

Modern Taxiing



Simulating Air Traffic Control Ground Operations: Preliminary Results from Project Modern Taxiing

Zarrin Chua¹, Mathieu Cousy², Fabien Andre², Mickaël Causse¹

¹*Institut Supérieur de l'Aéronautique et de l'Espace*

²*École Nationale de l'Aviation Civile*

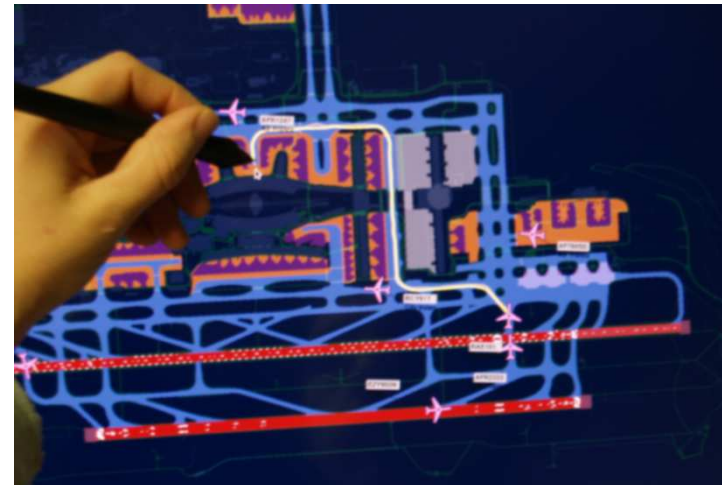


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- Current taxiing operations are expensive: e.g. fuel, time, emissions
 - Reliance on aircraft's main engines
 - Average taxiing time of 20 minutes around Charles-de-Gaulle
- Forecasted increases in traffic are a good opportunity to introduce automation
 - On-ground vehicles, automation for air traffic control officer (ATCO)
- How can we effectively introduce this technology?

Explore **automated taxiing options** that would enable **varying levels of automated assistance** and support the **technology transition period** in a non-intrusive manner

- Fleet of autonomous taxi robots (TaxiBots) at airport
 - Tractors that can tow the aircraft to and from the runway
- Percentage of aircraft equipped with DataLink
 - eTaxi: electronic Taxiing, autopilot system in the cockpit
- Intelligent ATCO interface
 - Smart algorithms for TaxiBot management, conflict detection, path suggestion, etc

