Enhancing Learning via ‘Novelty Insertion’

Employing the neuroscience of learning to create more effective pedagogical approaches

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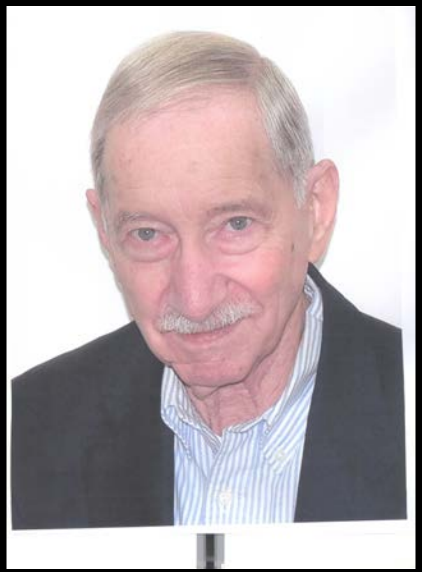
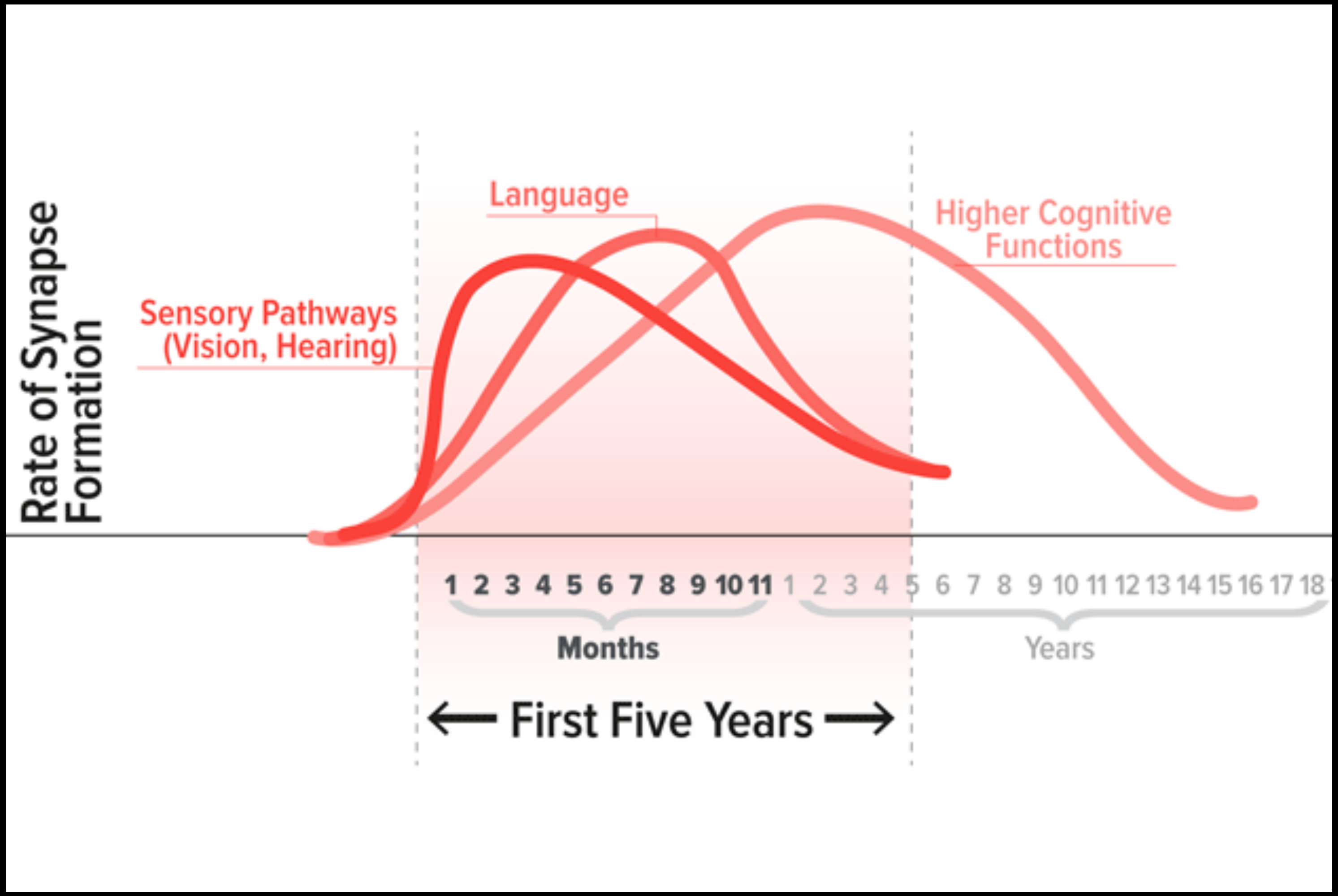
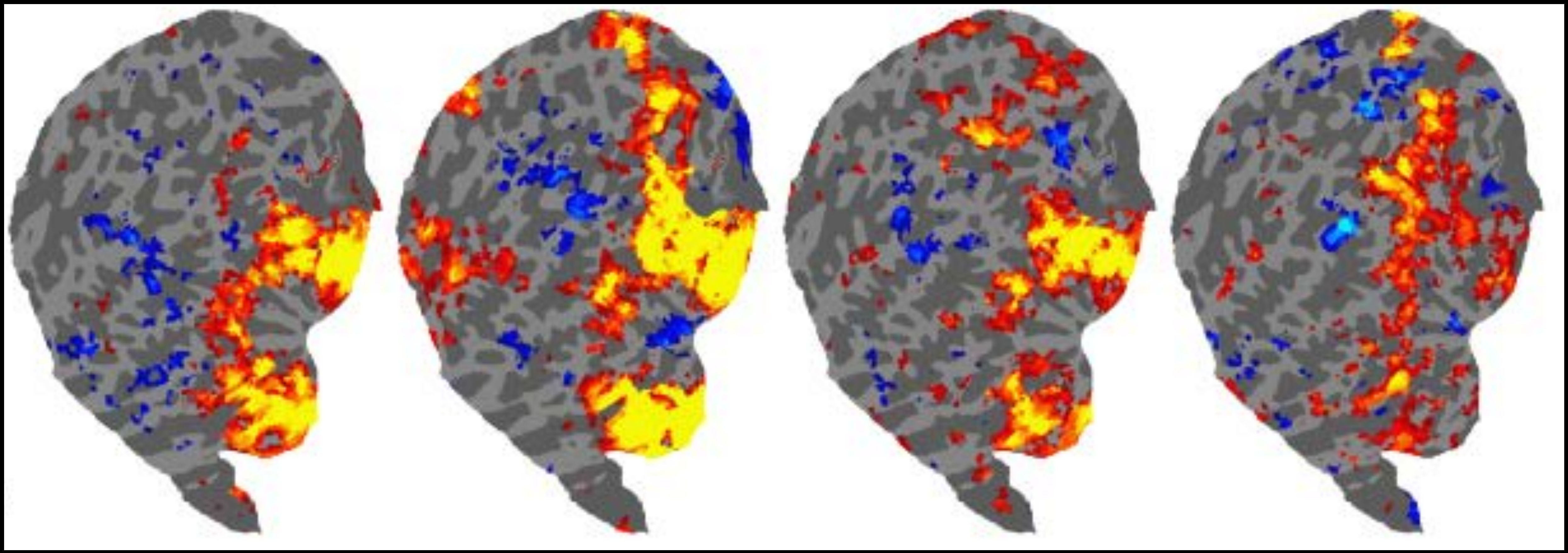



Our lab is interested in cortical plasticity



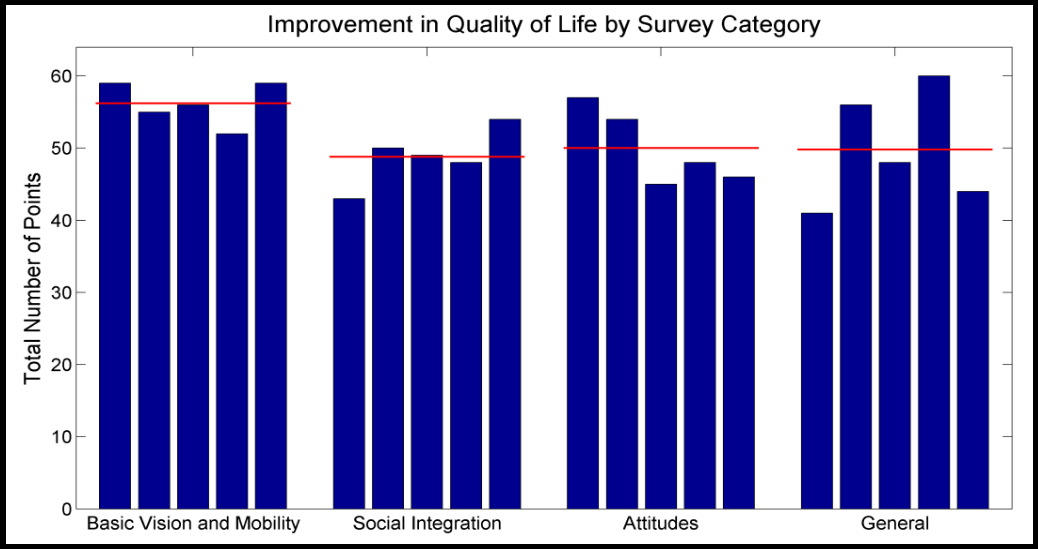
We find evidence of plasticity even late in the developmental timeline…

e.g. Progressive cortical de-correlation following sight onset



t-2 t+7 t+30 t+120

Soumitra


Improvement in Quality of Life by Survey Category
Total Number of Points
0
10
20
30
40
50
60
Basic Vision and Mobility
Social Integration
Attitudes
General

Although we now have evidence of plasticity, we do not really know what triggers this plasticity.

