Developing a Cost-effective, Real-time Surveillance Tool to Monitor Workers' PPE Concerns During Respiratory Pandemics

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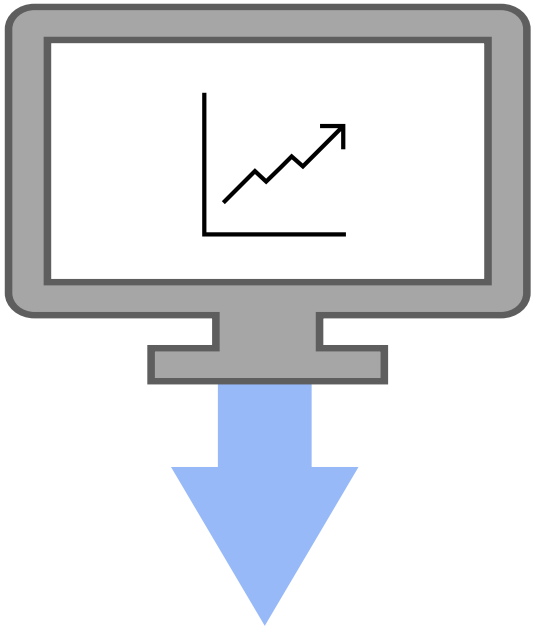
There is a need for *rapid and specific* information about the personal protective equipment (PPE) challenges workers face during respiratory pandemics.

Photos by (L to R): Getty Images/Hoptocopter; Getty Images/Svetikd; Getty Images/Kali9

No surveillance system currently exists to provide real-time and specific information on workers' PPE challenges.

Result: Lack of real-time evidence to guide occupational PPE guidance, interventions, and tailored communication.

PPE concern data is aggregated and monitored over time and by industry sector



Dissemination to federal agencies, industry groups, etc.

In the United States, workers facing unsafe working conditions can file a complaint with the Occupational Safety and Health Administration (OSHA).

How to File a Safety and Health Complaint

You (or your representative) have the right to file a confidential safety and health complaint and request an OSHA inspection of your workplace if you believe there is a serious hazard or if you think your employer is not following OSHA standards. The complaint should be filed as soon as possible after noticing the hazard. A signed complaint is more likely to result in an onsite inspection. Visit the Workers Rights and Protections webpage to learn more about your rights.

Online - Use the Online Complaint Form [Español]

Submit your complaint online to OSHA.

Fax/Mail/Email - Complete the OSHA Complaint Form [Español], or Send a Letter Describing Your Complaint

Complete the complaint form or letter, and then fax, mail, or email it back to your local OSHA office.

Telephone - Call Your Local OSHA Office or 800-321-6742 (OSHA)

OSHA staff can discuss your complaint with you and respond to any questions you may have.

In Person - Visit Your Local OSHA Office

OSHA staff can discuss your complaint with you and respond to any questions you may have.

https://www.osha.gov/workers/file-complaint

OSHA complaints may reveal worker PPE concerns

UPA ID	C-1566992
UPA Receipt Date	2021-02-03 14:30:00
Establishment Name	[redacted]
Site.Address.1	[redacted]
Site.Address.2	
Site.City	GRAND RAPIDS
Site.State	MI
Site.Zip	49503
Site.County	KENT
RID	552652
Receipt Type	Online
Formality	Nonformal
Inspection Number	
Hazard Description	1. Forced to work without personal protective equipment or lose job. 2. Required by management to knowing transport COVID-19 positive patients, without proper personal protective equipment. 3. The busses are not being cleaned properly; no disinfectant is being used. The same dirty rag used to clean the bus throughout the day.
Primary Site NAICS	485113 / 485113

Actual complaint from a dataset of ~75,000 COVID-19 closed OSHA complaints, January 2020 – July 2022.

OSHA complaints may reveal worker PPE concerns

"T8 CCR 5199 Provided with only one N95 and told to reuse it every shift, in multiple rooms T8 CCR 5144 Never been fit tested for respirators T8 CCR 3203(a)(4)(B) Nurses not told of exposures to Covid 19 patients T8 CCR 5199 Suspected Covid 19 patients not placed in negative pressure rooms T8 CCR 5199 Nurses requesting Powered Air Purifying Respirator for necessary procedures, not being provided due to shortages"

"1. No social distancing, customers sat in groups of ten to fifteen and without wearing facial masks. 2. Customers enter the business without facial masks, yet the sign on the entrance door states masks required. 3. Staff, waitresses and bartenders wore no facial masks while working."

"Employer not providing required masks for the employees. Employer requiring employees wear masks in a hot warehouse. Employees are getting sick, overheated, and nauseous from wearing masks in the heat."

"Employees having trouble breathing and getting migraines while wearing the face covers enforced by employer. The face cover fogs up glasses making it hard to drive forklifts or work on machines safely."

Hazard narratives from a dataset of ~75,000 COVID-19 closed OSHA complaints, January 2020 – July 2022.

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Many *types of PPE mentioned**

*In this study, 'PPE' is interpreted broadly and includes items that may provide only source control and not protection (e.g., masks).

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Not Worn

- By employees
- By non-employees

Quantity

Physiological

Cross-contamination

Fit Test

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We frame detection of PPE concerns as a machine learning task

'X' =

UPA ID	C-1711082
UPA Receipt Date	2020-12-23 00:00:00
Establishment Name	[redacted]
Site.Address.1	[redacted]
Site.Address.2	
Site.City	LAKEVILLE
Site.State	MN
Site.Zip	55044
Site.County	DAKOTA
RID	552700
Receipt Type	Email
Formality	Nonformal
Inspection Number	
Hazard Description	1. Customers and employees are in the workplace without wearing masks as mandated by Executive Order 20-81. 2. The employer isn't performing disinfection of surfaces including customer vehicles. 3. The employer isn't enforcing the mask mandate for employees and their families and customers who come into the shop.
Primary Site NAICS	811111 / 811111

y =

1	*Concern 1*
1	*Concern 2*
1	*Concern 3*
0	*Concern 4*
0	*Concern 5*
0	*Concern 6*
0	*Concern 7*
0	*Concern 8*
0	*Concern 9*
0	*Concern 10*
0	*Concern 11*
0	*Concern 12*
0	*Concern 13*

