

Competence Center of Manufacturing  
(*Centro de Competência em Manufatura*)

# Impact of HUD Design on Cognitive Load in UAV Control



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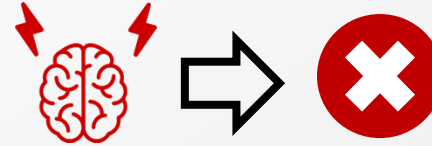
# Agenda

1. Introduction
2. The Research Project
3. Method
4. Results
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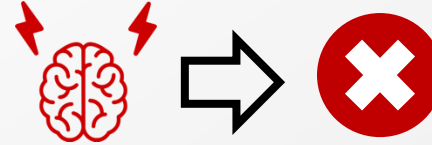
# Introduction

- Cognitive workload contributes for errors in decision-making and response capacities.



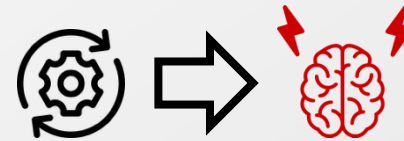
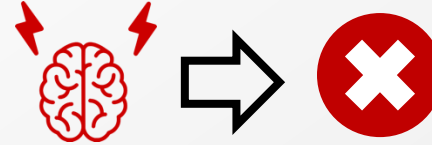
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- Automation and are being increasingly used in aviation.



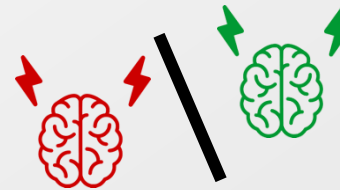
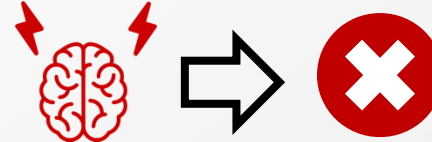
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- Automation and are being increasingly used in aviation.
- Automation can also increase cognitive workload.



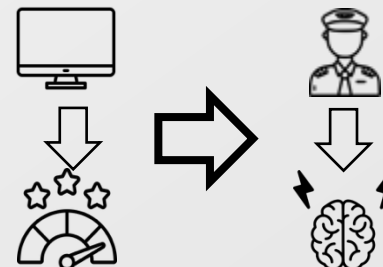
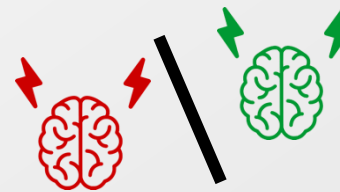
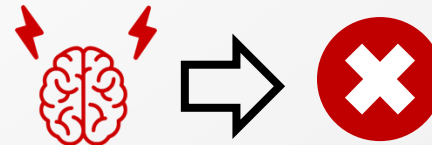
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- Automation can also increase cognitive workload.
- HUDs can affect the cognitive workload.



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- Automation and are being increasingly used in aviation.
- Automation can also increase cognitive workload.
- HUDs can affect the cognitive workload.
- Can we evaluate the HUD efficiency by assessing the pilot's workload?



**Evaluate how different HUD configurations influence the cognitive workload, physiological responses, and flight performance of pilots during remote control of an UAV under communication delay conditions.**

Test three HUDs with a 2-second delay.

Analyze subjective, physiological and performance data

Correlate data results.

Identify the most effective HUD configuration

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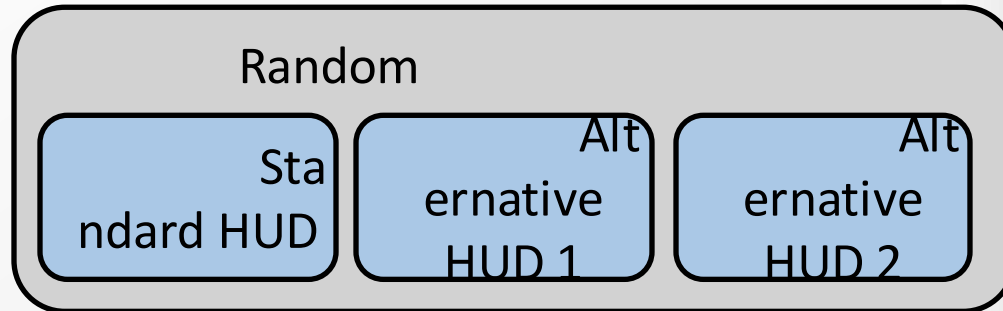
# The Research Project

- Air Domain Study (ADS)
  - A broader research initiative focused on human-machine interaction in UAV operations.
  - Uses a virtual simulator (ADS Simulator) to test pilot behavior in controlled flight scenarios.

