DATEXIS Research Group
@ Berliner Hochschule für Technik (BHT)

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- Research topics:

  ▶ **Natural Language Processing (NLP)**

  ● **Deep Learning / Transfer Learning / Knowledge Integration**

  ■ **Explainability**

  ⬣ **Clinical NLP**

Prototypical Networks for Interpretable Diagnosis Prediction
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  Collaboration with Charité Berlin

  CHARITÉ
  UNIVERSITÄTSMEDIZIN BERLIN

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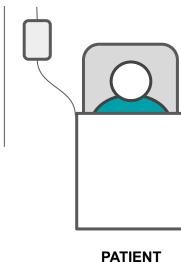
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Today's Talk

1. Task: **Clinical Outcome Prediction** from Admission Notes

2. Method: **Prototypical Networks** for Interpretable Diagnosis Prediction

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Clinical Outcome Prediction

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Clinical Outcome Prediction

- Starting Point:
  New patient gets admitted to hospital

PATIENT

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Clinical Outcome Prediction

- Starting Point:
  New patient gets admitted to hospital

- Patient state is documented in a **semi-structured clinical note**

- Medical professional predicts patient's trajectory and makes **first decisions**

PRESENT ILLNESS: 58yo man w/ hx of hypertension, AFib on coumadin and NIDDM presented to ED with the worst headache of his life. He had a syncopal episode and was intubated by EMS. Medication on admission: 1mg IV ativan x 1.

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FAMILY HISTORY: Mother had stroke at age 82. Father unknown.

SOCIAL HISTORY: Lives with wife. 25py. No EtOH

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PROBLEM:

Time for initial evaluation is short
→ Doctors might **miss certain risk signs**

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Time for initial evaluation is short
→ Doctors might **miss certain risk signs**

GOAL:

Support doctors by **enhancing** the considered **medical options & risks**

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Clinical Outcome Prediction Admission-to-Discharge Tasks

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DISCHARGE

DIAGNOSES:
430 Subarachnoid Hemorrhage
401 Essential Hypertension
250 Diabetes Mellitus [...]

PROCEDURES:
397 Endovascular Repair of Vessel
967 Invasive Mechanical Ventilation [...]

IN-HOSPITAL MORTALITY:
Not deceased

LENGTH OF STAY:
> 14 days

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Symptoms & Vitals
Pre-Conditions
Medications
General Risk Factors

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Clinical Outcome Prediction Data

Clinical Outcome Prediction Data

- Discharge summaries from **publicly available MIMIC-III** database [1]

- **50.000 ICU admissions** annotated with mortality, length of stay, 1.200 different diagnoses and 700 procedures

[1] Johnson, Alistair E. W. et al. "MIMIC-III, a freely accessible critical care database." Scientific Data 3 (2016)

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COURSE IN THE HOSPITAL: The patient was placed on home medications. He was put on rule out acute myocardial infarction routine, and he did in fact rule out. He had a stress test completed on the day of discharge which was normal, and he was discharged with a diagnoses of chest pain, acute myocardial infarction ruled out, urinary tract infection, fever secondary to UTI, diabetes mellitus type 2 non-insulin treated, hyperlipidemia with elevated triglycerides and an LDL elevated to 81 with new normal being less than 70.

DISCHARGE MEDICATIONS:
1. Enteric-coated aspirin 81 mg one daily. This is new, as the patient was not taking aspirin at home.
2. TriCor 48 mg one daily.
3. Zantac 40 mg one daily.

DISPOSITION: Recheck at Hospital with a regular physician there in 1 week. Consider Byetta as an adjunct to his diabetic treatment and efforts to weight control.

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Clinical Outcome Prediction Data

- Discharge summaries from **publicly available MIMIC-III** database [1]

- **50.000 ICU admissions** annotated with mortality, length of stay, 1.200 different diagnoses and 700 procedures

- Simulate **admission notes** from **discharge summaries** via common sections

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Clinical Outcome Prediction Previous Work

- Extension of BioBERT with additional pre-training step based on **unlabelled patient trajectories**

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Clinical Outcome Prediction Previous Work

CHIEF COMPLAINT: Headaches

PRESENT ILLNESS: 58yo man w/ hx of hypertension, AFib on coumadin presented to ED with the worst headache of his life. Brother reports states that patient has been complaining of headache for 2 days and that the patient has lost consciousness. He had a syncopal episode and was intubated by EMS.

