Improving Prediction Accuracy of User Cognitive Abilities for User-Adaptive Narrative Visualizations

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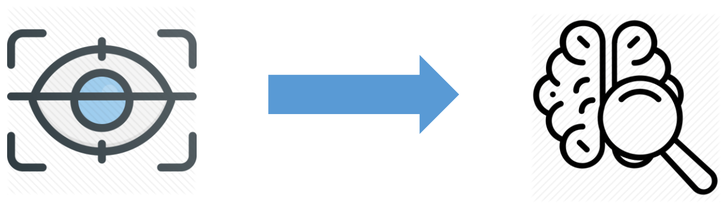
OVERVIEW



People with different cognitive abilities have different performance in processing different aspects of Information visualization

(Eye-tracking data can be leveraged to make predictions)

Motivation:

- Accurate prediction of user cognitive abilities results in better personalized support
- Support is most needed for the low class (need higher accuracy)

Contributions:

Extending current research on user-adaptive visualizations by:
- Improving prediction accuracy by fine tuning classification algorithms
- Proposing potential classifiers with better performance

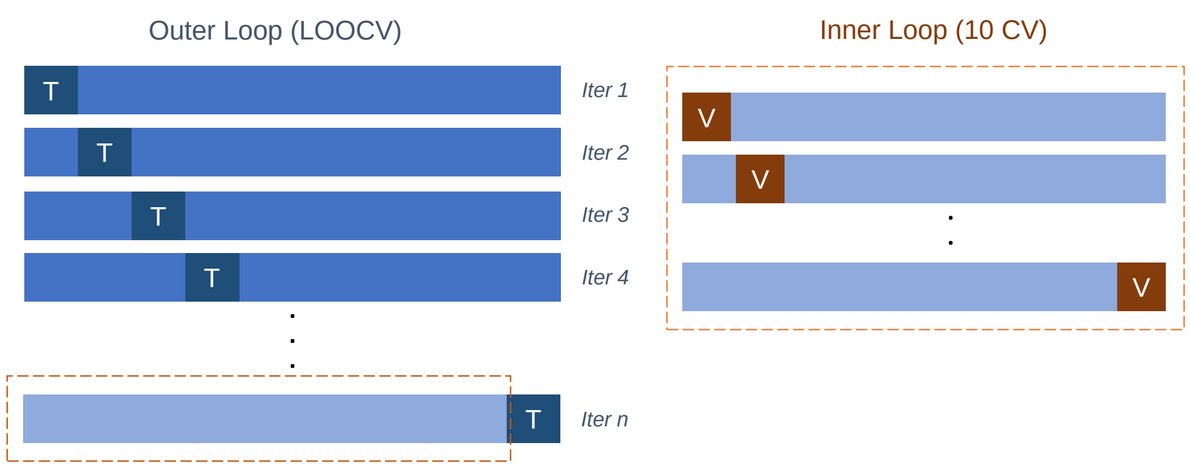
Related Work

4 different classifiers have been explored and evaluated for predicting 3 cognitive abilities across 15 infovis tasks

Cognitive Ability	Classifier	Best Window	Acc Overall	Acc Low	Acc High
READP	RF	4 tasks	0.66	0.65	0.67
VISLIT	RF	3 tasks	0.66	0.75	0.56
VERWM	XGB	10 tasks	0.70	0.73	0.67

The first step was establishing the feasibility of predicting cognitive abilities based on eye-tracking data. As a result:
- These classifiers were not tuned for maximum accuracy
- Alternative classifiers were not explored

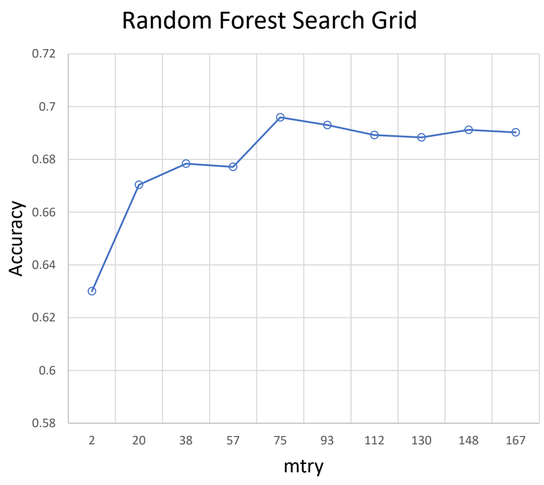
Tuning Pipeline

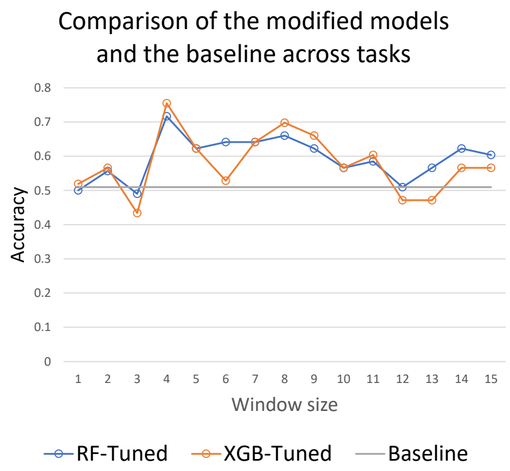


Outer loop: Evaluation (Generalization Accuracy)
Inner loop: Hyper-parameter Tuning

This nested structure avoids optimization bias by separating tuning and evaluation

