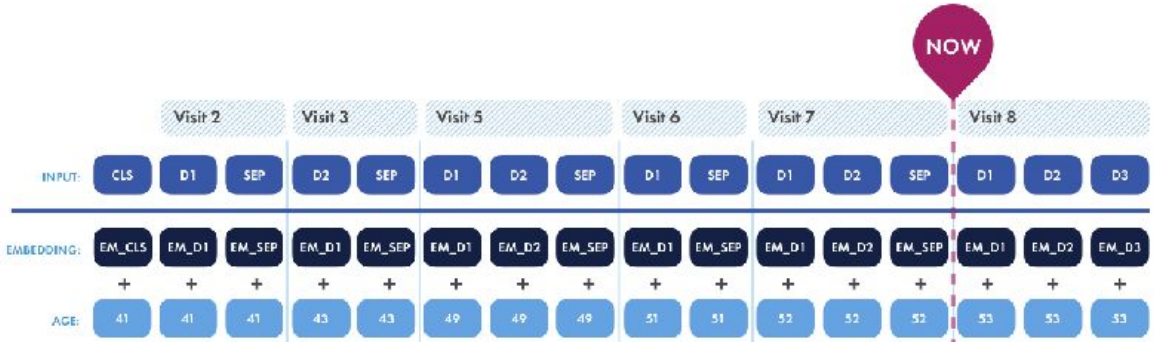

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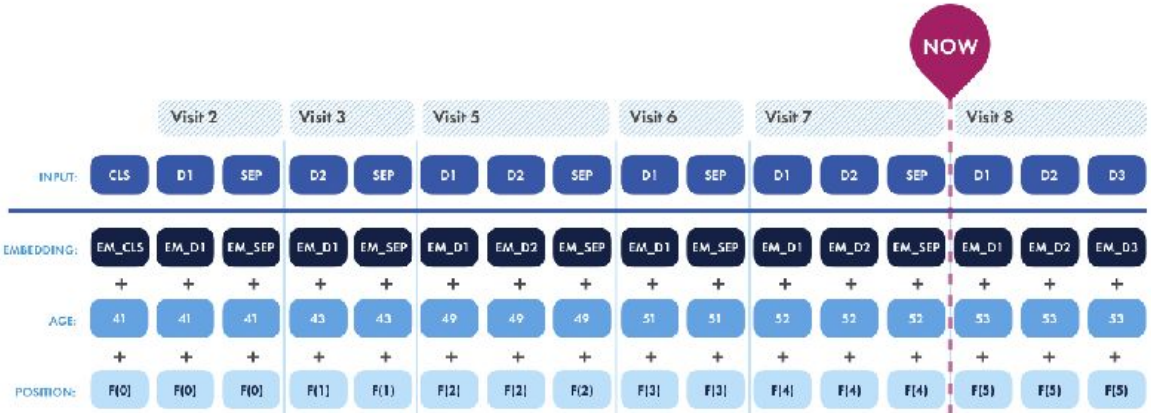

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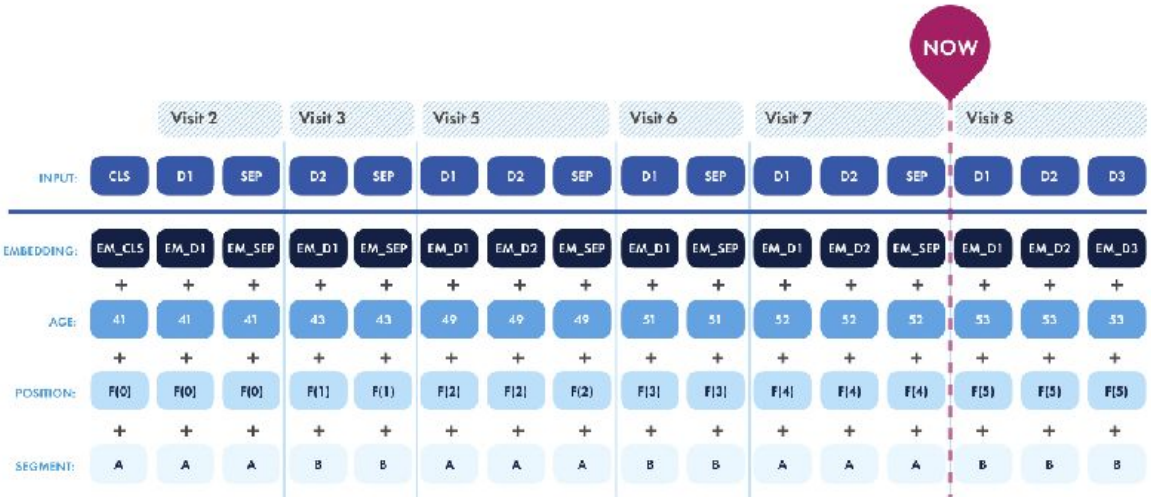

