Predicting Affect from Gaze Data during Interaction with an Intelligent Tutoring System

Natasha Jaques, Cristina Conati, Jason M. Harley, and Roger Azevedo

Roadmap

- Introduction & Contributions
- Related Work
- MetaTutor
- User Study & Eye Tracking Data
- Machine Learning Experiments
- Results
- Conclusion & Future Work

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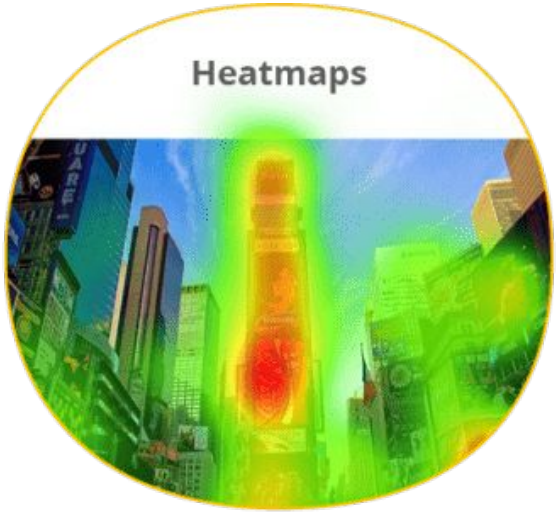
Introduction & Contributions

In what order did an **individual** look at things and for how long?



Where did a **population** focus their visual attention?

How did a **population** focus on one element versus another?

Introduction & Contributions

- Using eye tracking data as a stand alone tool
- In contrast with hand-engineered heuristics for gaze-based interventions and other non-gaze features (e.g. pupil dilation)
- Investigate boredom and **curiosity**
- Identify features most predictive of each emotion

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Related Work

Emotions in Academic Setting

- Student motivation
- Academic achievement
- Boredom
- Engagement
- Emphatic & supportive tutor

Detect Learner's Emotions

- Interaction logs
- Acoustic and dialog features
- Physiological sensors
- Posture
- Questionnaires
- ***Eye gaze***

“Unfortunately, positive emotions (including curiosity) declined over the course of the interaction, demonstrating a need for affective interventions”

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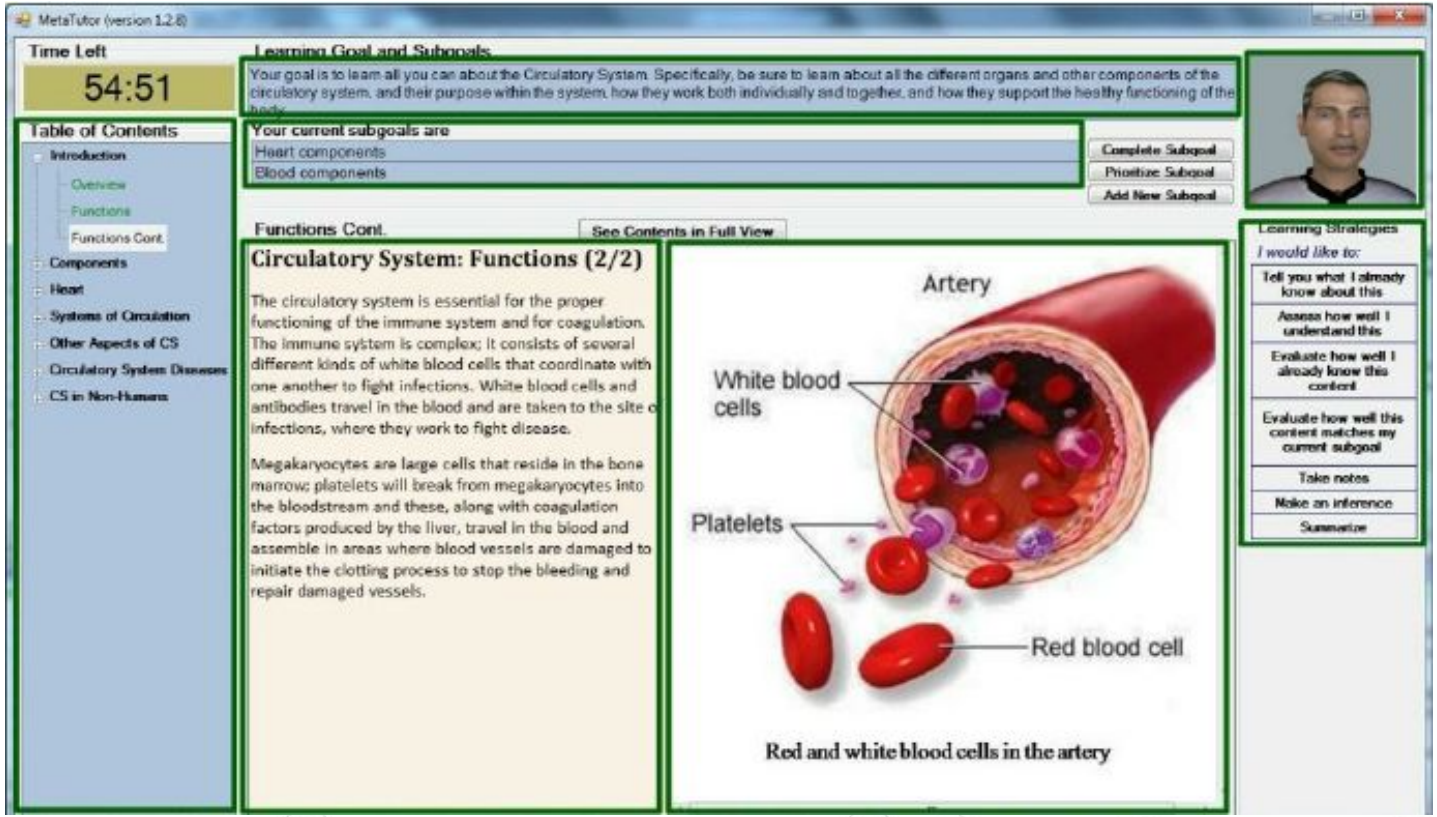
MetaTutor