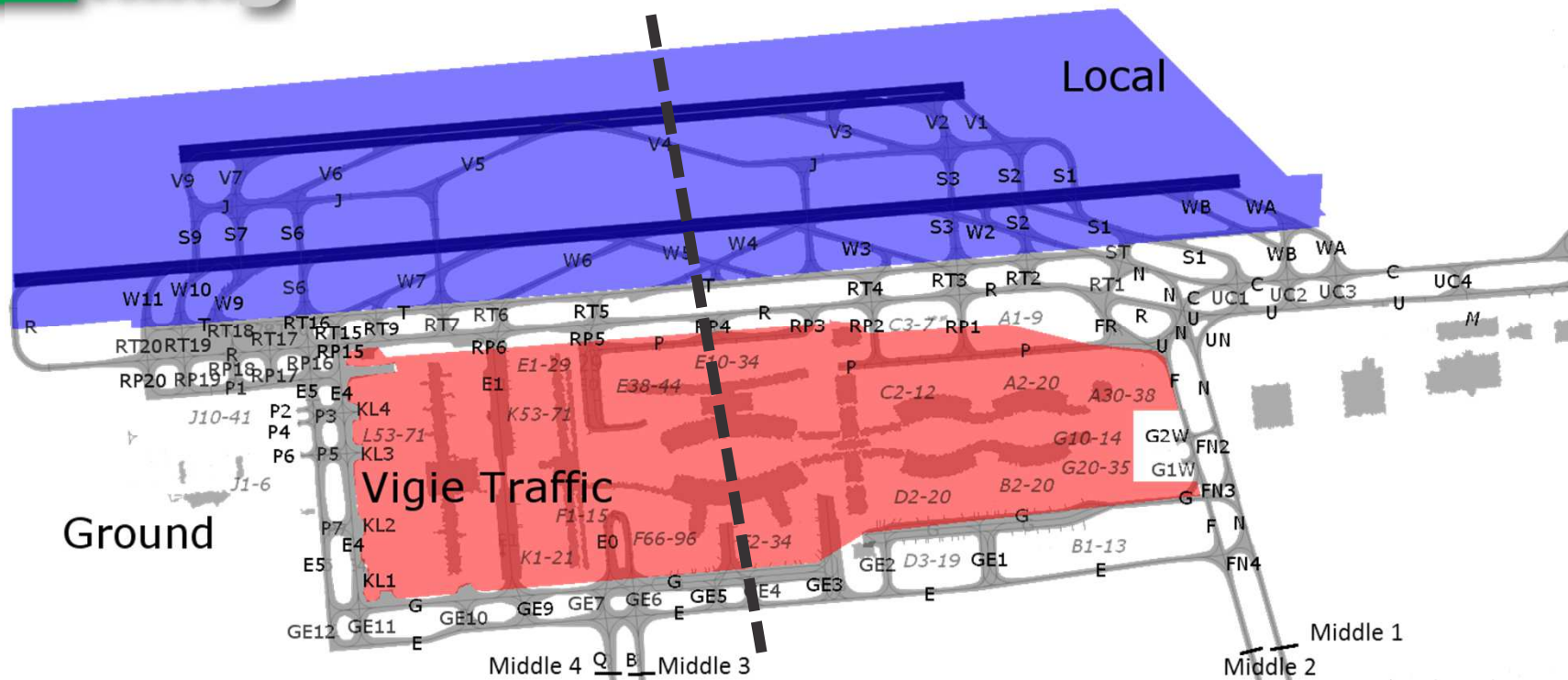


- How many TaxiBots will be added to operations ?
- How will the TaxiBots be managed by the ground ATCO ?
 - Possibly doubling number of vehicles on taxiways
- Where and what should we automate to help the ATCO?
- What and how will this information be provided to the controller?
- How will this work evolve with changes to the aircraft fleet ?

- Three human-in-the-loop experiments
 1. **Baseline/current technologies:** paper flight strips, radio communication
 2. **Interface:** with decision support system, conflict detection, etc
 3. **TaxiBot/eTaxi:** Interface + technology for ground operations

Currently wrapping up Exp 1, towards end of development for Exp 2

- **Today's talk**
 - Discussion of Validation Plan
 - Simulation Facility
 - Preliminary Results from first Experiment
 - Preview of Exp 2

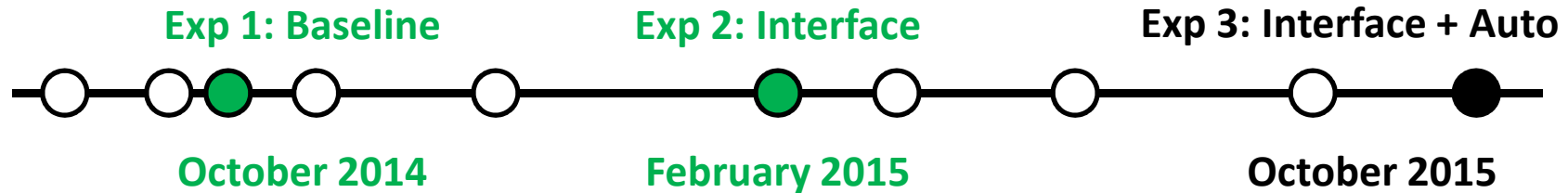


- South end of Roissy Charles de Gaulle Airport (Paris, France)
- Ground controller only
 - Local, Apron control, North ground are simulated
- Evaluating current and futuristic air traffic levels

