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PHILOSOPHY STATEMENT

Cornelius Lanczos, a mathematician working in the field of applied analysis, expressed the history of mathematics in three phases:

1) A given physical situation is translated into the realm of numbers,
2) By purely formal operations with these numbers certain mathematical results are obtained, [and]
3) These results are translated back into the world of physical reality (1988, p. 1). [1]

Formal papers, in subjects related to aviation, roughly follow the same course. However, there appears to be a weakness in aviation research, that being the omission of the third phase.

It is not good enough that conclusions are drawn, if those conclusions fail to improve the system observed. Clearly, the observed have a say in implementing the conclusions of research, but their failure to implement the conclusions drawn by the researcher may be more indicative of a lack of understanding than a lack of desire. Researchers tend to peer into complex systems as through a soda straw, forming formal opinions on the finite without understanding the complete system. Industry, ever mindful of the complete system, may find research irrelevant, because it makes much to do about nothing.

The editorial staff, to include those listed as consulting editors, is committed to the improvement of all individuals within the aviation community. We seek to enhance existing systems bearing in mind that small improvements must not upset the delicate balance between too little and too much help. We also seek to promote safety, not by lip service, but by demonstration in how we execute our studies and how we report our findings.

We feel that the best way to translate results back to the physical world is to incorporate the viewpoints of people around the globe. Without the influence of a worldwide community, we deny the significance of diversity, and ignore the perspectives of gifted scientists from different countries. It is our hope that each reader will feel the same.

[1]Lanczos, C. (1988). Applied Analysis. Mineola, NY: Dover Publications, Inc.

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EDITOR'S NOTES

Formal Papers

Aviators who train in simulators are susceptible to Simulator Sickness. Our lead article, by *David M. Johnson*, reports on a study of four hundred seventy-four Army aviators who were administered the Simulator Sickness Questionnaire prior to simulator exposure, immediately after exposure, and 12 hours later. The study focused on the issues of incidence and magnitude of simulator sickness, aftereffects, susceptibility, and amount learned.

This study by J*effrey P. Cashman, Joyce S. Nicholas, Daniel Lackland, Lawrence C. Mohr, Robert S. Woolson, Glenda Grones, J. Keith Rodgers, and Jeff B. Kilme*r was performed to determine if United States pilots in the Air Line Pilots Association International (ALPA) experience mortality at the same rate as the general United States Population. Information on over 72,000 pilots was gathered for the period January 1, 1980 through December 31, 2002.

Carla Hackworth, Kali Holcomb, Joy Banks, and David Schroeder present the results of an on-line survey conducted to assess the status of human factors programs in maintenance organizations. Questions focused on training, error management, fatigue management, and other human factors issues. A highly experienced group from more than 50 countries responded to the questionnaire. Results highlight the maintenance human factors strategies, methods, and programs that companies use to reduce human error.

Autonomous self-separation by pilots is close to one end of a continuum of operational concepts known as 'free flight', which could compose an evident paradigm change for global air operations. *Peter A. Hancock and Kip Smith* report on a purpose-specific simulation system especially focused on the issue of pilot-ATC interaction and the respective changes in functioning due to greater distribution of control. The paper describes this effort, its structure, function, and results, which have shown a consistent use of a time-to-contact threshold by pilots in resolving conflict situations.

Tom J. Caska and Brett RC. Molesworth report that caffeine in low doses has its most profound effect when pilots are experiencing fatigue or sleep deprivation. This study investigates the effects of low dose caffeine on pilots' performance during a crucial segment of flight. Thirty pilots were randomly divided, by caffeine intake, into three groups. The pilots performed two simulated instrument landing systems approaches. Caffeine was administered between the two flights and pilots' performances were measured and compared.

Flight instructors and student pilots will likely experience conflict due to hazardous attitudes. *Michael Wetmore, Philip Bos, and Chien-tsung Lu* investigates how interpersonal conflict resolution strategies can be applied in the flight school environment. This research can be used by aviation educators and flight instructors to understand, formulate, and apply conflict resolution strategies in both the classroom and the cockpit.

NEXRAD and onboard radar displays may produce conflicting weather representations that disrupt team decision-making processes and lower decision-making confidence *William R. Bailey III, Ernesto A. Bustamante, James P. Bliss, and Elizabeth T. Newlin* examines teaming factors such as communication level, leadership style, and differences in flight experience that could influence decision confidence when encountering conflicting weather information.

The shortage of qualified first officers is forecast to continue; therefore, the retention of students who are enrolled in Professional Pilot programs has become an important priority. *Wendy S. Beckman and Pamela M. Barber* present and discuss the findings from a survey designed to identify the factors that caused students to change from the Professional Pilot concentration to a different Aerospace concentration.

In U.S. Naval aviation, human error accounts for more than 80% of mishaps. *Paul O'Connor and Angela O'Dea's* paper represents the first attempt to summarize the elements of the U.S. Naval aviation safety program in a single document, and disseminate it to a non-military audience. It will identify the many areas that the U.S. Navy has learned from other high-reliability organizations, and delineate possible areas in which elements of the Navy's safety program could be adapted to mitigate the human factors causes of mishaps in commercial aviation.

Book Reviews

The Field Guide to Understanding Human Error by Sidney Dekker is reviewed by *Brittany Jones and Todd P. Hubbard.*

Delivering Excellent Service Quality in Aviation By Mario Kossmann is reviewed by *Ned S. Reese.*

KC

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Papers

Book Reviews

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Helicopter Simulator Sickness: Age, Experience, and Amount Learned

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Abstract

Simulator sickness was measured before and after exposure to a helicopter simulator that was being used for emergency procedures training. Research addressed these issues: incidence and magnitude of simulator sickness, aftereffects, susceptibility, and amount learned. Four hundred seventy-four Army aviators participated. The Simulator Sickness Questionnaire (SSQ) was administered prior to simulator exposure, immediately after exposure, and 12 hours later. The SSQ Total Severity score was significantly larger immediately after exposure than it was prior to simulator exposure or 12 hours later. Age was significantly and positively correlated with SSQ score, after the effect of flight experience was held constant. Flight experience did not correlate with SSQ score, after the effect of age was held constant. These results were consistent with postural instability theory. Both prior history of motion sickness and prior history of simulator sickness were significantly and positively correlated with SSQ score. SSQ score was not correlated with amount learned during training.

Background

Simulator sickness (SS) is a form of motion sickness (MS) that does not require true motion—but does require a wide field of view (FOV) visual display (Biocca, 1992; Mooij, 1988; Young, 2003). Several reviews of this phenomenon have been published (e.g., AGARD, 1988; Biocca, 1992; Ebenholtz, 1992; Johnson, 2005; Kennedy, Berbaum, Allgood, Lane, Lilienthal, & Baltzley, 1988; Kennedy, Berbaum, Lilienthal, Dunlap, Mulligan, & Funaro, 1987; Kennedy, Drexler, Compton, Stanney, Lanham, & Harm, 2003; Kennedy & Frank, 1985; Kennedy & Fowlkes, 1992; Kennedy, Lane, Lilienthal, Berbaum, & Hettinger,

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1992; Kolasinski, 1995; McCauley, 1984; Pausch, Crea, & Conway, 1992; Wright, 1995). Like all varieties of MS, an intact vestibular system is necessary to experience SS (Ebenholtz, 1992; Parmet & Gillingham, 2002). The term “vection” is used to describe a visually induced sense of self-motion. Whether found in a flight simulator or virtual reality simulation, vection causes a MS-like discomfort for a substantial minority of participants. This unpleasant experience is referred to as SS.

Signs and symptoms

SS is polysymptomatic (Kennedy & Fowlkes, 1992; Kennedy & Frank, 1985; Kennedy, Lane, Berbaum, & Lilienthal, 1993). Symptoms include nausea, dizziness, spinning sensations, visual flashbacks, motor dyskinesia, confusion, and drowsiness (McCauley, 1984). Observable signs of SS include pallor, cold sweating, and emesis (McCauley, 1984). The Simulator Sickness Questionnaire (Kennedy, Lane, et al.) lists symptoms of general discomfort, fatigue, headache, eyestrain, difficulty focusing, increased salivation, sweating, nausea, difficulty concentrating, fullness of head, blurred vision, dizzy, vertigo, stomach awareness, and burping. Reports of visual flashbacks and visual hallucinations have been documented (McCauley, 1984; Wright, 1995; Young, 2003) although they are rare.

Measurement

The current standard for measuring SS is the Simulator Sickness Questionnaire (SSQ) developed and validated by Kennedy, Lane, et al. (1993). The SSQ is a self-report symptom checklist. It includes 16 symptoms that are associated with SS. Participants indicate the level of severity of the symptoms that they are experiencing currently. For each of the symptoms there are four levels of severity (none, slight, moderate, and severe). The SSQ provides a Total Severity score as well as scores for three subscales (Nausea, Oculomotor, and Disorientation). The Total Severity score is a composite created from the three subscales. It is the best single measure because it provides an index of overall symptoms. All scores have as their lowest level a zero (no symptoms) and increase with increasing symptoms reported. An advantage of the SSQ is that a variety of symptoms can be measured quickly with the administration of this one questionnaire. Another advantage is that it allows quantitative comparisons across simulators, populations, or treatment variables over time. Kennedy et al. (2003) provided a categorization of SSQ Total Severity scores based on several thousand exposures of military aviators to aircraft simulators. A score of 0 means no symptoms, less than 5 means negligible symptoms, 5 – 10 minimal symptoms, 10 – 15 significant symptoms, 15 – 20 symptoms are a concern, and greater than 20 a problem simulator.

Incidence

The incidence of SS varies widely across simulators and conditions. A common method of presenting incidence is to list the percentage of participants who report at least one symptom. Using this method, various reviews have reported incidence to range from 10 to 88 percent (McCauley, 1984), from 27 to 88 percent (Kennedy & Frank, 1985), from12 to 60 percent (Kennedy et al., 1987; Kennedy & Fowlkes, 1992), and from 0 to 90 percent (Pausch et al., 1992). Wright (1995) limited his review to helicopter simulators and reported that the incidence ranged from 13 to 70 percent. Crowley (1987) reported an incidence rate of 40 percent for the Cobra Flight Weapons Simulator (FWS). Braithwaite and Braithwaite (1990) reported an incidence rate of 60 percent for Lynx crewmembers. Gower, Lilienthal, Kennedy, Fowlkes, and Baltzley (1987) collected data from aviators training in the Apache Combat Mission Simulator (CMS) and reported an incidence rate of 44 percent. Gower and Fowlkes (1989a) reported a 37 percent incidence rate from aviators training in the Cobra FWS.

SSQ scores

Mean SSQ Total Severity (SSQ-TS) scores after exposure to a helicopter simulator have varied between 7 and 20. Durbin, Havir, Kennedy, and Pomranky (2003) reported mean scores of 11.40 and 13.25 for experienced aviators operating two different Comanche simulators for 90 min. Kennedy, Berbaum, Smith, and Hettinger (1992) reported mean scores from pilots exposed to five Navy and Marine helicopter simulators that ranged from 12 to 18. Kennedy, Lane, et al. (1993) reported results from several hundred pilots operating four helicopter simulators. These mean post exposure scores ranged from a low of 7.00 for the CH-46E helicopter simulator to 18.80 for the SH-3 helicopter simulator. Kennedy et al. (2003) published the results of 3,000 pilots operating eight military helicopter simulators. The overall mean post-exposure score was 12.63.

Aftereffects

The potential for dangerous aftereffects of simulator exposure—including ataxia, loss of balance, flashbacks—has been known right from the beginning (Miller & Goodson, 1958; 1960). McCauley (1984) noted that the potentially dangerous aftereffects of simulator exposure could affect the ground or flight safety of afflicted aviators. Virtually every report refers in some way to the potential for dangerous aftereffects of simulator exposure. However, there are no documented cases of flight incidents or automobile accidents linked to prior simulator-based training (Crowley, 1987; Kennedy & Frank, 1985; McCauley, 1984; Wright, 1995).

Baltzley, Kennedy, Berbaum, Lilienthal, and Gower (1989) reported data from a study involving 742 simulator exposures across 11 simulators. Overall, 45 percent of the pilots reported experiencing symptoms of SS upon exiting the simulator. Of these, 75 percent said that their symptoms disappeared within 1 hr. Six percent reported that their symptoms dissipated in 1 to 2 hrs, 6 percent in 2 to 4 hrs, 5 percent in 4 to 6 hrs, and 8 percent said that their symptoms lasted longer than 6 hrs. The most common category of aftereffect was nausea (51%) followed by disorientation (28%). Braithwaite and Braithwaite (1990) reported that 17 percent of their sample experienced aftereffects. The most frequently stated aftereffects were nausea, which dissipated in 2 hrs, and headache, which sometimes lasted 6 hrs. Crowley (1987) reported that 11 percent of his sample experienced delayed effects of simulator training. The most commonly reported delayed symptom was a perception of illusory movement.

Some conclusions have emerged about the aftereffects of simulator exposure. First, approximately 10 percent of the sample will experience pronounced aftereffects (Kennedy et al., 1988; Kennedy & Fowlkes, 1992). Second, there is a significant positive correlation between the number and severity of symptoms reported immediately upon leaving the simulator, and the duration and severity of aftereffects (Chappelow, 1988; Silverman & Slaughter, 1995). Third, the aftereffects of simulator exposure usually wear off in an hour or two, but the persistence of symptoms longer than 6 hrs has been documented. For this reason, guidelines recommending a mandatory grounding policy after training in a flight simulator have been published (Chappelow, 1988; Crowley, 1987; Crowley & Gower, 1988; Kennedy et al., 1988; Kennedy et al., 1987; Kennedy, Lane, et al., 1992; Lilienthal, Kennedy, Berbaum, Dunlap, & Mulligan, 1987; NTSC, 1988; Parmet & Gillingham, 2002). The minimum recommended period from simulator to aircraft has ranged from 6 to 12 hrs and usually included the admonition to wait until the next day. In cases of severe discomfort, curtailment of other duties for up to 24 hrs has been recommended (Kennedy et al., 1988).

Susceptibility

SS is not only polysymptomatic; it is polygenic (Kennedy & Fowlkes, 1992; Kennedy & Frank, 1985). Kennedy & Fowlkes listed 13 factors that are implicated in causing SS. These were subdivided into three categories: individual, simulator, and task variables. Kolasinski (1995) described 40 factors that are associated with SS—also categorized as individual, simulator, and task variables. Pausch et al. (1992) reviewed several factors, with special emphasis given to simulator design. Three individual variables that increase susceptibility among aviators are prior history of motion sickness, flight experience, and age.

Prior history of motion sickness. People who have a history of prior episodes of MS will be more likely to experience SS in simulator-based training. Reviewers have reported that there is empirical evidence in support of this generalization (Johnson, 2005; Kennedy et al., 1987; Wright, 1995). Reported prior history of MS has been shown to correlate positively and significantly with SS during simulator-based helicopter training (e.g., Braithwaite & Braithwaite, 1990; Gower & Fowlkes, 1989a; Gower & Fowlkes, 1989b; Gower, Fowlkes, & Baltzley, 1989; Gower et al., 1987; Kennedy et al., 1988). The largest of these studies (Kennedy et al., 1988) reported the results of surveying 1186 pilots training in 10 Navy simulators. They reported a small, but statistically significant, positive correlation between reported prior MS and SS symptoms. In addition, both Lampton, Kraemer, Kolasinski, and Knerr (1995) and Lerman, Sadovsky, Goldberg, Kedem, Peritz, and Pines (1993) reported a significant positive correlation between prior history of MS and SS during simulator-based training in a tank driver simulator.

Flight experience. Flight experience is usually measured in terms of flight hrs (Tsang, 2003). It is widely understood within this research community that the more experienced aviators are more susceptible to SS than novices. This has been acknowledged in several reviews (Benson, 1988; Crowley & Gower, 1988; Johnson, 2005; Kennedy et al., 1987; Kennedy & Fowlkes, 1992; Kennedy & Frank, 1985; Kolasinski, 1995; Lilienthal et al., 1987; McCauley, 1984; Mooij, 1988; Parmet & Gillingham, 2002; Pausch et al., 1992; Young, 2003; Wright, 1995). Evidence of this relationship was discovered during the operation of the first visual helicopter simulator (Miller and Goodson 1958, 1960).

More recent evidence has supported this relationship—although not consistently so. Braithwaite and Braithwaite (1990) found a statistically significant positive correlation between flight hrs and SS among pilots training in a simulator for the Lynx helicopter. Crowley (1987) surveyed 112 Army Cobra pilots who were training in the FWS. Pilots with greater than 1,000 hrs of Cobra flight time were significantly more likely to report SS than pilots with fewer than 1,000 hrs of flight time. Gower and Fowlkes (1989b) assessed SS among 87 Army aviators training in a UH-60 simulator. They found a significant positive correlation between flight hrs and SSQ scores. Uliano, Lambert, Kennedy, and Sheppard (1986) assessed SS among 25 helicopter pilots. Their flight experience ranged from 360 to 2,860 hrs (*M* = 1,071). All participants operated a simulator representing the SH-60B Seahawk. Aviators with fewer than 900 hrs reported significantly less SS on all measures than those with 900 or more hrs.

Gower et al. (1989) collected data from 57 aviators with flight experience ranging from 450 to 7,000 hrs. The pilots were taking currency training in a simulator for the CH-47 helicopter. The authors found no correlation between flight hrs and SSQ scores. Gower et al. (1987) assessed SS among 127 Apache aviators with flight experience ranging from 150 to 8,400 hrs who were training in the CMS. The authors found no significant correlation between flight hrs and reported SS. Silverman and Slaughter (1995) collected data from 13 aviators as part of an operational test of a MH-60G PAVE Hawk simulator. The participants' total flight experience ranged from 350 to 15,327 hrs. The authors reported that there was no statistically significant correlation between reported SS and either total flight hrs or hrs for the specific MH-60G helicopter.

Age. Reviewers have claimed that susceptibility to SS varies with age in the same way that MS varies with age (e.g., Biocca, 1992; Kennedy & Frank, 1985; Kolasinski, 1995; Pausch et al., 1992; Young, 2003). That is, below age 2, infants are generally immune. Susceptibility is at its highest level between ages 2 and 12. There is a pronounced decline between ages 12 and 21. This decline continues, though more slowly, through adulthood until about age 50, after which SS is very rare. These claims were not based on research examining SS in simulators, but on the self-report data reviewed by Reason and Brand (1975) for MS in vehicles.

Perhaps the reason reviewers report conclusions based on surveys of MS symptoms, is because so little research has been performed examining the effect of age on susceptibility to SS. Braithwaite and Braithwaite (1990) administered questionnaires to 230 pilots attending training in a simulator for the Lynx helicopter. Age ranged from 23 to 42 years (*M* = 32). There was no relationship found between age and reported SS. Warner, Serfoss, Baruch, and Hubbard (1993) assessed SS in two wide-FOV F-16 flight simulators. Twenty-four male pilots participated in total. Sixteen were active-duty military pilots of mean age 28.6 years ("younger group"). Eight were older active-duty military pilots and former military pilots of mean age 52.1 years ("older group"). The task was a 50-min flight through a long, narrow, twisting canyon in each of the two simulators, in counter-balanced order, two weeks apart. One pilot from the younger group (1/16 = 6.25%) terminated a session prematurely due to severe SS. Three pilots from the older group (3/8 = 37.5%) terminated a session prematurely due to severe SS. The discomfort ratings collected from pilots who terminated prematurely were significantly higher than those from pilots who completed the flight. Among those pilots who completed the flight, there was no significant difference in discomfort ratings between the two groups.

Hein (1993) reported the results of 22 studies, involving 469 participants of both genders and a wide range of ages, over the course of 6 years. All studies took place in a fixed-base, automobile-driving simulator. Hein stated that age differences in susceptibility to SS were among the most consistent results. “Younger, male drivers adapt easily. Older drivers and women are severely susceptible to simulator sickness” (Hein, p. 611).

Age and experience. Aviation researchers investigating SS seldom aggregate their data by age. They are more likely to aggregate by aircraft flight hrs. Flight hours occupy a valued place in the world of aviation. However, among aviators, age in years and experience in flight hrs are strongly linked. Magee, Kantor, and Sweeney (1988) reported a statistically significant correlation between age and flight hrs ($r = 0.67$). This is because “As is common in most professions, piloting experience tends to accumulate with age” (Tsang, 2003, p. 525).

SS and Training

Does SS harm training? The fear that SS would limit the usefulness of simulators for training has existed for decades (Miller & Goodson, 1958, 1960). McCauley (1984) warned of compromised training and decreased simulator use caused by SS. This warning has been widely repeated. When researchers review the literature of SS, the possibility of compromised training and/or decreased simulator use is a common feature (Casali & Frank, 1988; Crowley, 1987; Crowley & Gower, 1988; Kennedy et al., 1988; Kennedy et al., 1987; Kennedy, Fowlkes, Berbaum, & Lilienthal, 1992; Kennedy, Lane, et al., 1992; Kolasinski, 1995, 1997; Lampton et al., 1995; Lilienthal et al., 1987; Mooij, 1988; Pausch et al., 1992; Uliano et al., 1986; Wright, 1995).

Given the primacy of this issue since 1958, it is remarkable how little empirical evidence there is on the subject. Chappelow (1988) administered questionnaires to Royal Air Force pilots training in air combat simulators. Respondents who had reported sickness symptoms were asked to assess the effect of the experience on their willingness to use the simulator in the future. A total of 214 pilots answered this question. Four percent reported that the experience decreased their willingness to use the simulator again. Sixty-eight percent responded that it had no influence. Twenty-eight percent stated that the experience increased their willingness to use the simulator again, because it provided good training and was fun.

Gower and Fowlkes (1989a) assessed the effect of SS on training by asking their sample of AH-1 pilots whether simulator-induced discomfort hampers training. They found two related results. First, there was a statistically significant positive correlation between SSQ scores and agreement with the statement that “discomfort hampers training.” The aviators who reported the most SS were more likely to agree that discomfort harms training. Second, only eight percent of their sample agreed, “discomfort hampers training.” Four percent were neutral on the question. Eighty-eight percent disagreed with the statement. These results were the self-reported opinions of Army aviators. No performance measures were presented to show that, in fact, those experiencing more discomfort learned less than their non-sick counterparts. Gower and Fowlkes (1989b) asked the same questions to their sample of UH-60 pilots and found the same pattern of results. First, there was a statistically significant positive correlation between SSQ scores and agreement with the statement. Second, this was the opinion of a small minority of their sample. Only 1 person (1%) of the 86 who answered this question agreed that discomfort disrupts training. Fifteen percent were neutral. Eighty-four percent disagreed with the statement. No data on performance during training were reported that would bear on the issue of SS and amount learned. Gower et al. (1989) found the same pattern of results with their sample of pilots training in the CH-47 flight simulator. There was a significant positive correlation between SSQ scores and agreement with the statement that "discomfort hampers training." Again, only 1 person (1.5%) agreed with the statement. Two people were neutral (2.9%). Of the 68 responses to this question, 65 (95.6%) disagreed with the statement. Finally, as before, no performance data were presented.

The results of these four questionnaire studies are clear. The vast majority of the aviators surveyed stated that the discomfort-producing potential of the devices did not detract from the training provided. However, a small minority of aviators—those experiencing the most sickness—held the opposite opinion. Given the importance of this issue, more research is needed. Measures of performance in learning the required program of instruction should be correlated with measures of SS. In agreement with Kolasinski (1997), the present author knows of no published research devoted to this question.

Theory

SS is a form of MS. The two major theories that explain MS also explain SS. The more common is the sensory conflict theory (Benson, 1978; Parmet & Gillingham, 2002; Reason, 1970, 1978; Reason & Brand, 1975). The major competitor is the postural instability theory (Riccio & Stoffregen, 1991).

Sensory conflict theory. The sensory conflict (SC) theory states that sensory inputs from the eyes, semicircular canals, otoliths, proprioceptors, and somatosensors are provided in parallel both to a neural store of past sensory patterns of spatial movement and to a comparator unit. This comparator unit compares the present pattern of motion information with that pattern expected based on prior motion history and stored in the neural store. A mismatch between the current pattern and the stored pattern generates a mismatch signal. This mismatch signal initiates both SS and the process of adaptation.

According to the SC theory, when an aviator is operating a new simulator the pattern of motion information presented by the senses is at variance with past experience in the flight environment. This conflict between the current sensory pattern and that pattern expected based upon past experience causes SS. However, with continued sessions operating the device the relative mismatch between current pattern and stored patterns decreases until one has adapted. Flight simulators attempt to simulate flight—that is, to trick the human perceptual system. However, no device can perfectly simulate all the physical forces of flight. This inability to simulate flight perfectly causes SS in experienced aviators. However, one need not be an aviator to know the discomfort of SS. Anyone with a normal vestibular system is susceptible to SS. The key concept is the mismatch between the novel motion environment (the current pattern of sensory stimulation in the simulator) and prior motion history (the patterns of sensory stimulation resident in the neural store).

Postural instability theory. The postural instability (PI) theory notes that sickness-producing situations are characterized by their unfamiliarity to the participant. This unfamiliarity sometimes leads to an inability to maintain postural control. This postural instability causes the discomfort—until the participant adapts. A prolonged exposure to a novel motion environment causes postural instability that precedes and causes the sickness.

PI theory states that there are individual differences in postural control. Evidence in support of these individual differences and their relationship to MS has been provided by Owen, Leadbetter, and Yardley (1998). Further, an imposed motion presented by a simulator can induce postural instability. The interaction of the body's natural oscillation with the imposed oscillation created by the simulator leads to a form of wave interference effect that causes postural instability. This instability is the cause of SS. Evidence in support of this theory—from participants exposed to simulated motion—has been reported (Smart, Stoffregen, & Bardy, 2002; Stoffregen, Hettinger, Haas, Roe, & Smart, 2000; Stoffregen & Smart, 1998).

SS, age, and theory. The SC and PI theories make different predictions in some instances (cf., Johnson, 2005). These two theories make opposite predictions concerning the effect of age on susceptibility to SS. The SC theory states that MS in all its forms must decline after about age 12 (Benson, 1978; Parmet & Gillingham, 2002; Reason & Brand, 1975). The reasons for this are that life experiences provide the neural store with a wealth of prior sensorimotor patterns of motion memories and that receptivity (the strength of the mismatch) declines with age. The SC theory predicts that SS will decline with age. When research shows that SS increases with age, these results are interpreted as being the product of a confounding with flight experience. Age and flight experience are strongly correlated among pilots (Magee et al., 1988; Tsang, 2003). The SC theory predicts that with increasing flight hours the relative mismatch between the sensorimotor pattern of aircraft flight and that of simulator "flight" will be greater and will engender more SS. However, this interpretation only exists because so much simulator research has taken place in the world of aviator training—a world where older aviators are also more experienced. The SC theory would predict that a large sample of adult non-aviators of widely different ages would show *decreasing* SS with increasing age.

The PI theory would make the opposite prediction. According to this theory, SS is caused by postural instability. Postural stability among adults is known to decline with increasing age—markedly so for the elderly (see below). Therefore, PI theory would predict that a large sample of adult non-aviators of widely different ages would show *increasing* SS with increasing age. Further, within any age cohort this theory predicts that greater instability will be associated with greater SS.

Postural instability and age. Age brings increased postural instability. All human sensory systems decline with age (Kane, Ouslander, & Abrass, 1994; Newman & Newman, 1987). Lord (2003) listed several documented age-related declines in visual capabilities, including acuity, peripheral vision, contrast sensitivity, and stereopsis. There are age-related changes in neuromuscular function, gait, and postural reflexes (Kane et al., 1994). The maintenance of postural stability involves the interaction of several bodily systems, but the contribution of the vestibular system is primary. Age dependent vestibular degeneration is an established fact for human beings as well as other mammals (Lyon, 2003, October).

Several researchers have measured postural stability as a function of age in healthy, non-institutionalized populations (e.g., Choy, Brauer, & Nitz, 2003; Gill et al., 2001; Matheson, Darlington, & Smith, 1999). Postural stability was defined as postural sway in these experiments and was measured in different ways. Matheson et al. (1999) measured postural stability in degrees of sway from the center of pressure in a sample of 76 subjects who ranged in age from 18 to 60+ years. The two major results were that 1) with an increase in age, there was a significant increase in sway, and 2) with an increase in the difficulty of the testing conditions (e.g., eyes closed), there was a significant increase in sway. Gill et al. (2001) recorded five measures of trunk sway in a sample of 147 males and females, who ranged in age from 15 to 75 years, on a battery of seven stance tasks, two stance-related tasks, and five gait tasks. The results showed significantly more sway for the elderly subjects on the stance and stance-related tasks. Choy et al. (2003) measured velocity of postural sway (m/s) on eight balance and stance tasks for a sample of 453 normal women aged 20 to 80 years. They found that with increasing age there was a significant increase in postural instability on both balance tasks and stance tasks. There was more sway with eyes closed, and more sway on a soft surface than on a firm one.

Lord (2003) noted that postural sway among older adults was influenced by several visual factors including acuity, peripheral vision, contrast sensitivity, and stereopsis. As visual capability in these areas decreased, postural sway increased. All these visual factors decline with increasing age. Thus, postural instability increases with increasing age with eyes open or closed, based on sensory deficits of the vestibular system, proprioceptors, and vision, along with degradation in motor control, muscle strength, and gait.

These age-dependent decrements in sensorimotor function are not mere laboratory curiosities. As people age they are increasingly likely to fall, and these falls are increasingly likely to result in serious injury or death (Kane et al., 1994). Falls are the leading cause of injury-related deaths for the elderly (Baker & Harvey, 1985). Among women, fall injuries begin to increase significantly at age 40 (Baker & Harvey). Falls are mentioned as a contributing factor in 40 percent of admissions to nursing homes (Tinetti, Speechley, & Ginter, 1988). In a prospective study, Tinetti et al. evaluated 336 non-institutionalized participants who were at least 75 years of age (*M* = 78.3). After a thorough medical, sensorimotor, and demographic evaluation, this sample was followed bi-monthly for 12 months. Thirty-two percent of this sample fell at least once during the follow-up period.

Tests of balance and gait at the evaluation were significantly correlated with falls during the follow-up period. Campbell, Borrie, and Spears (1989) used the prospective study method to follow 761 participants, all at least 70 years of age, for one year after an initial assessment. All falls were documented. Thirty-five percent of this sample fell at least once during the follow-up year. There was a significant positive correlation between age of participant and reported falls. For men, there was a significant positive correlation between body sway at initial assessment and reported falls during follow-up.

Buatois, Gueguen, Gauchard, Benetos, and Perrin (2006) also used the prospective study method to investigate several posturographic techniques and their relationship to falls among elderly persons. Two hundred and six healthy, non-institutionalized participants with no known balance pathologies were given a battery of several posturographic tests and then followed for 16 months. After this period, their data were aggregated into three groups: Non-Fallers, Single-Fallers, and Multi-Fallers. The Multi-Fallers were different from the other two groups at initial assessment in only two ways: 1) they showed significantly more body sway, and 2) they showed no postural adaptation.

Postural instability has been studied extensively, in several contexts, and using different methods. A consistent result has been that with increasing age there is an increase in instability. Therefore, if postural instability is the proximate cause of SS, as adherents of the PI theory claim, then a study of SS as a function of age should result in a statistically significant positive correlation between age and SS.

Purpose of this Research

The purpose of this research was to measure SS both before and after exposure to a helicopter simulator that was being used for emergency procedures training. Of particular interest was the relationship between SS, as reported on the SSQ, and participant age, flight hrs, prior MS, prior SS, and performance on a test of training effectiveness. This research was part of a program of instruction in simulator-based emergency procedures training that was being offered by the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) at Fort Rucker, AL. A description of this program can be found in Couch and Johnson (2005). Participants took this training as part of their AH-64A Aircraft Qualification Course (AQC). ARI's data collection effort was permitted on a non-interference basis. Hence, this research was not a controlled laboratory experiment, but rather a set of quasi-naturalistic observations.

Method

The Course of Instruction

All participants were flight students who had graduated from Initial Entry Rotary Wing training, had received their wings, and were enrolled in AQC. Many of these participants were transitioning from other aircraft after several years of aviation experience. The course was called AH-64A Back Up Control System (BUCS) Familiarization. This was simulator-based training concerning how to diagnose problems with the primary flight control system of the Apache, enable the fly-by-wire BUCS, and employ this back up system to fly and land the aircraft safely.

The Simulator

The ARI Simulator Training Research Advanced Testbed for Aviation (STRATA) provided the platform for this training. Detailed descriptions of STRATA can be found elsewhere (Johnson, 1997; Johnson & Stewart, 1999). The STRATA device was a fixed-base, full-mission simulator for the A-model Apache. The pilot and CPG cockpits were taken from an Apache aircraft. STRATA used a hydraulic digital control loading system to simulate the flight-control characteristics of the AH-64A. A G-seat and active five-point harness provided acceleration, deceleration, and motion cues. All controls, instruments, and displays were functional and integrated with each other. Both cockpits were provided with three 100-inch, rear projection visual displays providing each station with a 180-degree horizontal by 45-degree vertical out-the-window FOV. What the aviators saw out their windscreens was a highly detailed, geo-specific terrain database rendered by three CAE Medallion™ image generators.

Participants

A total of 474 aviators participated. All were enrolled in the AH-64A AQC course and voluntarily agreed to participate in this research. All were native speakers of English. All were in their usual state of health and fitness, and none had been ill in the week prior to the simulator session. 463 (97.7%) were males. The participants ranged in age from 20 to 58 years with a mean age of 30.4 (*SD* = 7.1). The range of total aircraft flight hrs for this sample varied from a low of 65 to a high of 17,000 with a mean of 1042.1 (*SD* = 1901.3).

Data Collection Instruments

Simulator Sickness Questionnaire. As described above (Kennedy, Lane, et al, 1993), the SSQ consisted of a 16-item checklist of symptoms. For each symptom, four levels of severity were listed. Instructions on the questionnaire asked each respondent to "Please indicate the severity of symptoms that apply to you <u>right now</u> by circling the appropriate word."

Prior to simulator exposure (Pre Questionnaire). A one-page questionnaire was administered immediately prior to the simulator session. It included the SSQ as well as four additional yes or no questions: 1) Are you in your usual state of health and fitness? 2) Have you been ill in the past week? 3) Do you have a prior history of motion sickness? 4) Do you have a prior history of simulator sickness?

Immediately after simulator exposure (Post Questionnaire). The SSQ was administered immediately upon exiting the simulator. If, during the session, there was an unscheduled break due to trainee discomfort, this "sickness event" was recorded by the author.

12 hours after simulator exposure (Aftereffects Questionnaire). A one-page questionnaire was filled-out by each participant approximately 12 hours after exiting the simulator. It included the SSQ as well as three yes or no questions: 1) Have you experienced any loss of muscular coordination or balance since leaving BUCS training? 2) Have you fallen down since leaving BUCS training? 3) Have you had an automobile or motorcycle accident since leaving BUCS training?

BUCS test. There were no formal tests of learning associated with this BUCS training that became a part of the student's AQC record. ARI developed a BUCS test for pedagogical purposes, but neither the students nor their instructors were made aware of the results. Each student was given two no-notice test scenarios—once each in the pilot cockpit and the CPG cockpit. There were four test scenarios. All test scenarios involved severances of some portion of the primary flight controls. All test scenarios occurred while either the pilot or the CPG had the controls and was "flying" the simulator.

Performance was scored by the BUCS subject matter expert (SME) based upon information available to him at the instructor station. This information was screens that showed the simulator's out-the-window view, screens that showed flight instruments, BUCS-specific information on the instructor's screen, video cameras showing both cockpits, and the crew's audio intercom system. Performance on each scenario was scored on a three-point scale: unsatisfactory (0), marginal (1), and satisfactory (2). Each student's total score could range from a low of 0 (unsatisfactory on both test scenarios) to 4 (satisfactory on both). To get a satisfactory score, the crewmember at the controls had to detect the problem, correctly diagnose it, communicate the situation to his or her fellow crewmember, execute the appropriate actions to enable the BUCS, get control of the aircraft, and return to straight and level flight. All scoring was performed by the BUCS SME, who was naïve as to the results of the SSQ.

Procedure

Crews arrived for BUCS training in two-hour blocks. Each crew consisted of two aviators (pilot, CPG). Upon arrival, trainees were ushered into a conference room, identified for purposes of the training record, and their demographic information was obtained, as well as their informed consent. Trainees who agreed to participate in the research, were native English speakers, and who met the health criteria, were administered the Pre Questionnaire.

Upon completion of the Pre Questionnaire, trainees were led into the simulator bay next door to begin their instruction. The BUCS SME introduced each crewmember to his or her cockpit station, closed the curtains, lowered the ambient illumination, checked communication, and began the 90-min instruction session. Mid-way through this session, the crewmembers switched cockpits—which provided the only scheduled break. This break lasted 3-5 min. The author was present at the instructor station during all simulator sessions and recorded a "sickness event" whenever a participant required an unscheduled break due to discomfort.

Upon the completion of instruction, trainees were returned to the conference room and immediately filled-out the Post Questionnaire. After this questionnaire, but prior to leaving the building, all participants were given the Aftereffects Questionnaire and a self-addressed envelope. Participants were asked to fill-out the Aftereffects Questionnaire following a delay of approximately 12 hrs. They were also instructed how to return the questionnaire to the author.

