Startle, Freeze and Denial: An analysis of Pathological Pilot Reactions during Unexpected Events

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Introduction

Acute stress reactions are common during life's emergencies. One only has to see the six o'clock news to see another disaster unfolding around the world somewhere. Earthquakes, floods, fires, ship sinkings, oil rig disasters or train wrecks - these are all relatively common and frequently involve considerable loss of life. The aftermath of these events often turns up a mixture of behaviour from those involved. Studies by several researchers, [1, 2, 3] both through eye witness accounts and interviews with survivors, have looked at why some people survived various disasters and others didn't. These survivors often reported seeing people who were apparently paralysed with fear and incapable of movement, even where such movement would have helped them survive.

Such inaction in the face of imminent threat is concerning from an aviation perspective. Passenger behaviour during aircraft accidents has followed similar patterns, with research[4, 5] showing that even in simulated evacuation trials, behavioural inaction was displayed by a number of passengers. Leach[3] suggests that around 10-15% of people display pathological behaviour when faced with life threatening situations, and certainly real-life aircraft examples such as the Manchester B737 fire [6] showed some degree of passive inaction amongst passengers.

This inaction, which is most likely an acute reaction to an overwhelmingly threatening stimulus, may be due to an elementary freezing mechanism within the brain, [7, 8] or indeed a coping/defence mechanism, which seeks to deny the existence or severity of the threat [9, 10]. Inaction may also be the result of a serious startle or surprise, with experiments by researchers showing that cognitive and dexterous impairment could last for up to 30 seconds following a strong startle [11, 12, 13, 14].

While these reactions would seemingly be typical of innocent participants in unfolding disasters, it would be expected by most people that pilots, who are generally well trained, often very experienced, and endowed with the 'right stuff'[15], would nonchalantly deal with critical emergencies competently and flawlessly. Unfortunately this would not appear to be

the case. Despite significant improvements in aircraft reliability over the last few years, the modern aircraft accident or serious incident is often peppered with human failings from the pilots. Air France Flight 447, Turkish Airlines Flight 1951, Colgan Air Flight 3407, Pinnacle Airlines Flight 3701 and West Caribbean Airlines Flight 3708 are just a few examples of flights where pilots mishandled critical events so badly that they failed to recover. In each of these cases there was some delay in acting, or incorrect action taken, which exacerbated the problem.

While pilots routinely practise engine failures, engine fires, depressurisations and major system malfunctions, the types of critical event which have become prevalent in recent accident data are commonly regarded as 'black swan' or highly unusual events [16] which, when unexpected, have created situations where pilots are very surprised and/or overwhelmed. This startle reaction, or an acute stress reaction such as freeze or denial, is sometimes exacerbated by a conditioned expectation for things never going wrong. This is an unintentional sense of complacency borne out of ubiquitous normality in line operations, week in and week out for long periods of time.

