

#### **Task 3: Human Systems Integration**

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### **Communication as an Index of Collaboration**

- An observable byproduct of collaboration; Think aloud "in the wild"
- Rich, multidimensional (pitch, amount, flow, speech acts, content)
- Reflects team cognition in terms of interactions; for us this is team cognition
- Allows operational assessment of collaboration...
- We anticipate communication data (radio or data comm) being available for real-time monitoring and analysis

## ATC Simulation Experiment Measures



# **ATC Simulator Experiment**



#### **3 Pseudo Pilots**



- 2 of 12 experienced FAA controllers
- Three pseudo pilots (students) each controlling 4-8 planes
- Three 25 min simulated approach scenarios (within Ss fixed factor):
  - Baseline: 4-5 aircraft at once, moderate workload (15 aircraft)
  - High Workload Nominal: 2 aircraft, increases to 10-12 at once (30 aircraft total)
  - High Workload Off Nominal: Traffic density same as High Workload – Nominal plus…
    - Pilot deviation
    - Runway switch (runway 25L to 07R)
    - Moderate turbulence in several arrival flows



#### Single Air Traffic Controller



# ATC Simulation Experiment

### CRITERION MEASURES

ATC performance – Loss of Separation
 PREDICTORS

- Controller-Pilot radio frequency transmissions
  - Volume how much communication over time
  - Flow who talks to whom patterns over time
  - Errors violated standard flow pattern
- Workload & Situation Awareness probes
- Biometric heart rate variability
- Facial expression
  - Affectiva software labeling
  - Pingbo Tang's research

# PHX TRACON (P50) on ATCo radar scope 3 ATC radar simulation scenarios, 25 min each



## 1 RNAV and 3 STARS arrival routes GA SSBST (G Arrivals from Mexico, etc rrivals from GA KLAX, KSFO (SAN, KONT, etc ŝ

3



# **Workload & Situation Awareness**



### LOS Events Per Minute over Two ATC Participants Increase Over Time and in High Workload Scenarios



### Over Three Times as Many Separation Breaches in High Workload Nominal as Baseline



# Subjective and Objective Workload Increase Over Time

Workload Probe at 3 min	Workload Probe at 12 min	Workload Probe at 21 min
<ul><li>2.25 sec to press "Ready"</li><li>1.6 workload rating</li><li>1 low – 7 high</li><li>(6 data points)</li></ul>	<ul><li>21.45 sec to press "Ready"</li><li>6.0 workload rating</li><li>1 low – 7 high</li><li>(6 data points)</li></ul>	<ul><li>11.85 sec to press "Ready"</li><li>6.5 workload rating</li><li>(1 low – 7 high)</li><li>(6 data points)</li></ul>

# **COMMUNICATION ANALYSIS**



#### Baseline

High WL

Cooke, N. J., Salas, E., Kiekel, P. A., & Bell, B. (2004). Advances in measuring team cognition. *Team cognition: Understanding the factors that drive process and performance*, 83-106. Kiekel, P. A., Gorman, J. C., & Cooke, N. J. (2017). Communication as team-level cognitive processing. In *Macrocognition in teams* (pp. 51-64). CRC Press.

Gorman, J. C., Foltz, P. W., Kiekel, P. A., Martin, M. J., & Cooke, N. J. (2003, October). Evaluation of Latent Semantic Analysis-based measures of team communications content. In *Proceedings of the Human Factors and Ergonomics Society annual meeting* (Vol. 47, No. 3, pp. 424-428). Sage CA: Los Angeles, CA: SAGE Publications.