Reading Proficiency

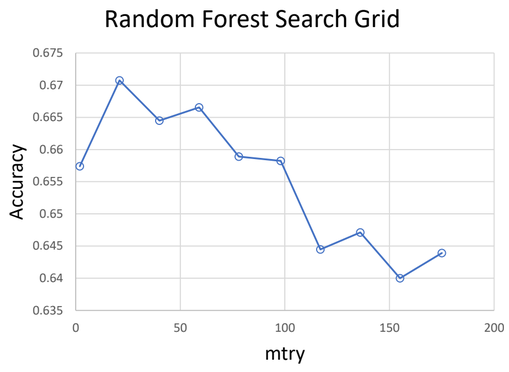


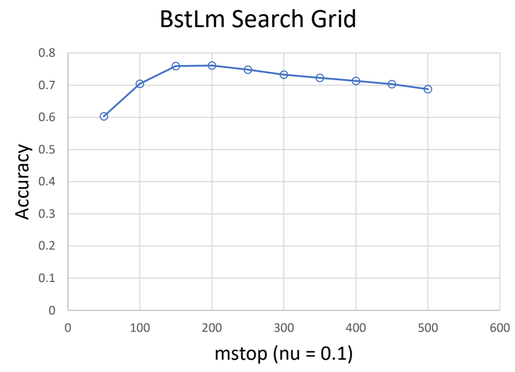


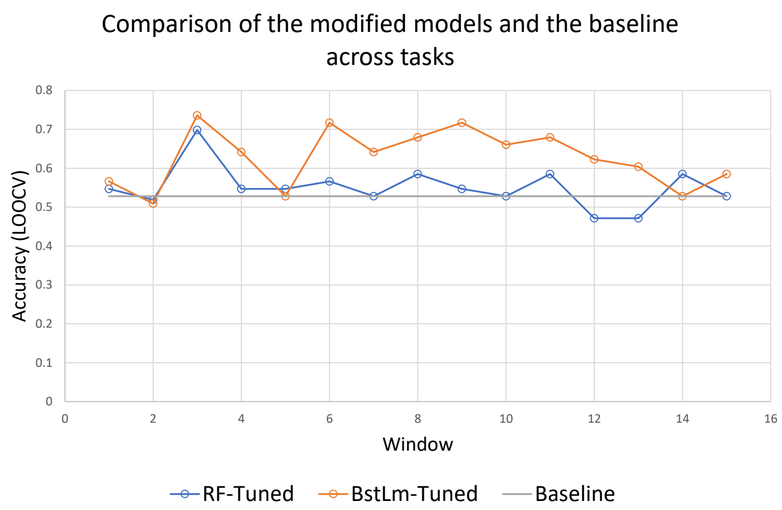
Model	Acc Overall	Acc Low	Acc High
RF (default)	0.66	0.65	0.67
RF (tuned)	0.72	0.73	0.70
XGB (tuned)	0.75	0.77	0.74

Improvements: 13.6%, 18.5%, and 10.4%
XGB: Accuracy for the low class was made higher than the high class

Visual Literacy





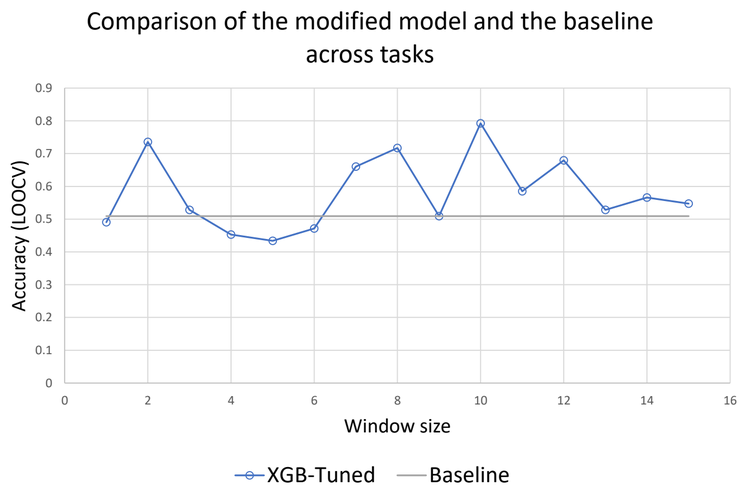


Model	Acc Overall	Acc Low	Acc High
RF (default)	0.66	0.75	0.56
RF (tuned)	0.70	0.79	0.60
BstLm (tuned)	0.74	0.79	0.68

Improvements: 12.1%, 5.3%, and 21.4%
BstLm: Higher overall accuracy and a better balance between the two classes

Verbal Working Memory

Model	Acc Overall	Acc Low	Acc High
XGB (default)	0.70	0.73	0.67
XGB (tuned)	0.79	0.88	0.70



Improvements: 12.9%, 20.5%, and 4.5%.
Predictions can still be made with an accuracy of 0.74 as early as two tasks until the user has performed 10.

Statistical Analysis

Paired samples t-test

READP: (p = 0.084, r = 0.42)
VISLIT: (p = 0.126, r = 0.47)
VERWM: (p = 0.012, r = 0.78)

The improvements were statistically significant for verbal working memory with a large effect

Future Work

It would be interesting to tune the classifiers based on each window to assess the possibility of earlier and more accurate predictions

- Depending on the data gathered so far we could use different models with different hyper-parameters

Reference

Eye-Tracking to Predict User Cognitive Abilities and Performance for User-Adaptive Narrative Visualizations