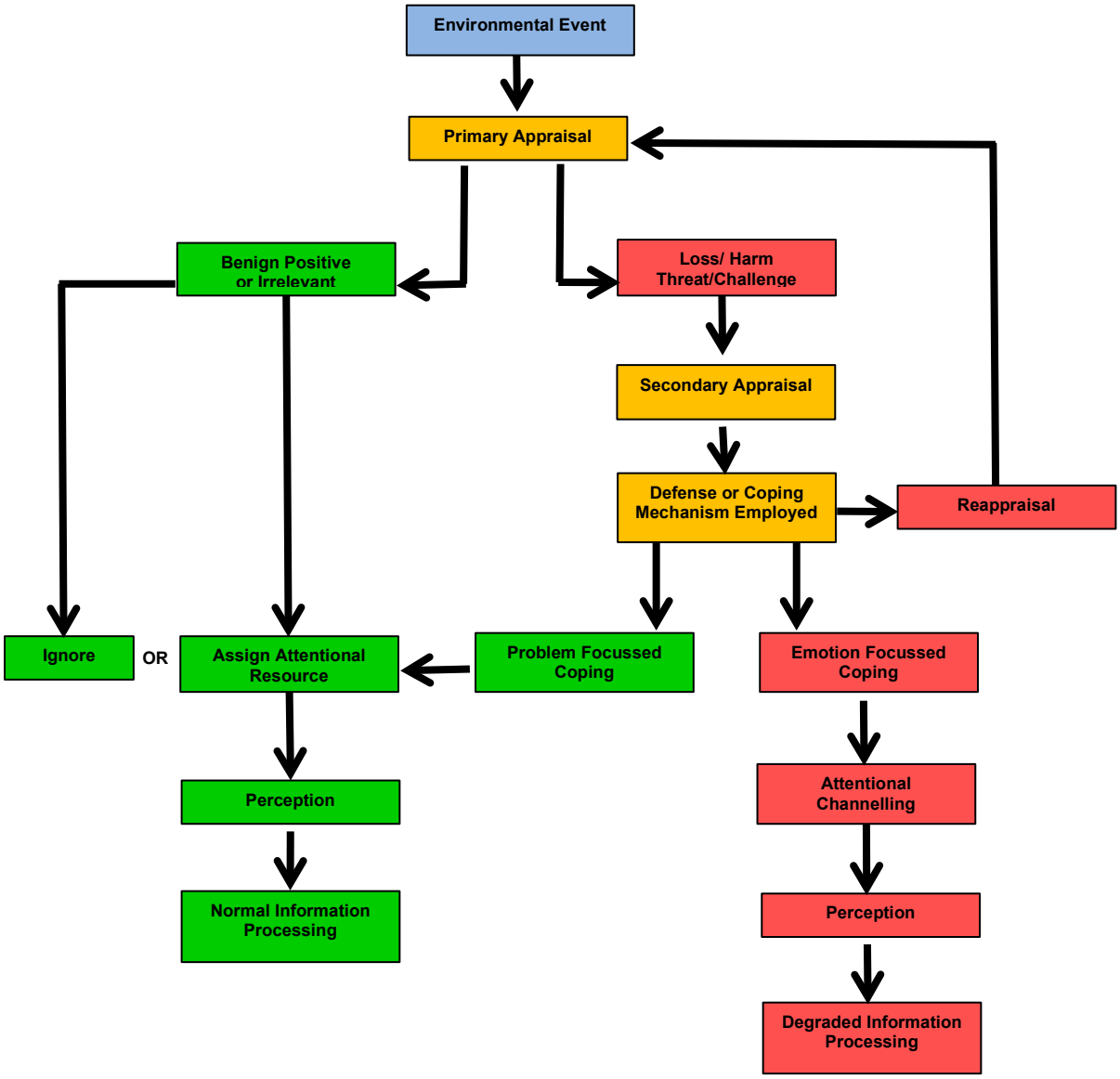
The inaction type behaviours of startle/surprise, freezing and denial will be examined further. Results of interviews with pilots who have experienced critical events are discussed and results from startle experiments in a flight simulator will be examined.

Discussion

Central to the acute stress reaction is an appraisal that some particular stimulus is threatening. Lazarus and Folkman [17] describe appraisal as *'an evaluative process that determines why and to what extent a particular transaction or series of transactions between the person and the environment is stressful'.* Lazarus & Folkman [17] further suggest that appraisal involves two distinct processes: primary appraisal which determines level of threat and secondary appraisal which determines an appropriate method of coping. This appraisal process is very rapid and appears to precede cortical processing[18, 19]. This is clearly advantageous in those situations where immediate action is required, but may induce an unwarranted pathological stress reaction in some cases.

Where a situation is appraised as threatening then humans will naturally apply some form of homeostatic coping or defence mechanism. This may take the form of trying to fix the problem; an entirely appropriate method, which is largely employed by most pilots in most situations. Where no immediate fix is at hand however, or the situation is appraised as being overwhelming, then the possibility exists that some form of emotional type coping mechanism will be employed. Emotionally focussed coping processes are largely pathological and may include processes such as avoidance, denial, self-deception or reality distortion [17, 20, 21]. These coping mechanisms can then have severe effects on the constructive processing of information, problem solving and decision making. In the aviation context this is very problematic in critical situations. The following model illustrates a conceptual model of threat, appraisal and information processing.

