What would you do if....? Improving pilot performance during unexpected events through in-flight scenario discussions

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Abstract

The ubiquitous reliability of the modern airliner has engendered a significant change in the traditional causes of aircraft accidents. Engine reliability in particular, coupled with sophisticated systems for flight path awareness such as Enhanced Ground Proximity Warning Systems (EGPWS), Vertical Situation Displays (VSD's), Head Up Displays (HUD's) and Electronic Flight Bags (EFB's), have greatly decreased the prevalence of controlled flight into terrain (CFIT) accidents. Inflight loss of control (ILOC) has become far more common than CFIT, often as a result of automation anomalies, failures or mismanagement. With engine failures and fires becoming relatively rare, it is the novel and unexpected events, coupled with human related mismanagement of those events, often through a lack of knowledge and/or expectation, which are weighing on modern accident statistics. A project was completed over 10 weeks at an Australasian Airline, where pilots were encouraged to discuss novel event scenarios. It was hypothesised that discussion of novel events would, in the absence of actual practice, develop a mental plan for the management of such events and also raise levels of expectation for such events. At the completion of the project all the pilots were asked to complete an online survey which outlined their perceptions of project utility, expectation and efficacy as a result of the discussions. While only 44% of available pilots responded, results were overwhelmingly positive.

Introduction

One of the benefits of continuous development and improvement in aircraft technology is an increase in aircraft reliability, both in engine reliability and aircraft systems reliability. This has obvious effects on flight safety, with events such as engine failures becoming very rare. In the last decade for example, across the world there were only two fatalities due to powerplant related systems malfunctions. This is remarkable given the average total of around 40 million flight hours per annum in jet aircraft with over 60,000lbs Maximum Takeoff Weight (Boeing, 2010).

The downside of this inherent reliability however, is the conditioned expectation that pilots develop that little will go wrong. Day after day of reliable operation without failure leads to an involuntary complacency brought about by a realistic expectation that the aircraft will not fail. However, aircraft accidents are still occurring – it is simply the nature of the cause which has morphed in recent years. Instead of engine failures and fires, or controlled flight into terrain, a new breed of problems is becoming more widespread. Loss of control due to breakdowns in situational awareness or poor decision making, coupled with auto mation mismanagement are commonly cited in

today's statistics. Indeed the type of accident or incident which features most commonly in contemporary incidents and accidents is the Inflight Loss of Control (I-LOC) which is often caused by the novel, unexpected event, which may never have even been considered by the pilots who experience it (Boeing, 2010; Rosenkrans, 2010; Taleb, 2010).

While the emphasis on pilot recurrency training and checking around the world remains centred on engine failure/fire management and handling, the reality is that these events are rare. Even with this training, pilots only practise emergency management for perhaps four days per year, with the other 360+ days flying on normal line operations, often with little or no exposure to non-normal events. It is not hard to see why this conditioned sense of normality occurs, and the lack of expectation of a non-normal event is simply a normal reaction to enduring normality. When some unexpected non-normal event does occur then, the lack of expectation and preparedness for such an event commonly leads to a heightened state of acute stress, with ensuing deleterious effects on information processing, situational awareness, decision making, and other important facets of the human machine interface.

The hypothesis proffered in this research project was that creating an increased level of expectation for novel events, would allow pilots to develop a "cognitive pre-plan", a schema or mental model, which they would be able to recall under stress in the event that some novel event occurred in the future. While the best method for developing these preconceived plans for dealing with novel problems would be to practise them repeatedly in the simulator, the practicality and expense of this is unrealistic. As a free alternative then, it was hypothesised that simple discussions about novel events, during the ample quiet time that occurs in international operations, would still allow pilots to develop these "cognitive pre-plans", which may simply be management processes which are transferable between different novel events, which would in turn build a level of efficacy for coping with such an event should it happen for real in the future.

Over a ten week period from early April to mid June 2010, an internal research project was conducted at a predominantly International Airline which operates 737's within the Australasian region. This project was entitled "What would you do if...?" and was designed to gauge pilot perceptions of relevance and utility in the use of novel event discussions to build a sense of efficacy for handling future novel emergency events. Pilots were asked to spend some free time enroute each day, discussing one or more novel events, including how they would manage them, who they would talk to, what actions they would take, what checklists they would use etc. At the end of the ten weeks, pilots were asked to complete a simple seven question survey on-line, which was used to gauge their perception of utility and value in the discussions. A total of 57 pilots responded to the survey from a total possible number of 128 pilots (44.5%). Of the responses approximately half were received equally from both Captains and First Officers, with a wide range of experience levels evident. Results were overwhelmingly positive and will be discussed further.

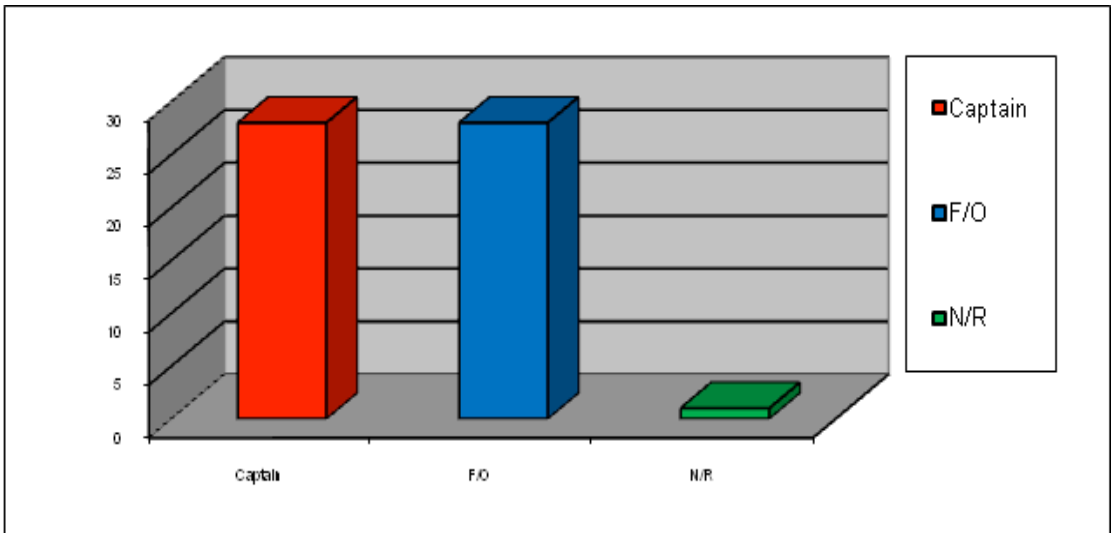
SURVEY RESULTS

The survey consisted of seven questions: two demographic questions and five questions on the exercise itself. A breakdown of the survey questions with the results are outlined below.

