Real-time Brain Sensing for Personalized Learning Environments

Anna Eng (aeeng@wpi.edu), Joseph Lima (jlima@ashland.k12.ma.us)
Faculty Mentor: Dr. Erin Solovey
Affiliates: Chris Micek, Alicia Howell-Munson, Theresa Mowad, Deniz Sonmez Unal, Dr. Catherine Arrington, Dr. Erin Walker

What is Cognitive Control?

The expected response (above) vs. the actual average response data collected from the fNIRS cap during the AX-CPT task (below).
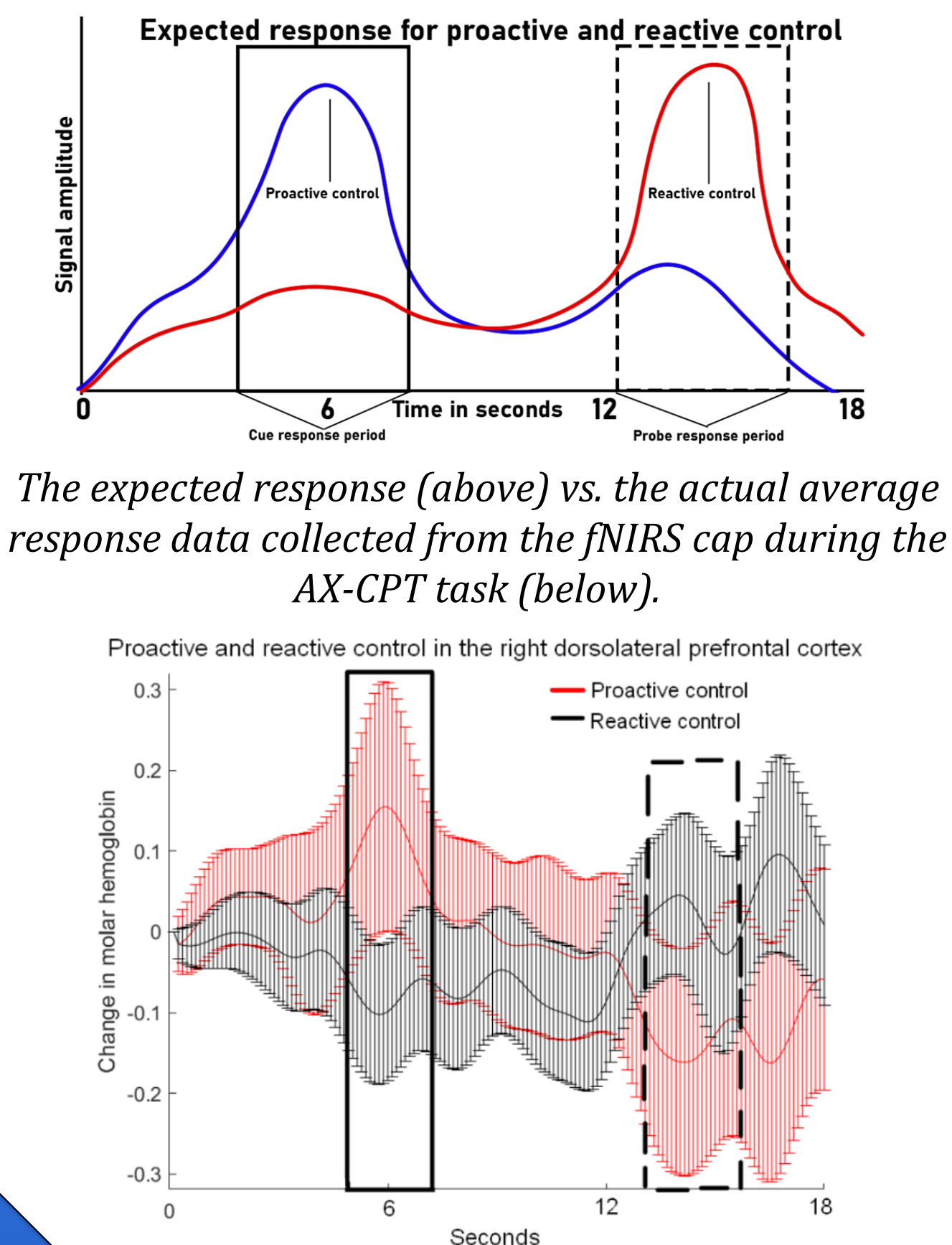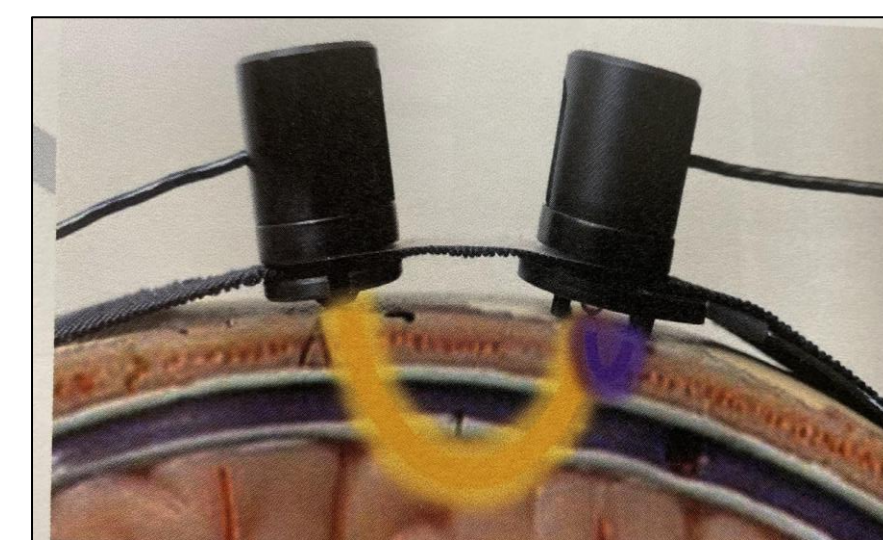
- Processes allowing information processing and behavior to vary adaptively depending on current goals
- Relevant types for this project:
  - **Proactive Control** - Goal-relevant information is actively maintained in mind at all times until the goal is reached
  - **Reactive Control** - Goal-relevant information is retrieved in a "just-in-time" manner
  - **Rule Search** - Looking for similarities between events
  - **Rule Following** - Expecting similarities between future and previous events
- Simple cognitive tasks
  - **AX Continuous Performance Task (AX-CPT)** - Measure proactive and reactive control states
  - **Rule Learning Task** - Measure search, discover, follow states