A Conceptual Model of Threat, Appraisal and Information Processing [22]



Denial

Where some stimulus is appraised as being particularly threatening and an emotionally focused coping mechanism is implicitly invoked, then the possibility exists that the stressful stimulus will simply be ignored. This denial of existence can be very effective in relieving stress, however continual reappraisal and denial is required for this very rudimentary coping mechanism to persist.

Denial may be a 'strategic' process. This is remarkably common, particularly in people with life threatening illnesses, where they would rather ignore the symptoms for some time, rather than confront the stressful possibility of mortality. While this could conceivably be problematic where situations such as deteriorating weather or aircraft status may compound a problem, generally the more immediate stressors requiring what we will describe as 'dynamic denial', are of greater concern in critical events. This dynamic denial, where critical

information is not processed as part of an acute stress coping mechanism, could have severe implications in situations such as airborne critical events where careful analysis and logical problem solving are required.

Breznitz [23] describes an increasingly pathological taxonomy of denial involving seven different stages. These include: denial of personal relevance, denial of urgency, denial of vulnerability, denial of affect, denial of affect relevance, denial of threatening information and denial of information. While the early stages are mildly concerning, the latter stages where threatening information or all information is denied, are particularly worrisome in the aviation context. Where some critical situation eventuates and an individual's brain unconsciously and involuntarily ignores the threatening cues which present themselves, then the chances of recovering from that critical situation are substantially reduced.

Research by the author involving interviews with pilots who had experienced critical events, showed that short term denial was relatively prevalent during emergencies, with pilots suggesting some level of denial was experienced in fifteen of the forty-five events canvassed. This was generally short term denial and did not turn out to be of catastrophic consequence, however it raises the question of how many fatal accidents have involved denial where recovery was not made at all, or delayed too long.

Freezing

While denial is quite difficult to quantify, most people are familiar with the concept of freezing under conditions of acute stress. "The deer caught in the headlights" is a common analogous phrase for this phenomenon, which is not uncommon in aviation accident and incident data. Similar conditions to freezing exist, such as catatonia, dissociation or tonic immobility, however these are all slightly different phenomena and different concepts to the behavioural or mental inaction described here.

Freezing is a rudimentary result of overwhelming threat, where the brain is unable to cope with the complexity and danger presented by sudden circumstances. Reports from survivors of disasters such as the Piper Alpha Oil Rig fire and the MV Estonia sinking [3] described people who were simply frozen or paralysed and unable to save themselves, despite encouragement or abuse from other passengers. Similarly, aviation has examples where pilots have simply frozen at inappropriate times during critical events. An Air Canada Captain in 1978 was one example, freezing after commencing a rejected takeoff at Toronto [24, 25]. In this case he closed the thrust levers, but failed to brake or select reverse thrust, simply staring straight ahead. The aircraft ran off the end of the runway at 70 knots, killing several people.

During research interviews by the author, one pilot described an approach where the Captain froze during an approach, having set up a high rate of descent. The aircraft continued to descend well below glidepath until becoming visual at very low level on collision course with an apartment block. Fortunately, once visual the Captain recovered and a last minute evasive manoeuvre narrowly avoided the building. The First Officer who had increasingly tried to alert the Captain to the glidepath deviation, had tried several times to take over and even resorted unsuccessfully to hitting the Captain to gain control.

Another interview revealed a situation where a military pilot, while practising high rotational spins under instruction, simply froze during recovery from a spin. The student became

unresponsive and the instructor pilot had to physically hit the student to get him to release his iron grip on the controls. A successful recovery was finally made close to bailout altitude.

Startle

The startle reflex is a universal response to a surprising stimulus. It invokes a pattern of aversive movement and aligns attentional resources to the source of the stimulus. This process is remarkably fast, with first signs of reaction occurring in as little as 14ms in some tests on humans [26, 27]. Given that cognitive processing of new stimuli takes over 500ms, [28] this "quick and dirty" reaction is clearly an innate process for avoiding harm.

The amygdala, which is strongly associated with emotional memory in the brain, appears to be where initial appraisal of threat is made. Projections from the amygdala then initiate the startle reflex and, where the threat persists, the full startle or surprise reaction [7, 8]. This involves arousal of the sympathetic nervous system, creating rapid changes in the body's systems. Changes include increasing heart rate and respiration rate, routing more blood flow to vital organs, and introducing hormones such as adrenaline (epinephrine) into the blood stream [29, 30]. This is commonly known as the fight or flight response and is the same process enacted during acute stress reactions.