Results

Scoring, Number of Observations, and Return Rate

The SSQ was scored as per Kennedy, Lane et al. (1993). The SSQ provides an index of Total Severity (SSQ-TS) as well as three subscale scores. The SSQ-TS score was used for statistical analyses because it was the single best index of overall SS. The BUCS test was scored as described above, providing each participant with a total score of 0 to 4. The author recorded a "1" for each participant who reported a history of motion sickness or a history of simulator sickness on the Pre Questionnaire. The author recorded a "1" for each participant who required an unscheduled break due to discomfort during a simulator session. A "1" was also recorded for each participant who answered "yes" to any of the three questions presented on the Aftereffects Questionnaire. The number of observations (*N*) upon which each result is based is presented along with the specific statistic. Some of the yes/no questions were added after data collection had already begun, so the *N* is not identical for all statistics. Of the 474 participants, 375 returned their Aftereffects Questionnaires for a return rate of 79.1 percent.

Incidence, SSQ Scores, and Sickness Events

Incidence of SS was defined as the percentage of total participants who reported at least one symptom of discomfort. Incidence prior to simulator exposure was 47.9 percent (227/474). Immediately post exposure the incidence rate was 68.1 percent (323/474). Incidence after 12 hours was 35.7 percent (134/375).

The mean SSQ-TS scores reported before simulator exposure, immediately after exposure, and 12 hours later are presented in Table 1. The difference of 8.14 between SSQ-TS Post and Pre was statistically significant (Wilcoxon Signed Ranks, $z = 11.03$, $p < .001$). The difference of 7.93 between SSQ-TS Post and 12 hours after was also statistically significant (Wilcoxon Signed Ranks, $z = 10.97$, $p < .001$). There was no statistically significant difference between SSQ-TS scores prior to exposure and scores 12 hours after.

Table 1
Mean SSQ Total Severity Scores, SD, and N Measured Prior to Simulator Exposure, Immediately Post Simulator Exposure, and 12 Hours after Simulator Exposure

Statistic	Prior (Pre Q)	Immediately Post (Post Q)	12 Hours After (Aftereffects Q)
M	4.59	12.73**	4.80
SD	7.39	16.89	10.45
N	474	474	375

** Post exposure score was significantly different from Pre (p < .001) and significantly different from 12 Hours After (p < .001)

There were 22 sickness events for an event rate of 4.6 percent (22/474). That is, 22 participants experienced such a high level of discomfort that training was stopped for an unscheduled break. This does not mean that 22 participants vomited. It means that their discomfort reached such a high level that a break was required.

Other Aftereffects: Muscular Coordination, Falls, Automobile or Motorcycle Accidents

Of the 375 participants who returned the Aftereffects Questionnaire, all answered the three yes/no questions. Twelve participants or 3.2 percent (12/375) reported that they had experienced a loss of muscular coordination or balance since leaving the training. Only one participant (0.27%) reported having fallen down in the 12 hrs since leaving the training. No participant (0%) reported having had an automobile or motorcycle accident in the intervening 12 hrs.

Susceptibility: Age, Flight Hrs, History of Motion Sickness and Simulator Sickness

Table 2 presents the bivariate correlations between SSQ scores and the susceptibility factors addressed in this research. These factors were prior history of MS, prior history of SS, total aircraft flight hrs, and age in years. These were correlated with two related measures of simulator sickness—SSQ-TS at the Post Questionnaire and the Difference Score (SSQ-TS Post minus SSQ-TS Pre). The parametric Pearson (r) and the nonparametric Spearman (r_s) were employed redundantly. All four susceptibility factors were expected to correlate positively with SSQ scores. That is, greater levels of each factor should be associated with greater levels of discomfort. Thus, all statistical probability values (p) are one-tailed. A negative correlation coefficient for any of these factors would be rejected as not statistically significant (*ns*).

Table 2
Parametric Pearson Correlations (r) and Nonparametric Spearman Correlations (r_s) Between SSQ Scores and Susceptibility Factors

Factors	N	Pearson r	Spearman r_s
SSQ-TS (Post) x Difference Score	474	0.90, $p < .001$	0.77, $p < .001$
Prior MS x SSQ-TS (Post)	180	0.19, $p < .01$	0.14, $p < .05$
Prior MS x Difference Score	180	0.14, $p < .05$	0.13, $p < .05$
Prior SS x SSQ-TS (Post)	180	0.24, $p < .001$	0.25, $p < .001$
Prior SS x Difference Score	180	0.29, $p < .001$	0.25, $p < .001$

Flight Hrs x SSQ-TS (Post)	438	0.12, p < .01	0.14, p < .01
Flight Hrs x Difference Score	438	0.12, p < .01	0.12, p < .01
Age x SSQ-TS (Post)	474	0.22, p < .001	0.19, p < .001
Age x Difference Score	474	0.20, p < .001	0.15, p < .001
Age x Flight Hrs	438	0.71, p < .001	0.74, p < .001

Three methodological points emerged from Table 2. First, the results were the same whether these data were correlated using the parametric r statistic or the nonparametric r_s. Second, the results were the same whether one used the Post score alone or the Difference Score. For these data, the two measures were highly and positively correlated ($r = 0.90$, $p < .001$). Third, age and flight hrs were strongly and positively correlated ($r = 0.71$, $p < .001$).

Table 2 shows the correlations between history of motion-related discomfort and SSQ scores from this simulator exposure. Reported prior history of MS was significantly and positively correlated with both SSQ measures ($r = 0.19$, $p < .01$; $r = 0.14$, $p < .05$). Reported prior history of SS was also significantly and positively correlated with both measures ($r = 0.24$, $p < .001$; $r = 0.29$, $p < .001$). The correlation coefficients for history of SS and SSQ scores were larger than those for history of MS and SSQ scores.

Age was significantly and positively correlated with SSQ score whether measured by Post score ($r = 0.22$, $p < .001$) or Difference Score ($r = 0.20$, $p < .001$). Flight hrs were also significantly and positively correlated with SSQ score ($r = 0.12$, $p < .01$) no matter how measured. That is, older aviators and aviators with a greater number of flight hrs were more likely to report increased SS. However, given the strong positive correlation between age and flight hrs reported above, these significant bivariate correlations were confounded with each other. The statistical technique of partial correlation allows one to untangle this confounding and estimate the true relationship between each factor and SSQ scores with the other factor held constant mathematically. Table 3 presents the partial correlation (*pr*) of age on SSQ scores, with the effect of flight hrs held constant. This table also presents the partial correlation of flight hrs on SSQ scores, with the effect of age held constant.

Table 3
Partial Correlation (pr) of Age and Flight Hrs on SSQ Scores

Factors		N	Partial Correlation (pr)
Age x SSQ-TS (Post)	[Flt Hrs controlled]	438	0.16, p < .001
Age x Difference Score	[Flt Hrs controlled]	438	0.14, p < .01
Flt Hrs x SSQ-TS (Post)	[Age controlled]	438	-0.03, ns
Flt Hrs x Difference Score	[Age controlled]	438	-0.01, ns

As shown in Table 3, the relationship between age and both SSQ measures, with the confounding effect of flight hrs held constant, was statistically significant (*pr* = 0.16, *p* < .001; *pr* = 0.14, *p* < .01). The same was not true for flight hrs. Once the confounding effect of age was removed, there was no relationship between flight hrs and either SSQ measure.

SSQ Scores and Amount Learned

Simulator-induced discomfort has been expected to correlate inversely with measures of amount learned. The sicker the pilot, the less that pilot was expected to learn. Hence, the author expected a negative correlation coefficient between SSQ scores and performance on the BUCS test. Thus, a one-tailed test was used. Table 4 presents the results of the bivariate correlations between both measures of SS and total score on the BUCS test. Again, the author employed the parametric Pearson *r* and the nonparametric Spearman r_s redundantly.

Table 4
Parametric Pearson Correlations (r) and Nonparametric Spearman Correlations (r_s) Between SSQ Scores and Performance on the BUCS Test.

Measures Correlated	N	Pearson r	Spearman r_s
BUCS test score x SSQ-TS (Post)	215	-0.01, ns	-0.01, ns
BUCS test score x Difference Score	215	0.01, ns	0.01, ns

Performance on the BUCS test did not correlate with scores on the SSQ. Amount learned as measured by performance on the BUCS test was not related to amount of discomfort reported. This result was contrary to the stated expectations of the author. However, the psychometric properties of the BUCS test were less than optimal, as demonstrated in Table 5.

Table 5
Descriptive Statistics of Results from the BUCS Test (N = 215)

M	Mdn	Mode	SD	Range of Scores	Percent of Total N Receiving Highest Score
3.62	4	4	0.63	1 to 4	69.8 (150/215)

Table 5 presents the descriptive statistics for the results obtained from the BUCS test. The maximum total score possible was four. Approximately 70 percent of the participants who were administered the BUCS test received this score. The median and mode were also four with a mean of 3.62. Clearly, there was a ceiling effect operating to reduce variability. Thus, the BUCS test was insufficiently sensitive to measure the critical dependent variable.

Discussion

Incidence, SSQ Scores, and Sickness Events

Incidence. Immediately after simulator exposure, the incidence rate reported in this research was 68.1 percent. This result was consistent with past research that showed incidences of SS ranged from 0 to 90 percent depending upon conditions and simulators (Kennedy et al., 1987; Kennedy & Fowlkes, 1992; Kennedy & Frank, 1985; McCauley, 1984; Pausch et al., 1992). Specific to helicopter simulators, Wright (1995) reported that by using the current lax criterion incidence rose to 70 percent. Kennedy and colleagues (Kennedy et al., 1988; Kennedy, Lilienthal, Berbaum, Baltzley, & McCauley, 1989) reported rates for helicopter simulators as high as 69 percent. Thus, the incidence rate reported in this research is consistent with earlier results.

SSQ scores. The mean SSQ-TS scores from this research were 4.59 (negligible symptoms) prior to simulator exposure, 12.73 (significant symptoms) immediately post exposure, and 4.80 (negligible symptoms) after 12 hours. Durbin and colleagues (Durbin et al., 2003) reported mean scores ranging from 4 to 6 prior to simulator exposure. For simulators representing helicopters, mean post exposure scores ranged from 7 to 20 (Durbin et al., 2003; Kennedy, Berbaum, et al., 1992; Kennedy et al., 2003; Kennedy, Lane et al., 1993). The largest study (Kennedy et al., 2003) reported the results of 3,000 observations of participants operating eight military helicopter simulators. The overall post exposure SSQ-TS score was 12.63. Thus, the results of the present research were consistent with prior research.

The incidence and SSQ measures showed that participants arrived for training reporting greater than zero symptoms, that these symptoms increased because of simulator exposure, and then returned to pre-exposure levels after a period of 12 hours. Results such as these are well established. For this reason, guidelines have been published (c.f., Crowley & Gower, 1988; Johnson, 2005; Kennedy et al., 1987; Lilienthal et al., 1987; NTSC, 1988; Wright, 1995). These recommend that participants avoid high-risk activities for hours after exiting the simulator.

Sickness events. In this research, 22 participants (4.6%) experienced such a high level of discomfort that training had to be stopped at least temporarily. These results were consistent with experience in the training community, where an informal rule-of- thumb has emerged that approximately 10 percent of participants will experience pronounced discomfort possibly leading to aftereffects (Kennedy et al., 1988; Kennedy & Fowlkes, 1992).

Other Aftereffects: Muscular Coordination, Falls, Automobile or Motorcycle Accidents

The potential for dangerous aftereffects of simulator exposure was noted early (Miller & Goodson, 1958; 1960). Virtually every report mentions this dangerous potential, although it is the rare report that provides any relevant data. Baltzley et al. (1989) reported the results of 742 exposures across 11 Navy and Army simulators. Of the pilots who experienced SS, the most common category of aftereffect was nausea (51%) and disorientation (28%). Crowley (1987) reported that 11 percent of his sample of helicopter pilots experienced aftereffects of simulator training. The most common delayed symptom was a perception of illusory movement.

In the present research, 12 participants (3.2%) reported a loss of muscular coordination or balance since leaving the simulator. One participant reported falling down and no participant reported having been involved in an automobile or motorcycle accident since leaving the simulator. These results were consistent with previous authors who reported that there were no documented cases of flight incidents or automobile accidents linked to prior simulator-based training (Crowley, 1987; Kennedy & Frank, 1985; McCauley, 1984; Wright, 1995). Thus, the current research supports the established conclusion that while the *potential* exists for simulator-linked safety issues, in *practice* no such linkage has been documented.

Susceptibility: Age, Flight Hrs, History of Motion Sickness and Simulator Sickness

In this research, age of pilots and flight hrs were strongly and positively correlated. Older aviators had significantly more flight experience than younger aviators. This finding has been reported before by Magee et al. (1988) and discussed by Tsang (2003). The Pearson coefficient reported by Magee et al. was 0.67, while in the present research it was 0.71. Thus, this finding was consistent with earlier research. A second methodological point concerned the dependent variable when analyzing data from the SSQ. The developers of the SSQ (Kennedy, Lane, et al., 1993) recommended using the post exposure score alone. Others (cf., Regan & Ramsey, 1996) used the difference between the post and the pre scores. In this research, the correlation between the two measures was strong, positive, and statistically significant. Hence, results reported in Table 2 showed no practical differences.

Age and flight hrs. Aviator age was positively and significantly correlated with both measures of SS after the confounding effects of flight hrs were removed by partial correlation. Aviator experience as measured by flight hrs, however, was not correlated with SS after the effects of age were removed. For these data, the factor that was responsible for making older, high-time aviators susceptible to SS was their age, not their flight hrs. However, although significant, this effect was not large. Warner et al. (1993) found that his older group was much more likely than his younger group to terminate the simulator session prematurely due to severe SS. Based upon research using an automobile-driving simulator, Hein (1993) reported that older drivers were more susceptible to SS than younger drivers. Magee et al. (1988) reported that a partial correlation of flight hrs against measured SS, with age held constant, resulted in a small (0.03) and statistically insignificant relationship. This last finding was directly comparable to the results for flight hrs as reported above in Table 3.

These results support the PI theory (e.g., Riccio & Stoffregen, 1991). This theory predicts that SS will increase with increased postural instability. Increasing adult age is indisputably associated with greater postural instability. Thus, the PI theory predicts that SS will increase with adult age. The SC theory (e.g., Reason & Brand, 1975) makes the opposite prediction. This theory predicts a reduction in SS with age because increasing age provides opportunities to experience—and adapt to—novel motion environments. In the world of aviation, where age and flight experience are highly correlated, proponents of SC theory have claimed that a primary variable influencing susceptibility to SS was aircraft flight hrs (e.g., Braithwaite & Braithwaite, 1990; Crowley, 1987; Gower & Fowlkes, 1989b; McGuinness, Bouwman, & Forbes, 1981; Miller & Goodson, 1958; 1960). The current research, in agreement with Magee et al. (1988), found that with age held constant, flight hrs were not related to SS.

Prior history of motion sickness. The present research found that prior history of MS was positively and significantly correlated with both SSQ measures. This result agreed with earlier research that has found a relationship between history of MS and discomfort levels during simulator training (Braithwaite & Braithwaite, 1990; Gower & Fowlkes, 1989a; 1989b; Gower et al., 1989; Gower et al., 1987; Kennedy et al., 1988; Lampton et al., 1995; Lerman et al., 1993). SS is a form of MS. Those who experience increased susceptibility to MS can logically be expected to experience increased susceptibility to SS.

Prior history of simulator sickness. The susceptibility factor that correlated most strongly with SSQ scores was prior history of SS. Participants who reported a history of SS were more likely to experience increased levels of discomfort upon simulator exposure in the present research. This result is a special case of the rule that prior history of MS is predictive of SS. Aviators who have experienced SS in previous simulators are more likely to experience SS in future simulators. Past behavior predicts future behavior.

SSQ Scores and Amount Learned

This research found no relationship between measures of SS and amount learned as assessed by the BUCS test. However, this result is suspect. The test was brief, covering only a small subset of the program of instruction. In addition, the test was insensitive, since a ceiling effect reduced variability. Finally, there was no measure of inter-rater-reliability as there was only one SME to perform the scoring. Given these weaknesses, one cannot argue that the hypothesized inverse relationship has been given a fair opportunity to emerge. Therefore, the question of whether SS reduces training effectiveness remains unanswered. Further, the author could find no prior research that directly and objectively tested this hypothesis. The research by Chappelow (1988) and by Gower and colleagues (Gower & Fowlkes, 1989a; 1989b; Gower et al., 1989) provided indirect evidence in the form of opinion surveys. These surveys reported that the preponderance of pilots believed that SS did not hamper simulator-based training.

Afterword: Prevention and Treatment

Aviators who train in simulators are susceptible to SS. Those with a prior history of SS are at an increased risk. The incidence of SS can be mitigated by observing simple guidelines. Several authors have published such guidelines in an effort to reduce the rate of SS among trainee populations (Braithwaite & Braithwaite, 1990; Crowley & Gower, 1988; Johnson, 2005; Kennedy et al., 1987; Kolasinski, 1995; Lilienthal et al., 1987; McCauley, 1984; NTSC, 1988; Wright, 1995). One important rule is this: Never schedule simulator sessions for greater than 2 hours for any reason. The longer the period spent operating the simulator, the greater the likelihood of significant discomfort (Gower & Fowlkes, 1989a; Gower et al., 1987; Kennedy & Fowlkes, 1992; Kolasinski, 1995; McCauley, 1984; Wright, 1995).

The most potent fix for SS is adaptation. Several reviewers have discussed adaptation to a novel simulated motion environment (Biocca, 1992; Crowley & Gower, 1988; Kennedy & Fowlkes, 1992; Kennedy & Frank, 1985; Kolasinski, 1995; Wright, 1995). Most participants adapt to the simulator after approximately six sessions (Biocca, 1992; Kennedy, Lane, et al., 1993; Wright). For those unfortunates who are unable to adapt, medicinal treatment exists (Benson, 1978; Crowley, 1987; Parmet & Gillingham, 2002; Regan & Ramsey, 1996).

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Mortality Among Airline Pilots in the United States

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Abstract

This study was performed to determine if United States pilots in the Air Line Pilots Association International (ALPA) experience mortality at the same rate as the general United States Population. Information on over 72,000 pilots, who were members of ALPA, was gathered for the period January 1, 1980 through December 31, 2002. Male and female pilots were analyzed separately. The mortality was observed using a standardized mortality ratio (SMR) with the United States population as the comparison. The results were studied for all cause mortality, all cancer mortality, all non-cancer mortality, and certain cause-specific deaths, where four or more deaths occurred. Of the 72,972 male pilots, 556 were deceased, making up 1% of the total male cohort. The SMR showed a significant decrease in all cause mortality, all cancer mortality, all non-cancer mortality, as well as most cause-specific mortalities. The study was performed in a young cohort and showed an overall healthy population when compared to the general United States population.

Airline pilots can encounter occupational risks that differ substantially from non-flying occupational settings. These risks include ionizing radiation, magnetic field exposure due to avionic equipment, fatigue from prolonged periods in the cockpit, and circadian disruption (Butler, Nicholas, Lackland & Friedberg, 2000; Nicholas et al., 1998; Lim, 2002; Wilson et al., 2003; Mitchell & Evans, 2004; Friedberg, Faulkner, Snyder, Darden & O'Brien, 1989; Friedberg, Snyder, & Faulkner, 1992; Friedberg, et al., 2002, Besco, Sangal, & Nesthus, 1995).

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Numerous mortality studies have been performed in the past, outside of the United States (US), comparing commercial passenger carrier crew to their general population (Kaji et al., 1993; Band et al., 1996; Irvine & Davies, 1999; Zeeb, Blettner, Hammer, & Langner, 2002; Blettner et al., 2003; Paridou et al., 2003). All studies reporting on aircraft accidents showed an increased mortality due to these accidents (Kaji et al., 1993; Band et al., 1996; Irvine & Davies, 1999; Zeeb, et al., 2002; Blettner et al., 2003). Cockpit crewmembers in Japan were reported to have a lower standardized mortality ratio (SMR), relative to population rates, in cardiovascular and coronary artery disease, as well as suicides (Kaji et al., 1993). Air Canada pilots were reported to have a decreased SMR in total causes of death, all cancers, and for all non-cancer diseases (Band et al., 1996). An SMR on British Airways pilots reported significant decreases in total number of deaths, all cancers, digestive organ cancer, stomach cancer, respiratory system cancer, trachea and lung cancer, bladder cancer, cerebrovascular disease, all heart and ischemic heart disease, non-malignant respiratory disease, influenza and pneumonia, bronchitis, and suicides. The same study reported an increase in aircraft accidents and malignant melanoma (Irvine & Davies, 1999). Male cockpit crew in Germany were reported to have a significantly decreased SMR for all causes, all cancers, buccal cavity cancer, bronchial tree and lung cancer, cerebrovascular disease, all cardiovascular disease, nonmalignant respiratory disease, liver cirrhosis, motor vehicle accidents, and suicides (Zeeb et al., 2002). A study of male airline cockpit crews in Europe reported a significantly higher SMR in malignant melanoma with a decreased SMR in pharynx, esophageal, stomach, bladder, and lung cancer. The study also showed decreased mortality for cerebrovascular disease, all cardiovascular disease, acute myocardial infarction, respiratory diseases, suicides, motor vehicle accidents, liver cirrhosis and external causes (excluding aircraft accidents) (Blettner et al., 2003). A Greek study reported no significant increases and a decreased SMR in the all causes of death category, as well as cardiovascular disease (Paridou et al., 2003). From the observed SMR studies, it appears there may be a lowered SMR, relative to population rates, for all combined causes as well as many cancers, with the exception of malignant melanoma and aircraft accidents. However, these results should not be compared across different study populations since the underlying structures (weights) are different (Hennekens & Buring, 1987; Kelsey, Whittemore, Evans & Thompson, 1996; Rothman, & Greenland, 1998).

The purpose of this study was to determine if United States (US) pilots in the Air Line Pilots Association International (ALPA) experienced mortality at the same rate as the general US population. The measure used was the standardized mortality ratio (SMR). To the authors' knowledge, this is the first SMR performed for an American cohort of airline pilots.

Methods

The standardized mortality ratio (SMR) was calculated as the observed number of US pilot deaths divided by the number expected based on rates in the general US population. These population rates corresponded to the age, gender, and calendar period (1980-2002) of the pilots.

Membership data for the pilots were obtained from ALPA, the largest airline pilot union in the world. All pilot members flying for any one of the 34 US airline members of ALPA were included, provided they were pilot members for at least 6 months during the study time period (from January 1, 1980 to December 31, 2002). Follow-up was calculated in person-years beginning with the date the pilot joined ALPA (or January 1, 1980, if the pilot was a member at the start of the study period) and ending at the first occurring of either death, termination of membership, or December 31, 2002. ALPA membership extends into retirement, with occupational status designated according to 22 classification codes. Classification changes constituting an exit from the cohort were death or termination of membership. Other classifications (including sick or personal leave) were followed to the end of the study. Data on living pilots were de-identified prior to receipt and included the join dates, classification dates, birth year, gender, and classification status. Information on pilots known by ALPA to be deceased included only those identifiers required for the cause of death search, with identifiers eliminated following the search. ALPA death information is based on report, typically from the airline with which the deceased was employed and/or a spouse, relative, or friend. For retired pilots, sources also include retired pilot organizations. Cause of death was determined by the US Department of Health and Human Services, Centers for Disease Control and Prevention (CDC), National Center for Health Statistics, using its National Death Index (NDI), and coded based on the International Classification of Diseases (ICD), 9th and 10th Revisions (World Health Organization, 1979, 1999).

SMRs were calculated for all-cause mortality and for specific causes with four or more occurrences, using the general US population as the comparison. Census data were taken from the years 1980, 1990, and 2000 to account for changes in the population over time (US Census Statistics, 1980; US Census Statistics, 1990; US Census Statistics, 2000). Person years were tabulated using 5-year age groups and the total study time period 1980-2002 was divided into three segments with a census year near the center of each segment. Specifically, the segments were 1980-1984, 1985-1994, and 1995-2002. Observed and expected numbers of events were tabulated within each age and time period and then summed. Observed events were taken directly from the pilot cohort. Expected events were calculated using mortality rates from the US population (NCHS, n.d., NCHS, 2002) weighted by the population structure of the pilot cohort. Person year calculations were made using Epicure, DATAB software. Exact Poisson 95% confidence intervals (Buchan, 2004) were calculated for all ratios.

Results

Data are from 72,972 male pilots and 3,682 female pilots. The mean age for male pilots was 43.09 years (standard deviation (SE) 9.09), mean age at entry to the cohort 34.39 years (SE 7.21), and mean number of years in the cohort 8.70 (SE 5.85). Female pilots had a mean age of 38.95 years (SE 7.96), with mean age at entry to the cohort 31.17 years (SE 5.79), and mean number of years in the cohort 7.78 (SE 5.61). Total follow-up time (expressed in person-years) is given for male and female pilots in Table 1.

Table 1
Total male and female person-years by age and calendar period.

Male person-years					Female person-years				
Age Group	Calendar Period			Total PYR	Age Group	Calendar Period			Total PYR
	1980-1984	1985-1994	1995-2002			1980-1984	1985-1994	1995-2002	
15-19	9	4	4	17	15-19	0	0	0	0
20-24	267	1936	2822	5025	20-24	16	173	285	474
25-29	2249	23097	25026	50372	25-29	134	1836	2308	4278
30-34	5483	62314	61870	129667	30-34	124	3265	4656	8045
35-39	3081	64021	97364	164466	35-39	29	2249	5498	7776
40-44	1165	44600	95563	141328	40-44	16	1007	4249	5272
45-49	545	27947	72501	100993	45-49	1	374	2224	2599
50-54	221	10378	50397	60996	50-54	0	115	838	953
55-59	34	3688	23727	27449	55-59	0	20	297	317
60-64	74	1062	7417	8553	60-64	0	4	60	64
65-69	4	274	2458	2736	65-69	0	0	14	14
70-74	5	103	503	611	70-74	0	0	0	0
Total	13137	239424	439652	692213	Total	320	9043	20429	29792

Of the 575 deaths reported by ALPA to have occurred between 1980 and 2002, only 17 were among female pilots, making up only 3% of the known deaths. Because of the small number of female deaths, these deaths are reported separately instead of included in the SMR calculation. Three of the 17 female deaths were due to air and space accidents, nine were non-cancer deaths, and five were cancer deaths. Of the five female cancer deaths, two were due to lung cancer. The remaining female cancer deaths and all female non-cancer deaths were due to causes with only one occurrence each.

Ninety-six percent of the total follow-up time (722,005 person-years) was among male pilots. Overall, it was a young cohort, with only 1.7% of the male person-years age 60 or older. Of the 72,972 male pilots followed, 556 (less than 1%) were deceased. Based on pilot data received from ALPA, 300 living males were excluded from SMR calculations due to missing or out of range values for birth year, join or classification dates. Among the known dead, 90 could not be tracked for cause of death by NDI, due to missing or incorrect identifying information (in particular, social security numbers were unavailable for 48 of the 90). Statistical adjustments to compensate for unknown causes of death (such as those suggested by Rittgen and Becker, 2000) were not used in this study since the number of known dead was available and could be used to correctly calculate the all-cause SMR. Cause-specific SMRs were calculated based on deaths with identified causes.

Results of the SMR calculations, using males in the general US population as the comparison, are shown in Table 2. Exact 95% confidence intervals are based on a Poisson distribution (Buchan, 2004). Confidence intervals not including the value of 1 are considered significant. The ICD 9 and ICD 10 codes are listed as well (World Health Organization [WHO], 1979, 1999). Causes with four or more occurrences not included in calculated SMRs are HIV, motor neuron disease, and death due to terrorism. HIV was not added to the ICD until 1987, and a CDC report stated deaths from 1987-1998 could not be compared to deaths occurring after 1998 (QuickStats, 2005). Counts of death were not available for motor neuron disease for the years 1980 and 1990 (Compressed Mortality File, 2005). Due to the unfortunate events occurring on September 11, 2001, five members of the ALPA cohort were killed. The cause of death code for these individuals is U011, a new code created by the NDI shortly after these events (Centers for Disease Control, 2001).

Table 2

SMR of Total Male Cohort for Causes with Four or More Deaths

Cause of Death	ICD 9 codes	ICD 10 codes	Observed	Expected	SMR	95% Confidence Interval
All Causes	001-999	A00-Y89.9	556	2542.57	0.22	(0.20 - 0.24)*
Cause Specific Deaths (466 Deaths)						
All Cancers	140-239	C00-C97	135	508.98	0.26	(0.22 - 0.31)*
Melanoma	172	C43	9	16.90	0.53	(0.24 - 1.00)
Brain	191	C71	15	26.38	0.57	(0.32 - 0.94)*
Prostate	185	C61	4	10.90	0.37	(0.10 - 0.94)*
Bone	170	C41	4	2.01	1.99	(0.54 - 5.09)
Colon	153	C18	13	37.63	0.35	(0.18 - 0.59)*
Esophagus	150	C15	6	20.47	0.29	(0.11 - 0.64)*
Pancreas	157	C25	8	26.36	0.30	(0.13 - 0.60)*
Rectum	154	C20	4	7.66	0.52	(0.14 - 1.34)
Stomach	151	C16	6	15.92	0.38	(0.14 - 0.84)*
Kidney	189	C64	4	16.08	0.25	(0.07 - 0.64)*

Bronchus and Lung	162	C33-C34	25	152.92	0.16	(0.11 - 0.24)*
Lymphatic and Hematopoietic	200-208	C81-C96	20	60.09	0.33	(0.20 - 0.51)*
All Lymphoma	200-2002	C81-85	9	30.82	0.29	(0.13 - 0.55)*
All Leukemia	204-208	C91-C95	9	21.80	0.41	(0.18 - 0.78)*
All non-cancers	001-139, 240-999	A00-C00, D00-Y89.9	331	2033.59	0.16	(0.15 - 0.18)*
Cerebrovascular Disease	430-438	I60-I69	4	70.10	0.06	(0.02 - 0.15)*
Diseases of the arteries, arterioles, and capillaries	441-448	I72-I78	9	5.60	1.61	(0.74 - 3.05)
Heart Disease	401-404, 410-417, 420-429	I00-I09, I11, I13, I20-I51	68	540.48	0.13	(0.10 - 0.16)*
Acute Myocardial Infarction	410	I21-I22	17	175.92	0.10	(0.06 - 0.15)*
Chronic Ischemic Heart Disease	412,414	I25	24	194.26	0.12	(0.08 - 0.18)*
Submersion & Suffocation	E910	W65-W74	6	13.68	0.44	(0.16 - 0.95)*
Motor Vehicle	E810-E819	**	26	166.61	0.16	(0.10 - 0.23)*
Homicide	E960-E978	X85-Y09, Y87.7	6	97.59	0.06	(0.02 - 0.13)*
Suicide	E950-E959	X60-X84, Y87.0	29	156.48	0.19	(0.12 - 0.27)*
Air & Space Accidents	E840-E845	V95-V97	104	5.73	18.14	(14.82 - 21.98)*
All non-cancers (excluding Air/Space Accidents)	001-139, 240-999 not E840-E845	A00-C00, D00-Y89.9 not V95-V97	227	2027.84	0.11	(0.10 - 0.13)*

*Indicates a significant difference

**Motor Vehicle Accidents (V02-04, V09.0, V09.2, V12-V14, V19.0-V19.2, V19.4-V19.6, V20-V79, V80.3-V80.5, V81.0-V81.1, V82.0-V82.1, V83-V86, V87.0-V87.8, V88.0-V88.8, V89.0, V89.2)

The all-cause mortality shows a significant decrease relative to the general US population. There were significant decreases in nearly all causes with the exception of diseases of the arteries, arterioles, and capillaries, cancer of the rectum, bone, and melanoma, which were not significantly changed. Air and space accidents were significantly increased. Air and space accidents accounted for 22% of the total number of identified causes of death, with 96% of these involving powered aircraft.

Discussion

The current study is the largest study performed in a US cohort of pilots. It includes both cargo and passenger carrier pilots. The study finds that this is a healthy cohort, when compared to the general US population (all cause SMR 0.22, 95% C.I. 0.20-0.24). When observed for cancer and non-cancer deaths, the SMRs were, again, significantly decreased (SMR 0.26, 95% C.I. 0.22-0.31 and SMR 0.16, 95% C.I. 0.15-0.18, respectively). As expected, the non-cancer SMR is lower when excluding air and space accidents (SMR 0.11, 95% C.I. 0.10-0.13).

While SMR methodology does not permit direct comparison of values across different study groups, an overall reduced mortality has also been reported among pilots in Japan, Canada, and Europe relative to their general population (Kaji et al 1993, Band et al., 1996, Blettner et al 2003). When considering this reduced mortality, it is important to examine potential sources of underestimation. Underestimation may be due in part to the healthy worker effect, or active worker effect, which can occur in any SMR study when comparing an employed population to the general population (Timmreck, 1998). There is generally a higher socioeconomic status, and often better access to health care in an employed population (Wen & Tsai, 1982). Pilots, in particular, undergo regular medical examinations as a requirement of their employment. In addition, many pilots have military experience, which requires military weight standards, and health promoting activities (Wynd & Ryan-Wenger, 2004). In addition to SMR studies, it should be noted that reduced mortality has been reported among retired airline pilots using survival analysis methodology (Besco et al., 1995). A source of underestimation specific to the current study is the use of known dead as indicated in ALPA membership files. While this information should be complete for active pilots, deaths among retired members could be missed. For passenger carrier pilots during the period of this study, the age of retirement was 60 years. Because only 1.7% of the male person years were among pilots aged 60 or older, underestimation of the SMR due to missed deaths should be minimized. Finally, the inability to track causes for some of the known dead, while not affecting calculation of all-cause mortality, may have lead to underestimation in cause-specific SMRs. Because of the young age of this cohort, continued follow-up is recommended. Other studies (Band et al., 1996; Zeeb et al., 2002) have reported increased mortality in aircraft accidents as well as malignant melanoma. Consistent with these reports, the current study found an increase in aircraft accidents; however, melanoma mortality was not different from that occurring in the US population. Although melanoma mortality was not increased in the current study, a previous study among ALPA members (Nicholas et al., 2001) suggested an increase in estimated melanoma incidence. A case control study on melanoma in a cohort of ALPA members is currently in progress to investigate potentially associated factors.

Conclusion

This study indicates that US pilot members of ALPA have experienced reduced disease-related mortality relative to the general US population. This is consistent with a healthy worker group and with indications of reduced mortality among pilots in other countries.

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A Survey of Maintenance Human Factors Programs Across the World

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Abstract

There are many international approaches to the regulation of human factors programs for aviation maintenance organizations. Transport Canada and the European Aviation Safety Agency have specific regulations regarding maintenance human factors. The Federal Aviation Administration has not yet established regulations but, instead, has created guidance documents and voluntary reporting programs for maintenance organizations. An on-line survey assessing the status of human factors programs in maintenance organizations was distributed. Questions focused on training, error management, fatigue management, and other human factors issues. A highly experienced group (i.e., over 65% had 20 years in aviation maintenance) from more than 50 countries, responded to the questionnaire. Results highlight the maintenance human factors strategies, methods, and programs that companies use to reduce human error.

An International Survey of Maintenance Human Factors Programs

United States (U.S.) airlines invest more than $10 billion annually to ensure the airworthiness of their fleets (Boeing, 2005). In the 2003 International Air Transport Association (IATA) safety report following a review of 92 accidents, they found that a maintenance factor initiated the accident chain in 26% of the accidents (IATA, 2004). Maintenance errors are responsible for an estimated 20 to 30% of engine in-flight shutdowns, costing approximately $500,000 per shutdown (W. Rankin, Boeing, personal communication, August 11, 2005). This would argue

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that the airlines and Maintenance and Repair Organizations (MROs) must continue to invest in human factors (HF) programs within maintenance organizations and on the flight deck.

While not the primary cause of aviation accidents in Australia, maintenance-related errors contribute to 4.5% of the overall aircraft accidents. In 1998, an Australian project surveyed licensed aircraft maintenance engineers. The Australian Transport Safety Bureau (ATSB) study focused on the events and conditions that pose a risk to the safety of the aircraft or maintenance workers (ATSB, 2001). The most common occurrence reported in the survey involved situations where aircraft systems were operated in an unsafe manner during maintenance. Incomplete component installation was the second leading occurrence. More than 95% of these occurrences involved human error. The most common errors involved memory lapses and procedural shortcuts. Time pressures, equipment deficiencies, inadequate training, coordination difficulties, and fatigue are examples of factors believed to precipitate these events. The ATSB recommended several areas that needed to be addressed to mitigate the identified concerns. They included programs addressing fatigue, improved recurrent training, crew resource management, and eliminating a blame culture (ATSB, 2001).

Wells (2001) reported that human factors (HF) issues are believed to be a factor in 50% of maintenance-related accidents. Maintenance errors can generally be divided into two major classes: failing to detect a problem or the introduction of an error during maintenance (Marx & Graeber, 1994). Patankar, Lattanzio, and Kanki (2004) examined maintenance Aviation Safety Reporting System (ASRS) procedural error reports. Within their analysis, several error themes emerged under the category of user error. Examples of these user errors included mechanics not reading or following the maintenance manual, mechanics overlooking required inspection items, and mechanics making logbook errors.

Companies are faced with implementing corrective actions in response to these errors and must realize how to prevent such errors. This requires organizations to move from blaming an individual worker to implementing a systemic approach to handle maintenance errors. Johnson (2001) suggested that HF programs can improve safety and reduce vulnerability to error—while maintaining efficiency. Therefore, remedial actions must improve performance, ensure that safety policies and practices are consistent, and, in doing so, reduce costs. Komarniski (2006) recently highlighted the requirements of a successful maintenance human factors (MHF) program. Buy-in from management, as well as the maintenance staff, is integral. Effective communication with a shared vision of preventing and reducing incidents by recognizing where errors may occur can produce substantial gains. To help companies develop a quality MHF program, the Federal Aviation Administration (FAA) released the Operator's Manual for Human Factors in Aviation Maintenance (FAA, 2006a). The guide includes chapters highlighting the impact of event investigation systems, proper use of technical documentation, HF training, shift and task turnover procedures, and fatigue.