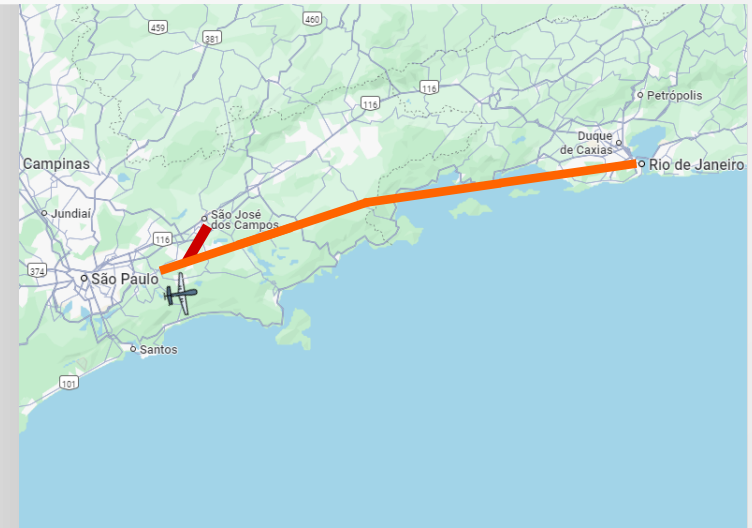


# The Research Project: *About The Experiment*

- Simulation Scenario
  - UAV flies between mapped cities.
  - A failure forces landing at an unmapped airport.
  - Communication with 2-second delay.
- Experiment Design
  - Ethics board and consented by the pilot.
  - 18 participants.
  - Briefing and training.
  - 3 missions:

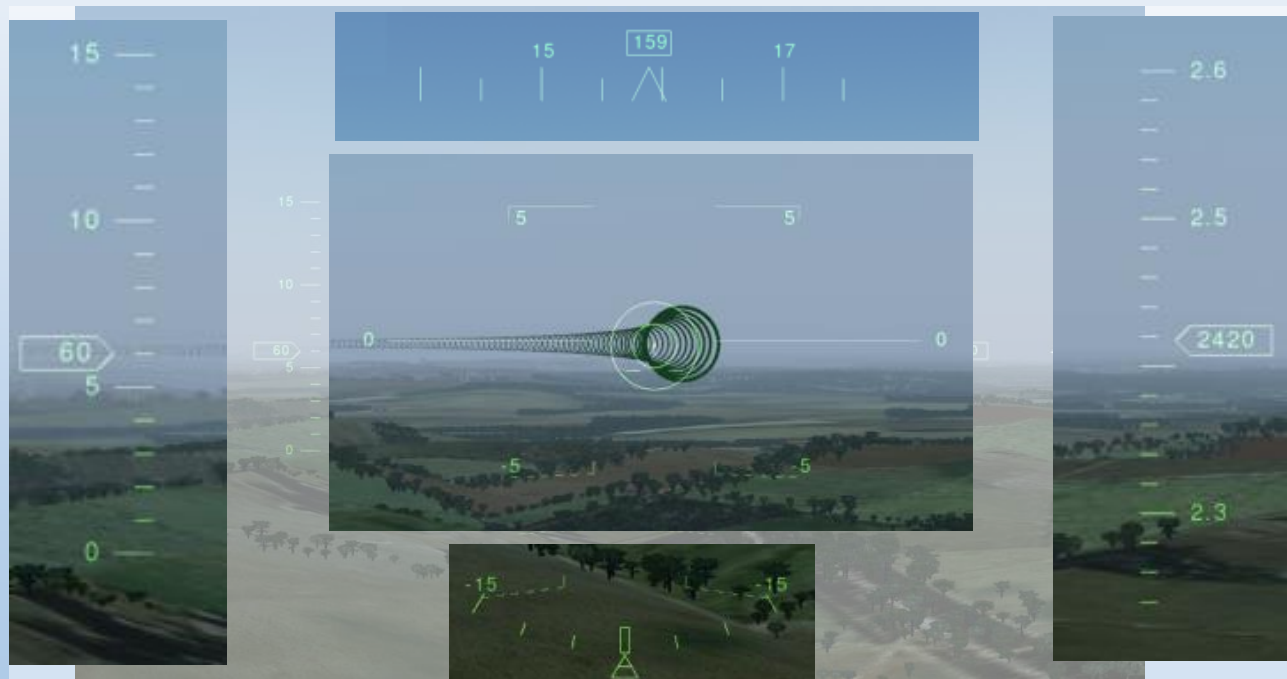


- Task: Follow green-ring waypoints, minimizing deviation.



