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Learning in Intelligent Tutoring Environments (LITE) Lab personnel at USMA, April 2011 (L-R):

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ARL

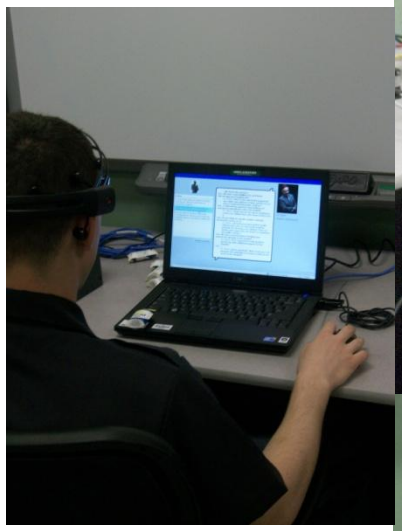
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

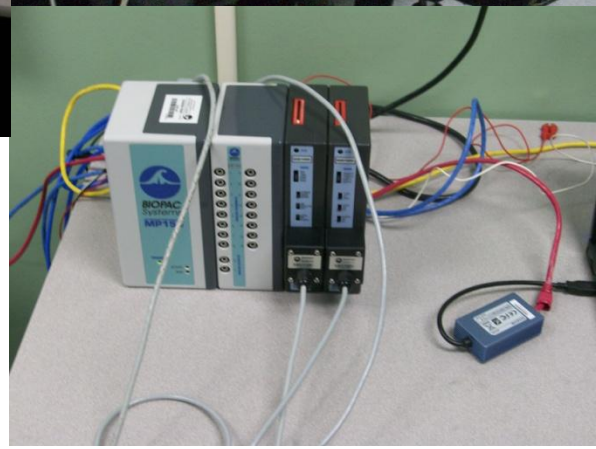
Real-Time Monitoring of ECG and GSR Signals during Computer-Based Training

ARL

OVERVIEW

- Objectives
  - Purpose
  - Research Questions
- Background
  - Engagement and Learning
- Methodology
  - Apparatus
  - Hypotheses
  - Analysis Approach
- Results
- Conclusions
- Future Work





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OBJECTIVES

- **Aim**
  - Assess impact of manipulations on states of interest in Cultural Meeting Trainer (CMT)
  - Identify sensors for tracking physiological metrics:
    - Can be tracked in real-time for informing system adaptations
    - Linked to cognitive and affective states associated with learning
      - Level of Attention (Cognitive Engagement)
      - Frustration/Excitement/Boredom (Arousal)
- **Purpose**
  - Make Computer-Based Tutoring Systems (CBTSs) adaptive to cognitive and affective states found to impact training outcomes
  - Evaluate tailoring approach for training mediation

BACKGROUND

- **Engagement**
  - Linked with information gathering, and periods of sustained attentional focus (Berka et al., 2007; Dorneich et al., 2004)
  - Disengagement and fatigue negatively impact training performance (Small et al., 1996)
  - Lack of engagement decreases learning (Baker, et al., 2004)
- **Arousal**
  - Correlated with retention in learning periods (Levonian, 1972)
  - Low arousal associated with rapid forgetting (Kleinsmith & Kaplan, 1963)
  - High arousal results in better memory performance central to the arousing event (Bradley et al.,1992)
- **Boredom**
  - Negatively correlated with learning gains (Craig, et al., 2004)
  - Negatively correlated with high retention (Small, et al., 1996)

BACKGROUND

- **Engagement**
  cognitive state

- **Arousal**
  affective state

- **Boredom**
  affective state

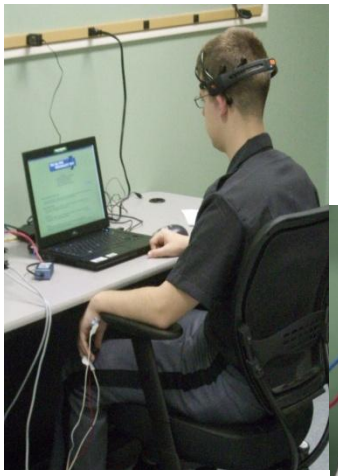
EEG can measure
- Attention
- **Engagement**
- Workload