Part 1: Demographics

Question 1: Are you a Captain or a First Officer?

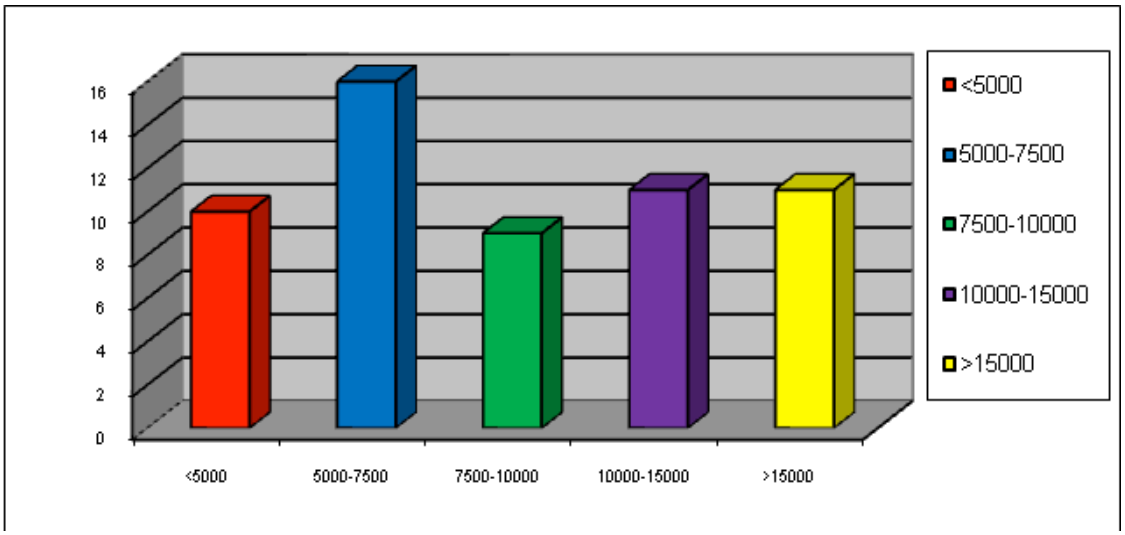
Captain	28
First Officer	28
No Response	1



The responses were evenly shared between Captains and First Officers. This seems somewhat logical given the two-way nature of the exercise, however prior to the survey, it was expected that a majority of responses would come from First Officers who were keen to expand their knowledge as a preparatory measure for commands. The fact that an equal number of Captains and First Officers responded suggests that Captains were just as interested in developing their personal database for dealing with novel situations as First Officers. This is encouraging, and perhaps points to recognition of the underlying reality of the threat associated with novel, unexpected events on flight safety.

Question 2: Approximately how many flying hours have you flown?

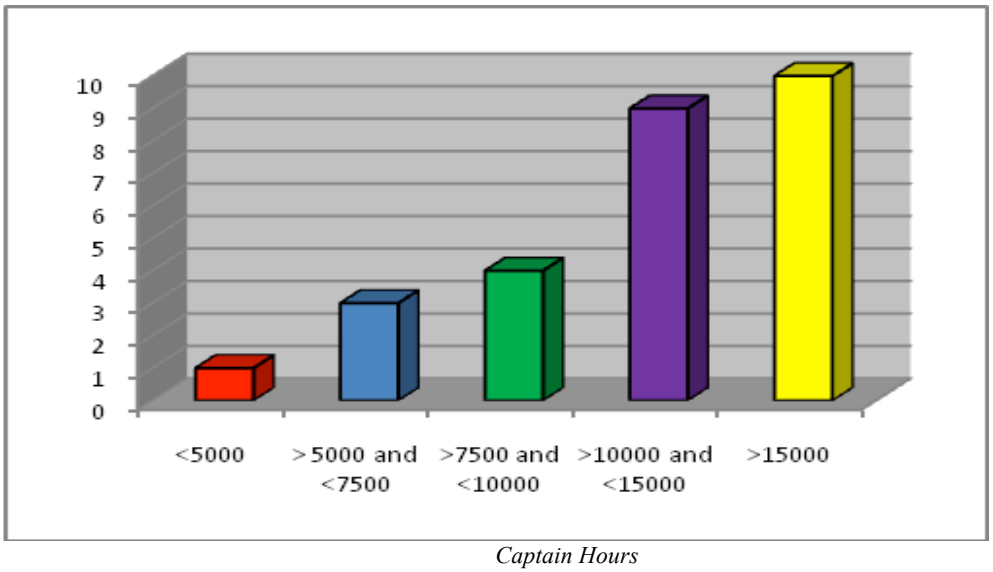
< 5000 hours	10
5000 - 7500 hours	16
7500 – 10000 hours	9
10000 – 15000 hours	11
> 15000 hours	11