# The Research Project: *The HUDs*

- Three Proposed HUDs
  - Standard HUD
    - Displays basic flight data: speed, altitude, pitch, and artificial horizon.
    - Includes concentric circles and trajectory lines for direction reference.



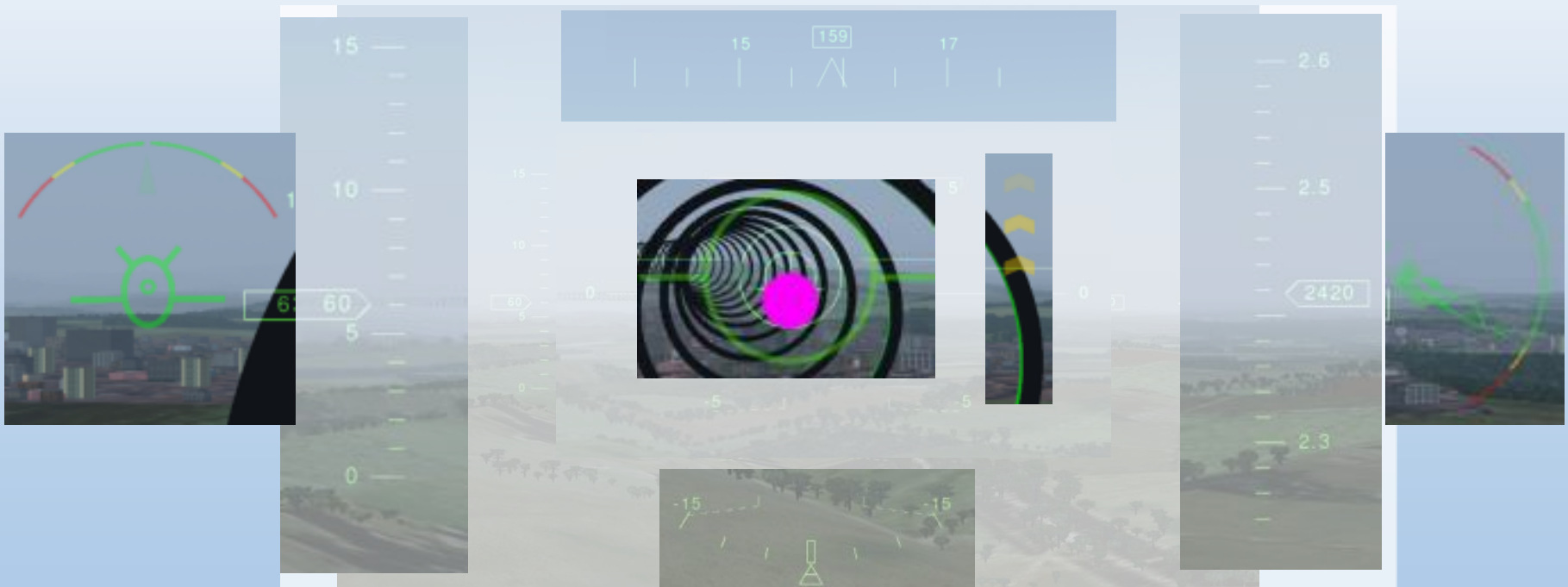
# The Research Project: *The HUDs*

- Three Proposed HUDs
  - Alternative HUD 1
    - Adds roll and pitch angle indicators on screen sides.
    - Uses square reticles to show predicted flight path, aiding in anticipation.



