Industrial and Systems Engineering
Texas A&M University

Multimodal Bio-Behavioral Approaches to Study Trust in Human-Robot Collaboration

4th Annual Workshop on Novel and Emerging Test Methods & Metrics for Effective HRI

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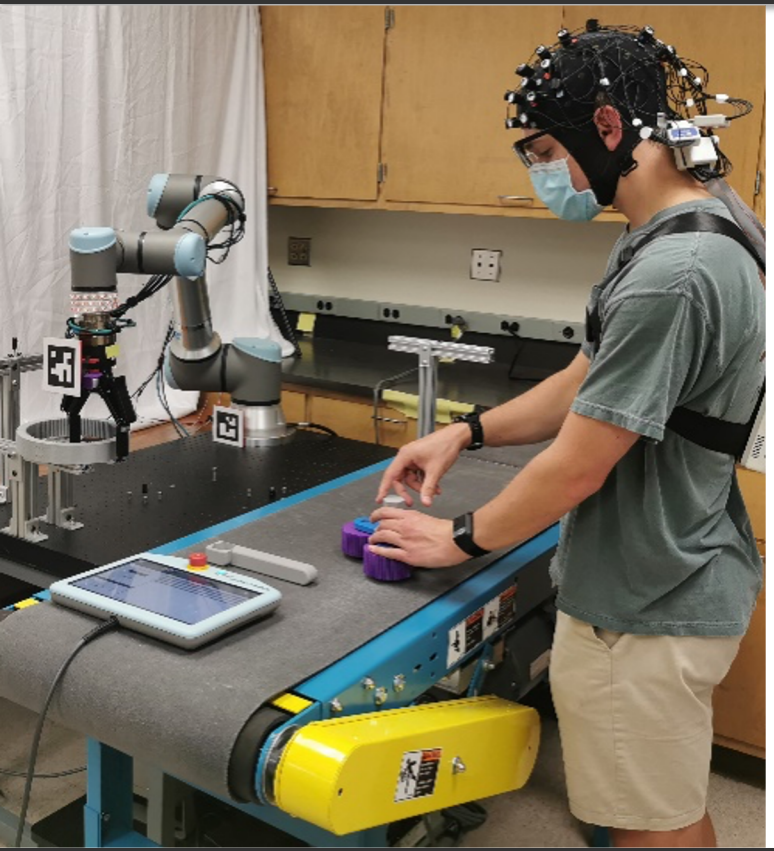
Current Methods and Challenges

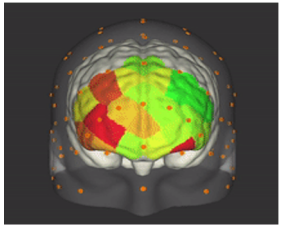


- Subjective trust measures
  - Invasive
  - Biased
  - Discrete and sparse
- Lack of human centered metrics
  - Human performance
  - Human behavior
  - Physical and cognitive states
- Hardcoded interaction

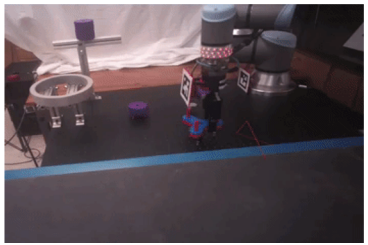
Need for New Perspectives

Multimodal Physiological Measurements

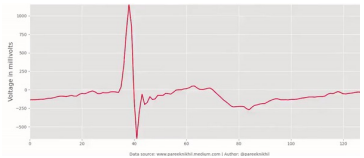
fNIRS
Measures Brain Activity



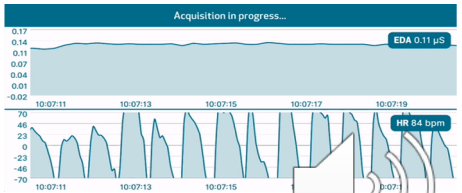
Tobii Pro
Measures Pupil Dilation, Gaze & Eye Tracking, & FP-View Camera



