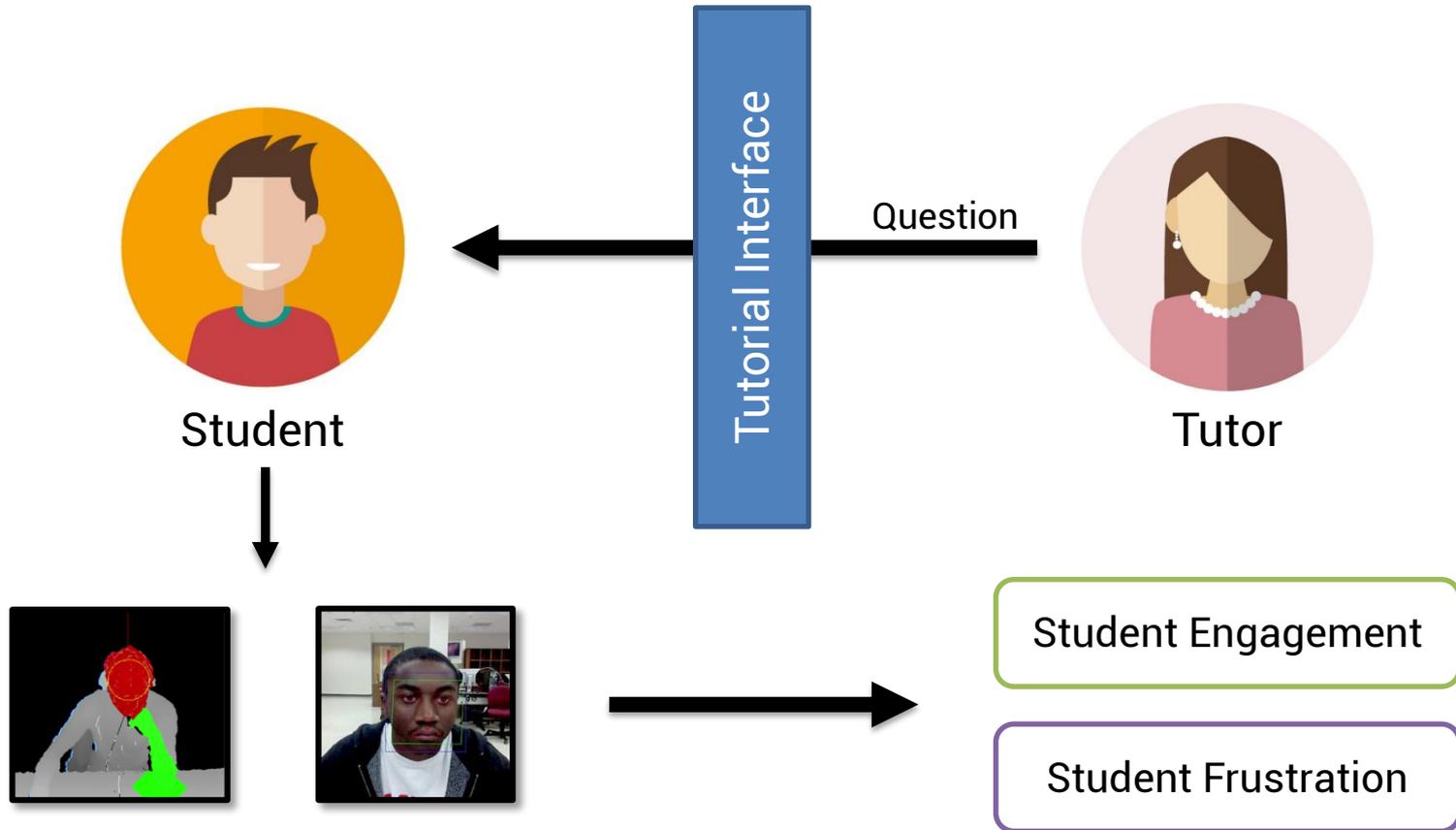# The Affective Impact of Tutor Questions: Predicting Frustration and Engagement

