The DART Matrix

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Background: Societal effects of child abuse

- Each year an estimated 1.25 million children in the United States are victims of abuse or neglect[15]
- Individuals who reported six or more adverse childhood experiences had an average life expectancy two decades shorter than those who reported none. [5]
- Children who experience child abuse & neglect are about 9 times more likely to become involved in criminal activity.[12]
- In one study, 80% of 21-year-olds who reported childhood abuse met the criteria for at least one psychological disorder. [6]
- For new cases in 2008 alone, lifetime estimates of lost worker productivity, health care costs, special education costs, child welfare expenditures and criminal justice expenditures added up to $124 billion.[8]

Background: Challenges to identification

- Around 80% of child maltreatment fatalities involve at least one parent as perpetrator.[3]
- More than 70% of the children who died as a result of child abuse or neglect were two years of age or younger.[3]
- More than 80% were not yet old enough for kindergarten.[3]

Emergency room visits represent a critical opportunity to identify abuse in pre-school years

Overall Goal: Identify all cases of child abuse in patients that enter the pediatric ED

- Challenge:
  - Kids are clumsy
  - Parents actively obfuscate
  - Affected by implicit biases[14]

- Implemented Detection, Assessment, Referral and Treatment (DART) consult team
  - Primes a set of injuries that are known to be associated with abuse
  - Empowers action upon observation

Description of the DART criteria

Based on the Cardiff Child Protection systematic review of abuse literature [5]

(1) fractures of the long bone, ribs or skull;

(2) intra-cranial injury (e.g. subdural, epidural or intraparenchymal hemorrhages);

(3) burns;

(4) solid organ injury by imaging or lab evidence;

(5) bruising of the ear, head, neck or torso, including facial, scalp or forehead hematomas;

(6) subconjunctival hemorrhage;

(7) a torn frenulum; and

(8) hemotympanum.

Providers are mandated to call a DART consult when any of these eight injuries are observed and document the consultation in the provider note

Is it working?

- Is DART responsible for identifying more cases of abuse?
- Collect data before and after implementation
  - Identify abuse
  - Identify DART
- Is DART being used as designed?
  - Identify the criteria
  - Identify if DART correlated with criteria
- Later questions
  - Does it alleviate implicit bias?
  - How might it be more effective?

Specific Goal: automate identification of DART consultations to apply to large set of EMRs to assess use and efficacy

Aim #1: Query Clarity using SQL to pull full text ED provider notes into database.

Aim #2: Identify the eight injuries in radiology reports and ED provider notes that should trigger the provider to involve the DART consult service.

