Checklists, Monitoring, and Multitasking in Cockpit Operations

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FAA Research Review
15-16 October, 2008
Forgetting to Perform Procedural Tasks

• 20 August 2008: MD-82 on takeoff from Madrid
  – Flaps not in takeoff position
  – Takeoff configuration warning did not sound

• Similar accidents occurred in U.S. in August 1988 (B727), August 1987 (MD-82)
  – Flaps not set and warning system failed

• 27 major airline accidents in U.S. between 1987 and 2001 attributed primarily to crew error
  – In 5 the crew forgot to perform a flight-critical task
  – Did not catch with the associated checklist
The Multitasking Myth: Handling Complexity in Real-World Operations

Loukia D. Loukopoulos, Key Dismukes, & Immanuel Barshi

- Chapter 1: Introduction
- Chapter 2: What is multitasking and how it is accomplished?
- Chapter 3: The Ideal: flight operations as depicted in flight operations manuals
- Chapter 4: The Real: flight operations add complexity and variability
- Chapter 5: Analysis of concurrent task demands and crew Responses
- Chapter 6: The research applied
- Glossary
- Index
- Appendices: A. Methods, B. Human Agents, C. Perturbations, D. Errors
- References
Compared Cockpit Cognitive Demands with FOMs and Training

- Ideal (FOM): Tasks are linear/sequential, predictable, and controllable

- Real (Jumpseat): Interruptions, concurrent tasks, tasks out of sequence, unanticipated new tasks

- Perturbations create multitasking demands
  - People overestimate ability to multitask
  - Common error: forgetting/failing to perform task element
  - Factor in many accidents

- Cognitive analysis of multitasking & prospective memory situations
Chapter Six: The Research Applied

• Reviewing and Revising Procedures
  – Setting flaps for takeoff
  – The original pre-takeoff procedure
  – The new pre-takeoff procedure

• Aviation and beyond
  – Improving the effectiveness of checklists and crew monitoring
  – Strategic management of concurrent task demands
  – Training and personal techniques

• Summary of recommendations
  – For organizations
  – For individuals

• Concluding thoughts
Checklist and Monitoring Study

• Update on progress since last year’s FAA research review
• These two crucial defenses failed in many accidents — Why?
• Method: Jumpseat observations and cognitive analysis of task demands
• First step: Identify types of error and surrounding circumstances
Data Collection Recently Completed

• 60 flights observed at three airlines
  – Large U.S. airline and large international airline with world-wide flights and a regional airline

• Aircraft:
  – B737 (29)
  – A320 (11)
  – EMB (10)
  – B757 (7)
  – B767 (2)
  – B777 (1)

• Pilot flying: Captain, 63%; First officer, 37%

• Pilot making the error: Flying pilot, 50%; Monitoring pilot, 50%
Preliminary Results

- Errors defined as deviations from published SOP, regulations or good operating practice
- 899 errors observed in 60 flights
  - Observations consist of narrative descriptions of error and context
- Narratives entered in database
  - Exploring ways to categorize and analyze data
**Phase of Flight at Time of Error**

<table>
<thead>
<tr>
<th>Phase</th>
<th>Count</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretaxi:</td>
<td>171</td>
<td>(19 percent)</td>
</tr>
<tr>
<td>Taxi-out:</td>
<td>78</td>
<td>(9 percent)</td>
</tr>
<tr>
<td>Takeoff/Initial Climb:</td>
<td>24</td>
<td>(3 percent)</td>
</tr>
<tr>
<td>Cruise Climb:</td>
<td>205</td>
<td>(23 percent)</td>
</tr>
<tr>
<td>Cruise:</td>
<td>74</td>
<td>(8 percent)</td>
</tr>
<tr>
<td>Descent:</td>
<td>210</td>
<td>(23 percent)</td>
</tr>
<tr>
<td>Approach (Vectors or Final):</td>
<td>89</td>
<td>(10 percent)</td>
</tr>
<tr>
<td>Landing:</td>
<td>2</td>
<td>(0 percent)</td>
</tr>
<tr>
<td>Taxi-in:</td>
<td>28</td>
<td>(3 percent)</td>
</tr>
<tr>
<td>Shutdown/Parking:</td>
<td>18</td>
<td>(2 percent)</td>
</tr>
</tbody>
</table>
## Errors Per Flight

<table>
<thead>
<tr>
<th>Category</th>
<th>Mean ± Standard Deviation</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monitoring</td>
<td>6.8 ± 3.9</td>
<td>(1-19)</td>
</tr>
<tr>
<td>Checklist</td>
<td>3.2 ± 2.9</td>
<td>(0-14)</td>
</tr>
<tr>
<td>Primary procedure</td>
<td>5.0 ± 4.8</td>
<td>(0-21)</td>
</tr>
</tbody>
</table>
## Checklist Error Types