MEDICATION ON ADMISSION: 1mg IV ativan x 1, metformin

PHYSICAL EXAM: Vitals: P: 92 R: 14 BP: 151/78 SaO2: 99% intubated. Cardiac: RRR. GCS E: 3   V:2 M:5 HEENT: atraumatic, normocephalic Pupils: 4-3mm. Abd: Soft, BS+ Extrem: Warm and well-perfused.

Predict Outcome

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Predict Outcome

ICD9 Diagnoses Predictions

250 diabetes mellitus
  2500 diabetes mellitus without mention of complication
331 other cerebral degenerations
  3314 obstructive hydrocephalus
401 essential hypertension
  4019 hypertension, unspecified
427 cardiac dysrhythmias
  4273 atrial fibrillation and flutter
430 subarachnoid hemorrhage
431 intracerebral hemorrhage
V586 Long-term (current) drug use
  V5861 Long-term (current) use of anticoagulants
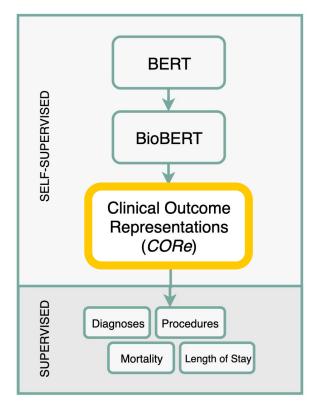
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Clinical Outcome Prediction Previous Work

EACL Paper:

Clinical Outcome Prediction from Admission Notes using Self-Supervised Knowledge Integration

- Extension of BioBERT with additional pre-training step based on unlabelled **patient trajectories**

- Details: **https://core.app.datexis.com**

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Prototypical Networks
for Interpretable Outcome Prediction

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Prototypical Networks
for Interpretable Outcome Prediction

- Doctors need more information about possible outcomes:

ICD9 Diagnoses Predictions

244 acquired hypothyroidism
  2449 hypothyroidism, unspec.
285 other and unspecified anemias
311 depressive disorder, not elsewhere classified
458 hypotension
518 other diseases of lung
  5188 other diseases of lung
733 other disorders of bone and cartilage
  7330 osteoporosis

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Prototypical Networks
for Interpretable Outcome Prediction

- Doctors need more information about possible outcomes:

  - Which **indicators** are there in the clinical note?

  - How did **similar patients** from earlier encounters develop during their stay?

ICD9 Diagnoses Predictions

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   2449 hypothyroidism, unspec.
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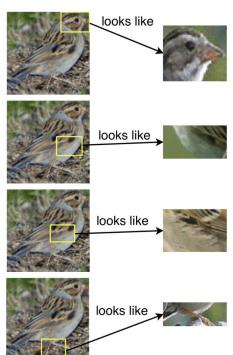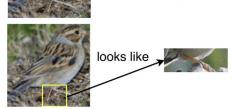
This looks like that: Deep learning for interpretable image recognition

Image to classify

looks like

looks like

looks like

looks like

Prototypical examples of bird species

[3]

[3] Chen, Chaofan et al. "This looks like that: deep learning for interpretable image recognition." NeurIPS (2019)

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This looks like that: This **patient** looks like that **patient**?

Clinical note to classify

PRESENT ILLNESS: Patient is a 35-year-old male pedestrian struck by a bicycle from behind with positive loss of consciousness for 6 minutes at the scene after landing on his head. At arrival at ER patient was confused, had multiple contusions noted on a head CT scan including bilateral frontal and right temporal contusions. His cervical spine and abdominal examinations were negative radiologically. The patient was then transferred to the Emergency Room. Patient had several episodes of vomiting during flight and during the trauma workup. He was assessed and was intubated for airway protection. The patient was given coma score of 9 upon initial assessment. Patient remaining hemodynamically stable throughout the transfer and throughout the workup in the ED.
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Clinical note to classify