# **COMMUNICATION ANALYSIS Closed Loop Communication**

**Coded as "0":** if an air traffic controllers communication followed a pilots or vice versa (A>P>A>P>A>P)

**Coded as "1":** if an air traffic controller communications was followed by another air traffic controller communication, or a pilot communication was followed immediately by another pilot communication. (A>P>A>P>P)

ATC/ Pilot	Time	Description	Deviation	Code
ATC (JetBlue 475)	01:50.0	JetBlue four seventy five desceding maintain six thousand	Not deviated	0
JetBlue 475	01:54.0	six throusand jetblue four seventy five	Deviation	0
American 912	01:57.7	Phx appraoch, this is american nine twelve with you on header one information tango	happened	1
ATC (American 912)	02:05.5	american nine twelve expect ILS? Runway two five left appraoch	Not Deviated	0
American 912	02:09.6	roger expect ILS? Runway two five left appraoch american nine twelve		0
Boutigue 805	03:14.3	Phoenix appraoch this is boutigue eight o five, we are with you at wide five we are at ten thousand we have information tango	Deviation happened	1
ATC (Boutigue 805)	03:24.1	boutigue eight o five phx appaoch roger expect ILS? Runway two five left appraoch	Not deviated	0

### **COMMUNICATION ANALYSIS** Pattern Change Variants (Deviations)

### **Communication Skip:**

- 1) Pilot A:ATC
- 2) ATC: Pilot B

#### **Step Over**

- 1) Pilot A: ATC
  - a) Halfway through communication Pilot B calls in
- 2) Pilot B: ATC

### **Normal Pattern Change:**

- Pilot A:ATC Communication is complete
- 2) ATC: Pilot B

#### **Error Correction**

- 1) ATC:Pilot
  - a) ATC makes error
- 2) ATC:Pilot
  - a) Gives corrected order

### Results of Coding Data for Closed Loop Communication Deviations

Trial	Participant	Deviations
Base	1	9
Base	2	17
Nominal	1	29
Nominal	2	34
Off Nom	1	31
Off Nom	2	36



In the high workload off-nominal conditions, most of the communication deviations happened during the unexpected events (e.g., turbulence)

# **COMMUNICATION ANALYSIS Recurrence Quantification Analysis (RQA)**

Identify recurrent patterns in behavioral sequences

- Recurrence Rate (RR): Quantify the overall tendency for recurrence in the systems (i.e. recurrence density)
- RR is an index of predictability of the closed loop-no closed loop pattern over time
- RQA can be done in real time and can provide indications of risk

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### COMMUNICATION ANALYSIS Predictability Decreases and Closed Loop Communication Deviations Increase with Increased Workload

**ATC #1** 



### High Nominal



# High-Off Nominal



 $\mathbf{RR} = \mathbf{0.58}$ 

**RR= 0.85** 

 $\mathbf{RR} = \mathbf{0.65}$ 

### COMMUNICATION ANALYSIS Predictability Decreases and Closed Loop Communication Deviations Increase with Increased Workload

#### **Baseline**

**ATC #2** 

**High Nominal** 

#### **High-Off Nominal**





RR= 0.85

RR= 0.62

100

150

Communication sequence

### COMMUNICATION ANALYSIS Closed Loop Communications Less Predictable with Workload Increases



### HEART RATE RESULTS Sample Entropy

- Sample Entropy quantifies information generated in time series (Interbeat Interval ~ time interval between the individual beats)
- Low Sample Entropy: Low information generation; greater regularity/ predictability of data, less complex pattern of variability
- High Sample Entropy: High information generation; more complex, less predictable pattern of variability

### **RESULTS: Sample Entropy**



# CONCLUSIONS

Data represent a preliminary look at 2 of 12 participants

Scenarios are generating LOS events

- High workload more LOS than Baseline
- 3x as many in high WL-nominal than baseline
- <sup>1</sup>/<sub>4</sub> breaches in off-nominal are <1nm</p>
- Both high workload scenarios have breaches lasting >5 min
- Workload also increases over time in each scenario
- What behavioral measures are predictive of workload and LOS?

# CONCLUSIONS

With increases in workload...

- Closed loop communication deviations increase
- Closed loop communication deviations become less predictable
- Heart rate variability becomes more predictable

### **Schedule and Milestones**