A possibility: 'Plasticity on Demand'

When learning demands are increased, the brain responds by enhancing its capacity to change.

Exposure to novelty is one way of increasing learning demands…

… does novelty lead to enhanced plasticity?

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Absolute Coding of Stimulus Novelty in the Human Substantia Nigra/VTA

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Summary

Novelty exploration can enhance hippocampal plasticity in animals through dopaminergic neuromodulation arising in the substantia nigra/ventral tegmental area (SN/VTA). This enhancement can outlast the exploration phase by several minutes. Currently, little is known about dopaminergic novelty processing and its relationship to hippocampal function in humans. In two functional magnetic resonance imaging (fMRI) studies, SN/VTA activations in humans were indeed driven by stimulus novelty rather than other forms of stimulus salience such as rareness, negative emotional valence, or targetness of familiar stimuli, whereas hippocampal responses were less selective. SN/VTA novelty responses were scaled according to absolute rather than relative novelty in a given context, unlike adaptive SN/VTA responses recently reported for reward outcome in animal studies. Finally, novelty enhanced learning and perirhinal/parahippocampal processing of familiar items presented in the same context. Thus, the human SN/VTA can code absolute stimulus novelty and might contribute to enhancing learning in the context of novelty.

response (Dommett et al., 2005; Horvitz, 2000; Redgrave et al., 1999). These other forms of salience can be reported by stimuli that are familiar and are therefore not contingent upon stimulus novelty. A preferential response of the dopaminergic midbrain to stimulus novelty would indicate a special biological relevance for novelty as a motivating (Kakade and Dayan, 2002; Schultz, 1998) and/or reinforcing (Reed et al., 1996) stimulus dimension also in humans.

A number of brain regions that provide input into the dopaminergic midbrain are capable of processing not only stimulus novelty but also other forms of stimulus salience. Most notably, the hippocampus and the amygdala are held to be closely functionally linked to the dopaminergic midbrain (Lisman and Grace, 2005) as components of a wider functional dopaminergic system termed the mesolimbic dopaminergic system. The hippocampus appears capable of comparing incoming information with stored memories (Lisman and Grace, 2005) and is sensitive to stimulus novelty (Duzel et al., 2003; Tulving et al., 1996) as well as to other forms of salience such as deviance or rareness and targetness even if reported by highly familiar stimuli (Crottaz-Herbette et al., 2005; Halgren et al., 1980). The amygdala, a structure that, together with noradrenergic nuclei of the brain stem, is critically involved in generating arousal to emotionally salient stimuli and in improving long-term memory for such stimuli (McGaugh, 2004), has a direct projection to the dopaminergic midbrain (Pitkanen, 2000). This projection is functionally relevant for displaying responses to biologically salient stimuli, for instance, for displaying orienting responses in appetitive conditioning (Lee et al., 2005). The orienting response, in turn, includes both autonomic (Lee et al., 2005) and motor (Holland, 1977) components.

An important approach to better understand the functional link between novelty processing and dopaminergic neuromodulation in humans would be to clarify whether the substantia nigra/ventral tegmental area

Novelty → Enhanced dopaminergic neuromodulation → Enhanced plasticity

↑ Engagement

↑ Learning

Project Hypothesis:

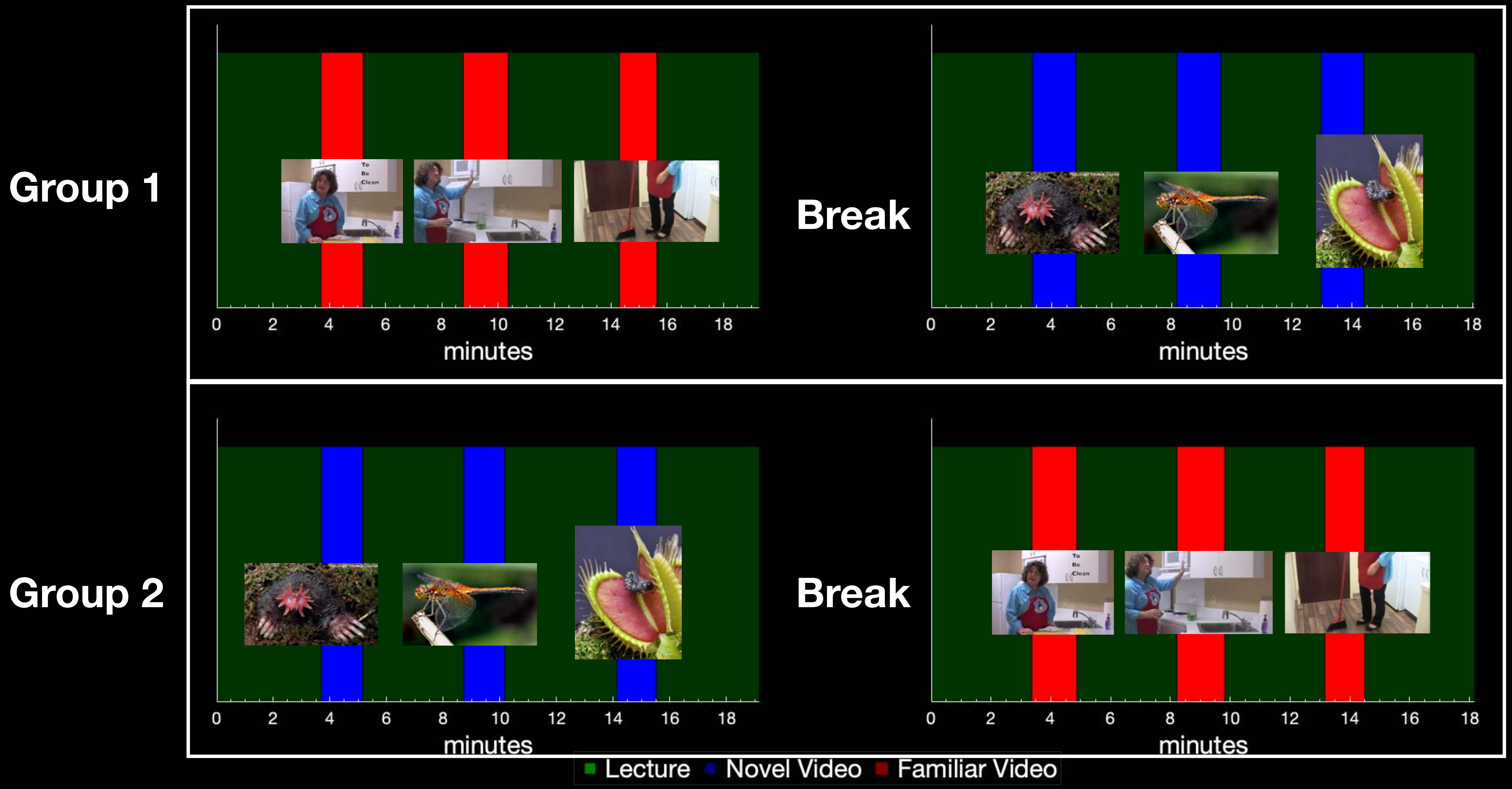
Novelty insertion in instructional videos might enhance their learning

Specific Goals:

- To create variants of instructional videos with novelty/familiarity insertion
- To determine whether novelty insertion heightens engagement
- To determine whether novelty insertion enhances learning