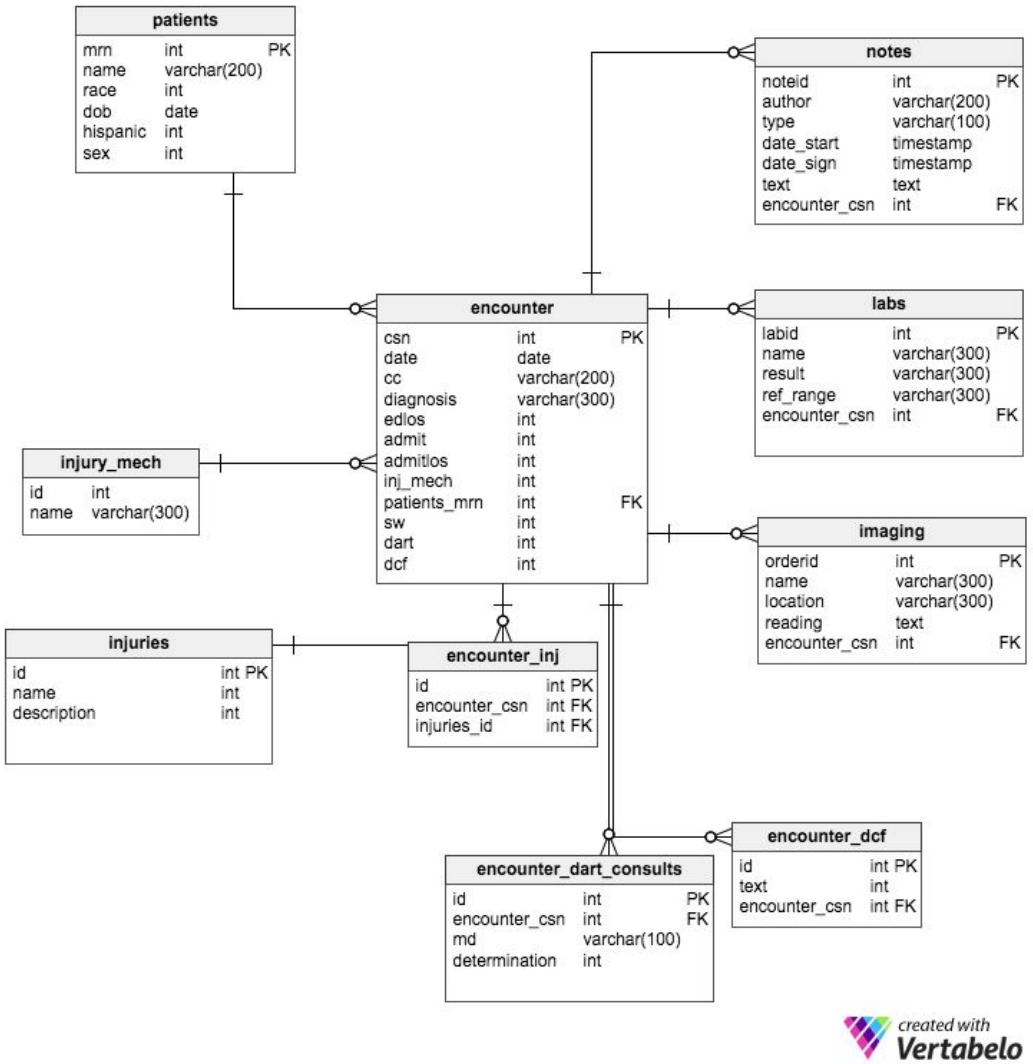
Aim #3: identify whether or not the DART service was called

The enabling work: 675 manually-annotated ED provider notes

- < 12 months of age
- visit to the emergency department
- chief complaint or diagnostic code consistent with injury
- April 2013 to June 2014
  - excepting a 3-month washout period from April 2014 - June 2014 after introduction of the intervention.
- manual chart review from the electronic health record (Epic)
  - demographics, exam findings, laboratory tests, imaging studies, DART and SW consults, and the ultimate determination of abuse by DART.
- manually classified as yes/no for each of the 8 injuries
  - further subdivision by location for the bruising category
  - yes/no for DART and SW consult
  - intentional/accidental/indeterminate for ultimate determination of abuse.

Aim #1: Notes into database

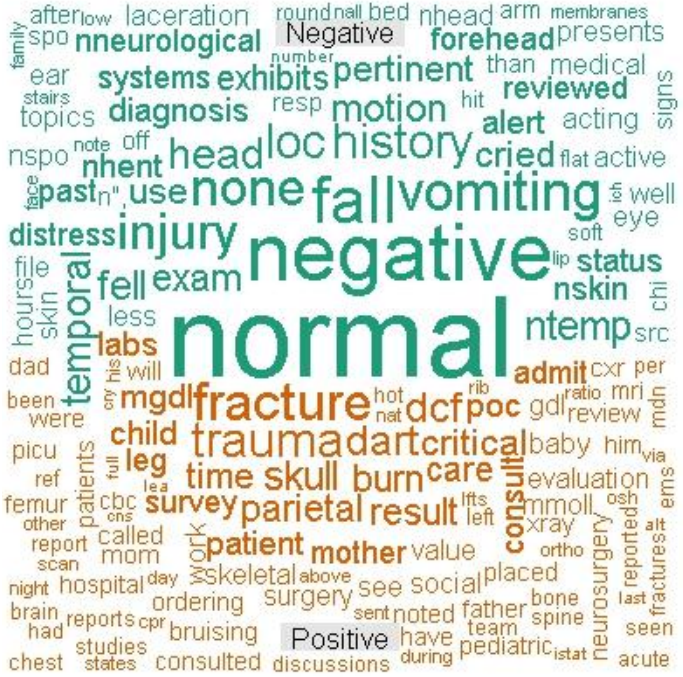
- Access to Clarity Obtained
- SQL query was written and executed on Clarity
- Microsoft SQL Server 2017
- extracted all free text notes
- Supported by Yale Joint Data and Analytics Team