What is Functional Near-Infrared Spectroscopy (fNIRS)?

Teammate, Joe, wearing a Functional Near-Infrared Spectroscopy (fNIRS) cap.

Representation of light travelling from a source to a detector in the fNIRS cap.

- Brain-imaging tool
  - Safe, portable, easy-to-use, and quick to set up
  - Increased use in Human-Computer Interaction (HCI) research
- Detects **hemodynamic changes**
  - Concentration changes of oxygen levels in the hemoglobin in blood
  - Brain activity measured continuously during interactive computing tasks
- Sensor arrangement
  - Mesh cap worn on the head
  - Uses infrared light to detect the hemodynamic response
  - Infrared light penetrates 1-3 cm deep into the cortex

What is an Intelligent Tutoring System (ITS)?

- Tool to aid students in the learning process
- Prompts student with question and may offer assistance in answering
- ITS adjusts to student's patterns in using the software
- Our experiment design: Uses the ASSISTments ITS (example provided)

P(A) = 0.4 and P(B) = 0.5. P(A and B) = 0.1. What is the probability that A or B occur, but not both?

1. Question
2. Confidence Level

How confident are you in solving this problem?
_____
Select one:
- 1 Not confident at all
- 2
- 3 Neutral
- 4
- 5 Exactly confident

3. **Proactive Control** Prompt and Rule Search

(Given when math skill required is being seen for first time)

Step 1: First determine the probability of only A, P(Only A). What is the probability that only A occur?
Think about how this step relates to the goal of the problem.
_____
Type your answer below as a number (example: 5, 3.1, 4 1/2, or 3/2):
0.3

4. Additional Open Response

Please type all the options that apply (e. g. 2, 3)
1 - I already knew how to solve this kind of problem
2 - My first answer was a guess
3 - I found out how to solve this kind of problem after solving this step
4 - I was surprised my first answer was not correct
5 - I made a math/format error

5. **Reactive Control** Prompt and Rule Following

(Given when math skill required is has already been seen)

Step 2: Second, determine P(only B). What is the probability that only B occur?
Think about how you are solving this step.
_____
Type your answer below as a number (example: 5, 3.1, 4 1/2, or 3/2):
0.4

What is the Connection to Education?