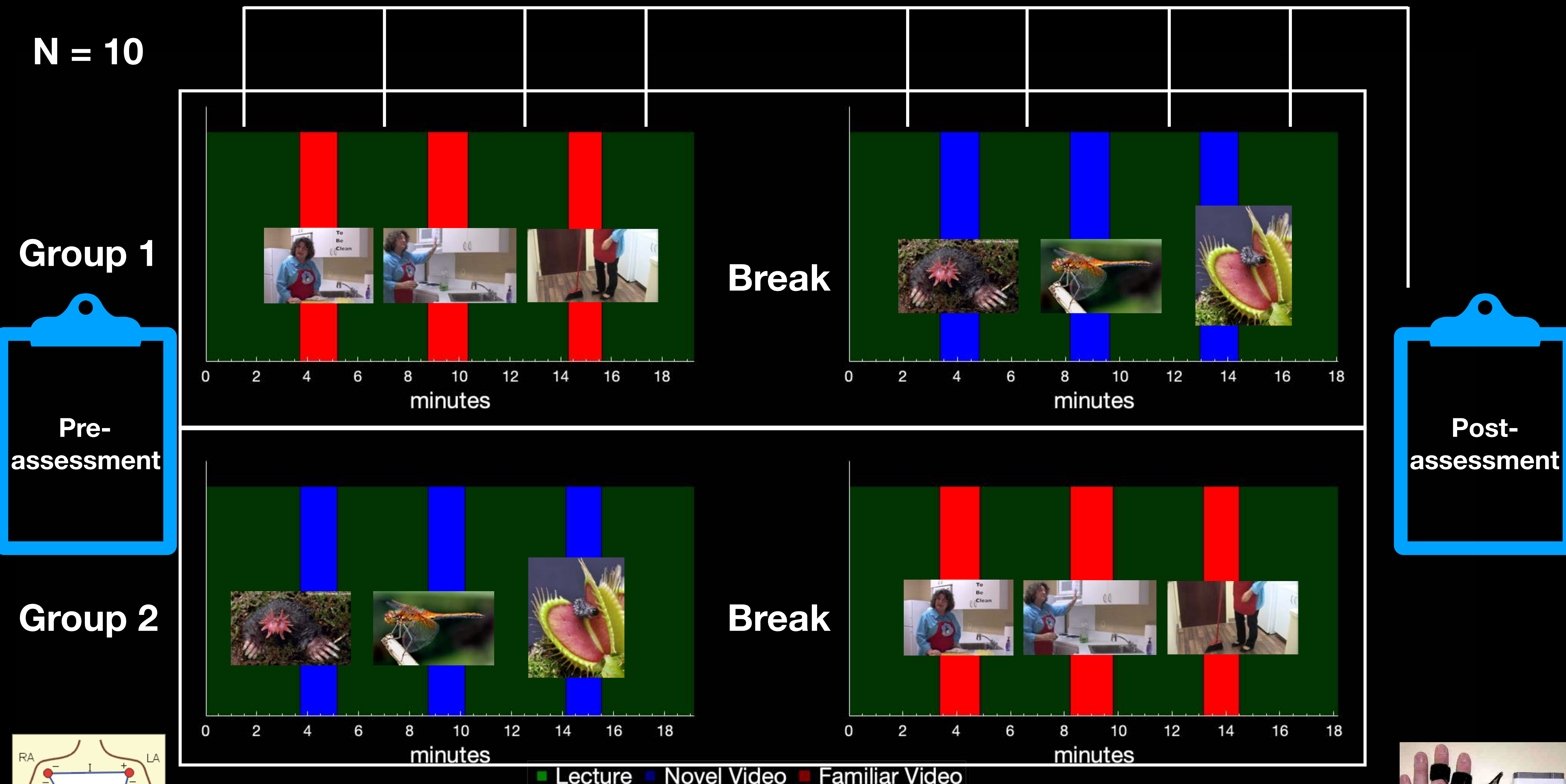
Pilot Overview

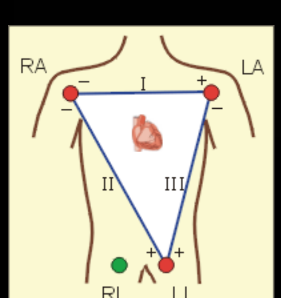
N = 10



Video Samples

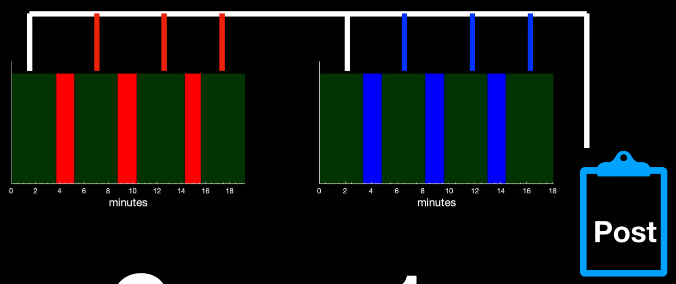
Pilot Overview



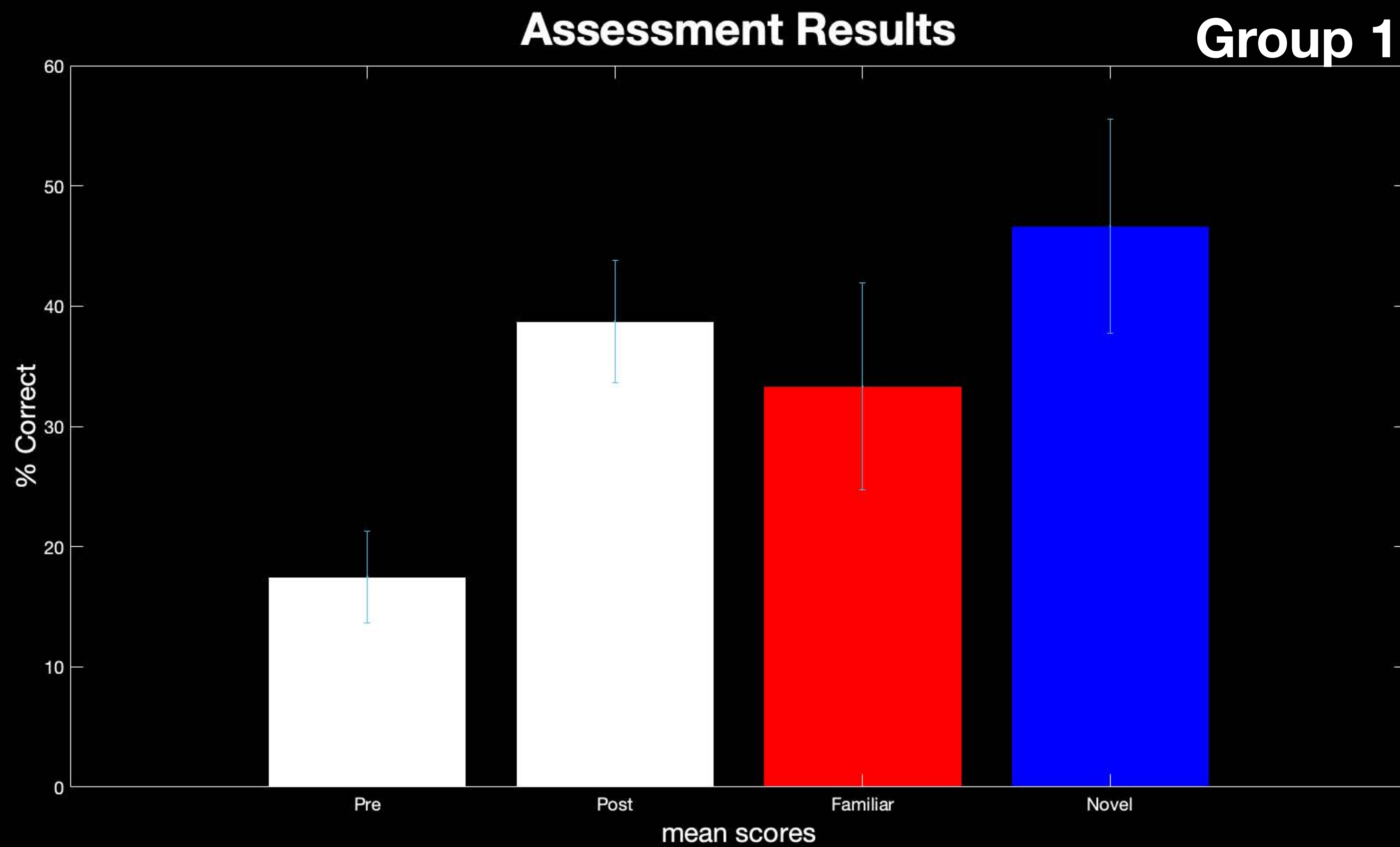


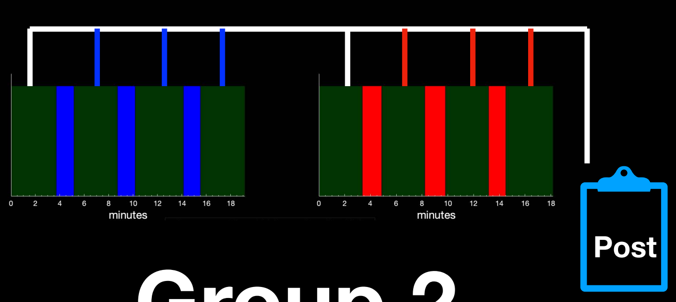
ECG

EDA



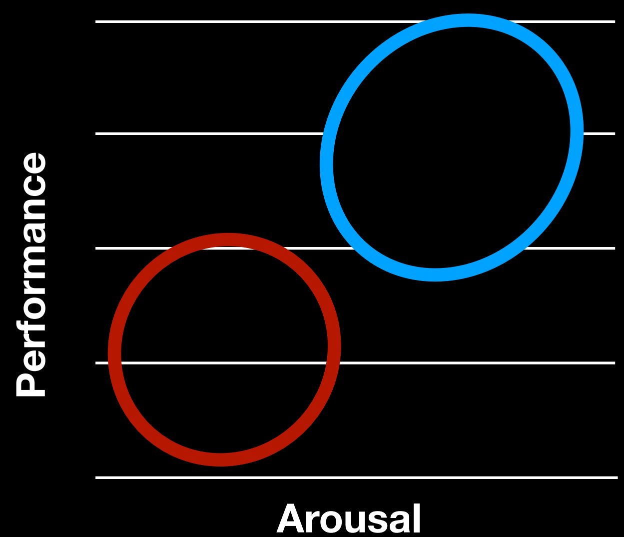
Group 1



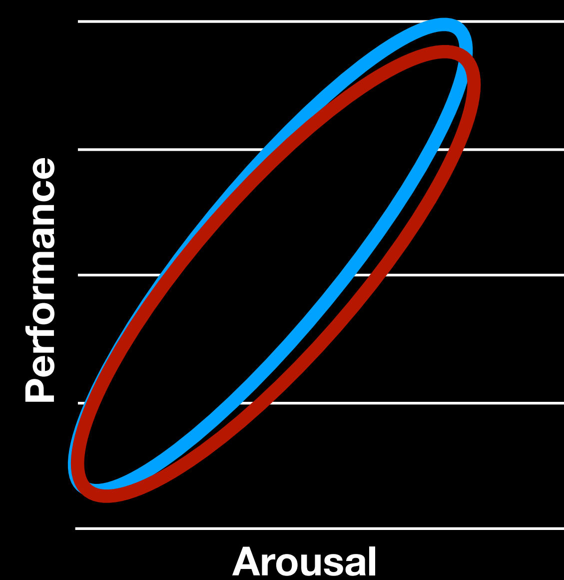


Group 2

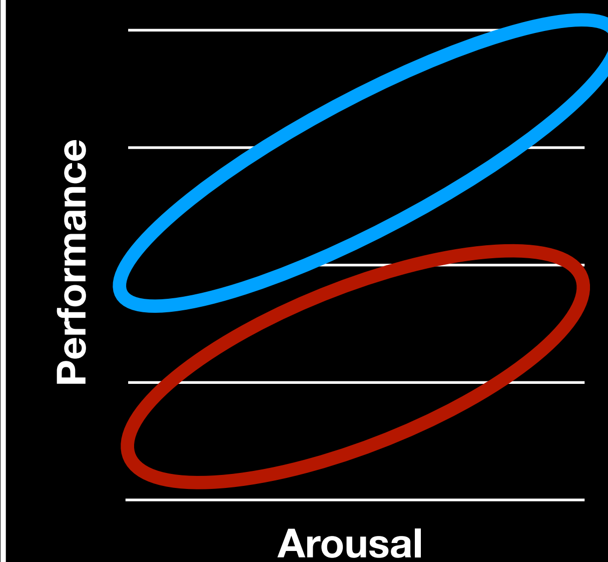
Result Scenarios



