The Design Of A Use(r)-Centered Pilot-IMS Interface

An Overview of the Activities and Products of the Cognitive Engineering Group
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Cognitive Engineering

**Goal:** Improve the safety of flight in icing conditions. Develop smart system to improve ice tolerance.

**Objectives:** Design human-centered interface that

a) informs pilots about presence/changes and performance effects of icing conditions

b) communicates IMS/IPS status/activities/limitations to crew in timely and effective manner

c) provides pilots with advisories for handling inflight icing encounters safely

**Approach:** Identify pilots’ information requirements

Develop candidates for human-centered cockpit interface

Evaluate effectiveness and robustness of candidates in simulator studies
Smart Icing System Review

Smart Icing System Review, September 30 – October 1, 2002

The Cognitive Engineering Group

WHAT?

Information Requirements

Information Automation/Representation

Advisory Functions/Decision Support

HOW?

Large-Scale Pilot Survey

Simulator Study Comparing Command vs. Status Display

Design and Testing of Alerting and Status Display

Simulator Study on the Effectiveness of Dynamic Reliability Information

Envelope Protection

Pilot Survey + Accident/Incident Reviews

McCray, Schroeder, and Sarter

McGuirl, Schroeder, McCray, and Sarter

McGuirl and Sarter

Schroeder and Sarter

THE COGNITIVE ENGINEERING GROUP

McCray, Schroeder, and Sarter

McGuirl, Schroeder, McCray, and Sarter

McGuirl and Sarter

Schroeder and Sarter

Smart Icing System Research
Cognitive Engineering

Icing Encounter

Detection → Diagnosis → Monitoring → Action Selection → Execution of Action

Attention Capture/Guidance

Possible IMS Functions

Status Display
Trend Display
Command Display
Envelope Protection; Flight Control Adaptation

Decision Support
Attention Capture and Guidance
Cognitive Engineering

Icing Encounter

Possible IMS Functions

Detection

Attention Capture/Guidance

Diagnosis

Status Display

Monitoring

Trend Display

Action Selection

Command Display

Execution of Action

Envelope Protection; Flight Control Adaptation
Multimodal Information Presentation

Comparison of Effectiveness of Visual and Tactile Cues For Presenting Icing-Related Information

- Modern flight decks impose considerable demands on visual and auditory channels

- Tactile channel is underutilized although powerful means of capturing attention and useful for providing some diagnostic information

- As more systems/data are added, multimodal information presentation becomes more important to avoid resource competition (Multiple Resource Theory)
Tactile Condition

- Vibrotactors placed on inside of the forearm.
- Cues were presented sequentially (wing → tail) cycled for 5 seconds.
The lack of any learned mapping of tactile patterns precluded having an substitutive tactile condition.
Detection of Icing Cues

Tactile group performed as well as the two visual groups
Accuracy in Identifying Icing Cues

- VA: 97.7%
- VS: 99.8%
- TA: 96.9%
- TA new: 98.3%

61% of misidentifications involved light and medium icing levels

Refinement to tactor cues resulted in a 59% reduction in misidentifications
Secondary Visual Task Performance

Tactile cues afforded better divided attention
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Icing Encounter

Detection → IMS Functions

Diagnosis

Monitoring

Action Selection

Execution of Action

Attention Capture/Guidance

Status Display

Trend Display

Command Display

Envelope Protection; Flight Control Adaptation

Decision Support
Decision Support

The IMS as a Decision-Support System:
A Simulator Study Comparing
Status and Command Displays

Beth Schroeder and Nadine Sarter

Note: Thesis document is included on the CD
- **Participants:** 27 instructor pilots

- **Flight experience:** average: 777 (827) hrs
  range: 200-4,600 hrs

- **3 conditions:**
  - baseline (no aid, except for icing probe)
  - status display
  - command display

- Medium-fidelity simulation of twin-engine aircraft
Decision Support

The Status Display
Decision Support

The Command Display
Decision Support

Stall frequency as function of display condition and accuracy of IMS information

Display Condition X Accuracy
Decision Support

Summary

- Status display appears to be preferable.
  - equally beneficial with accurate information
  - less vulnerable to effects of inaccurate information than command
  - fewer recovery errors