Alexandria K. Vail, Joseph B. Wiggins, Joseph F. Grafsgaard, Kristy Elizabeth Boyer, Eric N. Wiebe, and James C. Lester

Introduction
Overview

Student

Tutorial Interface

Question

Tutor

Student Engagement

Student Frustration

Introduction
Related Work

- Recognized need for modeling affect during learning
  (Paquette & Baker & D'Mello; Rowe & Lester, Forbes-Riley & Litman)

- Focus on frustration and engagement
  (Grafsgaard & Lester; Baker; Heffernan)

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Introduction
Related Work

- Significance of short-term over long-term nonverbal patterns
  (Grafsgaard, Calvo, D'Mello)

- Potential critical moments: tutor questions
  (Piaget, Stein and Levine, Hardy)

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Introduction
Research Question

What is the relationship between student engagement and frustration and his or her nonverbal behavior during critical moments of the tutorial interaction?

Multimodal Corpus
Study Overview

Domain: Introductory Java programming

- Computer-mediated human-human interactions

- N = 67 student-tutor pairs
  - 67 unique students
  - 5 unique tutors

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Multimodal Corpus
Tutorial Interface

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Multimodal Corpus
Multimodal Collection

Posture & Gesture

Task & Dialogue

Facial Expression

Electrodermal Activity

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Multimodal Corpus
Task & Dialogue Traces