Cannot control for arousal and make statement about effect of novelty: **not enough data!**



H_0: no relationship between novelty and learning

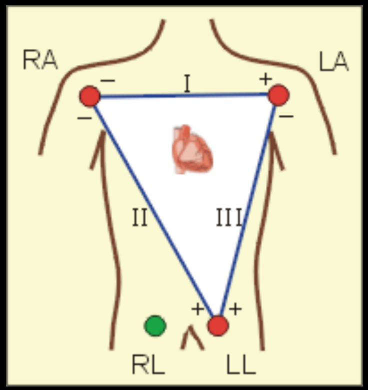


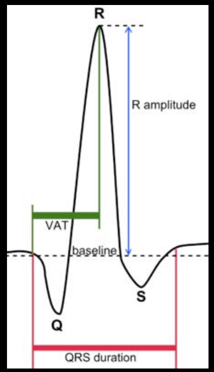
H_1: novelty enhances learning independently of arousal

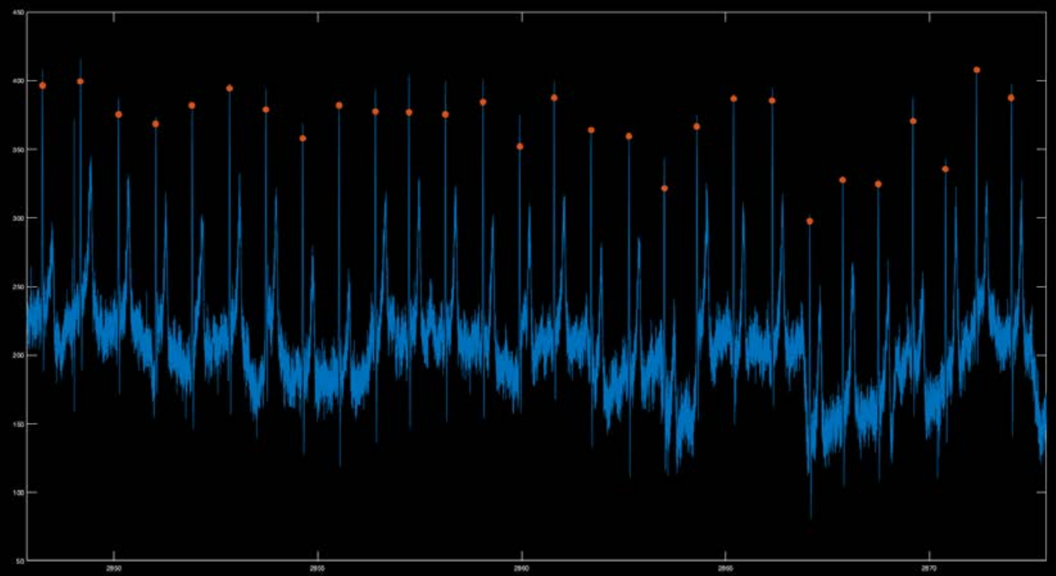
Novel **Familiar**

Physiological Recordings

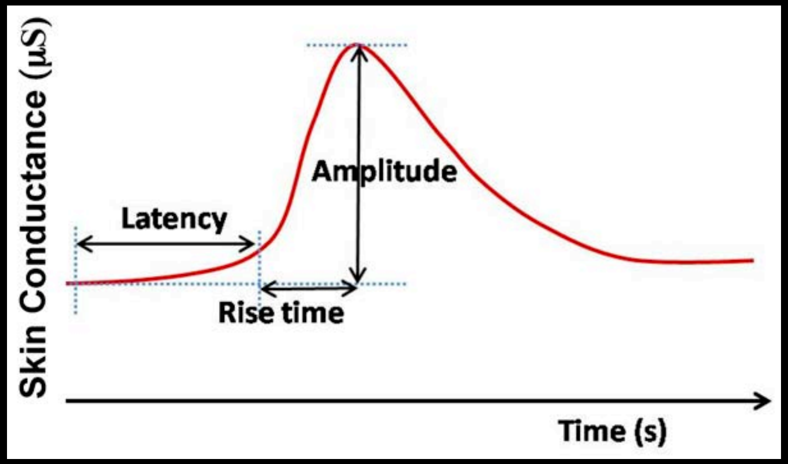
Electrocardiogram (ECG)