MetaTutor (version 1.2.8)
Time Left
54:51
Learning Goal and Subgoals
Your goal is to learn all you can about the Circulatory System. Specifically, be sure to learn about all the different organs and other components of the circulatory system, and their purpose within the system, how they work both individually and together, and how they support the healthy functioning of the body.
Your current subgoals are
Heart components
Blood components
Complete Subgoal
Prioritize Subgoal
Add New Subgoal
Table of Contents
Introduction
Overview
Functions
Functions Cont.
Components
Heart
Systems of Circulation
Other Aspects of CS
Circulatory System Diseases
CS in Non-Humans
Functions Cont.
See Contents in Full View
Circulatory System: Functions (2/2)
The circulatory system is essential for the proper functioning of the immune system and for coagulation. The immune system is complex; it consists of several different kinds of white blood cells that coordinate with one another to fight infections. White blood cells and antibodies travel in the blood and are taken to the site o infections, where they work to fight disease.
Megakaryocytes are large cells that reside in the bone marrow; platelets will break from megakaryocytes into the bloodstream and these, along with coagulation factors produced by the liver, travel in the blood and assemble in areas where blood vessels are damaged to initiate the clotting process to stop the bleeding and repair damaged vessels.
Artery
White blood cells
Platelets
Red blood cell
Red and white blood cells in the artery
Learning Strategies
I would like to:
Tell you what I already know about this
Assess how well I understand this
Evaluate how well I already know this content
Evaluate how well this content matches my current subgoal
Take notes
Make an inference
Summarize