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5. Final Embedding

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# BEHRT - Training

Standard BERT training:

1. Mask 12% of words
2. Replace 1.5% of words with noise
3. Perform Masked LM and update parameters

# BEHRT - Learning

3 tasks, predict:

1. Next visit's diseases
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2. Task 2 and 3 must have 6/12 months of visits after the 4th visit.

# BEHRT - Learning

3 tasks, predict:

1. Next visit's diseases (699k patients)
2. Diseases in next 6 months (391k patients)
3. Diseases in next 12 months (342 patients)

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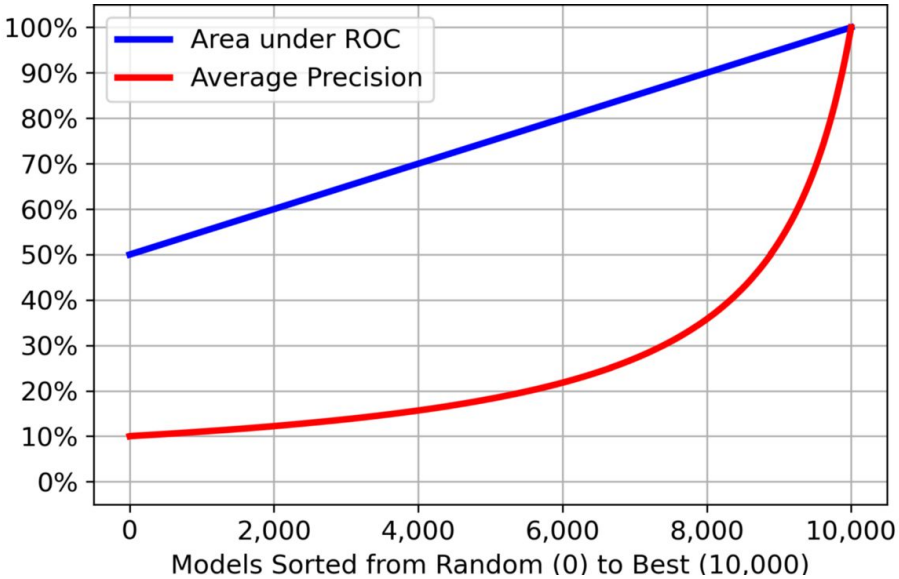
# BEHRT - Results

| Model Name | Next Visit (APS\|AUROC) | Next 6 M (APS\|AUROC) | Next 12 M (APS\|AUROC) |
|---|---|---|---|
| **BEHRT** | **0.462\|0.954** | **0.525\|0.958** | **0.506\|0.955** |
| Deepr | 0.360\|0.942 | 0.393\|0.943 | 0.393\|0.943 |
| RETAIN | 0.382\|0.921 | 0.417\|0.927 | 0.413\|0.928 |

# BEHRT - Results (Average Precision vs AUC-ROC)



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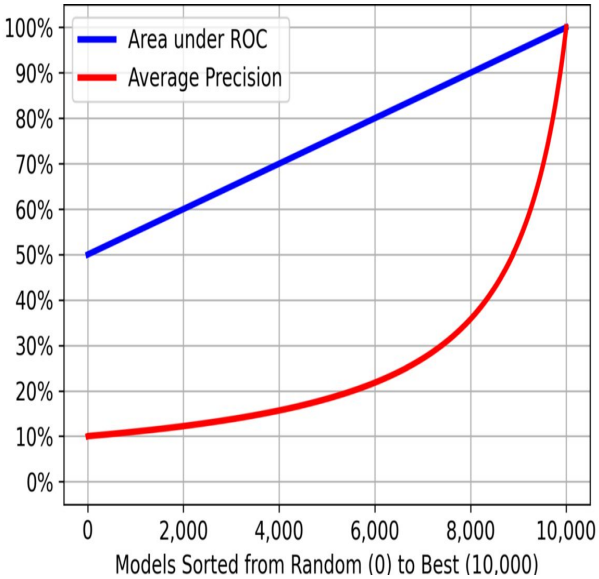