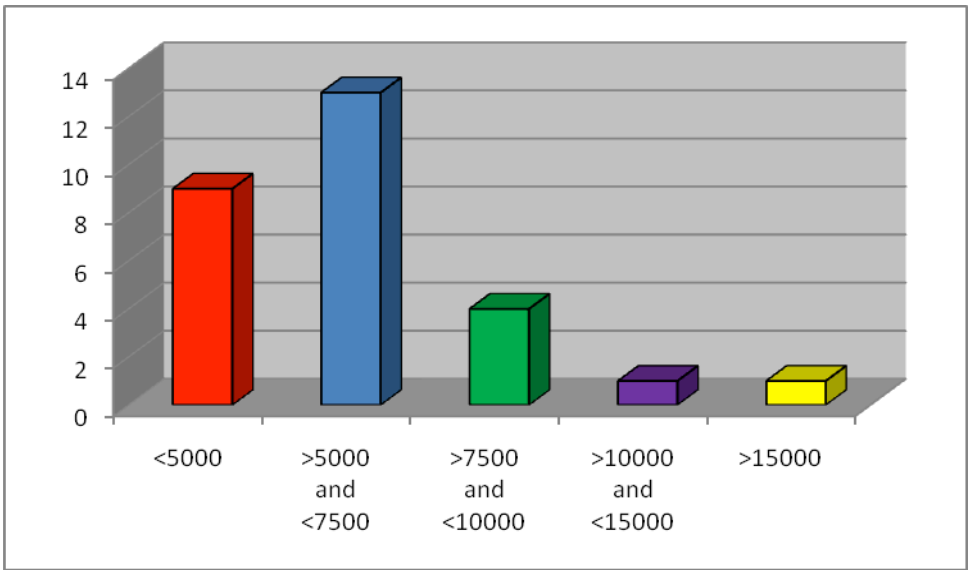
The amount of flying hours each respondent had flown presents some interesting information. It was anticipated that senior First Officers and junior Captains in the 5,000-10,000 hour band would be the largest group of respondents, with First Officers due for command keen to explore new scenarios and develop some expertise in problem solving prior to command training, and junior Captains who are perhaps relatively new to the role who are still keen to develop their experience base in a problem focussed methodology.

Of particular interest here are the number of very experienced pilots who chose to participate in the survey. Of the 57 respondents, 38% of respondents (n=22) were pilots with over 10,000 flying hours. Half of these were in the very experienced category (>15,000 hours), and this perhaps suggests two things: firstly, many of these would have started their careers on less reliable aircraft and are therefore intrinsically conditioned to expect failures at a higher level than pilots of less experience; and secondly, the more experienced pilots are possibly the ones who would have been engaged more by First Officers seeking to tap into their wide experience base.

The following graphs show the breakdown between Captain and First Officer experience levels amongst those who responded to the survey.



Captain Hours



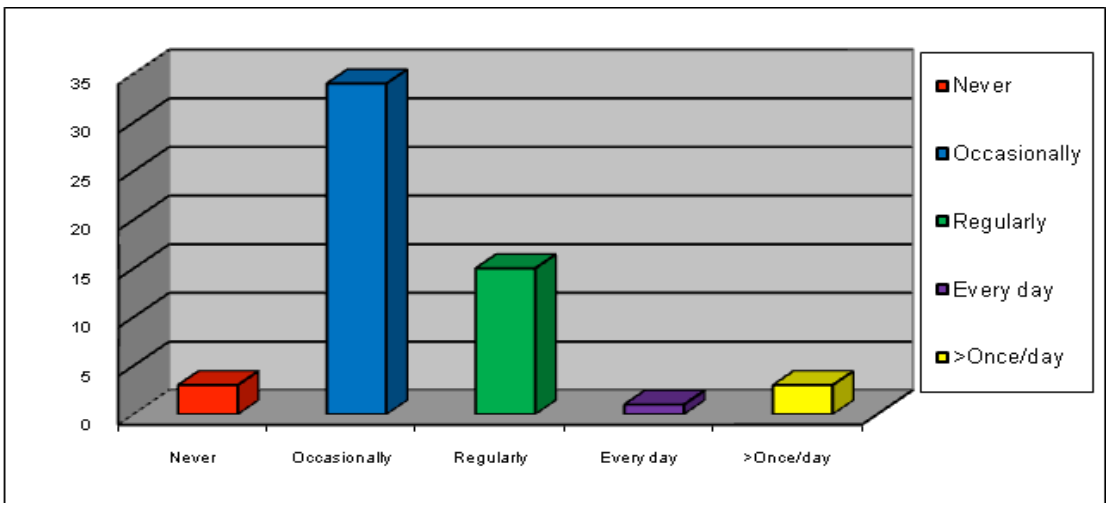
First Officer Hours

The fact that so many experienced First Officers and Captains participated in and responded to the survey suggests an awareness of the problems of automation reliability complacency effects.

Part 2: Survey Questions

Question 3: How often did you discuss novel or emergency events during the trial?

Never	3
Occasionally	34
Regularly	15
Every day	1
More than Once per day	3



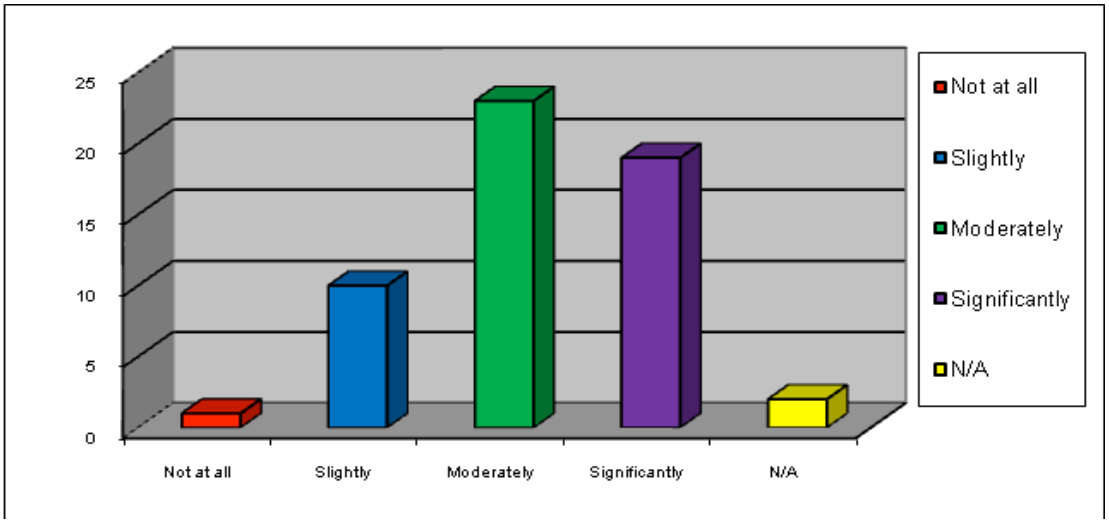
The results in this section are somewhat predictable. Convincing people to do something on a repetitive basis as part of a research project, is always a difficult job. Where people are not forced to do something then boredom, fatigue, lack of perceived personal relevance, and general lethargy, will often make it difficult for people to be motivated to participate. The amount of hours flown in a given trip, or a month, the perceived worth of the project, and the perceived benefits of the exercise, are also cognitive inertia hurdles that must be overcome.