Research Experience for Teachers

- *Project*: Brain Sensing for Personalized Learning Environments (Integrated Experiment Design)
- Peer conversations of teaching experiences
- Professional development around integrated STEM pedagogy

Experience Transfer to the Classroom

- Draft lesson plans to be used in 2022-2023 academic year
- Foster real-world problem solving skills in students
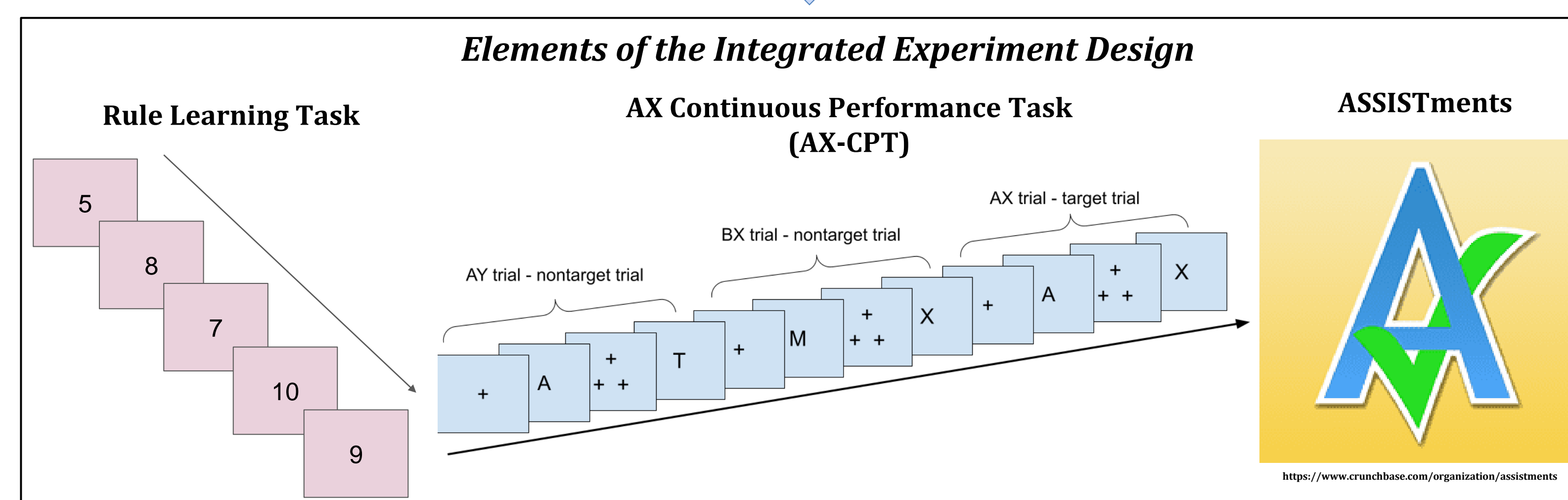- Share the authentic experience of how research is conducted at a university

U.N. Sustainable Development Goal 4 - Quality Education

- Show students the impact of education on people and the planet
- Ensure inclusive and equitable quality education
- Promote lifelong learning opportunities for all

https://www.un.org/sustainabledevelopment/news/communications-material/

Integrated Experiment Design

Teacher would ask, "What is my student thinking about when they are working on their STEM assignments?"

Elements of the Integrated Experiment Design

Rule Learning Task

AX Continuous Performance Task (AX-CPT)