There are a variety of international approaches to the regulation of HF programs for maintenance organizations. Transport Canada (TC) and the European Aviation Safety Agency (EASA) have established specific, yet differing, regulations regarding Maintenance Human Factors (MHF). These pertain to such items as initial and continuation training and formal error-reporting systems. The FAA has not yet established regulations but, instead, has created guidance documents and developed voluntary reporting programs for maintenance organizations. For now, the FAA has chosen to adopt a voluntary rather than a regulatory approach to MHF.

Objective 1 of the FAA's 2006-2010 Strategic Plan (FAA, 2006b) Increased Safety Goal intends "to reduce the commercial airline fatal accident rate." Another Flight Plan goal targets the provision of international technical leadership. In support of these objectives, the FAA conducted this international survey of maintenance-related companies to examine employee perceptions of how companies are implementing MHF initiatives. This project assessed the effect of voluntary versus regulatory approaches to MHF programs. Questions were developed to provide a broad understanding of the degree to which organizations had implemented several basic HF initiatives. Further, we examined how organizations apply HF principles in their day-to-day operations.

This paper describes a variety of safety practices and opinions prevalent among HF managers, quality control managers/executives, HF trainers, and labor organization representatives that work in the international airline maintenance industry. Because we were unable to systematically sample respondents, our conclusions are limited to a descriptive nature and do not necessarily reflect the opinions or practices of the entire aviation maintenance population. Our approach of gathering volunteer respondents prevented further statistical comparisons between groups. However, based on our sample, as described later in the paper, we are reasonably certain that we have respondents who represent the "best case" representation of international MHF programs.

Method

Potential respondents were identified in coordination with the Joint Aviation Authority Human Factors Working Group (primarily comprised of EASA member states), several airlines, and FAA representatives. Publications, including newsletters and notices, were sent to encourage international participation. Many contacts were made while attending aviation maintenance conferences. As interested parties provided their business cards or sent an E-mail in response to advertisement of the survey, E-mail addresses were entered into a spreadsheet. Invited respondents worked in maintenance organizations as engineers, quality assurance specialists, maintenance directors, and mechanics.

Questionnaire Content

The questionnaire contained 66 items with 12 potential follow-up items. Follow-up items were presented based upon pre-specified responses to specific items. The response options for many of the items on the survey included agreement (i.e., strongly disagree, disagree, neither, agree, strongly agree), importance (not at all, limited, moderate, considerable, great), policy (formal, informal, none), and yes, no, do not know.

For the most part, items were organized into eight categories: (a) demographics, (b) motivation for an HF program, (c) proactive HF support, (d) organizational policies, (e) HF training, (f) error management, (g) fatigue management, and (h) HF metrics.

Individual/organizational demographics. Respondents were asked to provide basic organizational and general individual demographic information. These items included specifying the type of maintenance operation in which the respondent was currently employed, country of employment, primary regulatory authority, job title, number of employees in their organization, and years of experience in aviation maintenance.

Motivation for human factors program. Respondents were asked to rate the importance of various factors to their organization when they implemented a MHF program (regulatory compliance, safety, or cost).

Proactive human factors support. This section assessed the level of support the respondent's organization received regarding their MHF program. Included were items inquiring if organizations received support from their regulator and if their management supported the MHF program in words and action.

Organizational policies. Respondents answered questions on the formal or informal policies in place regarding HF issues. For example, respondents were asked about their company's shift handover policy, safety policy, and quality assurance programs.

Human factors training. Respondents were asked about their organization's approach to HF training. The items focused on how much and what type of HF training was provided for employees of the organization, the type of employees who received the training, and the credentials of the maintainers (e.g., licensed or unlicensed). One additional item allowed respondents to provide additional remarks regarding HF training.

Error management. Respondents were asked to comment on their organization's approach to human error investigations, database management, and how they used the data. There was one open-ended comment item for additional remarks about error management.

Fatigue management. Respondents were asked if their organization currently had a fatigue management system, provided training on fatigue management, and if the organization recognized fatigue as a safety issue.

Human factors metrics. This section focused on the metrics utilized by the respondent's organization to assess their HF program. Additionally, respondents were asked whether the organization utilized cost-benefit and return-on-investment calculations to assess their HF program.

Respondent comments. Two items directly asked respondents for general feedback regarding their organization's maintenance program and for any additional comments about the survey.[1]

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1. This paper summarizes data for many but not all survey items. The complete survey is available upon request. Correspondence should be addressed to carla.hackworth@faa.gov.

Sample Distribution

An E-mail invitation with an explanation of the purpose of the questionnaire, as well as a link to the survey, including username/password information was sent to 647 potential respondents. Of the 630 valid E-mail invitations, 414 returned a valid questionnaire (i.e., defined as responding to at least one content item), which resulted in a response rate of 65.7%.

Sample Demographics

Respondents represented several occupations within the maintenance work-force, including: management, quality control, training, and labor (see Table 1). The respondents were employed in more than 50 countries. Not surprisingly, given the origin of the survey, many respondents (39.8%) worked within the United States. However, respondents from many other countries participated: Canada (8.7%), United Kingdom (7.2%), Australia (3.2%), Norway (3.0%), and Singapore (3.0%). A listing of all participating countries is included in the Appendix.

A majority of the respondents had a long history within aviation maintenance, 64.9% indicating they had more than 20 years of experience. Respondents worked in maintenance departments where the median number of employees at their company or engineering maintenance department was 300.

Table 1
Job Title of Respondents

Job Role Title	% of Respondents
Supervisor/Manager/ Coordinator	37.1
Quality Assurance/Quality Control/Airworthiness	28.4
Training	11.9
Engineering	6.2
Technician/Mechanic	4.4
Consultant/Professor	3.9
Inspector/Investigator	3.4
Labor Representative	3.1
Safety Analyst	1.8

The survey sample covered the entire aircraft maintenance industry, with more than one-third from an airline maintenance department, 27.3% from repair stations, 8.9% general aviation/business operations, and 5.6% from a training facility or maintenance school (Figure. 1).

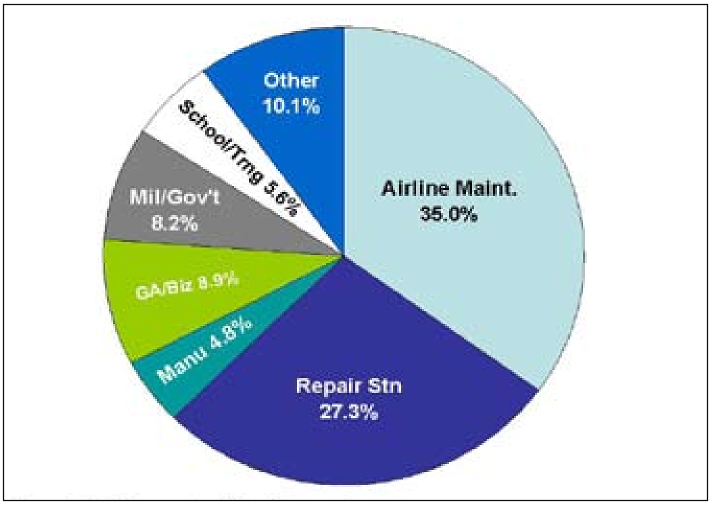

Figure 1. Employment Facility of Respondents.

For those who reported that they worked for an airline maintenance department or repair station, nearly two-thirds were from a major carrier, slightly over 20% were at a regional carrier, and the remaining worked in air taxi and corporate operations.

When asked for the primary regulatory authority that their company's maintenance operations were designed to comply with, the majority of respondents indicated the FAA (45.0%). However, as an indication of the diversity of responses, other authorities were identified as well. See Table 2 for a summary.

Table 2
Primary Regulatory Authority to Which Maintenance Operations Were Designed to Comply

Regulatory Authority Model	N	%
Federal Aviation Administration (FAA)	182	45.0
European Aviation Safety Agency (EASA)	95	23.5
Other National Aviation Authority (O-NAA)	72	17.8
Transport Canada (TC)	36	8.9
Civil Aviation Safety Authority (CASA) (Australia)	19	4.7

Data Analysis

Frequencies and proportions were calculated for each response option across items. For many items, percent positive was calculated by summing the top two response categories on the agreement (i.e., agree and strongly agree) and the importance (i.e., considerable and great importance) scales.

For several items, results are split by regulatory authority model (i.e., CASA, EASA, FAA, TC, and Other National Aviation Authority [O-NAA]). Keep in mind that this was the regulatory body that their company designed their maintenance programs to be in compliance with and, therefore, possibly not their country's regulatory agency. We make this point because some companies across the world may follow FAA or EASA regulations even though they are not regulated by either of those agencies.

Results

Motivation for Human Factors Program

Though there are many advantages to instituting an HF program within a maintenance operation, when asked to rate independently the importance of several factors when their organization implemented an HF program, 85.7% reported that flight safety was of considerable to great importance. Worker safety was also a high priority, at 80.9%. Further, over three-fourths (79.9%) indicated that regulatory compliance was also a strong motivator. Overall, cost was least important, at 59.7%.

When we examined responses by regulatory model, we found that flight safety was of the highest importance for CASA, FAA, and O-NAA. EASA and TC respondents noted that regulatory compliance was most important. See Figure 2 for all responses.

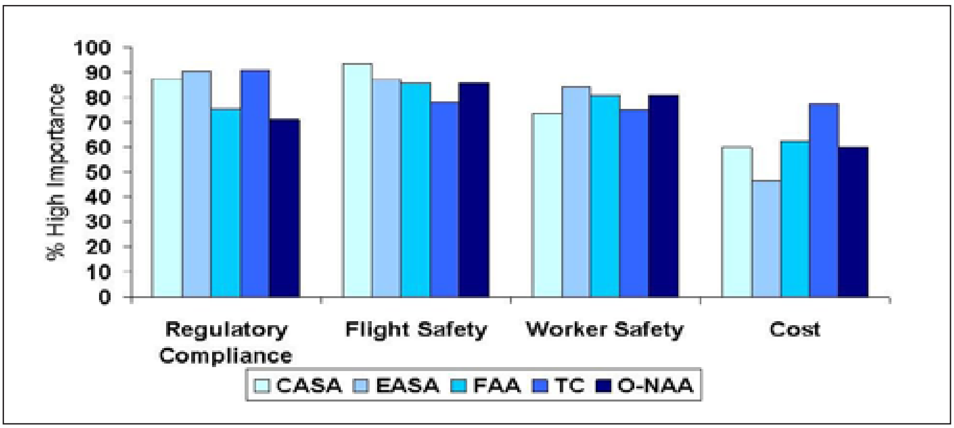

Figure 2. Motivating Factors for Human Factors Programs.

Proactive Human Factors Support

Slightly over 40% reported receiving support from their regulator for the implementation of their HF program, and 33.9% worked closely with their regulator to monitor their HF program. When support and working closely were broken out by regulatory model, respondents complying with TC reported receiving the highest level of support (57.1%), while those under O-NAA indicated the closest working relationship (44.4%). See Table 3 for all responses.

Table 3
Level of Support by Regulatory Model

Regulatory Model	Support % High Agreement	Work Closely % High Agreement
TC	57.1	35.7
CASA	46.2	28.6
O-NAA	39.3	44.4
EASA	39.1	28.6
FAA	38.3	31.9

Note. Percent high agreement was calculated by summing the agree and strongly agree response items

Respondents indicated encouragement from their manager/director of maintenance, with 64.8% reporting that senior management demonstrated support in words and action for MHF. Fifty-nine percent indicated (agree or strongly agree) that they had a formal means for supervisors and workers to provide suggestions on HF issues. When split by regulatory model, EASA respondents, by far, expressed the highest agreement, at 71.4%. This is in contrast to the second-highest group, O-NAA respondents, at 60.9% (Table 4).

Table 4
Formal Means for Supervisors and Workers to Provide Suggestions

Regulatory Model	% High Agreement
EASA	71.4
O-NAA	60.9
FAA	55.5
TC	53.3
CASA	46.7

Note. Percent high agreement was calculated by summing the agree and strongly agree response options

Keeping the lines of communication open between HF personnel and senior management is essential for a successful HF program. Thirty-nine percent reported that their company employed a formal method for their HF specialist(s) to provide regular briefings to senior maintenance management.

Nearly 36% of respondents indicated that they were active participants in industry or HF working groups. When examined by regulatory model, figures ranged from 31.3% to 44.8%, with TC leading the way.

Organizational Policies

The majority of respondents (72.3%) reported having a formal quality assurance (QA) process such as ISO9000. When asked if their QA program addressed HF, 46.3% said "yes" and 10.2% said "don't know." Most (88.6%) reported that their company had a formal safety policy, and an additional 7.8% reported an informal safety policy. These figures were consistent regardless of regulatory model. See Tables 5 and 6 for all responses.

Table 5
Quality Assurance Processes by Regulatory Model

	% QA Process	% QA Process Addresses HF
Overall	72.3	46.3
O-NAA	75.0	55.6
FAA	74.0	37.5
EASA	69.9	55.6
CASA	66.7	40.0
TC	66.7	50.0

Table 6
Formal and Informal Safety Policy by Regulatory Model

	Safety Policy	
	% Formal	% Informal
Overall	88.6	7.8
CASA	100.0	0.0
EASA	93.1	4.2

FAA	88.7	7.3
TC	90.0	10.0
O-NAA	80.0	13.8

Over 60% reported a formal shift handover policy, and an additional 22% reported an informal policy. See Figure 3 for a breakout of shift handover policy across regulatory model. Results were fairly similar; however, respondents that reported their HF practices were in line with EASA were most likely to have a shift handover policy (92.9%).

Interestingly, less than half (42.7%) reported their company had a formal policy to apply HF principles in writing or amending technical documentation. However, an additional 28% indicated an informal policy.

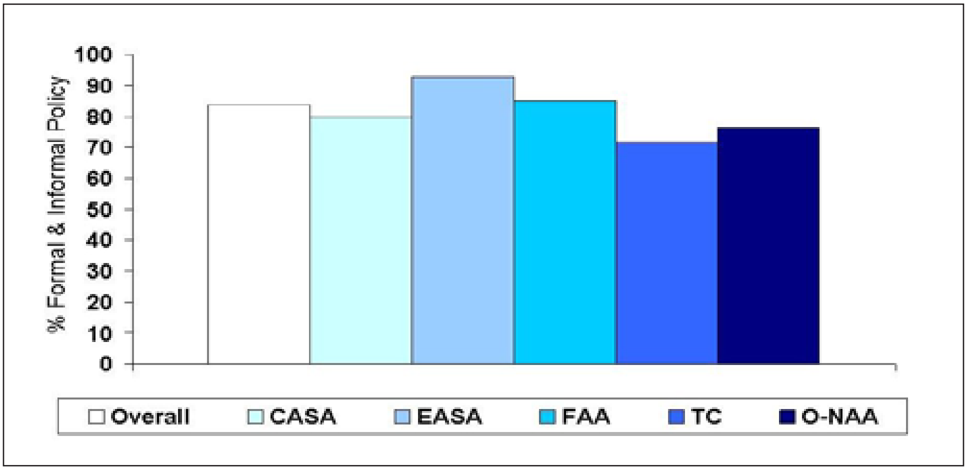

Figure 3. Shift Handover Policy by Regulatory Authority Model.

Human Factors Training

The issue of HF is introduced as part of training for new maintenance personnel by 66.6% of the represented companies. Further, 79.6% (agree and strongly agree) recognized the return on investment of initial HF training, and 76.1% recognized the return on investment of recurrent HF training.

Given differences in HF requirements across regulatory agencies, we suspected that there could be differences in the maturity of training programs. Indeed, this is what we found in that TC (77.4%) and EASA (71.6%) respondents reported having an existing course that met requirements. Respondents that indicated they modeled FAA regulations reported the lowest percentage (43.4%) regarding an existing HF course. See Figure 4 for all responses.

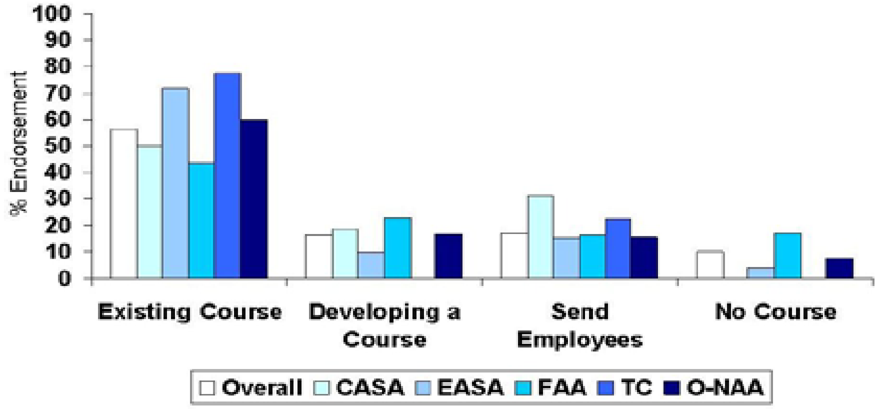

Figure 4. Current Position Regarding HF Training.

However, as is clear from the figure, it was not as if others were absent of training. In fact, their companies were in the process of developing a course, sending their employees to an existing course, or they had hired a consultant for training. One area in need of improvement was found for those that designed their program in compliance with the FAA. Over 17% of these respondents reported no course.

For respondents that reported having an HF course or were in the process of developing a course, the topic areas of the course were in line with best practices. For example, many reported that communication, human error, and factors related to fatigue were covered (Table 7).

Table 7
Topic Areas of Human Factors Course

Topic Area	%
Introduction to HF	96.4
Factors the contribute to human error	96.0
Communications	92.4
Effect of shift work and fatigue on performance	89.8
Event Investigation	74.7
Shift turnover	78.2
Other topics	32.9

To gauge the depth of workforce training, we asked for the percentage of employees and managers that had received at least 4 hours of HF training. Overall, on average approximately 60% of both licensed maintenance engineers/mechanics and managers had received at least 4 hours. When we split this by regulatory model, again we found differences with TC and EASA reporting the highest figures. See Figure 5 for all responses.

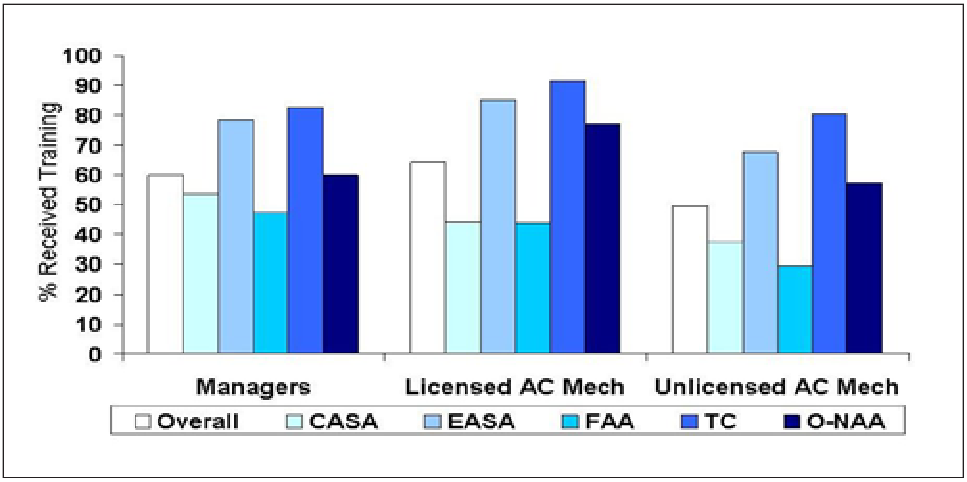

Figure 5. Percentage of Employees Who Have Received at Least 4 Hours of HF Training.

When asked about the breadth of their company's HF trainers, the majority of respondents (68.5%) reported that their trainers had maintenance/engineering work experience. Many trainers were said to have attended a 2-5 day HF course (61.7%) and/or a 2-5 day instructors' skills course (46.8%). Only a few (12.9%) reported that their HF trainers had no formal HF training. When we examined the results by regulatory model, CASA, EASA, and TC clearly had instructors with a well-trained and experienced background (Figure 6). By comparison, for those companies that modeled their program after the FAA, a higher percentage (23.4%) of their trainers were said to have no formal training.

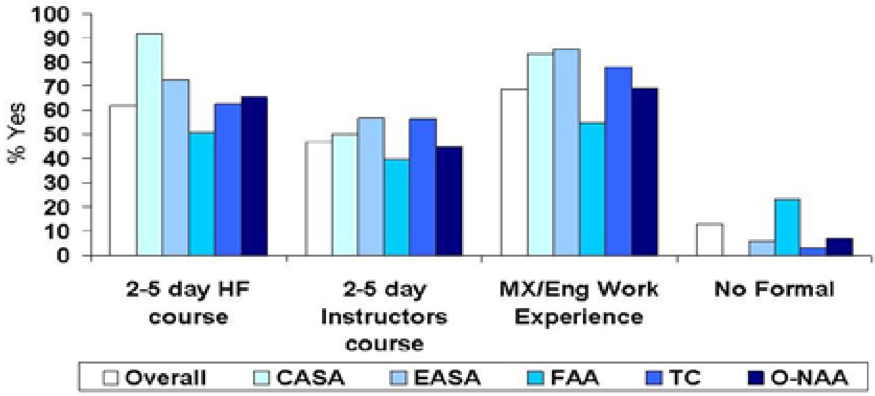

Figure 6. Training of HF Trainers.

Error Management

One of the key factors for a successful MHF program is the availability of a program to track maintenance error events and implemented corrections. Over half (55%) of the respondents reported that their error data were stored in a database. Differences were observed across regulatory model. Companies modeling EASA requirements reported the highest storage of error data (65.1%), while those modeling the FAA were the lowest at 49.1%. See Table 8 for all responses.

Table 8

Percentage Storing Error Data in a Database by Regulatory Authority

Regulator	% in Database
Overall	55.0
EASA	65.1
O-NAA	57.4
TC	56.3
CASA	53.8
FAA	49.1

Overall, organizations reported employing either a formal (64.8%) or informal (19.1%) program for their human error investigations. Of these organizations, 32.2% reported using the Maintenance Error Decision Aid (MEDA), 10.5% the Human Factors Analysis and Classification System (HFACS), 36.6% some modification of MEDA, and 35.1% indicated they used another program not listed.

Moving beyond storage of data and investigating single incidents, we wanted to know if companies had systemic programs in place to review and use their error data to prevent future occurrences. Tracking trends and the progress of interventions support the sustainment of an HF program. We found less positive results within this area. For example, less than half (46.5%) of our respondents indicated their company reviewed their database in a proactive manner (Table 9).

Table 9

Use of Human Error Data

Use	%
Recommendations are made from individual incidents investigated.	70.5
We review our error database periodically to identify concerns and plan interventions.	46.5
Senior management uses the information as part of a formal quality management process.	43.1
Within the past year, processes and procedures were changed as a result of the analysis of the error database.	33.7
Interventions are evaluated to assess their effectiveness.	26.9
We do not use our human error data	10.8

Moreover, most respondents (70.5%) indicated that their company generated recommendations from individual incidents but did not evaluate the effectiveness of interventions. Nor were procedures changed because of data analysis.

Fatigue Management

Over half (51.3%) of the respondents indicated that managing fatigue was an important element of their safety management system. The impact of fatigue on safety was recognized by 82.1%. However, only 24.9% indicated their organization had a fatigue management system. This figure was consistent across regulatory models. The inconsistency between belief and action was further evident in that only 35.9% reported that their organization provided training on fatigue management. However, regulatory adherence was found to have an impact with TC (45.2%) and EASA (40.8%) reporting higher figures than other regulatory models (Fig. 7).

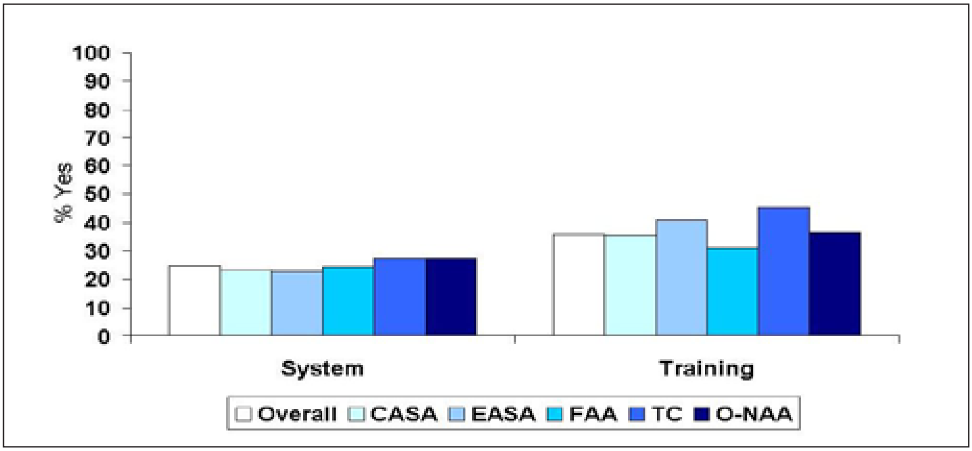

Figure 7. Fatigue Management System and Training by Regulatory Authority Model.

To explore the relationship between training and the impact of fatigue on safety further, we examined the responses of individuals that indicated their company had no plans for a human factors course. Nearly one-fourth said their company did not recognize fatigue as a safety issue.

Human Factors Metrics

Over half (54.4%) of respondents reported measuring the economic and other effects of errors/incidents. At present, less than 10% performed a cost-benefit to justify their HF interventions. However, 51% recognized that their company must improve their return on investment data regarding HF.

For some respondents, realization of the benefits from this investment has begun, with 27.2% reporting cost-benefit success stories because of their HF interventions. When asked for examples of success stories, respondents shared that their companies experienced a reduction in errors, improved on-time performance, improved workplace design, and reduced on-the-job injuries.

Discussion

The high response rate (66%; N=414) from experienced personnel (65% had 20+ years), from more than 50 countries is indicative of the high level of international interest in maintenance HF. The largest number of respondents was somewhat evenly divided between airlines and repair stations, with representatives from training organizations and general aviation (GA) maintenance facilities also participating. The generalizations here are most reflective of larger maintenance organizations. That is appropriate, since they were the primary target audience of the study. Forty percent of the respondents were from the U.S., which is also consistent with the current distribution of international aviation maintenance activity. (K. Michaels, AeroStrategy.com, personal communication, February 11, 2007). In summary, we can attribute reasonably accurate conclusions due to our diverse international participation.

During the design of this study, we expected to find extensive differences among countries because of national regulations regarding HF. The charts presented throughout this report have shown rankings, level of interest, and the nature of HF programs based mostly on regulatory model. There were more similarities than differences in the data.

Maintenance organizations institute HF initiatives because such programs help ensure flight safety and worker safety. Most respondents rated those factors as highly important. Of course, regulatory compliance is very important for companies modeling regulations from TC and EASA, as shown in the data. Nearly 1,200 U.S. repair stations comply with EASA regulations; therefore, they are also motivated by requirements beyond the FAA (EASA, 2007).

Support from the Regulator

TC was reported as providing the most support as a regulator. The FAA, EASA, and O-NAA received about the same rating for their support. In response to these findings, the FAA through the Flight Standards Service organization, and hopefully other authorities, will identify the best ways to empower the Aviation Safety Inspector workforce to provide additional HF support to the industry. One example of recent FAA MHF support to the industry is the Operator’s Manual for Human Factors in Aviation Maintenance (FAA, 2006a). The manual was written to assist companies with developing a quality MHF program. The FAA is also revising the MHF Website (www.hf.faa.gov) and is developing a new edition of the Web-based Human Factors Guide for Maintenance and Inspection. The FAA Flight Standards Service is also taking proactive measures to enhance and clarify additional guidance material for industry and for FAA personnel. Additionally, Flight Standards extended a previous Aviation Safety Inspector two-day maintenance resource management course to three days with additional coverage of HF topics.

Providing Human Factors Suggestions

Over half of respondents reported there were means for workers to provide HF suggestions to the company. EASA-modeled companies were well above the average. This is a very positive finding that is likely related to the European requirements for significant HF initial and continuation training for everyone, including managers. Reason and Hobbs emphasized critical elements of a safety culture that included creating an atmosphere of trust in which people are willing to take proactive steps to address HF issues (Reason & Hobbs, 2003).The result is that HF issues and language become a shared value among all segments of the workforce.

Event Reporting – The Good News

We were extremely encouraged to see the level of agreement regarding formal application of event investigations. Most had a formal or informal system. Over two-thirds of respondents said they were using Boeing's MEDA or some modification. This extensive use of the same reporting format could foster data sharing sometime in the future. In order for an organization to learn from past events, they must first have a reporting culture (Reason & Hobbs, 2003).

Industry Involvement

Another similarity among the respondents was their company's and their personal involvement in industry and government committee work related to HF in maintenance. Over a third of the respondents participated in such activities. This figure reinforces the earlier statement that our respondents represent the industry's best companies. Of course, this could also be an area for improvement.

Differences in Responses

Over half of respondents indicated that their company had an existing HF course. Respondents who modeled the FAA had the lowest percentage regarding having an existing HF training course. In response to the same question, respondents modeling TC and EASA reported over 75% percent. Because HF courses are not a regulatory requirement in the U.S., it was not surprising to find the largest percentage where no course existed was from companies that modeled the FAA. Obviously, this suggests that regulations are a reliable means of ensuring the presence of an HF training program.

Training the Trainer

As mentioned above, it is reasonable to expect companies, which model their program in accordance with FAA regulations, would have less training than companies that were required to have training. The question concerning background training of HF trainers clearly indicated that HF trainers of companies that designed their programs in accordance with FAA regulations had less formal training in comparison to the rest of the world. Companies modeling FAA regulations were at the bottom of the ratings with respect not only to HF training but also for train-the-trainer instruction for HF trainers. For respondents that modeled FAA regulations, 23% indicated that their HF trainers had no formal training.

The Human Factors of Technical Documentation

Proper use of technical documentation remains a high priority for the industry. Failure to follow procedures is a frequent cause of negative events (Nord & Kanki, 1999). Patankar, Lattanzio, and Kanki (2004) examined ASRS reports with a procedural error and found maintenance manuals and the minimum equipment list were often involved in the error. Many respondents' companies had a formal or informal policy to apply HF considerations to the development or modification of documentation. Effective use of error-reporting systems is an excellent way to raise human factors-related attention to technical documentation and procedures. Event investigations must drill down to the reason(s) that people did not use the documents or had difficulty understanding the documents.

Using Error Data – The Challenges

We have already commented on the positive efforts to investigate, report, and record event data. A majority of respondents said that event investigations lead to recommendations. However, fewer respondents reported that processes and procedures were changed in the last year because of the event database. We found that slightly over a quarter of companies have evaluated the effectiveness of their interventions. These numbers strongly suggest that the error data are not being used to their full potential.

Human Factors Metrics

Over half of the respondents reported that their company measured the cost of events. Few respondents' companies tried to cost-justify HF interventions, while over half of the respondents recognized the importance of demonstrating the return-on-investment in human factors programs. The FAA Operator's Manual for Human Factors in Aviation Maintenance (FAA, 2006a) offers a method to calculate return on investment. However, to do this properly, companies must track errors, estimate the cost of errors, and the cost of the interventions to calculate savings. As previously noted, few companies are tracking errors and interventions over time, which makes calculating savings over time impossible.

Fatigue Management Systems

One of the important findings of this survey is related to fatigue in aviation maintenance. The majority of respondents acknowledged the impact of fatigue on maintenance work. However, only a quarter of them had a fatigue management system and slightly over a third delivered training related to fatigue management. These numbers strongly suggest that the aviation maintenance industry and the regulators must monitor this situation and implement programs to ensure that worker fatigue management systems provide continuing safety.

Summary

This study reinforces the belief that MHF programs are valuable and important, and there are a variety of such programs throughout the world. For organizations that model agencies with regulatory requirements, the HF programs are more widely adopted, and the HF instructors are given more training to prepare them for their responsibilities. Regardless of the variety of international regulations on MHF, the industry reports that flight safety and worker safety are the primary reasons to have such programs.

HF programs reduce cost and foster continuing safety and control of human error in maintenance. This survey found that the best targets of opportunity for improvement are use of event-data reporting, creation of a fatigue management program, and increased use of data as a means of tracking errors over time to help or further justify the cost of HF programs.

Acknowledgements

The research team is grateful to all respondents and colleagues who participated in the design and completion of this study.

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Appendix

Number of respondents from each country

Country	Number
Argentina	4
Australia	13
Austria	1
Bahrain	1
Belgium	3
Bolivia	3
Brazil	3
Canada	35
Chile	3
China	3
Colombia	3
Cyprus	1
Denmark	1
Ecuador	1
El Salvador	1
Finland	1
France	3
Germany	6
Greece	10
Greenland	1
Guatemala	2
Hong Kong	6
Hungary	1
Ireland	2
Italy	1
Japan	3
Korea	2
Kuwait	1
Luxembourg	1
Malaysia	6
Malta	1
Mexico	4
Netherlands	2
New Zealand	3
Norway	12
Panama	4
Peru	1
Philippines	4
Poland	1
Portugal	2
Romania	1

Singapore	12
Slovenia	1
South Africa	5
Spain	8
Sweden	4
Switzerland	4
Taiwan	9
Thailand	1
Turkey	1
United Arab Emirates	3
United Kingdom	29
USA	160
Venezuela	3

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A Distributed Air Traffic Information Display Simulator: Design and Results

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Abstract

The National Airspace System (NAS) is vested in the interaction of multiple partners. Effective simulations of NAS require the participation of multiple operators. One reason why such an integrated simulation facility would be useful lies in its potential to test various proposed changes in NAS operations that have accompanied the introduction of impact technologies. Autonomous self-separation by pilots is close to one end of a continuum of operational concepts known as 'free flight', which could compose an evident paradigm change for global air operations. The configuration of autonomous control has been explored in our Laboratory in a programmatic series of research studies. We created a purpose-specific simulation system especially focused on the issue of pilot-ATC interaction and the respective changes in functioning due to greater distribution of control. The present paper describes this effort, its structure, function, and results, which have shown a consistent use of a time-to-contact threshold by pilots in resolving conflict situations.

A Distributed Air Traffic Information Display Simulator (DATIDS).

To support the design of autonomous control in commercial aviation, our collective research group, then at the University of Minnesota, created the DATIDS (Distributed Air-Traffic Information Display Simulator) system. DATIDS was purpose-designed to be a user-friendly research tool that provided a flexible array of experimental workstations for exploration of the decision-making, communication, and actions of any combination of (1) pilots, (2) pseudo-pilots, (3) air traffic controllers, and (4) airline dispatchers. Creation of this facility was supported by

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Grant funding from the Federal Aviation Administration and represented an experimental environment which was employed to support a number of experiments (e.g., Knecht, & Hancock, 1999; Murphy, Smith, & Hancock, 2004; Smith, Hancock, & Scallen, 1996; Smith, Scallen, Knecht, & Hancock, 1998). The DATIDS suite is shown in Figure 1.

One pilot, or multiple pilots, could be employed as participants in the distributed cockpit facilities. In the original instantiation of DATIDS, there was only a single pilot seated in a mockup of the captain's side of a Boeing 757 cockpit. Pilot controlled one of the aircraft in the simulated airspace. The paths of all other aircraft in the experimental scenario were scripted and under the real-time control of one or more 'pseudo-pilots.' An experimenter could assume the role of 'pseudo-pilot' for up to as many as thirty other aircraft ('targets') in the scenario. Alternatively, this function could be handed off to single, or multiple, associates. The DATIDS pseudo-pilot interface on the server enabled the experimenter to maneuver any of the target aircraft realistically in real time.

Figure 1. The Human Factors Research Laboratory's (HFRL, Univ. of Minnesota) Aviation Research Facilities. At the left, with the staircase, is a single-seat cockpit that housed a single (pilot) participant. Behind is a two-seat cockpit configuration. At right, one of the creators of the DATIDS system is seated at the ATC workstation.

An 'air traffic controller' could be designated as another experimental participant, seated at a mockup of an ARTCC sector controller's workstation. Again, there was the opportunity for the interaction of a single or multiple sector controllers with each other and with aircraft (and the pilot in the mockup of the cockpit). Finally, other experimental participants could act as 'airline dispatchers.' Further, single or multiple operator configurations were available. In the original DATIDS, this individual was seated at a mockup of a dispatcher's workstation at Northwest Airline's Systems Operations Center (SOC).

Simulation Functionality

In its initial configuration on a high-end Silicon Graphics machine, DATIDS supported en route flight scenarios with as many as thirty aircraft anywhere in the continental United States. DATIDS was also able to support either arrival or departure scenarios if files and routes were created to supply the graphics for the necessary "background" data, i.e., arrival fixes, runways, etc. The restriction to thirty aircraft was actually arbitrary, as was the decision to limit the data files of waypoints and jet ways to those in the contiguous forty-eight states. In principle, there is no reason why the whole, global airspace could not have been represented on the DATIDS system. In the second-generation of DATIDS, advances in PC technology allowed us to expand the simulation to include multiple glass cockpits and ATC workstations networked together to form a distributed array. The tasks of calculating aircraft movement, accepting inputs from several participants, recording data, and displaying graphic representations of a number of different electronic devices were separated and assigned to individual computers. The computers communicated over a local network to form a unified simulation. The PC-based system was significantly more cost-effective than its predecessor.