Perhaps surprising is that a handful of people actually participated in the exercises every day, or more than once a day. This indicates intrinsic interest, an underlying motivation (for example those close to command), and an ability to see the benefits of the exercise.

Of the respondents, only three people admitted to not participating at all, although the overall statistics are undoubtedly distorted here. It is likely that the wide proportion of non-respondents in the survey (n=71) did not participate in the scenario exercises, or if they did, felt insufficiently motivated by the benefits of the exercise to complete the on-line survey instrument. Of those who did participate the results to follow indicate an overwhelmingly positive response to the exercise, however this must be tempered by the number of people who didn't actually participate at all.

Question 4: Do you think that these discussions have raised your expectation level for surprise events?

Not at all	1
Slightly	10
Moderately	22
Significantly	20
Not applicable	2

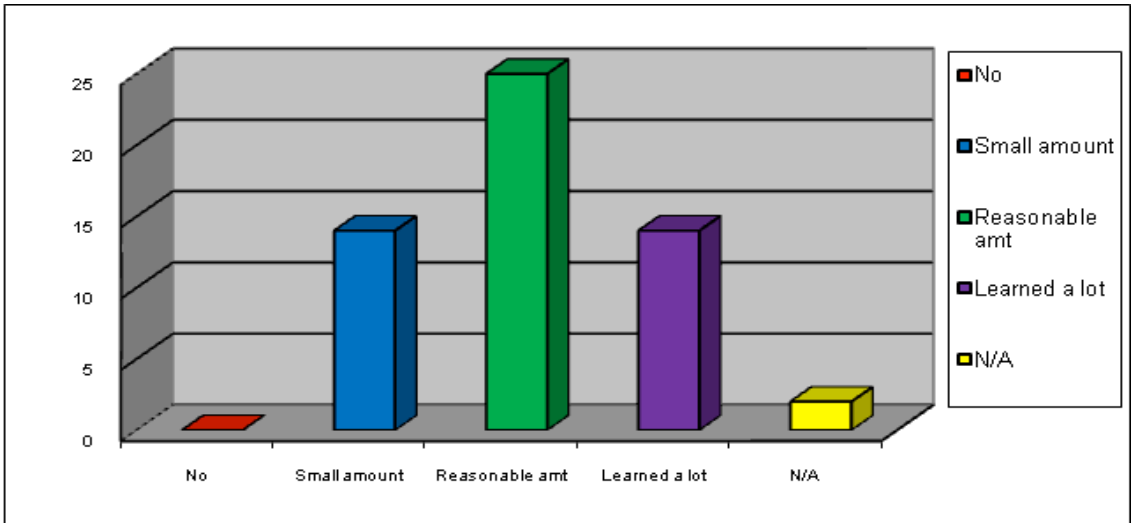


One of the concerning things that comes out of the ubiquitous reliability of modern aircraft is a conditioned expectation of normality. As recently as twenty or thirty years ago, the reliability of aircraft engines and systems was considerably lower, and pilots developed a healthy respect for the vagaries of aircraft reliability, with a moderate level of failure expectation. It is not inconceivable that a large proportion of pilots joining the industry today could reasonably expect to complete their careers having never suffered a real engine failure, a concept foreign to those who perhaps joined the industry in the sixties or seventies.

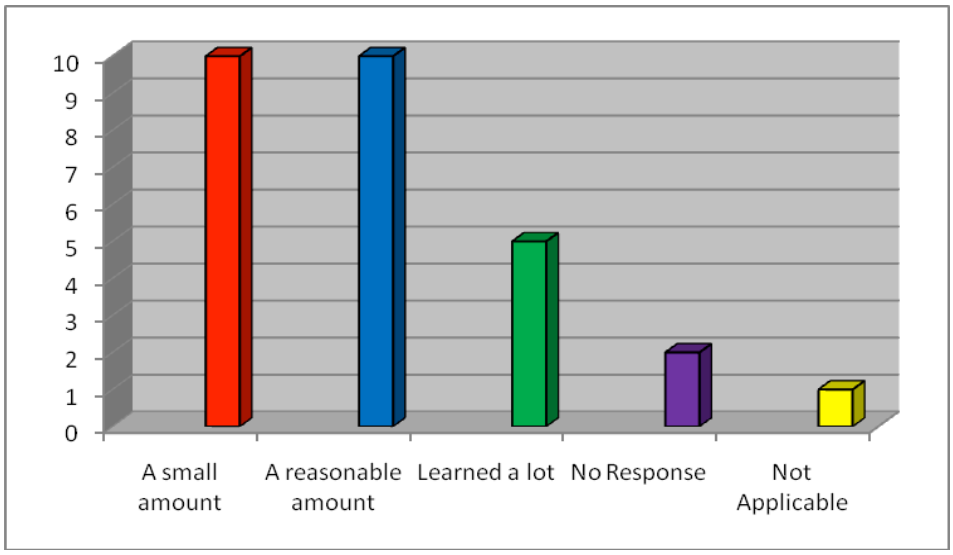
The result of this question is encouraging in that the mere discussion of novel events, has raised expectation levels amongst a considerable number of respondents. Simply highlighting the concept of conditioned complacency has at least raised the level of awareness of the problem. To achieve this long term would perhaps require an ongoing programme of novel event discussions, and some attention during simulator recurrency training to more novel events. To highlight the problem is one thing, but to see continued development of capabilities in handling such events would perhaps require some organisational interventions.

Question 5: As a result of these discussions would you say that you have learned anything new?