<table>
<thead>
<tr>
<th>Error Type</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item omitted or performed incompletely</td>
<td>50</td>
</tr>
<tr>
<td>Flow/Check performed as Read/Do</td>
<td>46</td>
</tr>
<tr>
<td>Responded to challenge without looking</td>
<td>36</td>
</tr>
<tr>
<td>Poor timing of checklist initiation</td>
<td>32</td>
</tr>
<tr>
<td>Checklist performed from memory</td>
<td>17</td>
</tr>
<tr>
<td>Checklist not called for</td>
<td>13</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>194</strong></td>
</tr>
</tbody>
</table>
Item(s) Omitted from Checklist
(50 instances)

• Common outcome, but several clusters of diverse situations
• Cluster: Checklist item deferred and later forgotten
  – Example: Early call for Approach checklist; last two items deferred
• Cluster: Checklist interrupted by external agent/event
  – Example: Departure Briefing interrupted. Last item never completed
  – Individuals fail to encode explicit intention to resume interrupted task
  – Absence of cues to prompt remembering to resume
• Cluster: Items overlooked without interruption or deferral
  – Normal cues absent? Attention diverted? Source memory confusion?
Performing Flow-then-check Procedure as Read-Do (46 instances)

- Problematic:
  - Not all flow items are on checklist
  - Defeats purpose of redundant check

- Why?
  - Inherently tedious to laboriously check habitual task just performed?
  - Reversion to old Read-Do procedure after company changed SOP?
Responding to Checklist Challenge without Visually Inspecting Items
(36 instances)

- Example: Captain responded “ON” to APU Bleed challenge, but bleed was actually off
  - Conceivably a case of looking without seeing
- Example: First officer did not look up from checklist card to verify items on overhead panel
- Why?
  - Perhaps relying on memory of having just set an item
  - Undermines independent verification
Checklist Performed Entirely from Memory
(17 instances)

• Example:
  – Captain performed Approach checklist without pulling out card
  – Captain performed After Takeoff checklist late without pulling out card
  – First officer pulled out card but ran Before Start Checklist without looking at it

• Why?
  – Using card is slow and awkward compared to fluent execution from memory
  – Response to time pressure?
  – Do checkpilots notice and correct this error?
Poor Timing of Checklist Initiation
(32 instances)

• Example: First officer, pilot flying, called for In-Range Checklist at 10,000 feet instead of 18,000 feet
  – Prospective memory error

• Example: Captain called for Taxi Checklist when aircraft was approaching runway intersection, causing first officer to go head down
Checklist Not Called For
(13 instances)

• Example: First officer omitted “Flaps up, After Takeoff checklist” call
  – PM failure while attention occupied with other tasks

• Example: First officer omitted Approach checklist on final approach

• Example: Approaching departure runway, captain did not call for Before Take checklist. First officer self-initiated and captain did not act surprised.
  – A norm for some crews?
## Monitoring Error Types

<table>
<thead>
<tr>
<th>Error Type</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Callout Omitted or late</td>
<td>214</td>
</tr>
<tr>
<td>Verification omitted</td>
<td>123</td>
</tr>
<tr>
<td>Failure to monitor aircraft at level-out</td>
<td>64</td>
</tr>
<tr>
<td>Pilot head-down at critical juncture</td>
<td>5</td>
</tr>
<tr>
<td><strong>total</strong></td>
<td><strong>406</strong></td>
</tr>
</tbody>
</table>
Callout Omitted or Late
(214 instances)

• Most frequent: Omission of “1000 feet to go” call
  – Prospective memory issue: Must switch attention between monitoring altimeter and other tasks. Lack of cues to prompt timely switch

• Most serious: Omission of callouts required during unstabilized approaches
  – Example: Monitoring pilot did not call out “Unstable” when approach remained unstable below 500 feet
  – Flying pilot can be too focused on trying stabilize flight path to evaluate whether possible to land safely
  – Similar to SouthWest 1455 at Burbank and American 1420 at Little Rock
Monitoring Issues

Verification Omitted
(123 instances)

• Example: Neither pilot reset altimeter climbing through FL180

• Example: Captain verified flap position by looking at and touching flap handle without looking at flap position indicator during Landing checklist
Failure to Monitor Aircraft
(64 instances)

- Example: Captain began cruise cockpit panel scan early and did not monitor level-off by automation
  - Poor workload management
  - Automation complacency?
- Crew occupied with weather avoidance did not notice fuel configuration EICAS message
Pilot Head Down at Crucial Juncture
(5 instances)

• Example: Captain called for second engine start shortly before crossing a runway, First officer went head down

• Example: First Officer started reviewing final weight data and inputting MCDU while aircraft moving through crowded ramp area

• Problematic workload management
  – Interferes with monitoring
  – Can lead to snowballing problems as crew get behind aircraft
How Often Were Errors Caught and by Whom?

