THE CHALLENGES OF MANAGING CONCURRENT AND DEFERRED TASKS

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ABSTRACT

Interruptions, distractions, and preoccupation with one task to the detriment of another task frequently play a role in aviation accidents. ASRS reports reveal vulnerability to lapses in monitoring and to failure to remember to complete deferred actions. Two questionnaire studies explored the availability and utility of techniques that pilots may use to reduce vulnerability to these errors.

INTRODUCTION

In normal line operations flight crews routinely manage multiple tasks concurrently. Even when crews practice good workload management (e.g., divide tasks among pilots and set priorities), each pilot frequently must manage more than one task at the same time. Preparation for engine start, taxi, climb-out, descent, and arrival are often especially busy. Highly experienced pilots, dealing mostly with familiar tasks, usually handle concurrent demands adequately by interleaving tasks as necessary. Nevertheless, concurrent task management is a point of vulnerability because controlled processing is a severely limited cognitive resource. This in turn limits human ability to attend to multiple tasks simultaneously and to remember to perform all the actions required by disparate tasks.

Chou, Madhavan, and Funk (1996) reported that 23 percent of 324 accident reports reviewed involved errors in cockpit task management and 49 percent of 470 ASRS incident reports selected by the investigators involved errors in cockpit task management. In our own informal analysis of 37 NTSB reports involving crew error, nearly half showed evidence of interruptions, distractions, or preoccupation with one task to the detriment of another task. Several other studies have examined the challenges of managing cockpit tasks (e.g., Raby & Wickens, 1994; Latorella, 1996; Rogers, 1996; Schutte & Trujillo, 1996, and Damos, 1997).

Dismukes, Young, and Sumwalt (1998) studied ASRS reports in which an airline crew paid inadequate attention to one task while performing another task. These reports revealed a wide range of activities that interrupted, distracted or preoccupied the pilots in these incidents. Most of these activities fell into one of four categories: communication (50%), head-down tasks (16%), abnormal situations (14%), or searching or responding to visual traffic (8%). Similarly, a wide range of activities were not adequately attended. Sixty-nine percent of these neglected activities involved monitoring the aircraft position, aircraft status, or the actions of the pilot flying. The large percentage of lapses in monitoring may in part reflect that a great deal of monitoring is required in cockpit operations. Also, monitoring may be especially vulnerable because it is often a vigilance task (monitoring for low frequency events) from which attention is readily diverted when more salient and engaging task demands arise.

Twenty-two percent of the neglected activities involved failing to perform an intended action—either an action that is normally and habitually performed (e.g., retracting speed brakes after leveling off in a descent) or an action that was deferred until a later time but forgotten (completing an interrupted checklist). Forgetting to perform an intended action involves *prospective memory*, an aspect of human cognition that has only recently begun to be studied in aviation settings (Stone, Dismukes, & Remington, in press). It is easy to forget to complete deferred actions in aviation operations because the intention to complete the deferred action often must be retrieved from memory at a time when the individual is busy with other demanding tasks. Also, deferring an action may remove it from the normal environmental cues (e.g., displays, callouts, procedural flows) that serve to trigger retrieval from memory.

In some incidents and accidents crews may neglect some tasks because of excessive workload. More commonly, however, sufficient time exists, in principle, to complete all essential tasks. Thus, rather than overload, the issue seems to be how well pilots can manage attention to keep track of concurrent tasks without becoming preoccupied with one task to the detriment of others. Workload management is usually taught in CRM classes, but attention management is not—indeed it is not clear that existing scientific knowledge is adequate for design of training in attention management.

QUESTIONNAIRE STUDIES

We have recently completed two questionnaire studies exploring the availability and utility of techniques that pilots may use to reduce vulnerability to lapses in monitoring and to lapses in prospective memory. In the first questionnaire we used ten incident scenarios from our ASRS study and asked respondents what techniques pilots could use to avoid making the mistakes reported in a given scenario. The 26 respondents were highly experienced airline pilots (mean total flight time was 10,592 hours; 88 % were/had been captains; 57% were check pilots; 68% were instructors). Six scenarios from the first questionnaire were selected for further study; four of these scenarios involved lapses in monitoring and two involved lapses in prospective memory. The responses to these six scenarios were codified to common wordings, referred to hereafter as “techniques”. The number of techniques generated per scenario ranged from four to eleven. Thirty-six techniques were generated altogether, with some overlap among techniques suggested for various scenarios.