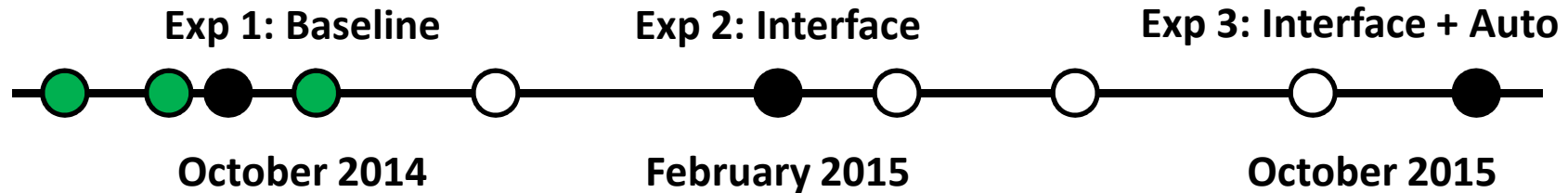


Validation Plan

Three experiments, several mini-experiments/workshops

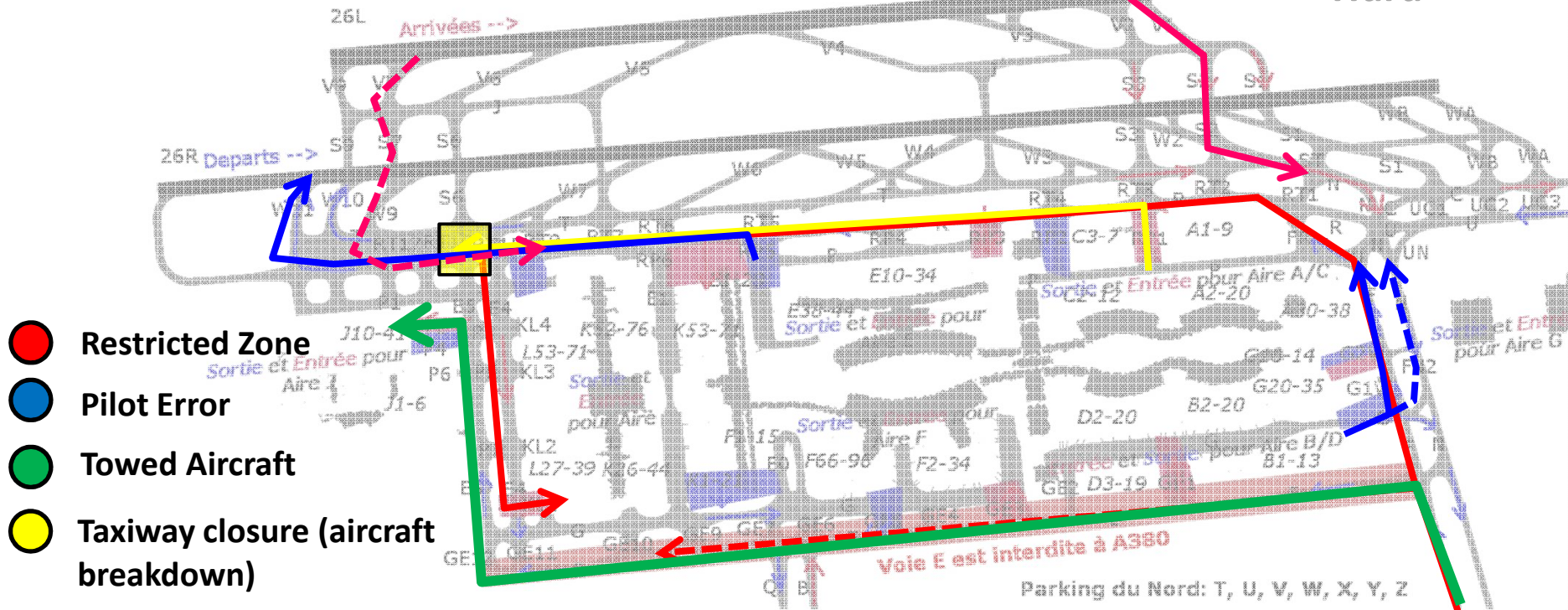
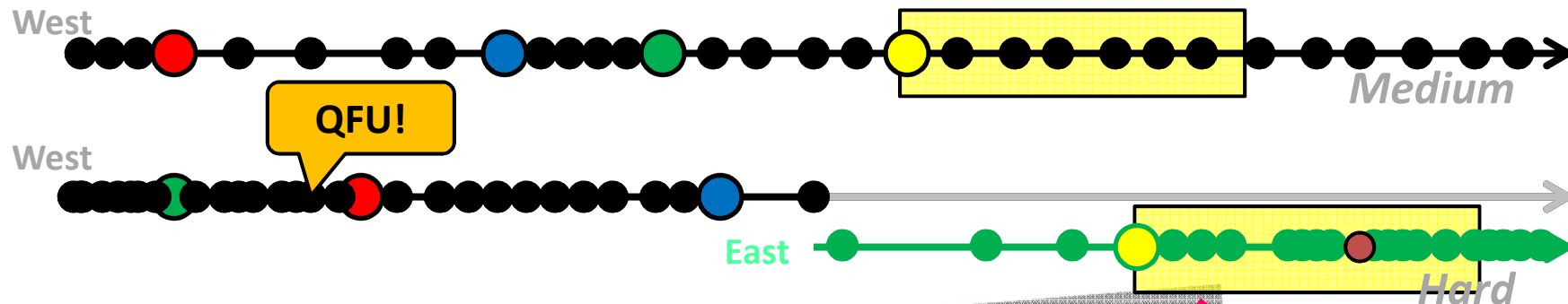


- 3 x 2 full factorial design
- Automation: three levels (corresponding to three experiments)
 - Baseline
 - Interface
 - TaxiBot/eTaxi
- Scenario: two levels of difficulty
 - Combination of traffic load and activity
 - **Medium**: traffic load of 50 movements/hr, standard activity
 - **Hard**: traffic load of 70 mvts/hr, standard activity + change in QFU



- Solicit ideas and remarks on the platform and automation
- Full experiment not required, <5 controllers, specialists
 - Feb : Scenario definition, path suggestion improvements
 - July : Finalization of scenarios
 - Oct : MoTa workshop on taxibots, interaction, algorithm
 - Nov : Conflict detection, automation level modality
- Ideas for future
 - **Finalization of parameters: timing of warning (and possible correlations with traffic load); managing taxibot return**
 - Appropriateness of solutions proposed by algorithm
 - Maximum capacity of traffic manageable by a singular CDG controller with MoTa

Each scenario takes about 35 minutes



- Idea is to compare operational and neurophysiological responses to each event, with and without automation assistance
- Other degrees of conflict are noted
 - Assignment of Aircraft Priority
 - Localized optimization (e.g. shortcuts)

Operational

- **Throughput**
- Fuel consumption
- **Taxi-in, taxi-out time**
- Number of bottlenecks

Subjective

- Workload (TLX)
- Situation awareness (SART)
- Trust in technology (SATI)
- Remarks on the technology

Behavioral

- Number of actions
- Clarity of commands
- Deviation from ideal trajectory

Neurophysiological

- Occular (eyetracker)
- Cardiographic (ECG)
- Cerebral activity (EEG, C_z)



* Solutions for Human-Automation Partnership in European ATM (**SHAPE**) **Automation Trust Index**