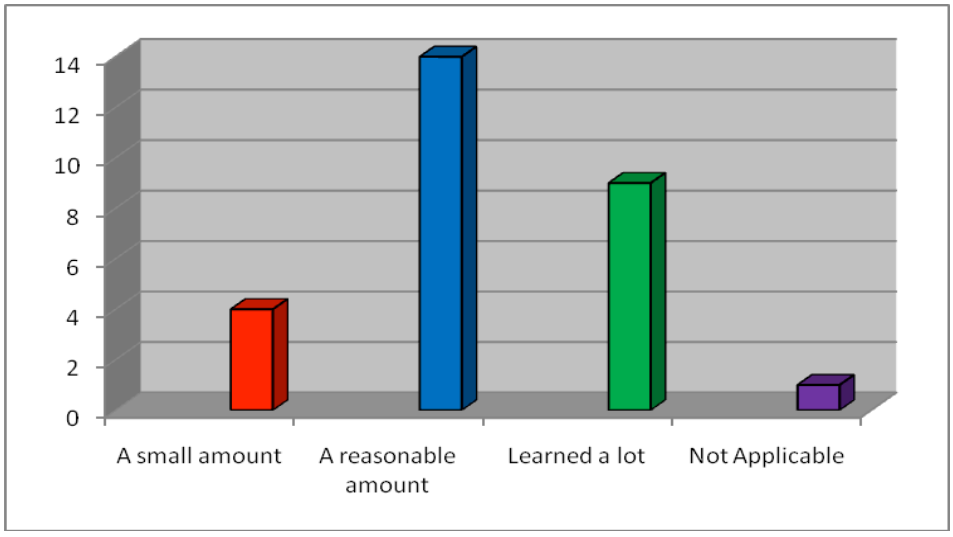
No	0
A small amount	14
A reasonable amount	24
Learned a lot	15
Not applicable	2



The majority of positive responses in this question came from First Officers, which is perhaps understandable, although some Captains still felt that they had learned a reasonable amount or in some cases learned a lot.



Captains' Learning



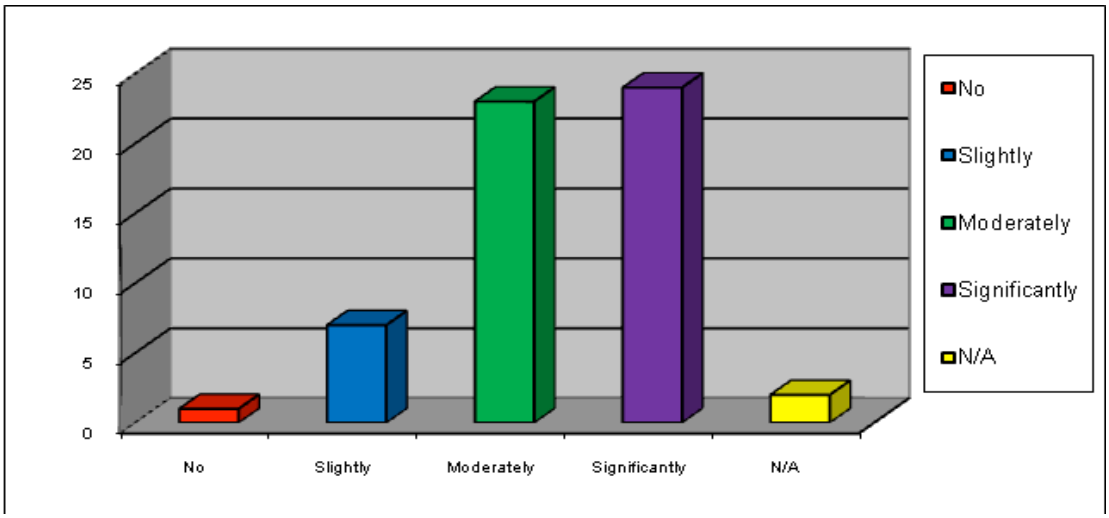
First Officers' Learning

The fact that the vast majority of respondents learned something suggests that the scenario discussions were effective. New learning which is reinforced through repetition and developed by mutual problem solving, has the ability to be recalled from long term memory even under the effects of acute stress. Strong memories are relatively impervious to stress effects which is why emergency checklist recall items should be regularly revisited (Collins, Gathercole, Conway, & Morris, 1993).

The expansion of pilot knowledge capabilities is one part of developing self-efficacy (Bandura, 1977). Where a challenging situation develops in the aircraft, the degree of stress experienced is largely relative to individual and crew perceptions of task management capability. Totally novel, and previously unconsidered events, are likely to engender significant stress, while events that are already in pilots' knowledge structures are likely to be viewed with some sense of control, engendering more manageable stress effects. The greater the knowledge database, the greater the chance of positive appraisals.

Question 6: As a result of these discussions do you think that you would be better prepared to handle one of these novel or emergency events if it happened unexpectedly?

No	1
Slightly	7
Moderately	22
Significantly	25
Not applicable	2



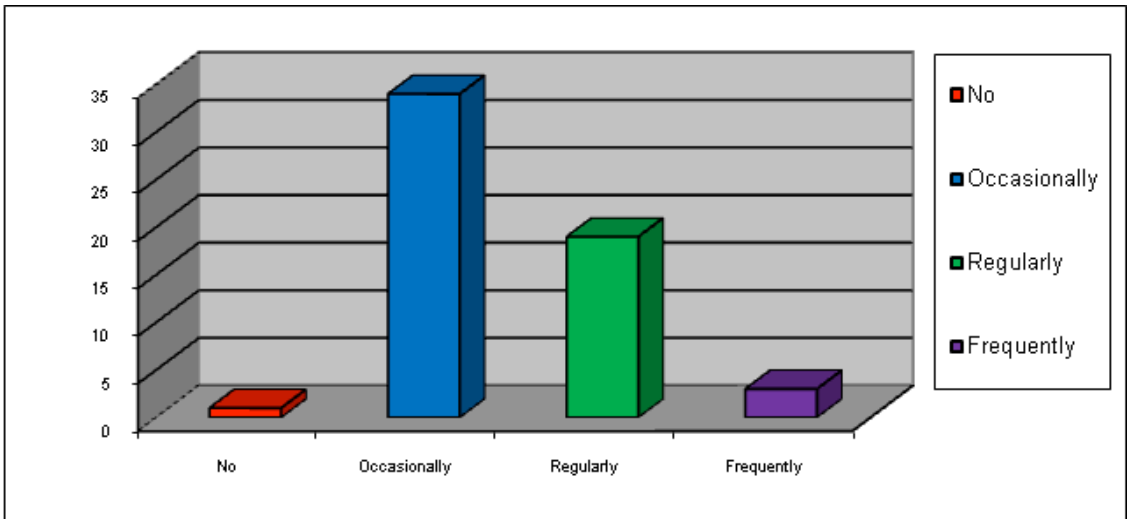
Pilots who have worked through a novel emergency scenario and developed a workable solution are much more likely to feel that the situation is controllable. This feeling of capability is likely to induce problem-focussed coping mechanisms during stressful situations, rather than emotion-focussed coping mechanisms such as denial or dissociation which can have substantially negative effects on situation outcome (Martin, Murray & Bates, 2010).