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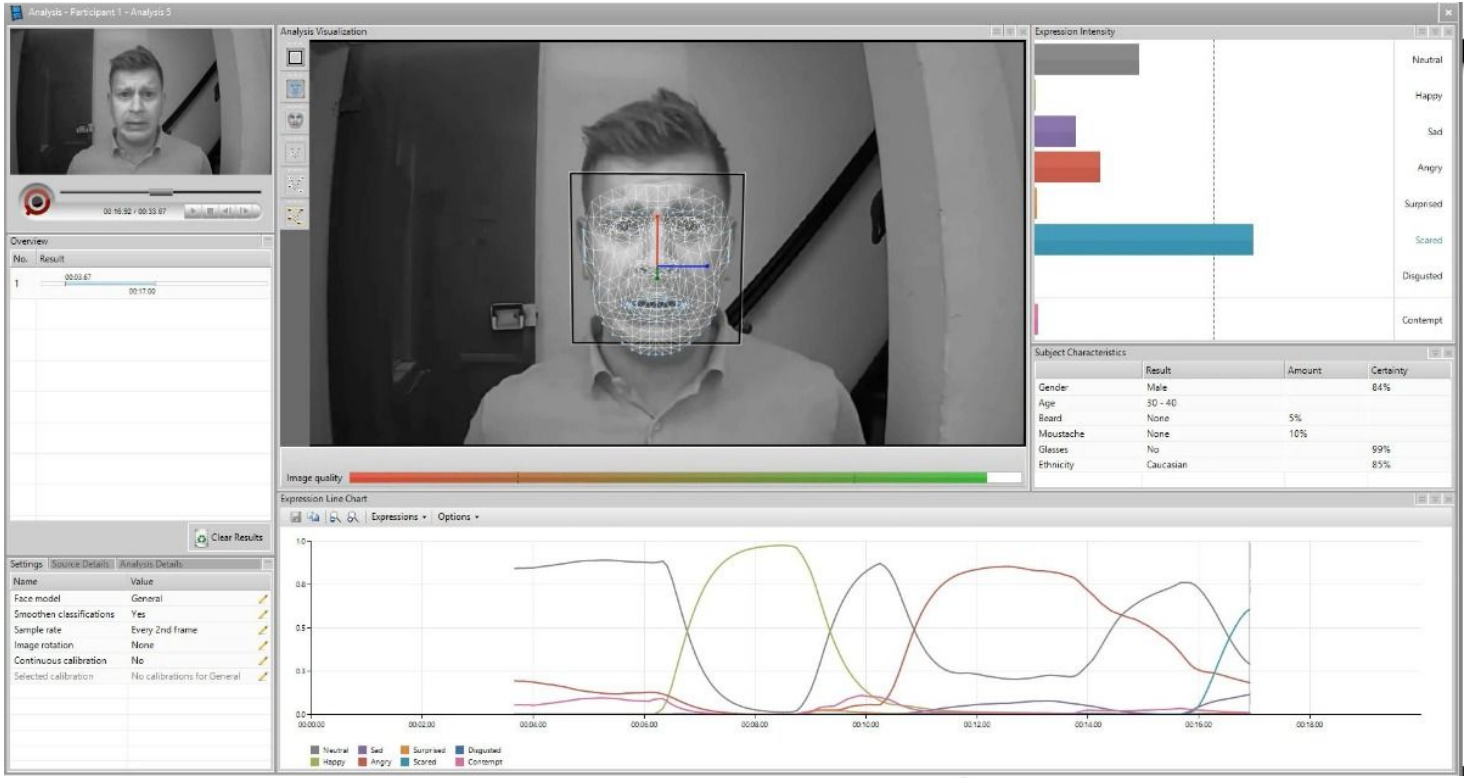
User Study & Eye Tracking Data

- 67 undergraduate students
  - 51 considered after data validation
- Used MetaTutor for about 90 minutes
- Data from number of sensors, including an eye tracker
- Self-reports
  - 5 per student
  - Likert scale between 1 (*strongly disagree*) and 5 (*strongly agree*)
  - Boredom : mean = 2.60, SD = 0.69
  - Curiosity: mean = 2.93, SD = 0.71

User Study & Eye Tracking Data



User Study & Eye Tracking Data

Fixations: persistent focus on a single point

Saccades: paths between two consecutive fixations

166 features in total

User Study & Eye Tracking Data

Application-Independent

- Number of fixations
- Fixation duration
- Saccade length
- Angle between consecutive saccades
- Angle between a saccade and the horizontal plane

Application-Dependent:

- Duration of longest fixation
- Proportion of fixations and time spent
- Gaze transitions
- Time of first/last fixation
- Total fixation time

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Machine Learning Experiments

- Two separate binary classification problems: ***boredom*** and ***curiosity***
- Emotion Present (EP) vs. Emotion Absent (EA)
- 10-fold cross validation
- Four algorithms used
  - Random Forests
  - Naive Bayes
  - Logistic Regression
  - Support Vector Machines

Machine Learning Experiments

- ***Accuracy***: percentage of correctly classified data points
- ***Cohen's kappa*****:** measure of classification performance which accounts for correct predictions occuring by chance
  - 0 if the predictions were no more accurate than chance
  - 1 when labels exactly match the ground truth values
- ***Feature reduction*** against overfitting
  - Principal Component Analysis (PCA)
  - Wrapper Feature Selection (WFS)