DATIDS Workstations

The Air-Traffic Control Workstation. The DATIDS simulation of an ARTCC sector controller's workstation recreated a circular composite radar screen (the Plan View Display, PVD), a computer read-out display (CRD), a panel of buttons and five dials. As shown in Figure 2, aircraft, routes, waypoints, and sector boundaries were drawn on the PVD. Each waypoint was accompanied by its name. Each aircraft had a configurable data tag that conformed to the standard format used by controllers of high-altitude sectors. The experimental participant used a trackball to re-center the radar field by clicking on a waypoint. Position and flight plan data, from the last aircraft the user clicked on, was displayed in the CRD in the upper right of the display. By clicking on the first dial (labeled RANGE), the user could zoom in or out by adjusting the radius of the displayed area. To mimic real ATC screens, aircraft were drawn as short lines perpendicular to their headings. To portray the refresh rate of ATC radar data realistically, the locations and data tags for aircraft on the screen were updated once every six seconds. This is slower than the sweep at an ARTCC and closer to the timing of a TRACON facility. It was chosen here in relation to the experimentation on future implementation of autonomous self-separation. Positions from previous updates remained on the screen and faded to black over time. The number of previous updates that remained visible could be manipulated using the HISTORY dial. An aircraft's filed flight plan and its projected path along its current heading could optionally be displayed as a thick lines extending in front of the aircraft on the radar screen using the bottom three dials. In Figure 2, the user elected to see the next 32 minutes of the flight plan for Delta 3220.

Figure 2. The DATIDS Air Traffic Control Display. The circular PVD shows a representation of flights in the sector with their data tags. The CRD in the box at upper right displays selected information about a specific flight. The ranks of buttons below the CRD are used to select the displayed information. Dials, at lower left, control the display on the PVD.

The Cockpit Workstation. With respect of the pilot position, DATIDS could be best described as a “mid-fidelity” simulation facility. It emulated only those controls and displays used in glass-cockpit aircraft to inform decisions about routing and (self-) separation and to execute flight maneuvers. The aircraft responded like a Boeing 757 with all the associated flight dynamics and response capacities. DATIDS did not emulate any of the controls used to sustain an aircraft in the air, e.g. fuel management, engines, etc. Three displays made up the cockpit workstation, (a) Primary Flight Display (PFD, Figure 3); (b) Cockpit display of traffic information (CDTI, Figure 4); and (c) Flight Management System (FMS) control screen and Multi-Control Display Unit (MCDU) panel.

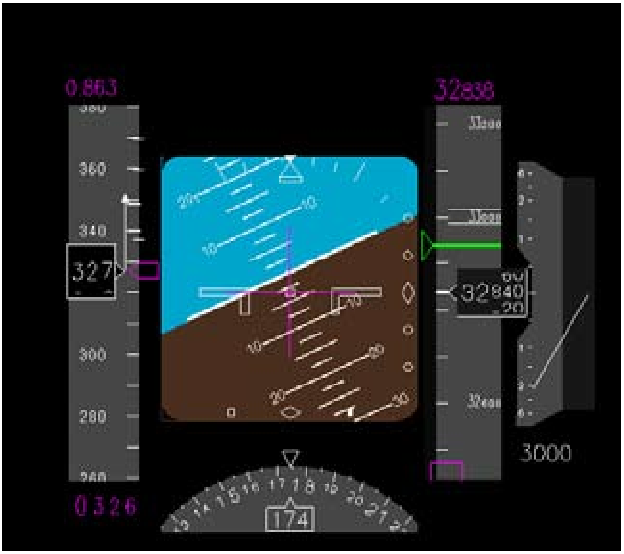

Figure 3. The Primary Flight Display. The portion of the compass rose at the base of the display shows the heading. The ladder at left shows the indicated airspeed in the present case is 327 knots. The ladder at right shows current altitude, being almost 33,000 ft. The pitch ladder in the center shows the horizon line and bank angle. The horizon, shown as the transition between blue and brown, indicates that the own-ship is very slightly nose down (since the magenta cross is below the horizon) and is banking to the right (at the angle shown by the solid white line on the horizon).

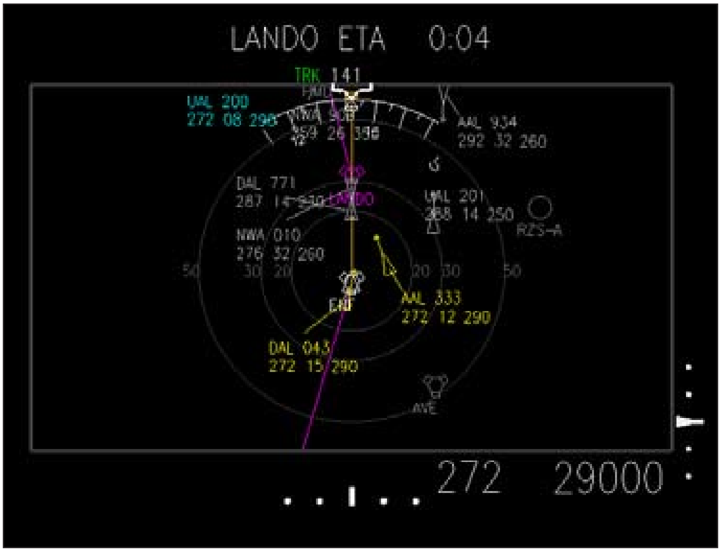

Figure 4. The Cockpit Display of Traffic Information (CDTI) used in the experiments supported by DATIDS. The illustration shows the ownership at the center of the display. The magenta line shows the own-ship's plotted path as derived

from its filed flight plan. As evident from the figures at the base of the display, the present altitude of the ownship is 29,000 ft. (flight level 290) with a speed of 272 knots. The information at the top indicates that the waypoint ‘Lando’ is approximately 4 minutes ahead. This fix is also shown on the central display area. In this version of the display, other aircraft were color-coded to reflect the severity of a potential violation of separation rules (5 nm horizontally and 2,000 feet vertically). Thus, the yellow data tags and aircraft symbols indicated that both Delta Air Lines (DAL 043) and American Airlines (AAL 333) are within a specified distance (which had been set by the experimenter). The use of a blue highlight for United Airlines (UAL 200) indicates a greater distance from its potential conflict with the ownship. Aircraft at a different altitude are not in potential conflict with the ownship and are represented in white.

Anticipating the arrival of ADSB communications, the radar screen of the CDTI displayed all the aircraft in its own (referred here as ‘own-ship’) vicinity within a pilot-selectable range. The PFD showed the aircraft’s heading, pitch, roll, speed, and altitude. Piloting commands were entered on a FMS button pad (Honeywell MCDU). The FMS control screen echoed the command being entered. The participant pilot could request data about other aircraft through the FMS pad. These Data were then displayed on the FMS display. We have not illustrated the FMS here since it was a piece of standard operating equipment, used in its standard mode.

The “Pseudo Pilot” and Experimenter Workstation. The pseudo-pilot and experimenter’s workstation, shown in Figure 5, was a simplified version of the cockpit workstation. It displayed a list of all aircraft in the simulation. When an aircraft was selected, its current altitude, speed, heading, and flight plan are displayed. The user could then issue heading deviations, speed alterations, altitude changes, and flight plan corrections just as a pilot could using the MCDU in the cockpit workstation(s).

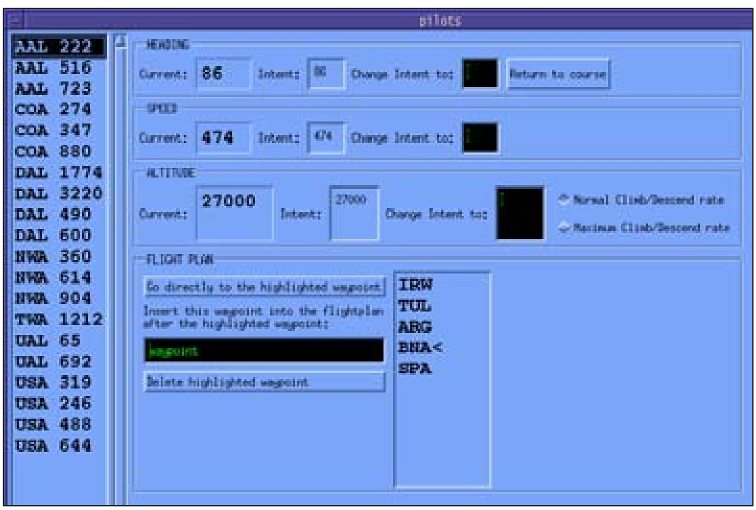

Figure 5. The ‘Pseudo-Pilot’s’ and Experimenter’s Workstation enables real-time control of aircraft in the traffic scenarios. At left is a listing of all the aircraft in the scenario. Generally, only a subset of the aircraft on the list is present in the sec-

tor at any one time. The boxes along the top of the display are editing panels that echo the current operational data of the aircraft highlighted at left (i.e., AAL 222). Editing the data in these panels changes the operational parameters for the selected aircraft. The flight plan for the selected aircraft is shown below the heading, speed, and altitude panels. This window allows the 'pseudo-pilot' or experimenter to change the plan of any flight at any time during the scenario.

DATIDS Data Collection Capacities

The DATIDS server recorded and time stamped all the commands received from each workstation. After the completion of an experiment, the server could be employed in a "playback" mode using only the recorded commands as input. In playback mode, the server wrote to file the records of events that occurred during the session. The types of events recorded varied with the nature of the research. New data extraction and analysis routines were routinely developed, added, or changed, and implemented simply by modifying specific software modules and running in playback mode. As a result, any experimental session conducted previously could be used to test novel hypotheses. Information about participant behavior that was not reflected in aircraft performance was recorded at that participant's workstation. For example, ATC workstations recorded the dial settings selected by the participant for display on the PVD. Cockpit workstations recorded CDTI settings, range and view, and how long each respective screen remained in a setting. This construction was designed to capture the requisite data to facilitate analysis of pilot and controller strategies for free-flight operations.

Hardware Requirements

Hardware requirements for the second and subsequent versions of DATIDS included a server-client network of PCs with high-speed processors running Linux and connected by Ethernet. The graphical displays were programmed to run in the X11 Windows environment and use an OpenGL-compliant graphics library package. The X server used MetroLink's MetroX software. Some of the stations required more than one display. For each display monitor, a Matrox Millennia video card was required. The X server could then be configured to display on up to four monitors. Each computer also required an ISA Ethernet network adapter.

The mockup of the Boeing 757 cockpit contained three 640x480 VGA monitors, a Honeywell MCDU FMS keypad, and a dashboard with six buttons aligned vertically along the rightmost screen, three lighted buttons, and two rotary dials. The FMS pad, the buttons, and the dials on the dashboard were wired into the computer through an analog/digital input/output circuit board. The ATC workstations used one 17" or larger monitor and one trackball. The experimenter's workstation presented the ATC workstation on one monitor and the pseudo-pilot workstation on a second.

Findings Using DATIDS

The DATIDS simulation was used in a number of experiments investigating the decision making and maneuver selection by currently certified commercial airline pilots (e.g., Knecht, & Hancock, 1999; Murphy, Smith, & Hancock, 2004; Smith, Hancock, & Scallen, 1996; Smith, Scallen, Knecht, & Hancock, 1998). In these experiments, the pilots exercised autonomous control of all decisions regarding routing and conflict avoidance with no assistance from air traffic control (and see Scallen, Smith, & Hancock, 1997). The exercise of autonomous control by pilots is an end-member of the continuum of operational concepts known as 'free flight' (Smith, Hancock & Scallen, 1996). One of the more remarkable findings that emerged from the DATIDS system concerned the timing of pilots' detection of potential conflicts with other aircraft. Here we present these previously unpublished results.

Experimental Participants

Ten highly experienced and currently certified commercial airline pilots (flight hours: mean 9,177, range 6,000 to 24,000; age: mean 51.9, range 38 to 63) volunteered to participate. Participants were certified to fly one or more of the following glass-cockpit aircraft types: Airbus 320, DC9/10, MD80/90, Boeing 474-400, 757, and 767. The pilots received instructions, signed an informed consent form, and became familiar with the DATIDS cockpit and its displays in a series of practice scenarios; afterwards, the pilots individually flew a series of twelve realistic but challenging en-route flight scenarios.

Experimental Design and Procedure

Pilots were instructed to maintain standard FAA aircraft separation (5 nm. horizontally and 1,000 feet vertically) between their aircraft and 6 to 16 other aircraft. They were free to make all decisions about routing and separation without the support or intervention of air traffic control. In all but 1 of the 12 scenarios, pilots encountered realistic but challenging traffic conditions including crossing traffic, merging traffic, and being overtaken by other traffic.

Table 1 shows the incomplete block design of the 12 En Route scenarios. The design manipulated (a) two dimensions of airspace complexity; (b) traffic count at three-distinct levels and; (c) relative bearing of traffic at five levels. Traffic count, a common metric of airspace complexity (e.g., Hopkin, 1980; Smith, Scallen, Knecht, & Hancock, 1998) was defined as the total number of aircraft within 150 km of the pilot's aircraft prior to and during the scheduled conflict. Relative bearing is defined with reference to the direction of flight of the pilot's aircraft. Thus, traffic with a relative bearing of 0° is flying in the same direction as the pilot and traffic with a relative bearing of 180° is approaching the pilot head-on. Roughly, half of the traffic with intermediate values of relative bearing approached from the left and half from the right.

Table 1
The manipulations of traffic count and relative bearing in the 12 en-route air traffic scenarios.

Traffic	Relative bearing of conflicting traffic					No
count	0°	45°	90°	135°	180°	conflict
6		X	X	X		
9	X	X	X	X	X	X
16		X	X	X		

In a series of shake-down flights, the pilot who volunteered to serve as our subject matter expert commented that the 0° values of relative bearing (being overtaken) and 180° value (head-on collision at the same altitude) were unrealistic but challenging. To reduce the time participants would have to spend in the simulator, we retained only one instance of each of these bearings. The 11 conflict scenarios developed violations of minimum separation rules within 6 minutes if the pilot followed the preprogrammed flight plan. The twelfth scenario, a control condition, contained no scheduled conflict.

Pilots were asked to think aloud as they navigated through traffic in the En Route scenarios. Their concurrent verbal reports were recorded on a Dictaphone recorder with a Telex hands-free headset. Separation and relative velocity for each aircraft were calculated with respect to the pilot's aircraft and recorded at approximately 5 Hz throughout the scenario. A Sony 8 mm camcorder with audio input from the Telex system was used to record trials and add a time stamp for correlation of the verbal protocol and flight data. The verbal reports and videos were scored to determine when a pilot first indicated detection of an impending conflict (detection time). The target aircraft that motivated the pilot's conflict detection and subsequent action was determined by verbal recording and confirmed in subsequent computer playback of the session. The separation and relative velocity for each target aircraft at its detection time are the data used in the analysis.

Experimental Results

Grouping across participants and scenarios, the pilots were able to maintain the FAA separation criteria in 84 of the 110 conflict scenarios. In 28 of these 84, the pilot did not verbalize with sufficient clarity to identify the detection time or target unambiguously. Each circle in Figure 6 represents the separation and relative velocity between the pilot's aircraft and a target aircraft at its detection time for 1 of the 56 conflicts that were clearly detected and successfully resolved. The fuzziness of some circles reveals where data overlap. The relatively high percentage of successful resolutions (84/110 = 76%) reveals that the pilots were generally able to extract time-to-contract information from the flat-panel CDTI. The potentially troubling failure rate of 24% (26/110) only derives because these scenarios were purposed-developed to present such intense challenges that they might not be resolvable without augmented support (e.g., Knecht, 2007). The resolution rate in this experiment should not be interpreted as predictor of failure rates of self-separation in fully functional, free-flight conditions.

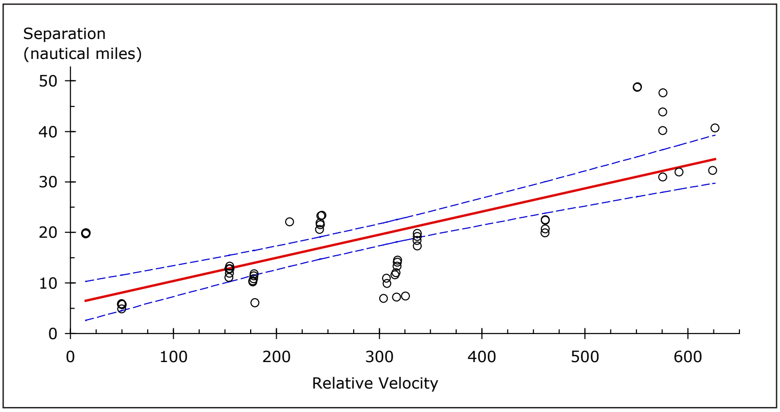

Figure 6. Pilot conflict detection times and least-squares linear regression analysis. Curves represent ±95% confidence interval for the regression line. Plotted points may overlap.

Figure 6 is a phase plane representation of en route air-traffic dynamics (Phatak & Bekey, 1969; Smith & Hancock, 1995). A phase plane is a state space in which one of the axes is the time derivative of the other (Jagacinski & Flach, 2003). In Figure 6, the vertical axis is separation, the distance between the locations of the pilot's aircraft and the target aircraft in nautical miles. The horizontal axis is its derivative, velocity in knots. Here, velocity is the relative velocity of the two aircraft, the sum of the components of their velocities in the direction of their separation. Points near the vertical axis represent conflicts in the overtaking scenario that unfolded slowly. Points at the far right represent conflicts with aircraft approaching nearly head-on and, accordingly, with high relative velocity. Points close to the horizontal axis represent conflicts that occurred within two minutes of the beginning of the scenario.

The data shown in Figure 6 are collapsed across the manipulations of traffic count and relative bearing. In spite of this diversity of conflict opportunity and the variation, which results from intrinsic individual differences, the data exhibit a significant linear trend. Least-squares linear regression defined a line with an intercept of 5.8 nautical miles and a slope of 0.046 hours = 2.75 minutes ($r^2 = .52$, $n = 56$). The 95% confidence interval for the line, shown with dashed curves in Figure 6, indicates that the Y-intercept is statistically indistinguishable from the 5-mile FAA criterion for minimum horizontal separation.

Discussion

In this experiment, the pilots were instructed to maintain standard FAA aircraft separation and were free to make all decisions about routing and separation. A necessary component of decision making about self-separation is the detection of impending potential conflicts. For the pilots in our experiment, the only source of this information was the flat panel CDTI of Figure 4. The critical information was the rate of closure of the gap separating the soon-to-be-coincident objects (the ownship and the target). These pilots were able to extract information about gap closure from the flat-panel display. Here, they did not rely upon the direct perception of the expanding optic array (Gibson, 1954, 1979; Lee, 1974, 1976); rather they were able to extrapolate time-to-contact information from the representational display. However, the notion that time-to-contact information is critical in conflict avoidance is still preserved and represents the most remarkable outcome of this procedure. It is here as if the pilots have used a very primitive avoidance strategy, derived from terrestrial navigation, and transposed this self-same property into the representational space of commercial flight. This transposition of maneuvering strategy has extremely important implications for the design and operations of a national Airspace System predicated on distributed self-separation. This finding is consistent then with the proposition that pilots monitor gap variations as symbols representing traffic move across a flat-panel display. It further reveals a common linkage between ecological and information-processing based approaches to spatio-temporal navigation (and sees Hancock & Diaz, 2001). This result is but one example of how a comprehensive simulator facility such as DATIDS can encourage both pragmatic efforts in relation to practical objectives (e.g., free flight) and yet still invoke fundamental theoretical issues.

Acknowledgements

DATIDS was conceived and initiated by Drs. Peter Hancock and Kip Smith, while the system itself was designed and built by Mark Coyle, Darryl Lonnon, James Klinge, Michael McGrath, Avik Mohan, Neil Smeby, and Dr. Stephen Scallen who were all at the University of Minnesota, Human Factors Research Laboratory at the time of creation. The credit to solving all the practical problems attendant on realizing the operational system should go to the latter individuals. The consulting domain expert was Mr. Guy Smith. The development work and experimentation were supported by FAA Grants 93-G-048, P.A. Hancock, Principal Investigator, and 98-G-018, Kip Smith, Principal Investigator. John Zalenchek was the Technical Monitor for the first grant and Thomas McCloy was the technical monitor for the second. The views expressed here are those of the authors and do not necessarily represent those of any named agency. We are grateful for the helpful comments of two unknown reviewers. Further information concerning the DATIDS system and its present status can be had from Kip Smith, kip.smith@liu.se.

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The Effects of Low Dose Caffeine on Pilot Performance

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Abstract

Pilots often use caffeine, in the form of coffee, during critical phases of flight to enhance performance. This study investigates the effects of low dose caffeine on pilots' performance during a crucial segment of flight. Thirty pilots were randomly divided into three groups (0mg/kg, 1mg/kg, & 3mg/kg of caffeine). The pilots performed two simulated instrument landing systems approaches. Caffeine was administered between the two flights and pilots' performances were measured and compared. The results failed to reveal any differences between the three groups. In contrast, a group by sleep interaction was significant. The results suggest for a normal well-rested person, caffeine at relatively low doses, similar to that used by pilots, has no measurable effect on performance. In contrast, for a person not well rested, caffeine in low doses noticeably improves performance. Results are discussed from an applied perspective and alternate methods of enhancing performance are reviewed. Recommendations are made for future studies in this field.

Throughout the history of aviation, human error has been the causal factor of many accidents and incidents worldwide (Nagel, 1988). Certain phases of flight pose greater risks than others, for example the descent, approach, and landing phases of flight (Graeber, 1988). According to Boeing's statistical summary of commercial jet airplane accidents from 1959 to 2005, the greatest number of fatal accidents occurred during the landing phase of flight (Boeing, 2006). The major contributing factor to these incidents was cited as 'crew error' or otherwise known as 'human error'.

During critical phases of flight, such as landing, the pilot and crew experience high workloads and are often required to make rapid decisions with a high level of accuracy. They are also required to be cognisant of their surrounding, including

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the performance of the aircraft and any other aircraft in the vicinity, while at the same time perform numerous other tasks crucial to the flight. Attention to detail and high levels of concentration are critical to the operation. However, after a long and potentially fatiguing trans-continental flight or a busy domestic schedule, the pilot and crew may find that they are unable to perform their usual duties with the same degree of accuracy and efficiency (Caldwell, 1997). This scenario can be further intensified with increasing workload during an instrument approach in bad weather or with unforseen circumstances. To help combat these particular situations, pilots often employ various coping strategies such as planning energy use, active coping, mental withdrawal, communicating with other crew members, and coffee drinking (Petrie & Dawson, 1997). It is the latter of these coping strategies that is the focus on this research, and specifically how caffeine at low doses improves pilots' performance.

According to Petrie and Dawson, (1997) and Caldwell, (1997) caffeine is widely used to help alleviate the symptoms of fatigue and increase alertness. While coping strategies such as planning energy expenditure, and active coping are more effective than caffeine over the longer term (Petrie & Dawson, 1997), anecdotal evidence derived from the aviation industry suggests that the availability and immediacy of caffeine makes it an attractive contingency for those situations involving unpredictable high workload or less than ideal planning.

Caffeine intake by pilots generally occurs through drinking coffee or tea, and to a lesser extent through the consumption of cola or energy beverages. A typical serving of coffee or tea contains between 30 and 120 mg of caffeine, while cola based drinks contain between 20 and 90 mg of caffeine per serving (Segall, 2000; D'Anci & Kanarek, 2006) (see Table 1 for typical caffeine content per 12oz serving for an individual weighing 176lb). In the case of coffee, the quantity of caffeine per serving can vary dramatically based on the duration in which the coffee has been roasted and the way the beverage has been brewed. In terms of the duration of roast, the lighter roasts, which have been roasted for a short duration, contain significantly more caffeine than the darker roasts, which have been roasted for a longer duration (D'Anci & Kanarek, 2006).

Table 1

Caffeine content per 12oz serving for an individual weighing 176lb/80kg.

Product	Caffeine per 12oz/340mls serve (mg)	Equivalent servings for an 176lb/80kg person (cups)		
		Experimental Groups		
		0 mg/kg	1 mg/kg	3 mg/kg
Coffee				
Brewed	200	0	0.4	1.2
Instant	30-120	0	2.6 - 0.6	8.0 - 2.0
Tea				
Leaf or bag	30-120	0	2.6 - 0.6	8.0 - 2.0
Cola beverage			`	
Regular	30-90	0	2.6 - 0.8	8.0 - 2.6
Diet	39-50	0	2.1 - 1.6	6.2 - 4.8

According to Fredholm, Battig, Holmen, Nehlig, and Zvartau, (1999) caffeine is the most widely consumed behaviourally active substance in the world. Caffeine, while common to many widely consumed drinks including tea, coffee, cola beverages and some energy drinks, it is also present in some foods including, chocolate and certain candies. Caffeine can even be found in some medicines such as non-narcotic analgesics including aspirin (Daly, 1993).

While the vast majority of the empirical research examining the effects of moderate to high dose caffeine use (between 4 and 7 milligrams per kilogram) on human behaviour concludes in favour of the drug for enhancing performance such as vigilance (Smith, Kendrick, Maben, & Salmon, 1994), sustained attention (Smith et al., 1994), mood (Herz, 1999), self-rate alertness (Kohler, Pavy, Van Den Heuvel, 2006), physical performance, (McLellan, Bell, & Kamimori, 2004; Tucha, Walitza, Mecklinger, Stasik, Sontag, & Lang, 2006; Wiles, Coleman, Tegerdine, & Swaine, 2006) and decision-making (Lyvers, Brooks, & Matica, 2004), research examining its effect at low dosages, typically what is consumed by pilots appears less conclusive. Specifically, while Smit and Rogers (2000) found that as little as 12.5mg of caffeine can significantly improve cognitive performance (reaction time, rapid visual information processing), and mood amongst subjects from the general population, Gillingham, Keef, Keillor, and Tikusis, (2003) found that 300mg of caffeine had no effect upon marksmanship accuracy and precision with military reservists. The inconsistency in results between low dose caffeine studies are further illustrated by Lieberman, Wurtman, Emde, Roberts, and Coviella, (1987) who found that as little as 32mg of caffeine significantly improved auditory vigilance and visual reaction time with healthy male subjects, while Tucha et al., (2006) found that 1.5mg/kg or 3.0mg/kg of caffeine failed to improve hand writing dexterity in right handed adults.

In contrast to the mixed results pertaining to the effects of caffeine at low doses under normal operating conditions, studies, which involve the administration of caffeine under conditions where participants experience sleep deprivation or exposure to severe environmental and operational stress, repeatedly demonstrate the beneficial effects of caffeine in a dose-dependent manner (Lieberman, Tharion, Skukitt-Hale, Speckman, & Tulley, 2002; Kamimore, Johnson, Thorne, & Belenky, 2005; McLellan et al., 2004). Specifically, Lieberman et al. (2002) found that the administration of 100, 200, or 300mg of caffeine following 72 hours of sleep deprivation to US Navy Seal trainees mitigated many of the adverse effects associated with the lack of sleep. According to Lieberman et al. (2002) the most notable improvements occurred with visual vigilance, choice reaction time, and alertness in a dose-dependent manner.

Caffeine administered in repeated dosages throughout the day has also been shown to consistently improve performance (Brice & Smith, 2002; Hindmarch, Rigney, Stanley, Quinlan, Rycroft, & Lane, 2000). Moreover, Brice and Smith demonstrated that four 65mg doses of caffeine over a five hour period (1000, 1100, 1200, and 1300 hours) is consistent with one 200mg dose in terms of improving alertness and performance on simple and choice reactive tasks, as well as more complex dual tasks involving tracking and target detection.

Caffeine affects the central nervous system and alters brain functions on both a molecular and cellular level (Daly, 1993). Caffeine achieves this by acting as an antagonist at adenosine receptors. Adenosine receptors are found throughout the body including the heart, gastrointestinal tract, blood, and respiratory system. Adenosine receptors are responsible for the uptake and transmission of adenosine. Adenosine is formed during the breakdown of adenosine triphosphate and is said to be the primary energy source for the majority of the cells in the human body (D'Anci & Kanarek, 2006). Adenosine is considered to be a neuromodulator, which achieves its behavioural effect by "inhibiting the conduction of messages at synapses that use other neurotransmitters such as dopamine and norephinephrine" (D'Anci & Kanarek, 2006. p189). Therefore, caffeine can be described as a drug that cancels out the neuromodulatory effect of adenosine, hence causing an increase in the stimulation of neuronal activity which in turn results in increased heart rate, blood pressure and a reduction in the feeling of fatigue.

Once consumed, the peak effect of caffeine generally occurs within 15 minutes and in some cases may take 2 hours (Arnaud, 1993; D'Anci & Kanarek, 2006). The half-life of caffeine varies among individuals, and is about 3 to 7 hours in healthy adults (D'Anci & Kanarek, 2006). In regular caffeine users, the positive stimulant effects of caffeine can be reversed in the short term if the use of the drug is ceased. Mild withdrawal symptoms of caffeine can include headaches, irritability, mental confusion, nervousness, reduction in energy, and fatigue (D'Anci & Kanarek, 2006; Daly, 1993). Typically, these symptoms begin 12 to 24 hours after the last administration of the drug (Dews, O'Broem, & Bergman, 2002). According to Smit and Rogers, (2000) studies that examine the effects of caffeine on performance, where participants are required to abstain from consuming caffeine for an excess of 12 hours prior to the research, may not fully be aware if the results obtained were due to the effects of caffeine, or a reversal of the negative consequences of caffeine withdrawal.

The purpose of the current study was to examine the impact of caffeine on pilots' performance under conditions that reflected as much as possible, those commonly experienced by pilots. Therefore, only caffeine in dosages equivalent to that typically consumed on the flight deck was investigated (between one and three cups). Furthermore, since anecdotal evidence suggests that pilots tend to consume caffeine directly prior to a crucial phase of flight such as at the top of descent, the effects of caffeine was investigated within a time frame reflective of this environment (between 20 and 30 minutes from touchdown). Since caffeine withdrawal has also been identified as a factor that impacts on the results of caffeine based studies, all participants were asked to abstain from consuming caffeine products for a period of six hours prior to the research. In addition, the conditions surrounding the experiment were controlled, as much as possible, to ensure the pilot participants were not sleep deprived or fatigued. Finally, as part of the recruitment process, and solely for ethical reasons, all potential participants were informed prior to the study that the research was concerned with the effects of caffeine on pilots' performance. While providing participants information about the purpose of the study is not unique to this research (see Kamimore et al., 2005; Smit & Rogers, 2000; Lyvers et al., 2004; Tucha et al., 2006), it is important to acknowledge that this may have influenced participants, resulting in a 'placebo effect'. Nevertheless, the researchers viewed the potential risk of this occurring to be significantly less than the risk associated with administering a drug (i.e., irregular heartbeats (arrhythmia), increase blood pressure, respiratory problems, renal and nervous system problems (Daly, 1993; D'Anci & Kanarek, 2006)) albeit legal, to unsuspecting participants.

Employing a between-subjects repeated measures experimental design, pilots were asked to fly two simulated Instrument Landings Systems (ILS) approaches with the administration of caffeine occurring between the two flights. Data relating to pilots' performance in terms of mean deviation from the glide path both horizontally and vertically were calculated and then compared between the two flights.

Method

Participants

Thirty participants were recruited from the University of New South Wales Aviation flight training school and various other flight training schools located at Bankstown airport. All participants were required to hold a current Class 1 Aviation Medical Certificate, indicating they were medically fit for flying. The participants were randomly divided into three groups (0mg/kg, 1mg/kg, & 3mg/kg). The mean age was 23.13 (SD = 4.21) years and the mean total flight experience was 704.53 (SD = 1125.85) and the mean total instrument flying experience was 47.67 (SD = 108.43). In order to determine if there were any differences between the three groups in terms of age or flight experience, a series of univariate analyses of variance were conducted. With alpha set a .05, the results of a univariate analysis of variance failed to reveal any statistically significant differences between groups in terms of age $F(2,27) = .065$, $p = .937$, $\eta^2 = .005$, total hours flying experience $F(2, 27) = .095$, $p = .910$, $\eta^2 = .007$, and total instrument flying experience $F(2, 27) = .155$, $p = .857$, $\eta^2 = .011$. As a result, it can be concluded that the three groups (0mg/kg, 1mg/kg, and 3mg/kg) were not significantly different in terms of the age, mean flying experience, and mean instrument flying experience.

Design

The experiment was a single blind, between-subjects repeated measures design. The aim of the experiment was to examine pilots' performance (psychomotor and cognitive performance) in response to low caffeine dosages while operating a computer based flight simulator. The study comprised one independent variable, with three levels (0mg/kg, 1mg/kg, and 3mg/kg of caffeine). The dependant variables were the horizontal and vertical deviations from the prescribed approach path for runway 34 right into Sydney (Kingsford Smith) International for the baseline and post-treatment flights (see Figure 1).

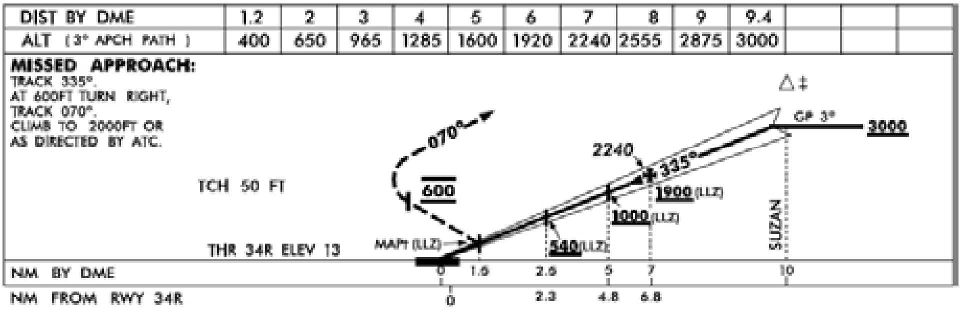

Figure 1. Prescribed ILS approach for runway 34R into Sydney International, Australia (Airservices Australia, 2005).

Participants' horizontal precession (deviation from localiser) on the instrument landing system was calculated by analysing flight data obtained by X-planes data-out feature. Similar to the horizontal precision, vertical precision (deviation from glide slope) was calculated using absolute numerical values obtained from the data analysis process. A mean absolute score for each dependent variable was then calculated, and was said to represent the overall performance of the pilot.

Apparatus and Stimulus

The material comprised two personal computers, one nineteen inch liquid crystal display monitor, one ceiling mounted projector, with a Techniques 2 x 2 meter projector screen, and a Personal Computer Aviation Training Device (PCATD) with Cirrus rudder pedals. The flight simulator software comprised X-Plane 8.4TM developed by Laminar Research Corporation, while the PCATD was manufactured by Precision Flight Controls. Other materials comprised of an information sheet, consent form, demographic questionnaire, personal weight scales, Zuckerman's Sensation Seeking scale, Hunter Risk Perception scale 1 and 2, pharmaceutical grade caffeine, and lemon juice.

A flight data recorder, which is a function of the X-Plane software, was used to record the input from the pilot and the position of the aircraft. Nine specific data points were saved every one-fifth of a second and included: (a) time elapsed, (b) throttle, (c) pitch, roll, heading, (d) latitude, longitude, altitude, (e) distance travelled (f) height above ground level (g) height above mean sea level, (h) ILS Nav 1 Horizontal deviation, and (i) ILS Nav 1 Vertical deviation. Data obtained relating to the Horizontal deviation, pilots' displacement left or right from the runway centre line was measured in feet, while vertical deviation, pilots' displacement above and below the glide path was measured in degrees.

Procedure

Participants were initially weighed and then asked to complete pre-experiment demographics and consent forms. Those participants who indicated that they did not abstain from caffeine consumption for a period of 6 hours prior to the experiment as directed, were excluded from the study (2 participants excluded). Participants were then asked to fly two simulated ILS approaches into Sydney International for runway 34R. Each flight took approximately ten minutes to complete. Between the two flights, and depending on which group participants were assigned, they were asked to consume a lemon based solution containing either, zero, one or three milligrams of caffeine per kilogram of body weight. Following consumption of the lemon based solution, participants were provided a distracter task that took approximately 30 minutes and involved completing Zuckerman's Sensation Seeking scale and Hunter's Risk Perception scale 1 and 2. The purpose of the distracter task was to allow sufficient time for the caffeine administered to be absorbed. Finally, at the conclusion of the second flight, participants were offered a glass of water to counter the possible dehydration effect of caffeine, debriefed, and thanked for their participation.

Results

The main aim of the study was to examine the effect of caffeine at low doses on pilots' performance (combination of cognitive and psychomotor). This involved measuring and comparing deviations, both horizontally and vertically from the glide path during the two ILS approaches. This was achieved by transferring the data obtained from X-Plane directly to Statistical Package for the Social Sciences, version 12.

The effects of prior sleep

Prior to analysing the results of each test flight in relation to the main dependent variable, it was important to establish first, that the results being examined were not subject to any external influences such as the quantity of sleep prior to the testing phase. Since this has been previously identified as a factor that influences cognitive performance, all participants were reminded the day prior to the experiment to maintain as much as possible normal sleeping patterns. Like most instructions, rules, or regulations, their sheer presence does not guarantee compliance. Therefore, a univariate analysis of variance was employed to determine whether differences existed between groups based on individual's response to a question regarding the quantity of sleep acquired the night prior to testing. The results revealed a main effect for group (0mg/kg, 1mg/kg & 3mg/kg) $F(2, 27) = 6.87$, $p = .004$, $\eta^2 = .34$. A Fisher's Least Significant Difference (LSD) post hoc test revealed that the significant difference lie between the 1mg/kg group (7.95, $SD = 1.46$) and the 3mg/kg group (5.80, $SD = 2.50$) and the 0mg/kg group (8.20, $SD = 9.20$) and the 3mg/kg group (5.80, $SD = 2.50$). These results suggest that the quantity of sleep participants had varied, prior to the experiment, between groups. Specifically, the participants in the 3mg/kg group had, on average less sleep prior to the study than the participants in either of the placebo or 1mg/kg group. As a result, sleep was included as a covariate in all analyses.