Twenty techniques were suggested for avoiding lapses in monitoring; these fell into six categories:

1. <u>Manage workload</u> (9 techniques)[1]: Rearrange the sequence of tasks to reduce workload at critical junctures (5); divide responsibilities among crew and stick to it (2); and manage workload to keep within acceptable limits (e.g., tell ATC “unable to comply”) (2).
2. <u>Recognize multi-task demands and dividing attention among them</u> (4 techniques): Identify specific things to monitor and periodically switch attention (2); divide attention between two tasks and use discipline to avoid preoccupation with either (1); and break concurrent task into subtasks and pause between subtasks to monitor (1).
3. <u>Review task in advance to identify critical junctures and establish monitoring</u> (2 techniques): Brief departure procedure in advance, and discuss plan of action and ascertain pilot flying (PF) has set task up correctly .
4. <u>Raise red flag in vulnerable situations and increase vigilance</u> (2 techniques): Pilot not flying (PNF) announce when going head-down, and PF treat situation as high risk when PNF goes off-line.
5. <u>Assign neglected task higher priority</u> (2 techniques): Assign monitoring task higher priority than other tasks, and give collision avoidance priority over navigation.
6. <u>Create a visual, auditory, or tactile reminder</u> (1 technique): PNF call out progress so PF can monitor while performing other tasks.

The large proportion of workload management-related techniques may reflect the fact that workload management is part of CRM training, which almost all major airline pilots receive. Reviewing tasks in advance, when practical, and figuratively raising red flags to heighten attention in vulnerable situations also seem generally consistent with CRM principles. However we are aware of no research addressing how effective these techniques may be in reducing vulnerability to lapses in monitoring specifically. Creating salient reminder cues, breaking concurrent tasks into subtasks and pausing between subtasks to monitor, and identifying specific things to monitor are all consistent with a cognitive perspective on how individuals might manage concurrent tasks. However little research exists to predict how effective these techniques might be. In some circumstances it is appropriate to assign one task higher priority than another task, but in other situations both tasks may be crucial and both must receive adequate attention..

Seventeen techniques were suggested for avoiding lapses in prospective memory; these fell into four categories:

1) <u>Create a habit linking memory item to habitual actions</u> (6 techniques): Always turn wheel light on when landing clearance received and make light switch part of final scan before landing; always check landing clearance at 1000 foot call; always check landing clearance at outer marker; put ground control frequency in standby radio when cleared to land and make radio head part of final scan; add landing clearance to final checklist as personal technique; and do descent checklist (and set altimeters) at FL180.
2) <u>Manage workload</u> (3 techniques): manage workload to keep within acceptable limits; divide

[1] Number of techniques in each sub-category are in parenthesis.

responsibilities among crew and stick to it; and First Officer fly the airplane so the Captain can manage the abnormal.

3) Create a visual, auditory, or tactile reminder (3 techniques): Hold checklist or mike or keep hand on radio until call to tower; write down ATC instructions; and leave descent checklist in visible location until altimeters reset.
4) Execute task immediately (2 techniques): call tower early (even though instructed to delay call), and set PNF altimeter or standby altimeter as soon as possible, then set PF altimeter at FL180.
5) Miscellaneous (3 techniques): Enhance encoding of intentions in memory (e.g., repeat ATC instructions aloud); adhere to SOP (if landing clearance is on final checklist); and do not accept aircraft with multiple equipment problems in poor weather.

These are all personal techniques—none are taught in typical CRM classes. Creating salient reminder cues is probably the most common technique people use in everyday life to reduce vulnerability to prospective memory lapses, but this technique may not be practical in all cockpit situations. From a cognitive perspective, creating a habit linking a memory item to habitual actions is potentially effective, but considerable effort is required to develop the habit and a separate habit must be developed for each memory item. A cognitive perspective also suggests that enhanced encoding of intentions should facilitate retrieval from memory, though it is not clear to what degree.