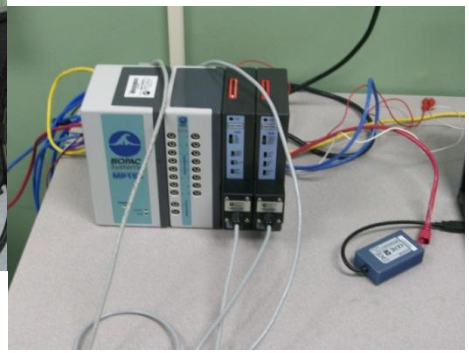
GSR can measure
- Anxiety
- **Arousal**
- **Boredom**
- Frustration
- Stress

ECG can measure
- Anger
- **Arousal**
- Attention
- **Boredom**
- Fear
- Stress

METHODOLOGY: APPARATUS

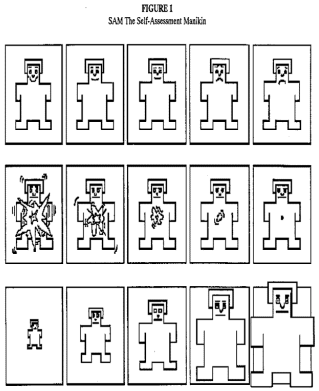
- **Emotiv EPOC Neuro-Headset**
  - 14-Channel Electroencephalogram (EEG) headset
  - Proprietary metrics used for purpose of maintaining low cost (Three Detection States):
    - Engagement
    - Short-Term Excitement
    - Long-Term Excitement





- **BIOPAC's MP150 System**
  - Collected both ECG and GSR data
    - 500Hz sampling rate

- **Self-Report Measures**
  - Mood via Self-Assessment Manikin
  - Self-Reported Engagement via ITC-SOPI



