Predicting Learning from Student Affective Response to Tutor Questions

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Modeling student learning during tutorial interaction is a central problem in intelligent tutoring systems.

This paper presents an analysis suggesting that observing students' multimodal behaviors may provide deep insight into student learning at critical moments in a tutorial session.

In particular, this work examines student facial expression, electrodermal activity, posture, and gesture immediately following inference questions posed by human tutors.

The findings show that for human-human task-oriented tutorial dialogue, facial expression and skin conductance response following tutor inference questions are highly predictive of student learning gains.

These findings suggest that with multimodal behavior data, intelligent tutoring systems can make more informed adaptive decisions to support students effectively.

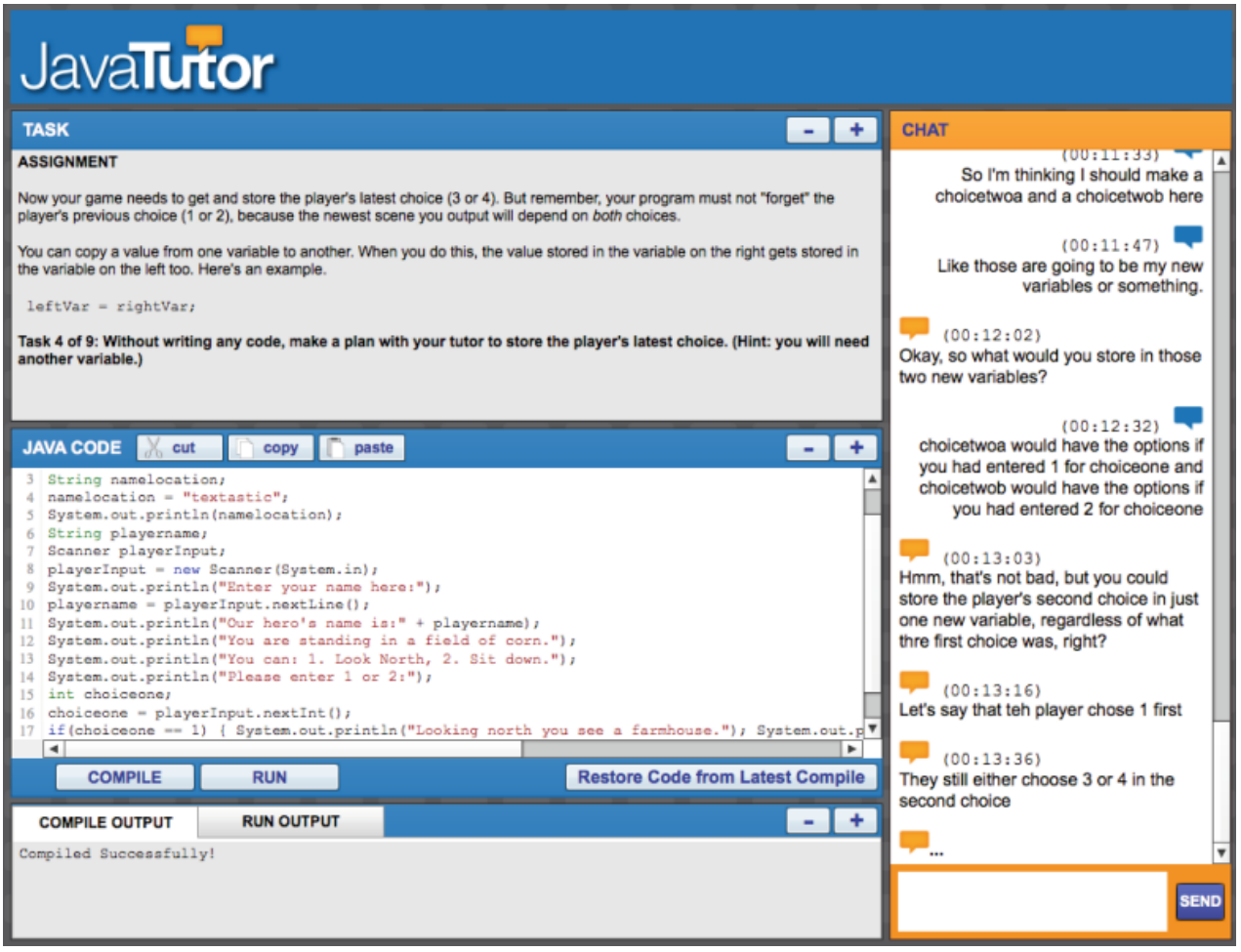
ITS目的：A fundamental goal of the intelligent tutoring systems (ITS) community is modeling student learning during tutoring so that an ITS can effectively adapt its tutorial support