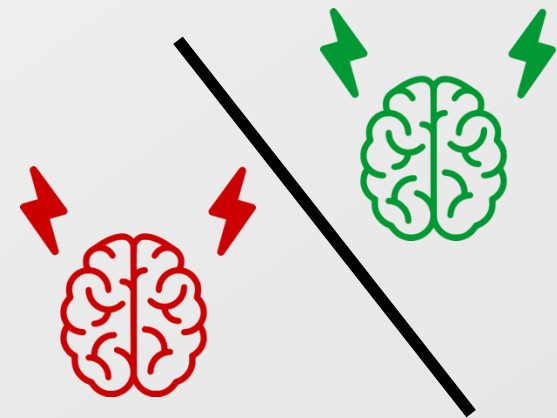
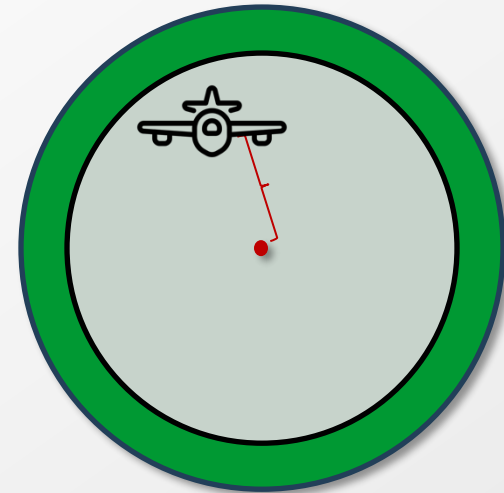
# The Research Project: *The HUDs*

- Three Proposed HUDs
  - Alternative HUD 2
    - Features dynamic color-coded cues (green/yellow/red) for pitch, roll, and speed.
    - Combines fixed and moving reticles to indicate trajectory safety.
    - Chevron indicators suggest throttle adjustments based on altitude trend.



# The Research Project: *Workload Measurement Methods*

- Performance Evaluation
  - Measured by average distance from the center of visual waypoints (green rings).
  - Lower distance indicates better flight control and accuracy.
- Subjective Workload Measurement
  - NASA-TLX
    - After each flight.
  - ISA (Instantaneous Self-Assessment)
    - During Flight.
  - SWORD (Subjective Workload Dominance)
    - After the 3<sup>rd</sup> flights.
- Physiological Measurements
  - EDA (Electrodermal Activity)
  - ECG (Electrocardiogram)
  - Eye Tracking