Detecting PPE concerns in ***X*** = Using ***X*** to predict vector ***y***

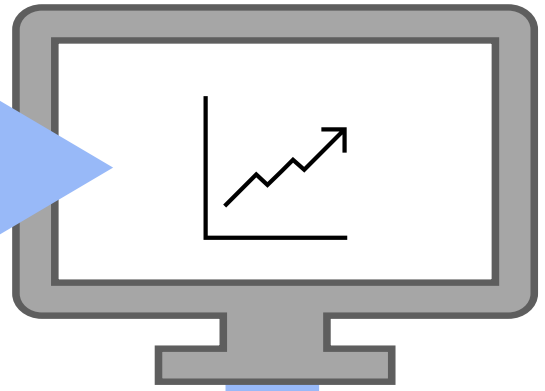
Vision: Develop a surveillance system capable of monitoring worker PPE concerns in real-time

OSHA complaints received in real-time

Trained machine learning model

ML model detects PPE concerns present in each complaint

PPE concern data is aggregated and monitored over time and by industry sector



Dissemination to federal agencies, industry groups, etc.

Our initial study focuses on feasibility

Can a machine learning (ML) model accurately detect various PPE concerns?

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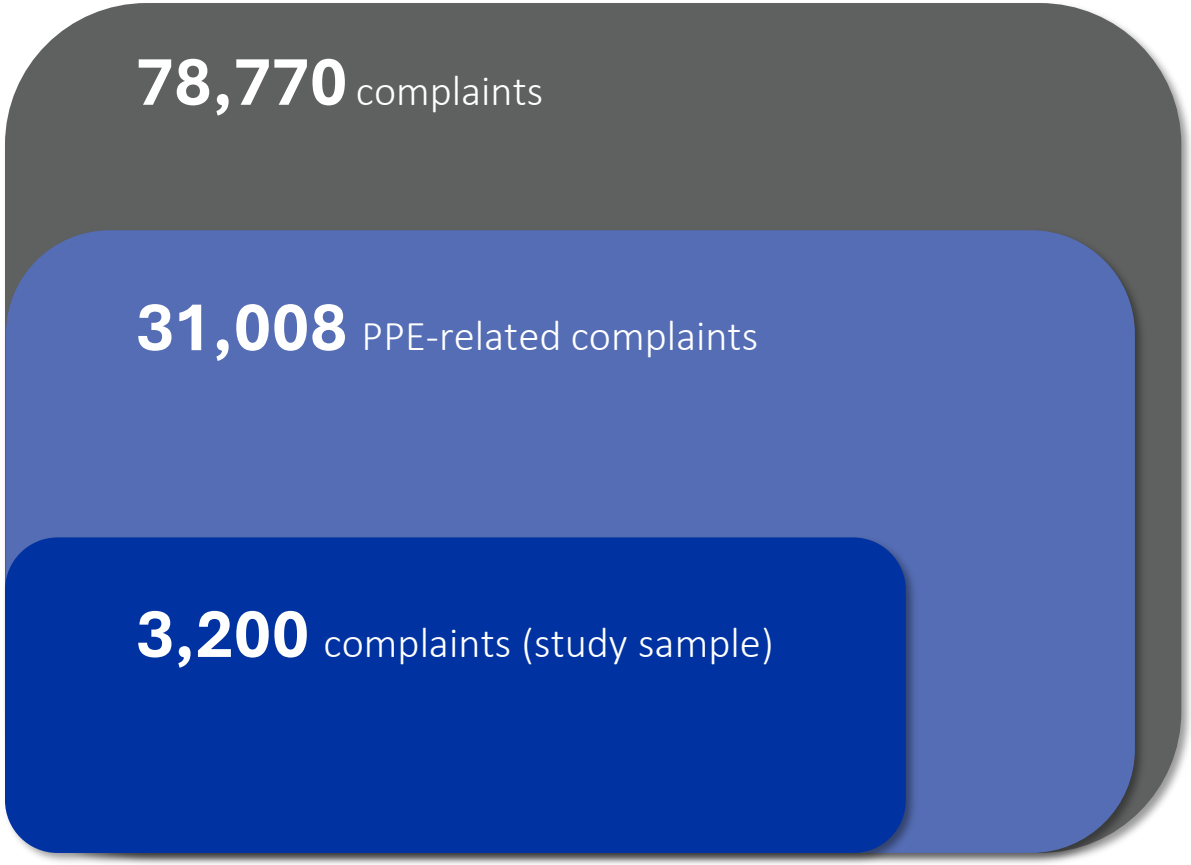
Data → Coding Frame → ML Development Dataset → Train and evaluate ML model



- **Closed COVID-19 OSHA complaints from Jan 2020 – July 2022**
- **Used PPE keywords list to identify PPE-related complaints**
- **Randomly sampled 3,200 PPE-related complaints for study sample**
  - 3,121 distinct narratives used for subsequent ML tasks

Can a machine learning (ML) model accurately detect various PPE concerns?

Data → Coding Frame → ML Development Dataset → Train and evaluate ML model

- **Two coders:**
  - Drafted & refined frame (200 narratives)
  - Independently coded remaining narratives using frame for intercoder agreement analysis
- **Ultimately focused on 13 concerns**
  - High agreement (Krippendorff's $\alpha > 0.80$)
  - Appeared in >1% of complaints
- **Reconciled coding disagreements to arrive at fully-labelled ML development dataset**

Concern	*n*	%
Quantity	1,144	36.7
Enforce Usage	1,052	33.7
Not Worn by Employees	705	22.6
Worn Incorrectly by Employees	136	4.4
Not Worn by Non-employees	95	3.0
Not Worn (unspecified)	79	2.5
Enforce Correct Usage	69	2.2
Cross-contamination	66	2.1
Discouraged/prohibited	63	2.0
Training	60	1.9
Fit Test	50	1.6
Physiological	47	1.5
Disinfection/maintenance	34	1.1
Size or Fit	27	0.9
Worn Incorrectly by Non-employees	9	0.3
Worn Incorrectly (unspecified)	8	0.3
Respiratory Protection Program	7	0.2
Counterfeit	5	0.2
Expired	2	0.1