The six scenarios and associated techniques were used in a second questionnaire in which pilots rated the effectiveness and practicality of the techniques for preventing the lapses reported in each scenario. One hundred and fifteen respondents from six airlines rated the techniques on five-point Likert scales (1 = low effectiveness or practicality; 5 = high effectiveness or practicality). Respondents' mean total flight time was 10,936 hours; 93% were/had been captains; 86% were check pilots; 91% were instructors.

Because of space limitations only data from two scenarios are presented here; the data from the other four scenarios are quite similar. Table 1 presents a monitoring scenario in which the autopilot did not capture the intended level-off altitude and the crew did not monitor adequately for altitude capture. The average effectiveness ratings of the 9 techniques ranged from 3.7 to 4.2, and the average practicality ratings ranged from 3.5 to 4.1. The two average ratings for each technique closely paralleled each other, raising a question of how well the respondents used the two ratings to discriminate different attributes of the techniques. The standard deviations of the ratings were fairly large, but the utility of the SD here is limited because many of the distributions were strongly skewed. For this reason we computed an agreement coefficient R(wg) = [1 – observed variance/maximum possible variance] (James, Demaree, & Wolf, 1984). R(wg) values can range from 1 (all raters assigned the same rating) to 0 (ratings were distributed evenly over all possible values); R(wg) = 0.5 indicates moderate agreement. R(wg) scores for this scenario ranged from .26 to .59 for effectiveness and ranged from .19 to .50 for practicality. Thus, even though the average ratings for all techniques were fairly high, respondents differed substantially in assessing how effective and how practical these technique are.

Table 2 presents a prospective memory scenario in which the crew was instructed to call tower at a later point and forgot to make the call, landing without clearance. The average effectiveness ratings of the 11 techniques ranged from 2.5 to 3.9, and the average practicality ratings ranged from 2.0 to 3.9. R(wg) for effectiveness ranged from .01 to .51. R(wg) for practicality ranged from .11 to .45.

DISCUSSION

Concurrent task demands are ubiquitous in flight operations. Even when pilots have time to perform all essential tasks, they are vulnerable to error because of inherent difficulties in switching attention appropriately among tasks. If concurrent tasks can be practiced together under consistent conditions, pilots may learn to interleave components of separate tasks into what is effectively a single integrated task that can be performed with a high degree of automaticity. However in many situations one of the tasks is variable or the way two tasks combine is unpredictable, and in these situations considerable mental effort is required to keep attention moving between the tasks. In our ASRS study the most frequently reported competing tasks that distracted or preoccupied pilots were communication, head-down activities, abnormal situations, and searching for visual traffic. All of these tasks have unpredictable aspects and all make substantial demands on limited attentional resources.

The most commonly reported category of neglected tasks was monitoring (of aircraft position or status or of the actions of the pilot flying/taxiing). The next largest category was forgetting to perform intended actions (prospective memory). Our first questionnaire identified a number of techniques that pilots might use to reduce vulnerability to lapses in monitoring and vulnerability to forgetting to complete intentions. In a monitoring scenario from our second

Table 1. Scenario 6

At 10,000 ft Approach cleared A/C to 13,000 ft. and gave revised routing. FO (PNF) put raw data on NAV display for CA while rebuilding departure on FMS, which required considerable attention because A/C was close to newly assigned radial. FO missed “1000 to go” call and did not look up until A/C was at 13,600 ft. CA said he had engaged the autopilot shortly before level off and had expected it to capture.