Research [11, 12, 13, 14] has shown that cognitive and dexterous impairment can last for up to 30 seconds following a strong startle. This has significant implications for aviation where sudden, unexpected and critical events are typical of aircraft emergencies. A number of recent accidents such as Colgan Air Flight 3407 and Air France Flight 447 are instances where the effects of startle are strongly suspected to have affected pilot reactions during critical events. A significant number of other accidents and incidents where pilots have performed less than optimally during critical events are cases where startle or surprise may also have contributed to a poor outcome.

Recent startle research in an airline simulator using 18 type rated pilots, showed approximately one third of pilots (n=7) performed very poorly during a critical event when startled. In the experiment a startling stimulus was introduced 40 feet above decision altitude on an approach where the cloud base was 100 feet below the minima. While five pilots performed nominally and six displayed some slight reactionary delay, seven of the eighteen pilots showed either impulsive behavior (immediate go around) or significant delays in reactions. Three pilots continued descent to below 100 feet AGL and two pilots continued to land despite severely unstable approaches. EGPWS warnings of "Pull Up" were encountered on two of the three approaches which had become unstable and continued below 100 feet. While this was a relatively small sample size, the results were both statistically ($p<0.05$) and qualitatively significant, with the majority of pilots admitting to having experienced physiological and cognitive effects following the startle.

Conclusion

Humans are particularly susceptible to the effects of acute stress, with unexpected, threatening and critical events often presenting circumstances where some individuals fail to cope well. The stress reaction has been shown to have severe effects on working memory and other cognitive functions, with constructive thoughts being replaced by task-irrelevant, anxious thoughts. The acute stress response, which is associated with an appraisal of threat,

can create situations in some people where they are completely overwhelmed and freeze, or institute some coping mechanism such as denial.

Denial, which is an emotion-focused coping mechanism, is a very rudimentary process. Interviews with pilots who had experienced aircraft emergencies showed that a brief period of denial was not unusual, although in all of the cases discussed, it was quickly overcome as rational processing kicked in. Dynamic denial could, if it persisted, be particularly detrimental to the outcome of the situation, although it is impossible to tell from historical accident data whether denial has been involved. However, there are several examples of instances where pilots took no action at a time when intervention was required, indicating that dynamic denial is at least a possibility. Further research in this area is required.

Freezing is an acute stress reaction in response to some overwhelming stressor. It has been shown to be relatively common during various disasters and noted both in real-life and simulated aircraft accidents and evacuations. It appears that the cognitive processes required to initiate action are overcome by an acute sense of dread, with the working memory being consumed by irrelevant thoughts of fearful outcome. ‘Paralysed’ or ‘petrified with fear’ are common recollections from some people who have survived such critical situations.

Startle or surprise is a normal human reaction to some unexpected stimulus. Where the stimulus is appraised as threatening, activation of the sympathetic nervous system institutes widespread changes in the body. This arousal, which is also associated with the acute stress reaction, is generally known as the fight or flight reaction and has been shown to have significant effects on cognitive and psychomotor processes. Research shows that startle is strongly suspected in adverse pilot reactions during a number of recent accidents and was shown to adversely affect about one third of pilots in recent simulator experiments.

Inaction type behaviours induced by startle, freezing or denial are likely to have significant effects on safety, with undesired aircraft states, serious incidents and accidents being possible results. Further research and development of interventions for future training are warranted.

References

1. Fritz, C.E. & Marks, E. S. (1974). The NORC studies of human behaviour in disaster. *Journal of Social Issues, 10*, (3), 26-41.
2. Glass A.J.(1959). Psychological aspects of disaster. *JAMA, 171*, 222-5.
3. Leach, J. (2004) Why People 'Freeze' in an Emergency: Temporal and Cognitive Constraints on Survival Responses. *Aviation, Space, and Environmental Medicine, 75, (6), 539 – 542*
4. Muir H, Marrison C, Evans A. Aircraft evacuations: The effect of passenger motivation and cabin configuration adjacent to the exit. London, UK: Civil Aviation Authority; 1989. CAA Paper 89019.
5. Muir, H.C., Bottomley, D.M. & Marrison, C. (1996). Effects of cabin configuration and motivation on evacuation behaviour and rates of egress. *International Journal of Aviation Psychology, 6,* (1), 57-77.