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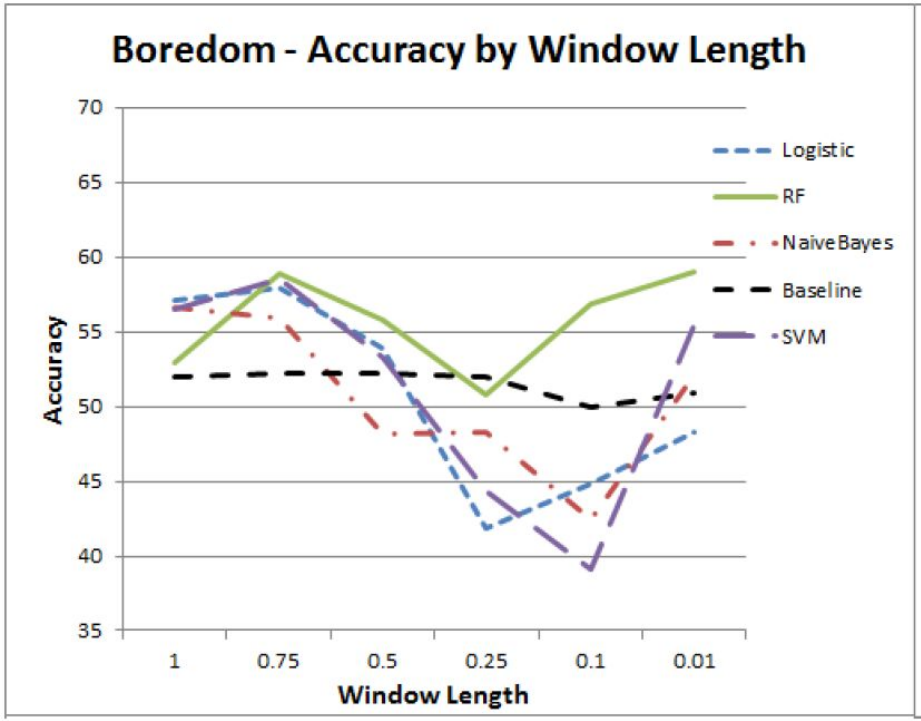
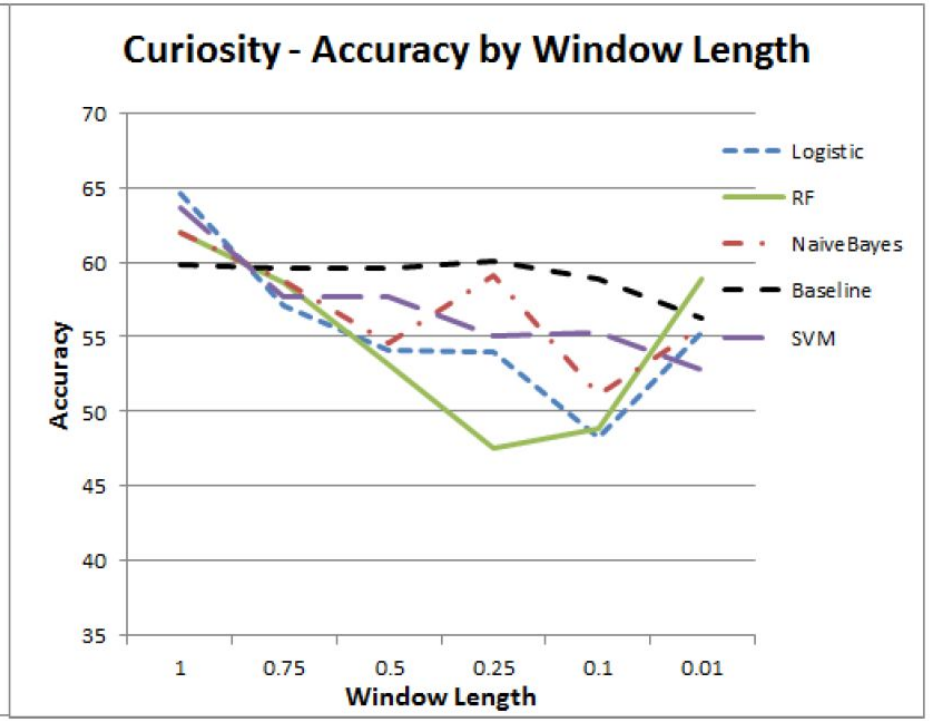
Predicting Self-Reports across the Interaction

