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If We'd Only Listen! What Research Can Tell Us About Aircrew Fatigue.

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Performance decrements associated with fatigue are significant risk factors of occupational, motor vehicle, and aviation accidents. The substantial number of recent aviation occurrences involving aircrew fatigue and the slow progress of related rulemaking prompted the TSB to include fatigue management on its 2018 Watchlist of key safety issues. At the same time, a finding of aircrew fatigue in a 2017 NTSB investigation into a near-taxiway landing prompted some journalists to argue that there are few, if any, research studies showing how fatigue affects flying ability, and that current efforts in fatigue management may not be effective. This paper explores research in psychology where effects of fatigue on human performance were identified, and describes correlative changes in pilot performance, with a focus on the approach and landing phases of flight. Examples from recent TSB air transportation safety investigations are used to illustrate.

Around midnight on July 7, 2017, Air Canada flight 759, on approach to San Francisco International airport, almost landed on a taxiway where four commercial aircraft holding hundreds of passengers and crew were lined up waiting to be cleared for departure. The taxiway was adjacent and parallel to the active runway. In September 2018, the U.S. National Transportation Safety Board (NTSB) released its report into the incident, which represented one of the closest calls of a potentially disastrous accident in history. The NTSB determined that the flight crew had misidentified the taxiway as the landing runway. Amongst other findings, aircrew fatigue due to circadian disruption and the length of continued wakefulness was cited as a contributing factor to the crew's misidentification of the intended landing surface, their ongoing expectation bias, and their delayed decision to initiate a go-around. Although both crew met Canadian flight duty time and rest requirements, at the time of the incident the pilot flying had been awake for more than 19 hours, and would have been permitted by the regulations to remain on duty for a further 9 hours. The NTSB concluded that Canadian aviation regulations in effect at the time of the incident did not always allow for sufficient rest for reserve pilots, a situation that could result in these pilots flying in a fatigued state during their window of circadian low.

As a consequence to this incident, some journalists (e.g., Nunes, 2018) argued that there were few, if any, research studies showing how fatigue affects a pilot's flying ability, and that current efforts in fatigue management in air transportation may not be effective. While anything that increases the demand for more research into the effects of fatigue on aviation safety is appreciated, the journalist's conclusion is unfounded. Knowledge and understanding of recent psychological research in fatigue and human performance does, in fact, tell a great deal about how fatigue affects a pilot's performance.

While there are typically between 1000 and 1100 aviation occurrences reported to the TSB each year under mandatory reporting requirements, practical considerations dictate that only about 2% are fully investigated by the TSB. Therefore, it is challenging to estimate statistically the prevalence of fatigue-related aviation accidents. Nevertheless, review of those investigations where fatigue was concluded to have played a role can increase our understanding of the issue. Between 1991 and 2017, there were 43 TSB air investigations that made formal findings related to fatigue; 22 made findings about fatigue as a cause or contributory factor, and 26 made findings about fatigue as a risk. Thirty-four investigations made findings regarding fatigue on the part of air crew and, of these, 12 (35%) involved the approach and/or landing phases of flight.

The objective of this paper is to review some of what is currently known in psychology about the effects of fatigue on human performance that would predict corresponding changes in pilot performance. In the interest of brevity, the focus is on the approach and landing phases of flight, with examples from TSB aviation investigations used to illustrate.

Sleep-related fatigue and flying

Although there are various other types of fatigue that can affect human performance (e.g., physical, mental, and lethargic fatigue), fatigue that is related to the amount and quality of sleep obtained is biological in nature. Consequently, it cannot be prevented by, for example, characteristics of personality, intelligence, education, training, skill, compensation, motivation, physical size, strength or practice. In this context, "fatigue" is conceptualized as a continuum between being asleep and being fully awake. Sleep-related fatigue can be caused by acute or chronic sleep disruptions, extended periods of wakefulness, circadian (daily) rhythm effects, medical and psychological conditions, and sleep disorders. Performance impairments associated with fatigue are significant risk factors and predictors of occupational accidents and injuries (Dawson et al., 2011), motor vehicle accidents (TIRF, 2016), and aviation occurrences.

Flying an aircraft is a complex activity. It requires a human operator – the pilot – to perceive, process and integrate many different sources of information in a high workload environment, to perform many sub-tasks concurrently, and to make and change plans on short notice. To make effective decisions in this environment, pilots need to have an accurate understanding of their goals, decisions, and information requirements, as well as the state of the aircraft, other crew, and any passengers. Situation awareness – the perception of elements in the environment within a volume of time and space, comprehension of their meaning, and projection of their status in the near future (Endsley, 1995) – is paramount.