Logs including dialogue messages, coding changes, task progress

Tutor Inference Questions

– Questions that require reasoning about content knowledge or formulating a plan

– *e.g., How do you think this problem can be solved?*

Tutor Evaluative Questions

– Questions that require the student to evaluate his or her own understanding

– *e.g., Do you understand so far?*

Multimodal Corpus
Facial Expression Features

- Facial expression recognition by FACET commercial software

- 19 Facial Action Units

- **AU Evidence:** Measure of confidence in the presence of each expression

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Multimodal Corpus
Gesture Features
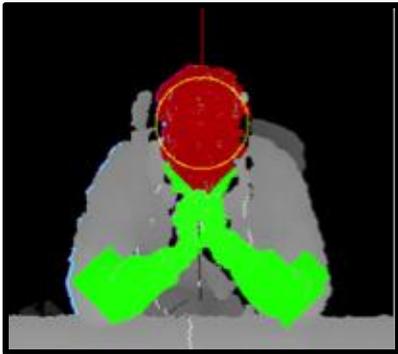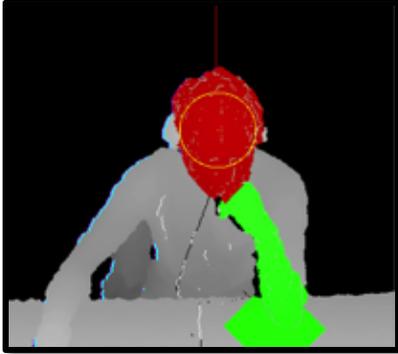
- Kinect depth camera images
- Detects amount of time one or two hands touching the lower face
- Algorithm based on surface propagation from center of head
(Grafsgaard et al., 2012)
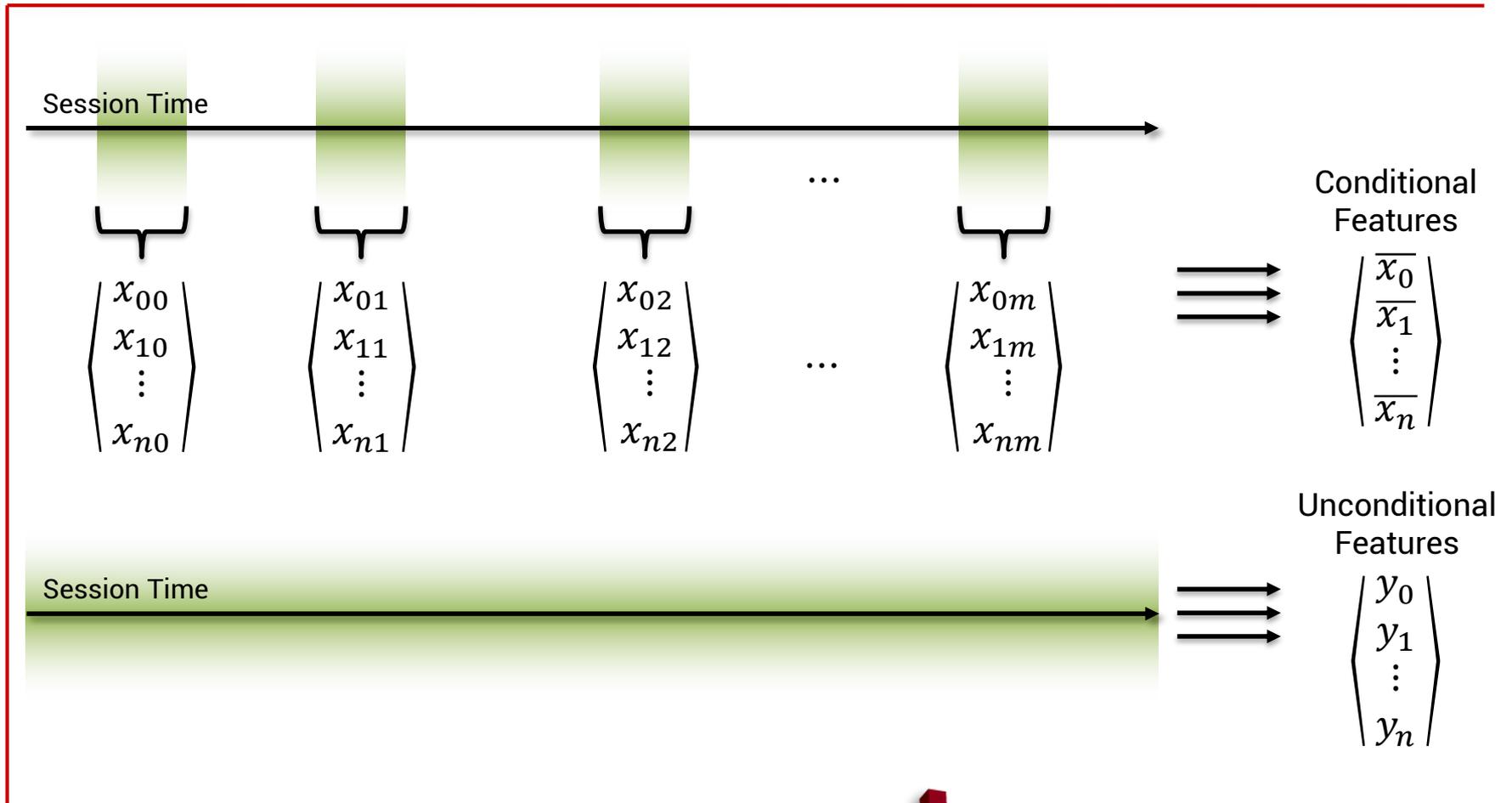
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Analysis
Overview

Tutor
How can we solve this problem?

Session Time

3-second interval

Multimodal Features

Avg AU4 = 1.20   1H Gesture = 57%   SCRs = 5
Avg AU7 = -0.21   2H Gesture = 3%
Avg AU9 = 0.02   Avg Distance = 1.34
...   ...

$$\left\langle \begin{matrix} x_0 \\ x_1 \\ \vdots \\ x_n \end{matrix} \right|$$

Analysis
Overview

Session Time

$$\begin{pmatrix} x_{00} \\ x_{10} \\ \vdots \\ x_{n0} \end{pmatrix} \quad \begin{pmatrix} x_{01} \\ x_{11} \\ \vdots \\ x_{n1} \end{pmatrix} \quad \begin{pmatrix} x_{02} \\ x_{12} \\ \vdots \\ x_{n2} \end{pmatrix} \quad \cdots \quad \begin{pmatrix} x_{0m} \\ x_{1m} \\ \vdots \\ x_{nm} \end{pmatrix}$$