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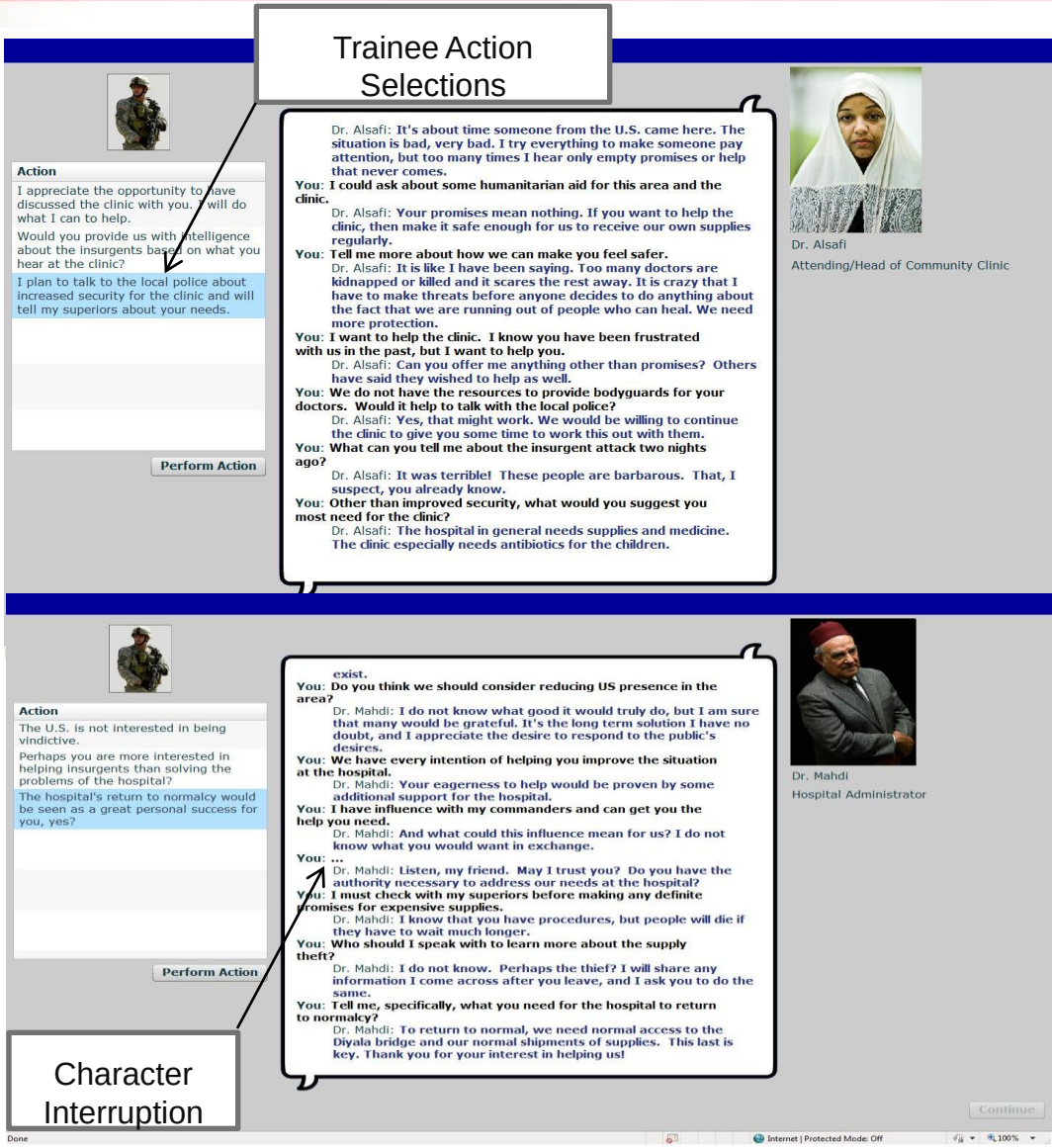
METHODOLOGY: APPARATUS

- **Cultural Meeting Trainer (CMT)**
  - Web-based flash system prototype applied for cross-cultural interaction training
  - Specifically designed for training cross-cultural norms and customs associated with phases of negotiation

- **CMT Designed Scenarios**
  - Well-Defined No Interruption (WDNI)
  - Ill-Defined No Interruption (IDNI)
  - Ill-Defined Interruption (IDI)



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METHODOLOGY: EXPERIMENTAL DESIGN

- **Particpants**
  - 19 Cadets with BIOPAC GSR/ECG data

- **Counter-Balanced Within Subject Design (IV's)**
  - Clarity of Task Execution (Well-Defined vs. Ill-Defined)
  - Presence or Absence of Character Interruptions

- **Procedure (Scenario Conditions Presented in Random Order Across Participants)**
  - Introductory Conversation →

    Rest → Scenario1 → Survey →

    Rest → Scenario2 → Survey →

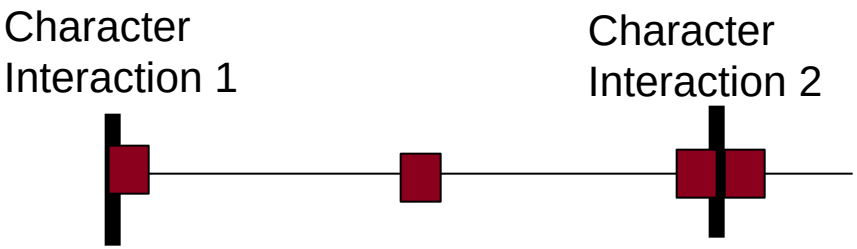
    Rest → Scenario3 → Survey

METHODOLOGY: HYPOTHESES

- **Exploratory Hypotheses**
  - **H_1**: An interruption in expected task flow will produce a noticeable response in physiological metrics reliably across participants
  - **H_2**: Physiological and self-reported metrics will produce reliably different outputs between well-defined and ill-defined task objectives
  - **H_3**: Physiological data will correlate with self-reported levels of engagement and mood