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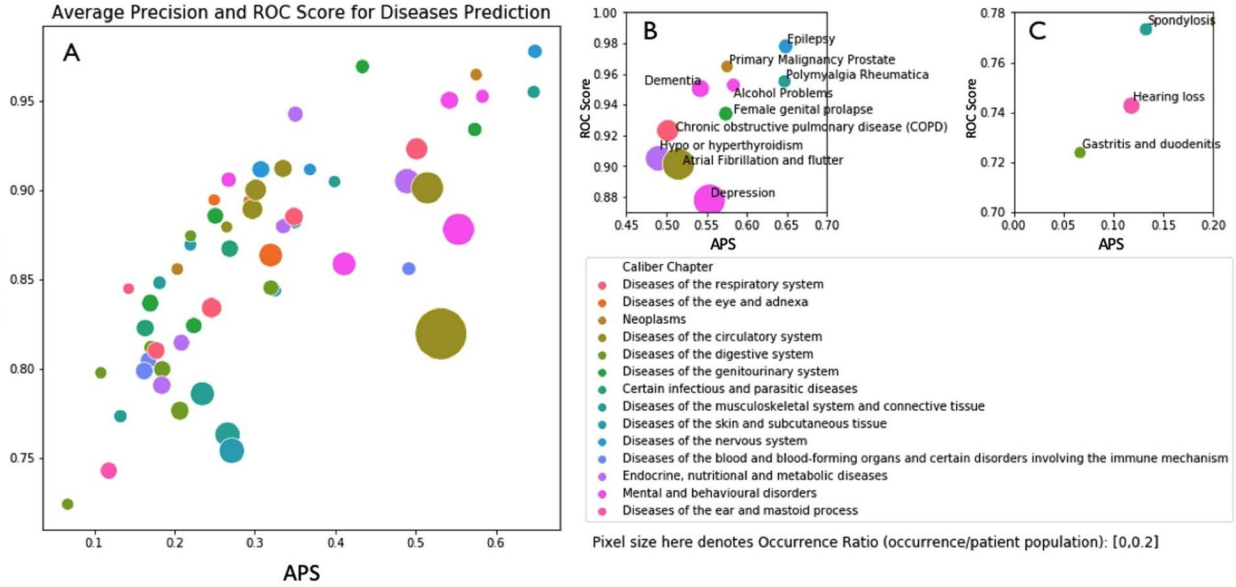


Pixel size here denotes Occurrence Ratio (occurrence/patient population): [0,0.2]

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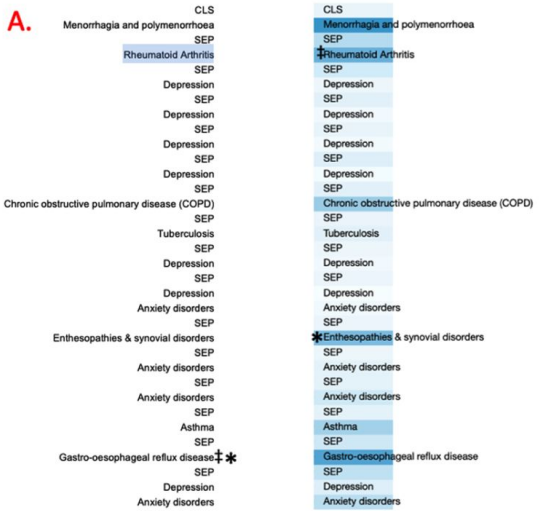
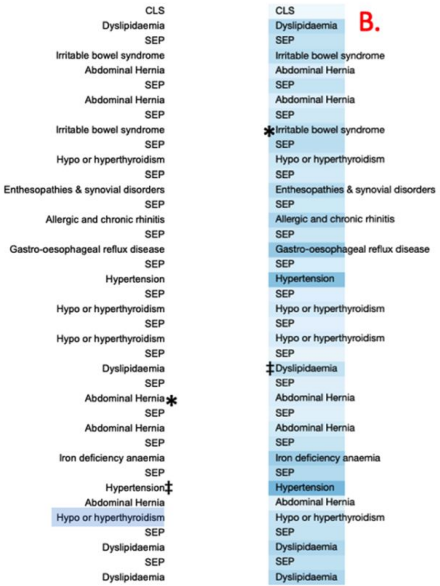