Conditional Features

$$\begin{pmatrix} \overline{x_0} \\ \overline{x_1} \\ \vdots \\ \overline{x_n} \end{pmatrix}$$

Session Time

Unconditional Features

$$\begin{pmatrix} y_0 \\ y_1 \\ \vdots \\ y_n \end{pmatrix}$$

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Analysis
Features Summary

1. Average measure of each facial action unit
2. Percentage of time in which one- or two-hands-to-face gesture is present
3. Average student distance from workstation
4. Average difference between highest and lowest posture point (i.e., leaning)
5. Number of skin conductance responses observed

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Analysis
Features Summary

1. **Average measure of each facial action unit**
2. **Percentage of time in which one- or two-hands-to-face gesture is present**
3. Average student distance from workstation
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Analysis
Stepwise Regression Modeling Procedure

- Standardized all features and outcomes:

$$z = \frac{x - \mu}{\sigma}$$

- Optimized leave-one-student-out cross-validation

- Required strict $p < 0.05$ cut-off value (after a Bonferroni correction)

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Predictive Model
Student Frustration

- Self-reported outcome collected at end of tutorial session
- NASA-TLX workload survey
    - Frustration Level
- Rating from 1 to 100

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Predictive Model
Student Frustration − Tutor Evaluative Questions

Frustration =	R^2	p
-0.7039 ∗ AU12 Lip Corner Puller	0.0764	0.014
-0.6279 ∗ AU28 Lip Suck	0.2471	0.030
-0.1635 (intercept)		1.000
Leave-One-Out Cross-Validated R^2 = 0.3235		

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Predictive Model
AU12 Lip Corner Puller

- Associated with **less** frustration after evaluative questions

- Typically related to smiling
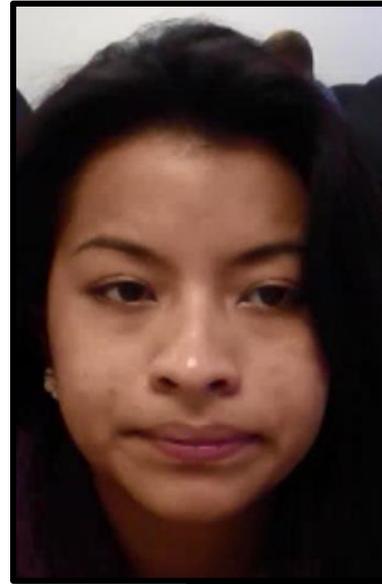
Aaron Lee / YouTube

Predictive Model
AU28 Lip Suck

- Associated with **less** frustration after evaluative questions
- Sometimes related to fidgeting, perhaps a "self-manipulator" for emotion regulation

Predictive Model
Student Frustration – Tutor Inference Questions

Frustration =	R^2	p
+0.5660 * AU6 Cheek Raiser	0.2893	0.022
+0.3635 * AU20 Lip Stretcher	0.0499	0.019
-0.0174 (intercept)		1.000
Leave-One-Out Cross-Validated R^2 = 0.3392		