Percentage of 3,121 distinct narratives containing each concern

40% of OSHA complaints were PPE-related

93% **of PPE-related complaints expressed a concern in our coding frame**

- Vast majority expressed 1-2 concerns

96 % **of PPE-related complaints came from five NAICS sectors**

- Health Care and Social Assistance (23%)
- Retail Trade (15%)
- Manufacturing (14%)
- Accommodation and Food Services (12%)
- Transportation and Warehousing (9%)

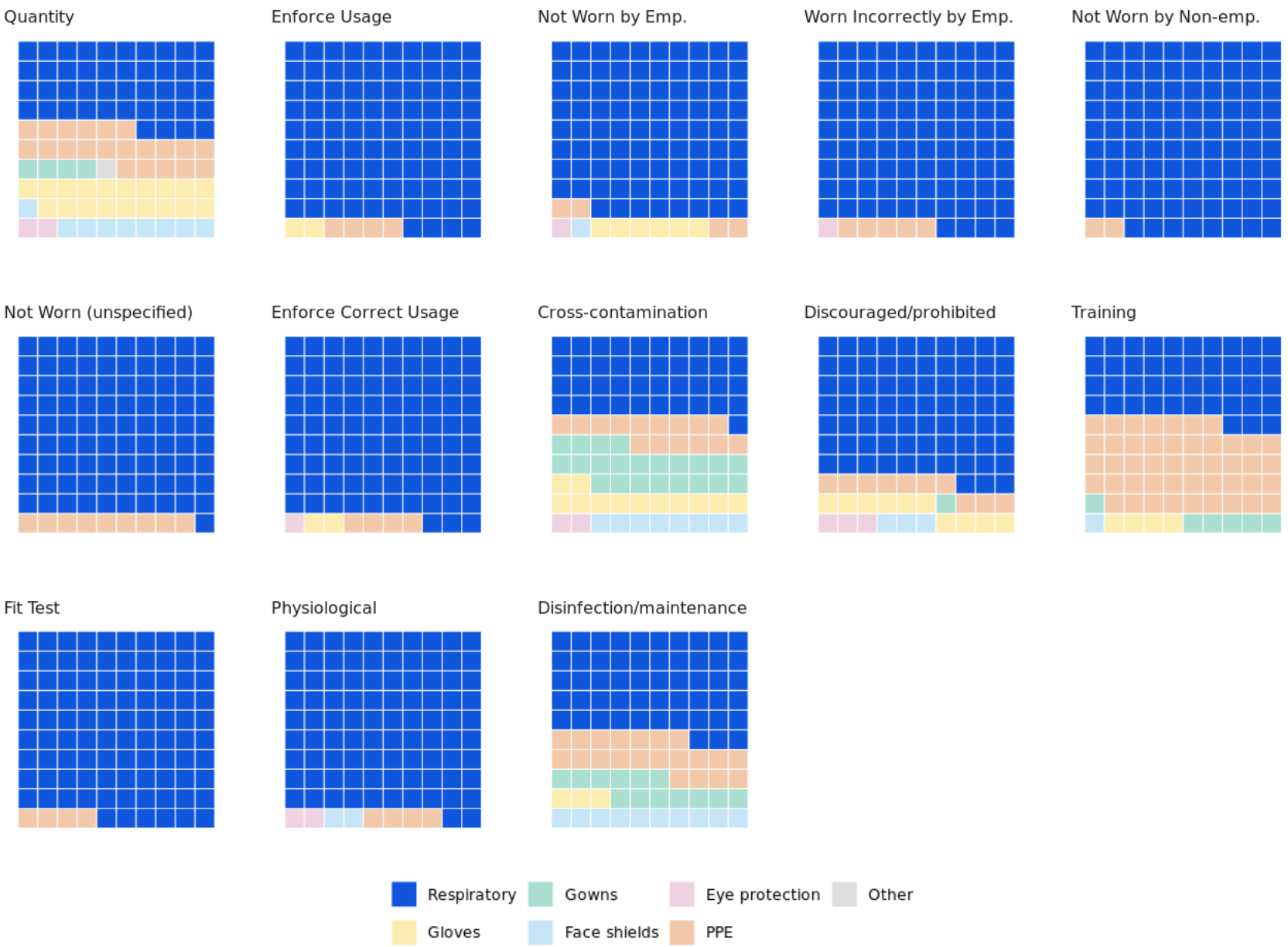
Based on study sample (simple random sample of 3,200 PPE-related complaints).

NAICS = North American Industry Classification System.

Concerns were most frequently expressed about **respiratory PPE***, for most concerns in the study sample.

*Respiratory “PPE” here includes face-worn products for source control such as masks and face coverings.

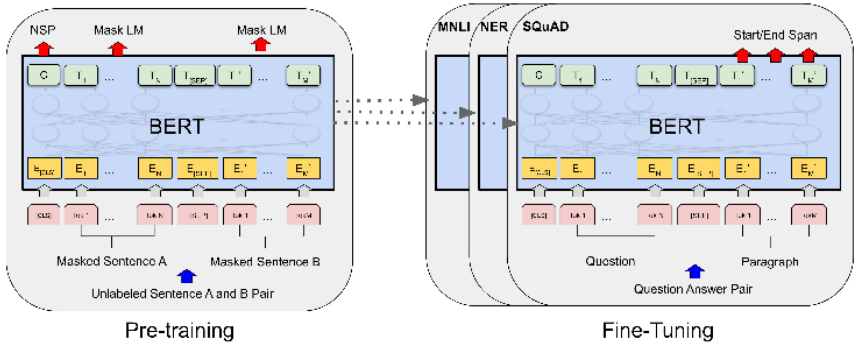
1 square = 1%.



Can a machine learning (ML) model accurately detect various PPE concerns?