ASSISTments

AY trial - nontarget trial
BX trial - nontarget trial
AX trial - target trial

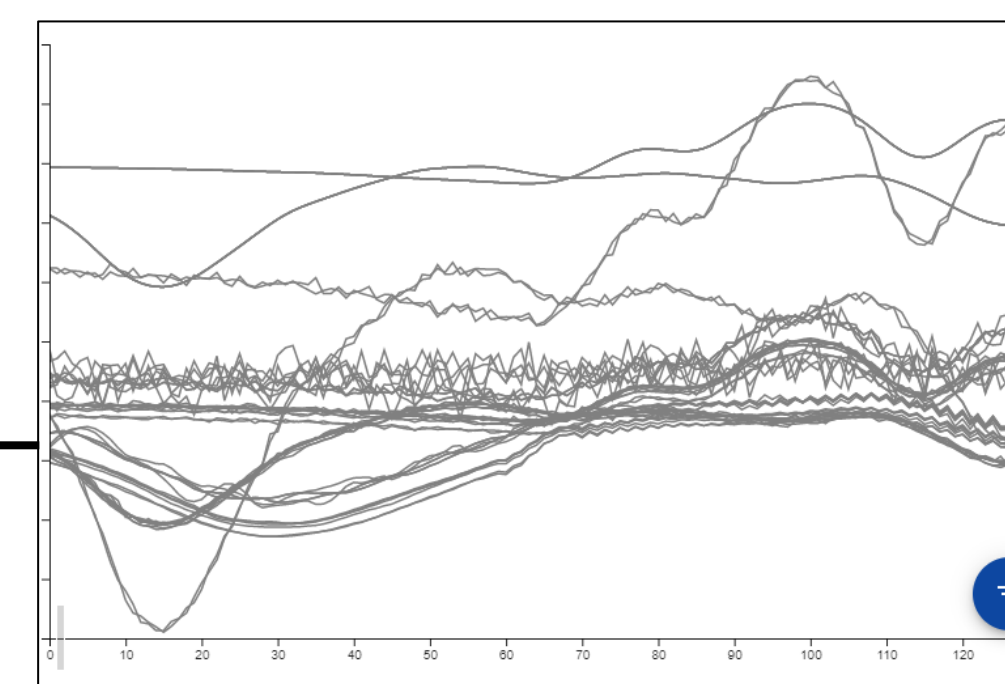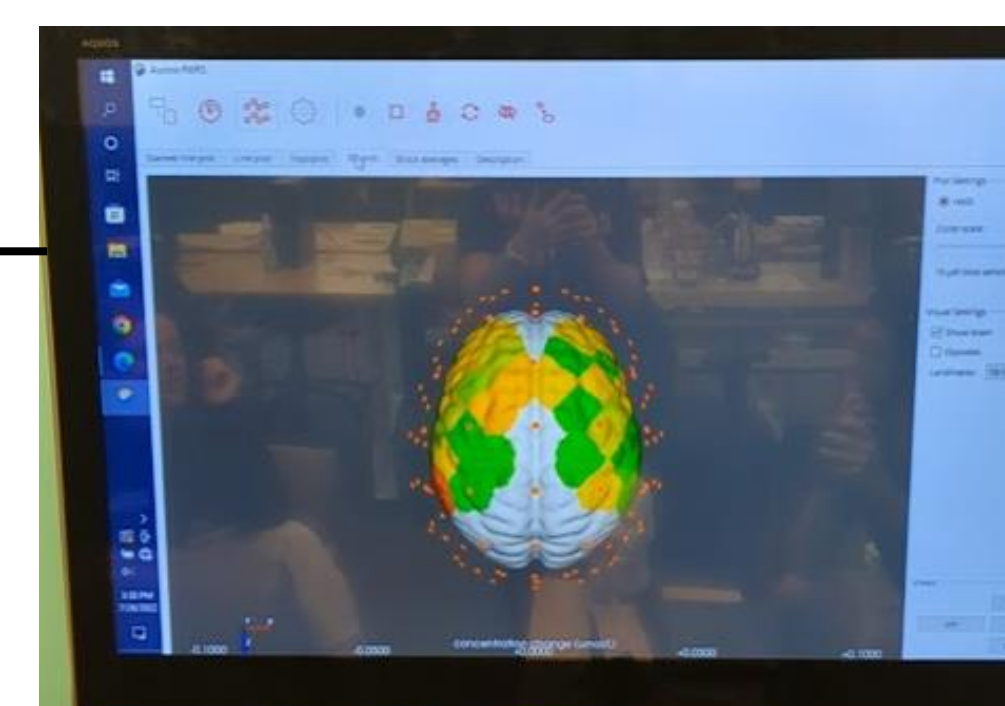https://www.crunchbase.com/organization/assistments

Previous research
1. Developed baseline states of cognitive control in ITS
2. Based on behavioral data and neural signatures
3. Measured and explored manipulation of cognitive control states in ITS

The integrated experiment
1. Will measure cognitive control states
2. Will apply in real-world ITS use, through behavioral and neural data
3. Will collect data from 80 participants to create a large, public dataset

fNIRS data presented through different visualization tools.

Improving the ASSISTments Models

Possible Areas of Future Research

- Adaptability to different student age groups (e.g. middle school, high school, etc.)
- Applicability to emergent multilingual learners
- Applicability to students with learning disabilities
- Extension to additional subject areas (e.g. science, history, etc.)