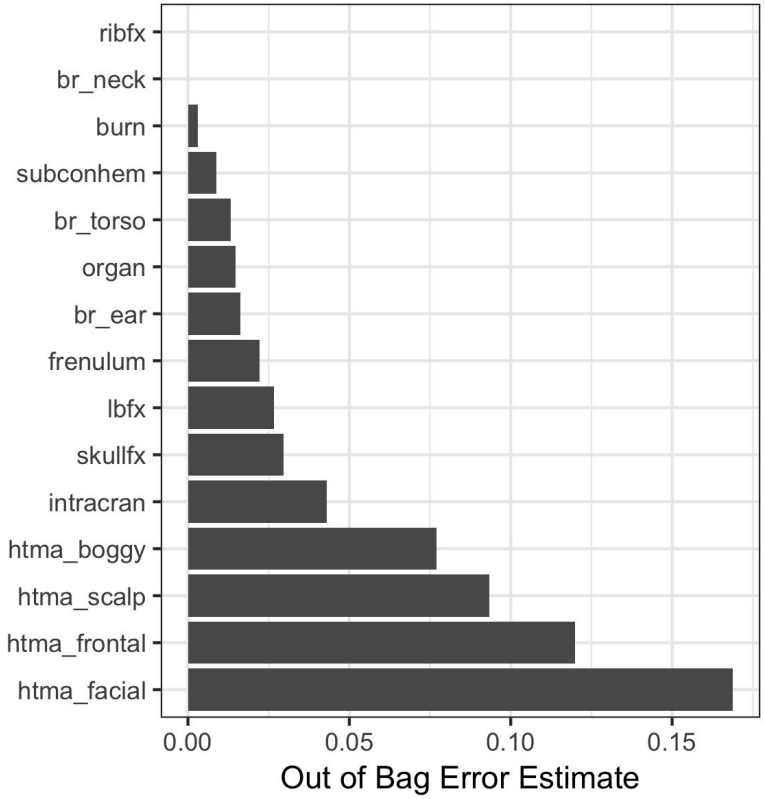
Aim #2: Use NLP to identify the eight injuries

Commonalities

Comparison



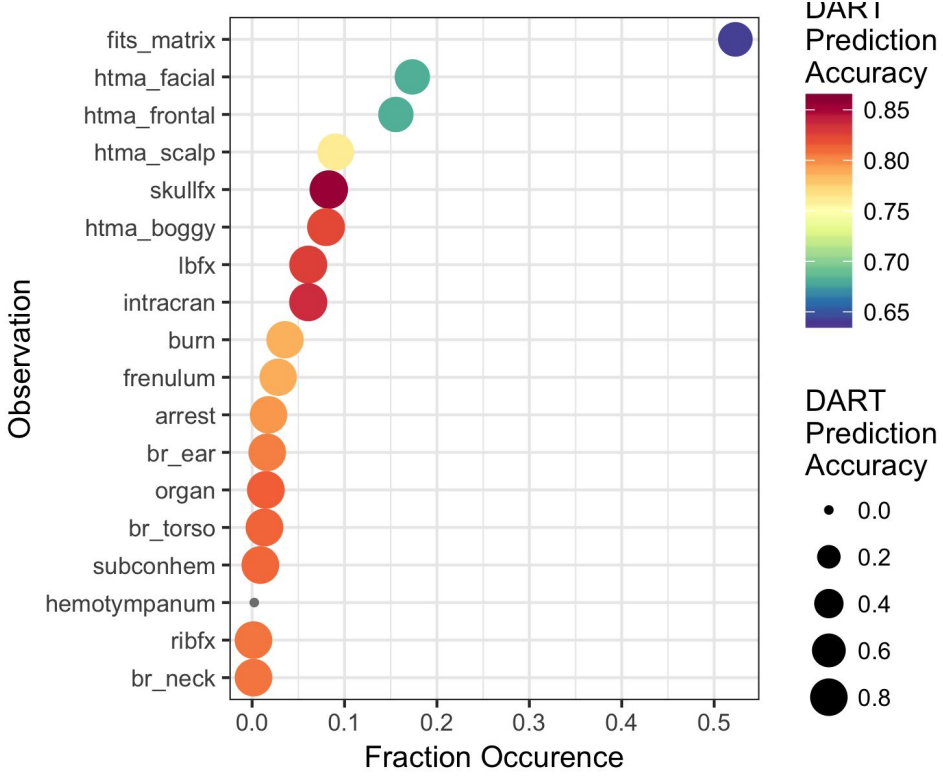
Aim #2: Use NLP to identify the eight injuries