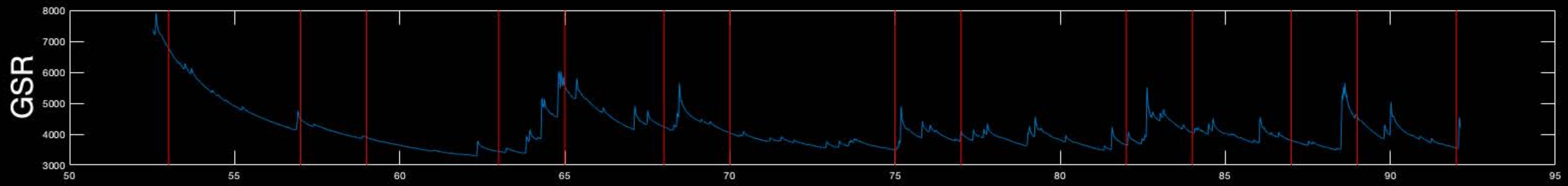






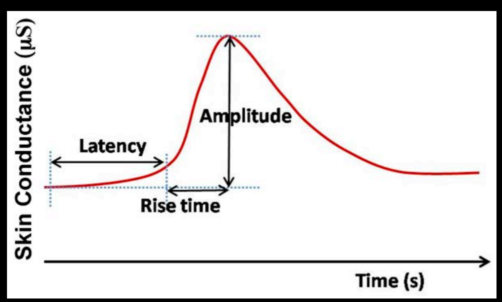
Electrodermal Activity (EDA)

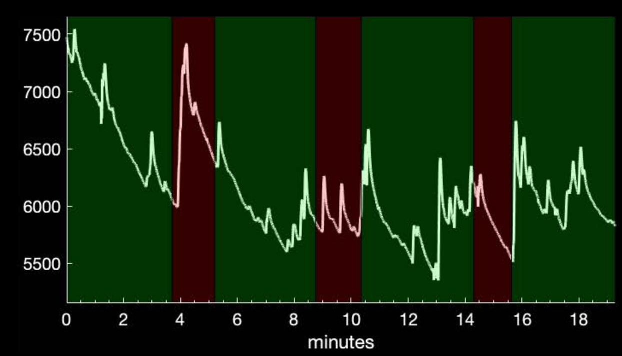




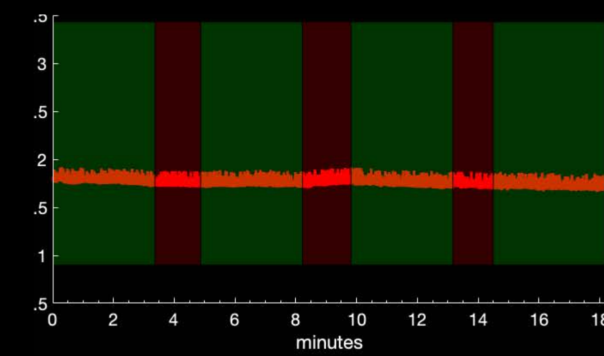
Signal Processing

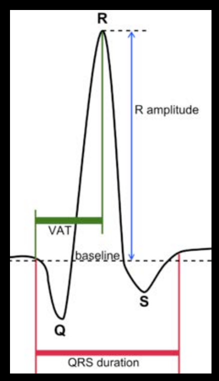
Raw EDA





Raw ECG

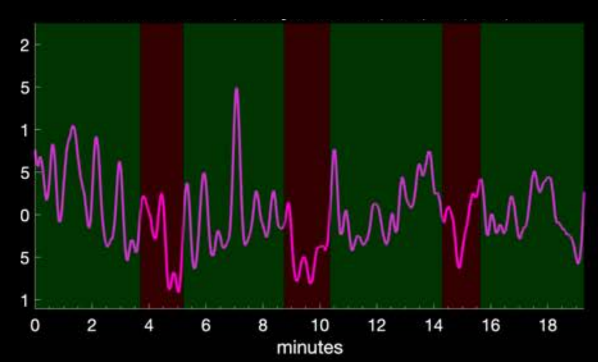


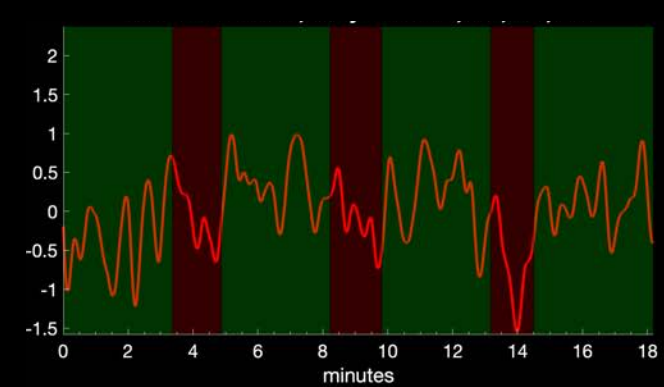


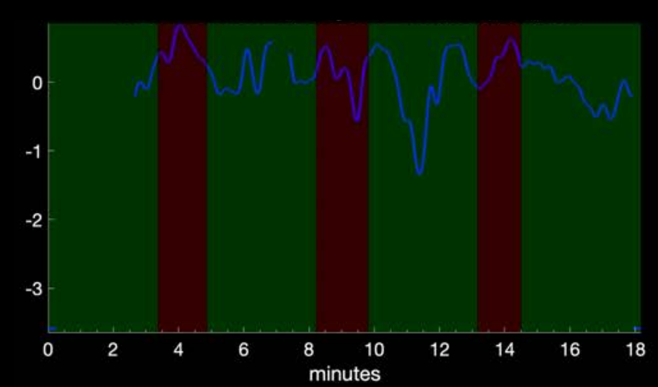
- Extract phasic signal
- Peak detection

- R-Peak detection
- RR interval calculation

- Point Process Model of Heart Rate Variability





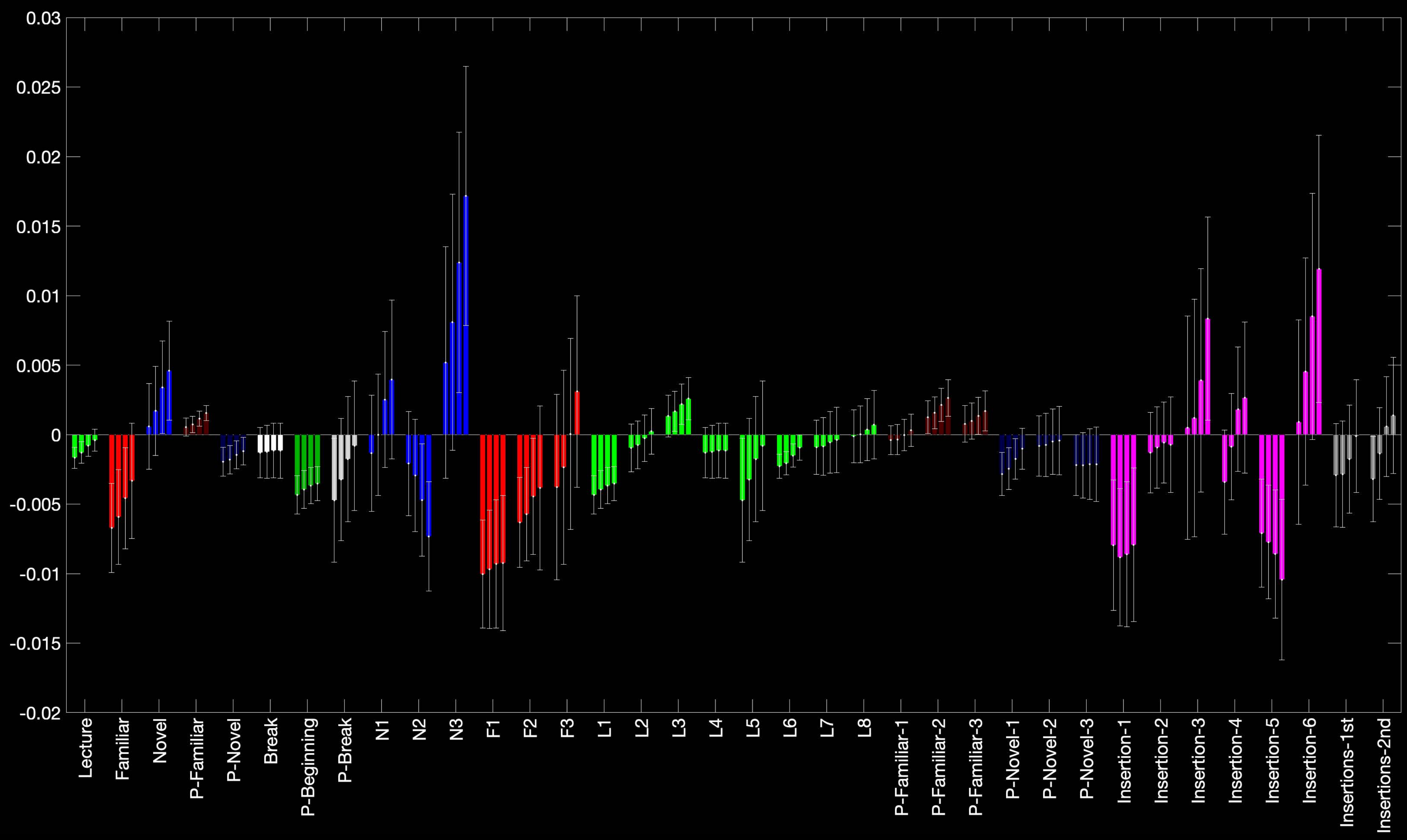


Optimizing the indices By investigating:

