Human Factors Research Methods
Human Factors Research Methods: An Overview

- Experimental Methods
  - Relationships studies
    - independent variables → dependent variables
  - Comparative studies
- Descriptive Methods
  - Literature Review
  - Observation
  - Surveys and Questionnaires
  - Incident and Accident Analysis
  - Modeling and Simulation
  - Meta-Analysis
- Always involve human subjects/participants (directly or indirectly)
Human Factors and Aviation Safety

Primary Causes of Aircraft Accidents

- Flight Crew: 55%
- Airplane: 17%
- Weather: 13%
- Misc./Other: 7%
- Airport/ATC: 5%
- Maintenance: 3%

Source: Boeing Commercial Airplanes
Human Factors Research Methods In My Cockpit Task Management (CTM) Research

CTM: Process by which pilots selectively attend to multiple, concurrent flight tasks to safely and effectively complete a flight.

Lockheed L1011

Boeing 777
Developing a Conceptual Framework For CTM: Literature Review, Analysis, and Modeling

• Literature Review
  • Cockpit Resource Management (e.g., Lauber, 1986)
  • Human error in aviation (e.g., Nagel, 1988; Wiener, 1987; Ruffel-Smith, 1979)
  • Cognitive psychology (e.g., Navon & Gopher, 1979; Wickens, 1984)
  • Systems theory (e.g., Padulo & Arbib, 1979)

• A Model of CTM
  • initiate tasks to achieve goals
  • assess status of all tasks
  • terminate completed tasks
  • prioritize remaining tasks based on
    – importance:
      1. aviate
      2. navigate
      3. communicate
      4. manage systems
    – urgency
    – other factors (?)
  • allocate resources (attend) to tasks in order of priority

Determining the Significance of CTM: Accident Analysis

- **CTM Error Taxonomy**
  - Task Initiation: early / late / incorrect / lacking
  - Task Prioritization: incorrect
  - Task Termination: early / late / incorrect / lacking

- **Method:**
  - Reviewed 324 National Transportation Safety Board (NTSB) Aircraft Accident Reports (1960 – 1989)
  - Developed pre-impact timelines, classified CTM errors

- **Findings:** 80 CTM errors in 76 (23%) of the accidents

<table>
<thead>
<tr>
<th>CTM Error</th>
<th># Accidents</th>
<th>% CTM Accidents</th>
<th># CTM Errors</th>
<th>% of All CTM Errors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task Initiation</td>
<td>35</td>
<td>46</td>
<td>35</td>
<td>44</td>
</tr>
<tr>
<td>Task Prioritization</td>
<td>24</td>
<td>32</td>
<td>24</td>
<td>30</td>
</tr>
<tr>
<td>Task Termination</td>
<td>21</td>
<td>28</td>
<td>21</td>
<td>26</td>
</tr>
</tbody>
</table>

Determining the Significance of CTM: Incident Analysis

- **Method:**
  - Reviewed 470 Aviation Safety Reporting System (ASRS) incident reports:
    - Controlled Flight Toward Terrain incidents
    - In-flight engine emergency incidents
    - Terminal flight phase incidents
  - Identified concurrent tasks, classified CTM errors
- **Findings:** 231 (49%) of the incidents involved CTM errors

<table>
<thead>
<tr>
<th>CTM Error</th>
<th># Incidents</th>
<th>% CTM Incidents</th>
<th># CTM Errors</th>
<th>% of All CTM Errors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task Initiation</td>
<td>137</td>
<td>59</td>
<td>145</td>
<td>42</td>
</tr>
<tr>
<td>Task Prioritization</td>
<td>133</td>
<td>58</td>
<td>122</td>
<td>35</td>
</tr>
<tr>
<td>Task Termination</td>
<td>83</td>
<td>36</td>
<td>82</td>
<td>23</td>
</tr>
</tbody>
</table>


**Conclusion:** CTM is a significant factor in flight safety.
**Understanding CTM: Incident Analysis**

- Does cockpit automation level affect task performance?
- **Method:**
  - Reviewed 420 NASA ASRS incident reports
    - 210 advanced technology + 210 conventional technology
      - large commercial transport aircraft
      - 2 pilots
  - Reviewed narratives
  - Constructed task models
  - Classified errors
  - Comparison with t-tests
- **Findings:**
  - Error rate higher for advanced technology aircraft \((p = 0.036)\)
  - Error rate decreasing \((p = 0.032)\)