Horizontal and Vertical Precision

The main aim of the current experiment was to examine the effect of caffeine on pilot performance, in terms of improvements in deviations both horizontally and vertically from the glide path. As a result, data obtained from the two flights (pre/ post) were analysed for the 30 participants using a repeated measures analysis of variance, with caffeine as the between-subjects factor and sleep as a covariate. The ANOVA test assumptions were satisfactory. Using an alpha level of .05, the results failed to reveal a statistical significant difference between group and mean horizontal deviation $F(2, 26) = .52$, $p = .60$, $\eta^2 = .04$; and between group and mean vertical deviation $F(2, 26) = .26$, $p = .77$, $\eta^2 = .02$. These results suggest that there were no differences between group and pilot performance. In contrast, the results revealed a main effect for test session (pre/post) for both horizontal deviation $F(1, 26) = 10.22$, $p = .004$, $\eta^2 = .28$; and vertical deviation $F(1, 26) = 7.89$, $p = .009$, $\eta^2 = .23$. These results suggest a learning effect, where all groups improved from the first to the second flight. Finally, the results revealed an interaction between test session (pre/post) and sleep for both horizontal deviation $F(1, 26) = 5.64$, $p = .02$, $\eta^2 = .18$ (see Figure 2); and vertical deviation $F(1, 26) = 5.54$, $p = .03$, $\eta^2 = .18$ (see Figure 3). In order to determine the precise nature of the interactions, a series of paired repeated measures analyses were conducted on each dependent variable with sleep as the covariate. The results revealed one interaction for horizontal deviation and two interactions for vertical deviation. All interactions involved the 3mg/kg group. Specifically with the horizontal deviation, the sole interaction was evident between test session (pre/post) and sleep for the 1mg/kg and 3mg/kg group $F(1, 17) = 20.89$, $p = .0001$, $\eta^2 = .55$, while with the vertical deviation, an interaction was evident between the placebo and 3mg/kg group $F(1, 17) = 4.59$, $p = .047$, $\eta^2 = .21$ and the 1mg/kg and 3mg/kg group $F(1, 17) = 7.45$, $p = .014$, $\eta^2 = .31$. These results suggest that caffeine had the greatest effect on those pilots who slept the least in the past 24 hours.

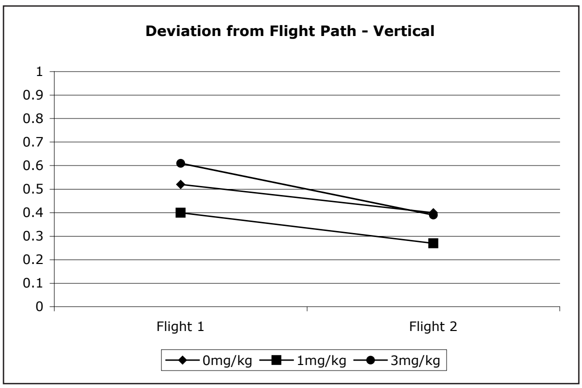

Figure 2. Mean horizontal deviation from flight path between flight one and two distributed across group.

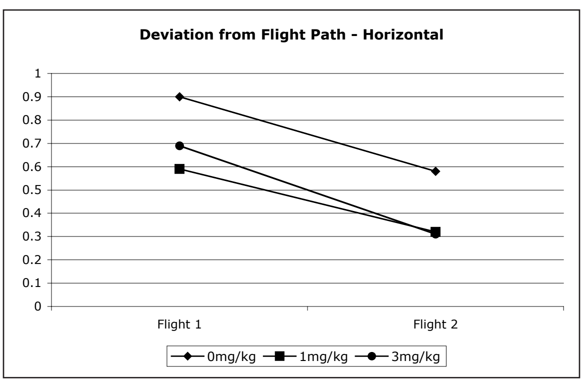

Figure 3. Mean vertical deviation from flight path between flight one and two distributed across group.

Finally, in order to ensure that participant's performance was not biased by their ability to operate the simulator, due to the sensitivity of the flight controls, a univariate analysis of variance was conducted between groups in terms of mean absolute roll over a 2nm segment of flight, during the initial flight. With alpha set at .05, the results failed to reveal a statistical significant difference between group $F(2, 27) = .98$, $p = .39$, $\eta^2 = .07$. This suggests that all group members experienced a similar level of control sensitivity.

Discussion

The primary aim of the present study was to examine the effects of low dose caffeine consumption on pilots' flying performance, under conditions which reflected as much as possible, those normally experienced (30 minutes post consumption during a crucial phase of flight). Two simulated flights were undertaken, where in both flights pilots were asked to complete an ILS approach into Sydney International on runway 34R. Depending on the group assigned, a placebo, 1mg/kg, or 3mg/kg of caffeine was administered between the two flights and pilots' performance, in terms of mean deviation from glide path horizontally and vertically was compared and analysed. It was hypothesised that caffeine would have a dose-dependent effect on pilots' performance.

The results failed to support the hypothesis. An inspection of the results revealed that irrespective of the group assigned, pilots equally improved from the first to the second flight, suggesting a learning effect. This result suggests that caffeine at low doses, equivalent to 1mg/kg and 3mg/kg has no measurable effect on pilots' performance during a simulated ILS approach.

In contrast to the results pertaining to differences between groups, a significant interaction was evident between performance (horizontally and vertically) and sleep. A closer examination of the data revealed that those participants who experienced the least amount of sleep, and hence improved the most, were overrepresented in the 3mg/kg group. Nonetheless, this result suggests that caffeine in low doses has its most profound effect when pilots are experiencing fatigue or sleep deprivation.

The results in part, support the anecdotal evidence derived from the aviation industry relating to the use of caffeine in enhancing pilots' performance. Specifically, it appears that the benefits derived from caffeine in low dosages, relate more to the cognitive state of the individual, in terms of level of alertness or fatigue opposed to the quantity of caffeine consumed.

While this result is interesting, and may account in part for the variability in results from other low dose caffeine studies (see Tucha et al., 2006; Gillingham et al., 2003), future research needs to investigate the impact of caffeine in low dosages on fatigued or sleep-deprived individuals to accurately determine its full effect.

Similarly, the converse of this may also be true, in that caffeine in low dosages may only noticeable enhance performance in well-rested individuals when engaged in a task that is considered highly cognitively demanding. While Snel, Lorist, and Tieges, (2004) and Tucha et al., (2006) have found evidence of this with caffeine in moderate dosages, there appears to be limited research examining its effect in dosages more akin to the present research. As a result, future research should examine the effects of caffeine at low dosages, with well-rested individuals on tasks which are considered highly demanding.

Limitations

The results of this study should be interpreted with the presence of certain limitations. Specifically, in the present study it was assumed that a direct relationship existed between quantity of sleep and cognitive preparedness. While evidence in support of this can be derived from Kohler et al., (2006) Kamimori et al., (2005) and Lieberman et al., (2002) future research should consider employing an objective measure to determine this relationship. Similarly, it would also be prudent to investigate the effects of low dose caffeine on fatigue opposed to sleepiness in isolation, as research has indicated that both the effects and countermeasures for these two conditions are very different (Philip et al., 2005). Finally, and while there is no evidence to suggest that the nature of the experimental design (single-blind) adversely impacted on the research, future research should nonetheless consider employing a double-blind experimental design to reduce the potential of any researcher bias.

Conclusion

In summary, caffeine has been cited as a coping mechanism to help manage fatigue and improve performance (Fredholm et al., 1999). On the flight deck, caffeine is employed to alleviate some of the symptoms associated with sleep loss, fatigue, a busy work schedule, or just to improve pilot performance (Petrie, & Dawson, 1997; Caldwell, 1997). The results of the present study suggest that caffeine in low dosages only appears to be an effective mechanism to achieve these performance enhancements when pilots are fatigued from lack of sleep. While the results positively reflect the short-term benefits of caffeine in low dosages with sleep deprived individuals, from an operational perspective, alternates such as increasing sleep time and reducing exertion prior to duty, planning energy expenditure, and employing active coping strategies while on duty, as prescribed by Petrie and Dawson, (1997) and Petrie, Powell, and Broadbent, (2004) may be more effective performance enhances than relying on caffeine alone in the long-term.

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Conflict Management Strategies in the Flight Training Environment

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Abstract

Hazardous attitudes are a part of aviation. Interpersonal conflicts are part of the human experience. Thus, flight instructors and student pilots will likely experience conflict due to hazardous attitudes on a regular basis. Flight instructors practicing avoidance do not help students recognize and overcome their hazardous attitudes. Accommodating flight instructors can find themselves deferring to inappropriate student pilot behavior. Flight instructors with a competitive style of conflict management can intervene in a decisive, forceful manner in the interests of safety. A compromising instructor can inadvertently send the wrong message to a student in regards to the aeronautical decision-making process. The collaborative instructor spends as much time and energy as needed to work with the student pilot until any flight training issues associated with hazardous attitudes are resolved to the mutual satisfaction of both.

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This study investigates how interpersonal conflict resolution strategies can be applied in the flight school environment. More specifically, this paper examines the positive and/or negative flight training consequences that particular conflict resolution styles may have on student pilots with hazardous attitudes. This research can be used by aviation educators and flight instructors to understand, formulate, and apply conflict resolution strategies in both the classroom and the cockpit. Our overall goal is to show how these conflict management styles can be used to promote safer and more productive aviation education and flight training environments.

Whether we like it or not, whether we care to admit it or not, hazardous attitudes are a part of aviation (Jensen, 1995; Kern, 1998; and, Fallucco, 2002). For example, where would the Wright Brothers be without a certain amount of antiauthority? Without some invulnerability, would Lindbergh have been willing to cross the Atlantic? Who would have been the first to break the sound barrier if Yeager did not have a little bit of macho? Unfortunately, the cost to the aviation community for these hazardous attitudes usually exceeds any potential benefit. Over the years, hazardous attitudes have been a contributing factor in far too many aircraft accidents and fatalities (Trollip & Jensen, 1991; Krause, 1996; and Wetmore & Lu, 2006).

In many respects, hazardous attitudes are as much a part of the flight-training environment as is the weather (FAA, 1999). For example, students depend upon their flight instructors to learn how to use the flight controls to compensate for crosswinds during landing. Those same students also depend upon their instructors to learn how to recognize and compensate for hazardous attitudes (FAA, 2002a; FAA, 2002b; FAA, 2002c; and, FAA, 2004). Which would be more dangerous: a student pilot who cannot perform a crosswind landing, or a student pilot who never learns how to recognize and control their hazardous attitudes?

What do hazardous attitudes have to do with interpersonal conflict? It is inevitable that all of us will be involved in interpersonal conflicts at one time or another because of the countless number of people who flow in and out of our lives on a daily basis (Wilmot & Hocker, 2001). Conflict is a part of the human experience (Bolton, 1979). It is the rare individual who goes through life without having to deal with interpersonal conflict.

Interpersonal conflict is not necessarily a bad thing for a group of people or an organization (Lulofs & Cahn, 2000). Obviously, when handled poorly, conflict can be very destructive. When managed properly, conflict can be the genesis for creative problem solving within a group. By utilizing a carefully thought out productive resolution strategy, conflict can be a beneficial innovative force within an organization (Moore, 2003).

Hazardous attitudes and conflict resolution come together in the flight-training environment. Student pilots are probably going to evidence hazardous attitudes to one degree or another (FAA, 1999). Consequently, their certified flight instructors (CFI) are going to have to deal with those hazardous attitudes. Inevitably, there is bound to be conflict between the student and instructor as they work through these issues. A beneficial and productive resolution of these hazardous-attitude-based conflicts should result in a pilot who is better able to assess risk and make good aeronautical decisions. On the other hand, a harmful and destructive resolution of these hazardous-attitude-based conflicts could result in a pilot who still takes unnecessary risks and lacks good aeronautical decision-making (ADM) skills. In addition, unresolved conflicts can have a detrimental affect on the implementation of standardization and innovation in a flight school (Wetmore, Lu & Bos, in-press).

Literature Review

Hazardous Attitudes

Hazardous attitudes are a contributing factor in 86% of general aviation accidents that involved a fatality (Wetmore & Lu, 2006). This study established that hazardous attitudes correlate to greater risk-taking, poorer aeronautical decisions, increased pilot error, and decreased utilization of cockpit resources. Wetmore & Lu (2005a) found that pilot age does not correlate to displayed hazardous attitudes. The acquisition of advanced pilot certificates and the accumulation of flight experience correlate to a reduction in displayed hazardous attitudes (Wetmore & Lu, 2005b). Finally, certain educational pedagogies (philosophies, ideologies, and theories) were found to have either ameliorating or exacerbating affects on student pilots with hazardous attitudes depending on the specific attitude and pedagogy (Wetmore, Lu & Caldwell, 2007).

The hazardous attitudes of antiauthority, impulsivity, invulnerability, macho, and resignation can adversely affect a pilot's judgment and thus impact the safety of a flight (FAA, 1991). A list of the hazardous attitudes along with pilot-type descriptors is shown in Table 1.

Table 1
Hazardous Attitudes & Pilot Type Descriptors

Hazardous Attitude	Pilot-type Descriptors
Antiauthority	Violates rules and regulations Argues with CFI Disobeys ATC Defiant Contrary Rebellious
Impulsivity	Makes decisions without thinking Fails to plan ahead Reckless Rash Unpredictable Careless

Invulnerability	Unaware of danger Oblivious to risk Unrealistic Irresponsible Fear-less Blind-sighted
Macho	Tries to impress others Overly aggressive Bold Brash Show-off Braggart
Resignation	Gives up easily Too reliant upon others Submits passively Lacks confidence Insecure Indecisive

Wiener & Nagel (1988) found that hazardous attitudes are one of the most important aspects of human factors as applied to the aeronautical decision making process. A hazardous attitude can be defined as the personal motivational predisposition that affects a pilot's ability to make good decisions and sound judgments while flying an airplane (FAA, 1999). The individual personality characteristics and attitudes can have a profound impact on a pilot's behavior (Hunter, 2005) and consequently on their decision-making skills (Murray, 1999). The reduction of hazardous attitudes relies primarily upon the identification of a thought as hazardous and the application of an appropriate antidote (FAA, 1991).

Antiauthority. People with antiauthority reject the authority of public agencies and the opinions of recognized experts (see Table 1). Antiauthority is an attitude found in people who do not like being told what to do (FAA, 1999). It is an attitude where people are resentful towards rules, regulations, and procedures (Wetmore, Lu & Caldwell, 2007). They proceed with an inadvisable course of action despite the rules and training (FAA, 2001). They typically reject the rules and regulations of the Federal Aviation Administration (FAA), the directions and instructions given by air traffic control, and the advice of their own flight instructor.

Impulsivity. Pilots with impulsivity act on sudden, spontaneous urges (see Table 1). They feel the need to take immediate action (FAA, 1999). They act recklessly without thinking about the consequences (Wetmore, Lu & Caldwell, 2007). These pilots do not take the time to consider all options and to select the best course of action (FAA, 2001).

Invulnerability. The invulnerable pilot believes that they are incapable of being injured, damaged, or wounded (see Table 1). They think that accidents happen to other people and not to them (FAA, 2001). They are unrealistic pilots who refuse to admit the possibility that they could ever be involved in an accident or an incident (Wetmore, Lu & Caldwell, 2007). Pilots who think this way are more likely to take unnecessary risks (FAA, 1999).

Macho. Macho is an exaggerated sense of masculinity that stresses attributes such as courage, virility, and aggressiveness (see Table 1). Pilots with macho are often trying to impress other people (FAA, 1999). Macho pilots are bold pilots who have something to prove to themselves or others (Wetmore, Lu & Caldwell, 2007). They are often trying to prove that they are better than other pilots (FAA, 2001).

Resignation. Resignation in aviation is the act of submitting passively to a critical or dangerous flight condition (see Table 1). Pilots with resignation do not see themselves as being able to make a difference in the outcome of a flight (FAA, 1999). A resigned pilot is one who gives up control of the aircraft in a difficult situation (FAA, 2001). They feel helpless and prefer to relinquish control of the flight's outcome to someone else (Wetmore, Lu & Caldwell, 2007).

Conflict Resolution Strategies

Individuals involved in a conflict tend to exhibit certain behaviors and employ particular styles and tactics (Lulofs & Cahn, 2000; and, Wilmot & Hocker, 2001). A summation of these conflict management styles along with some of their major attributes and characteristics is presented in Table 2.

Table 2
Conflict Management Styles & Characteristics

Conflict Management Style	Characteristics & Attributes
Avoidance	Low concern for others Low concern for self Hide behind policies and procedures Lack of commitment Evasive Withdrawn
Accommodation	High concern for others Low concern for self Obliging Acquiescent Gives in easily Reluctant to take responsibility
Competition	Low concern for others High concern for self Domineering Aggressive Selfish Argumentative

Compromise	Moderate concern for others Moderate concern for self Cooperative Conciliatory Willing to negotiate Willing to make concessions
Collaboration	High concern for others High concern for self Problem-solver Respectful Trusting Dedicated to the best solution

Avoidance. Some individuals, when faced with a potential conflict, prefer not to get involved (Lulofs & Cahn, 2000). They would just as soon avoid the environment that created the conflict. They tend to either withdraw from the situation mentally or physically by keeping silent or by being absent (see Table 2). People who practice avoidance are hoping that the problem will go away without the unpleasantness of a confrontation. The benefits of this strategy are that sometimes the forces, which induced the conflict, disappear and the conflict is resolved without any action on the part of the participants (Wilmot & Hocker, 2001). The trouble with this strategy is that it does nothing to address the causes, which initiated the conflict and often leads to criticism, more avoidance, and possibly an escalation of the conflict.

Accommodation. When it comes to conflict, accommodating people (see Table 2) usually try to smooth over the difficulty by acquiescing to the wishes and/or desires of other people (Lulofs & Cahn, 2000). This can be a successful conflict management tactic when the issues at hand are relatively unimportant to the individual. However, there are disadvantages to overusing this tactic. Prolonged use of accommodation can lead to feelings of resentment on the part of the accommodator and to domineering behavior on the part of the recipient of the accommodations (Wilmot & Hocker, 2001).

Competition. Competitive people often try to dominate a conflict and force their own personal solution to the problem upon the other participants by being aggressive, selfish, and argumentative (Lulofs & Cahn, 2000). This can be an invaluable resolution strategy when the situation calls for quick, decisive action (Wilmot & Hocker, 2001). The downside to this type of conflict style is that the person who is subjected to it often feels as if they have been left out of the decision-making process and that their role in the relationship has been diminished (see Table 2).

Compromise. For those individuals who prefer workable solutions to conflict resolution, compromise is usually the strategy of choice (see Table 2). Compromisers search for solutions that lead to the least amount of dissatisfaction among the participants (Lulofs & Cahn, 2000). The upside to this give-and-take style of conflict resolution is that none of the participations are completely dissatisfied with the outcome. The downside to compromise is that it has the potential to eliminate the possibility of employing the optimal solution to a problem (Wilmot & Hocker, 2001). It also prevents the use of creative and imaginative solutions in certain situations.

Collaboration. Collaborators use critical-thinking and problem-solving skills to arrive at creative, integrative, and mutually agreeable solutions to a problem (Lulofs & Cahn, 2000). The benefit of this style is that in a perfect collaboration, all of the participants agree that their collective solution to the problem is the best solution (see Table 2). A disadvantage of collaboration is that not every issue requires a major investment of time, effort, and emotional commitment in order to achieve a successful resolution (Wilmot & Hocker, 2001). Another area of concern is that certain people tend to take advantage of the collaboration process to manipulate the other participants unjustly.

Research Questions

The research problem addressed by this paper is how case-based reasoning (CBR) and flight training scenarios (FTS) can be used to associate hazardous attitudes, qualitatively, to conflict resolution strategies in the flight-training environment. The research questions, which address this phenomenon, are listed below:

1. How often are specific hazardous attitudes a contributing factor in general aviation accidents that involved a fatality?
2. What are representative FTS in the flight-training environment for a hazardous attitude derived interpersonal conflict between a flight instructor and a student?
3. How can the theories of conflict management be applied to beneficial effect by a flight instructor when training a student pilot with hazardous attitudes?

Research Methods

Case-based reasoning

Cases from the National Transportation Safety Board (NTSB) aviation accident database (NTSB, n.d.) were used to determine the frequency of occurrence for specific hazardous attitudes in general aviation accidents that involved a fatality. Our CBR is that if hazardous attitudes are present and measurable in the accident data, then it is likely that those same attitudes were probably present during flight training.

A random number generator from Norusis (2004) was used to randomly select 50 general aviation accidents that involved a fatality from the NTSB aviation accident databases. The NTSB case numbers for each accident are listed in Appendix A. Factual Reports for each of the 50 accidents was downloaded from the NTSB website. The years 1997 to 2002 were selected because the vast majority of the Factual Reports had been upgraded from Preliminary to Final status. These reports were analyzed for evidence of hazardous attitudes.

It is important to note that this study relied upon the NTSB Factual Reports and not the Probable Cause Reports. The Factual Reports often contain pertinent and relevant information concerning the pilot's behaviors and actions that are not listed in the Probable Cause Reports.

The first step of our analysis was to use the Factual Reports to assemble a chain of events for each accident. The researchers had to agree on what constituted an event and the sequence of events. Next, the Factual Reports were examined for evidence of the pilot's behaviors or actions indicative of hazardous attitudes. Again, the researchers had to agree on what constituted a pilot behavior and/or action and if that behavior and/or action was reflective of a hazardous attitude. In addition, there had to be corroborating evidence in the Factual Report for each hazardous attitude determination.

Flight Training Scenarios

The FTS described below are fictionalized accounts based on actual events witnessed by the authors in the flight-training environment. It should be noted that these scenarios have not been subjected to any scientific methodology or scrutiny. These scenarios are presented so the reader can more fully understand how hazardous attitudes can be the genesis of conflict during flight training. In no way should these scenarios be considered inclusive or exclusive. The reader should be aware that these scenarios are just illustrative representations of the almost unlimited number of ways that hazardous attitudes can contribute to interpersonal conflicts between flight instructors and student pilots.

Validity & Reliability

The researchers believe that the qualitative phenomenological data in this study can be interpreted accurately and with confidence, thus establishing good internal validity (Wiersma & Jurs, 2005). The interpretations and conclusions of this investigation should be applicable to most flight-training environments resulting in good external validity (Creswell, 2003).

Internal reliability for this study was established by using consistent data collection methods and having all of the researchers agree on data analysis, results, interpretations, and conclusions (Wiersma & Jurs, 2005). The authors did not uncover any similar aviation related studies in the literature. Without similar studies for comparison, it is difficult to evaluate the external reliability of this study. However, the researchers believe that enough methodology procedures and descriptions have been provided for other investigators to replicate this study.

Genesis of Conflict

Antiauthority

Case-based reasoning. Antiauthority was displayed by 46% of the accident pilots in this study (see Figure 1). The most common evidence for antiauthority was a disregard for Federal Aviation Regulations (FAR).

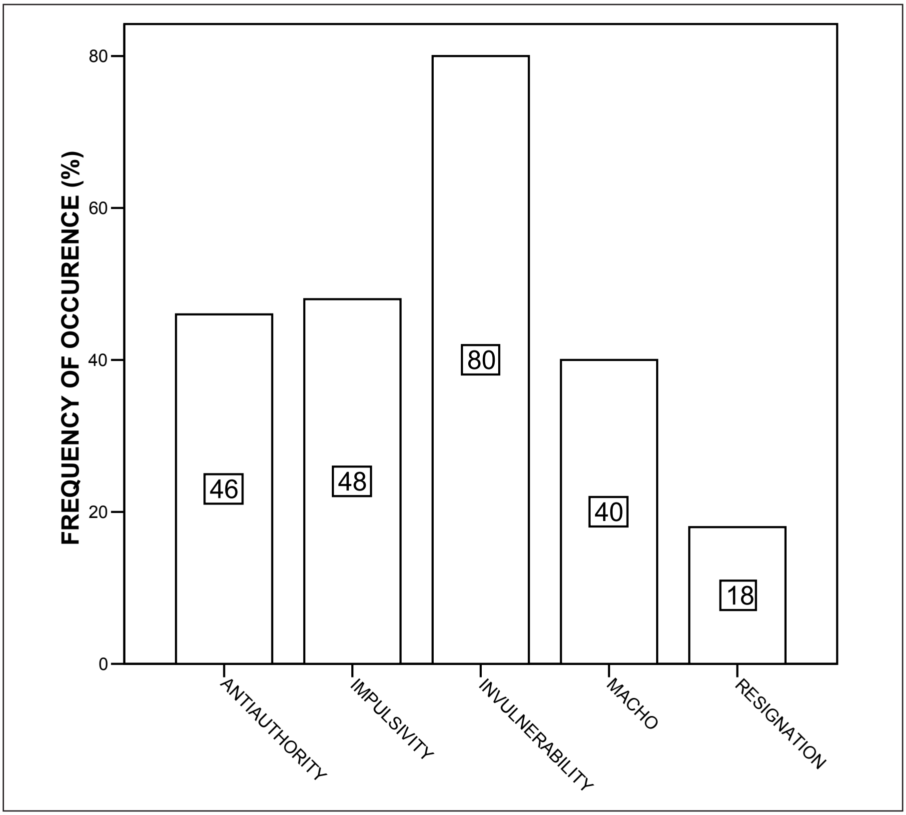

Figure 1. Hazardous Attitude Frequency of Occurrence in General Aviation Accidents that involved a Fatality

Flight training scenario. A student pilot with antiauthority is not inclined to follow all of the rules and regulations, which govern their flight training. In addition, they are not disposed towards following the advice of their flight instructors. This sets the stage for conflict as shown in the scenario below:

> A private pilot student with excellent skills gets signed off by her CFI for a solo cross-country flight. The student decides that it would be fun to buzz the sorority house where she and her friends live. The student knows that this is a violation of FAR 91.119(b), which prohibits flight below 1,000 feet over congested areas (FAA, 2006). After the flight, her CFI finds out about the buzzing incident and confronts the student. Understandably, the CFI is upset with the student's willful violation of the regulations. The student cannot understand why the CFI is making such a big deal over something that did not harm anybody.

Impulsivity

Case-based reasoning. Impulsivity was exhibited by 48% of the accident pilots in the inquiry (see Figure 1). The most common evidence for impulsivity was the failure of the pilot to perform required pre-flight actions.

Flight training scenario. A student pilot with impulsivity is prone to act without thinking about the consequences of their action. They often hurry through, or neglect to perform, required piloting responsibilities. This reckless behavior can lead to conflict as described in the example below:

> A commercial student pilot is getting ready to go on a dual, nighttime cross-country flight with their CFI. The student is in a hurry and impulsively launches the flight without calling the Flight Service Station (FSS) and checking for Notices to Airmen (NOTAMS) relevant to the route of flight. Subsequently, the student and the instructor fly through a Temporary Flight Restriction (TFR) and get in trouble with the FAA. The CFI is distressed because the student did not perform the required pre-flight actions. The student is angry because he feels that the CFI should also bear some of the responsibility for the incident.

Invulnerability

Case-based reasoning. Invulnerability was displayed by 80% of the accident pilots in this study (see Figure 1). The most frequent evidence for impulsivity was a general disregard for safety during the course of the flight as evidenced by risk-taking behavior on the part of the pilot.

Flight training scenario. A student pilot with invulnerability does not believe that anything bad is ever going to happen to him/her. They have an unrealistic expectation for success in dangerous or risky situations. This lack of caution can lead to conflict as shown in the scenario below:

> An instrument student pilot and the instructor are performing a Very High Frequency Omni-directional Range (VOR) approach in Instrument Meteorological Conditions (IMC). The student is flying the airplane. The student, because of his feelings of invulnerability, elects to descend below the Minimum Descent Altitude (MDA) upon arriving at the Missed Approach Point (MAP). As soon as the CFI realizes the student has intentionally gone below the MDA, the CFI abruptly seizes control of the airplane and executes the missed approach procedure. The student is aggravated because his ego has been bruised by the CFI's actions. The CFI is infuriated because descending below the MDA is extremely dangerous.

Macho

Case-based reasoning. A macho attitude was exhibited by 40% of the accident pilots in this investigation (see Figure 1). The most common evidence for macho was an attempt by the pilot to try to impress passengers, or an audience on the ground, with their supposedly superior flying skills.

Flight training scenario. A student pilot with macho has something to prove to themselves or others. They compensate for feelings of inferiority by overstressing masculine attributes such as courage and aggressiveness. It should be noted that a macho attitude is not necessarily gender specific. This overly bold behavior can lead to instructor/student conflict as shown in the example below:

> A commercial pilot in training for a CFI certificate is flying with a new instructor for the first time. The student wants to impress this new instructor

> with his flying skills. During a power-on stall demonstration, without warning, the student intentionally spins the airplane. This particular training aircraft is neither approved nor certificated for intentional spins. The CFI is extremely upset because spinning this type of airplane was dangerous and unnecessary. The student is disgruntled because he believes that his CFI is over-reacting to the incident.

Resignation

Case-based reasoning. Resignation was displayed by 18% of the accident pilots in this study (see Figure 1). The most common evidence for resignation was a pilot who allowed someone else to make the aeronautical decisions for them.

Flight training scenario. Students with resignation are prone to giving up in difficult situations. A more subtle form of resignation occurs when a student pilot relinquishes control of the decision-making process concerning a flight to someone else. This passive and indecisive type of behavior can lead to conflict in the flight-training environment as described in the following scenario:

> A commercial multi-engine student pilot has planned an instrument cross-country flight with her instructor. The weather is IMC along the route of flight and there are thunderstorms across the region. The student has enough experience flying in weather to know that she does not want to execute this particular flight plan. However, the flight instructor really wants to go and applies pressure on the student to accept the flight. The student, against her better judgment, gives up control of the situation and agrees to go. During the flight, they are caught in an embedded thunderstorm. The student is badly frightened by the experience and very upset with the instructor for pressuring her into taking the flight.

Conflict Resolution Strategies in Flight Training

As illustrated in the cases and scenarios described above, flight instructors are probably going to have interpersonal conflicts with their students due to hazardous attitudes. These instructors have two choices. They can be reactive by going from conflict to conflict without any consideration on how to manage those conflicts or they can be proactive by giving the matter some forethought and developing conflict resolution strategies for specific behaviors.

Avoidance

The flight instructor who practices avoidance tends to hide behind the policies of their flight school when it comes to conflict during flight training (see Table 2). They use the standardization of the flight training lesson plans and syllabus as a low-energy and low-commitment method to resolve problems with students. They are not concerned enough about the quality of their flight instruction to search for creative, imaginative, and innovative solutions.

Flight instructors who use avoidance do little to benefit a student pilot with hazardous attitudes (see Table 3). Students should be taught to recognize and be aware of their hazardous attitudes (FAA, 1999) because hazardous attitude problems seldom go away without direction and intervention on the part of the instructor. A flight instructor who avoids the issue does nothing to help the student to recognize and overcome their hazardous attitudes and thus become a safer pilot. Avoidant instructors are usually neither popular nor unpopular in a flight school because they rarely get involved in controversial issues.

Table 3

Conflict Management Styles & Hazardous Attitudes

Student Pilot Hazardous Attitude		Accommodation	Competition	Compromise	Collaboration
Antiauthority	DET	DET	DET	DET	BEN
Impulsivity	DET	DET	BEN	DET	DET
Invulnerability	DET	DET	BEN	DET	BEN
Macho	DET	DET	DET	DET	BEN
Resignation	DET	DET	DET	DET	BEN

BEN: indicates that this flight instructor conflict management style could potentially be beneficial for a student pilot with this particular hazardous attitude.

DET: indicates that this flight instructor conflict management style could potentially be detrimental for a student pilot with this particular hazardous attitude.

Accommodation

Flight instructors with an accommodating style are reluctant to take responsibility for the kind of pilots their students are going to be in the future (see Table 2). They may identity a hazardous attitude during training but then acquiesce too easily to the student's explanations or rationalizations for their conduct. Accommodating instructors are generally quite popular in a flight school because they try to find solutions to problems that will gain the support and approval of the students.

It is unlikely that an accommodating style of conflict management on the part of flight instructors will benefit student pilots with hazardous attitudes (see Table 3). Flight instructors are supposed to provide their students with guidance, supervision, and restraint (FAA, 1999). For example, when it comes to violating the rules (antiauthority), a flight instructor has to provide the appropriate guidance and not give-in to the wishes of a student. Alternatively, when a student wants to impress friends by performing a dangerous maneuver (macho), a flight instructor should demonstrate the proper restraint and not use accommodation to facilitate the student's behavior.

Competition

Competitive flight instructors have an aggressive, challenging style of teaching in the cockpit (see Table 2). When these instructors spot a problem with a student's piloting skills, they tend to favor a straightforward approach to correcting the deficiency. When these instructors detect a flaw in a student's behavior, they tend to address the problem in an almost confrontational manner. Some students respond well to this type of style on the part of the instructor. For the most part, however, students are put-off by a competitive instructor. Consequently, competitive instructors often find themselves to be both loved and hated by students in a flight school.

Flight instructors have to find productive methods to counteract hazardous attitudes in their students (FAA, 1999). For students with antiauthority, macho, and resignation, a competitive style on the part of the instructor might only make those attitudes worse. For example, a student pilot with macho is likely to attempt risky and dangerous maneuvers in an attempt to prove to themselves and others how good they are at flying. A competitive instructor might be inclined to contend with this type of student by demonstrating his or her own flying skills. This could inadvertently get both the instructor and the student caught up in cycle of competitive and dangerous flying exploits

Good ADM and judgment skills are adversely affected by hazardous attitudes (FAA, 1991). Thus, certain student behaviors necessitate intervention on the part of the instructor. A competitive style of conflict management can be an effective method of dealing with some student pilot's hazardous attitudes depending upon the student and the situation (see Table 3). In some circumstances, time and safety can be immediate concerns. For example, when a student with impulsivity and/or invulnerability tries to execute a touch and go after a long landing on a short field with obstacles, a flight instructor with a competitive style can intervene in a decisive, forceful manner in the interests of safety. In this situation, the danger cannot be avoided, and a suitable accommodation cannot be made, and there is not enough time for the instructor to attempt collaboration or compromise.

Compromise

Flight instructors who employ a compromising style during training tend to sacrifice enforcement of the Practical Test Standards (PTS) (FAA, 2002a; FAA, 2002b; FAA, 2002c; and, FAA, 2004) in order to promote harmony in the cockpit (see Table 2). They may also make compromises with their students when it comes to safety issues. These instructors believe that if they make concessions during flight training, they will gain the approval of the students. As a result, compromising instructors generally enjoy good reputations in a flight school.

Hazardous attitudes have a detrimental affect on a pilot's ability to make good judgments and good decisions (FAA, 1991). A compromising instructor can inadvertently send the wrong message to a student in regards to this decision-making process. In other words, the instructor may be trying to improve their relationship with a student by compromising on the standards and thus inadvertently reinforce behaviors that are either unsafe, unprofessional, or both. For example, the private pilot practical test standards for a short field landing require that touchdown be made within 200 feet of a specified point on the runway (FAA, 2002a). A student with resignation who cannot meet this standard may feel like they are not a very good pilot and want to give up on the maneuver. A compromising instructor, in order to bolster the student's confidence and self-image, might change the touchdown requirement during training from 200 to 400 feet. In this situation, what has the instructor really taught the student? When it comes to flight safety and professional flight training, there is not a lot of room for compromises in the flight training environment (see Table 3).

Collaboration

Flight instructors that utilize collaboration are dedicated to providing the best possible training to their student pilots. These enthusiastic instructors expend a significant amount of time and energy building trust and earning the respect of their students (see Table 2). What makes these instructors so effective is their willingness to work hard to find the optimal solutions to problems encountered in the flight-training environment. Collaborative instructors try to achieve conflict resolutions that provide the most benefit to their students. Instructors who use this type of conflict management style are generally well liked and well respected in their flight schools by both students and administrators.

Student pilots should be taught to examine their judgments and decision-making process carefully, for any hazardous attitude influences (FAA, 1991). The collaborative instructor spends as much time and energy as needed to work with the student until any flight training issues associated with hazardous attitudes are resolved to the mutual satisfaction of both. For example, take a student pilot with antiauthority who refuses to follow the advice of their instructor. This student could very well have excellent flying skills. However, their behavior adds an unnecessary element of risk to all aspects of their flying. Avoidance, accommodation, competition, and compromise (see Table 3) on the part of the flight instructor will do very little to help this student become a safer pilot. Only by working with the student in a collaborative manner can the instructor get this student to come to the realization and self-awareness that their antiauthority attitude is introducing unnecessary risk to their flying.

If the student suffers from impulsivity, then collaboration might not be an effective style for a flight instructor. Impulsive students are prone to acting without thinking. If this spontaneous behavior poses a threat to the safety of the training flight, there may not be enough time for the instructor to collaborate with the student on a more appropriate course of action. In this situation, it is probably safer for the instructor to intervene immediately.

Recommendations

The authors would like to make the following proposals and recommendations concerning this research:

1. Propose that a new term, Aviation Conflict Management (ACM), be introduced to the lexicon of aviation terminology. ACM is the proper application of conflict resolution management tactics, styles, and strategies in the flight training and cockpit environments.
2. Recommend that aviation educators include ACM in their educational curriculum. ACM subject matter would complement the topics already taught in most collegiate CFI and CRM courses.