- Sliding window size and shape
- Cropping response window to different lengths
- Latencies of signals relative to each other and subject

- Normalized by baseline
- Applied window functions
- Averaged across participants
- *Calculated slope for some metrics
- Calculated statistics

Comparison of Arousal Across Experiment



Some Questions About Arousal

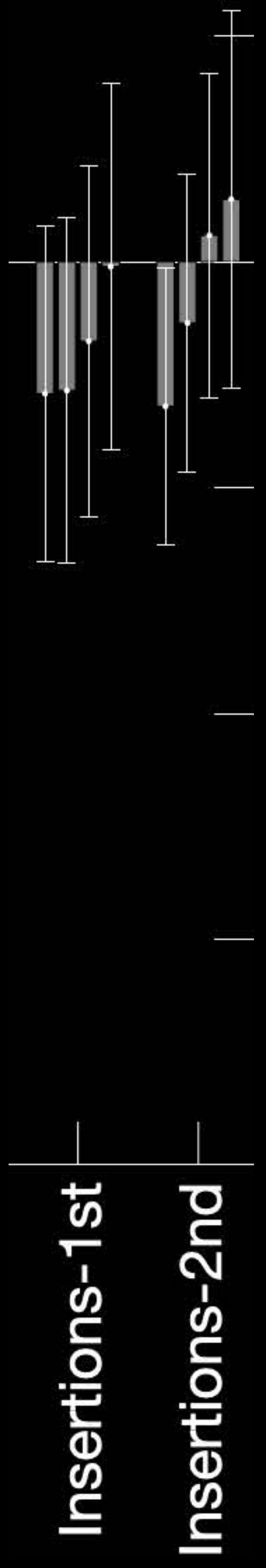
Does video type affect arousal?

N = average arousal during novel insertion
F = average arousal during familiar insertion
L = average arousal during lecture

Using EDA peak rate slope as an index of arousal:

N > L > F

Does elapsed time affect arousal?



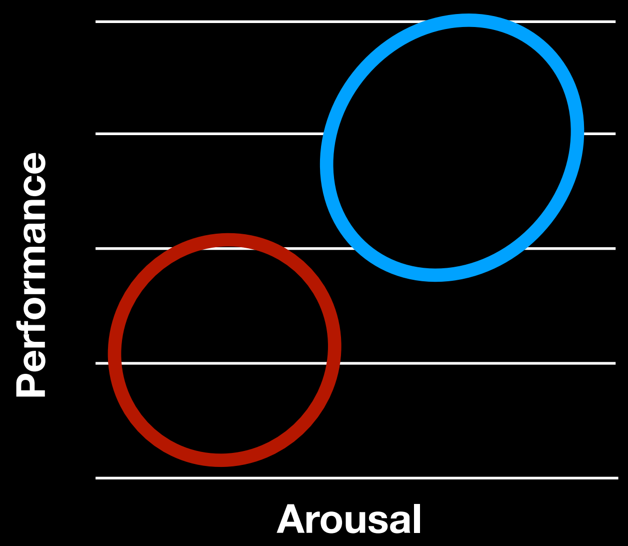
P1,P2 = arousal during first and second halves of experiment, regardless of if there were novel or familiar insertions

Using EDA peak rate slope as an index of arousal:

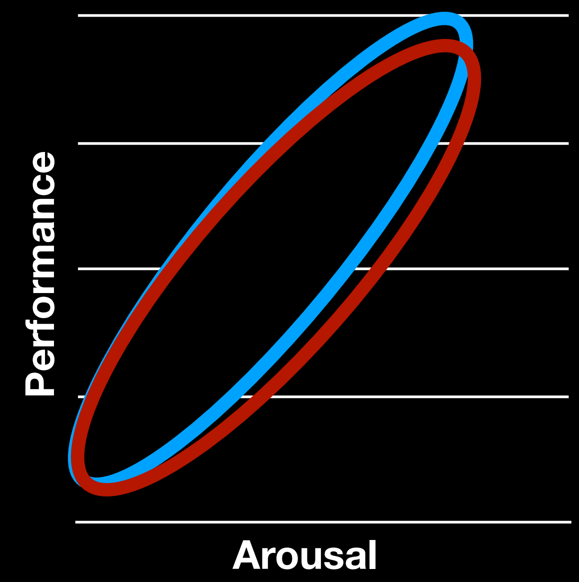
P1 = P2

Synthesizing Arousal and Performance Results

Result Scenarios



Cannot control for arousal and make statement about effect of novelty: **not enough data!**



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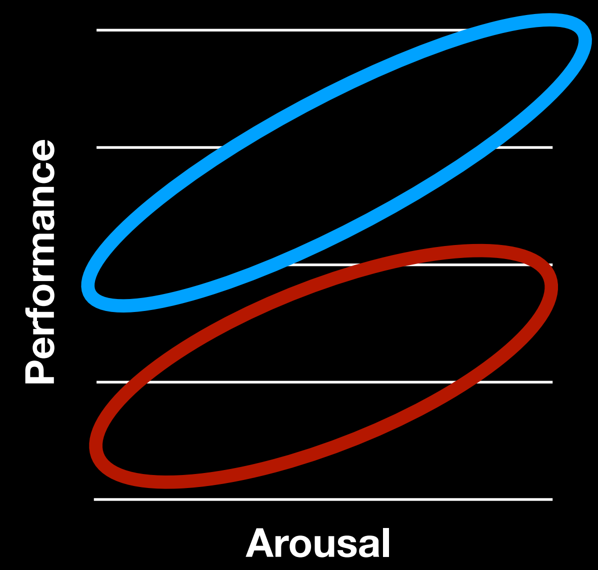
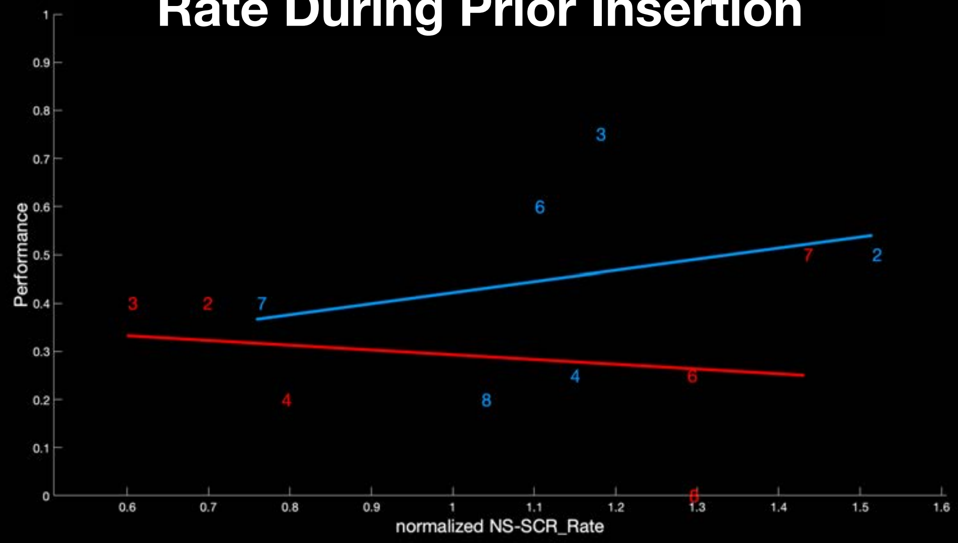