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Prototypical patient from former encounters

struck by a bicycle …

loss of consciousness for 6 minutes …

coma score 9 …

looks like

loss of consciousness

… struck by vehicle

cerebral hemorrhage

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Concept: **Prototypical Network**

prototype vectors

c1: cerebral hemorrhage

PubMedBERT ENCODING

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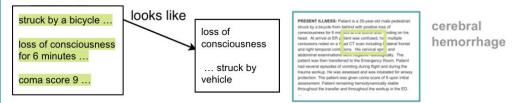…

c1

c2

c5

c2: bone bruise

c5: spinal cord injury

- Classification dependent on **proximity in vector space**

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Problems with **Prototypical Network** approach

prototype vectors

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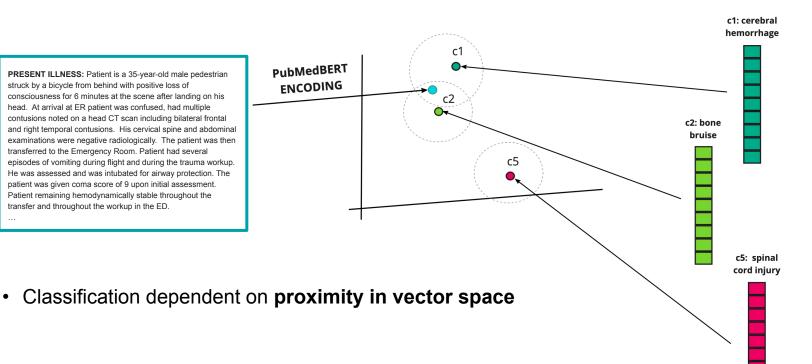
PubMedBERT ENCODING

c1

c2

c5

c1: cerebral hemorrhage

c2: bone bruise

c5: spinal cord injury

- **Multi-label**: Document vector must be **close to multiple prototypical vectors** (11 diagnoses / patient in average in MIMIC-III)

- No indication **which parts of the text are important** for which diagnosis

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Concept: **Prototypical Network + Label-wise attention**

attention vectors

prototype vectors

PubMedBERT Encoding

c1

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c1

c2

c2: bone bruise

c5

c2

c5: spinal cord injury

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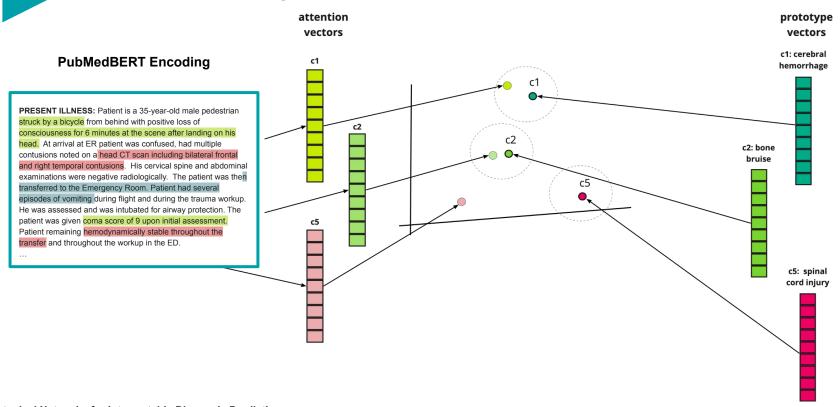…

c1

c2

c5

c1

c2

c5

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- Attention vectors **weight tokens** based on their **importance for each diagnosis**