6. Air Accidents Investigation Branch (1988). *Report on the accident to Boeing 737-236 Series 1, G-BGJL at Manchester International Airport on 22 August 1985 (Aircraft Accident Report 8/88).* London: Her Majesty's Stationery Office
7. Le Doux, J.E. (1996). *The emotional brain*. New York: Simon and Schuster
8. Le Doux, J. E. (2000). Emotion circuits in the brain. *Annual Review of Neuroscience, 23*, 155–184.
9. Carver, C. S., Scheier, M. F., & Weintraub, J. K., (1989). Assessing coping strategies: A theoretically based approach. *Journal of Personality and Social Psychology, 56,* (2), 267-283.
10. Folkman, S., Lazarus, R. S., Dunkel-Schetter, C., DeLongis, A. & Gruen, R. J. (1986). Dynamics of a stressful encounter: Cognitive appraisal, coping, and encounter outcomes. *Journal of Personality and Social Psychology, 50*, (5), 992-1003
11. Thackray, R. I., & Touchstone, R. M. (1983). Rate of recovery and subsequent radar monitoring performance following a simulated emergency involving startle. *FAA Office of Aviation Medicine Report No. FAA-AM-83-13*
12. Vlasek, M. (1969). Effect of startle stimuli on performance. *Aerospace Medicine, 40,* 124-128
13. Woodhead, M. M. (1959). Effect of brief noise on decision making. *Journal of The Accoustic Society of America, 31,* 1329-1331.
14. Woodhead, M. M. (1969). Performing a visual task in the vicinity of reproduced sonic bangs. *Journal of Sound Vibration, 9,* 121-125.
15. Wolfe, T. (2001). *The right stuff.* New York: Bantam Books
16. Taleb, N.N. (2010). *The black swan.* New York: Random House Publishing
17. Lazarus, R. S., & Folkman, S. (1984). *Stress, appraisal, and coping.* New York: Springer.
18. Duckworth, K. L., Bargh, J. A., Garcia, M., & Chaiken, S. (2002). The automatic evaluation of novel stimuli. *Psychological Science, 13*, 513 – 519
19. Zajonc, R. B. (1980).Feeling and thinking: Preferences need no inferences. *American Psychologist, Vol 35*, (2), 151-175
20. Lazarus, R. S. (1966). *Psychological stress and the coping process.* New York: McGraw-Hill.
21. Monat, A. & Lazarus, R. S. (1991). *Stress and coping.* New York: Columbia University Press
22. 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 Symposium of the Australian Aviation Psychology Association, Sydney, 19-22 April, 2010.*
23. Breznitz, S. (1983). The seven kinds of denial. In S. Breznitz (Ed.) *The Denial of Stress.* New York: International Universities Press.
24. 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.
25. Stokes, A. F. & Kite, K. (1994). *Flight stress: Stress, fatigue, and performance in aviation.* Aldershot, UK: Ashgate.

26. Simons, R. C., (1996). *Boo!: Culture, experience, and the startle reflex.* USA: Oxford University Press.
27. Yeomans, J.S. & Frankland, P.W. (1996). The acoustic startle reflex: Neurons and connections. *Brain Research Reviews, 21,* 301-314
28. Asli, O. & Flaten, M.A. (2012). In the blink of an eye: Investigating the role of awareness in fear responding by measuring the latency of startle potentiation. *Brain Science, 2*, 61-84
29. Jansen, A.S.P., Van Nguyen, X., Karpitsky, V., Mettenleiter, T.C. & Loewy, A.D. (1995). Central command neurons of the sympathetic nervous system: Basis of the fight or flight response. *Science, 270*, (5236), 644-646.
30. Stratakis, C.A. & Chrousos, G.P. (1995). Neuroendocrinology and pathophysiology of the stress system. *Annals of the New York Academy of Sciences, 771,* 1-18