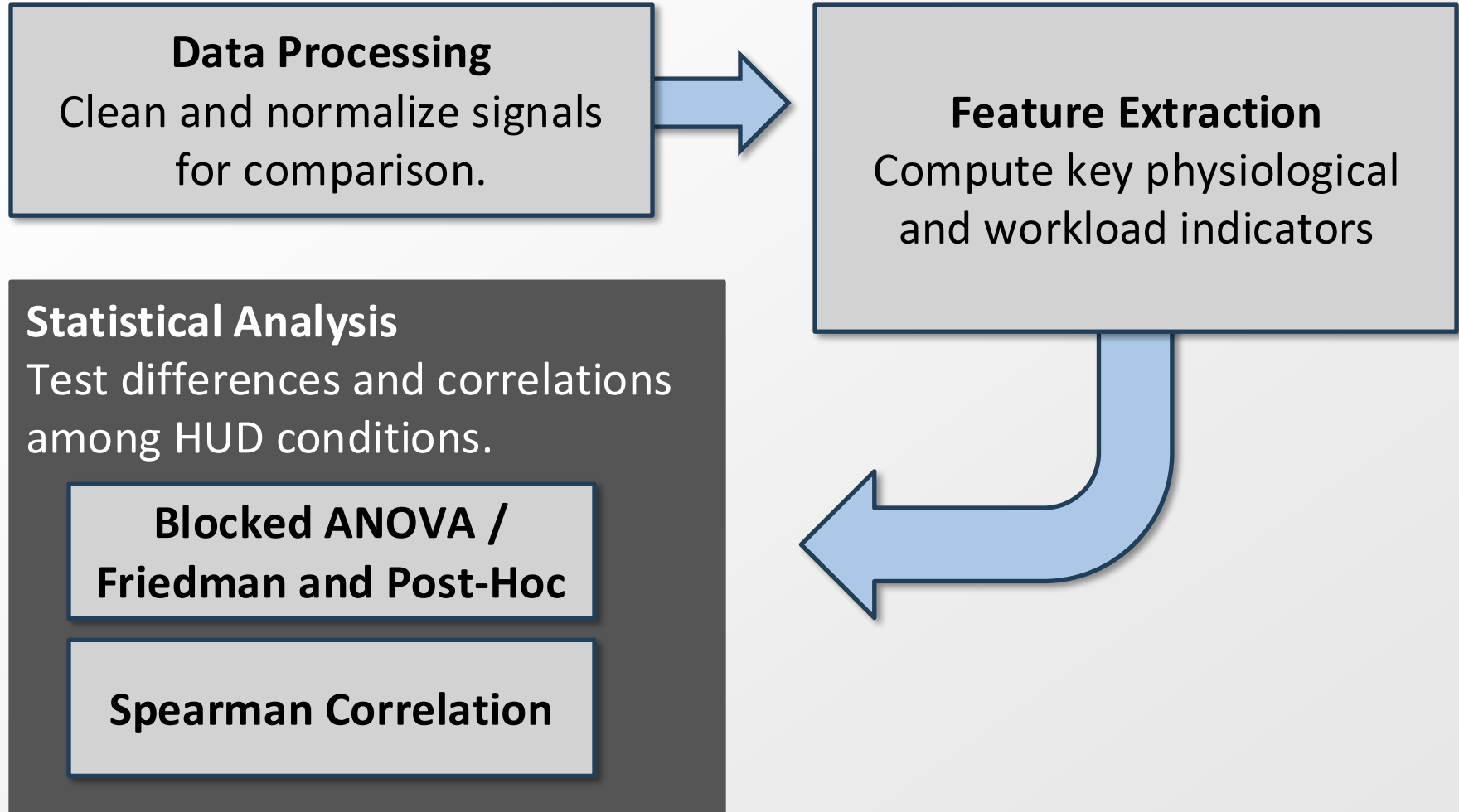


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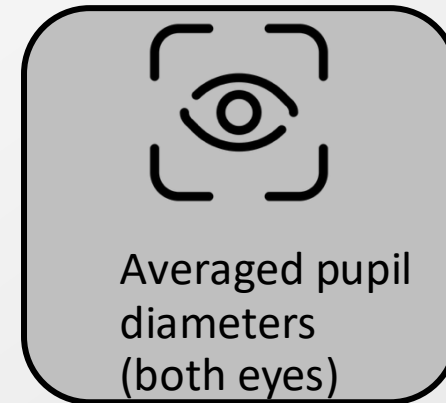
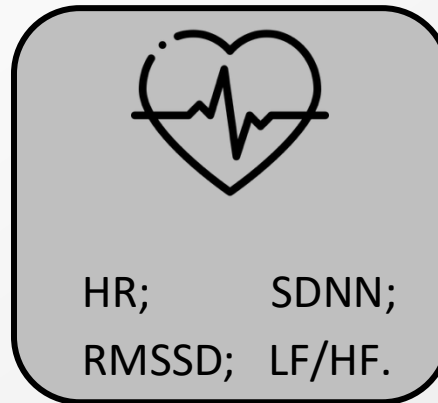
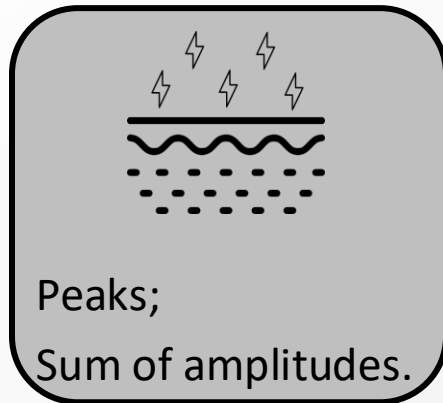
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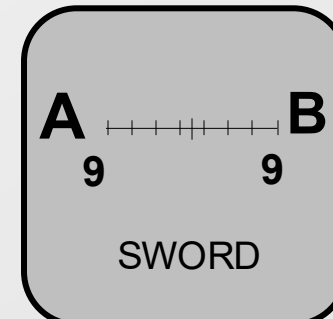
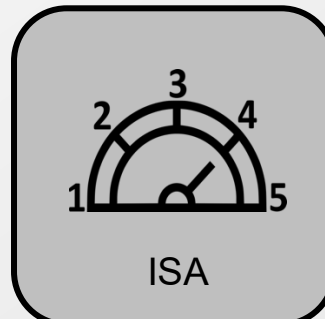
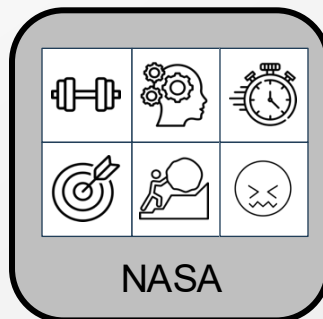
# The Method: *Data Processing and Feature Extraction*