Lowercase > tokenization > rm numbers, stopwords, punctuation, whitespace > Porter stemming > threshold 5 words (~1700 words) > random forest model

- Some injuries insufficiently frequent for training & test error prediction
- Random Forest OOB estimates
- Htma's bad, everything else >95% accuracy (except where too low to estimate)
- Potential problem if poorly estimated words are most frequent (what accuracy is needed?)

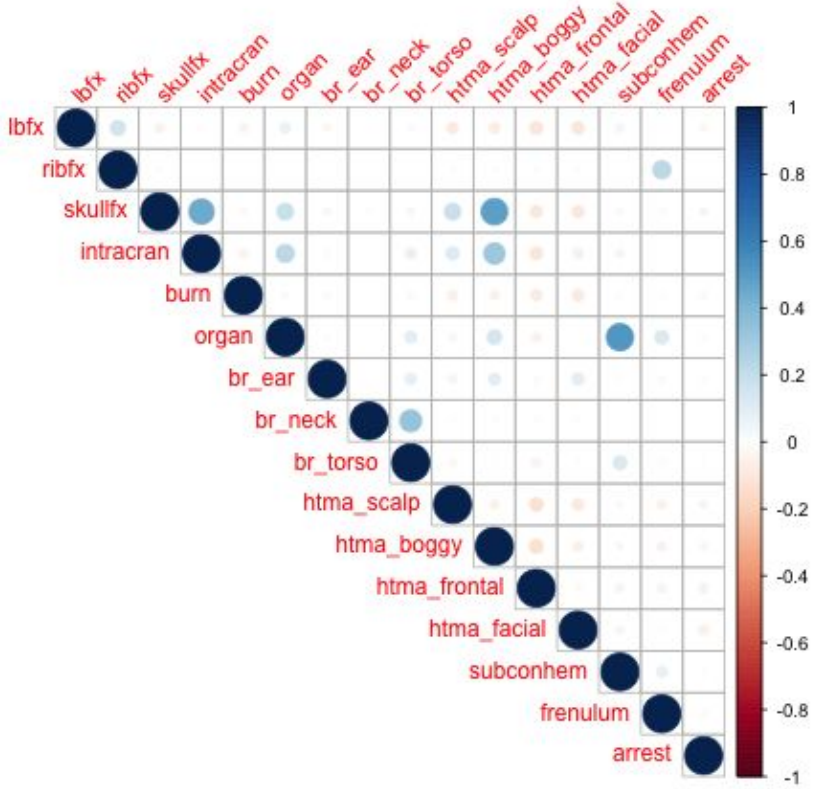
Aim #2: Use NLP to identify the eight injuries



Pursue NLP model refinement or push ahead?