举例子，这些数据能够做什么

For example, multimodal data such as facial expression, posture, and gestures can predict affective outcomes, such as frustration and engagement [7,8]. Additionally, multimodal data can contribute to inferring incoming student characteristics, including self-efficacy [9], personality [10], and domain expertise [11].

学生的表情，皮肤电导率，与未来的成绩相关

The results show that a subset of facial expression events, together with skin conductance response, immediately after tutor questions are highly predictive of students' future performance on a posttest.



实验设备：

Data were collected using multiple multimodal sensors as seen in Fig. 2, including a Kinect depth camera, an integrated webcam, and a skin conductance bracelet (see following subsections for more detail).

Normalized learning gain was calculated using the student's pretest and posttest scores, as shown in Eq. 1.

$$norm\_gain = \begin{cases} \dfrac{post - pre}{1 - pre} & post > pre \\ \dfrac{post - pre}{pre} & post \leq pre \end{cases} \quad (1)$$

主要关注提问环节（which is considered to be a crucial step in knowledge acquisition）

脸部表情特征：FACET软件

皮电活动特征：Skin conductance，tonic紧张的, which changes gradually over time, and phasic恐慌的, which changes in abrupt peaks [25] in response to a stimulus.

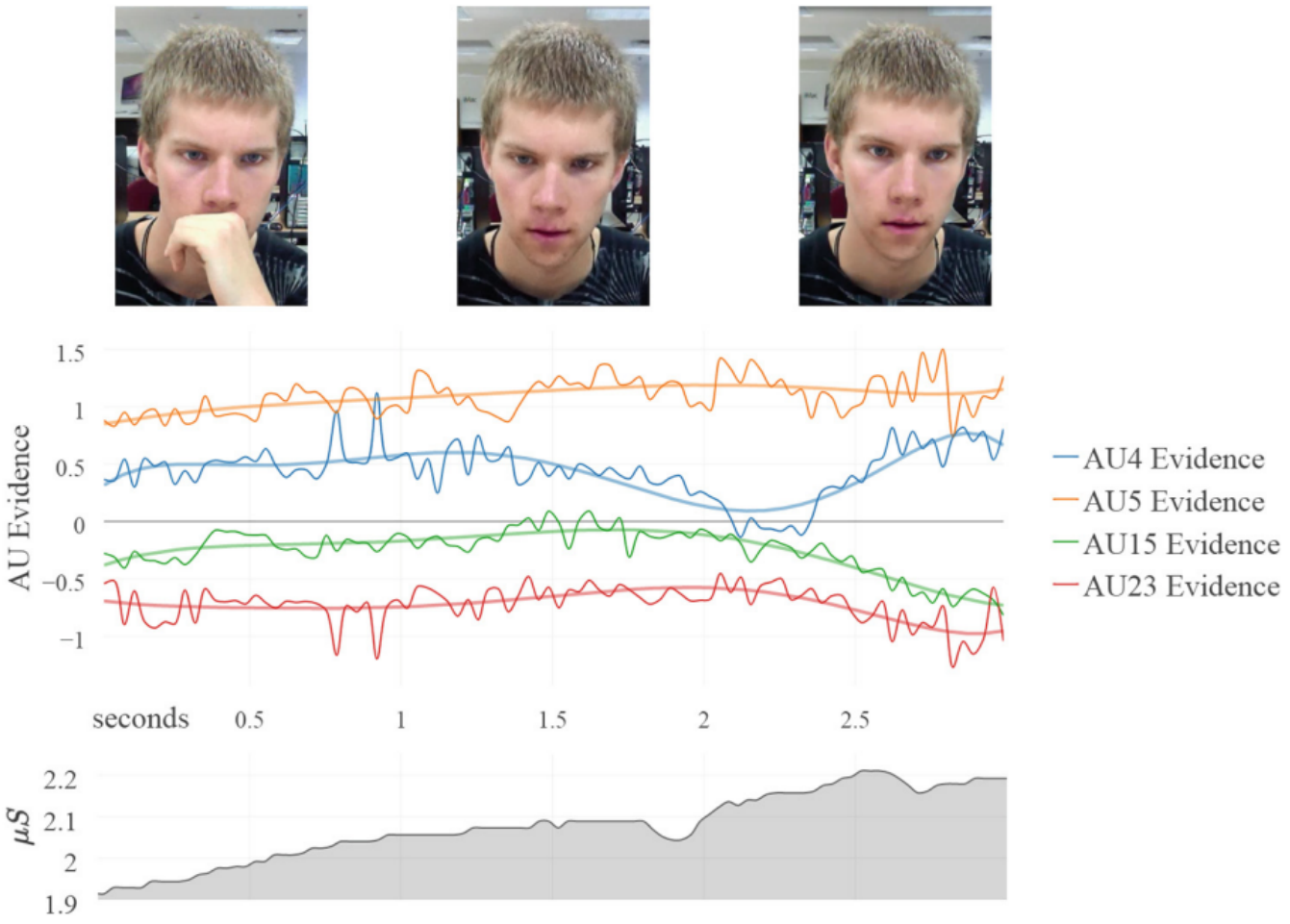
总共采集五种数据，最后发现只有前两个关联度最高

1. Average Evidence measure for each of the facial expression action units during the interval.
2. Number of skin conductance responses (SCRs) identified during the interval.
3. Percentage of the interval in which a one-hand-to-face or two-hands-to-face gesture was observed.
4. Average student distance from the workstation during the interval.
5. Average difference between the highest and lowest points of the student's body from the workstation during the interval (indicating leaning).

分析方法：

All features were standardized by subtracting the mean and dividing by the standard deviation. This set of features was then used in a stepwise regression modeling procedure that maximizes the leave-one-student-out cross-validated R2 value (the coefficient of determination), while enforcing a strict p-value cut-off of $p < 0.05$ after Bonferroni correction for the significance of each included feature.