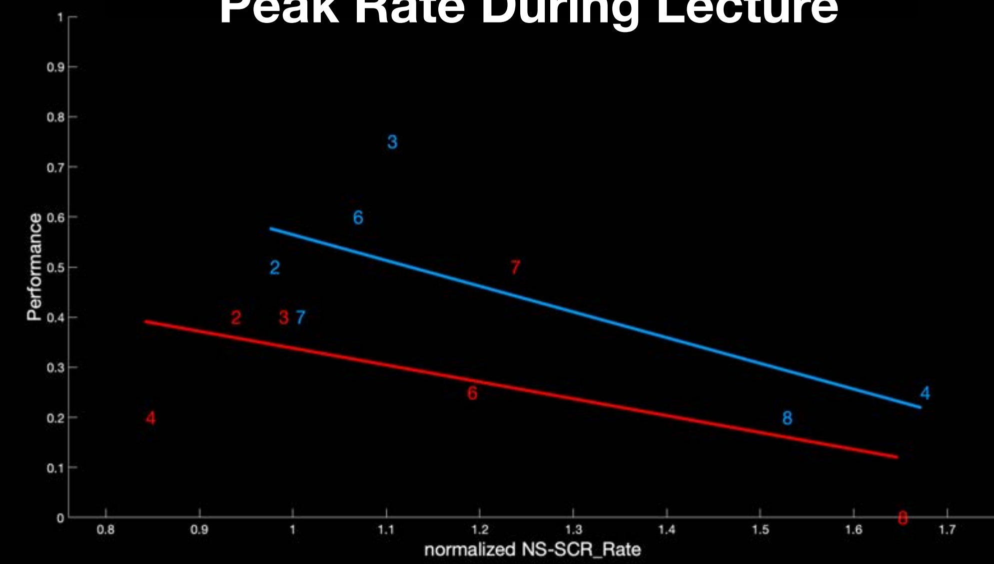
H_1: novelty enhances learning independently of arousal

Novel **Familiar**

Performance vs. EDA Peak Rate During Prior Insertion

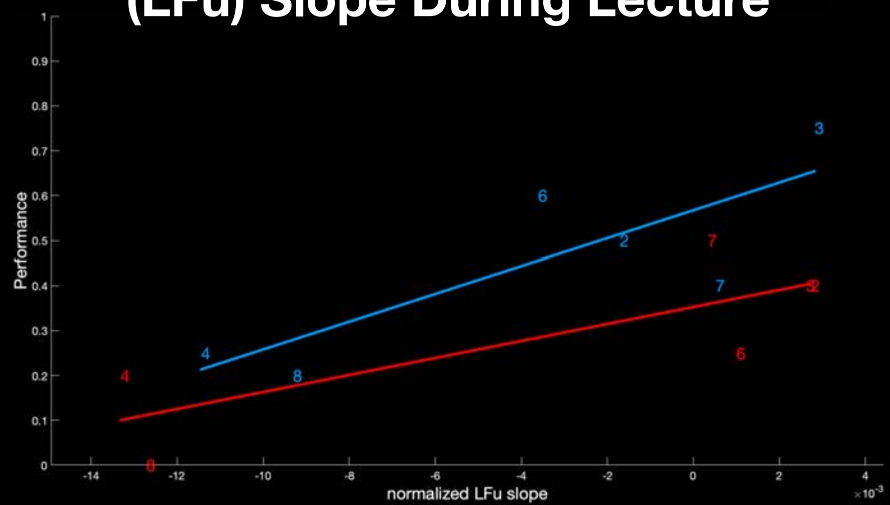


Performance vs. EDA Peak Rate During Lecture

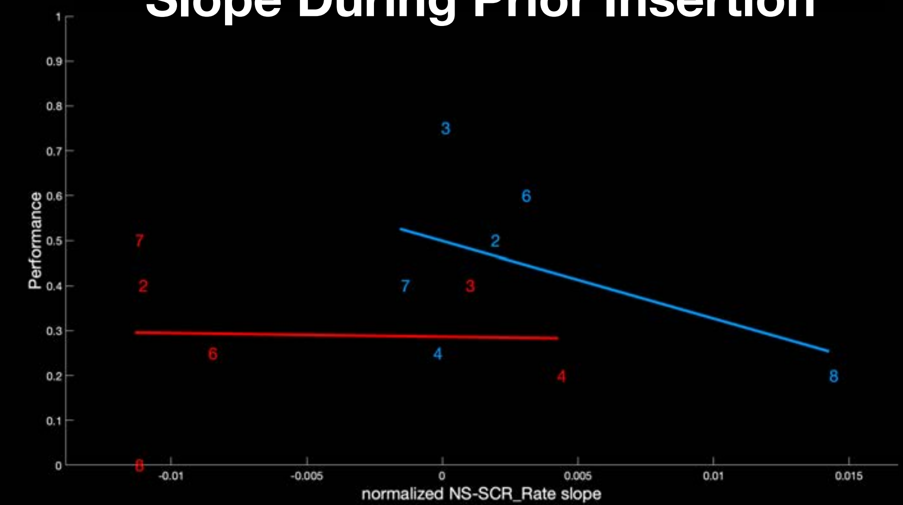


Pilot results suggest that novelty may enhance learning while controlling for arousal

Performance vs. HRV Balance (LFu) Slope During Lecture



Performance vs. EDA Peak Rate Slope During Prior Insertion



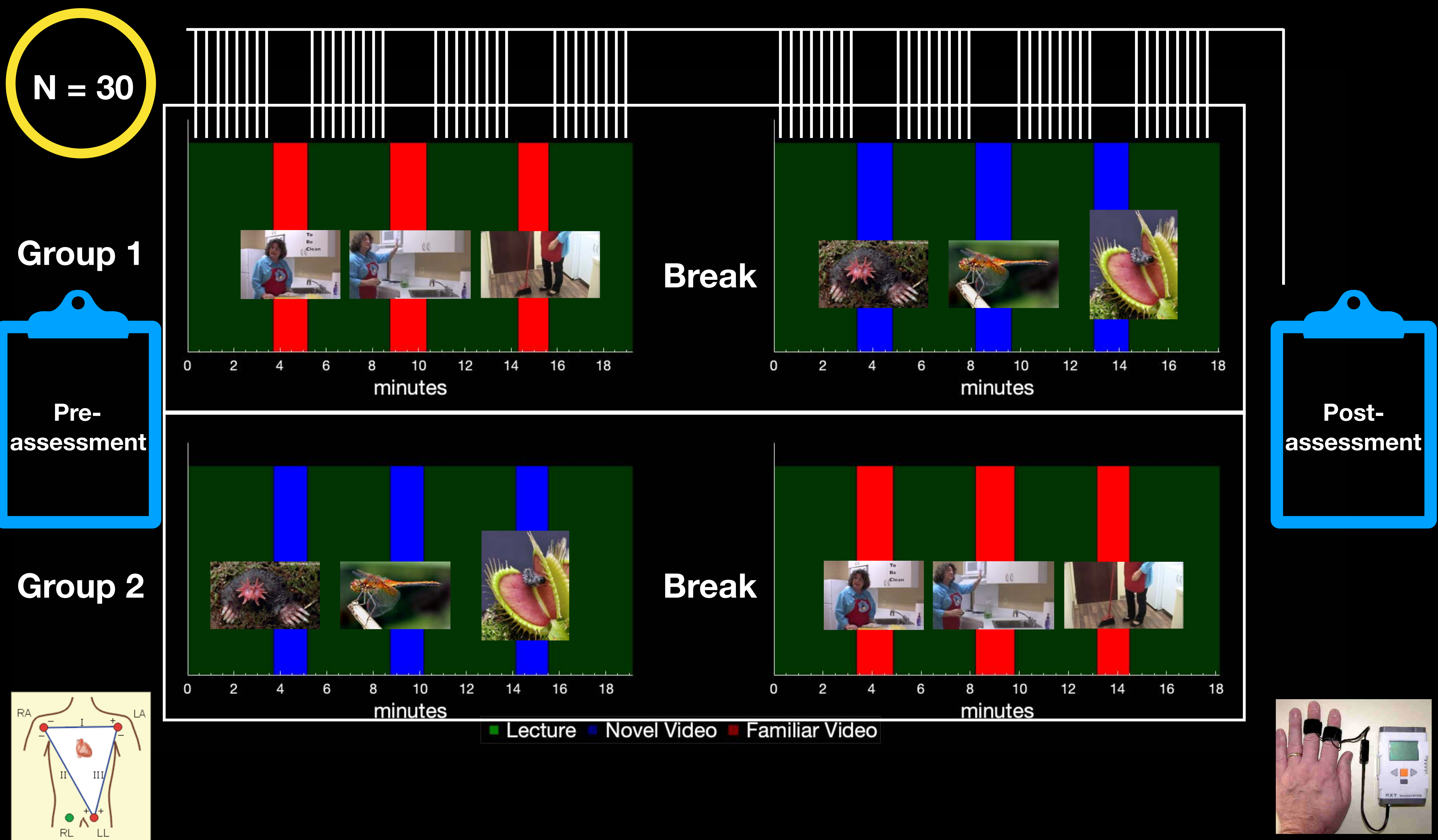
Novel | Familiar

Limitations

- Low statistical power
- Within-subject design
- High variability lecture content
- Few controlled factors between “novel” and “familiar” videos