Error trapped (18%); error not trapped (82%)

When trapped, trapped by:

Captain  
(39%)
First officer  
(40%)
ATC  
(11%)
Flight attendant  
(1%)
Aircraft warning system  
(1%)
Jumpseat observer  
(7%)

Crewmember trapping error:
  Pilot making error  
(21%)
  Other pilot  
(89%)
What are the Major Themes?

• Still analyzing data—impressions only
• 899 errors seem a lot
  – But thousands of opportunities of error on every flight
• Wide range in error rates/flight
  – Some due to flight conditions and observer familiarity with aircraft
  – Still substantial variation among crews—standardization issue?
• Unrealistic to expect 100% reliability among human operators
  – Especially when switching attention among multiple tasks
Major Themes
(continued)

- Monitoring and checklist callouts are especially likely to be dropped during high workload
  - Lose the error-trapping protection when it is most needed
- Subtle reason why error-trapping functions are the first to go
  - Primary procedural errors (e.g., setting flaps) give feedback (e.g., takeoff abort)
  - Monitoring & callout errors rarely lead to bad consequences (though safety compromised)
  - Without feedback loop, errors increase, though pilots may be unaware of it
Major Themes
(continued)

• Many errors were inadvertent errors of omission
  – Prospective memory research: human brain not well equipped to remember to perform tasks that are interrupted, deferred, or performed out of normal sequence.
  – The Multitasking Myth provides a cognitive account of this vulnerability and gives detailed countermeasures

• Some errors of omission were not inadvertent
  – Performing checklists from memory, etc.
  – Correct procedure goes against the grain for fluent performance of habitual tasks
  – Pilots “streamline”, perform tasks quickly and fluently but lose the protection provided by the procedure
“Streamlining” of Checklists

• Does training adequately explain to pilots their vulnerability to streamlining and its danger?

• How rigorous is checking of checklist deviations?
  – Deviations are subtle and fleeting. Checkpilots focus on big picture
  – Without feedback loops, procedures will be streamlined to be fast and to minimize mental workload

• Do companies write stringent, perhaps idealistic procedures but tacitly condone streamlining?
  – If procedures are unrealistic, should be rewritten
Ways to Improve Checklist Use and Monitoring
(from The Multitasking Myth)

- Beyond engineering considerations, procedures must reflect realities of operating conditions and human information processing.

- Loukia’s study found SOPs often idealistic, failing to capture dynamic & complex nature of real-world conditions and task demands:
  - Conflicts arise among procedural demands, operational demands, and human cognitive capabilities.

- Recommend companies periodically analyze SOPs for conflicts and hidden traps:
  - Start with incident reports
  - Create team of experienced pilots
  - Consult with human factors experts
One Company’s Overhaul of Normal Procedures

• Taxi checklist produced conflict between:
  – Procedural demand: preparing aircraft for departure and
  – Operational demands: controlling movement of aircraft—following taxi route—maintaining awareness of airport layout, aircraft position, position of other aircraft—communication

• Shifting attention among multiple tasks was a major factor in rejected takeoffs and runway incursions

• In-flight procedures, e.g.:
  – Schedule flows & checklists to avoid conflict with transitions between ATC during climb-out and descent

• Performing tasks out of normal sequence often leads to forgetting task elements
  – Deferring flaps for movement on contaminated taxiways not necessary for all aircraft types
Ways to Improve Checklist Use and Monitoring
(continued)

• Training:
  – Don’t stop with telling pilots what to do
  – Explain what errors occur and why
  – Use real-world scenarios, e.g., snowballing workload in unstabilized approaches
  – Why quality of checklist execution erodes unwittingly
  – Need for slow, deliberate execution that goes against the grain

• Expand workload management portion of CRM
  – Traditionally focuses on distribution of tasks and handling overload
  – Add ways pilots can avoid amplifying workload problems with better timing of task initiation
  – Explicitly address time pressures and dangers of rushing
Ways to Improve Checklist Use and Monitoring (continued)

• Insure company policies & practices do not implicitly reward rushing and risky decision-making

• Company guidance for monitoring is much too vague
  – Specify what to monitor and when
  – Specify and emphasize wording and timing of callouts

• You get what you check and what you reward
  – Include how checklists are run and monitoring performed in line and sim checks
  – Reward correct use, not streamlining
More Information