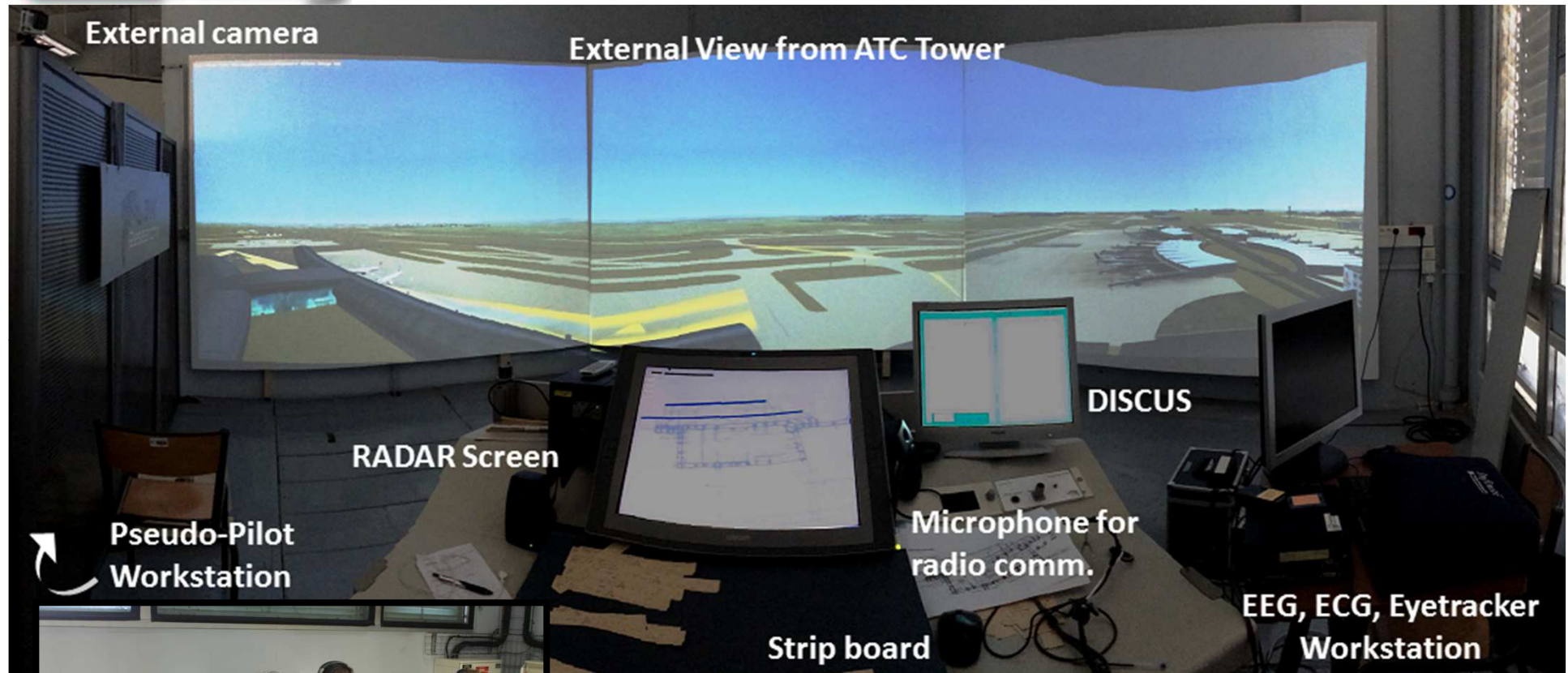
- Pool of international ATCOs: active, retired, instructors
 - Small and large airports, Charles-de-Gaulle
- Twelve participants per experiment (36 individuals total)
- Matched demographics between experiments
 - Tests for CDG memory retention between experiments
- Each session is 3 hours long
 - Airport manuals/maps sent prior to each experiment
 - **Practice:** Open discussion about CDG layout
 - **Calibration:** eyetracker, electroencephalogram (EEG), electrocardiogram (ECG)
 - **Run 1:** Medium or Hard
 - **Run 2:** Medium or Hard
 - Subjective measures are collected after each run, overall comments at end



Simulation Facility

Ecole Nationale de l'Aviation Civile

Toulouse, France



- External view is based on FlightGear
- The MoTa platform centered around ivy bus