## ■ Physiological Data

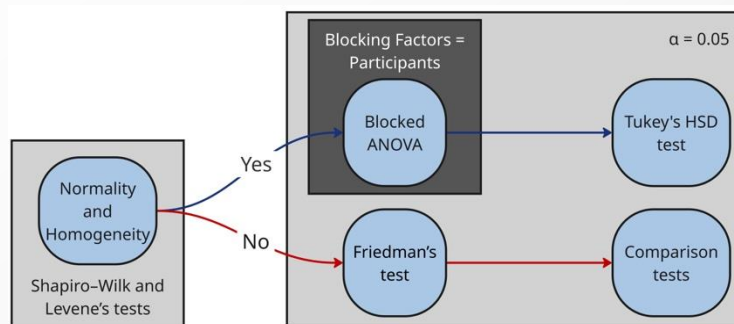
- Signals filtered and normalized relative to each participant's individual baseline.



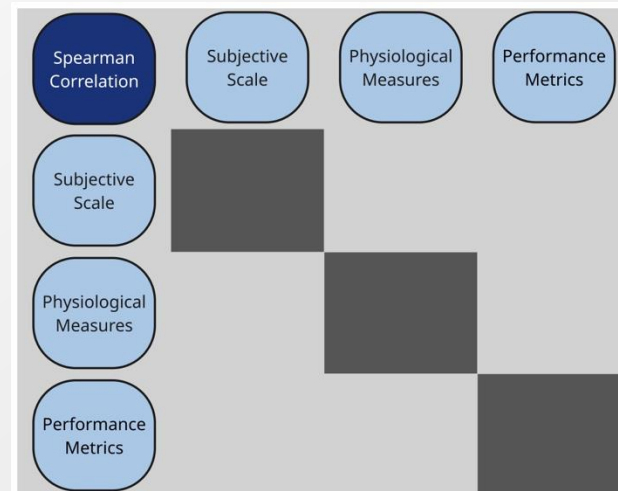
## ■ Subjective Scales



## ■ Comparative Analysis (HUD Conditions)



## ■ Correlation Analysis



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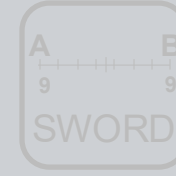
# Results and Discussions:



- HUD 2.0 showed a significantly lower mental workload ( $p \approx 0.05$ )



- Trend toward lower workload with HUD 2.0, but no clear statistical difference.



- 79% of pilots rated HUD 2.0 as the least demanding; No HUD was considered the most fatiguing (58%).



- HUD 2.0 resulted in smaller average deviations, though differences were not statistically significant.



- ECG and EDA
  - No static. differences
- Eye Tracking
  - Lower cognitive effort. In HUD 2.0



- Positive
  - NASA-TLX and SWORD
  - ECG and EOG subtler
- Negative
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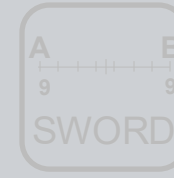
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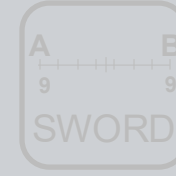
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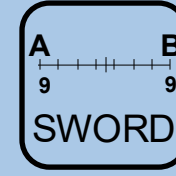
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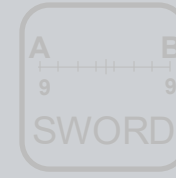
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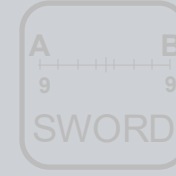
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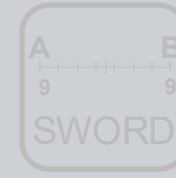
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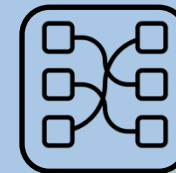
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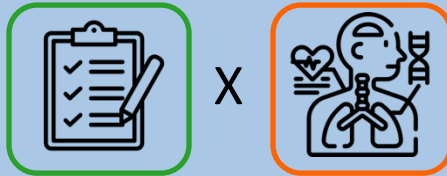
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## Conclusions and future works:



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- Subjective metrics were more sensitive than physiological data.



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- Test more demanding scenarios baseline.



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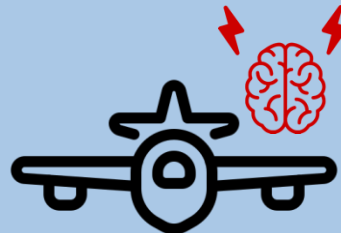


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  - Aeronautics Institute of Technology (ITA)
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# Thank you!



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Marina Ronconi de Oliveira  
Andrew Gomes Perera Sarmiento  
Moacyr Machado Cardoso Junior  
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