Data → Coding Frame → ML Development Dataset → **Train and evaluate ML model**

- **BERT (Bidirectional Encoder Representations from Transformers)**
  - Large language model
  - *Pre-trained* on large amount of text
  - Can be *fine-tuned* on smaller task-specific dataset to perform specific text classification task
  - Accounts for word position and context
- **We use distilBERT, a lightweight version of BERT that is faster to train without a significant decrease in predictive performance**



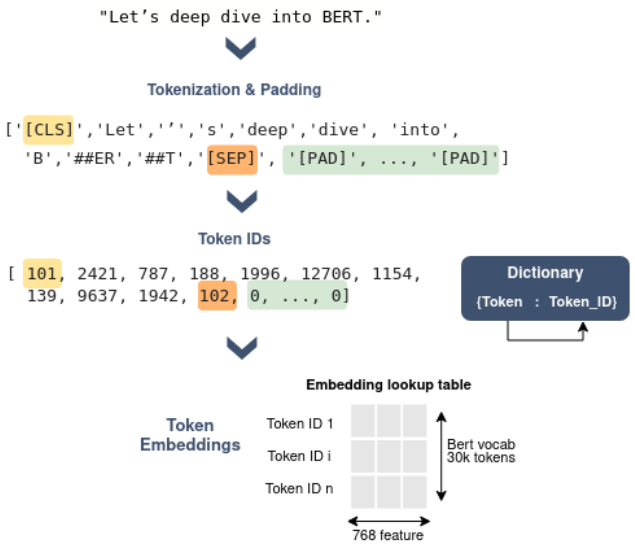


Image credits: (top right) Devlin et al. 2019, (bottom right) Elizabeth Press 2024

Can a machine learning (ML) model accurately detect various PPE concerns?

Data → Coding Frame → ML Development Dataset → **Train and evaluate ML model**

- **Use 75% of development dataset to train model, 25% to evaluate model**

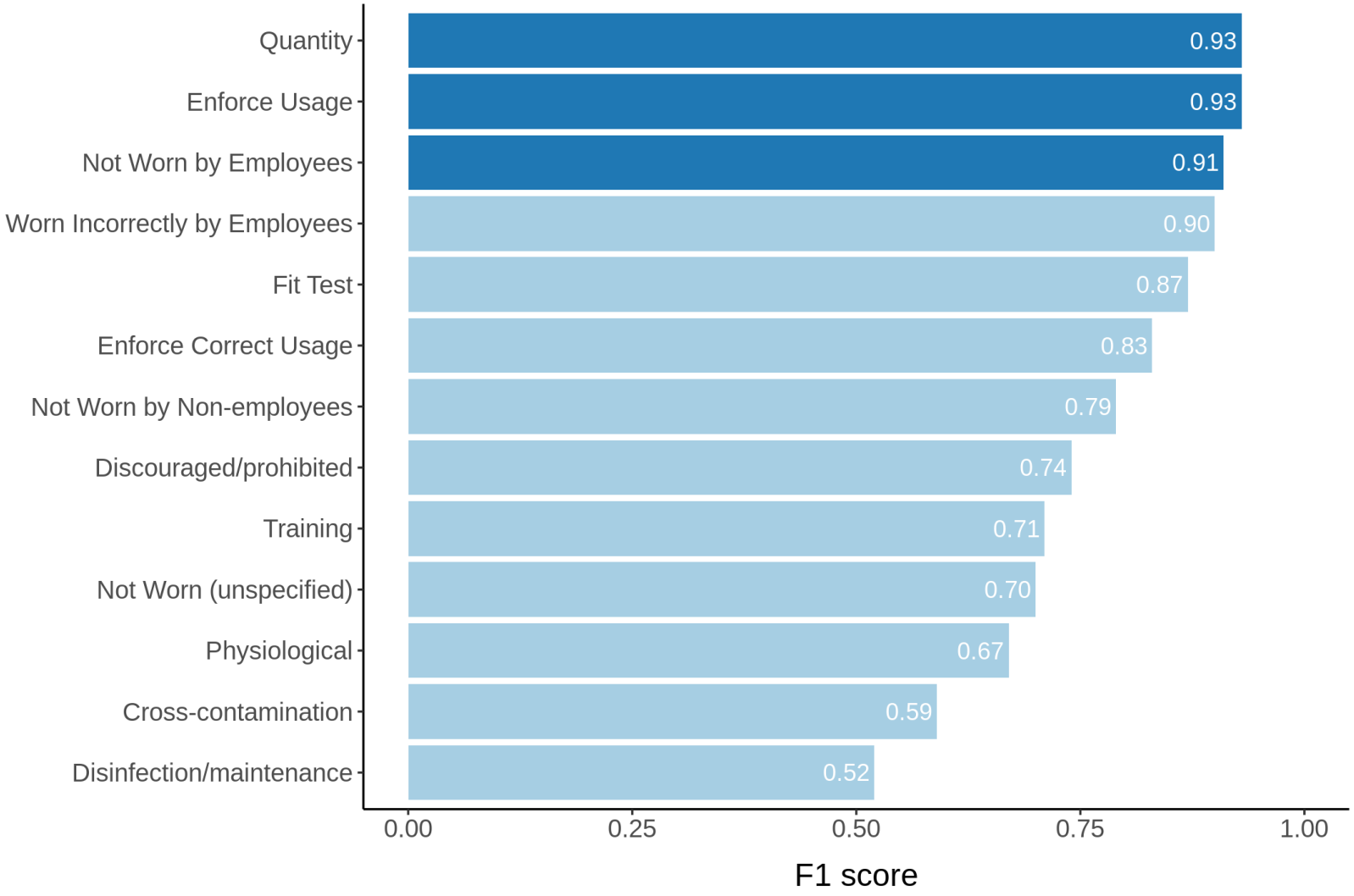
- **Assess model's ability to detect each PPE concern:**

1. **Precision** $\frac{\text{\# detected AND containing the concern}}{\text{\# detected}}$

2. **Recall** $\frac{\text{\# containing the concern AND detected}}{\text{\# containing the concern}}$