Actiheart
Measures Heart Rate Variability



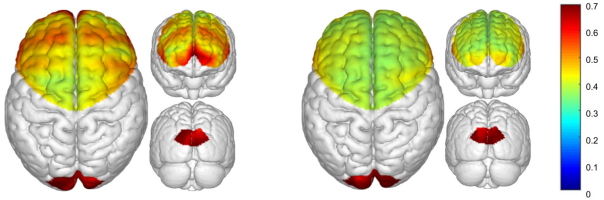
Empatica E4
Measures Heart Rate Variability & Skin Conductance



Brain Activity

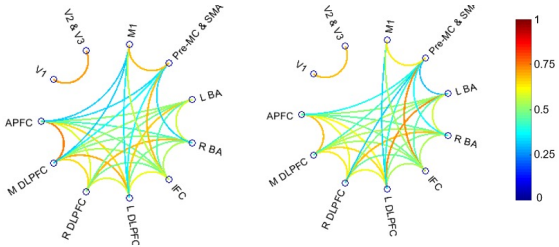
- Unbiased, objective, and continuous
- Why fNIRS/EEG? Cost effective, and ambulatory data collection in naturalistic settings
- Neural correlates of trust

Brain Activations

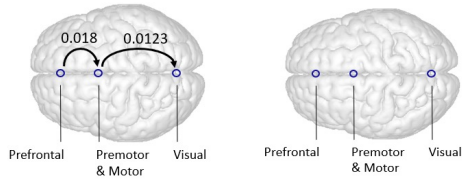


Reliable Unreliable

Functional Connectivity

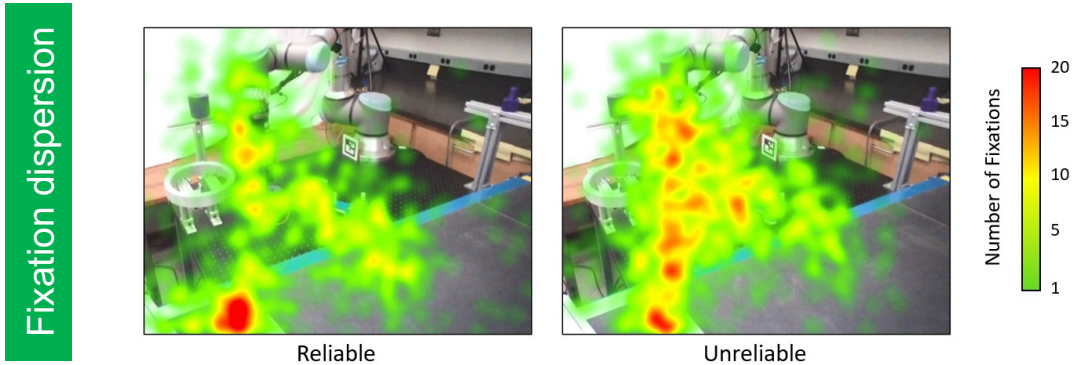


Effective Connectivity



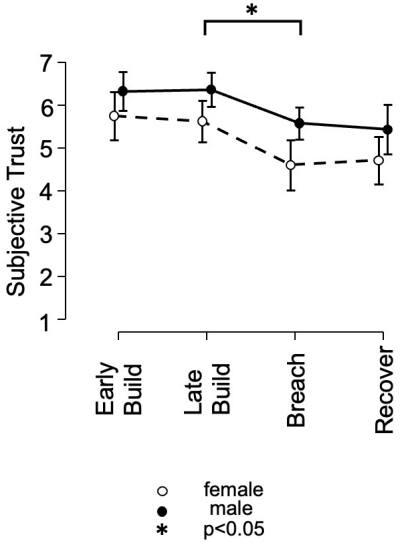
Eye-tracking

- Types of eye-movements: **gaze**, **saccade, and fixation**
- **Bottom-up:** stimulus that attract fixations independent of the internal state of an observer.
- **Top-down**: cognitive influences on the chosen fixation locations based on the current aims of an observer