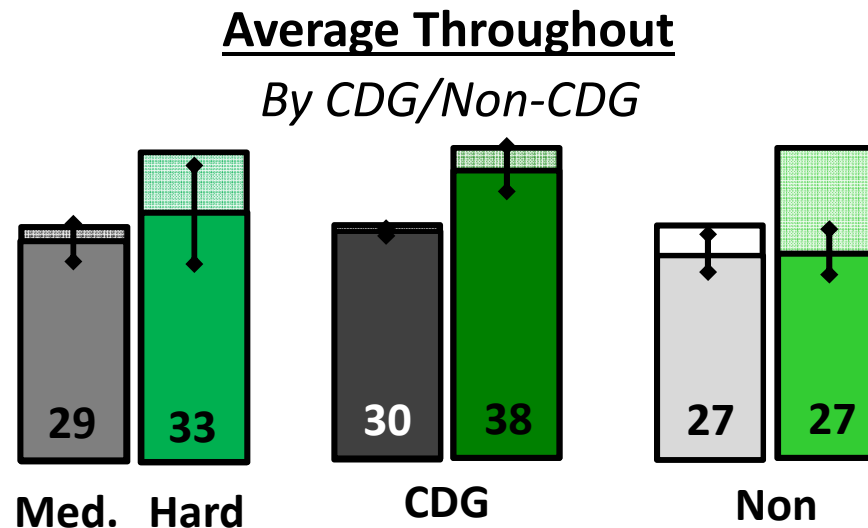
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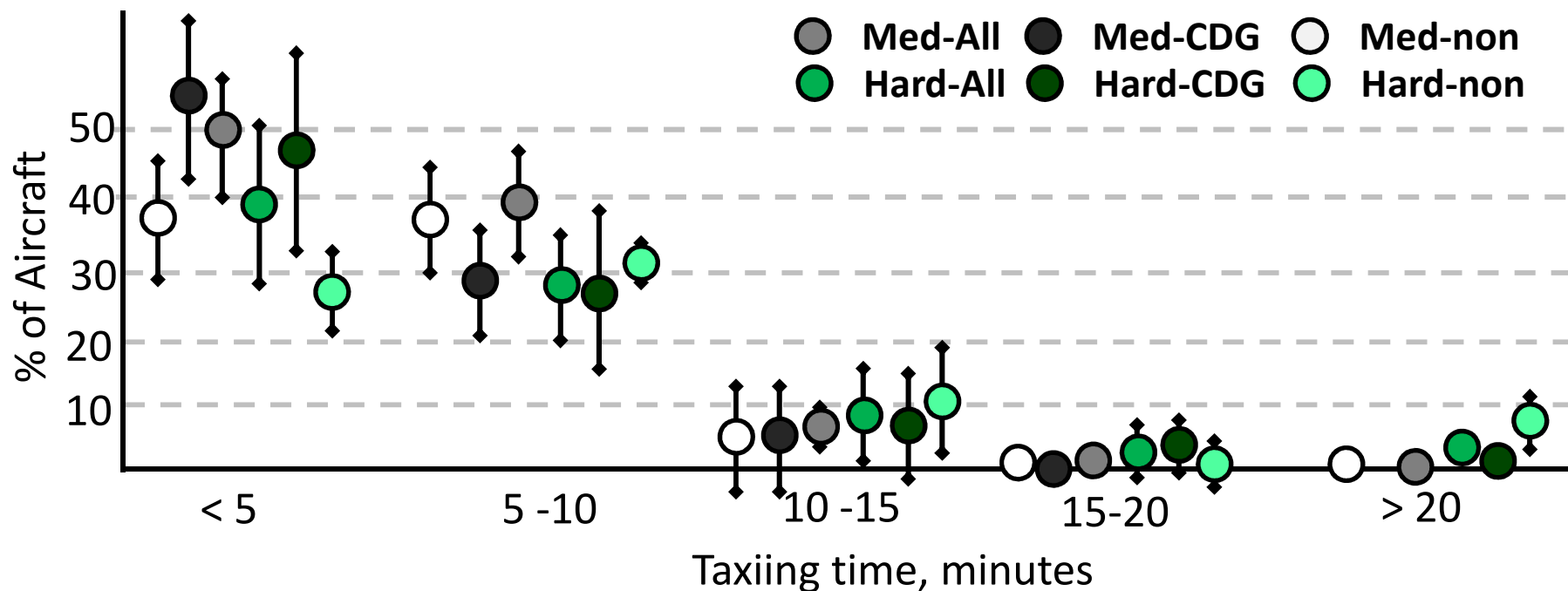
Preliminary Results