The approach and landing phases of flight represent periods of high workload even for highly skilled flight crew, and comprise a number of psychological elements, including:

- attending to, and perceiving, instruments, controls, and outside environmental conditions;
- making control inputs in a timely manner;
- remembering information and inputs; interacting effectively with other crew and ATC; and
- assessing and understanding the changing situation and associated risks; making effective decisions and solving problems – to either commit to landing or to perform a go-around.

The following sections present some of the primary psychological constructs that underpin pilot performance during the approach and landing phases of flight. The findings of research examining the effect(s) of fatigue on these constructs is briefly summarised and, for each construct, the corresponding effects on actual pilot performance that would be predicted are described and illustrated using occurrences investigated by the TSB.

Attention

Human attention and the capacity to process information are limited. Because human information processing takes place constantly, and because there is so much information available in the environment, it is necessary for pilots to cope with this flow by filtering out less important information to attend to the important information. A pilot's ability to attend to critical stimuli within their environment will be impaired if they are distracted or inattentive, and will result in impaired situation awareness (Endsley, 1995). In one study (Sanders & Reitsma, 1982), university students performed watchkeeping sessions during which either a centrally or a peripherally located signal was presented intermittently. One night's sleep loss slowed responses and led to missed stimuli, and impaired reactions to peripherally presented targets more significantly than centrallly presented ones. Similarly, vigilance, or the ability to sustain attention on a task for a given period of time, is impaired by fatigue (Dinges et al., 1997), which also increases distractibility. Fatigued participants performing the psychomotor vigilance task (PVT), a simple visual-manual reaction time task, with an attractive distraction task show a significant increase in both head turns towards the distracting stimulus and lapses on the PVT compared to when they are not tired (Anderson & Horne, 2006).

Fatigue's limiting effects on attention will impair a pilot's ability to attend to and detect stimuli in the environment. The TSB has investigated air transportation accidents where fatigue has had negative effects on pilot attention during the approach and landing phases of flight. For example, on 22 December 2012, a Fairchild SA227-AC Metro III charter flight departed Winnipeg, Manitoba at 1939 Coordinated Universal Time as a charter flight to Sanikiluaq, Nunavut (TSB investigation A12Q0216). Following several unsuccessful visual approaches, visual contact with the runway environment was made after passing the missed approach point. Following a steep descent, a rejected landing was initiated at 20 to 50 feet above the runway; however, it was too late - the aircraft struck the ground approximately 525 feet beyond the departure end of the runway. The 2 flight crew and 1 passenger sustained serious injuries, 5 passengers sustained minor injuries, but 1 lap-held infant was fatally injured. The investigation determined that frustration, fatigue resulting from a flight delay and shortened sleep the night before the flight, and an increase in workload and stress resulted in crew attentional narrowing and a shift away from well-learned, highly practised procedures, which contributed to the accident.

Information processing

Fatigue reduces the rate of information processing, which can affect the speed with which a person can identify important information, process and react to it. One often-cited research finding is that 17 hours of wakefulness produces slowing in psychomotor functioning equivalent to a blood alcohol concentration (BAC) of 0.05% (Dawson & Reid, 1997). Belenky et al. (2003) chronically sleep-restricted participants for one week and compared them to non-sleep-restricted controls. For those who were restricted to 3 or 5 hours of sleep per night, PVT responding slowed and lapses (non-reactions) increased steadily over the 7 days.

Slowed or inaccurate information processing would be expected to impair pilot performance during approach and landing, when a pilot must perceive and react to constantly changing information and stimuli. The TSB has investigated air occurrences where impairment in information processing from fatigue has played a causal role. For example, at 2145 eastern daylight time on 02 August 2001, a Cessna 182 aircraft departed on an instrument flight rules flight from Kuujjuaq to La Grande-Rivière, Quebec (TSB investigation A01O0210). Thirty nautical miles north of destination, the pilot established radio contact with the Flight Service Station (FSS), who informed the pilot that the ceiling was 300 feet overcast with a visibility of 8 statute miles in haze. The pilot was planning to conduct a global positioning system approach; however, minutes later at 0223 local time, the aircraft struck the ground. The pilot, who was the sole occupant, was fatally injured. Counting ground and air times, the pilot had likely been on duty 8 to 10 hours per day for the two days preceding the accident and, on the accident day, flew a distance of over 1900 nautical miles, for a flight and duty day of over 20 hours. The flight was conducted single-pilot, crossed six time zones over relatively featureless terrain, in instrument meteorological conditions (IMC), at night. Based on these factors, it was concluded that fatigue likely affected the pilot's performance and contributed to the accident.