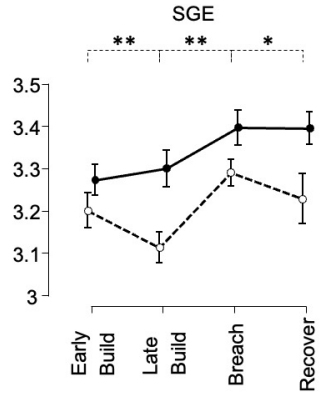
Eye-tracking: Gaze entropy

Subjective trust



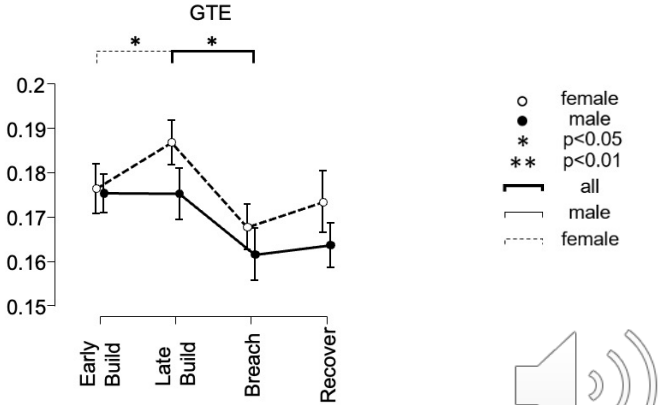
Stationary Gaze Entropy (SGE)

- Estimates overall spatial dispersion of gaze



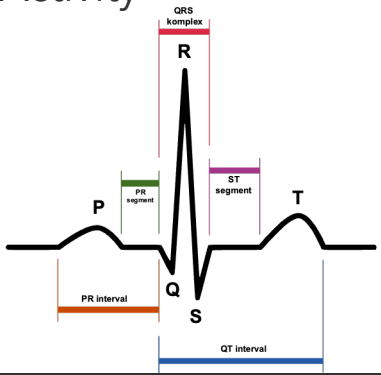
Gaze Transition Entropy (GTE)

- Estimates uncertainty when predicting the next fixation location given the current fixation



Heart Rate Variability (HRV)

- Insight into parasympathetic and sympathetic nervous systems
- Frequency domain HRV
  - HF – Parasympathetic Activity
  - LF & VLF – Sympathetic Activity
  - LF/HF ratio



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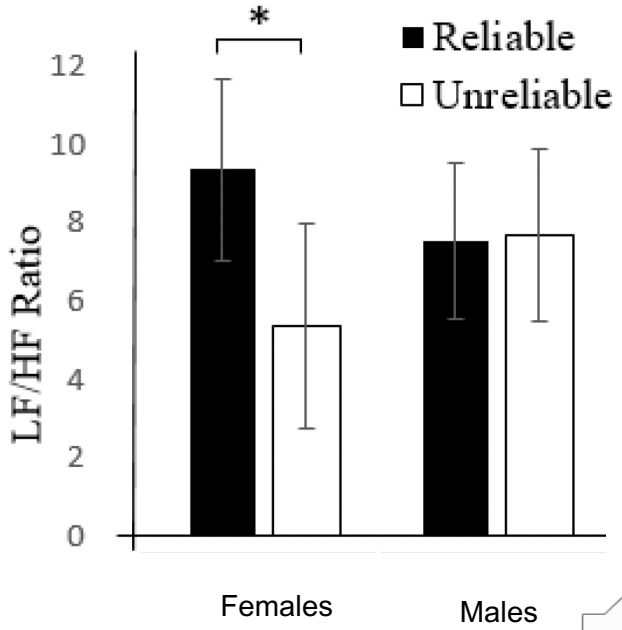
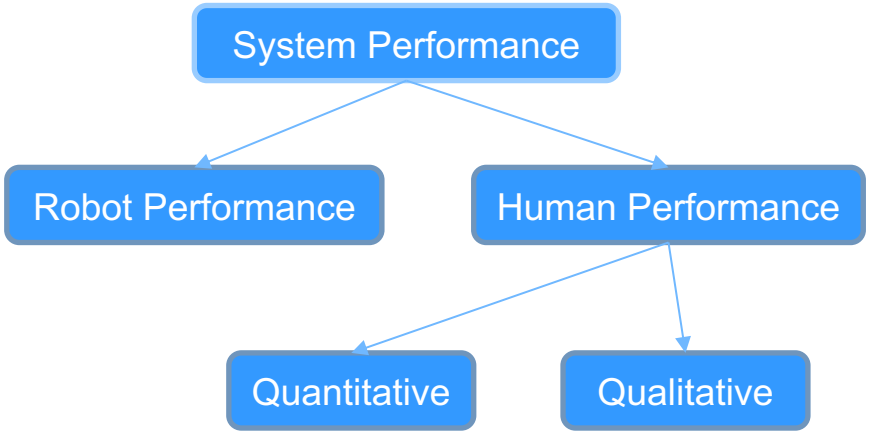