Technique	Effective Mean(SD)	Practical Mean(SD)	R(wg) E/P
PF: When PNF must go off line, treat situation as high risk, requiring extra vigilance.	4.2 (.93)	4.1 (.98)	0.57/ 0.50
Crew: Rearrange sequence of tasks to reduce workload (use the raw data until level-off, then reprogram the FMS) at critical junctures.	4.1 (.95)	4.1 (1.0)	0.54/ 0.49
PNF: Be aware that must perform two tasks concurrently. Divide attention between the two tasks (programming FMS and monitoring altitude level-off) and use discipline to avoid concentrating on one task to the exclusion of the other task.	4.0 (.91)	3.6 (1.0)	0.58/ 0.41
Crew: Assign responsibilities and stick to them. PF should fly the aircraft and not watch PNF programming FMS.	3.9 (1.1)	3.8 (1.1)	0.33/ 0.30
PNF: Discuss plan of action or ascertain that the pilot flying has set up his/her task correctly before turning to other tasks. This may also help the PNF remember to switch attention to check aircraft status at critical transitions.	3.9 (.90)	3.6 (1.0)	0.59/ 0.40
PNF: Rearrange sequence of tasks to reduce workload at critical juncture (suspend FMS work at 1000ft To Go call).	3.9 (1.0)	3.5 (1.2)	0.47/ 0.19
PNF: Assign monitoring task higher priority than other tasks (reprogramming) performed concurrently.	3.8 (.95)	3.6 (1.0)	0.54/ 0.47
PNF: announce going head-down when starting to program the FMS	3.7 (1.2)	3.7 (1.2)	0.26/ 0.23
PNF: Break concurrent task up into subtasks and pause between subtasks to monitor (pause between FMS inputs to check altitude).	3.7 (.96)	3.5 (1.0)	0.53/ 0.47

NOTE: R(wg) E/P denotes R(wg) for Effectiveness and Practicality ratings, respectively.

Table 2. Scenario 2

Final Approach in “minimums” weather. ATC request to keep speed high resulted in elevated workload during final approach. Before reaching the outer marker (OM), Approach instructed them to call tower upon reaching LOM. Crew forgot to call tower and landed without clearance.

Technique	Effective Mean(SD)	Practical Mean(SD)	R(wg) E/P
Develop habit of turning on wheel-well light when landing clearance received. Make light switch part of final scan.	3.9 (1.0)	3.9 (1.1)	0.43/ 0.41
Manage workload to keep within acceptable limits (e.g., tell ATC unable to keep speed up when conditions are this demanding).	3.9 (.99)	3.5 (1.2)	0.51/ 0.27
Repeat aloud to the other pilot the instruction to call tower at the outer marker.	3.7 (1.0)	3.8 (1.0)	0.45/ 0.45
If “landing clearance” is not an item on company SOP for 1000-foot call, make it a personal technique to check landing clearance at this point.	3.7 (1.1)	3.6 (1.2)	0.37/ 0.27
If “landing clearance” is an item on company SOP for 1000-foot call or on landing checklist, adhere to SOP.	3.6 (1.2)	3.5 (1.2)	0.17/ 0.18
Create a visual/tactile reminder such as holding the checklist or the mike or keeping a hand on the radio until calling tower (PNF).	3.6 (1.0)	3.3 (1.2)	0.48/ 0.26
Make the call to tower a personal checklist item at the outer marker.	3.5 (1.1)	3.3 (1.2)	0.28/ 0.17
If “landing clearance” is not an item on company’s landing checklist, make it a personal technique to check landing clearance at this point. Do not call checklist complete without landing clearance.	3.2 (1.2)	2.9 (1.2)	0.18/ 0.14
Put ground control frequency in standby radio when cleared to land. Make radio part of final scan.	3.1 (1.1)	3.1 (1.2)	0.34/ 0.23
Call tower early, right after instruction from approach.	3.0 (1.3)	2.4 (1.3)	0.05/ 0.11
Write instruction down.	2.5 (1.4)	2.0 (1.1)	0.01/ 0.28

NOTE: R(wg) E/P denotes R(wg) for Effectiveness and Practicality ratings, respectivel questionnaire, highly experienced pilots on average rated all of these techniques above the mid-point of the effectiveness scale and above the mid-point of the practicality scale. In a prospective memory scenario, the respondents also on average rated most of the techniques above the mid-point of both scales.

These results must be interpreted with caution because the level of agreement among respondents for each technique ranged from moderate at best to quite poor. The agreement coefficients may have been low because respondents disagreed about which techniques are most effective/practical or because respondents differed systematically in how highly they rated all techniques or for both reasons. We are further analyzing these data to distinguish these possibilities. At the moment we hesitate to recommend that pilots use these techniques but we plan laboratory and simulation studies to better evaluate their potential.

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