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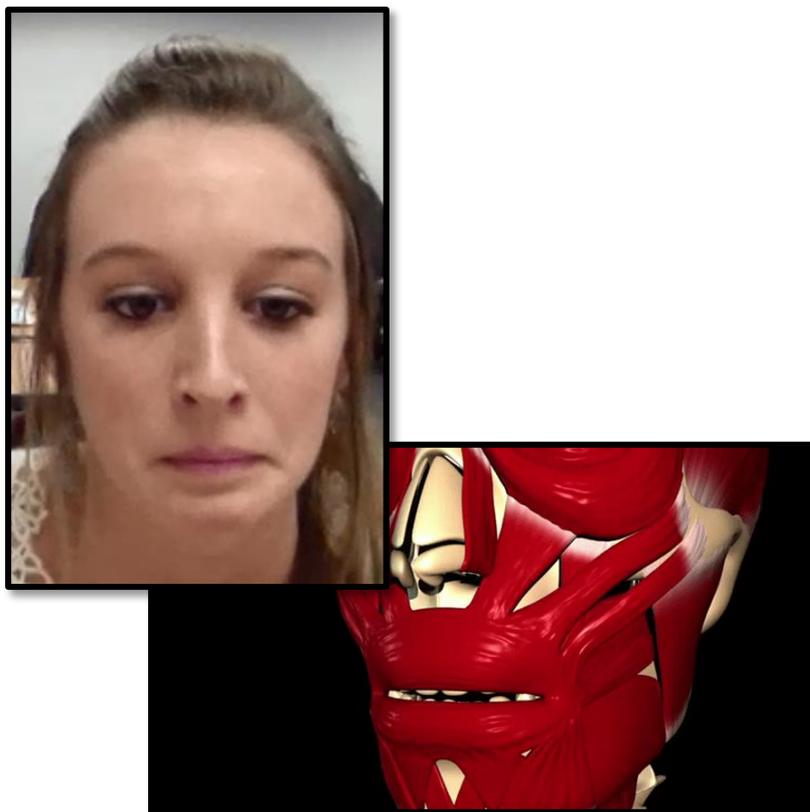the intelliMEDIA group

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Predictive Model
AU6 Cheek Raiser

- Associated with **more** frustration after inference questions

- Related to pain expressions

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Predictive Model
AU20 Lip Stretcher

Aaron Lee / YouTube

- Associated with **more** frustration after inference questions

- Previously found to coincide with moments of embarrassment or "awkwardness"

Predictive Model
Student Engagement

- Self-reported through survey at end of tutorial session

- Parts of User Engagement Survey
  - Focused Attention, Felt Involvement, Endurability
  - Excluded: Perceived Usability, Aesthetics, Novelty
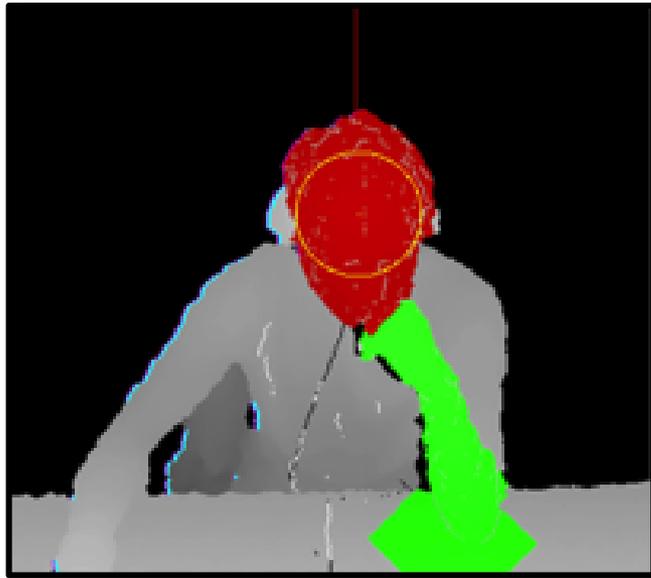
- Rating from 1 to 85

Predictive Model
Student Engagement – Tutor Evaluative Questions

Engagement =	R^2	p
+0.4422 * One Hand-to-Face Gesture	0.1815	< 0.001
-0.5989 * AU10 Upper Lid Raiser	0.1831	< 0.001
+0.5770 * AU12 Lip Corner Puller (session-wide)	0.2280	< 0.001
+0.5097 * AU26 Jaw Drop	0.0514	< 0.001
-0.2941 * AU2 Outer Brow Raiser (session-wide)	0.1923	0.003
+0.2467 * AU5 Upper Lid Raiser (session-wide)	0.0295	0.002
+0.1792 * AU24 Lip Pressor	0.0566	0.018
+0.4100 (intercept)		1.000