3. Recommend that flight instructors include ACM discussions as part of the flight training for all pilot certificates and ratings. ACM training would fit in well with the ADM and CRM training already provided to student pilots.
4. Propose that ACM be incorporated in all FAA PTS. ACM could be added to the list of special emphasis areas in the PTS or ACM subject matter could be included as part of the discussion on CRM.

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Appendix A: NTSB Case Numbers

MIA03LA019	FTW02FA040	MIA01FA028	ATL00FA082
DEN03FA002	MIA01LA212	LAX00FA314	LAX99FA020
SEA02FA175	DEN01FA135	DEN00FA104	FTW99LA007
MIA02FAMS3	FTW01LA152	FTW00FA079	FTW98FA384
MIA02FA162	CHI01FA180	MIA00FA017	CHI98FA299
ANC02FA038	FTW01FA129	FTW99FA211	LAX00FA283
FTW02LA151	DEN01FA096	MIA99FA142	FTW98FA325
LAX02FA134	MIA01FA072	LAX99FA091	ATL98FA060
NYC02FA044	MIA01FA071	LAX99FA036	ATL98LA029
LAX02FA049	NYC01FA040	FTW00FA063	LAX98FA091
ATL98LA032	ATL98FA030	SEA98FA040	ATL97FA115
MIA97FA219	ANC97FAMS1	LAX97FA210	IAD97LA083
SEA97FA120	MIA97FA152		

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Analysis of Aircrews' Weather Decision Confidence as a Function of Distance, Display Agreement, Communication, Leadership, and Experience

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Abstract

NEXRAD and onboard radar displays may produce conflicting weather representations that disrupt team decision-making processes and lower decision-making confidence. This study examined teaming factors such as communication level, leadership style, and differences in flight experience that could influence decision confidence. Twelve commercial pilot-copilot teams reacted to weather information provided by NEXRAD and onboard radar displays while flying a simulated route. However, the agreement between these two sources of weather information varied during the flight. Results showed that aircrews that had similar flight experience and high levels of communication reported higher confidence in their decisions as they approached the weather threat. Also, decision confidence increased as aircrews approached the weather event regardless of changes in display reliability, suggesting a possible escalated commitment bias. These findings may be used to improve crew resource management (CRM) when aircrews are attempting to interpret and respond to advanced weather display information.

Commercial flight crews make several important decisions when interpreting weather information. The quality of these decisions could potentially influence

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flight safety, passenger comfort, fuel consumption, and flight time. Newly developed technologies increase the variety and capabilities of weather information presented to flight crews, yet factors such as conflicting weather representations and weather distance may affect the quality of weather deviation decisions. Many researchers have suggested that participative leadership and increased communications may improve collaborative decision making under such conditions (e.g., Chemers, 2000; Foushee, 1982; Vroom, 2000). More empirical research needs to be conducted to examine the effects of communication and leadership styles on flight crews' ability to accurately interpret and respond to information presented on advanced weather displays.

Graphical Weather Displays

Commercial flight crews traditionally obtain weather related information from a variety of sources. They consult several types of printed reports as well as onboard radar to gather information about turbulence, wind currents, icing, lightning, hail, and precipitation. Based on examinations of one or more of these sources of information, flight crews often make decisions that could potentially affect safety, comfort, and efficiency. Recent technological advances made weather information from ground-based radar sources, such as Next Generation Radar (NEXRAD), available in the cockpit. NEXRAD is a Doppler radar that integrates information about wind and precipitation on a single graphical display. This technology also allows weather information to be updated often, so that pilots can determine past, present, and future weather states, and plan accordingly.

Integrated graphical weather displays such as NEXRAD offer a number of potential advantages. Many researchers have suggested that presenting concurrent weather information from multiple sources may allow flight crews to draw conclusions with minimal cognitive expenditure. For example, the Proximity Compatibility Principle (PCP) suggests that displaying multiple parameters may constitute less of a processing drain on aircrew members (O'Brien & Wickens, 1997). In addition, Wickens (2000) notes that integrated displays may reduce drains on selective attention because multiple sources of weather information that normally compete for flight crews' attention may be viewed concurrently.

In addition to consolidating multiple sources of weather information, integrated graphical weather displays are also capable of presenting and updating weather information in near-real-time. Sherman and Craig (2003) suggest that the reliability of weather information might be improved by presenting it rapidly to the flight crews. In turn, this may also improve flight crews' interpretations of weather trends such as developing or decaying weather patterns (Boyer, Campbell, May, Merwin, & Wickens, 1995). In general, integrated graphical weather displays, such as NEXRAD, may allow pilots to manage risks more effectively (Orasanu, Davison, & Fischer, 2001). In fact, O'Brien and Wickens (1997) have demonstrated that in some circumstances pilots can make better judgments from integrated information than when such information was presented separately.

Despite the many benefits of using integrated graphical weather displays, problems may arise when they are combined with other sources of weather information, such as the aircraft's onboard radar. Lindholm (1999) notes that combining integrated graphical weather information with other displays may result in excessive visual clutter that can cause information to be undetected or misinterpreted over time. Wickens and his colleagues have also noted the implications of excessive visual clutter on performance indices such as workload, errors, and response time (Wickens, Kroft, & Yeh, 2000).

Onboard and NEXRAD radar systems differ with respect to their degree of complexity and capabilities. These differences may produce conflicting weather representations between the two systems. Visual clutter and conflicting weather representations may decrease the reliability of weather information available to flight crews.

An area that has been overlooked by researchers until recently concerns the responsiveness of teams to displayed weather information. Many of the principles governing display design were formulated from research using individual participants. In very few cases, have researchers investigated how teams (for example, a pilot-copilot team) might react to variations in weather display format.

Collaborative Decision Making

Many psychologists today believe that training focused on team interdependence and communication is the best way to prevent disorder and maintain the lines of communication (Sexton & Helmreich, 2000; Wickens, 1995). For example, Foushee's (1982) research regarding cockpit resource management has suggested that flight crews' responsiveness to weather displays is likely to depend on the leadership styles and communication tendencies of the flight crew.

Even though Foushee (1982) and others have pointed out the desirability of effective communication and coordination between members of the flight crew, researchers have typically assessed only individual reactions to cockpit displays. Given the importance of collective decision making in the cockpit (Foushee, 1982), it is important to investigate the impact of integrated graphical weather displays on teamed decision making, particularly when the incoming weather information from different sources is incongruent. Thus, more empirical work is needed to isolate and quantify the effects of social factors such as communication on weather display interpretation, responsiveness, and team decision-making confidence.

Communication among flight crewmembers can vary widely in style and in its effects affects on performance. Effective communication in the cockpit is often determined by the leadership style of the pilot. Therefore, by studying various pilot leadership styles, it may be possible to determine which type of communication works best during situations of disorder and ambiguity, where the potential for human error is greatest. Thus, pilot leadership style may be an essential component in the management of human error (Helmreich, Merritt, & Wilhelm, 1999).

Normative Decision Theory

In the early 1970s, Vroom and Yetton developed Normative Decision Theory (NDT) to characterize participative and autocratic leadership styles (Chemers, 2000). According to this theory, the participative leader promotes two-way communication and allows others to have equal influence in the decision making process. Conversely, the autocratic leadership style involves very little communication between the leader and other team members. Therefore, an autocratic leader makes all of the team decisions without relying on input from other team members (Chemers, 2000).

The NDT states that the effectiveness of each style of leadership is dependent on the situation (Chemers, 2000). Specifically, the theory suggests that the autocratic style is more effective in situations where the tasks are clear and optimal choices are obvious. In these situations, very little communication is needed in the decision making process, allowing the autocratic leader to make quick decisions (Vroom, 2000).

Conversely, the participative style is more effective in an ambiguous environment when the optimal decision is not readily apparent. This style is also more effective when faced with very important decisions (Vroom, 2000). The increased level of two-way communication may help to clarify the situation and improve teamed decision making (Chemers, 2000).

Studies on leadership in the cockpit have indicated that participative leadership may be effective at minimizing the number of errors made in the cockpit (Foushee, 1982; Sexton & Helmreich, 2000). In addition, Nicholas and Penwell (1995) examined the leadership styles of aviators and found that the more effective leaders employed a predominantly participative leadership style and that a strict autocratic style "does not lend itself to effective operation of complex, technical machinery" (Nicholas & Penwell, 1995, p.70).

Although NDT describes the ideal leadership style for a given situation, it does not identify factors that actually determine which style a pilot is likely to adopt. For example, differences in flight experience between Captains and First Officers may dictate the style of leadership and the level of communication, which is employed in the cockpit. Therefore, it is important to examine other theories that consider the role of experience in collaborative decision making.

Naturalistic Decision Making

Naturalistic environments are dynamic task settings that often require high stakes decisions to be made under conditions of time pressure and uncertainty (Orasanu & Connolly, 1993). Because errors in naturalistic settings carry severe consequences, naturalistic decision makers must typically rely on their expertise to rapidly assess the situation and respond accordingly. Hence, naturalistic models are contrasted with analytic approaches, such as Normative Decision Theory, that do not consider the role of domain knowledge in decision-making processes.

Klein's (1989) Recognition-Primed Decision (RPD) model is often used to describe experts' decision-making processes in naturalistic environments. The basic principle of RPD is that experts use their domain knowledge to classify a situation as typical or atypical and then retrieve a potential response from memory that is associated with that particular situation. According to Klein and Crandall (1995), the response is evaluated using mental simulation to enact the resultant sequence of events consciously. If the mental simulation produces an adequate result, the response is adopted. Otherwise, expert decision makers will either reconsider the situation or sequentially evaluate alternate responses until an acceptable mental simulation is produced (Klein & Crandall, 1995).

Klein's RPD model demonstrates the efficacy of experts' decision-making process under conditions of time-pressure and ambiguity. In particular, the RPD model suggests that experts devise a satisficing approach that does not require an exhaustive evaluation of all possible scenarios and their associated responses (Orasanu, 1997). Such an approach allows experts to rely on their domain knowledge to disambiguate the situation and focus on workable options that produce fast results (Dreyfus, 1997; Klein & Crandall, 1995). Conversely, non-experts typically rely on more deliberate decision-making strategies that are aimed at determining an optimal response through an exhaustive search and comparison of alternatives (Dreyfus, 1997; Orasanu, 1997). For example, some normative decision theorists believe that decision makers develop a preliminary set of alternatives and compare each alternative to a particular value structure, such as passenger safety, economy, or comfort (Gardiner & Edwards, 1975). This approach allows non-experts to compensate for their lack of experience by thoroughly analyzing the potential trade-offs for each alternative. However, this approach is less efficient compared to RPD and therefore not ideal (Dreyfus, 1997; Orasanu, 1997).

Previous studies of pilots' weather-related decisions have been successful in correlating pilots' experience (in terms of flight hours) to naturalistic decision-making models such as RPD. For example, some researchers (Driskill et al., 1997; Hunter, Martinussen, & Wiggins, 2003) have found that experienced pilots tended to adopt a non-compensatory strategy that is consistent with RPD when making weather-related decisions. In addition, other studies have indicated that many weather-related mishaps are attributed to novice pilots' inability to utilize RPD models to quickly diagnose and avoid dangerous weather conditions (Burian, Orosanu, & Hitt, 2000; Wiegmann, Goh, & O'Hare, 2002; Wiggins & O'Hare, 1995). It is important to note that these studies have focused largely on single-pilot aircraft in general aviation. Therefore, it is important to examine how differences in flight experience impact collaborative decision-making strategies among commercial aircrews.

Both normative and naturalistic decision theorists agree that communication is a valuable asset in team decision-making. For example, Orasanu (1997) states that in naturalistic environments, a second crewmember can play an integral role in information scanning, error monitoring, identifying constraints, and evaluating alternatives. Therefore, it is reasonable to assume that both expert and less experienced pilots will benefit from participatory leadership styles and high levels of communication, especially under time pressure in ambiguous situations. However, given the fact that experts and non-experts rely on entirely different decision-making strategies, it is likely that participatory leadership and high levels of communication will only be beneficial for flight crews that have similar levels of flight experience.

Confidence in Decisions

Naturalistic decision making (NDM) is useful for situations where people make decisions under ambiguous circumstances (Lipshitz & Strauss, 1997). When making decisions under uncertainty, people often make the best guess with the information available. NDM is an effective method for explaining this decision making process, yet it fails to explain how this affects people's confidence in their decisions.

Previous research on monetary investments provides insight into decision makers' confidence when faced with uncertain outcomes. Escalation of commitment describes the tendency for people to perceive their initial decisions more positively if they were involved in the initial decision making process (Russ, 2004). Research concerning escalation of commitment was in response to the tendency for investors to invest time, money, and effort into failing investments (Staw, 1976). People often view investment decisions positively despite information that indicates a poor investment of resources.

One possible explanation for escalated commitment is the notion of sunk costs (Staw, 1976; Garland, 1990). The term "sunk costs" refers to people's reluctance to abandon a project once they invest time and resources. Escalation of commitment may occur because of people's self-justification. People are unwilling to admit their effort and resources were a waste (Staw, 1976).

Escalation of commitment is important to consider in decision making over time because it suggests that confidence in initial decisions may influence subsequent decisions. This is especially important in aviation where weather information may be unreliable. Pilots frequently make important path deviation decisions with limited and often unreliable information.

Goal of this research

Based on the previous literature, it was apparent that many issues must be investigated before integrated graphical weather displays in the cockpit could be considered useful. The purpose of this study was to examine aircrew-teaming issues that could affect decision-making confidence, particularly when the information from NEXRAD and onboard radar systems were incongruent.

The NDT provided a theoretical basis for determining the optimal leadership and communication characteristics that were believed to assist the flight crews in avoiding errors when faced with conflicting weather information. However, naturalistic models of decision making such as Klein's (1989) RPD model illustrate key strategic differences between expert and novice decision-making processes (Dreyfus, 1997; Orasanu, 1997). Therefore, we were particularly interested in examining whether differences in flight experience between the Captain and First Officer (FO) influence the efficacy of normative leadership and communication principles.

There were a number of reasons for selecting decision-making confidence as the criterion variable of interest for this study. First, it is difficult to isolate a single optimal weather deviation decision especially when confronted with disparate weather information. Given the fact that pilots' value structures (i.e., safety, passenger comfort, fuel consumption, and flight time) may be weighted differently depending on the perceived severity, course, or source of the weather event, there could be a number of situations where the decision to deviate or stay the course could be equally justified. On the other hand, decision-making confidence provides a rich, and potentially more dynamic, indicator of CRM. In particular, it gauges the magnitude of concurrence for a given decision that is not captured by overt performance measures. Lastly, decision-making confidence allowed us to examine escalation of commitment as a function of distance to the weather event. While the effects of time pressure on weather decisions are well documented (see Lusk, 1993), the influence of escalated commitment has not been extensively explored in the context of aviation. Given the fact that weather deviation decisions must often be made with limited or unreliable information, we felt that pilots' confidence on initial deviation decisions may influence subsequent decisions as they flew closer to weather events.

This study attempted to determine whether flight crews correctly applied the principles of Normative Decision Theory, as well as whether the theory held true when an integrated graphical weather display was added to the cockpit. Specifically, the study sought to examine flight crews' decision-making confidence as a function of distance to potential weather threats when presented with either congruent or conflicting weather information from two separate systems. Additionally, the second goal of this study was to assess the effects of communication level, leadership style, and difference in flight experience between the Captain and FO on flight crews' decision-making confidence.

Hypotheses

Display Agreement. We predicted that pilots' decision-making confidence would be higher when information from the onboard and NEXRAD displays were congruent. This hypothesis was consistent with available theories of machine trust (Muir, 1994) suggesting that redundant displays of information are trusted and reacted to more readily (Bliss, Jeans, & Prioux, 1996; Selcon, Taylor, & Shadrake, 1991).

Communication Level and Leadership Style. We also predicted higher levels of communication would be associated with higher decision-making confidence as pilots drew closer to the impending weather threat. Chemers (2000) suggested that participative leaders would display more dialog interactions than authoritative leaders. Therefore, in the conditions where flight crews encountered ambiguous information (i.e., conflicting weather information) and were faced with an important decision (i.e., closer to the weather event), higher levels of communication and decision making confidence should be observed.

Differences in Flight Experience. We also predicted that flight crews with lower differences in flight experience would report higher decision-making confidence compared to flight crews with large differences in flight experience. Researchers such as Dreyfus (1997) and Orasanu (1997) have noted that novice decision makers tend to utilize more deliberate strategies compared to experts. We expected that this difference might diminish decision-making confidence with larger variations in flight experience between the Captain and FO.

Escalation of commitment. We also predicted that pilots' confidence in their decision to deviate from potential weather threats would increases as they flew closer to the threat. Past research on escalation of commitment has shown that people are less likely to abandon an initial decision after they have invested time and effort (Staw, 1976). In addition, people tend to view initial decisions more positively if they were involved in the decision making process (Russ, 2004).

Method

Experimental Design

We used a multilevel experimental design. Flight crews' team-based decision-making confidence constituted the dependent measure. Flight crews' decision-making confidence at each distance level from the potential weather threat (i.e., 160nm, 80nm, 40nm, 20nm) was nested within each flight crew, which was composed of a Captain and FO. Flight crews flew a roundtrip from New York, NY to Miami, FL. Throughout each flight leg, flight crews encountered three potential weather threats, for a total of six potential weather threats. However, to increase the reliability of the dependent measure, experimenters aggregated flight crews' decision-making confidence across the two flight legs for a total of four data points, one at each distance point. In half of these potential weather threats, information incoming from the Onboard and NEXRAD systems was either congruent or conflicting. Therefore, display agreement was used as a level-one varying covariate. Level-two predictors included team communication level, leadership style, and difference in flight experience between the Captain and the FO.

Participants

Twenty-four male commercial aviation and air carrier pilots participated in this study. We used a purposive sampling strategy to obtain flight crews composed of a Captain and FO. Through an agreement with Lockheed Martin and NASA Langley, we recruited pilots from six different airlines: American Airlines, Delta, FEDEX, Northwest, United Airlines, and U.S. Airways. Twelve of the pilots were Captains and 12 were FOs. As an incentive to participate in this study, pilots were compensated with approximately $2,000 each. This monetary compensation covered all travel expenses, food, logging, and pilots' time spent completing the study. Researchers randomly assigned pilots to flight crews consisting of a Captain and a FO. Captains' age ranged from 46 to 60 years (M = 55.33, SD = 4.01), whereas FOs' age ranged from 34 to 56 years (M = 46.00, SD = 6.02). Captains' flight experience ranged from 10,000 to 19,000 flight hours (M = 13,166.67, SD = 2,910.27), whereas FOs' flight experience ranged from 5,000 to 13,800 flight hours (M = 8,845.83, SD = 2,383.80).

Measures

Distance from the potential weather threat. Experimenters presented flight crews with weather information regarding potential weather threats at four distance points from the center of the potential weather threat: 160nm, 80nm, 40nm, and 20nm. Flight crews received static images of potential weather threats at each of these distance points through two automated systems: a real-time onboard weather system and a delayed NEXRAD weather system. The focus of this study was not to examine how crews' decision-making confidence changed as a function of increasing the distance away from potential weather threats. Therefore, we coded the variable distance as: -160nm, -80, -40, -20nm from the center of the potential weather threat. The major reason for doing this was to ease the interpretation of results.

Display agreement. Given the fact that the onboard system presented real-time weather information, whereas the NEXRAD system presented delayed information, flight crews either received congruent or conflicting information regarding the potential weather threat from the two systems. However, it is crucial to emphasize the fact that we did not cross display agreement with distance from potential weather threats within the same potential weather threat. Therefore, for each potential weather threat, flight crews either received congruent or conflicting information at each distance point away from the potential weather threat, but the level of agreement was constant throughout each distance point.

Communication level and leadership style. Researchers designed a data recording form used to collect subjective ratings of crew communication levels and leadership style. The form was distributed to two raters who reviewed videotaped recordings of the experimental sessions. The raters used the form to record each team's communication level and leadership style along a series of decision points. These decision points corresponded to the weather display presentations that occurred at 160nm, 80nm, 40nm, and 20nm from the center of each of the potential weather threats.

Communication level referred to the frequency of communications that pertained to the interpretation of, or response to, the weather information. Communications that did not relate to the weather events (i.e., "chatter") were not considered in the ratings. The communications could be initiated by the Captain or FO and include providing or requesting new information as well as commenting on previously received information. The raters used these criteria to classify communication levels as being either low (i.e., infrequent communication) or high (i.e., frequent communication).

The raters then classified the leadership style of the Captain as either authoritative or participative based on the leadership styles defined by the Normative Decision Theory. Thus, authoritative leaders were Captains who did not allow their FOs to have equal influence in the decision making process. This meant that the Captain did not initiate dialog with the FO and was not receptive to the FOs attempts to initiate dialog. Conversely, participative leaders were Captains who involved their FOs in the decision making process by initiating dialogs as well as participating in dialogs initiated by their FOs.

Each rater first reviewed the videotaped recordings individually to produce their initial ratings of communication level and leadership style. Then, to maximize the quality of the ratings, both raters subsequently met to discuss the differences in their ratings and come to a consensus. The ratings were then dummy coded as either zero (for low communication and authoritative leadership) or one (i.e., for high communication and participative leadership). This dummy coding procedure was used to ensure that the slopes and intercepts of the latent growth model were indicative of differences between groups.

Difference in flight experience. Given that we randomly assigned Captains and FOs from different airlines with varying levels of flight experience, we included the difference in flight experience between the Captain and the FO as a team-level predictor of confidence in decision making.

Decision-making confidence. Once flight crews received information from both the Onboard and the NEXRAD weather systems, they had to make team-based decisions and answer each of four weather deviation questions at each distance point from the potential weather threat (i.e., 160nm, 80nm, 40nm, and 20nm). The first question required flight crews to rate their confidence that a weather threat actually existed on a 0 to 100 continuous rating scale. The second question assessed flight crews' confidence that they should avoid the potential weather threat and deviate from the predetermined flight path, also on a 0 to 100 continuous rating scale. The third question required flight crews to make an ultimate decision of whether or not to deviate. However, for the purposes of maintaining experimental control, flight crews were not allowed to actually deviate from the predetermined flight path. The results from the previous questions were analyzed elsewhere (Bustamante, Fallon, Bliss, Bailey, & Anderson, 2005). However, the focus of this study was the last question, which assessed flight crews' confidence in their decision to the third question. Flight crews' confidence in their decision was also measured on a 0 to 100 continuous rating scale.

Materials

Flight simulator. The simulated round-trip flight from New York to Miami was completed using an EPIC AV-B/IFR General Aviation Flight Console linked to a Pentium 4 IBM-compatible computer running Microsoft Flight Simulator 2004. A rudder control module, sub panel assembly, external power quadrants, and avionics stacks were also attached to the console, which came equipped with a flight yoke and basic flight instruments. Experimenters simulated flight dynamics within Microsoft Flight Simulator using a Boeing 737 aircraft model.

Weather Displays. The Onboard and NEXRAD weather displays were modeled using Visual Basic software and presented on a Pentium 4 IBM-compatible computer located to the right of the flight console. Graphical Onboard (Figure 1) and NEXRAD depictions of weather (Figure 2) were periodically presented to flight crews to notify them of potential weather threats.

The Onboard system presented weather information from the flight crews' point of view, and it was presented as the aircraft approached the weather threat at 160nm, 80nm, 40nm, and 20nm from the weather threat. The NEXRAD system presented weather information from a "god's eye" point of view, and it was presented at 160nm, 80nm, 40nm, and 20nm from the weather threat. The NEXRAD system updated information as it approached the weather threat by zooming in the specific waypoint, thereby providing flight crews with more resolution of the area.

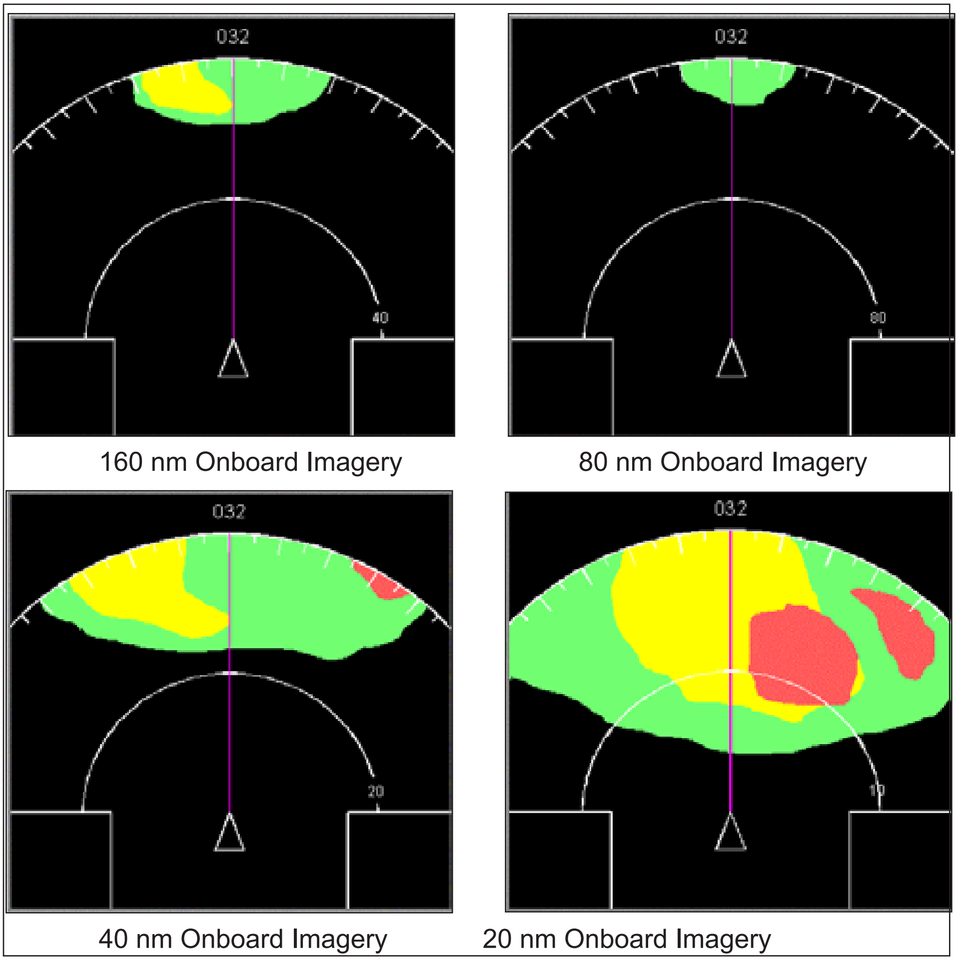

Figure 1. Sample Onboard weather imagery.

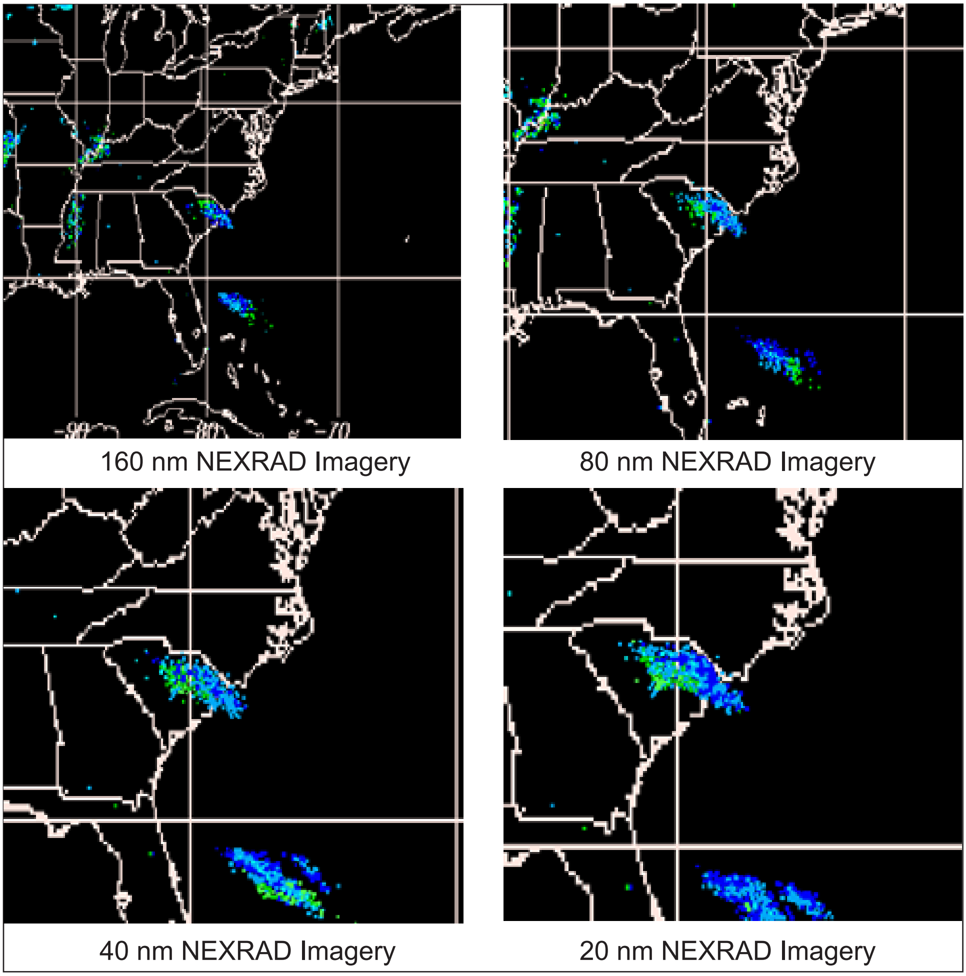

Figure 2. Sample NEXRAD weather imagery.

Procedure

After entering the experimental laboratory, pilots completed an informed consent form. They then completed a background information form to provide demographic information that included flight experience, age, and sex. After being familiarized with the simulator setup, pilots were randomly assigned a role as Pilot Flying (PF) or Pilot-Not-Flying (PNF) and shown the predetermined flight plan. To familiarize flight crews and reduce practice effects, experimenters instructed them to first fly a practice flight from Sacramento, CA to Los Angeles, CA. Flight crews were not required to take off or land, but were instructed to maintain an altitude of 19,000 feet, and an airspeed of 325nm per hour through the use of the autopilot.

Prior to each flight leg, flight crews also received preflight briefing information. This information included the flight path and a minimal packet of weather information. The weather packet included information such as wind speed, direction, and convective activity along the projected flight path. Experimenters informed flight crews that this information was 8 hrs old. The usefulness of this information was limited by its age to ensure that flight crews would focus more on the weather displays.

During the practice flight, flight crews encountered a single potential weather threat. During most of the flight, the weather displays did not present any information on the monitor. The program displayed weather information only at set distances from potential weather events. Weather events represented potential thunderstorms at specific waypoints that were considered threats to flight safety. At each distance point (i.e., 160nm, 80nm, 40nm, 20nm) from the center of the potential weather threat, the Onboard and NEXRAD weather displays appeared on the weather display monitor, as well as the four weather deviation questions. At this point, the PF was instructed to disengage the autopilot and fly the plane manually. The Captain and FO collaborated to complete the series of deviation questions based on the onboard radar and NEXRAD information. Although pilots were permitted to work together, they were reminded that the Captain would give final approval of any deviation decision that was reached. After reaching a decision, the simulation was paused to allow pilots to individually complete a series of questionnaires geared toward assessing their individual level of trust on the Onboard and NEXRAD weather systems, their perceived level of workload, and their perceived level of situation awareness. Results from these measures were published elsewhere (Bustamante, Fallon, Bliss, Bailey, & Anderson, 2005).

After completing the practice flight, flight crews began to fly the specified route from New York to Miami. During the flight, flight crews encountered three weather events. Graphical displays of weather (Onboard and NEXRAD) occurred at 160nm, 80nm, 40nm, and 20nm away from the center of each potential weather threat. Each distance represented a decision point that required flight crews to decide whether and how to perform weather avoidance maneuvers based on the representation of weather provided by the Onboard and NEXRAD displays. At each decision point, the PF disengaged the autopilot and manually flew the plane. After deciding on a course of action, the simulation was briefly paused to allow each pilot to complete the trust, workload, and situation awareness questionnaires. The simulation was resumed after the questionnaires were completed and the flight crews continued along their original flight route. However, as previously mentioned, to maintain experimental control, although flight crews made deviation decisions, they were not permitted to deviate from the flight path.

After completion of the first flight leg, the flight crews took a 1-hour break for lunch and then reconvened for the second experimental flight leg. The Captain and FO switched roles for the second flight leg. The Captain and FO switched roles for the second experimental flight leg, such that the PF during the first experimental flight leg was the PNF during the second experimental flight leg and vice versa. Once flight crews completed both experimental flights, experimenters debriefed and dismissed them.

Results

Descriptive Statistics

Preliminary statistics showed that flight crews' decision-making confidence ranged from 55.00 to 100 (M = 90.21, SD = 9.46). The flight crews' decision-making confidence data were normally distributed (*Skewness* = -1.18, SE = .25;

Kurtosis = 1.49, *SE* = .49). Furthermore, a box-whiskers plot of mean flight crews' decision-making confidence scores for each flight crew indicated that there were only three potential outliers. However, this does not raise a major issue of concern given that the normality assumption is based on the distribution of residuals of the final fitted model as opposed to the observed scores of the dependent measure.

Reliability of Decision-Making Confidence Ratings

Given that flight crews provided a decision-making confidence rating after each presentation of a potential weather threat, we assessed the test/retest reliability of the measure. Results from this analysis showed the average test/retest reliability of pilots' ratings of their confidence in their flight deviation decisions was .94. These findings suggest that although we used a single-indicator measure of decision-making confidence, it was still a highly reliable measure.

Inferential Statistics

Flight crews' reported decision-making confidence during each of the distance points (i.e., 160nm, 80nm, 40nm, and 20nm) away from the center of each weather threat were nested within flight crew. Because of this nested nature of the data, we conducted a latent growth model of flight crews' decision-making confidence using the Hierarchical Linear Model (HLM) program. All models were estimated using full maximum likelihood estimation to allow for comparisons of deviance tests. Models were built using a forward approach, starting with the random-effects analysis of variance (ANOVA) and including a set of variables based on whether or not they improved the overall model fit and were statistically significant predictors of flight crews' decision-making confidence.

Random-effects ANOVA. Results showed the grand mean of flight crews' decision-making confidence across all 4 distance points and all 12 teams was significantly different from zero, β_{00} = 90.21, *SE* = 2.06, $t(11)$ = 43.75, $p < .001$. However, from a purely mathematical point of view, this test of statistical significance was somewhat trivial given that although the range of the decision-making confidence scale (i.e., 0 – 100) included a value of zero, it is quite unlikely to obtain such a score for the grand mean. More importantly though, results showed the variance component due to differences between flight crews was significantly different from zero, τ_{00} = 45.65, $\chi^2(11)$ =114, $p < .01$. The level-one variance component was 42.85. An analysis of the intraclass correlation coefficient revealed approximately 51.52% of the variance in crews' decision-making scores was due to differences between teams. Last, the deviance test was significantly different from zero, $\chi^2(3)$ = 660/43, $p < .001$, suggesting the random-effects ANOVA was not a good-fitting model for the data.

Latent growth model as a function of distance to the potential weather threat with display agreement as a level-one predictor. The next model analyzed was a linear growth model of flight crews' decision-making confidence as a function of distance to the potential weather threats in the presence or absence of display agreement. Distance was coded as -160, -80, -40, and -20 to represent the distance in nm away from the center of weather threats. Display agreement was coded 0 = no, 1 = yes. Neither variable was centered to facilitate interpretation of results. Additionally, their interaction was included in the model. Therefore, β_{00} no longer represented the grand mean of flight crews' decision-making confidence across all weather threats and all teams. On the contrary, in this model, β_{00} represented the expected mean value of flight crews' decision-making confidence at the center of the weather threat in the absence of display agreement.

Results showed that the expected mean value of flight crews' decision-making confidence at the center of the weather threat in the absence of display agreement was significantly different from zero, $\beta_{00} = 88.48$, $SE = 2.37$, $t(11) = 37.33$, $p < .001$. Results from this model also showed a statistically significant effect of display agreement on flight crews' decision-making confidence, $\beta_{20} = 7.21$, $t(11) = 3.06$, $p < .05$. These results suggested that in general, flight crews' decision-making confidence was higher in the presence of display agreement.

A χ^2 difference test between this model and the previous random-effects ANOVA was statistically significantly different from zero, $\chi^2(12) = 64.85413$, $p < .001$, which suggested that this model significantly improved the fit to the data.

Although display agreement was the only level-one variable that had a statistically significant effect, we decided to further explore the second-level of analysis, or in this case, the team-level of analysis because all the random coefficients for the intercept and slopes of distance, display agreement, and their interaction were statistically significantly different from zero. As a result, we conducted a final model, including communication level, leadership style, and differences in flight experience between Captains and FOs.

Final model. In this model, all level-one predictors were coded and used in the same manner as before. All level-two predictors were entered uncentered for the same reasons already previously discussed.

Results showed a statistically significant three-way interaction effect between distance to the potential weather threat, communication style, and display agreement, $\beta_{31} = .14$, $t(8) = 2.70$, $p < .05$. These results suggested that flight crews who had a higher level of communication, particularly in the presence of display agreement, reported higher decision-making confidence (Figures 3 and 4).