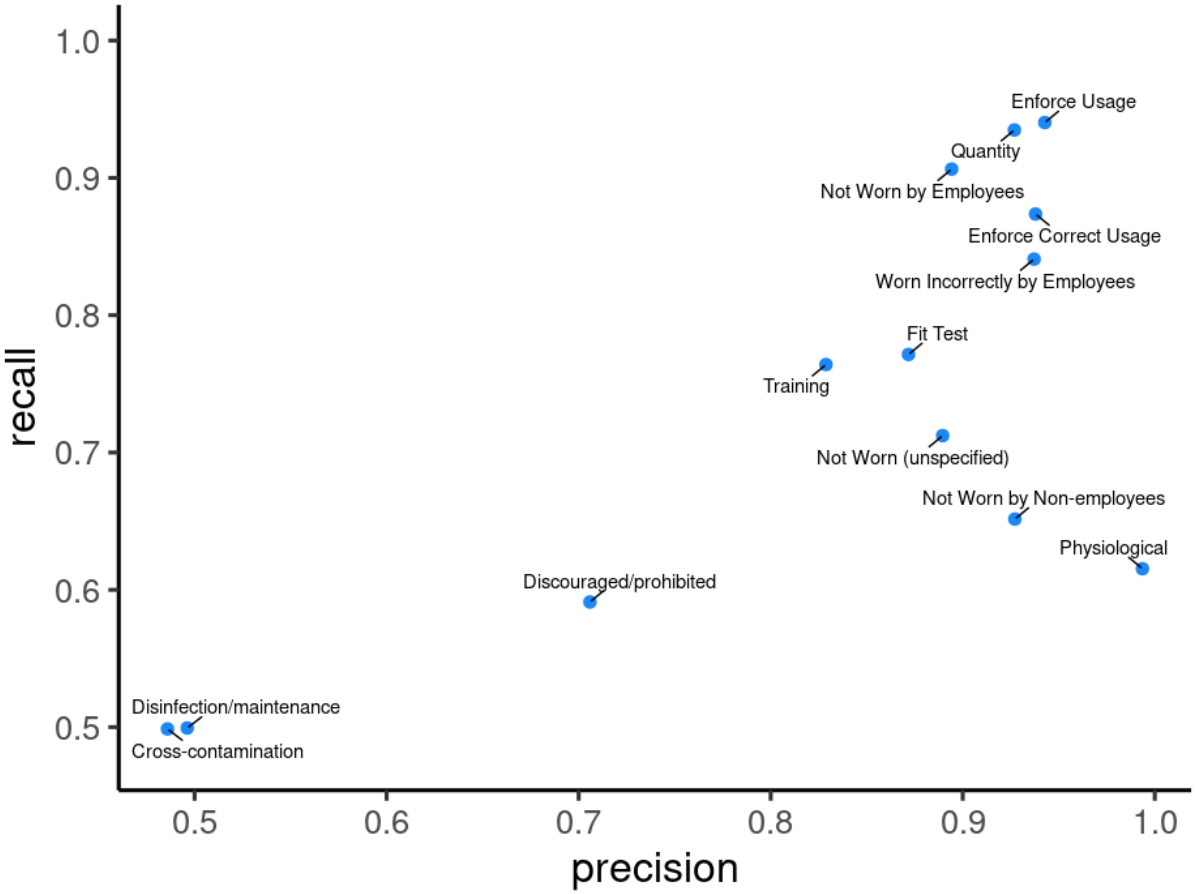
3. **F_1 score** $\frac{2}{\text{precision}^{-1} + \text{recall}^{-1}}$

BERT-based model accurately predicted several concerns



*Plot depicts mean F1 score averaged over 150 train-test splits. SE < 0.004 for top three concerns, SE < 0.045 for rest.

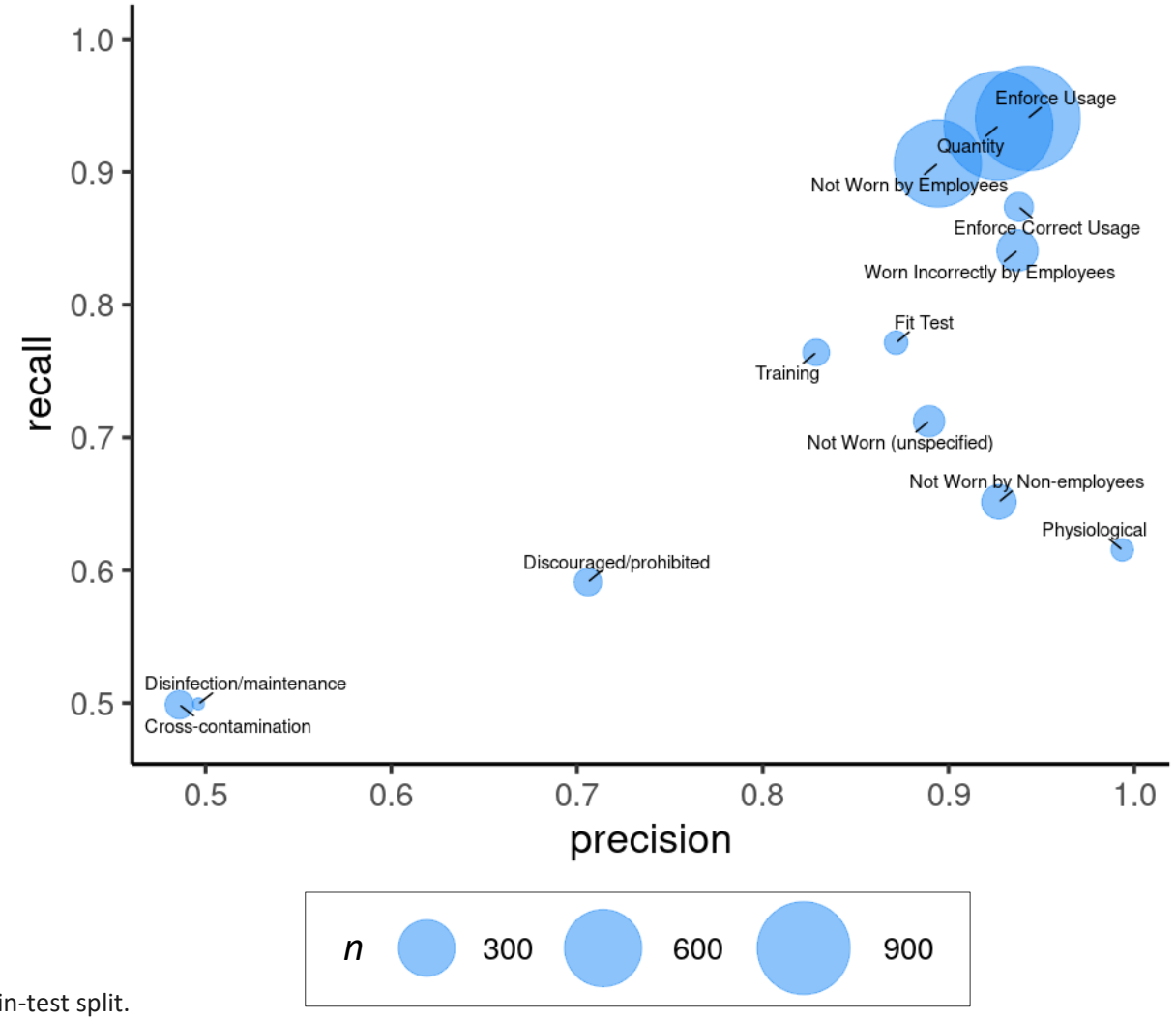
BERT-based model accurately predicted several concerns