10 participants: 4 CDG, 6 non-CDG

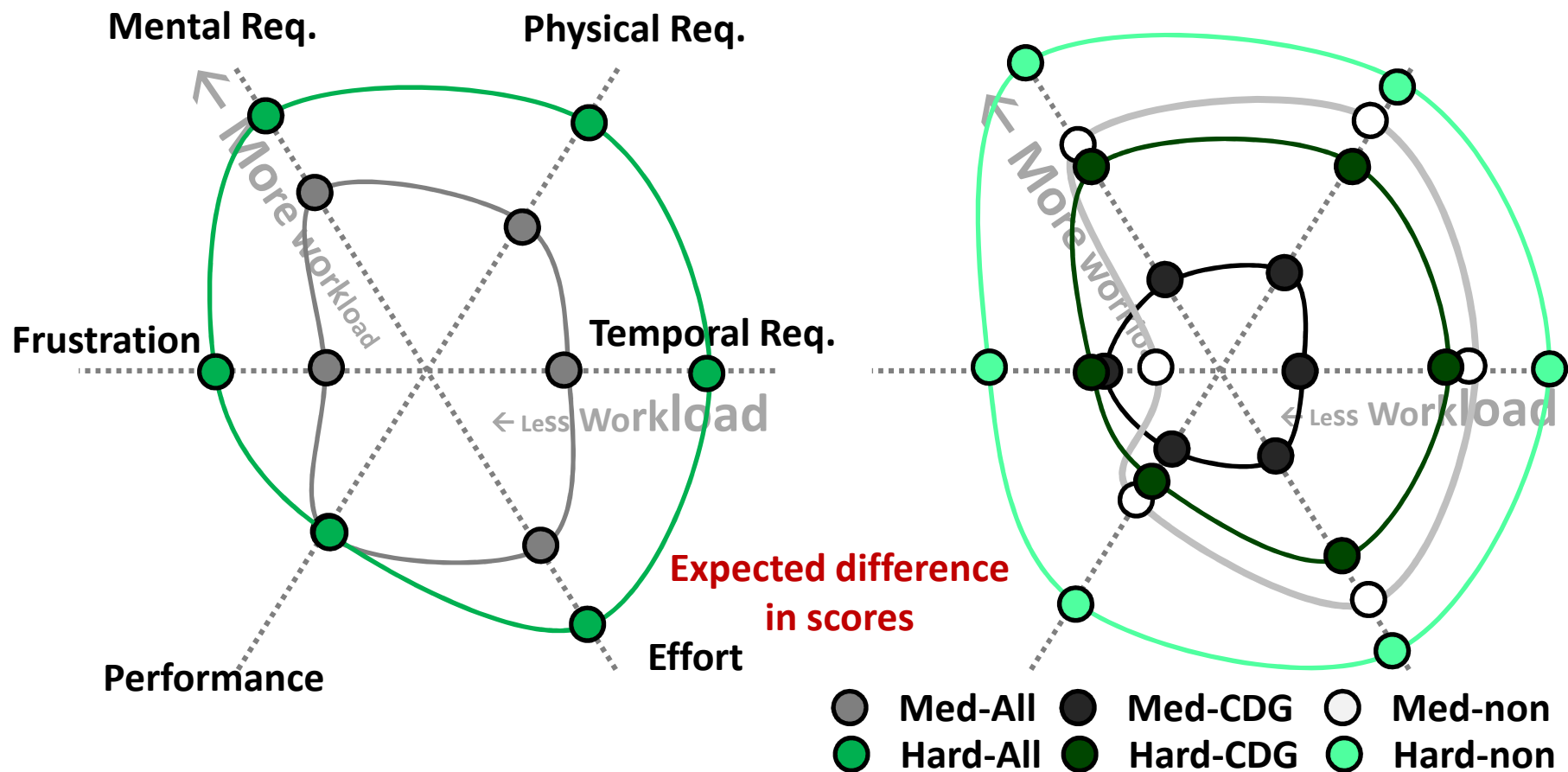
- **Medium:** max of 31 movements in 35 minutes
- **Hard:** max of 41 movements in 35 minutes
 - One ATCO handling all traffic, rather than splitting into two zones
- Scenarios designed for higher rates, ATCOs can advance aircraft



- Results are shown for taxiing time through south ground sector only
 - Taxiing from North usually adds another 7-10 minutes
 - Aircraft simulated to accelerate at max possible under velocity constraints at airport
 - Will likely normalize this time to shortest standard route