**Task Prioritization Error Frequency**

<table>
<thead>
<tr>
<th>Submission Period</th>
<th>Advanced Technology</th>
<th>Traditional Technology</th>
<th>Total Errors by Submission Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>1988-1989</td>
<td>13</td>
<td>7</td>
<td>20</td>
</tr>
<tr>
<td>1990-1991</td>
<td>11</td>
<td>5</td>
<td>16</td>
</tr>
<tr>
<td>1992-1993</td>
<td>4</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td><strong>Total Errors by Aircraft Technology</strong></td>
<td><strong>28</strong></td>
<td><strong>15</strong></td>
<td></td>
</tr>
</tbody>
</table>

Understanding CTM: Simulator Study

- What are the factors that affect task prioritization in the CTM process?
- Method: simulator study
  - Professional pilot participants
  - Difficult San Francisco approach scenarios
  - Task prioritization Challenge Probe Points (CPPs)
  - Stop sim or record & replay for interviews on CPPs: “Why did you ...?”
  - Analysis with ANOVA
- Findings: Prioritization Factors
  1. Procedural compliance
  2. Task importance
  3. Task salience
  4. Task status
  5. Time/Effort requirements
  6. Task urgency

Improving CTM: Experimental Study (Training)

- Can task prioritization be trained?
- APE Mnemonic: Assess, Prioritize, Execute
- Simulator Experiment
  - Licensed pilot participants
  - Independent variable: training (Descriptive, Prescriptive, None/Control)
  - Dependent Variables
    - Task Prioritization Error Rate
    - Prospective Memory Recall
  - Flight – training / no training – flight
  - ANOVA of results

Improving CTM: Experiment (System Comparison)

• Can CTM be facilitated by a cockpit aid?
• AgendaManager (CTM aid) vs. EICAS (conventional pilot warning/alerting system)
• Simulator Experiment
  • Professional pilot participants
  • Independent Variables: Alerting (AMgr vs. EICAS), Scenario
  • Dependent Variables: CTM metrics
  • Flight 1 (EICAS/AMgr) – Flight 2 (Amgr/EICAS)
• ANOVA of results


Findings

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>AMgr</th>
<th>EICAS</th>
<th>sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within subs. correct prioritization</td>
<td>100%</td>
<td>100%</td>
<td>NS</td>
</tr>
<tr>
<td>Subs. fault correction time (sec)</td>
<td>19.5</td>
<td>19.6</td>
<td>NS</td>
</tr>
<tr>
<td>A/F programming time (sec)</td>
<td>7.9</td>
<td>5.9</td>
<td>NS</td>
</tr>
<tr>
<td>goal conflicts % corrected</td>
<td>100%</td>
<td>70%</td>
<td>0.10</td>
</tr>
<tr>
<td>goal conflict resolution time (sec)</td>
<td>34.7</td>
<td>53.6</td>
<td>0.10</td>
</tr>
<tr>
<td>Subs./Aviate correct prioritization</td>
<td>72%</td>
<td>46%</td>
<td>0.05</td>
</tr>
<tr>
<td>Mean # unsatisfactory tasks</td>
<td>0.64</td>
<td>0.85</td>
<td>0.05</td>
</tr>
<tr>
<td>% time all tasks satisfactory</td>
<td>65%</td>
<td>52%</td>
<td>0.05</td>
</tr>
<tr>
<td>Mean participant rating (-5 - +5)</td>
<td>4.8</td>
<td>2.5</td>
<td>0.05</td>
</tr>
</tbody>
</table>
1. Automation may demand attention.
2. Automation behavior may be unexpected and unexplained.
3. Pilots may be overconfident in automation.
4. Behavior of automation may not be apparent.
5. Failure assessment may be difficult.
6. Mode transitions may be uncommanded.
7. Mode awareness may be lacking.
8. Mode selection may be incorrect.
9. Situation awareness may be reduced.
10. Understanding of automation may be inadequate.

Operating Room Human Factors Research: Observation and Modeling

- Observed surgical procedures in Oregon hospital.
- Interviewed surgeons, nurses, assistants.
- Developed IDEF0 process (functional) model of laparoscopic cholecystectomy (gall bladder removal using minimally invasive procedures) for future error identification.

Systemic vulnerabilities to Verres Needle insertion

- Improperly visualize underlying anatomy.
- Miss important cue for needle placement.
- Choose wrong insertion angle.
- Fail to stabilize abdominal wall.
- Misinterpret the degree of needle resistance ...
- Err in sensing the click of the needle
- etc.

Validated by post hoc literature review.