* Plot depicts results from a single train-test split.

BERT-based model accurately predicted several concerns

Most *frequent* concerns predicted with highest precision and recall



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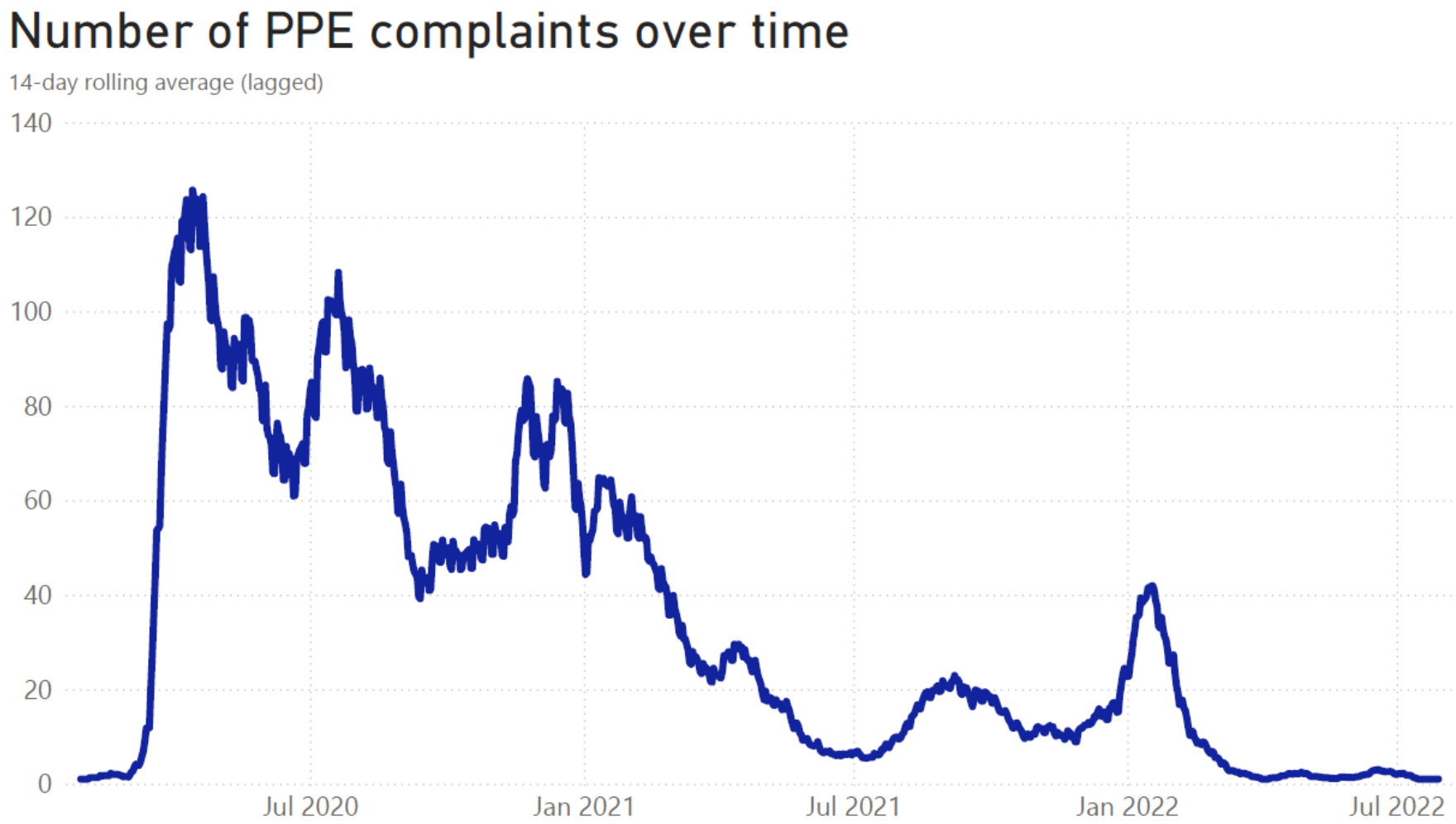
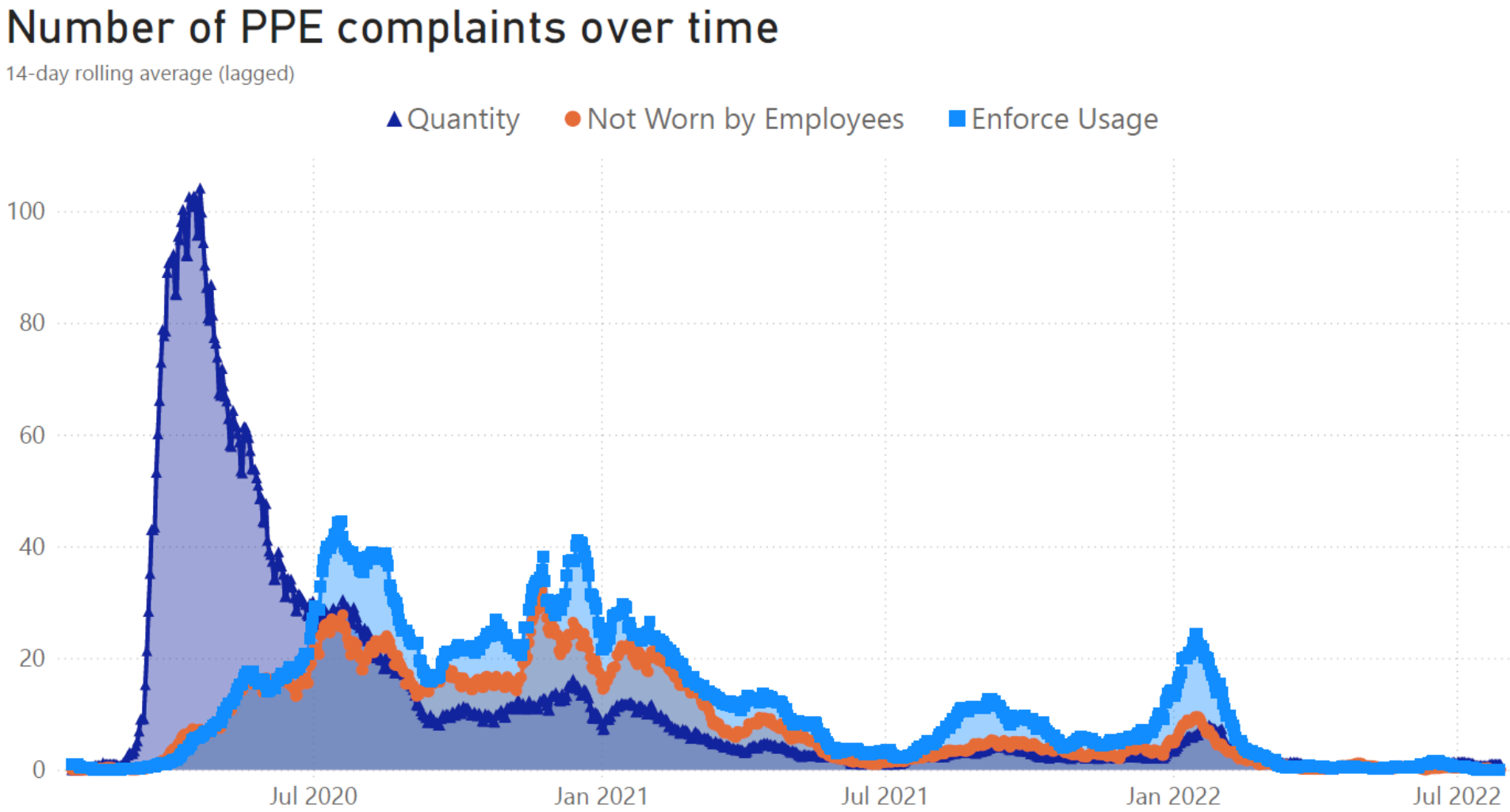
Towards Real-time Surveillance