- Fits_matrix pred acc = 0.65
- Most common injuries least predictive
- Some rarely observed (3 with 1 obs)
- Many have similar prediction accuracy, may be correlated

Aim #2: Use NLP to identify the eight injuries



- htma_boggy & skullfx & intracran
- subconhem & organ
- Br_neck & br_torso (low frequency)

Conclusion: Injuries will not be equivalently useful for predicting DART

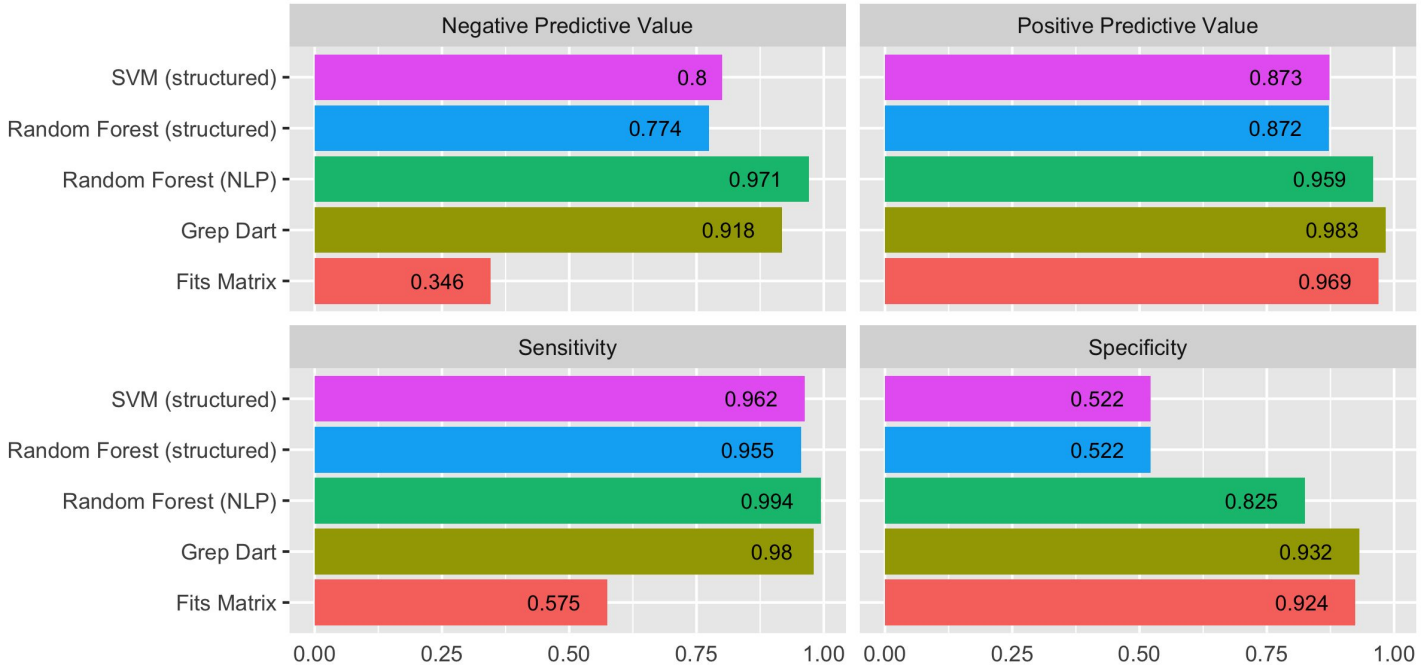
- proceed to modeling of DART

Aim #3: Identify whether the DART service was called

Train:test, 7:3

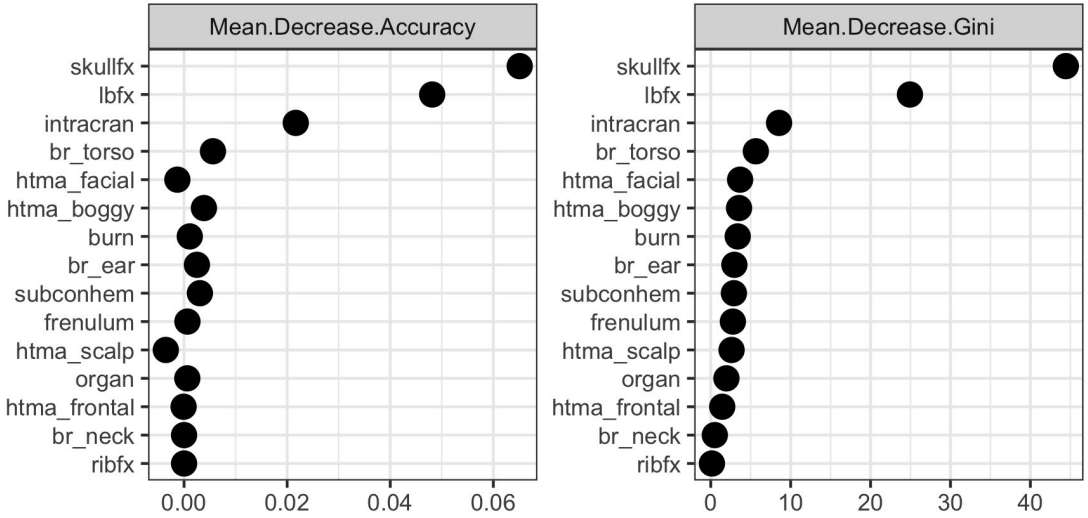
0	1
543	132

SVM tuned for cost and gamma with 5-fold CV



Aim #3: Identify whether the DART service was called

Returning to the question of variable importance



- Random forest model using the structured data
- Frontal and facial hematomas are relatively ineffectual in the model
- Fractures are important
  - Radiology reports were not included in the model

Specific Goal: automate identification of DART consultations to apply to large set of EMRs to assess use and efficacy

Aim #1: Query Clarity using SQL to pull full text ED provider notes into database.

- Database created
- SQL queries generated
- Notes pulled into database

Aim #2: Identify the eight injuries in radiology reports and ED provider notes that should trigger the provider to involve the DART consult service.

- NLP random forest models
- OOB error estimates range from 1-15%

Aim #3: identify whether or not the DART service was called

- Providers are not calling a DART consultation every time any of the eight injuries are observed (~65% of the time)
- Matrix of injuries accurate NLP on the notes corpus performed best

Future Directions

- Refine NLP models using radiology reports
- Refine NLP model of DART
- Consider reducing / focusing the eight injuries
- Apply to larger dataset
- Look for changes post adoption of DART
- Predict abuse

