Understanding Students' Emotional States While Learning Computer Programming

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Abstract

Prior research has highlighted the challenges students face in introductory programming courses. In a large-scale study, Bennedsen et al. reported an average failure rate of 28% for the CS-1 course. The high failure rate is often attributed to fast-paced learning environment. The development of a customized learning approach has been emphasized to improve the students' learning experiences. The proposed research aims to analyze bioindicators that can be used to provide real-time, personalized learning support.

Introduction

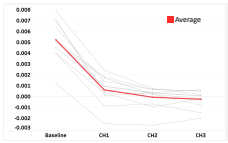
Our study investigates how bioindicator responses evolve as learners engage in coding activities of increasing difficulty (**RQ1**), and how these responses vary across levels of programming expertise (**RQ2**). Specifically, we focus on the core body motion, heart rate, and skin temperature as indicators of learners' cognitive and affective states. By identifying which indicators are capable of differentiating levels of programming expertise, this work aims for affect-driven instructional interventions, such as dynamically adjusting the task difficulty.

Methodology / Approach

- 15 participants (8M + 7F), with no programming background (6 novices) and prior programming background (9 Experts)
- 3-minute baseline followed by three 15-minute Python coding challenges of increasing difficulty: 1. Variables and I/O, 2. Conditional statements, and 3. Loops.
- Metrics computed per signal per phase: Average, slope, CV
- Paired t-tests compared BL to phases within participants; independent t-tests compared skill groups (Novice vs. Expert)

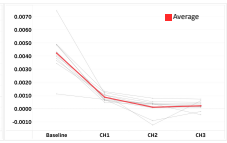
RQ1

Slope of Abdomen Temperature (°C/s) vs. Phase



BL vs. All Challenges: $p < 0.00001$*

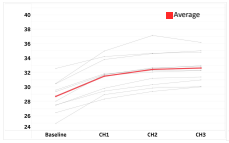
Slope of Right Ankle Temperature (°C/s) vs. Phase



BL vs. All Challenges: $p < 0.00001$*

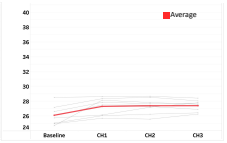
- Temperature rise rate drops sharply from baseline to CH1
- May reflect blood vessel constriction and redirection from body to the brain under cognitive load

Average Abdomen Temperature (°C) vs. Phase



BL vs. All Challenges: $p < 0.00001$*

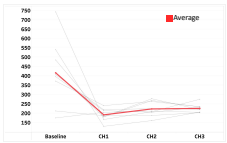
Average Right Wrist Temperature (°C) vs. Phase



BL vs. All Challenges: $p < 0.004$*

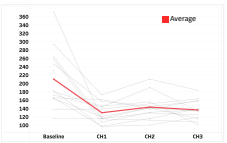
- Overall temp. continues rising across all phases
- May reflect metabolic heat cumulation from cognitive effort

CV Right Wrist Angular Magnitude (%) vs. Phase



BL vs. All Challenges: $p < 0.02$*

CV Vertical Nose Movement (%) vs. Phase

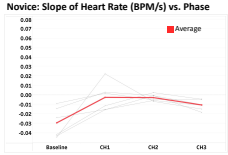


BL vs. All Challenges: $p < 0.003$*

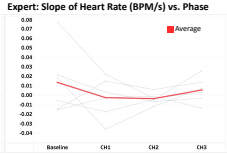
- Variability drops at CH1 and stays low
- Each response signals task engagement

RQ2

Novice: Slope of Heart Rate (BPM/s) vs. Phase



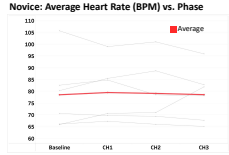
Expert: Slope of Heart Rate (BPM/s) vs. Phase



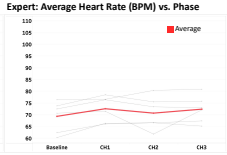
- Novice HR trends negative at baseline, rises at CH1
- Expert HR remains relatively stable throughout

Statistically significant ($p < 0.05$)* **BL** $p = 0.011$*, **CH1** $p = 0.950$, **CH2** $p = 0.600$, **CH3** $p = 0.013$*

Novice: Average Heart Rate (BPM) vs. Phase



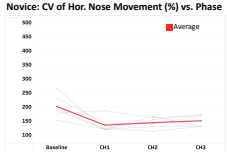
Expert: Average Heart Rate (BPM) vs. Phase



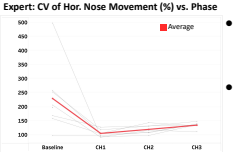
- Novice avg. HR is consistently higher than experts
- May reflect greater anxiety in less experienced coders

BL $p = 0.107$, **CH1** $p = 0.134$, **CH2** $p = 0.141$, **CH3** $p = 0.144$

Novice: CV of Hor. Nose Movement (%) vs. Phase



Expert: CV of Hor. Nose Movement (%) vs. Phase



- Novice head movement more variable than experts
- Experts show more stable gaze patterns during coding

BL $p = 0.840$, **CH1** $p = 0.048$*, **CH2** $p = 0.066$, **CH3** $p = 0.133$

Discussion

- Temperature is the strongest bioindicator: significant across average, slope, and CV
- Movement signals reflect task engagement: wrist and head stabilize once coding begins

Conclusion / Future Work

- This pilot study provides evidence that physiological bioindicators can detect emotional state changes during coding tasks.
- Future work should address current limitations including sample size and neurodivergent participants.

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