Temporal trends in PPE complaints can be assessed



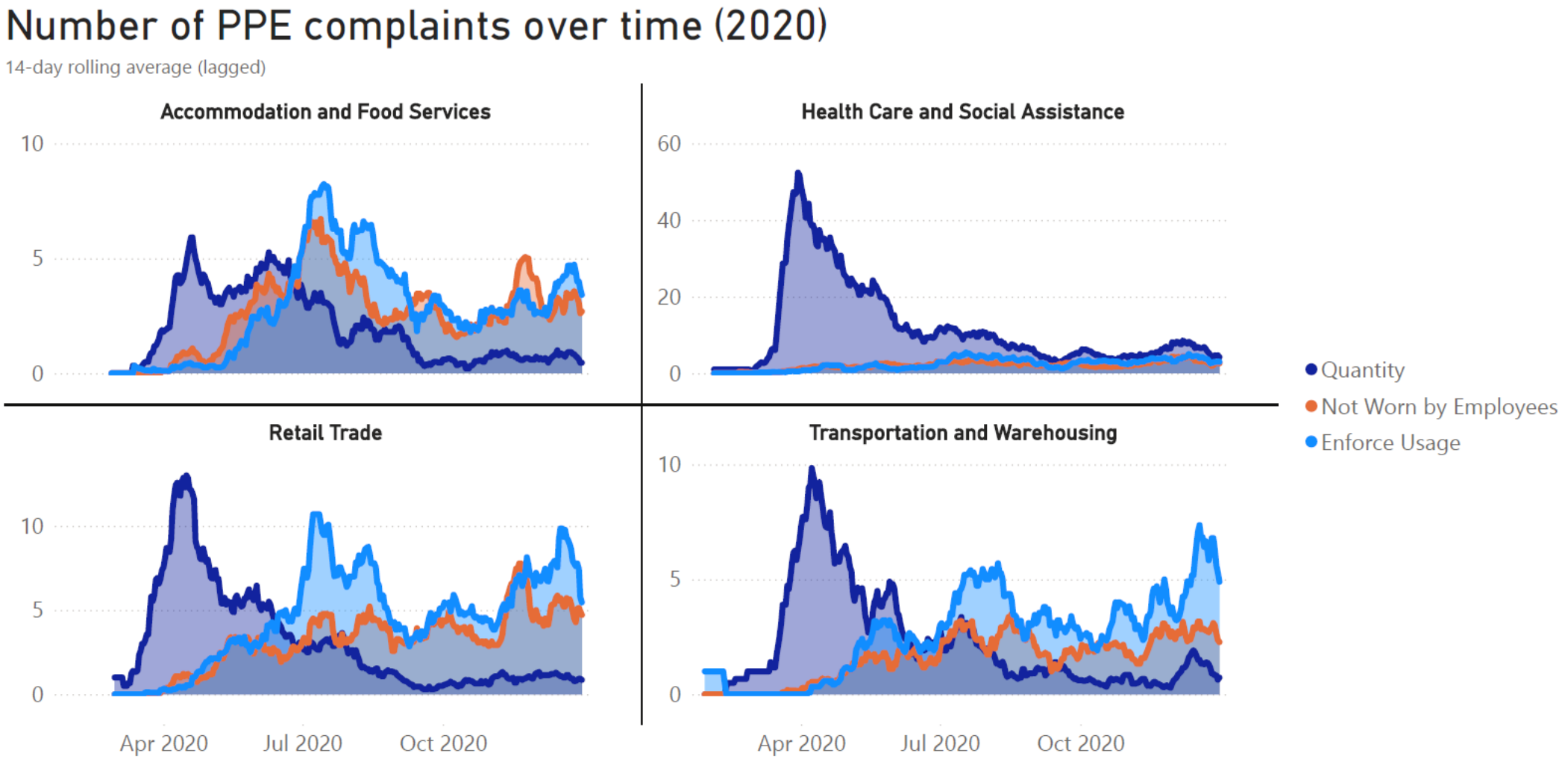
*All 31,008 PPE-related complaints.