Future direction: prediction of abuse

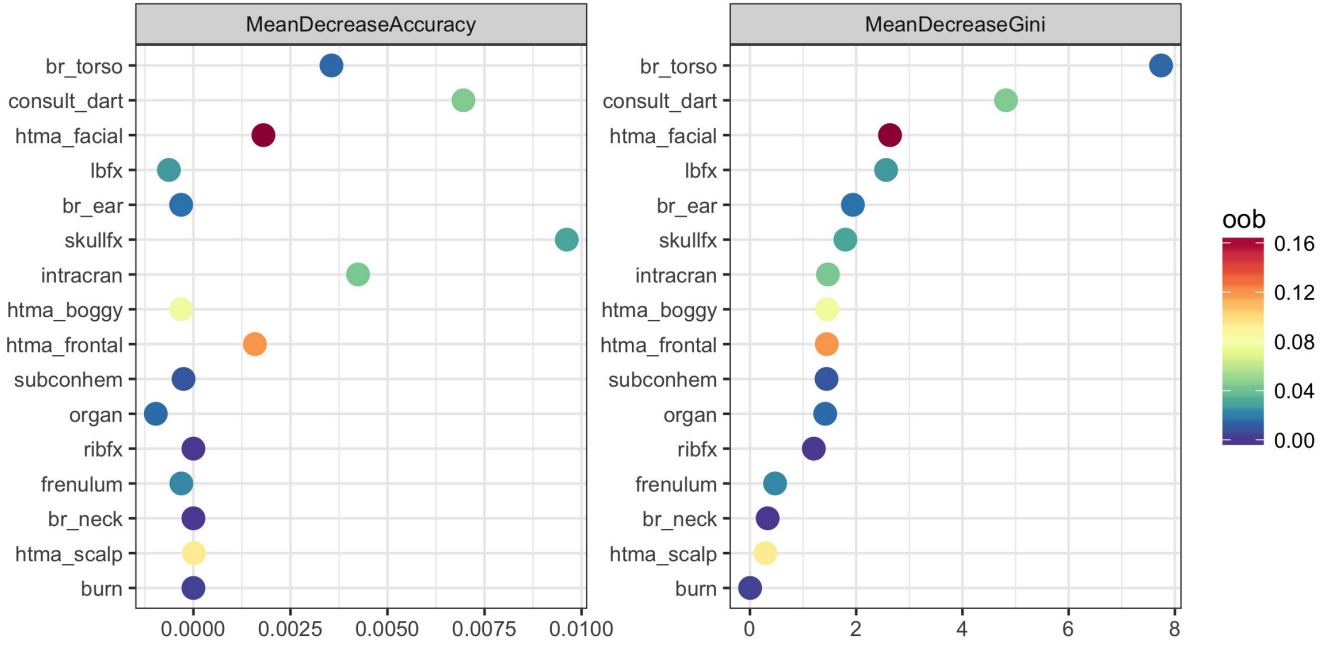
Assumption: If DART = 0, abuse = 0

0	1
652	23

OOB err: 3.83%

Confusion matrix:

	0	1	class.err
0	622	7	0.011
1	18	5	0.783



Future directions: Imputation of abuse NA values

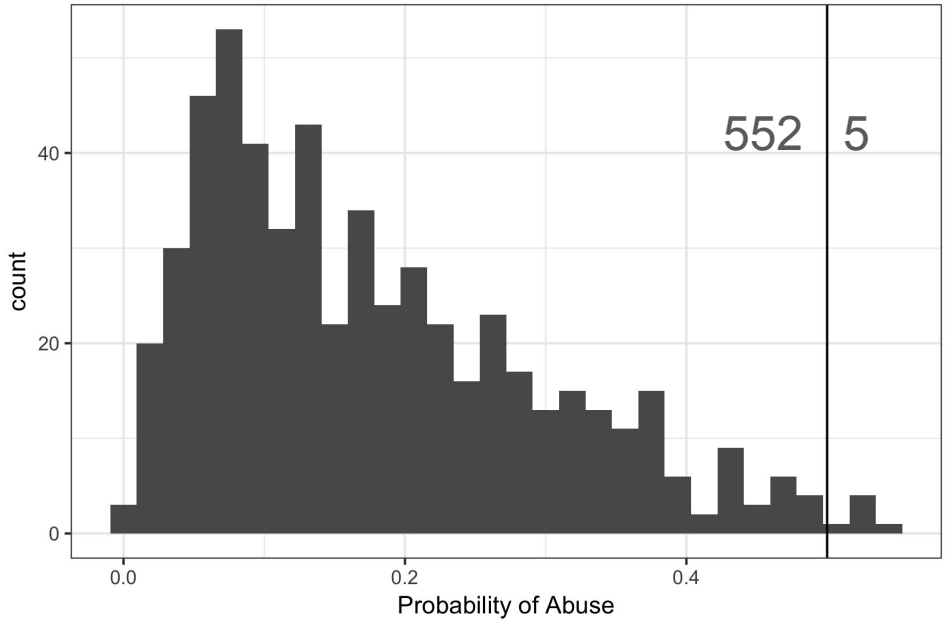
Remove assumption: If DART = 0, abuse = NA

0	1	NA
95	23	557

OOB estimate of error rate: 19.49%

Confusion matrix:

	0	1	class.err
0	93	2	0.021
1	21	2	0.913



Author Contributions

EP conceived the project, generated the training dataset, SQL queries and database. NN and DS analyzed the data. EP and DS wrote the paper. For detailed code contributions please see https://github.com/mastoneq/thedartmatrix .

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Thank you!