- ***Goal:*** determine the amount of gaze data preceding the self-report that should be used for optimal prediction performance
- ***Baseline:*** a majority-class baseline, using t-tests with a Bonferroni adjustment
- ***Four 4x6 General Linear Models:*** boredom accuracy/kappa, curiosity accuracy/kappa as the dependent variables
  - 4 classifiers
  - 6 window lengths
  - Treat one train/test split as a single point

Predicting Self-Reports across the Interaction





Predicting Self-Reports across the Interaction

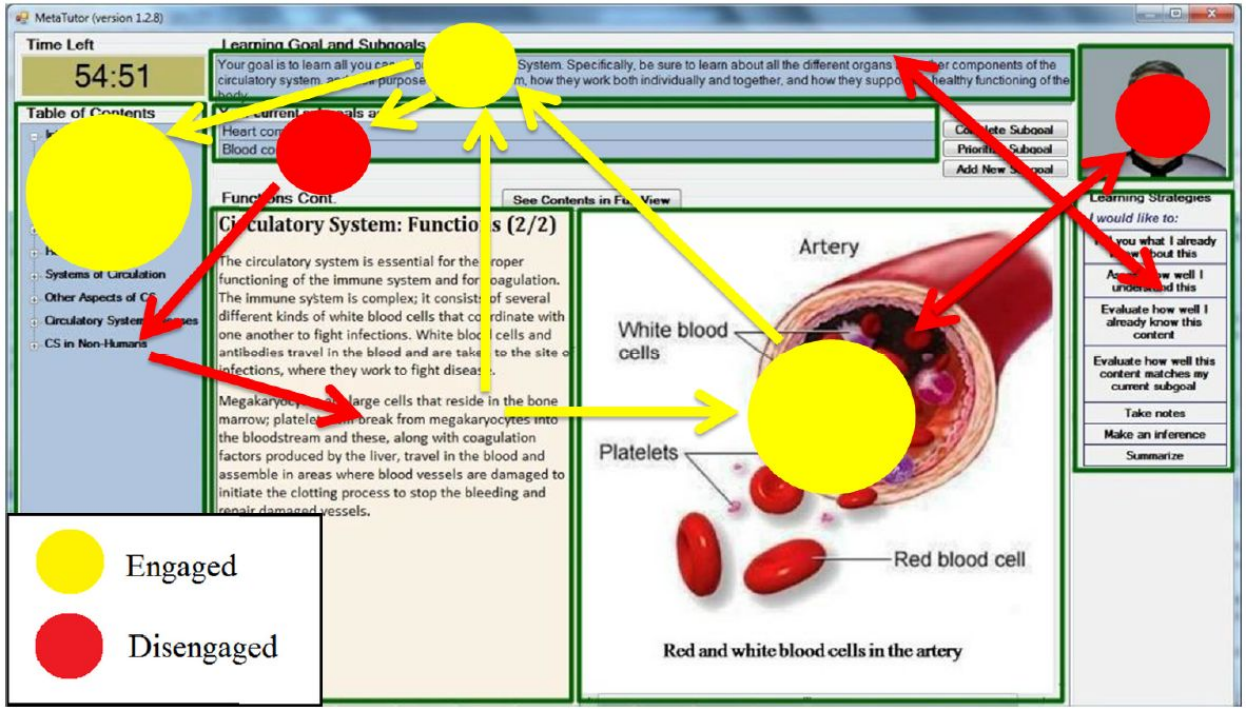
- No significant effects of the classifier
- Main effect of **window length** both for boredom and curiosity
  - Low p-value
  - High eta squared value
- Significantly better than baseline
  - Boredom at 75% and 100% (10.5 minutes and 14 minutes)
  - Curiosity at 100% (14 minutes)

“This study provides empirical evidence that [using a 20 second interval for affect labeling] may not always be appropriate, depending on the data used for prediction.”

Identifying Important Features

- ***Goal:*** examine features selected by the WFS process
- ***Arrows:*** gaze transitions
- ***Circles:*** features related to the AOI (circle size increases with the number of related features found)