Leave-One-Out Cross-Validated R^2 = 0.9224

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Predictive Model
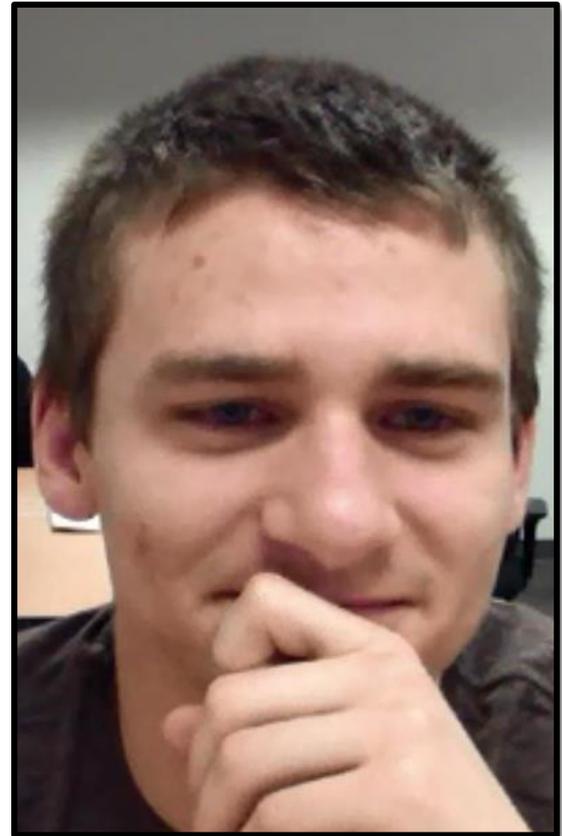## One Hand-to-Face Gesture

- Associated with **more** engagement after evaluative questions
- Potential indicator of thoughtful contemplation
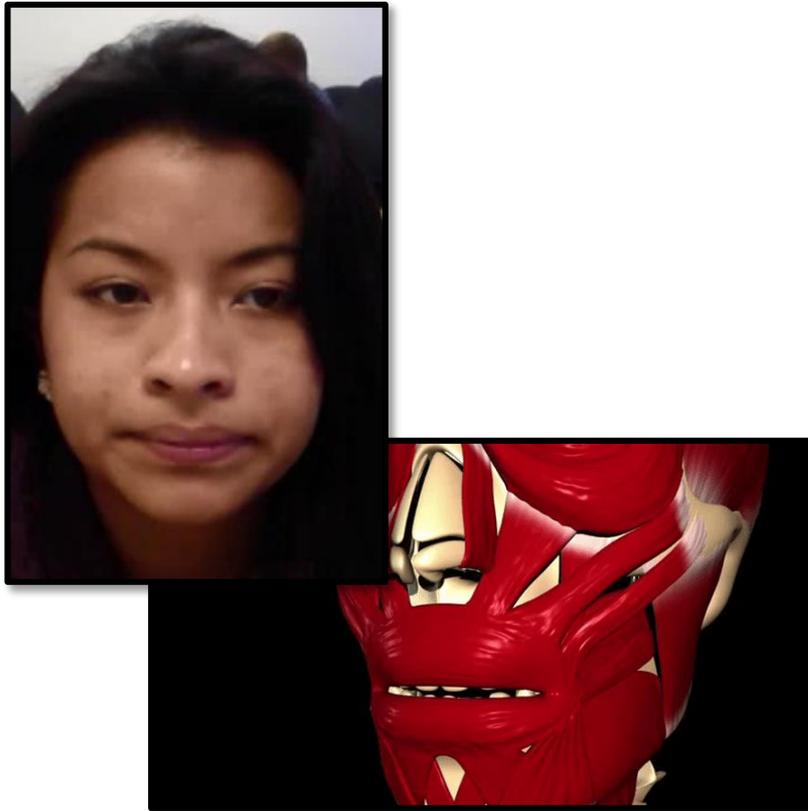
Predictive Model
AU10 Upper Lip Raiser