In A, BEHRT shows strong relationships between:

1. Rheumatoid Arthritis and Menorrhagia and polymenorrhoea
2. Rheumatoid Arthritis and Enthesopathies & synovial Disorders
3. Gastro-oesophageal reflux disease and Rheumatoid Arthritis (not shown‡)
4. Gastro-oesophageal reflux disease and Enthesopathies & synovial Disorders (not shown*)

In B, BEHRT shows strong relationships between:

1. Hypo or Hyperthyroidism and Hypertension
2. Hypo or Hyperthyroidism and Gastro-oesophageal reflux disease
3. Hypertension and Dyslipidaemia (not shown‡)
4. Abdominal Hernia and Irritable Bowel Syndrome (not shown*)



# BEHRT - Interpretability (gender)

**Table S7.** Predictions of Gender-Specific Diseases (Test Predictions from Next 6 Months)

| Disease Name | Disease Gender | Male Predictions | Female Predictions |
|---|---|---|---|
| Hyperplasia of Prostate | M | 384 | 0 |
| Hydrocoele (incl infected) | M | 36 | 0 |
| Male Infertility | M | 1 | 24 |
| Primary Malignancy Prostate | M | 557 | 0 |
| Erectile Dysfunction | M | 425 | 1 |
| Menorrhagia and Polymenorrhoea | F | 0 | 697 |
| Endometriosis | F | 0 | 47 |
| Female Genital Prolapse | F | 0 | 865 |
| Female Infertility | F | 2 | 36 |
| Benign Neoplasm of Ovary | F | 0 | 69 |
| Postmenopausal Bleeding | F | 0 | 140 |
| Primary Malignancy Breast | F | 0 | 11 |
| Primary Malignancy Ovarian | F | 1 | 193 |

Male (M) and Female (F) Predictions imply label predictions >0.5

# BEHRT - Interpretability

**Population Statistics**

Table S1: Statistics of Cohorts Selected Prediction Tasks

| Characteristics | | Next Visit | Next 6 M | Next 12M |
|---|---|---|---|---|
| Gender | Male | 41.80% | 42.30% | 41.70% |
| | Female | 58.20% | 57.70% | 58.30% |
| Ethnicity | White | 46.40% | 48.30% | 47.40% |
| | Unknown | 43.80% | 44.00% | 44.50% |
| | Indian | 0.40% | 0.50% | 0.50% |
| | Other | 0.30% | 0.30% | 0.30% |
| | Pakistani | 0.20% | 0.30% | 0.20% |
| | Black Carib | 0.20% | 0.30% | 0.20% |
| | Other Asian | 0.10% | 0.10% | 0.10% |
| | Black African | 0.10% | 0.10% | 0.10% |
| | Mixed | 0.10% | 0.10% | 0.10% |
| | Bangladeshi | 0.08% | 0.07% | 0.07% |
| | Black Other | 0.07% | 0.06% | 0.06% |
| | Chinese | 0.06% | 0.06% | 0.05% |
| Age Start | 0.25 Quantile | 45 | 46 | 46 |
| | 0.5 Quantile | 58 | 60 | 59 |
| | 0.75 Quantile | 70 | 71 | 70 |
| Age End | 0.25 Quantile | 56 | 58 | 58 |
| | 0.5 Quantile | 70 | 71 | 71 |
| | 0.75 Quantile | 81 | 82 | 82 |
| Unique Codes | 0.25 Quantile | 7 | 8 | 8 |

# Takes and future steps

1. Shows potential to provide value for health
2. Treatments, prescriptions, notes not used here
3. The vectors and attention weights can be used for research
4. These datasets are difficult to access and there aren’t a lot of them