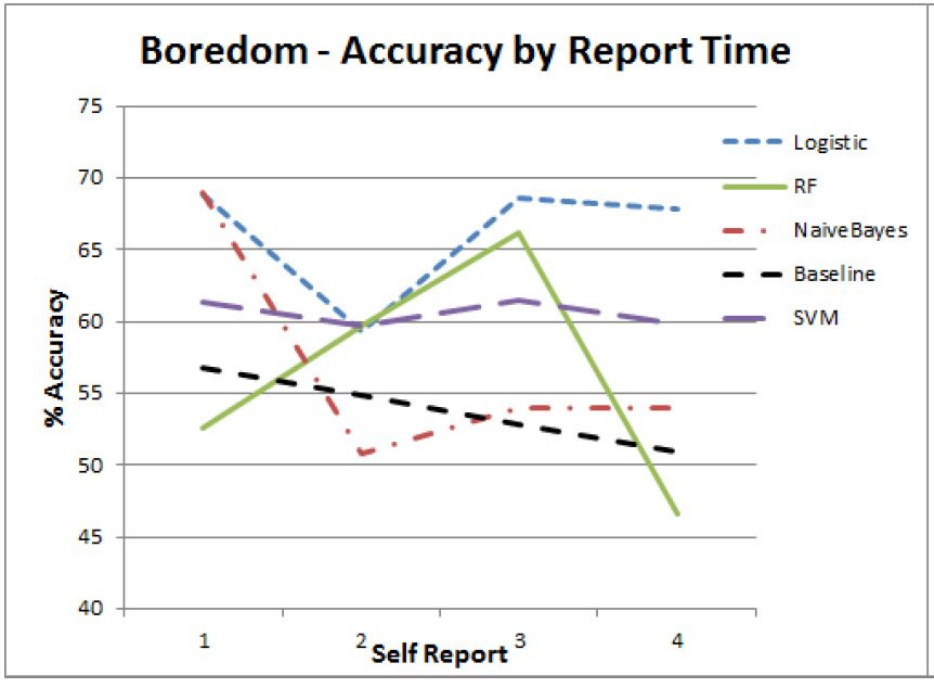
Identifying Important Features

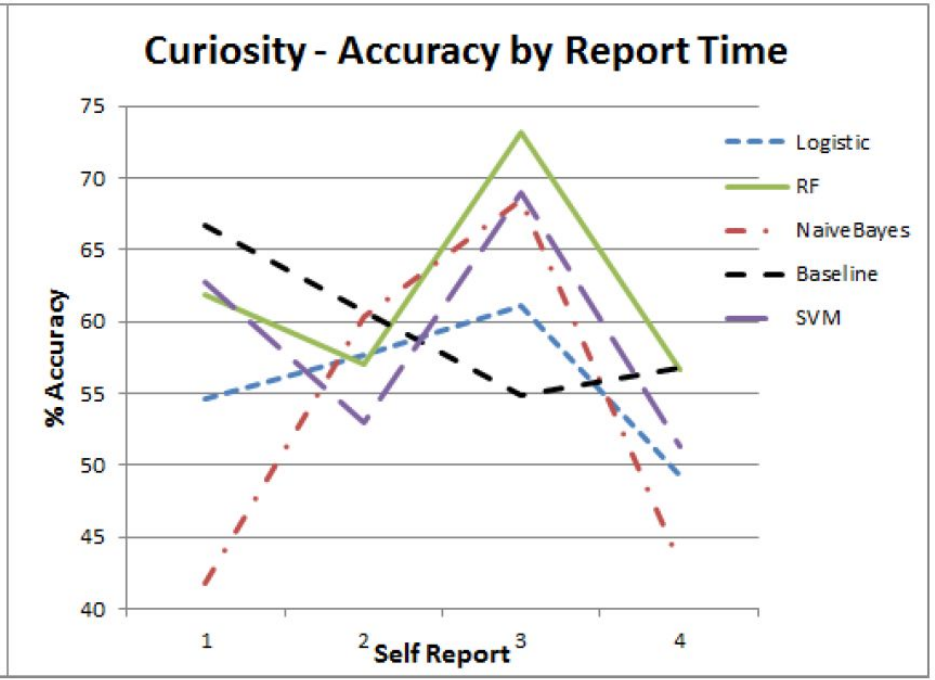


Time-Dependent Effects on Prediction

- ***Goal:*** improve performance by treating each self-report time as its own classification problem
- ***Four 4x4 General Linear Models***
  - 4 classifiers
  - 4 report times