METHODOLOGY: APPROACH TO ANALYSIS

- **Post-Processing of BIOPAC Data :**
  - ECG Signal Processed for Real-Time Heartbeat Detection
  - GSR Features Extracted: Mean; Standard Deviation; and Signal Energy
  - Each metric is Processed for Defined Areas of Interest
    - 16 Second Samples Before, After, and Halfway Between System Interactions



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ECG Signal

- 2nd order band-pass, derivative, squared, integrated, thresholded
  - Filter Response: $\frac{s*w_0}{s^2+ s*\frac{w_0}{Q}+ w_0^2}$ (with a center frequency of 5 and a Q value of 4)
  - $\frac{\mathrm{d}}{\mathrm{dx}} = y(nT) = \frac{1}{8} * T[-x(nT-2T) - 2x(nT-T) + 2x(nT+T) + x(nT+2T)]$
  - Squaring: $y(nT) = [x(nT)]^2$
  - MWI: $y(nT) = \left(\frac{1}{N}\right) * [x(nT-(n-1)T + x(nT-(N-2)T + \cdots + x(nT)]$
    (N is 30 samples, or a 3.6 millisecond delay for this work)

Pan, J., Tompkins, W.J.: A real-time QRS detection algorithm. IEEE Trans. Biomed. Eng. BME, 32(3): 230-236 (1985)

GSR Signal

- Smoothing $y[n] = \frac{1}{\tau}x(n) + \frac{\tau-1}{\tau}y(n-1)$
- Normalization $s(t) = \frac{s(t)-\mu_s(t)}{\sigma_s(t)}$
- Second Difference Energy $\sqrt{\int_t \frac{d^2}{dt^2}(s(t))}$

Kapoor, A., Burleson, W., & Picard, R. W. Automatic prediction of frustration. International Journal of Human-Computer Studies, 65, p. 724-736 (2007)

RESULTS: BIOPAC ANALYSIS

- Analysis showed ECG data to display minimal variance over time and across scenarios, including the IDNI scenario.
  - This can be seen when looking at the correlations between ECG metrics

- Significant differences were found for all GSR metrics (Mean, SD, and Signal Energy) when examining the effect of task clarity(Ill- vs. Well-Defined):
  - IDI against WDNI: [Mean, $t(18) = -2.643$, $p<.025$; SD, $t(18) = -2.323$, $p<.05$; and Signal Energy, $t(18) = 2.414$, $p<.05$]
  - IDNI against WDNI: [Mean, n/a; SD: $t(18) = -2.472$, $p<.025$; and Signal Energy, $t(18) = 2.965$, $p<.01$]

- No correlations present between BIOPAC metrics and self-report scores (Mood and Presence)

- Interruption in scenario interaction had no noticeable impact on BIOPAC data (H_3)

DISCUSSION: BIOPAC

- Interaction scenarios without clear goals, such as in the ill-defined interaction context, are likely to produce lower levels of arousal (GSR) (H_2)
  - Supported by work examining the relation between performance and stress through compensatory control of one's attention and effort (Hockey, 1986)
  - Interaction scenarios with unclear goals produce greater variability (as seen by Signal Energy) in GSR outputs across time.

- There were no reportable differences in dependent variables between the IDI and IDNI scenarios (H_1)
  - This is an indication that the instructional event of interrupting users had no effect on their arousal levels.

- No variability among cadets in self-report or engagement surveys

CONCLUSIONS

- Additional research is required to:
  - Assess the effect varying methods of task intervention has on cognitive engagement across multiple computer-based platforms

- Future work to assess real-time changes in trainee affect is motivated by the ability of the GSR signal to detect significant differences among experiences

- Models of student affect need be constructed and utilized in real time in order to be practical. Metrics developed here will further this work

Questions?