Memory

Short-term memory allows the temporary storage of information. Working memory temporarily stores information while it is being manipulated for tasks such as reasoning. Both types of memory are impaired by fatigue. Babkoff et al. (1988) tested participants who were deprived of sleep for up to 72 hours. Participants responded to a visual memory and search task where randomly chosen target letters were selected from background non-target letters. As the target letters were not presented together with the letter matrix, participants had to remember the target letters during the task. Response speed and accuracy decreased over time depending on the level of sleep restriction.

A pilot must be able to recall a large body of knowledge from memory, and must be able to apply this information using working memory to a constantly changing operational environment, especially during approach and landing. The TSB has investigated accidents where fatigue's effects on memory have had causal or contributory effects. For example, in June 1994, a Swearingen Merlin II was returning to Thompson, Manitoba after having completed a MEDEVAC flight (TSB investigation A94C0088). After being cleared for approach, the aircraft descended below the minimum beacon-crossing altitude, struck the non-directional beacon tower in a wings-level attitude, and crashed. Both crewmembers were fatally injured, and the flight nurse was seriously injured. The TSB determined that the flight crew lost altitude awareness during the localizer back course approach and allowed the aircraft to descend below a mandatory level-off altitude. Contributing factors to the occurrence were the crew's deviation from a published approach procedure, ineffective in-flight monitoring of the approach, rapidly developing localized fog conditions, and pilot fatigue. The accident occurred just after midnight after both pilots had been awake for about 17 hours and on duty for about 9 1/2 hours. The investigation concluded that the decision to deviate from the published approach profile – in essence, taking a shortcut – was consistent with the effects of fatigue, as were the failure to reset navigational instruments and altimeter and accurately monitor the approach.

Problem solving / decision-making

As time awake increases, general cognitive performance deteriorates. Problem solving, vigilance and communication tasks show a 30% decrement after 18 hours of wakefulness and a 60% decrement after 48 hours (Angus, Pigeau, & Heslegrave, 1992). Duty requirements that extend a crewmember's time awake beyond 18 hours can be expected to result in marked impairment in information processing and problem solving abilities. Fatigue will also reduce a person’s flexibility in their problem-solving approach to a situation that is perceived to be different from the routine, so that they perseverate and repeat previously ineffective responses (Horne, 1988). Perseveration increases the likelihood that the normal routine will be maintained, leading to a failure to revise the original plan and make it difficult for a fatigued person to devise and try a novel solution. This has obvious repercussions for pilots during approach and landing.

In general, performance on more complicated tasks, such as decision-making, is degraded to a higher degree than performance on easier tasks such as simple counting when people are fatigued (Lamond & Dawson, 1999). In a simulator study using military pilots (Previc et al., 2009), 34-hour sleep deprivation was associated with degraded flying precision, but no changes in instrument scanning, suggesting that the fatigue impaired information processing and decision-making rather than eye-scanning behaviour. In another military simulator experiment (Caldwell et al., 2004), pilots showed significant decrements in mood, cognition, central nervous system activation, and flight skills in the predawn hours during a night without sleep. Control errors sometimes doubled and pilots experienced central nervous system alterations, which degraded information-processing capacity and reaction time. Information processing was impaired, and a wide array of basic capabilities were degraded as a result of compromised vigilance, poor situation awareness, and slow reaction time. If an emotional component is involved, as is often the case in emergency situations, decision-making is significantly impaired after 23 hours of wakefulness, even if large amounts of stimulants like caffeine are consumed (Killgore, Grugle, & Balkin, 2012).

The TSB has investigated accidents where aircrew problem-solving and decision-making impairments caused by fatigue were a causal factor. For example, in January 2012, an Enerjet Boeing 737-700 was operating from Fort St. John to Fort Nelson, British Columbia (TSB investigation A12W0004). At 1117 Mountain Standard Time, during the landing rollout, ENJ401 overran the runway end by about 230 feet. There were no injuries to the 112 passengers or 6 crew members and no damage to the aircraft. The investigation determined that the captain did not attain appreciable sleep in the 24 hours preceding the flight and was fatigued, which led to the captain continuing the approach when the aircraft was not in a stabilized configuration, consistent with what is known with “fatigue-induced reduction in forward planning and a focus of attention towards salvaging the flight”.

Conclusions

Psychological constructs and related skills that are sensitive to the effects of fatigue are often similar to those skills that are required in an emergency, or high workload, situation such as during the approach and landing phases of flight. Based on the research reviewed in this paper, the contention of some journalists (e.g., Nunes, 2018) that there are few, if any, research studies showing how fatigue affects a pilot’s flying ability, is obviously unfounded.

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