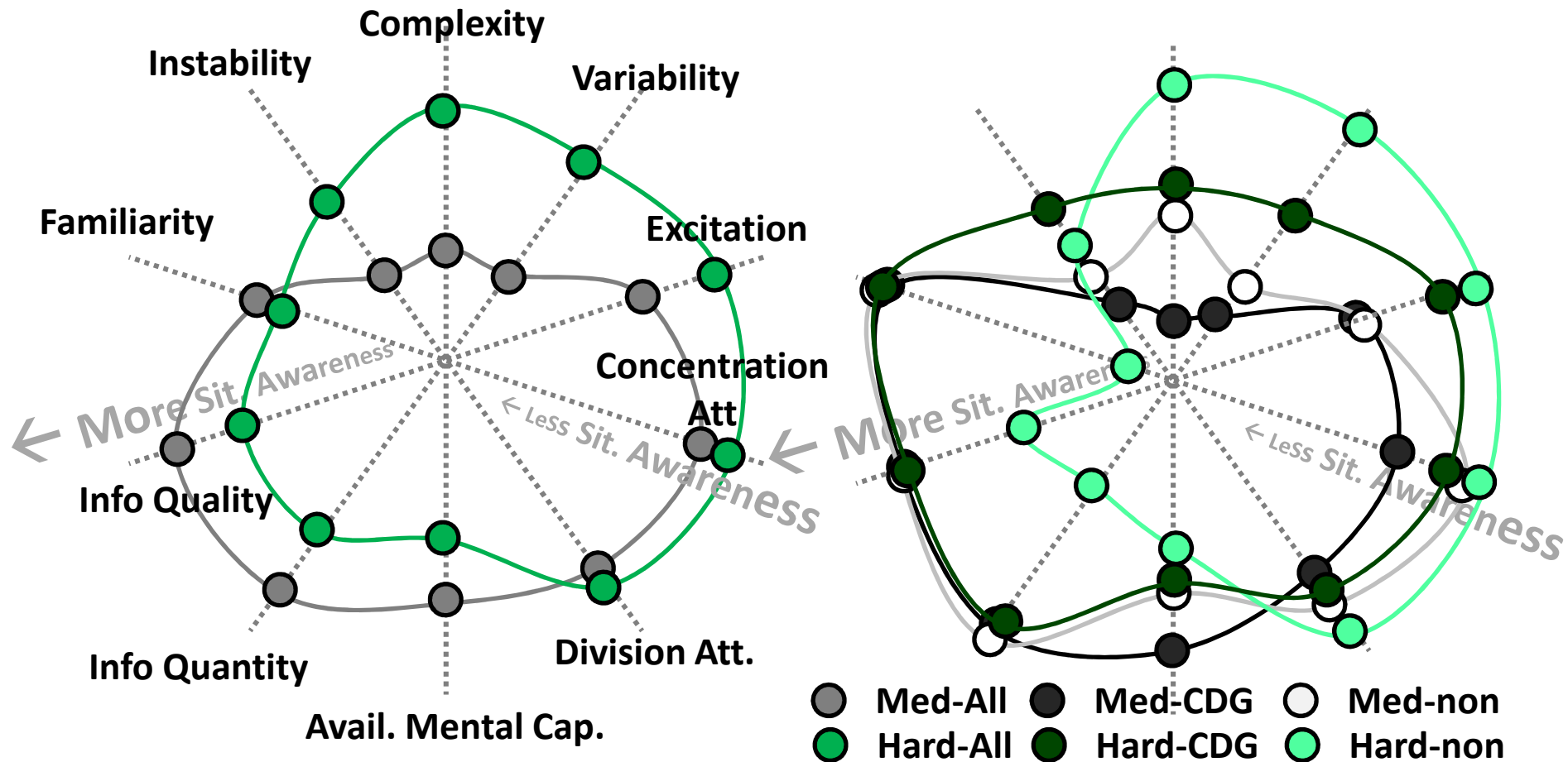


- **Workload:** NASA Task Load Index (TLX)
 - 1 is low workload, 7 is high

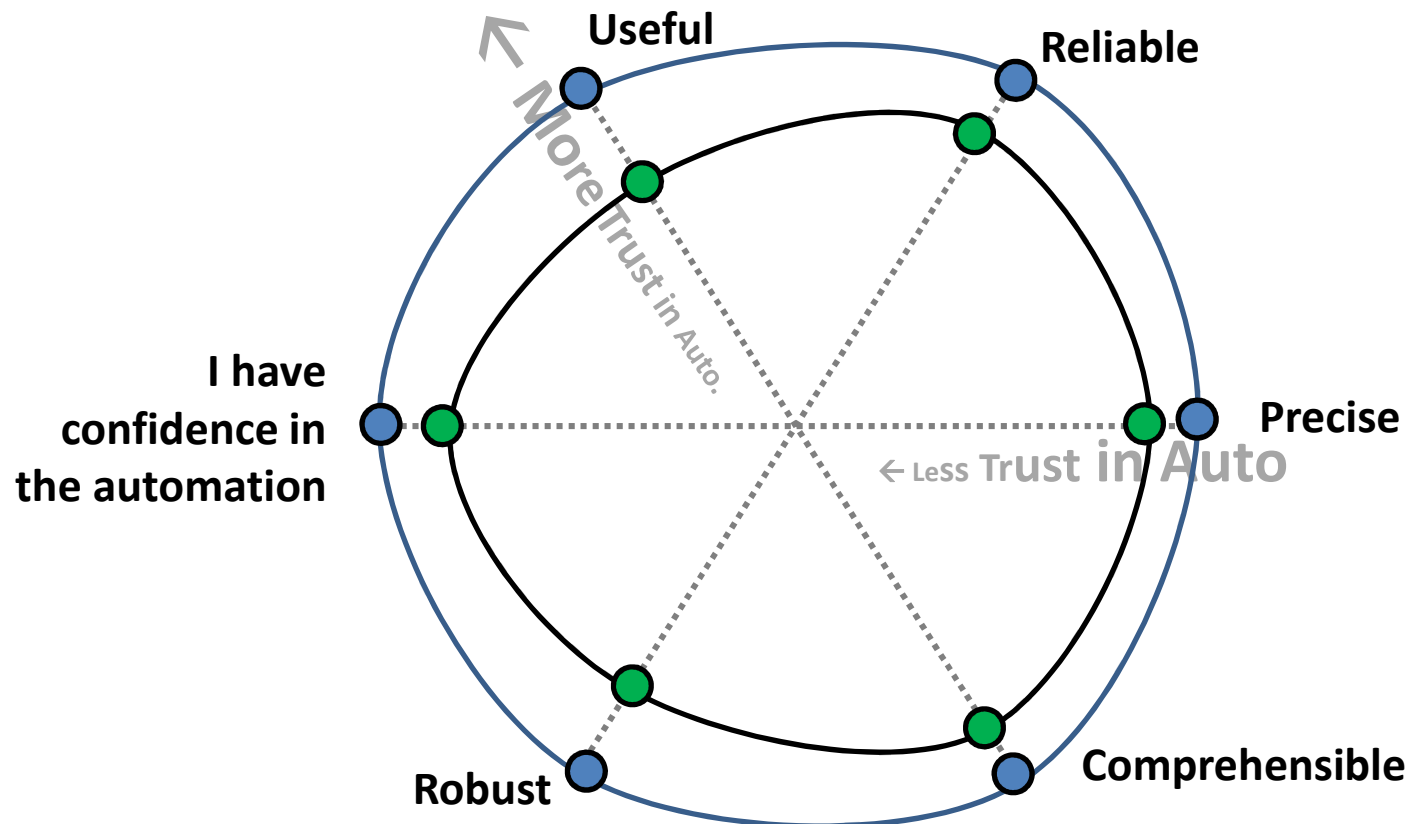


- **Situation Awareness Rating Technique (SART)**

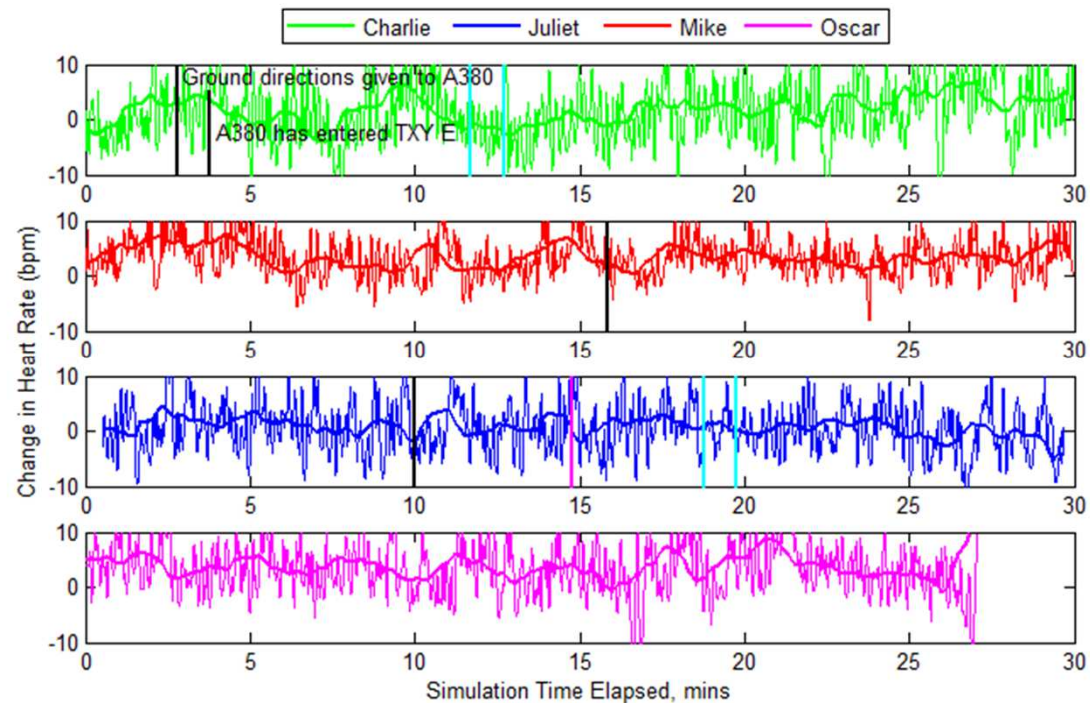
- 1 is low situation awareness, 7 is high



- SHAPE (Solutions for Human Automation Partnerships in European ATM) **Automation Trust Index (SATI)**
 - 0 is little degree of trust, 6 is high degree



- Evaluate participant response (**heart rate, cerebral activity, pupil dilation, reaction time**) to each event (**pilot error, restricted taxiway, taxiway closure, tractor, change in QFU**)
- Noting: # of aircraft affected, possible collisions, etc
- In progress ... !



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Preview of Experiment 2

Interface with conflict detection algorithm, path suggestion

- Automation
 - Use of common A-SMGCS concepts
 - Clearance monitoring
 - Conflict detection (short-term and strategic)
 - Path suggestion based on airport rules
 - DataLink
- Novelties
 - Shared authority between algorithm and ATCOs
 - Exploration of Multi-Agent System (MAS) algorithm for conflict resolution proposal

- Human-Machine Interface
 - Label-based interactions (and an additional timeline)
 - Exploring multimodality: voice and gesture recognition, eye gaze
- Path input
 - Validate proposed route if it fits
 - Rapid interaction to allow user-defined route
- Wide set of clearance types to match actual controller methods (and to keep automation in the loop)
 - Give way, follow this aircraft, hold short of, etc.



- TaxiBot interaction
 - Grouping TaxiBots to minimize radar footprint (match routes)
 - Exploring methods to communicate Aircraft priorities between:
 - TaxiBot with Aircraft + Aircraft
 - Taxibot + Aircraft
- More workshops and interactive sessions planned for 2015
 - Evaluating methods of information representation to ATCOs (e.g. events)
 - Possible parallel study regarding the integration of DMAN information
- Further reflection on procedure evolutions required
- Use of MAS modeling for taxibot simulation

Project MoTa is exploring the usage of **autonomous TaxiBots, eTaxi**, and an **intelligent interface** to permit **varying levels of automation** that can **transition and support** the ground air traffic controller to future traffic loads.

Three experiments are planned to evaluate the three stages of MoTa: **baseline, interface, automation**. We are **between Experiments 1 and 2**. Mini-experiments to **iterate on** and **explore** side concepts continue.

Our Air Traffic Control Tower simulator is simulating two scenarios, **Medium (current)** and **Hard (futuristic)** and is capable of evaluating other scenarios. In addition to operational and subjective measures, we are also collecting behavioral and neurophysiological data.

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Questions ?

Acknowledgements

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