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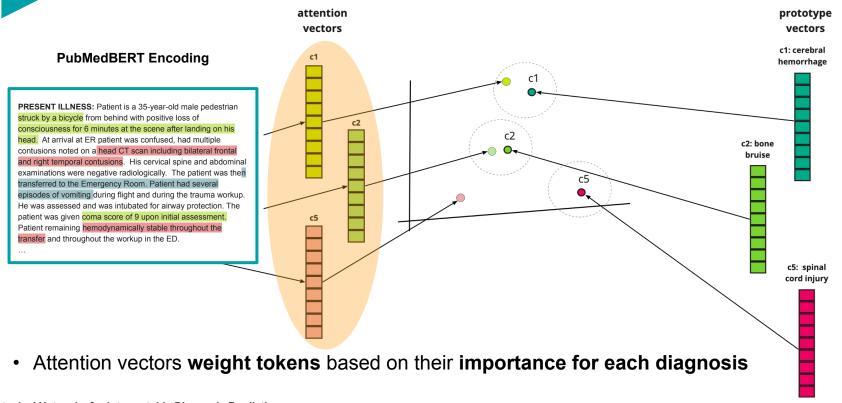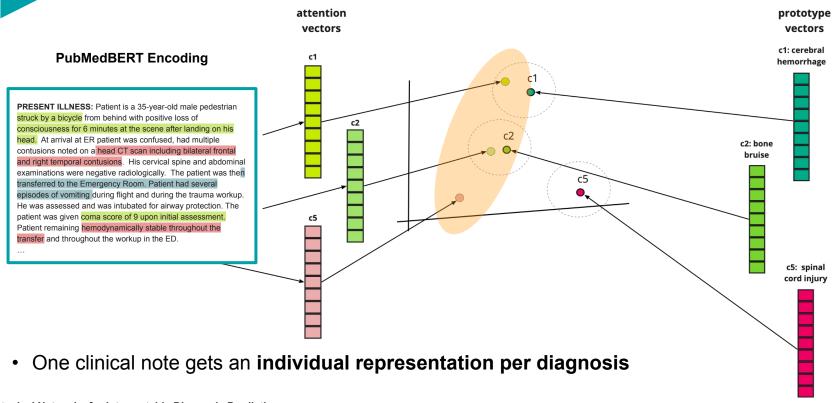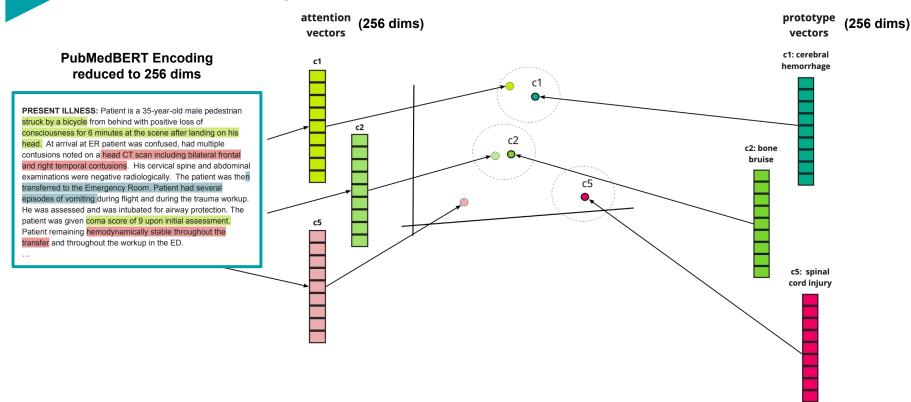…

c1

c2

c5

c1

c2: bone
bruise

c5

c1: cerebral
hemorrhage

c2

c5: spinal
cord injury

• One clinical note gets an **individual representation per diagnosis**

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Concept: **Prototypical Network + Label-wise attention**

attention vectors (256 dims)

prototype vectors (256 dims)

PubMedBERT Encoding reduced to 256 dims

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Prototypical Networks Initializations

PubMedBERT Encoding
reduced to 256 dims

attention vectors (256 dims)

prototype vectors (256 dims)

PRESENT ILLNESS: Patient is a 35-year-old male pedestrian struck by a bicycle from behind with positive loss of consciousness for 6 minutes at the scene after landing on his head. At arrival at ER patient was confused, had multiple contusions noted on a head CT scan including bilateral frontal and right temporal contusions. His cervical spine and abdominal examinations were negative radiologically. The patient was then transferred to the Emergency Room. Patient had several episodes of vomiting during flight and during the trauma workup. He was assessed and was intubated for airway protection. The patient was given coma score of 9 upon initial assessment. Patient remaining hemodynamically stable throughout the transfer and throughout the workup in the ED.
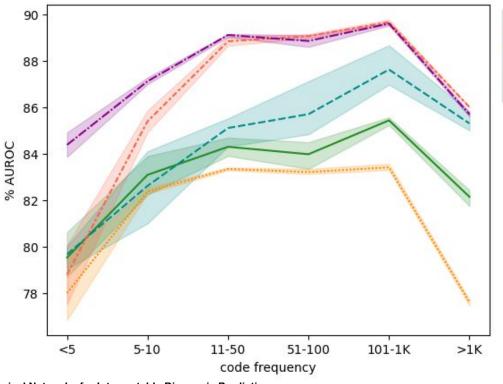…

c1

c2

c5

c5

c1: cerebral hemorrhage

c2: bone bruise

c5: spinal cord injury

Initialize prototype vectors with **centroid of training samples** for regarding diagnosis

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Prototypical Networks Initializations