The overwhelmingly positive response to this question suggests that respondents felt that they had developed some new capabilities to deal with novel emergencies, and as a result would be better prepared should some similar situation occur. Positive individual interpretation of capabilities to deal with emergencies is an important facet in developing self-confidence and self-efficacy.

Of the respondents who suggested they would be moderately or significantly more prepared to handle a novel emergency as a result of the scenario discussions, the pre-survey hypothesis was that First Officers had the most to learn, and would form the majority here, however, results were almost equally split between Captains and First Officers (n=23 versus n=25). This suggests that Captains' perceptions of utility were very high generally.

Question 7: Is it likely that you will continue to discuss such events in the future without being asked to, now that the trial is over?

No	1
Occasionally	33
Regularly	20
Frequently	3



This question raises an interesting situation going forward. Rather than being bored by talking about novel emergencies, a considerable number of pilots felt that the exercise was so worthwhile that they would continue to discuss novel emergency scenarios in the future, with a significant proportion (40%) suggesting they would do so on a regular or even frequent basis. Only one respondent felt that the exercise was not worth repeating, and that person was one who had not actually participated in the scenario discussions.

This question is directly related to the previous question in that those who felt the exercise was useful tended to say that they would continue the discussions even though the research project is over. The utility of the discussions was clearly effective for the majority of those who participated and this utility created an intrinsic motivation for more scenario discussions.

DISCUSSION

Expectation is borne out of repetition and context, and can be conditioned in such a way as to induce unintentional complacency. Where nothing out of the ordinary happens day after day, the brain unwittingly becomes conditioned to normalcy, and levels of expectation for unexpected or novel events appear to dwindle. This has led on numerous occasions in recent years, to situations of acute stress being experienced during unexpected events, which have in turn been poorly handled. In some cases this has resulted in serious incidents, accidents or undesired aircraft states.

The reliability of modern aircraft has enhanced overall flight safety significantly, and by and large, as technology improves, system reliability will continue to become less of a factor in aircraft accident causation. Systems such as Enhanced Ground Proximity Warning Systems, Head Upper Displays, Vertical Situation Displays, and even Electronic Flight Bags, have contributed tremendously to a reduction in Controlled Flight into Terrain and Loss of Situational Awareness (SA) events. Inflight

Loss of Control (ILOC) has now become the biggest cause of accidents, in what has been a relatively quick transition from CFIT as the historically principal cause over the last few decades (Boeing, 2010).

The one thing which has had constant presence is the human factor in aircraft mishaps. The nature of the human-machine interface has changed somewhat, but the complexity of the ever-more sophisticated automation has simply resulted in a different type of human error, rather than reducing it. Breakdowns in SA are commonly noted in ILOC statistics, and this is largely due to the complexity and lack of transparency in the automation, but also due to breakdowns in vigilance and attention due to an over-reliance on machine perfection.

Airlines go to great lengths to encourage pilot standardisation, and repeated replication of routines, such as scans, flows and checklists. The hypothetical clone that did everything the same flight after flight, without error, would in some ways make an ideal airline pilot, although such an individual would lack the flexibility to deal with the real-life dynamic realities of the aviation environment. The one thing which does come from reliance on Standard Operating Procedures (SOP) and repetition is a mentality of habit. This is a positive in terms of error management strategies, but has the longer term effect of operant conditioning, which may include a gradual trend towards complacency (Alkov, Gaynor, & Borowsky, 1985). A gradual drift towards complacency, developed slowly through month after month, year after year of normalcy in operations, is a natural human tendency, and one that is often only modified by a significant complacency disruption event, such as an emergency. Where that emergency involves a novel situation, which is largely unexpected due to conditioned expectation of normalcy, then the surprise of the event, coupled with the complexity of a novel solution, can sometimes overwhelm the capabilities of the unsuspecting individual (Thackray, 1988).

Brain plasticity theory suggests that the more associations are made, the greater the ready access there is to semantic and episodic memory structures (Andreassi, 2007; Collins, Gathercole, Conway, & Morris, 1993; Ratey, 2002). Novel situations which have not been previously considered at all, require an extensive amount of working memory capacity to develop a creative solution, at a time when acute stress has a significantly deleterious effect on working memory function. Where pilots have previously experienced a situation, either directly or vicariously through discussion, then the level of self-efficacy is likely to be considerably greater, which has a positive effect on stress levels and therefore working memory function (Bandura, 1977).

Stress is an individual's reaction to their perception of threat, and it manifests itself physiologically, emotionally, and cognitively (Cox, 1978; Stokes & Kite, 1994). The perception of threat comes about through a conditioning process, a gradual learning of what is fearful and what isn't, which we develop throughout our lives. The amygdala, which is part of the emotional centre of the brain, is largely responsible for this appraisal of threatening stimuli, and is continuously involved in evaluating the environment for meaningful components (Le Doux, 2000). Where the amygdala does detect something which has been previously associated with harm, threat, loss, or even challenge, then it will induce autonomic bodily reactions to help manage those stressors (Duckworth, Bargh, Garcia, & Chaiken, 2002). These are commonly referred to as "fight or flight" reactions, and involve the activation of the sympathetic nervous system which enables the individual to deal physically with a threatening situation, and to orient the attentional system.