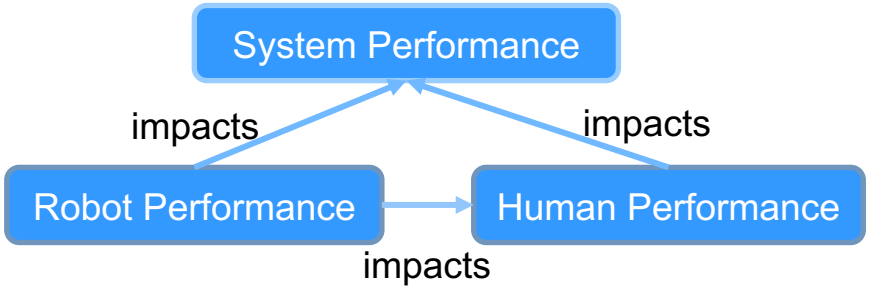
Performance and Behavior Delineation



- Accuracy
- Precision
- Efficiency
- Utilization

- Slips
- Mistakes
- Lapses

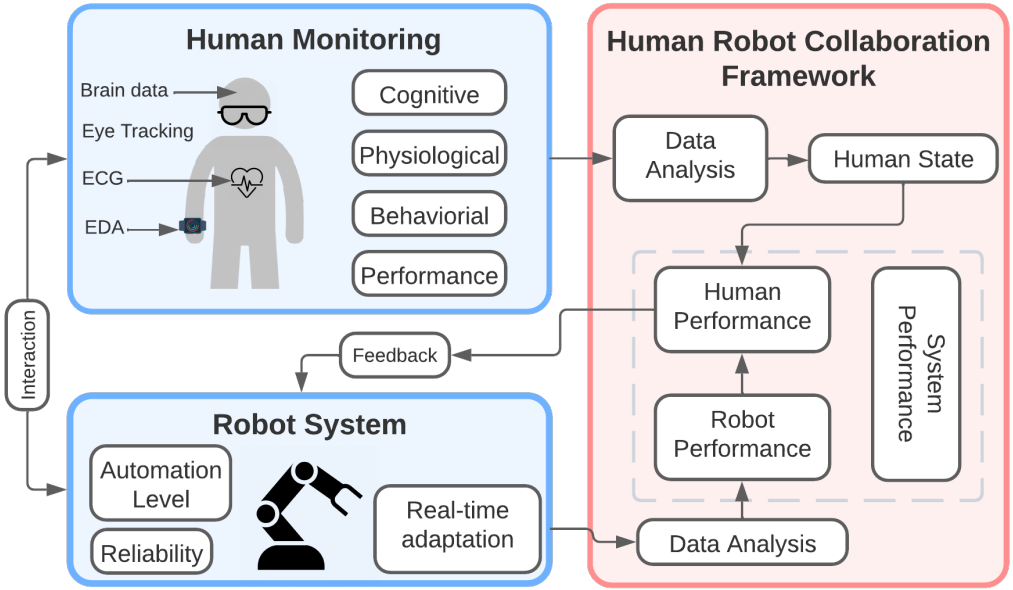
Performance and Behavior Delineation



- Robot performance impacts human performance
- Transparency in robot performance is critical