Operating Room Distractions and Interruptions

Research in collaboration with OHSU Department of Surgery

- Simulated laparoscopic cholecystectomy
- 18 OHSU 2\textsuperscript{nd} & 3\textsuperscript{rd} year surgical residents
- Independent Variable: Distracted vs non-distracted
- Dependent Variables:
  - Damage to organs
  - Collateral blood loss
  - Remembering to announce closure
  - Total and cauterizing times
- Results: 8 out of 18 committed errors when distracted versus 1 out of 18 when not distracted

Distractions/Interruptions

<table>
<thead>
<tr>
<th>Distraction</th>
<th># Errors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual movement</td>
<td>0</td>
</tr>
<tr>
<td>Ringing cell phone</td>
<td>1</td>
</tr>
<tr>
<td>Question about “crashing” patient</td>
<td>4</td>
</tr>
<tr>
<td>Side conversation</td>
<td>3</td>
</tr>
<tr>
<td>Question about choice of profession</td>
<td>2</td>
</tr>
<tr>
<td>Dropped metal tray</td>
<td>0</td>
</tr>
</tbody>
</table>

A Comparison of Human and Near-Optimal Task Management Behavior

• Objectives
  • Framework for studying human TM behavior & performance
  • Study human TM strategy, tactics
  • Compare human TM performance with near-optimal heuristic (tabu search)

• Background
  • Common TM situations
  • Engineering models of TM

• Method: “Simulator” Experiment
  • Apparatus: Tardast TM “game”
  • Participants: 10 OSU students
  • 5 randomized scenarios
  • IVs: DRs, CRs, Ws
  • DVs: scores, strategies, tactics
  • Compared with tabu search heuristic

• Results
  • Human < tabu (not by much)
  • Different strategies, tactics

• Conclusions
  • Too many tasks → too few
  • Over-attention to salient stimuli
  • Tardast a useful framework

Human Factors Research Methods: Summary

- **Experimental Methods**
  - Relationships studies
    - independent variables $\rightarrow$ dependent variables
  - Comparative studies

- **Descriptive Methods**
  - Literature Review
  - Observation
  - Surveys and Questionnaires
  - Incident and Accident Analysis
  - Modeling and Simulation
  - Meta-Analysis

- Always involve human subjects/participants (directly or indirectly)
A Human Factors Study

adapted from the MSIE thesis research of William Secor
Introduction

- Pervasiveness of multi-tasking
- Human limitations in multi-tasking
- Potential for automated aiding of human multitasking
- (Overview of paper)
Background/Literature Review

• Attention, Multi-Tasking, and Task Management

  - theories of attention

  - importance & difficulties of multi-tasking, task management

  - task (mis-)management significant to flight safety

  - Tardast (ETME precursor) as an environment in which to study task management etc.
Background/Literature Review

- **Automation**
  - information acquisition automation
  - information analysis automation
  - decision and action selection automation
  - action implementation automation

- **Automated aiding of task management?**
Objective

● Answer the research question:

Is task management performance improved by the introduction of information acquisition or analysis automation?
Methodology

- Participants: 30, ≥ 18 years of age, both genders
- Apparatus: ETME
  - no automation (baseline)
  - with acquisition automation: highlight critical tasks
  - with analysis automation: show time to red
Methodology

- **Experimental design**
  - Independent Variable and levels: automation level
    1. no automation (baseline)
    2. acquisition automation
    3. analysis automation
  - Dependent Variable and measure: ETME score

\[
S(T) = \sum_{i=1}^{n} \sum_{t=0}^{T} w_i q_i(t)
\]

- Null hypothesis, \( H_0: \bar{S}(T_{\text{final\_none}}) = \bar{S}(T_{\text{final\_acq}}) = \bar{S}(T_{\text{final\_ana}}) \)
Methodology

• Experimental procedure
  1. P reads & signs informed consent
  2. P randomly assigned to treatment order
     i. none-acq-ana
     ii. none-ana-acq
     iii. acq-ana-none
     iv. acq-none-ana
     v. ana-acq-none
     vi. ana-none-acq
  3. P trains for first set (e.g., none), then performs first set
  4. P trains for second set (e.g., acq), then performs second set
  5. P trains for third set (e.g., base), then performs third set
Methodology

- Control of extraneous variables – to prevent them from becoming confounding, e.g.,
  - time of day … ?
  - age … ?
  - computer experience … ?
  - gaming experience … ?
  - gender … ?
  - etc.
- Data collection: experimenter records scores
- Statistical analysis
  - t-tests
  - ANOVA
Results (Hypothetical)
Discussion

- Acquisition > Analysis > No Automation
- Analysis > No Automation:
  - statistically significant
  - practically significant?
- Acquisition > Analysis:
  - statistically significant
  - practically significant?
  - why?
- Generalizable?
- Technically feasible?
- etc.
(Summary,) Conclusions and Recommendations

• (Summary)
• Conclusions
  • Acquisition > Analysis > No Automation in ETME
  • etc.
• Recommendations
  • Explore other means of acquisition/analysis automation
  • Repeat in higher fidelity simulator
  • etc.