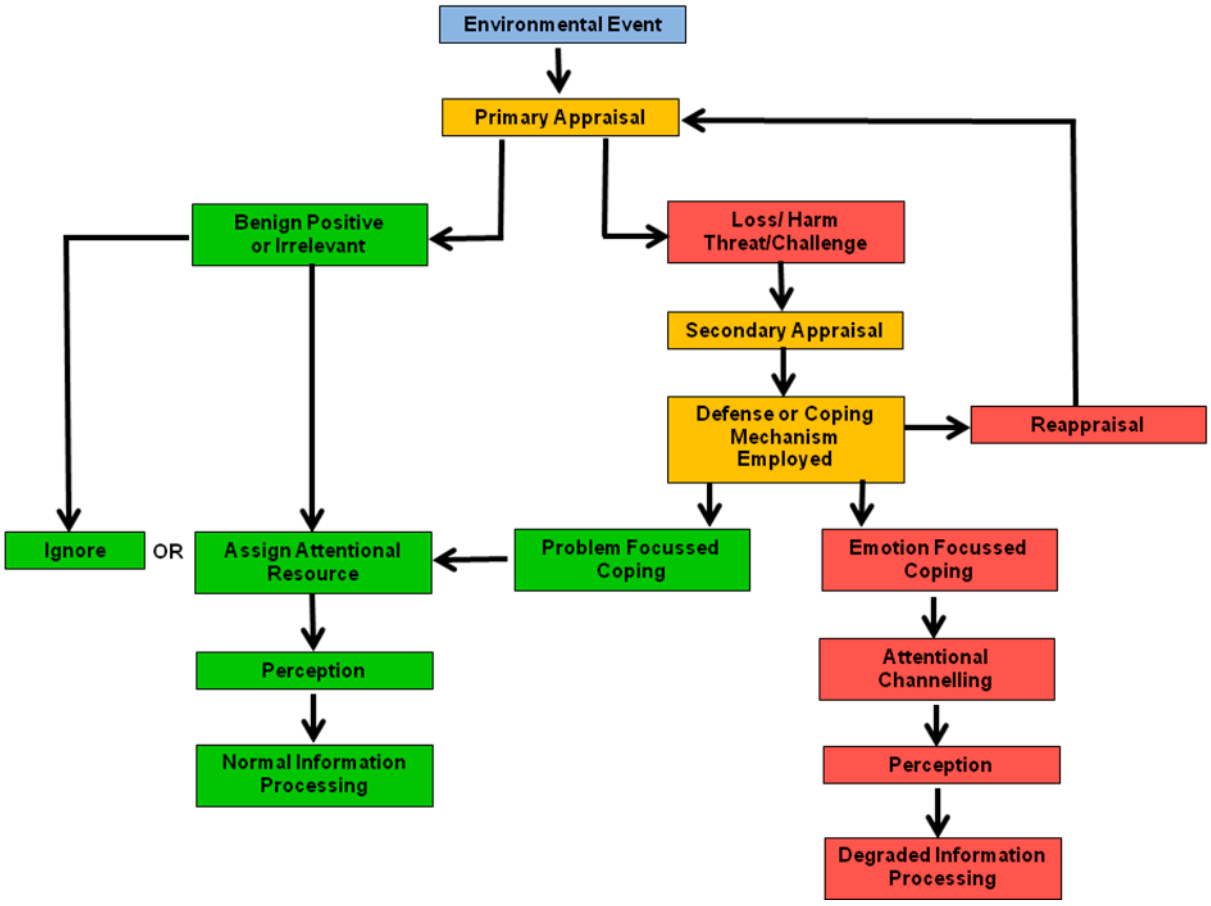
The other role of the amygdala and its related brain structures is the ongoing evaluation of coping mechanisms which would relieve the stress. This "secondary appraisal" is a process designed to alleviate an organism's stress by employing compensatory or coping strategies in order to return it to a state of homeostasis, or neutrality. These coping mechanisms may be long term strategies (generally called defence mechanisms) or may be short term, dynamic solutions employed to ease the perception of the situation.

Coping mechanisms fall under two distinct categories: problem focussed coping, and emotion focussed coping (Lazarus, 1966, 1999). Problem focussed coping strategies are generally employed where the individual has some control over the situation and can take some positive action to change or remove the problem (Lazarus & Folkman, 1984). This is largely a rational, orchestrated mechanism which facilitates normal information processing, with nominal working memory and long term memory function.

The second form of coping is the principal area for concern. Emotion focussed coping is generally employed where an individual feels no control over the situation, and is forced to take some

withdrawl type action to avoid the harsh reality of the situation (Monat & Lazarus, 1991). Techniques such as denial are common in these types of situations, however other dissociative mechanisms such as freezing may also occur (Lynn & Rhue, 1994). Any of these emotion focussed coping mechanisms are very likely to be detrimental to situation outcome, and generally involve a partial or total breakdown in normal information processing.

The following model proposes a conceptual relationship between appraisal, coping, and information processing. It distinguishes between appraisals which are benign, positive, or irrelevant, and therefore have no real effect on information processing, and those which involve harm/loss threat, or challenge. Of these, problem focussed coping mechanisms generally are positive means of effecting an actual change in the situation, and are effective means of dealing with problems, largely without breakdowns in information processing. Emotion focussed coping is simply a mechanism for changing the perception of a situation and may involve pathological processes which severely interfere with information processing. Any breakdowns in information processing will in turn adversely affect situational awareness and decision making.



(Martin, Murray & Bates, 2010)

The effects of individuals or even whole crews being bogged down in emotion-focussed coping strategies are potentially enormous, and real. The following accident was a typical example of an entire flight crew who had adopted a maladaptive coping mechanism and subsequently crashed after takeoff:

"*A Check Pilot was in the right seat, with the pilot being checked in the left seat. A third pilot, who was being checked next was in the front right passenger seat. The aircraft was making a simulated*

engine failure after V_1 following a number of other exercises. As the aircraft got airborne the Check Captain retarded the right power lever to idle to simulate an engine failure. The flying pilot, who noticed that more control force was necessary to rotate the aircraft than normal, tried to control the yaw induced by the loss of power, and attempted to use 5 degrees roll towards the live engine to assist with directional control. It quickly became obvious that something was not right and the flying pilot struggled to control the roll, while the rate of climb started to reduce, and a descent started. The aircraft's right wing finally collided with the ILS Glideslope antenna tower some 25 seconds after the simulated engine failure. It transpired that full flap from the previous landing had not been reset to the takeoff flap position before commencing the takeoff. Neither the pilot at the controls nor the Check Captain did anything to arrest the slow right drift into the clearly illuminated ILS tower, or to recover speed/climb/acceleration capability by applying power to the idling right engine, despite the fact that there was at least 25 seconds in which either pilot could have taken action to prevent the accident." (Heaslip, Hull, McLeod, & Vermil, 1991).

