Charting the Human Performance Envelope: Results from simulator experiments

Alia Lemkaddem, CSEM, Switzerland
Outline

• Background
• Human Performance Envelope
• Simulator experiments
• Database
• Extracted features
• Results
• Ongoing work
• Conclusion
Background

- Many safety critical domains rely on human operators (Air traffic control, Aviation, Maritime, Rail, Military, Medical, etc.)

- In Air Traffic Management, incidents are often the result of 2 or more factors

- This has led to the notion of a Human Performance Envelope (HPE)

- Need to know when operators are approaching the edges of acceptable human performance, e.g. when should automation take over?
# Simulator experiments

8 different runs were defined

<table>
<thead>
<tr>
<th></th>
<th>Run 1</th>
<th>Run 2</th>
<th>Run 3</th>
<th>Run 4</th>
<th>Run 5</th>
<th>Run 6</th>
<th>Run 7</th>
<th>Run 8</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Turbulence throughout whole scenario</strong></td>
<td>Medium</td>
<td>High</td>
<td>High</td>
<td>x</td>
<td></td>
<td>Medium</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td><strong>Approach and RWY change during initial approach (between IAF and FAF)</strong></td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Low fuel situation throughout whole scenario</strong></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Delay vectors during initial approach (between IAF and FAF)</strong></td>
<td></td>
<td>x</td>
<td></td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Loud noise during final approach (between FAF and landing)</strong></td>
<td></td>
<td></td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Low visibility throughout whole scenario</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td><strong>Localizer interference during final approach (between FAF and landing)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td><strong>Wind shift during final approach (between FAF and landing)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
</tbody>
</table>

**Baseline**

- **M WL**: Medium WorkLoad
- **H WL**: High WorkLoad
- **VH WL**: Very High WorkLoad
- **H Stress**: High Stress
- **High SA**: High/reduced Situation Awareness

*Project #6 HUMAN PERFORMANCE ENVELOPE*
Database

Performance data obtained from the simulator:

- Speed
- Heading or track
- Altitude
- Vertical speed
- Localizer
- Glideslope
- Application of procedures
Database

Subjective data:

- NASA-TLX
- ISA
- 10D-SART
- Samn-Perrelli
- Debriefings
  - Performance curves
  - Behavioral markers
Database

Physiological data:

- Eye tracking glasses (electro-oculogram, EOG)
  - Pupil dilatation
  - Blinking rate
  - Gaze direction

[Image of eye tracking glasses]

[Image of cockpit interface]

[Website: www.smivision.com]
Database

Physiological data:

- CSEM vest:
  - Two electrocardiograms (ECG) leads
  - A transthoracic bio-impedance
  - Skin temperature
  - Accelerometer
  - Multi-channel photoplethysmography (PPG)
Extracted features

ECG signal

- RR intervals (ms)
- Heart Rate, HR (bpm)
Extracted features

Heart rate variability (HRV)

- HRV in time domain:
  - SDNN (standard deviation of NN intervals, ms)

- HRV in frequency domain:
  - HF (High frequency, 0.15 – 0.4 Hz, ms²)
  - LF (Low frequency, 0.04 - 0.15 Hz, ms²)
  - VLF (Low frequency, 0.0033 - 0.04 Hz, ms²)
Results on a single pilot

Run 3: High workload
Run 4: Very High workload

Phase 1 = Start -> TOD glideslope
Phase 2 = TOD -> Decision altitude
Phase 3 = Decision altitude -> End
Results on a single pilot

Run 8: High workload, high stress, high/reduced SA
Results on a single pilot

Run 8: High workload, high stress, high/reduced SA

Phase 1 = Start -> TOD glideslope
Phase 2 = TOD -> Decision altitude
Phase 3 = Decision altitude -> End
Results on a single pilot

HRV features

A) SDNN (ms)

B) HRV HF (ms²)

C) HRV LF (ms²)

D) HRV LF (ms²)

WLN Stress SA Mixed
Results of group analysis

WL  Stress  SA  Mixed

A)  B)
Results of group analysis

WL  Stress  SA  Mixed

A)  B)
Ongoing work

Performance vs physiological parameters

**Run 3  Pilot 1**
- LOC Deviation
- OAS Deviation
- HR
- SQNN

**Pilot 1**
- Mean FP Deviation
- Mean HR
- Mean SQNN

**Heart Rate (bpm) / SQNN (ms)**
- Baseline
  - 0.063141316
  - 64.7587272
  - 46.9384933

- High Wt.
  - 0.226022457
  - 71.9429370
  - 40.3694343
Conclusion

- Physiological measures such as HR, SDNN, HF, LF and VLF are sensitive to an increase in workload and/or stress.

- **High/reduced SA** (Run 6) was very often **not significant** to the baseline.

- **HR and SDNN** were particularly sensitive to the **increase in workload**.

- **HRV features** derived from the spectral analysis (**HF**, **LF** and **VLF**) showed a significant response to the **increase of stress**.

- Normalization of the **HR** is important in the group analysis (reliable baseline is required).
Thank you