- Associated with **less** engagement after evaluative questions
- Component of prototypical disgust

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Predictive Model
AU12 Lip Corner Puller

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- Associated with **more** engagement in general
- Often related to smiling

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Predictive Model
AU26 Jaw Drop

- Associated with **more** engagement after evaluative questions

- May be indication of focus

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Predictive Model
AU2 Outer Brow Raiser

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- Associated with **less** engagement in general
- Component of the "fear brow", a display of anxiety

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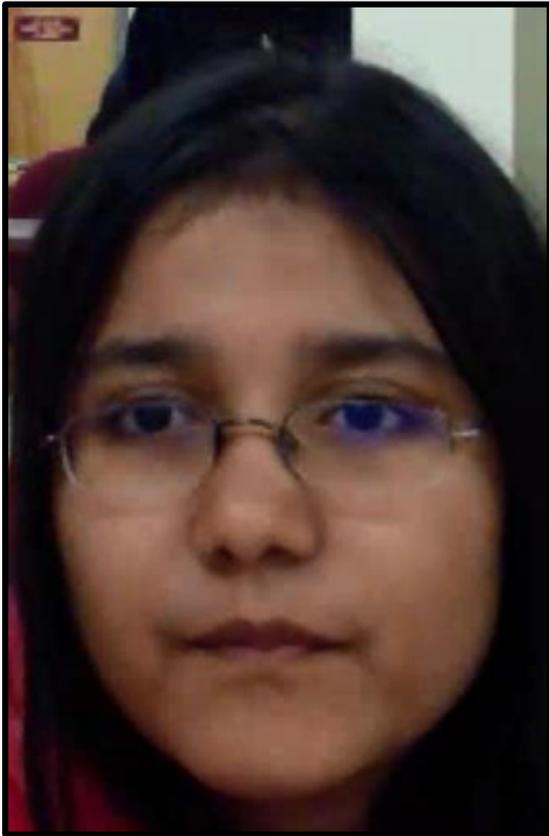
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Predictive Model
AU5 Upper Lid Raiser

- Associated with **more** engagement in general
- Previously found to indicate focused attention

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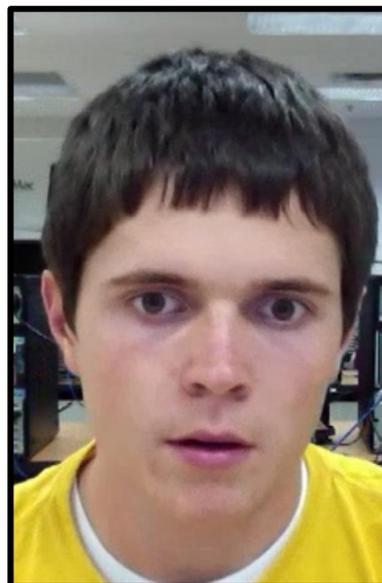
Predictive Model
AU24 Lip Pressor

- Associated with **more** engagement after evaluative questions
- Component of prototypical anger

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Discussion

Frustration

- Facial expression predictive
- Predictive power resulting from only short-term reactions

Engagement

- Facial expression and gesture highly predictive
- Mix of short-term and session-wide behaviors

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Conclusion

- Multimodal traces can provide insight into student affective outcomes

- Short-term nonverbal behavior during tutoring can be significantly predictive of student frustration and engagement

- Facial expression and hand-to-face gestures at critical moments were highly predictive

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Future Work

Goal: Understanding nonverbal behavior with respect to affective outcomes

- Student nonverbal behavior after other important tutorial events

- Combinations of multiple event types for increased prediction

- Implications of these observations for adaptive systems

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Acknowledgments

Collaborators

Eunyoung Ha   Aysu Ezen-Can
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Funding

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