This case wasn't a particularly novel event, however the lack of performance was unexpected, even in the midst of emergency training. Because it varied from the expected course of events, the crew was unable to apply problem solving techniques and resorted instead to an emotion-focussed coping mechanism i.e. they froze. There are numerous other examples available of similar situations, invariably in situations which were unexpected and/or novel.

CONCLUSIONS

A NASA study of airline crew performance found that 85 percent of "textbook" emergencies (those that the crews had trained for) were handled well, while only seven percent of "new" emergency situations were handled with the same degree of success (Peterson 2007). This suggests that novel events are poorly considered in normal line operations and warrant further consideration.

The "What would you do if....?" exercise was designed to gauge pilot perceptions of utility for discussion based scenario management for novel, unexpected events. The hypothesis was that simply talking about novel events, and creating solutions in a relaxed, stress free environment, would allow pilots to develop a cognitive "pre-plan" which could be stored away as a long-term memory, to be revisited in the event that such a situation, or even some unrelated novel event ever occurred for real. Having a "model" solution to a complex problem already stored away, lets individuals use that knowledge to resolve future situations very quickly, simply by using or modifying a solution which has already been determined to work. The alternative, where a complex novel situation is encountered without having been previously considered, requires an enormous amount of cognitive effort, at a time when information processing is severely impaired by stress, and possibly at the expense of other processes such as situation awareness.

The vast majority of respondents in the survey (95%) expressed the opinion that they had learned from the exercise and would be better prepared in the future as a result, and that they were so cognisant of the utility of the exercise (98%) that they would continue to discuss novel scenarios, even after the project had finished. These statistics are perhaps distorted by the fact that over half the pilot population available did not respond, and it is quite likely that the majority of those may not have participated in scenario discussions, or did so sparingly.

The positive benefits of novel event scenario discussions appear evident from the survey results. Greater sense of self-efficacy, greater breadth and depth of technical and operational knowledge, and an increased level of expectation for such events, are some of the immediately obvious benefits. Ancillary benefits may be improved scan rates, better vigilance, and greater system awareness, which come about simply through greater levels of concentration and attention.

Encouraging pilots to discuss novel events where time permits is likely to have positive effects during the management of future novel events. The scope of scenario discussions is only limited by imagination, and the greater the number of novel events considered, the wider the benefits that will ensue. As part of Command Upgrade training, new Captains would be ideally encouraged to develop the habit of scenario discussion and to take it forward with them onto the line.

Further research is warranted across a wider and more diverse sample. The effects of various national cultures on scenario acceptance would be variables worth further analysis also.

References

Andreassi, J. L. (2007). *Psychophysiology: Human behaviour and physiological response.* Mahwah, NJ: Lawrence Earlbaum Associates.

Alkov, R.A., Gaynor, J.A., & Borowsky, M.S. (1985). Pilot error as a symptom of inadequate stress coping. *Aviation Space & Environmental Medicine, 56*, 244-247.

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioural change. *Psychological Review, 84,* 191-215.

Boeing, (2010). *Statistical Summary of Commercial Jet Airplane Accidents: Worldwide Operations 1959-2009* Retrieved from: http://www.boeing.com/news/techissues/pdf/statsum.pdf

Collins, A.F., Gathercole, S.E., Conway, M.A., & Morris, P.E., (1993). *Theories of memory.* Hove, UK: Lawrence Erlbaum Associates

Cox, T. (1978). *Stress.* Baltimore, MD: University Park Press.

Duckworth, K. L., Bargh, J. A., Garcia, M., & Chaiken, S. (2002). The automatic evaluation of novel stimuli. *Psychological Science, 13*, 513 – 519.

Rosenkrans, (2010). *Special purposes*. Retrieved 3 December, 2010 from: http://flightsafety.org/asw/aug10/asw_aug10_p30-35.pdf

Heaslip, T. W., Hull, N., McLeod, R. K., & Vermil, R. K. (1991). The frozen pilot syndrome. In *Proceedings of the 6th International Symposium on Aviation Psychology,* Columbus, Ohio, 782-787.

Lazarus, R. S. (1966). *Psychological stress and the coping process.* New York: McGraw-Hill.

Lazarus, R. S. (1999). *Stress and emotion: A new synthesis.* New York: Springer Publishing Company Inc.

Lazarus, R. S., & Folkman, S. (1984). *Stress, appraisal, and coping.* New York: Springer.

LeDoux, J. E. (2000). Emotion circuits in the brain. *Annual Review of Neuroscience, 23*, 155–184.

Lynn, S. J., & Rhue, J. W. (1994). *Dissociation: Clinical and theoretical perspectives.* New York: The Guildford Press

Martin, W.L., Murray, P.S., & Bates, P.R. (2010). The effects of stress on pilot reactions to unexpected, novel, and emergency events. In *Proceedings of the 9th International Australian Aviation Psychology Association Symposium,* Sydney, April 18-22, 2010.

Monat, A. & Lazarus, R. S. (1991). *Stress and coping.* New York: Columbia University Press

Peterson, B. D. (2007). Emergency procedures: AOPA Safety Advisor. *Operations and Proficiency No 12,* Frederick, MD: AOPA Air Safety Foundation

Ratey, J. J. (2002). *A users' guide to the brain: Perception, attention, and the four theatres of the brain.* New York: First Vintage Books

Stokes, A. F. & Kite, K. (1994). *Flight stress: Stress, fatigue, and performance in aviation.* Aldershot, UK: Ashgate.

Taleb, N. N. (2010). *The black swan: The impact of the highly improbable* (2nd ed.). New York, USA: Random House Publishing.

Thackray, R. I. (1988). Performance recovery following startle: A laboratory approach to the study of behavioural response to sudden aircraft emergencies. *FAA Technical Report No. DOT/FAA/AM-88/4, Civil Aeromedical Institute, Federal Aviation Administration,* Oklahoma City, USA.