PubMedBERT Encoding reduced to 256 dims

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…

attention vectors **(256 dims)**

c1

c2

c5

prototype vectors **(256 dims)**

c1: cerebral hemorrhage

c5: spinal cord injury

Initialize attention vectors with **TF-IDF weighted average** of **trainings tokens** for regarding diagnosis

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Full Pipeline

- Trained **end-to-end** with **Binary Cross Entropy** loss

- Prototype vectors can be used to retrieve **most prototypical patients**

- Attention vectors can be used to highlight **relevant parts in the text**

This patient looks like that patient

Clinical note to classify

looks like

cerebral hemorrhage

skull fracture

Prototypical examples of earlier patients with known diagnoses
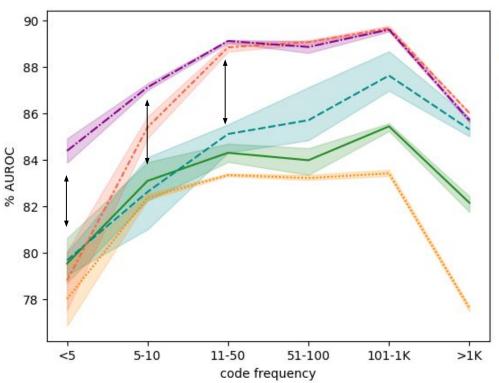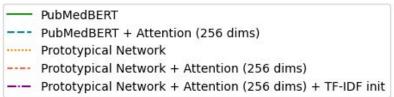
acute respiratory failure

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Results per class frequency

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Results per class frequency

- Largest gains compared to PubMedBERT in **rare ICD9 codes** (<5 to 100 occurrences in train set)

- **TF-IDF** initialization strongly improves **zero-** and **few-shot** cases

- Prototypical Network approaches **more stable** for different seeds

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Interpretable Outcome Prediction

CHIEF COMPLAINT: Headaches

PRESENT ILLNESS: 58yo man w/ hx of hypertension, AFib on coumadin presented to ED with the worst headache of his life. Brother reports states that patient has been complaining of headache for 2 days and that the patient has lost consciousness. He had a syncopal episode and was intubated by EMS.

MEDICATION ON ADMISSION: 1mg IV ativan x 1, metformin

PHYSICAL EXAM: Vitals: P: 92 R: 14 BP: 151/78 SaO2: 99% intubated. Cardiac: RRR. GCS E: 3   V:2 M:5 HEENT: atraumatic, normocephalic Pupils: 4-3mm. Abd: Soft, BS+ Extrem: Warm and well-perfused.

Predict Outcome

https://protopatient.demo.datexis.com

250 Diabetes mellitus: 0.293

331 Other cerebral degenerations: 0.253

348 Other conditions of brain: 0.354

401 Essential hypertension: 0.445

427 Cardiac dysrhythmias: 0.433

430 Subarachnoid hemorrhage: 0.246

518 Other diseases of lung: 0.247

780 General symptoms: 0.324

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Interpretable Outcome Prediction

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**Prototypical Patients for
Subarachnoid hemorrhage:**
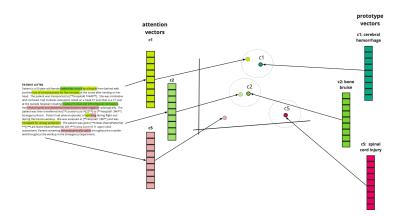
Patient 348A2123, 23.02.2014

chief complaint : headache started last week present illness : pt is a 52 year old left handed female with htn and migraines who present to the clinic with acute onset headache started on tuesday . she reported that the headaches persisted even with otc medications . she was seen at ABC hospital where a head ct demonstrated a sah . medical history : htn medication on admission : unknown allergies : no known allergies / adverse drug reactions physical exam : 1 gcs 15 e : 4 v : 5 motor 6 gen : wd / wn […]

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Prototypical Networks for Interpretable Clinical NLP Next Steps

- Introducing **multiple prototypes per diagnoses**

- Creation of **new prototypes** e.g. when new diseases are discovered

- Latest Publication:
  This Patient Looks Like That Patient:
  Prototypical Networks for Interpretable
  Diagnosis Prediction from Clinical Text
  AACL-IJCNLP, Nov. 2022

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Thank you!

Please contact me for discussions & feedback

bettyvanaken@gmail.com

🐦 @betty_v_a

in betty-van-aken

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HEALTHCARE