结果：



(a) AU4 Brow Lowerer (b) AU5 Upper Lid Raiser (c) AU15 Lip Corner Depressor (d) AU23 Lip Tightener

一些结论：

- Lip Corner Depressor : learn less(This action unit has been found in prior task-oriented studies to be a strong predictor of lack of focus[26])
- Lip Tightener : frustration or focused concentration [26,27] , was positively associated with learning, but immediately following tutor inference questions it was negatively associated.老师提问和学习时这个表情含义不同，今后的研究要区分困难和专注
- Upper Lid Raiser : following tutor inference questions was positively predictive of learning in the current study, and it has previously been found to indicate focused attention in task-oriented domains [26]. Expressing this indicator of engagement directly following tutor questions may suggest that the student is thinking critically about the solution. 表明学生正在思考
- Brow Lowerer : following tutor questions was predictive of increased learning in the current study. AU4 has been associated with frustration [7,8]

总结：

Modeling student learning during tutoring is central to intelligent tutoring systems. The results presented here demonstrate that student multimodal traces can provide insight into cognitive-affective phenomena while yielding accurate predictions of student learning during tutoring sessions.

未来工作：

Future work should investigate how student multimodal signals at other critical moments in tutoring sessions are related to student learning. For example, introducing new concepts, or when a student reaches an impasse, are likely key moments in tutoring. Another promising direction for future work is to examine affective outcomes such as frustration or engagement, since multimodal signal analysis holds much promise for providing real-time predictions of these phenomena as well. It is hoped that this line of work will lead to powerful, domainindependent predictive measures of learning and other cognitive-affective phenomena thatintelligent tutoring systems can use to adaptively support student learning.