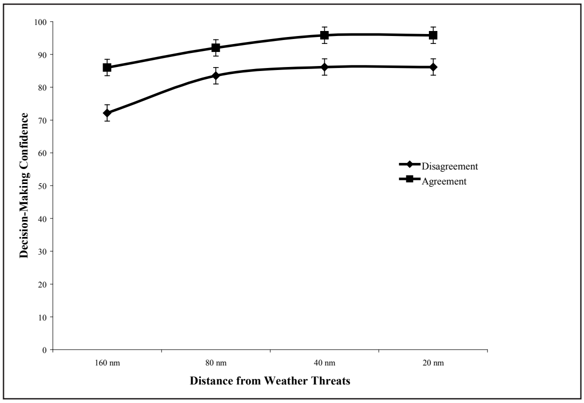

Figure 3. Flight crews' decision-making confidence as a function of distance to potential weather threats and display agreement (low-communication level).

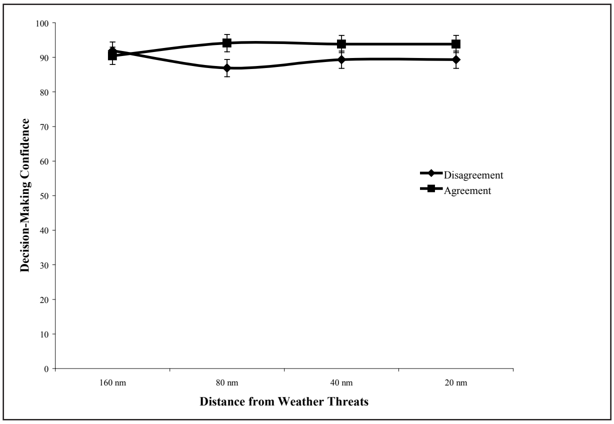

Figure 4. Flight crews' decision-making confidence as a function of distance to potential weather threats and display agreement (high communication level).

Results also showed a statistically significant three-way interaction effect between distance to the potential weather threat, display agreement, and difference in flight experience, β_{33} = -.00001, $t(8) = 2,34$, $p < .05$. These results suggested that flight crews who had lower differences in flight experience between the Captain and FO and had a high level of communication, reported higher decision-making confidence, particularly in the presence of display agreement (Figures 5 and 6).

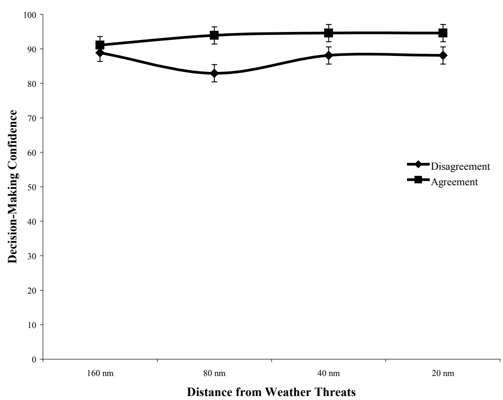

Figure 5. Flight crews' decision-making confidence as a function of distance to potential weather threats and display agreement (low flight experience difference crews).

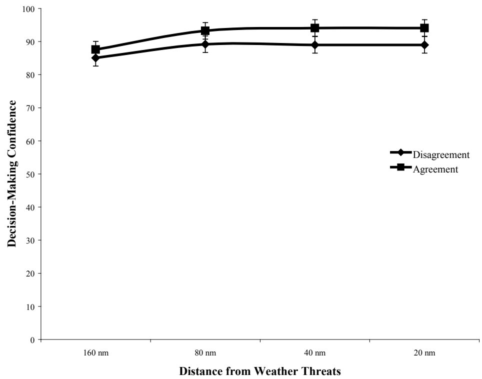

Figure 6. Flight crews' decision-making confidence as a function of distance to potential weather threats and display agreement (high flight experience difference crews).

Discussion

Display Agreement

The results supported our hypothesis about display agreement. In general, pilots' decision-making confidence was higher in the presence of display agreement. One possible explanation is that pilots believe that their decisions are more accurate when they receive confirmatory information such as when the congruence between displays appears to be highly reliable. This finding supports previous research that demonstrated the importance of redundancy in flight displays (Selcon et al., 1991). It also provides further evidence that pilots may attempt to utilize weather information from many sources, including NEXRAD imagery, to help them make deviation decisions (Beringer & Ball, 2004).

Communication Level and Leadership Style

The results partially supported our hypothesis regarding pilots' level of communication and leadership style. Pilots who had a higher level of communication reported higher confidence in their decisions as they approached the potential weather threat. This finding was consistent with previous research findings that frequent communications improves teamed decision making in ambiguous environments or when faced with very important decisions (Chemers, 2000; Vroom, 2000). In this study, conflicting weather information was used to generate ambiguity, and the approaching weather event was used to increase decision importance. However, it is interesting to note that participants who were rated as participative leaders did not have a significant effect on decision-making confidence. This finding seemingly opposes our observations regarding team communication based on NDT. For example, Vroom (2000) suggested that participative leaders would inherently promote more two-way interactions. We inferred such an increase in two-way interactions would be reflected in higher levels of communication and presumably higher decision-making confidence. However, it is important to note that high levels of communication do not necessarily equate to increases in two-way interactions. For example, it is possible for one team member to communicate frequently in response to weather information (e.g., give orders, describe his or her thoughts about the situation, etc.) without soliciting input from the other team member. Such behavior would typically be characterized as autocratic. However, it is possible the less vocal team member is providing both verbal (e.g., "I agree") and non-verbal (e.g., nodding, smiling, etc.) cues that make elaborate two-way interactions superfluous, in which case it is difficult to assess whether a true autocratic or participative leadership style is being employed. On the other hand, it is important to consider the potential disjunct between effective decision-making and high decision-making confidence. NDT research has generally only considered the former in terms of performance outcomes. However, it is possible that effective decision making can occur with low levels of confidence. For example, a novice FO may ultimately defer to the decisions of the highly experienced captain without fully understanding the problem or the solution. As Dreyfus (1997) and Orasanu (1997) noted, novices tend to prefer more deliberate decision-making strategies compared to the satisficing approach of experts. A participative leader is not required to be instructive in their decision-making strategies and despite their best efforts, they may not be capable of resolving all lingering doubts of novice crewmembers.

Difference in flight experience

The results supported our hypothesis regarding differences in flight experience between the Captain and FO. Flight crews who had lower differences in flight experience between the Captain and FO reported higher decision-making confidence. Previous research in naturalistic decision making (NDM) has contrasted the decision-making strategies of experts and novices under conditions of time pressure and uncertainty (e.g., Dreyfus, 1997; Orasanu, 1997). In general, these studies have demonstrated that novices tend to utilize an exhaustive comparison of alternatives in an attempt to determine an optimal response, whereas experts typically rely on their domain knowledge to develop a workable solution that produces quick results. Hence, it is apparent that both procedural and temporal differences between novice and expert decision making may diminish the efficacy of increased two-way interactions as prescribed by NDM theorists, especially when novices and experts are paired under conditions of ambiguity and time pressure.

Escalated Commitment

The results supported our hypothesis about changes in confidence as a function of distance to the potential weather event. As expected, pilots' decision-making confidence increased as they approached the potential weather threat. This finding was consistent with previous literature suggesting that distance from an upcoming weather event influences pilots' decisions (Bustamante et al., 2007). Past research found that greater confidence in the initial weather deviation decision resulted in increased growth in confidence over time. Therefore, pilots who were initially highly confident tended to have greater increases in confidence as they drew closer to the weather threat (Bustamante et al., 2007). A possible explanation for the increase in decision-making confidence is the potential for escalated commitment bias. Pilots may be more likely to regard their initial decision with greater confidence if they were involved in the decision making process (Russ, 2004).

Past research on escalated commitment has focused on the notion of sunk costs. The term "sunk costs" describes an investor's tendency to continue to invest time and resources despite information that the original investment is failing (Staw, 1976; Garland, 1990). Pilots may exhibit escalated commitment because of their investment of time and effort towards their decision to deviate or maintain their current heading. People often continue to invest resources in a poor decision because they are averse to admitting they were wrong (Staw, 1976). Although the pilots were unable to deviate from their flight path, pilots tended to exhibit escalated commitment because they devoted time and effort to their deviation decisions.

Another explanation for escalated commitment is the outcome uncertainty (Hantula & DeNicolis-Bragger, 1999). People tend to demonstrate increased escalated commitment when they are less able to predict the outcome based on their decision. In this experiment, pilots made their deviation decisions under uncertainty so they were unable to predict if their decision to deviate would have adverse consequences.

Kadous and Sedor (2002) demonstrated that escalation of commitment is also, due to the decision maker's information processing. The experiment showed that participants who were explicitly told to focus on their projects success were more likely to acquire information about the project's feasibility. Most importantly, people demonstrated less escalated commitment when they had access to information about the project's success. People who were focused on the project's feasibility searched for relevant project information that was helpful when deciding whether to terminate the project (Kadous & Sedor, 2002). This research suggests that pilots will acquire relevant weather information when their focus is on the success of their decision.

Escalated commitment has important implications for aviation safety. The results of the study suggest that pilots view their initial deviation decision more positively over time. Past research has shown that people continue to view their initial decision positively despite new, contradictory information. This suggests that pilots may be unwilling to reevaluate their decision when they receive weather updates. The pilot's inflexibility may result in adverse consequences, unless they learn to be confident in their decision-making ability rather than their initial decision.

Limitations and Future Research

Some aspects of our study require further investigation. The major limitation of our study was the tradeoff between ecological validity and experimental control, which is a problem in most laboratory studies. Our study did not include all weather information sources that pilots utilize during an actual flight such as air traffic control, flight service specialists, and the airline's dispatcher. In addition, our study lacked the dynamics of actual flight operations. Specifically, we were unable to simulate a dynamic onboard system that would have allowed us to present weather information throughout the experiment. Future research should consider field studies or high-fidelity simulations to investigate these factors.

Another potential limitation of this study was the small sample size. Due to budget constraints, we were only able to collect data from 24 commercial airline pilots. However, we attempted to maximize the generalizability of the results by sampling from a variety of different airlines. In addition, the significant statistical results with adequate effect size and power indicate that the sample size was sufficient for the study.

We only included a subset of variables that affect CRM, namely leadership style and communication. Other factors, such as workload and SA have been discussed elsewhere (Bustamante et al., 2005) regarding weather-related decisions. Future studies should examine additional individual, team, and organizational factors that could potentially affect CRM in weather-related decisions.

Conclusions

Despite the limitations of this study, our findings have a number of training and safety implications for commercial aircrews. In particular, our findings suggest that pilots can benefit from the additional weather information provided by NEXRAD displays. However, the problem with this approach is that NEXRAD imagery is currently unable to be updated in real time and therefore may conflict with the onboard radar system. As a result, pilots' decision-making confidence may be reduced when attempting to interpret the conflicting weather information. Therefore, future research should be aimed at improving data link technology that will enable NEXRAD imagery to be presented in real time.

Our findings also underscore the importance of CRM training in weather-related decisions. In particular, our study showed that increased two-way communications between the Captain and FO can increase confidence in their weather-related decisions. However, our study also indicated that this benefit depends largely on the experience of aircrew. Decision-making confidence may decline if there is a significant gap in experience between the Captain and FO. Therefore, future research should focus on methods to maximize domain knowledge of weather-related decision making in both initial and recurrent CRM training.

Lastly, our findings suggest a possible escalated commitment bias in pilots' weather-related decisions. In general, pilots' decision-making confidence increased as they approached the potential weather threat regardless of changes in the weather displays. Therefore, initial pilot training should include decision training so that pilots learn to trust their decision making ability rather than trusting previous decisions. Furthermore, pilots should make decisions based on the most current information available to avoid escalating commitment.

Acknowledgement

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Factors Impacting Student Retention in a University Professional Pilot Program

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Abstract

Regional air carriers are currently hiring graduates of university Professional Pilot programs with relatively low flight time, yet are not able to fill all of their open positions. Since this shortage of qualified first officers is forecast to continue, the retention of students who are enrolled in Professional Pilot programs has become an important priority. In this study, seniors graduating from the Aerospace Department at Middle Tennessee State University (MTSU) were surveyed to identify the factors that caused them to change from the Professional Pilot concentration to a different Aerospace concentration, if in fact they had done so. The survey responses indicate that students transferred from the Professional Pilot concentration at a significantly greater rate than other Aerospace concentrations, and financial constraints, time constraints, and job prospects were cited as the leading reasons for the change. Significant differences between the Professional Pilot and other Aerospace students were found in the areas of: a) retention rates of students who had family in the industry, b) loan amounts due at graduation, and c) rate of participation in Aerospace student organizations.

The expansion of regional air carriers in the last several years has sparked a growing need for entry-level regional airline pilots. An internet search of five representative regional airlines' websites revealed that hiring flight time minimums for regional pilots are at record lows (Table 1).

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Table 1
First Officer Minimum Flight Time Requirements (As Listed on Respective Air Carrier Websites on November 30, 2007)

Air Carrier	Minimum Hours Required (Total/Multi)
American Eagle (www.americaneaglecareers.com/pilots.html)	500/100
Atlantic Southeast Airlines (http://www.flyasa.com/careers/pilot.php)	500/50
Comair Airlines (http://www.airlineapps.com/transition/45/pilots.asp)	600/100
Mesa Air Group (http://www.mesa-air.com/pilots.asp)	500/100
Trans States Airlines (http://www.transstates.net/careers.html#pilots)	500/50

Randy Babbitt (former President of the Airline Pilots Association) and Bryan Bedford (current Chairman and CEO of Republic Airways) both spoke of the current pilot shortage in their respective presentations at the 32nd FAA Forecast Conference held in March 2007 (Federal Aviation Administration, 2007b). Additionally, at the February 2007 annual winter meeting of the Aviation Accreditation Board International, a panel discussion was held to consider the "Pilot Supply Pipeline." During this panel presentation, Jackie Carlon of Flight Safety International indicated that the number of pilot new hires was forecast to be approximately 15,000 for 2007. Other members of the panel stated that their companies' hiring minimums had dropped significantly due to the current pilot shortage (Bushy et al., 2007). While AIR, Inc. is more conservative in forecasting approximately 10,000 new pilot hires for 2007 (AIR Inc., 2007) the fact remains that the industry is currently in the midst of a hiring boom at the regional level.

The lack of availability of pilots for entry-level regional airline jobs can be traced to both a decrease in the number of student pilot starts, as well as a decrease in the number of pilot certificates issued, over the last several years. According to the Federal Aviation Administration's Aerospace Forecast, Fiscal Years 2007-2020 (2006):

> Student pilots are important to general aviation and the aviation industry as a whole. In 2006, according to statistics compiled by the FAA's Mike

> Monroney Aeronautical Center, the number of student pilots decreased by 2.7%. This is the second consecutive year of decline in this important pilot category (p. 21).

With regards to issuance of certificates, the FAA's Airmen Certification Data (FAA, 2007a) indicates that 20,217 Private Pilot Certificates were issued in 2006, a decrease from the 28,659 Private Pilot Certificates that were issued five years earlier in 2002. Similarly, a decline has been seen every year since 2002; this was not just a one-year drop. In addition, the number of Commercial Pilot Certificates issued in 2006 was 8,687, as compared to 12,299 issued in 2002. Once again, a steady yearly decline has been experienced. It can therefore be seen that, throughout the pilot training pipeline, the number of participants has decreased.

The FAA indicates: "The industry is trying to stimulate interest in flying, but the data suggests that more made need to be done" (Federal Aviation Administration, 2006, p. 21). While university flight schools are the obvious place to look to supply the needed pilots to industry, there is a high rate of attrition of students from university Professional Pilot programs across the country. In fact, some institutions report as high as a 75% attrition rate for students enrolled in aviation degree programs (Bowen, 1999). To manage the current pilot shortage successfully, one critical area to examine is how to increase the retention rate of students enrolled in university Professional Pilot programs. If the factors that influence a student's likelihood of persevering in a Professional Pilot program can be determined, perhaps the effects of these factors can be controlled; i.e., efforts can be made to alleviate the factors that have a negative impact on retention, while factors that have a positive effect on retention can be further strengthened.

While a review of the literature revealed no specific publications regarding the factors impacting retention of university Professional Pilot flight students, publications were found addressing factors in student retention at both the institutional level and in technology-based degree programs. Lau (2003) indicates there are several reasons students fail to persevere in academic programs. These factors include, "lack of finances, poor student-institution fit, changing academic or career goals, or unrelated personal circumstances" (p. 2). Similarly, Anderson-Rowland (1997) indicates that the three primary reasons undergraduate students change majors have been identified as employment demands, financial problems, and family problems. In addition, Anderson-Rowland found that students in technological fields (engineering) indicate the existence of family members or other role models in the particular field are especially important to creating and sustaining an interest in that field. The identification of these factors was used in the development of the survey questions for this study.

Research Questions:

1. Do students in the Professional Pilot concentration have a significantly different retention rate than the other four Aerospace concentrations at Middle Tennessee State University (MTSU)?
2. What factors cause students who initially enroll in the Professional Pilot concentration to subsequently change from that concentration?
3. Regarding these factors, are there significant differences between Professional Pilot students and students in the other Aerospace concentrations?

Methodology

Participants

During the 2006-2007 academic year, a survey was administered to all 143 graduating seniors who were enrolled in a section of the Aerospace Seminar at MTSU. As a capstone course which is required in every Aerospace concentration, all graduating seniors in the Aerospace Department are required to complete this Aerospace Seminar class. There are five possible Aerospace concentrations at MTSU – Professional Pilot, Maintenance Management, Dispatch/Scheduling, Administration, and Technology. Unfortunately, it was not possible to contact students who left both the concentration and the Aerospace Department.

Survey

While the survey that was administered had broader context in terms of internal feedback to the Aerospace Department, particular questions were designed to assist in the identification of factors that caused students to change concentrations. Ten questions addressing retention factors were included in an overall survey of 23 questions focused on academic and administrative features of the Aerospace program. To address the question of how previous knowledge of the profession influences a student's likelihood of persevering in the Professional Pilot curriculum, two specific influences were examined. On one survey item, students were asked to self-report, on a Likert scale, their familiarity with the aviation industry prior to matriculating into the Aerospace program at MTSU. On a second survey item, students were asked to indicate whether they had family members employed in the aerospace industry.

To assist in identification of the factors contributing to a student concentration change, a question was developed which provided students the ability to rank, from most important to least important, the reason(s) they changed concentrations. This survey question can be viewed in the Appendix.

To evaluate the financial constraints area, two survey questions were developed. The first question requested the student provide the amount of loans, if any, they would have incurred by the time of graduation. The second question, which evaluated time constraints, requested the student indicate the number of hours they were employed each week at a part-time job and whether they participated in any Aerospace student organizations. To examine the issue of job prospects" the survey item asked whether the student has secured or intends to seek employment in their area of concentration. The survey was pilot tested for validity by three graduate students and three faculty members in the MTSU Aerospace Department.

Procedure

To analyze the survey responses of interest, descriptive statistics as well as chi square or t-test analysis (as appropriate) were performed to determine significant differences between both Professional Pilot students and students in the other four Aerospace concentrations. These analyses were also were performed to determine significant differences between Professional Pilot students who completed the program versus those that changed to other concentrations. A t-test analysis was only used in cases of continuous data that was approximately normally distributed. In each case when a t-test was utilized, the null hypothesis was that there was no significant difference in the mean of the two groups being compared. When a chi-square analysis was used, the null hypothesis was that there was no significant difference between the frequency of the response being analyzed and what was expected, given the sample population.

Results

One hundred twenty-six student responses were received out of the possible 143 students enrolled in the Aerospace Seminar class, sections in the fall 2006 and spring 2007, giving an 88% response rate. All the students in attendance willingly completed the survey. The basic demographic information obtained from the survey indicated that 83% of the respondents were male, and the average age of the students at the time of the survey was 22.83 years.

One of the questions in the survey asked students to identify the concentration in which they entered the Aerospace Department. In addition to one of the five specific concentrations, they could also have been "undeclared" at the time of entry. Approximately 93% of students indicated having selected their initial concentration by the end of the first semester of their freshman year. Students were asked to identify the concentration in which they anticipated graduating. Table 2 summarizes the responses received for these two questions.

Table 2
Student Selection of Aerospace Concentration

Concentration	Students Initially Selecting Concentration	Students Graduating in the Concentration
Professional Pilot	54%	29%
Technology	2%	2%
Maintenance Management	6%	10%
Administration	12%	28%
Dispatch/Scheduling	22%	32%
Undeclared	3%	Not Applicable

Because all five concentrations both gained and lost students between this group of students' matriculation into the Department and graduation, the percentage of students graduating in each area was effected by increases as well as decreases. Since the goal of this study was the examination of retention issues, the number of students that transferred *out* of a particular concentration was examined specifically (Table 3).

Table 3
Number of Students Changing From Each Aerospace Concentration

Concentration Exiting	Number of Students
Professional Pilot	35
Technology	2
Maintenance Management	2
Administration	1
Dispatch/Scheduling	1
Undecided	3

Based on the responses indicated in Table 3, it was clear that the largest number of students that changed concentrations, while remaining in the Aerospace major, were those that began in Professional Pilot. In fact, Professional Pilot students experienced a 51% attrition rate within the department, while all of the remaining Aerospace concentrations combined experienced a 16% attrition rate. The students that chose to remain in the Aerospace Department after changing from the Professional Pilot concentration largely migrated to either Administration (19 students) or Dispatch/Scheduling (10 students). In addition, three students transferred into the Professional Pilot concentration from other areas, bringing the net number of Professional Pilot graduates to 36 (Table 4). A chi-square analysis showed a statistically significant difference, $\chi^2(1, N=126) = 11.09$, $p = .0008$, was found between the frequency at which Professional Pilot students changed from their initial concentration and the frequency at which students in other Aerospace concentrations changed from their initial concentration. Given this, continued investigation into the reasons for this higher rate of attrition was warranted.

Table 4
Frequency of Change from Professional Pilot Concentration as Compared to All other Aerospace Concentrations

Number of Students Changing from Initial Aerospace Concentration			
	Changed Concentration	Remained In Concentration	Total
Professional Pilot	35	33	68
All Other Aerospace Concentrations	9	49	58
Total	44	82	126

Prior Knowledge of the Aerospace Industry

It was of interest to determine if knowledge of the Aerospace industry prior to enrolling at MTSU had an impact on whether students completed their initial degree program, especially for Professional Pilot students. Students who initially were in the Professional Pilot concentration were compared to Aerospace students who initially were enrolled in one of the other four concentrations (Table 5). The analysis showed there was no statistically significant difference, $\chi^2(4, N=126) = 6.38$, $p = .1724$, between students that began in the Professional Pilot concentration and Aerospace students that began in the other four Aerospace Department concentrations.

Table 5
Exposure to Industry Prior to Entering Aerospace Concentrations

Self-Reported Exposure to Industry Before Entry	Professional Pilot Selected as Initial Concentration (68 students)		Initial Concentration Other than Professional Pilot (58 students)	
	Percent	Number	Percent	Number
None	23	16	21	12
Very Little	26	18	22	13
Some	34	23	28	16
Quite a Bit	15	10	17	10
Thoroughly Indoctrinated	2	1	12	7

Next, to investigate if prior knowledge of the industry affected Professional Pilot's rate of concentration change specifically, Professional Pilot students who did not change concentrations were compared to Professional Pilot students who did change concentrations, as seen in Table 6. A chi-square analysis showed no significant difference between the prior exposure to the Aerospace industry of those students who completed the Professional Pilot concentration and those that did not, $\chi^2(4, N=88) = 1.608$, $p = .8073$.

Table 6
Exposure to Industry for Students That Changed from Professional Pilot and That Stayed in Professional Pilot through Graduation

Self-Reported Exposure to Industry Before Entry	Students Who Began in Professional Pilot and Changed (35 students)		Students Who Began in Professional Pilot and Graduated in Professional Pilot (33 students)	
	Percent	Number	Percent	Number
None	23	8	24	8
Very Little	29	10	24	8
Some	34	12	33	11
Quite a Bit	11	4	18	6
Thoroughly Indoctrinated	3	1	0	0

In addition to self-reported exposure to the aerospace industry, family employment in the industry was examined, as this would seem to increase a student's knowledge of the industry. Aerospace students in concentrations other than Professional Pilot reported that 36.21% had family involved in the industry, while students initially in the Professional Pilot concentration reported that 23.53% had family in the industry. The breakdown of responses, used for a chi-square analysis of the data, can be seen in Table 7. A significant difference, $\chi^2(1, N=37) = 11.63$, $p = .00065$, was found in the number of students that changed concentration when Professional Pilot majors who had family employed in the Aerospace industry were compared to students in other Aerospace concentrations who had family employed in the industry.

Table 7

Number of Students Changing Concentration When a Family Member Was Employed In the Aerospace Industry

	Changed Concentration		Remained In Concentration	
	Percent	Number	Percent	Number
Professional Pilot	63	10	37	6
All Other Aerospace Concentrations	10	2	90	19

Factors Leading to Change of Concentration Once Enrolled

This study sought to identify factors that caused students to change concentration once they were enrolled. Students ranked factors from the following list: Difficulty of program, subject matter not what they anticipated, job prospects after graduation, financial constraints, time constraints, part-time job, family constraints, pressure from parents, pressure from peers, medical reasons, and other (a blank was provided by ‘other’, so students could provide the reason).

In Table 8, the number of times a particular reason appeared in students’ top three reasons for changing concentrations can be seen. Only factors occurring with a frequency greater than one are listed.

Table 8

Frequency a Reason Appeared in Students Top Three Reasons for Changing Concentration

Reason Indicated	Change from Professional Pilot Concentration Number of Responses	Change from All Other Concentrations Number of Responses
Financial constraints	20	2
Time constraints	11	3
Job prospects	9	5
Subject matter different than expected	6	1
Difficulty of program	4	3
Part-time job	5	1

Since the number of students changing from concentrations other than Professional Pilot was so small, the response rate on the “reasons for change” question for other than Professional Pilots was correspondingly small. Given the small numbers, it was not possible to use a statistical analysis to determine if the responses differed significantly between Professional Pilot students and other Aerospace students. However, of the reported "top three" reasons for changing concentrations for the Professional Pilot students, "financial constraints" was listed as the number one reason in 18 of the 20 responses. In addition, the indication of financial constraints, time constraints, and job prospects as the leading reasons for change by Professional Pilot students was important, and was used for further analysis.

Part-Time Employment

As both a financial constraint (presumably working at part-time employment to help pay for school expenses) and a time constraint, the current job obligations of students that left the Professional Pilot concentration were compared to those graduating in the Professional Pilot concentration. Students were asked to indicate the average number of hours per week they spend in part-time employment. It was found that students graduating from the Professional Pilot concentration reported working a mean of 19.82 hours per week, while those Aerospace students, who changed from the Professional Pilot concentration earlier in their college career, reported working a mean of 21.09 hours per week. Using a two-tailed t-test, no statistically significant difference, $t(66) = .3605$, $p = .7196$, was found between the hours worked by Professional Pilot students who left the Professional Pilot concentration and those that did not. The mean weekly hours worked by students who were graduating in the Professional Pilot concentration were also compared to all other students majoring in Aerospace, who reported mean hours worked per week of 21.92 hours. Students that changed from the Professional Pilot concentration earlier in their collegiate careers and who are graduating in a different Aerospace concentration made up one subset of these students. Once again, a two-tailed t-test revealed no significant difference, $t(124) = .8115$, $p = .4186$, in hours worked between these two groups of students.

Outstanding Loans

As another means of examining financial constraints, surveyed students were asked to indicate their amount of outstanding loans upon graduation. Sixty-one percent of graduating Professional Pilot students indicated having an outstanding loan upon graduation, with an average amount owed of $9,986. In the other Aerospace concentrations, 47% of graduating students indicated that they would have a loan due at graduation, and reported owing an average balance of $8,044. The loan amounts due at graduation were compared using a two-tailed t-test, and no statistically significant difference between Professional Pilot students' loan amounts and non-Professional Pilot students' loan amounts were found, $t(124) = .8304$, $p = .4079$.

However, it appeared from the data that many students who began in the Professional Pilot concentration had incurred a large loan balance *before* changing to a different concentration. Therefore, an analysis of loan amount due at graduation was done for students who had ever been enrolled in the Professional Pilot concentration, versus those that had never been enrolled in the Professional Pilot program. Students who started in the Professional Pilot concentration indicated an average loan balance of $10,434 while students who were never in the Professional Pilot concentration indicated a loan balance of $6,017. A two-tailed t-test was performed to compare these means, and there was found to be a significant difference in the loan balances of students who had ever been in the Professional Pilot curriculum versus those who had always been in a different Aerospace concentration, $t(124) = 2.1734$, $p = .0317$.

Job Prospects

Table 10 shows that 94% of those students graduating in the Professional Pilot concentration indicated they would work in this area upon graduation, while 83% of the remaining Aerospace students indicated that they would work in their concentration area. Given that one cell in Table 9 had a frequency of less than 5, a Yates chi-square analysis (to correct for small cell size) was performed to determine if there was a significant difference between Professional Pilot graduates' and other Aerospace concentration graduates' rate of pursuing a career in their concentration. No significant difference was found, $\chi^2(1, N{=}126) = 1.851$, $p = .1737$.

Table 9
Pursuit of Career in Concentration after Graduation

	Yes		No	
	Percent	Number	Percent	Number
Professional Pilot	94%	34	6%	2
All Other Aerospace Concentrations	83%	75	17%	15

Participation in Aerospace Student Organizations

Finally, students were asked to indicate if they had ever participated in any of the Aerospace student organizations on campus. Since many student organizations foster relationships among students and provide potential career information that may be important for retention, this was considered important. It was found that approximately 42% of the graduating Professional Pilot students indicated that they had participated in Aerospace student organizations, as compared to 61% of the students in other Aerospace concentrations. A chi-square analysis found a significant difference in rate of participation in Aerospace student organizations by Professional Pilot students as compared to students in other Aerospace concentrations, $\chi^2(1, N{=}126) = 3.9375$, $p = .0472$.

Discussion

The first research question addressed whether the rate of retention in the Professional Pilot concentration was significantly lower than that of the other four Aerospace concentrations at MTSU, and this was indeed found to be the case. Many students who are interested in the Aerospace career field choose Professional Pilot as their initial concentration because it is a highly visible, well-known choice within the industry. Conversely, areas such as Administration and Dispatch/Scheduling are relatively unknown to those who have had little exposure to the industry. As part of their required curriculum, Aerospace students at MTSU take an “Introduction to Aerospace” class during their freshman year, which provides discussion regarding the various career options available in the aerospace industry. Therefore, a large part of the tendency to change from Professional Pilot to other concentrations may be attributable to students coming to realize that other options exist.

It was thought that students who had prior knowledge of the Aerospace industry would be statistically more likely to initially pick the “correct” concentration for their interests and abilities, but this was not the case. There was no difference in the prior knowledge of the industry for students who graduated from the Professional Pilot concentration, students who initially enrolled in but subsequently changed from the Professional Pilot concentration, and students who initially enrolled in and subsequently graduated from one of the other four Aerospace concentrations. However, when students reported having family members who were employed in the Aerospace industry there was a significant difference in the retention rate of Professional Pilot students and students in the other concentrations. That is, Professional Pilot students with family in the industry were more likely to change concentrations than students in the other Aerospace concentrations. This seems to indicate that students who have family involved in the industry were encouraged, either by the influencing family member or by their own perception of the industry, to pursue a career as a Professional Pilot. However, in many cases, this did not prove to be the appropriate concentration for them. On the other hand, the students who had family in the industry and initially chose a concentration other than Professional Pilot were very likely to remain in that concentration through graduation.

With regard to the second and third research questions, the factors that cause Professional Pilot students to change concentration, students’ reported reasons for change revealed that financial constraints, time constraints, and job prospects were the top three identified reasons. In fact, financial constraints were the number one reason for change for 90% of the students who left Professional Pilot. In the investigation of the “financial constraints” area, two particular survey results are relevant. The first, the number of hours spent in part-time employment, was not significantly different for Professional Pilots versus students in other concentrations. However, in the second area, the loan amount incurred as an undergraduate, it was found that students who had ever been enrolled in the Professional Pilot concentration had a significantly higher loan balance projected to be due at graduation than did students who had never been enrolled in the Professional Pilot concentration. It therefore seems likely that the prospect of having a large loan amount due after graduation, in a career field with low starting salaries, was a very significant factor for students who elected to change concentrations from Professional Pilot.

Although job prospects after graduation were cited as a leading reason for changing from Professional Pilot, almost all Professional Pilot graduating seniors indicated they would begin employment in a position in their concentration, and there was no significant difference between these graduates and students in the other Aerospace concentrations. Job prospects for Professional Pilots, both in flight instruction and at the regional air carriers, are much better now than they were when these graduating students were freshmen (most commonly, academic year 2003-2004). Therefore, it is possible that the weaker employment prospects, during that time, caused students to change concentrations prematurely. Given that possibility, Aerospace faculty need to continually and effectively communicate to students the employment cycles that are inherent in the aviation industry.

While part-time job obligations affected the "time constraints" area, which was identified as a leading reason for changing from the Professional Pilot curriculum, participation in student Aerospace organizations was examined as another possible parameter of judging student time constraints. The rationale of this approach was that students who have little free time available would be less likely to participate in such organizations. A statistically significant difference was found between Professional Pilot and other Aerospace students, with Professional Pilot students being less likely to participate in these organizations. Although the part-time job hours worked did not vary significantly, Professional Pilot students are required to spend a minimum of eight hours per week engaged in a flight lab during the majority of the semesters they are in school, with many students spending far more hours per week in flight training than that minimum requirement. If those hours are added to the hours they spend at a part-time job, the number of hours available for other activities is decreased considerably. Thus, the lesser participation in Aerospace student organizations by Professional Pilot students may be indicative of the lack of time for such endeavors. Unfortunately, this lack of participation may also contribute to a lesser sense of cohesion with other Professional Pilot students, and reduce the positive motivational force of developing relationships with fellow students. This lack of participation could further contribute to the lower rates of retention in the Professional Pilot concentration.

Conclusions

Given the amount of previous student exposure to the Aerospace industry, including having a family member working in the industry, does not necessarily help students enter the Aerospace Department in the 'correct' concentration, providing a course early in a student's college career similar to the Introduction to Aerospace course at MTSU is critical. In such a course, students should be exposed to the variety of careers available in the industry, and will then be better informed regarding the options that are available to them. Again, given that Professional Pilot is one of the most visible careers in Aerospace, it is likely that a number of students will be attracted to the industry based on their perception of that career, but will ultimately change to a career within the industry that better suits them. While the purpose of this study was to identify the factors that cause retention issues for Professional Pilots students, this career field is not right for everyone and many individuals now employed in the Aerospace industry who were initially attracted to a Professional Pilot career, have since determined their strengths lie in other areas. While retention in Professional Pilot curriculums is important, it is equally important that students pursue a career that will be satisfying to them.

It is very important that the discussion of the various career fields in the industry be handled equitably and comprehensively during a course such as Introduction to Aerospace. Faculty members must be sure that not only the current state of the industry is discussed, but that the cyclical nature of the hiring cycles in the industry is revealed and understood by students. This level of understanding of the industry is also necessary for the flight instructors in any Professional Pilot program. Since Professional Pilot students tend to have closer contact and develop more personal relationships with their flight instructors than with academic faculty, particularly during the early stages of flight training, flight instructors' influence on their students can be quite large. For instance, in the fall of 2003, when the students surveyed in this study were freshmen, flight instructors were facing an industry in which furloughs and air carrier bankruptcies dominated the aviation news scene. This view of the industry was no doubt communicated to their students, who may have concluded that being a Professional Pilot was a poor career choice. Conversely, today's flight instructors, who are being hired very quickly and with very little flight time, may well leave this year's freshman class with false perceptions and expectations of how the industry works. As long as this cycle of limited information is perpetuated, as an industry we will continue to "chase our tails" concerning attracting and retaining an appropriate numbers of students.

Since Professional Pilot students report lesser participation in Aerospace student organizations than do students in other Aerospace concentrations, making efforts to increase that rate of participation may be warranted. While there are other organizations available for Professional Pilot students, membership on the National Intercollegiate Flying Association (NIFA) flight team is an obvious choice. However, the time commitment for that particular organization is quite large, and for students already feeling time constrained, perhaps it is not viewed as a possibility. But, faculty encouragement of students to participate in either the flight team or other organizations for Professional Pilots, particularly early in their college career, may assist students in forging relationships that positively affect their desire to remain in the program.

Finally, since financial constraints were identified as the number one reason for changing from the Professional Pilot concentration, making students aware of all possible financial aid and scholarship opportunities is obviously important. However, only so much can be done in this area, as in many cases students (and their parents) are discouraged by the low starting salaries versus the high amount of student loans necessary to prepare for an entry-level job. This being the case, the need to continue to work towards more cost effective and efficient flight training is evident. The use of training devices, simulators, and more effective training paradigms hold out the possibility of equally effective training at lower costs. These alternatives should be explored and implemented whenever possible, as the financial burden of entering the Professional Pilot workforce appears to be a strong factor in the departure of many students from the concentration.

Areas for Further Study

The largest limitation of this study is that no data was available from students who changed from an Aerospace concentration and left the Aerospace Department completely. Although the Department has one of the highest retention rates of Departments in the College of Basic and Applied Sciences at MTSU, around 10% of Aerospace freshmen who return to the university for their sophomore year, do not return to the Aerospace Department. There is currently no mechanism for easily identifying or contacting these students, but it would provide a more comprehensive understanding of retention issues if they could be surveyed regarding their reasons for changing majors.