Temporal trends in PPE complaints can be assessed



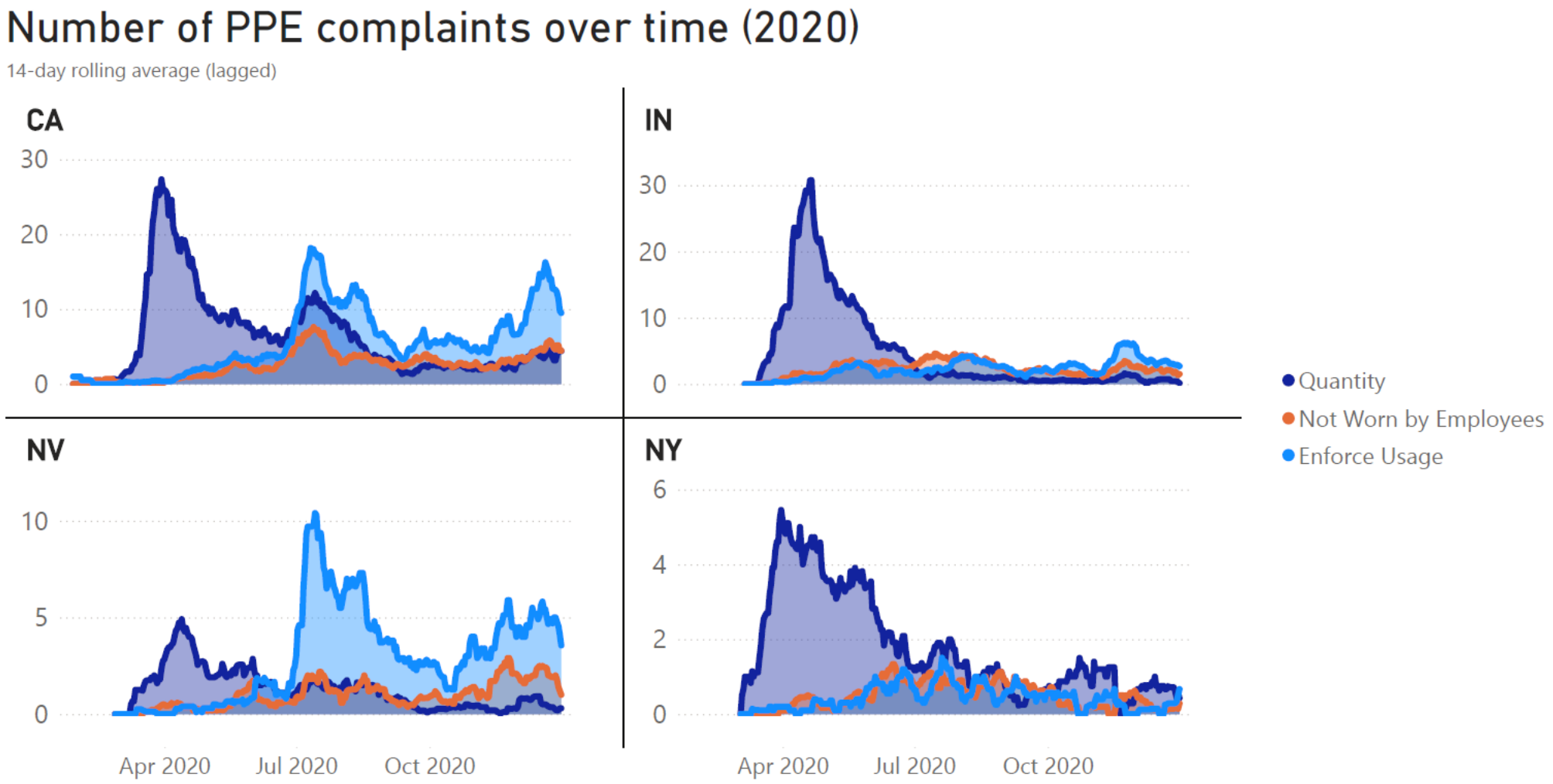
* All 31,008 PPE-related complaints: manually-coded study sample and ML-coded out-of-sample complaints.

Industry-specific patterns in PPE complaints can be assessed



* All 31,008 PPE-related complaints: manually-coded study sample and ML-coded out-of-sample complaints.

Geographic patterns in PPE complaints can be assessed



*Manually-coded study sample and ML-coded out-of-sample complaints.

Limitations of feasibility study

- **Self-selection in reported complaints**
- **“Concept drift”: future respiratory pandemic could manifest differently**
- **Focused simply on predictive performance, but understanding of surveillance priorities & risks also needed**

Machine learning using OSHA complaints is a promising approach for monitoring workers' PPE concerns during a respiratory pandemic.

NIOSH®

National Personal Protective Technology Laboratory

Visit the NIOSH NPPTL website:
https://www.cdc.gov/niosh/npptl/default.html

For more information, contact:

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NoraPayne@cdc.gov

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