Next Steps

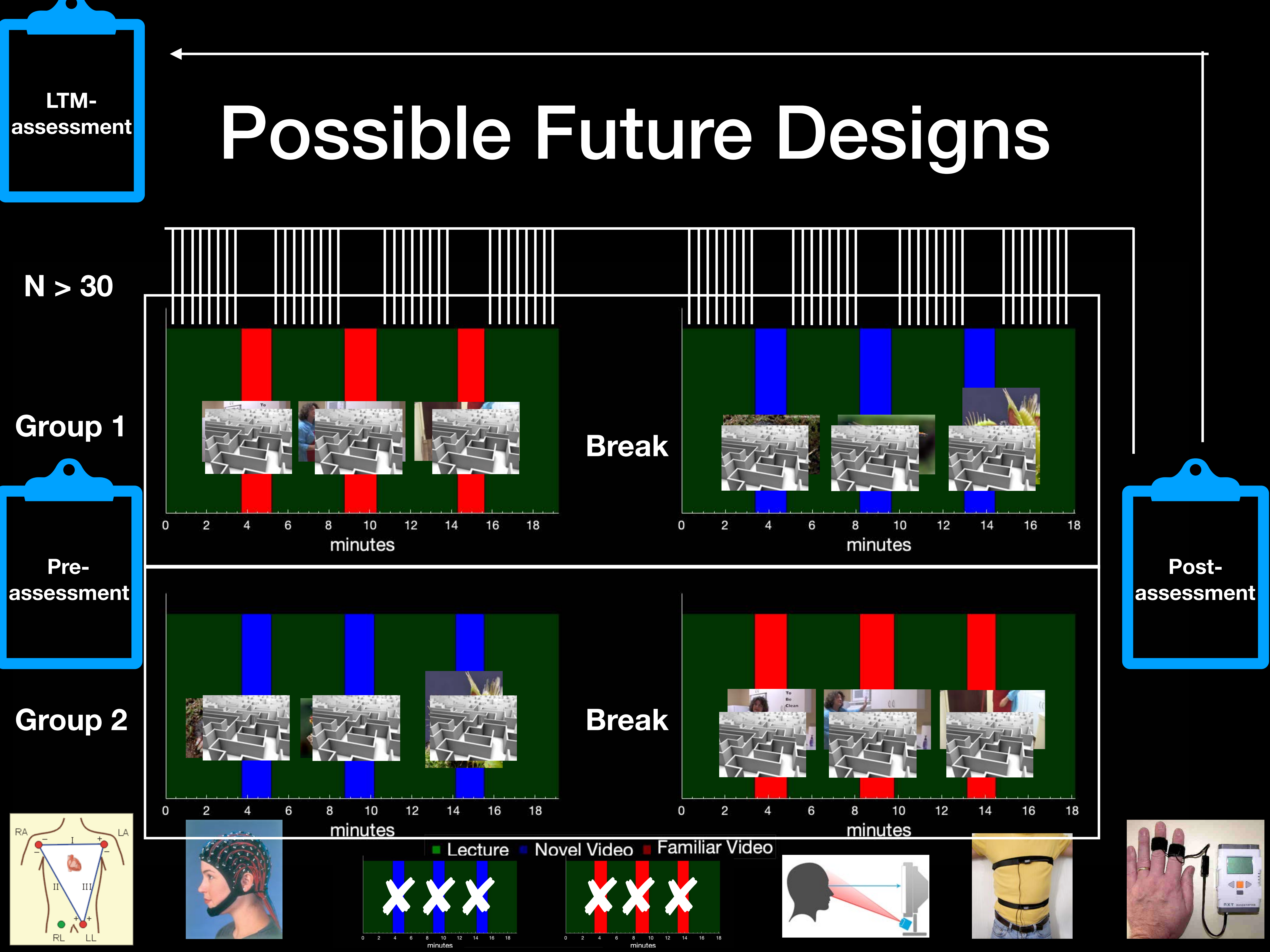
Next Phase



N = 30
Group 1
Group 2
Pre-assessment
Post-assessment
Break
Break
0 2 4 6 8 10 12 14 16 18
minutes
Lecture
Novel Video
Familiar Video
RA
LA
RL
LL
I
II
III

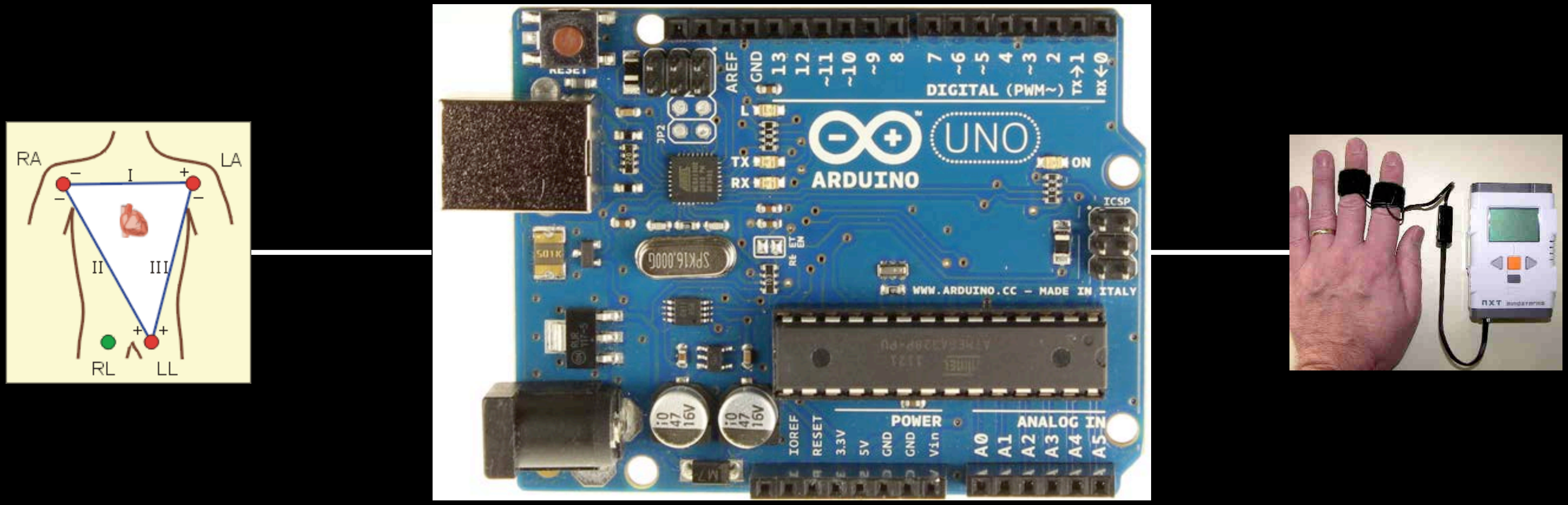
Possible Future Steps

Possible Future Designs



Remote Experimentation

- Online study
- Portable Sensor Box



Summary

- Created experiment structure for studying learning in online lectures
- Found preliminary results suggesting a possible positive effect of novelty on learning
- We are working on a variety of improved techniques to provide better statistical power and experimental control
- We hope that this project can inform the development of more effective online learning

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- Sidney Diamond
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- Matt Groth
- Lara Cavinato
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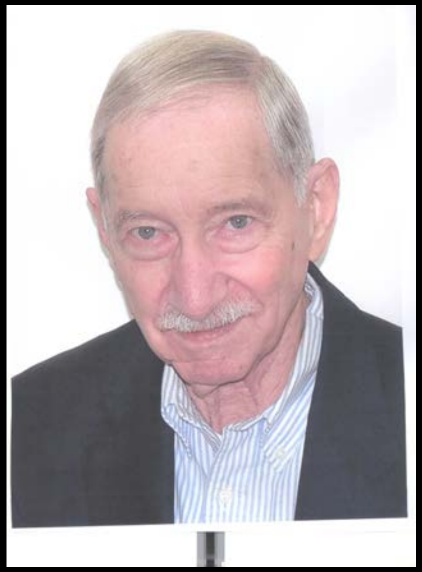
- Kana Okano and Steven Shannon for helping us to use the EEG Laboratory of the Martinos Imaging Center at MIT
- MIT Integrated Learning Initiative (MITILI)
- All of our participants!



If you or someone you know would like to participate in our next experiment, please email anniec@mit.edu, thank you!