Concerning further study, there are plans to repeat the study with the 2007-2008 MTSU graduating Aerospace class, with some minor changes made to the survey. For example, it would have been helpful to know the specific relationship between the student and any family members employed in industry, as well as the position in the industry that person holds. With that information, it could be determined if there was perhaps undue influence upon students to follow in a family member's footsteps, instead of simply providing more insight into the industry. In addition, when the reason for changing concentration was indicated as "job prospects," there is a need to differentiate more specific reasons, such as "starting salaries after graduation" versus "long term salary potential." These changes will be made before the study is conducted a second time.

Finally, this study was conducted at MTSU only, and therefore the results are not necessarily applicable to other universities that have Professional Pilot programs. To generate more data that is applicable, the study should be replicated at other institutions.

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Appendix

Survey Question Regarding Reasons for Changing Concentration

If you changed concentrations while in the Aerospace Department, what was the reason(s)? Please rank from most important (number 1) to least important, leaving blank those that do not apply.

_____ Subject matter not what was anticipated

_____ Difficulty of program

_____ Job prospects after graduation

_____ Financial constraints

_____ Time constraints

_____ Part-time job

_____ Family constraints (spouse, children)

_____ Pressure from parents

_____ Pressure from peers

_____ Medical reasons

_____ Other, please specify _____________

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The U.S. Navy's Aviation Safety Program: A Critical Review

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Abstract

Safety research has shown that human error, as opposed to mechanical failure, is a major causal factor in accidents in high-reliability organizations. In U.S. Naval aviation, human error accounts for more than 80% of mishaps. This paper represents the first attempt to summarize the elements of the U.S. Naval aviation safety program in a single document, and disseminate it to a non-military audience. The program is discussed in the context of safety research carried out in other military and high-reliability organizations. The many areas in which the U.S. Navy has learned from other high-reliability organizations are identified, and areas in which the elements of the Navy's safety program could be adapted to mitigate the human factors causes of mishaps in commercial aviation delineated.

Just as in commercial aviation, the mishap rate in U.S. Naval aviation has sharply declined since the 1950s (see Figure 1). Over the years there have been great advances in material technology, fuels and oils, aerodynamics, meteorology, radio communications, and navigation facilities that have all helped in reducing

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the number of aircraft accidents. Further advances in safety have been made through improvements in procedures and standards.

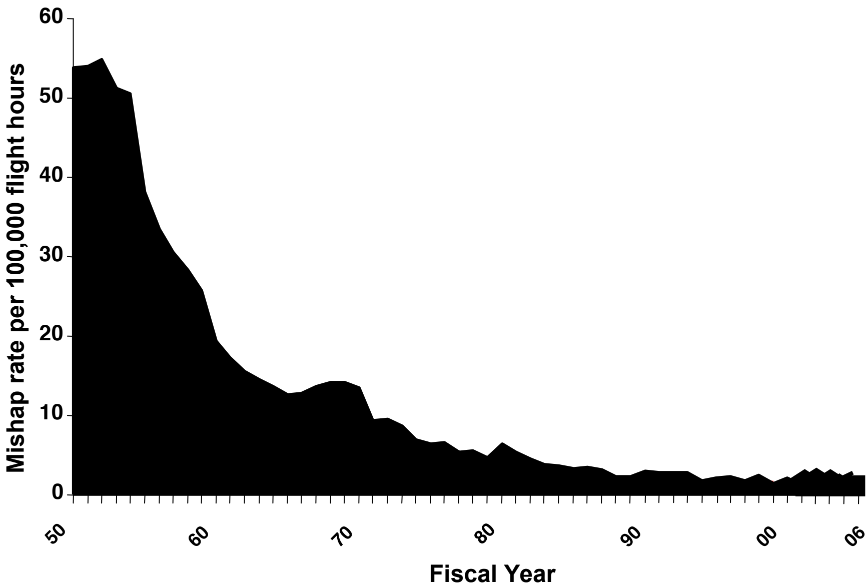

Figure 1. U.S. Naval major aviation mishap rate. (Edward T. Hobbs, personal communication, March 5, 2007).

Although the absolute mishap rate has decreased, the proportion of mishaps attributed to human error has not decreased at the same rate as the mishaps involving mechanical and environmental factors (Wiegmann & Shappell, 2003). In naval aviation, human error accounts for more than 80% of mishaps (Naval Safety Center, 2006). This finding is not unique to naval aviation, between 80% and 90% of all work related accidents and incidents can be attributed to human error (Health and Safety Executive, 2002; Hollnagel, 1993, Reason, 1990). Therefore, just as with other high-reliability organizations (e.g., commercial aviation, nuclear power generation, offshore oil production, medicine), there is recognition within naval aviation of the need to address the human causes of mishaps. Some of the techniques used to address the human factors causes of U.S. Naval aviation mishaps are adapted from other branches of the U.S. military and high-reliability organizations (e.g., safety climate surveys, crew resource management). However, others are unique to U.S. Naval aviation (e.g., human factors reviews).

This paper represents the first attempt to summarize the elements of the U.S. Naval aviation safety program in a single document, and disseminate it to a non-military audience. The program will be discussed in the context of safety research carried out in military and other high-reliability organizations. It will identify the many areas that the U.S. Navy has learned from other high-reliability organizations, and delineate possible areas in which elements of the Navy's safety program could be adapted to mitigate the human factors causes of mishaps in commercial aviation.

U.S. Naval Aviation Safety Program

The goals of the U.S. Navy aviation safety program are to eliminate hazards and enhance the safety awareness of squadron personnel. The safety program's "only purpose is to preserve human lives and material resources and, thereby, enhance readiness" (Chief of Naval Operations, 2001a: 2-1). The elements of the U.S. Navy's aviation safety program can be divided into three categories: training, proactive hazard recognition, and safety performance evaluation (see Table 1). Each of these elements will be discussed below.

Table 1
Elements of the U.S. Navy's Aviation Safety Program.

Training • Aviation Safety Officer • Aviation Safety Commander • Crew resource management • Safety standdown • Publications
Proactive hazard identification • Human factors review • Operational risk management • Safety councils • Anymouse reporting Military flight operational quality assurance (MFOQA) Pulse plus • Hazard report
Safety performance evaluation • Mishap investigation and reporting • Safety surveys • Safety climate assessment - Safety climate workshops - Safety climate surveys.

Training

Learning is an important requirement for improving safety performance in high-reliability organizations (Carroll, 1998). The U.S Naval aviation safety program includes safety training developed for specific personnel within the squadron, as well as safety training that is applicable to every member of an aviation squadron.

Aviation Safety Officer Course

Every U.S Navy and Marine Corps squadron has an aviation safety officer (ASO). The ASO is a naval aviator whose primary roles are to advise the Commanding Officer (CO) on all aviation safety matters, assist the CO in establishing and managing the command aviation safety program, and maintain aviation safety records and squadron mishap statistics (Chief of Naval Operations, 2001a). The ASO is trained for this role at the Navy/Marine Corps School of Aviation Safety. The ASO course is 23 days of instruction in safety programs, human factors, aerospace medicine, mishap investigation, mishap reporting, aerodynamics, and structures.

Aviation Safety Command Course

The commitment of senior personnel to safety is crucial to maintaining a successful and sustainable safety program. Aviators that have been selected for command of a squadron attend a six-day aviation safety command course at the Navy/Marine Corps School of Aviation Safety to prepare them for the role of a squadron CO. The Aviation Safety Command course can be regarded as an abbreviated version of the ASO course (see above) that has been specifically tailored for the role of senior leadership personnel.

Crew Resource Management Training

The civil aviation industry was instrumental in developing Crew Resource Management (CRM), a training program designed to reduce error and increase flight crew effectiveness (Wiener, Kanki, & Helmreich, 1993). Due to the success of CRM training in civil aviation, it is now the most widely applied technique for providing team training to operations personnel in high-reliability organizations (see Flin, O'Connor, & Mearns, 2002 for a review), and military aviation.

The goal of naval CRM training is to "improve mission effectiveness by minimizing crew preventable errors, maximizing crew coordination, and optimizing risk management" (Chief of Naval Operations, 2001b). Unlike commercial aviation, the U.S. Navy considers CRM training to be an operational training program, as opposed to a safety training course. However, if CRM's goal of reducing preventable crew errors is achieved, improvements in safety would also be an inevitable outcome of CRM training. The content of the U.S. Navy's CRM training is driven by seven skill areas (decision making, assertiveness, mission analysis, communication, leadership, adaptability/ flexibility, and situational awareness) and associated behaviors required for effective aircrew coordination (Prince & Salas, 1993). Every naval aviator must receive ground training and a CRM evaluation during an actual or simulated flight, by a CRM instructor, or facilitator, once a year.

As has been the case with CRM in commercial aviation (see O'Connor, Flin & Fletcher, 2002; Salas, Wilson, Burke, Wightman & Howse, 2006), evaluations of the effectiveness of the U.S. Navy's CRM training have been reported in the scientific literature. Course participants were found to be enthusiastic in their reactions to the training (Baker, Bauman, & Zalensy, 1991; Salas, Fowlkes, Stout, Milanovich,

& Prince, 1999; Stout, Salas, & Carson, 1994; Stout, Salas, & Kraiger, 1996) there was a positive shift in attitudes to the topics addressed in CRM training (Alkov, 1989; Alkov, 1991; Alkov & Gaynor, 1991; Baker et al., 1991; Salas et al., 1999; Stout et al., 1994) there was an increase in knowledge (Stout et al., 1996); and an improvement in CRM behavior of aircrew as a result of attending the training (Salas et al., 1999; Stout et al., 1994; Stout et al., 1996). Alkov (1989) and Alkov and Gaynor (1991) also reported a decrease in the mishap rate for three naval aircraft communities (helicopters, attack bombers, and multiplaced fighters) as a result of CRM training.

Safety Standdown

A safety standdown is a dedicated period of safety training carried out by the squadron. The purpose is to provide a period of time, typically a morning or afternoon, in which the command focuses specifically on safety. During a safety standdown, no flying is carried out. The training typically consists of a series of presentations concerned with safety issues that are of particular relevance to the squadron.

Publications

The Naval Safety Center publishes two monthly magazines devoted to aviation safety. The focus of Approach is for aviators, and Mech is for squadron maintenance personnel. Both magazines contain stories from naval aviators and maintainers regarding real-life situations in which a mishap was narrowly avoided, as well as information on the Navy's safety programs. The Naval Safety Center's website (www.safetycenter.navy.mil) also has links to safety related instructions, presentations, articles, etc.

Discussion: Safety Training

In terms of safety training, there is little commercial aviation can learn from the U.S. Navy's safety program. Commercial aviation companies employ specially trained safety professionals, carry out recurrent safety and CRM training, and there are many different commercial aviation safety publications published by airlines, regulators, and aviation safety interest groups. However, there is much for the U.S. Navy to glean from commercial aviation in terms of integrating CRM training into technical training, developing CRM training for automated aircraft, and the use of behavioral markers to assess the CRM skills of aviators. Commercial aviation has made great strides in developing and utilizing behavioral marker systems such as the NASA/University of Texas Behavioral Markers (FAA, 2004a, 2006a) and NOTECHS (see Flin et al, 2003). A behavioral marker system is a taxonomy or listing of key non-technical skills associated with effective and safe task performance in a given operational job position (CAA, 2006). Behavioral marker systems have been developed for use by military aviation (e.g., TARGETS, Targeted Acceptable Responses to Generated Events or Tasks; Fowlkes, Lane, Salas, Franz, & Oser, 1994). However, unlike commercial aviation, behavioral markers have not yet been widely adopted by U.S. naval aviation.

Proactive Hazard Identification

The purpose of the proactive approach is to recognize and address hazards before they result in a mishap. The early identification of hazards reduces the need to wait for the system to fail in order to identify weaknesses and to take remedial actions (Flin, Mearns, O'Connor, & Bryden, 2000).

Human Factors Review

The Human Factors Council (HFC) and the Human Factors Board (HFB) are used by commanding officers to maintain an awareness of the physical conditions, the psychological well-being, the attitudes, and the motivation of their aircrews. The HFC is a regular -- every month for Marine, and once per quarter for Navy squadrons (Chief of Naval Operations, 2001a), proactive, informal review of all officer and enlisted aircrew. The members of the HFC include at a minimum: the CO or Executive Officer (XO, second-in-command of the squadron), the ASO, the operations officer, the training officer, the Naval Air Training and Operating Procedures Standardization (NATOPS) officer, -- the individual in the squadron responsible for flight safety training -- and the flight surgeon (Chief of Naval Operations, 2001a). The personal and professional characteristics of the aircrew are discussed in order to identify potential impacts on their flight performance. Information obtained from the HFC is confidential, and is not to be used for disciplinary or administrative reasons. The CO alone acts on this information, the sole purpose is for the enhancement of safety (Chief of Naval Operations, 2001a). If the HFC should identify a member of the aircrew who may be having some minor issues, then the HFC members will identify ways in which the member could be helped. However, if the HFC identifies more serious issues that may interfere with a crew member's ability to safely perform flight duties, then the CO could convene an HFB.

The HFB is a formal human factors review of a member of the aircrew. It focuses upon identifying and mitigating the concerns about the members' ability to perform their flight duties safely. It is non-punitive; the focus is on helping the individual resume their responsibilities as an effective squadron member. The HFB should include, at a minimum: the ASO, flight surgeon, and any other officers of the CO's choosing (Chief of Naval Operations, 2001a). Examples of situations in which a HFB would be appropriate are a single or sustained deficiency in performance, failure to achieve expected training goals, a preponderance of life stressors, and aeromedical problems, e.g., poor physical fitness, recurring airsickness (Commander Naval Air Forces, 1997).

Operational Risk Management

Operational risk management (ORM) is a decision making tool designed to increase operational effectiveness by anticipating hazards and reducing the potential for loss (Chief of Naval Operations, 2004). ORM is utilized Navy-wide, and is not specifically a naval aviation safety program. Nevertheless, given the dynamic nature of flight operations, the ORM concepts have particular relevance to naval aviation. The Navy's ORM program grew out of ideas originally developed to improve safety in the development of new weapons, aircraft and space vehicles, and nuclear power. The U.S. Army was the first branch of the military to adopt the ORM principles, in 1991, to reduce training and combat losses. As a result of the success of ORM in the U.S. Army, it was adopted by the U.S. Navy in the late 1990s (Chief of Naval Operations, 2004).

ORM should be applied to all aspects of a command's operations and activities. ORM consists of three elements: principles, steps, and levels (Naval Safety Center, 2006). The principles are concerned with risk assessment; steps involve hazard analysis, and methods to address the hazards; and levels describe time-related factors regarding the implementation of risk management. The principles of ORM are: (a) accept risk when benefits outweigh costs; (b) accept no unnecessary risk; (c) anticipate and manage risk through planning; and (d) make risk decision at the proper level. The steps of ORM are: (a) identify controls; (b) assess hazards; (c) make risk decisions; (d) implement controls; and (e) supervise. The three levels of ORM are: (a) time critical, an 'on the run' mental or oral review of the situation; (b) deliberate, used in the planning phase of an operation; and (c) in-depth, a very thorough and detailed risk assessment (see Chief of Naval Operations, 2004). Although not mandated, it is common practice for squadron COs to require aviators to complete a deliberate ORM worksheet prior to a flight. The aircrew identifies potential hazards, and a numerical risk assessment code is applied to assess whether or not they should go ahead with the mission.

Squadron Safety Councils

For naval aviation squadrons there are two committees in place to address safety issues: the Aviation Safety Council (ASC) and the Enlisted Aviation Safety committee (EASC). These committees consider a range of safety issues involving the squadron's current operations and personnel. These issues may include procedures, flight line hazards, or human factors causes of aviation mishaps. The purposes of the ASC are to "review command plans, policies, procedures, conditions, and instructions to ensure their currency, correctness and responsiveness to safety recommendations" (Chief of Naval Operations, 2001a: 2-4). The ASC consists of the ASO, ground safety officer (the individual at the squadron who is responsible for non-aviation safety matters), and the flight surgeon. The EASC includes an enlisted representative from every work center in the command. The EASC meets monthly to discuss safety deficiencies, and provide recommendations for improving safety practices and awareness.

'Anymouse' Reporting

Every squadron shall provide a mechanism for anonymously reporting hazards (Chief of Naval Operations, 2001a). In most squadrons, this consists of a locked box in which squadron members can anonymously post any concerns. Generally, the box is emptied by the ASO, and the information given to the CO for action. Although specific processes may vary from squadron to squadron, the concept is the same: a mechanism for anonymous reporting may facilitate a report of a safety issue that otherwise would go unreported due to fear of retribution or embarrassment.

The FAA (2002) provided guidance to commercial aviation companies on setting up an Aviation Safety Action Program (ASAP) to encourage employees to voluntarily report safety information. U.S. Naval aviation has also begun fielding an anonymous reporting system based upon NASA's Aviation Safety Reporting System (ASRS) called Pulse Plus. The ASRS database is a collection of incident reports that are voluntarily submitted to NASA for use by aviation safety researchers. ASRS and other confidential reporting systems such as the United Kingdom's Confidential Human Factors Incident Reporting Programme (CHIRP) have been invaluable in improving safety in commercial aviation. For example, data in the ASRS database has been used to study error types (Sarter & Alexander, 2000), situation awareness (Jones & Endsley, 1996), and alarm related accidents (Bliss, 2003). The information from confidential reporting systems has been used to redesign aircraft, air traffic control systems, airports, and pilot training to reduce the likelihood of human error (Tamuz, 1994). It is hoped that the Navy's Pulse Plus system will also prove valuable in capturing safety related information that would otherwise be unreported by aviators.

The U.S. Navy has also started to field a flight data-monitoring program called the military flight operational quality assurance (MFOQA). MFOQA is based upon civilian aviation's voluntary flight operational quality assurance (FOQA) program. FOQA uses quick access recorders (QARs) to identify deviations for flight parameters specified in the standard operating procedures (CAA, 2003). This information can be used to identify inadequate procedures, ineffective training and briefing, poor CRM skills, fuel inefficiency and environmental impact, aerodynamic inefficiency, power plant deterioration, and systems deficiencies (Holtom, 2000). FOQA programs allow the early identification of safety trends, which could lead to accidents (FAA, 2004b).

Hazard Report

A hazard report (HAZREP) is a method for highlighting hazards in naval aviation before they lead to a mishap (Chief of Naval Operations, 2001a). "A hazard is a potential cause of damage or injury that is under human control" (Naval Safety Center, 2001: 14). There are four purposes of HAZREPs: (a) to report a hazard and the remedial action taken to address the hazard, so others can take similar action; (b) to report a hazard and recommend corrective action for others; (c) to report a hazard so some other organization can determine the appropriate corrective action; and (d) to document a continuing hazard in order to establish risk severity (Naval Safety Center, 2001). A HAZREP is submitted by the squadron to the Naval Safety Center via mail, e-mail, or the web enabled safety system (WESS; a web based system for developing a HAZREP). It is also possible to submit an anonymous HAZREP in which only the Naval Safety Center knows the name of the individual who submitted the report. HAZREPs can be submitted to address non-human factors hazards. In fact, the vast majority of HAZREPs are not concerned with human factors issues. Reason (1997) comments that it is not an easy task to persuade people to file a report about a near miss, especially if this requires divulging their own errors. It is for these reasons that U.S. Naval aviation has started fielding Pulse Plus and MFOQA.

Commanding Officer's Safety Policy

A CO should establish a written set of aviation safety goals and safety policy that defines how squadron personnel should attain these goals (Chief of Naval Operations, 2001a).

Discussion: Proactive Hazard Reporting.

The use of FOQA and ASRS, as used in commercial aviation, have served as good models for proactive hazard reporting in U.S. Naval aviation. Another commercial aviation safety program that may have benefits for U.S. naval aviation is the Line Operations Safety Audit (LOSA). LOSA involves specially trained observers collecting safety related information on environmental conditions, operational complexity, and flight crew performance during normal flight operations (FAA, 2006a). These observations are non-punitive and the findings are aggregated to identify trends in error prevalence and flight crew management, crew performance strengths and weaknesses, and threat and error linkages with undesired aircraft states (Klinect, Murray, Merritt, & Helmreich, 2003).

The elements of proactive hazard reporting used by U.S. Naval aviation that may have applications for improving safety in commercial aviation are human factors reviews and operational risk management. Alkov, Borowsky, and Gaynor (1982) and Alkov, Gaynor, Borowsky (1985) evaluated the life style changes and personality characteristics of U.S. naval aviators who had been involved in a mishap. They compared the responses of the aviators who had made an error that contributed to the mishap, to those aviators who were involved in a mishap, but did not make an error. It was found that that when compared to the 'not at fault' aviators, the 'at fault' aviators were significantly more likely to have had pre-existing major life stressors such as marital problems, problems with interpersonal relationships, recent trouble with supervisors, and recent trouble with peers. Other research with military aviators has shown that acute stress (e.g., Otsuka, Onozaw, & Miyamoto, 2006), personality (e.g., Parsa & Kapadia, 1997), fatigue (e.g., Hardaway & Gregory, 2005), or aspects of national culture (Soeters & Boer, 2000) can have a detrimental effect on the safety performance of aviators.

Similarly, in commercial aviation there are many studies that have identified the detrimental effects of personal factors such as stress (e.g., Loewenthal, Eysenck, Lubitsh, Gortin, & Bicknell, 2000), fatigue (e.g., Goode, 2003), and hazardous thought patterns (e.g., FAA, 1991; Hunter, 2005, 1995) on aviator performance, Taken together, these studies suggest the identification of aviators engaged in these types of behavior through an intervention program such as human factors reviews should be considered an important technique for mishap prevention.

The ORM process may also have utility for commercial aviation, especially considering that 37% of commercial mishaps can be attributed to decision errors (Shappell, et al., 2007). The importance of risk management is recognized by the FAA. "A formal system of hazard identification and safety risk management… is essential in controlling risk to acceptable levels" (FAA, 2006b: 9). Further, the risk management strategy proposed by the FAA, is based upon the same steps as the U.S. military's ORM program (FAA, 2006b). Therefore, basing a risk management strategy on a system that is already developed, and applied, may serve as a useful model for commercial aviation companies.

Safety Performance Evaluation

Evaluating the safety program is crucial to ensure it is achieving the goal of improving safety. Traditionally, safety performance in high-risk organizations has been assessed solely on the basis of ‘lagging indicators’ of safety such as fatalities, or mishap rates. However, more recently, high-risk organizations including U.S. Naval aviation have also started to examine ‘leading indicators’ of safety such as safety audits or measures of safety climate (Flin et al., 2000). Examples of leading indicators used in commercial aviation, which were discussed earlier, are FOQA, ASRS, and LOSA. The use of leading indicators of safety allows issues to be addressed before they result in a mishap. The reason for the shift in focus is that in the last 20 years the severe aviation mishaps rate has decreased to such low levels (see Figure 1), that it ceases to be a useful measure of safety performance. Therefore, there is a need to utilize other metrics of safety performance. The U.S. Naval aviation’s leading and lagging metrics of safety performance are described below.

Mishap Investigating and Reporting

The collection and accurate analysis of accident data is essential for improving workplace safety (Dismukes, Berman, & Loukopoulous, 2007; Kayten, 1993; Wiegmann & Shappell, 2001). However, this is not an easy goal to achieve. For example, Gordon, Flin, & Mearns (2005) argued that many accident reporting systems used by the offshore oil industry in the UK lacked a firm theoretical framework for identifying the human factors causes of accidents.

Unlike commercial aviation, an independent body does not investigate a U.S. Naval aviation mishap. Should a squadron have an aviation mishap, an aviation mishap board (AMB) will be formed to investigate. At a minimum, the AMB will consist of: an ASO, a flight surgeon, an officer knowledgeable about aircraft maintenance, an officer knowledgeable about aircraft operations, and a senior member who is in-charge of the board (Chief of Naval Operations, 2001a). All of the members of the AMB are in the U.S. Navy/Marine Corps, and only the senior member is from a different squadron. The AMB is responsible for investigating and reporting the cause(s) of the mishap up the military chain-of-command in a standard form to the Naval Safety Center. The flight surgeon assigned to the AMB is the individual primarily concerned with the investigation of the human factors causes of a mishap. The flight surgeon uses the Human Factors Analysis Classification System (HFACS) to delineate the human factors causes of the mishap. HFACS has been used to investigate and classify human error in military, commercial, and general aviation (Shappell et al, 2007).

Safety Survey

The purpose of a safety survey is to provide a periodical assessment of a squadron’s safety program (Chief of Naval Operations, 2001a). An informal survey can be conducted by squadron personnel, or by staff from a sister squadron. However, a squadron must request a formal safety survey from the Naval Safety Center biennially, regardless of whether an informal survey was carried out. The safety surveys ensure a squadron is effectively utilizing the safety programs described in this paper.

Safety Climate/Culture Assessment

Widely accepted definitions of safety climate and culture do not exist. Zohar (1980) defined safety climate as a summary of perceptions that employees share about their work environment. Safety climate describes employees' perceptions, attitudes, and beliefs about risk and safety (Mearns & Flin, 1999). It is a "snapshot" of the current state of safety in a squadron. Safety culture is a more complex and enduring trait reflecting fundamental values, norms, assumptions and expectations, which to some extent reside in societal culture (Mearns & Flin, 1999). Measurement of safety culture requires in-depth investigation including an analysis of how organizational members interact to form a shared view of safety. A squadron CO can obtain quantitative information on the unit's safety climate using the Naval Aviation Command Safety Assessment Survey (CSAS), and qualitative information on the unit's safety culture through a safety culture workshop.

The CSAS was developed by the U.S Naval Postgraduate School to assess the safety climate of Naval aviation squadrons (Desai, Roberts, & Ciavarelli, 2006). It has also been adapted for use with medical personnel (see Gaba, Singer, Sinaiko, Bowen, & Ciavarelli, 2003). The CSAS is a 61-item attitude questionnaire based upon research in high-reliability organizations (see Desai et al, 2006). Attitude questionnaires have been widely used to assess the safety climate of an organization (see Flin et al., 2000). The CSAS is an online survey completed periodically by all members of the squadron. The results of a squadron's survey are only available to the CO. However, aggregated data is made available to all COs for comparison of their squadron's performance with their peers. Desai et al., (2006) examined the responses of 6,361 individuals in U.S. Navy squadrons and found a positive association between the responses on the CSAS and minor or intermediate severity mishaps, but no association between the responses and major mishaps.

The safety culture workshop identifies potential hazards that might interfere with mission accomplishment. They also identify command strengths. A safety culture workshop is facilitated by specially trained senior naval aviators. The facilitators spend time looking around the squadron, watching people working, and having informal conversations with a cross section of squadron personnel. Following the informal phase of the workshop, the facilitators carry out focus group discussions with squadron personnel. The information gleaned from the workshop is then summarized and given back to the squadron's CO. The CO should use this information to focus on areas that require better risk assessment and risk controls.

Discussion: Safety Performance Evaluation.

Researchers appear to agree that a combination of quantitative (safety climate) and qualitative (safety culture workshops) techniques provides a comprehensive evaluation of the safety culture of an organization (Wiegmann, Zhang, von Thaden, Sharma, & Gibbons, 2004). Despite a recognition that a positive safety climate is important in preventing accidents (FAA, 2006b), there are few documented examples of the use of safety climate questionnaires in commercial aviation (Wiegmann, et al., 2004). Further, where safety climate questionnaires have been used in other high-reliability organizations, they generally represent a single research effort rather than a continuous effort to track safety climate over time. Particular examples of the use of safety climate tools in commercial aviation include: the commercial aviation safety survey (Gibbons, von Thaden, & Wiegmann, 2006), organizational safety culture questionnaire (Block, Sabin & Patankar, 2007), and the maintenance resource management technical operations questionnaire (Taylor & Thomas, 2003).

The U.S. Navy has taken the CSAS beyond a research tool and is using it as a mechanism for providing periodic feedback on command safety climate to COs. The combination of a web-based system for obtaining responses from participants, and providing feedback to COs, is an efficient system for data collection and reporting. Further, it allows a squadron's responses to be compared over time, and be judged against other squadrons, it is an effective safety culture tracking method for senior personnel. Therefore, it is suggested that the method of implementation of the CSAS by the U.S. Navy represents a framework for commercial aviation to allow senior management to obtain feedback regarding the state of safety within the organization.

The other element that would benefit safety in commercial aviation is the safety culture workshop. The information obtained from the safety culture workshop complements the findings from the safety climate questionnaire. The safety culture workshop provides the opportunity for personnel to voice concerns that may not have been addressed in the climate questionnaire, or that required more in-depth discussion.

Conclusion

Commercial aviation has generally provided the model for the vast majority of the elements of the U.S. Navy's safety program. However, the U.S. Naval aviation's experience in implementing operational risk management, human factors councils, and safety climate/culture assessment, may be worthy of consideration in improving safety in commercial aviation, as well as other high-reliability organizations.

The main weakness with the U.S. Navy's aviation safety program is, apart from CRM training, the individual elements of the program have not been scrutinized to evaluate their impact on safety. The regulators of commercial aviation, such as the FAA, CAA, and Joint Aviation Authority (JAA), are arguably more rigorous in their demands for identifying the effectiveness of a safety program prior to recommending its implementation. However, the failure to adequately assess the effectiveness of safety training programs is a weakness that is not confined to naval aviation; many of the safety programs used in high-reliability organizations have not been subjected to detailed scrutiny. In high-reliability organizations with low numbers of accidents and multiple safety programs, evaluating the effectiveness of a particular safety program is challenging. To illustrate, in a review of the methods 113 UK aviation companies use to evaluate the effectiveness of CRM training, only 60% of companies carried out an evaluation of reactions, 21% an evaluation of attitudes, 36% a knowledge assessment, 53% an assessment of the effect on behavior, and 33% evaluated the effect of CRM training on the organization (O'Connor, Flin, Fletcher & Hemsley, 2002b). Oftentimes political or economic pressure results in the necessity for a safety program to be implemented without a proper evaluation of its effectiveness. Nevertheless, researchers must continue to attempt to conduct robust research on the effectiveness of safety programs to ensure that organizations are getting a good return on investment.

For the airline industry, improving safety makes financial sense. Rose (1990) found the lower profitability in the airline industry is correlated with higher accident and incident rate, particularly for smaller carriers. The same is true of naval aviation. In a climate of shrinking budgets, the accidental destruction of in excess of 700 aircraft per year as occurred in the 1950s is simply unacceptable. Fleming (2001) outlines a number of indicators of a high level of safety culture maturity: (a) a sustained period without a recordable accident or high potential incident; (b) no complacency in the organization, coupled with a constant paranoia that the next accident is just around the corner; (c) a range of measures to monitor performance; and (d) confidence in the safety processes. If naval aviation is to meet the U.S. Secretary of Defense's goal of zero preventable accidents and achieve a 75% accident reduction in 2008, as compared to the 2002 mishap rate (U.S. Secretary of Defense, 2007); and if commercial aviation is to improve upon, it's safety performance, this is the level of safety culture to which they must strive.

Endnotes

All opinions stated in this paper are those of the author and do not necessarily represent the opinion or position of the U.S. Navy, Naval Aviation Schools Command, or the Navy/Marine Corps School of Aviation Safety.

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Book Reviews

The Field Guide to Understanding Human Error by Sidney Dekker

A Book Review

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When it comes to accidents in safety sensitive organizations, managers are quick to point fingers and place blame, labeling the mistake as "human error." In response, Sidney Dekker presents us with this book, urging us to abandon our old worldview of human error and to be, instead, more open-minded. He asks us to reconsider how we view human error, taking into account how the events leading up to the accident appeared to those involved; a view that is more ethnographic than theoretically deductive. He asks us to see the occurrences leading up to the accident as it appeared inside the situation, not from the outside looking in. In Dekker's view, the majority of the time we will find that the actions taken made sense at the time, making it not human error, but instead common sense actions, at least as it appeared to those involved. He offers this information in a useful and fluid manner, drawing on pictures and diagrams to expand the reader's understanding, as each point is made clearer. To direct the attention of the reader, Dekker uses bullets to outline significant points within chapters. To reinforce his points of view and to perhaps instill in the reader the importance of getting it right when investigating human error, Sid provides us with a wonderful summary of the preceding chapters and a chance to reflect.

Unlike other human factors literature, Dekker does not use a lot of complicated and useless jargon, but instead makes his book readable and useful to those who would truly like to change the way they see safety within a system. This is not to say that the philosophical basis upon which Dekker builds his case for a particular view of human error lacks sufficient muscle. Anyone who has read other works by Dekker, particularly Ten Questions about Human Error, would agree that he has a profound understanding of those philosophies that collide with or offer support to a new and more beneficial view of human error.

He uses generic and varied examples to reiterate his points, making it applicable to diverse organizations. Although his focus is on aviation, he also used

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examples that involved the activities of sailors, power plant operators, and many others in safety sensitive work. Many of the examples not only clarify his statements, but also expand the scope and relevance of the book.

Dekker's book is interesting in that it doesn't just simply state that there is a problem with the way human error is popularly defined; he goes further, identifying an ideal view of human factors in accident investigation. Besides giving the reader suggestions for implementing alternative solutions to system errors, he also provides a roadmap to follow, for those just beginning their accident investigation careers. No matter if the reader is an upper level executive in an aerospace company, a member of an accident investigation team, a safety engineer, or a university student, Sid's Field Guide is equally as useful. This book presents important ideas for those who regulate human factors investigation and research, making it an essential read for the academician, the research analyst, and the government regulator.

Perhaps one of the more provocative and evocative ideas presented is the notion that the term "human error" is not only a vexing concept; it also lacks the efficacy to reduce errors. Dekker gently urges his readers to transform their minds, to let in a fresh perspective on human performance in complex systems. For the reader who is only familiar with the type of reporting offered by the U.S. National Transportation Safety Board, and the type of analysis that is largely a deconstruction of the accident, with some hindsight analysis, post hoc, Sid's nouvelle lumière is indeed a new light on the same subject.

More than a useful checklist for the practitioner, Dekker's Field Guide also makes good sense as a supplemental text in university courses on human factors, crew resource managements, accident investigation, aerospace safety, ethics, law, and aviation management. However, if your students are not ready for the philosophical discussions in the Field Guide, we suggest adding a philosophy prerequisite. We, at Oklahoma State University, just did.

A brief note on Sid's experience might help readers decide to buy this book. Sid earned all of his ratings and licenses from private pilot to air transport pilot, to include a type rating in the Boeing 737. Academically, he earned his PhD from The Ohio State University, cultivating a specific interest in cognitive systems engineering, which he converted to an interest in pilot performance issues. As a pilot and as an academician, he is more than qualified to address the issues of error and human performance.

We strongly encourage readers to buy the book and with it, Ten Questions about Human Error. First, read Ten Questions and then read the Field Guide. You will get a good workout in the theoretical basis of Sid's arguments concerning human error in Ten Questions and you'll get a practical guide to follow in this Field Guide.

International Journal of Applied Aviation Studies, Volume 7, Number 2

Delivering Excellent Service Quality in Aviation By Mario Kossmann

A Book Review

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The thesis of this text is to provide summary information for external and internal service providers to assist them in improving service quality in the aviation industry. The author further identifies the three major sectors in the aviation industry as airlines, airports and aircraft manufacturers as those who would benefit most from reading this text.

The author has captured a difficult topic with a very simplified approach. His approach was to establish a basis, or foundation, upon which to present the processes he recommends. In Chapter 1, the author discusses the target audience that is focus of the text. This includes an explanation of their relative roles in the industry and how they can benefit from the processes he promotes. Again, his focus in on the airlines, airports, and aircraft manufacturers considered the core elements of the industry. He lists the major airframe manufacturers within the international community as members of the manufacturing sector. Identifying the airline sector, the author lists all of the traditional major international carriers as well as number of the carries that make up the genre of 'low cost' airlines. The identification of examples of the airport sector, however, did not provide a list of international but rather focused on European airports – German airports in particular.

Chapter 2 was used to present the author's "theoretical considerations," which included a series of state-of-the-art theories and frameworks selected to assist in the understanding and application of the processes to be recommended in Chapter 3. The author presents what appears to be a very complex process of developing and managing what is referred to as a "service quality cycle." However, with careful reading one realizes that, as complicated as it appears on the surface, it actually represents a simple approach to building in service quality into existing processes.

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Chapter 4 presents a case study designed to illustrate the implementation of the processes described in Chapter 3. The case study is based on the aircraft manufacturing sector of the industry as previously described by the author.

The author has clearly conducted considerable research on developing and managing service quality as a concept. The text is full of cited research and proposed theoretical approaches. The text includes fifty figures, fifty-five tables, and one formal case study and has the appearance of a well constructed academic research thesis.

I submit that the text has two primary weaknesses. First, the author describes the core elements of the aviation industry to be the airlines, the aircraft manufacturers, and the airports. The author does not recognize the regulatory authorities, national and international, as being participants in the industry at large. Indeed, the very environment and operational foundations of the industry are described by and supported within a framework of regulations. To exclude the regulatory sector as a "player" in the aviation industry does not address the topic adequately.

Secondly, the text seems to imply an international scope but most of the citations and references, including examples and the primary case study, are European in nature. In an age of rapidly expanding economies supported by equally expanding national civil aviation systems it is essential to recognize the great diversity of systems, process, and culture that readers have to consider in developing an approach to quality management. Readers should be aware that the text does not necessarily represent an objective international perspective.

My expectation upon beginning this review was that I would be exposed to a global approach to managing service quality in the aviation industry – from an international perspective. What I discovered was an information-rich treatise on available information regarding the topic of service quality with an aviation emphasis. I would recommend this text to the following:

- Individuals within the industry that are interested in alternative approaches to building a "service-quality cycle" process into their system. It provides considerable research and an insight into approaches the research community suggests.
- Instructors teaching aviation management courses would benefit from using this text as supplemental reading.