- Still need better support for trust calibration as well as long-term planning and decision-making
Supporting trust calibration: The case for dynamic reliability feedback

John McGuirl

Note: Thesis document is included on the CD
Trust Calibration

Use of automated systems, such as decision aids, has been linked to several factors including:

- users’ confidence in performing the task
- task complexity
- risk involved in task
- perceived and actual reliability of the automation

Trust calibration refers to how closely perceived reliability matches actual reliability
Trust Calibration Experiment

Participants: 30 U of I instructor pilots

Flight experience:
Average: 825 hrs
Range: 275-2400 hrs

Session 1 (1 hour)
- introduction to icing symptoms, simulator, and experiment

Sessions 2 and 3 (2 hours each)
- simulator practice
- 14 data trials (7 cruise + 7 ILS approaches)
- debriefing at the end of Session 3
Trust Calibration Experiment

**Between-subjects variable**
- reliability information (static vs dynamic)

**Within-subjects variables**
- type of DSS (command vs status)
- accuracy of decision aid (correct vs incorrect)
- familiarity with situation (wing vs tail icing)
- taskload (cruise vs ILS approach)
- reliability level (high, low, variable)
- reliability display availability (continuous vs on-demand)
  - dynamic group only
Trust Calibration Experiment

Cockpit Display
Trust Calibration Experiment

De-briefing indicated the potential to mis-interpret the arrow length to indicate magnitude of required pitch input.
Cockpit Display
Trust Calibration Experiment

Reliability Trend Display

Provided a 5-minute history of reliability

Y-axis values omitted to avoid fixation on a particular value

Reliability was high for the first minute of each trial

High

Variable

Low
Trust Calibration Experiment

**Dependent Variables**

- appropriateness of initial and secondary response to icing
- stall events
- tracking performance
- detection of navigation-aid failures

- reliability display sampling (dynamic group only)
Stall frequency as a function of availability of reliability information

- Static: 64%
- Dynamic: 36%
Trust Calibration Experiment

Stall frequency as a function of reliability information and decision aid accuracy

![Graph showing stall frequency as a function of reliability information and decision aid accuracy. The graph compares accurate and inaccurate conditions, with lines representing static and updated data.]
Trust Calibration Experiment

Stall frequency as a function of decision aid type and decision aid accuracy

(Schroeder, 2000)
Trend Display Sampling

Icing Phase

- No Icing
- Initial Alert Minor Physical Cues
- Moderate Physical Cues
- Strong Physical Cues
- Buffeting begins
- Buffeting

Samples / min

0 0.5 1 1.5 2 2.5 3 3.5

Trend Display Sampling begins

Initial Alert

Minor Physical Cues

Moderate Physical Cues

Strong Physical Cues

Buffeting begins

Buffeting
Pilot compliance with decision aid vs. DSS accuracy

Reliability averages to 70% overall.
Trust Calibration Experiment

Reversal of compliance as a function of reliability information display

% trials with reversal

- Static: 7
- Dynamic (high): 10.5
- Dynamic (variable): 26
- Dynamic (low): 16
Trust Calibration Experiment

Perceived accuracy as a function of DSS and information type

![Graph showing perceived accuracy ratings for Status and Command with Static and Dynamic conditions. The ratings are 81 and 64.7 for Status Static and Dynamic, respectively; 85.7 and 66.3 for Command Static and Dynamic, respectively.]
Trust Calibration Experiment

Detection of navigation-aid failure as a function of reliability information type

![Bar chart showing detection rates for static and dynamic conditions. The static condition has a detection rate of 13.3%, while the dynamic condition has a detection rate of 20%.]
Summary

Providing system reliability feedback afforded better trust calibration, resulting in less over-reliance and fewer stall events.

Also appears to have reduced automation bias, allowing for more flexible, adaptive responses for error recovery.

Given the added information, command display may be more desirable.

Further work is needed to explore situations which contain
- less predictable reliability feedback
- larger number of possible diagnoses
Overall Design Concept

Sample Sequence of Possible Icing Encounter and Associated IMS Indications
Future Work

- Addition/substitution/integration of auditory and tactile feedback for supporting time-sharing and attention management

- Review and evaluation of SIS interface concept from a systems engineering perspective

- Collaboration with other team-members on the refinement of the envelope protection/flight control adaptation approach and indications