Time-Dependent Effects on Prediction



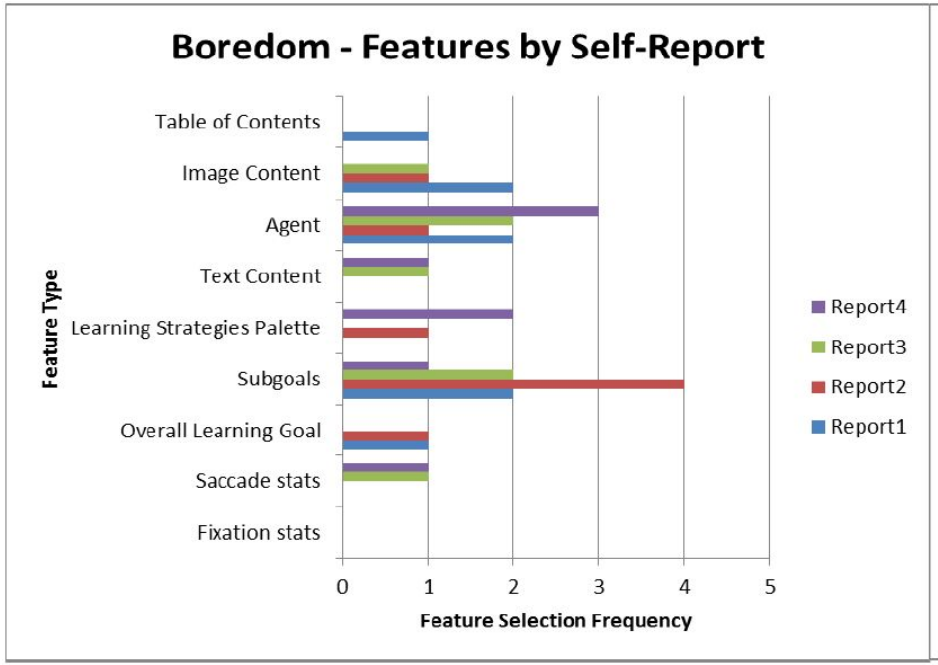


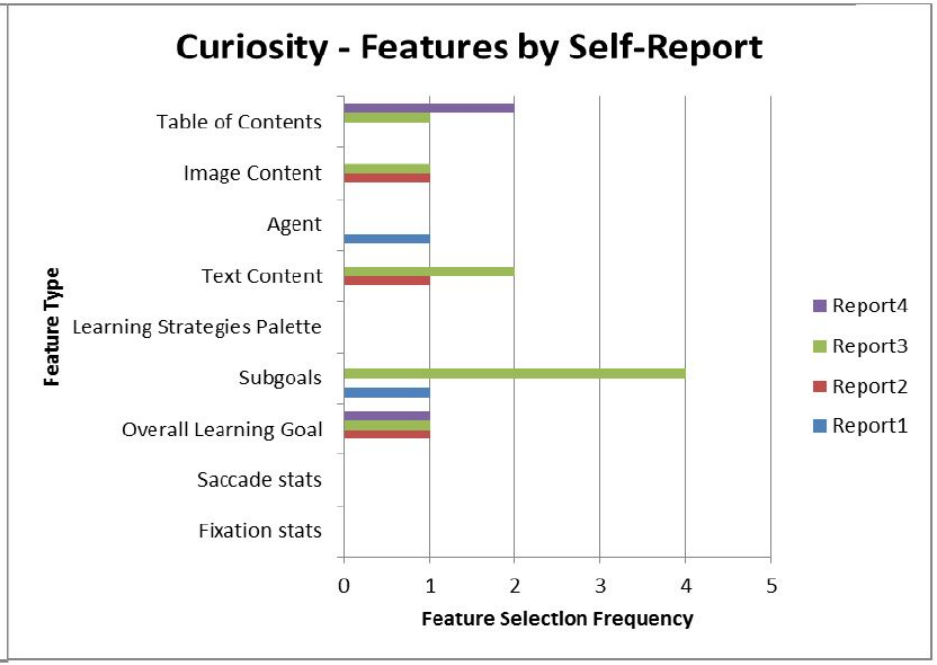
Time-Dependent Effects on Prediction

- No significant effects for **boredom**
  - Logistic Regression performing the best
  - Single self-report time results are better
- Effect of report time for both kappa and accuracy for **curiosity**
  - Amount of time spent interacting with MetaTutor affects the relationship between gaze and affect

“The results of this section seem to indicate that the relationship between gaze and affect varies over time. Different gaze features would be more informative at different report times.”

Time-Dependent Effects on Prediction





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Conclusion

- Eye gaze data *alone* - a useful tool
- Longer intervals for predicting affect
- Temporal information can increase accuracy

Future Work

- Use additional data sources
- Develop intervention strategies