Implications

- Improved understanding of HRC
- Near real-time robot adaptation
- Personalized interactions
- Reduction in cognitive load and worker fatigue
- Improved system performance

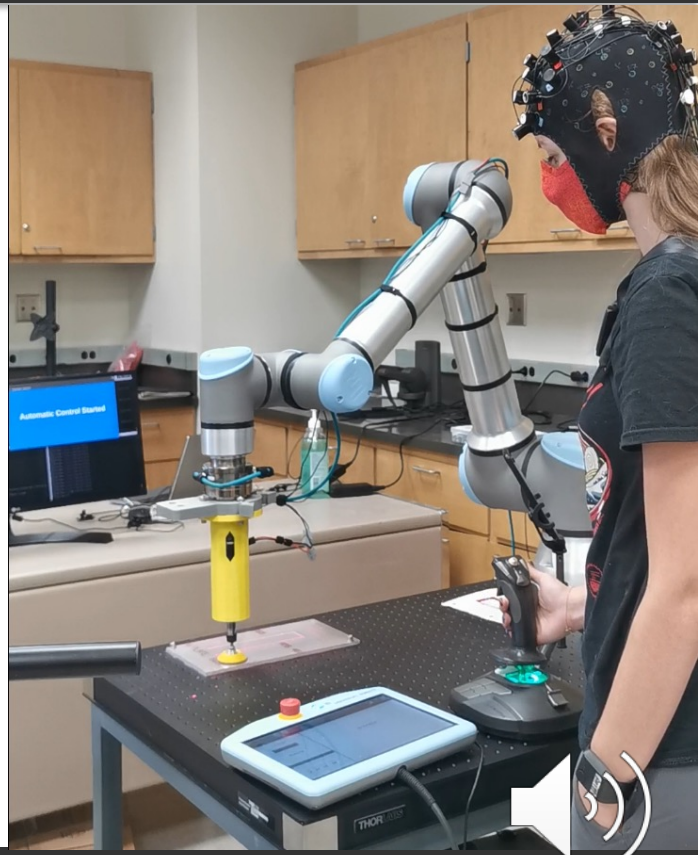


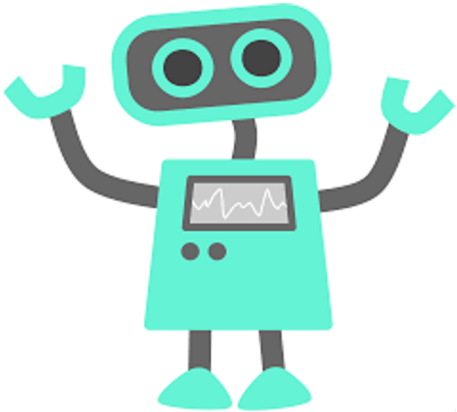
Conclusion

Multimodal Bio-Behavioral measures can objectively account for trust

Humans are inherently different from one-another and their behaviors are transient

Physiological measures allows for in-situ robot adaptation





Questions?

Relevant work

- Hopko, S., Wang, J., & Mehta, R. (2022). Human Factors Considerations and Metrics in Shared Space Human-Robot Collaboration: A Systematic Review. *Frontiers in Robotics and AI*, *9*.
- Hopko, S. K., & Mehta, R. K. Neural Correlates of Trust in Automation: Considerations and Generalizability Between Technology Domains. *Frontiers in Neuroergonomics*, 26.
- Hopko, S. K., Mehta, R. K., & McDonald, A. D. (2021, September). Trust in Automation: Comparison of Automobile, Robot, Medical, and Cyber Aid Technologies. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 65, No. 1, pp. 462-466). Sage CA: Los Angeles, CA: SAGE Publications.