An Analytical Study of the Effects of Age and Experience on Flight Safety

Patrick C. Guide
Embry-Riddle Aeronautical University - Daytona Beach

AN ANALYTICAL STUDY OF THE EFFECTS OF AGE AND EXPERIENCE ON FLIGHT SAFETY

by

Patrick C. Guide

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This thesis was prepared under the direction of the candidate's thesis committee chairman, Dr. Richard S. Gibson, Department of Aeronautical Science, and has been approved by the members of his thesis committee. It was submitted to the School of Graduate Studies and Research and was accepted in partial fulfillment of the requirements for the degree of Master of Aeronautical Science.

THESIS COMMITTEE:

Dr. Richard S. Gibson
Chairman

Dr. Gerald D. Gibb
Member

Dr. Jefferson M. Koonce
Member

Dr. John A. Wise
Member

Department Chair, Aeronautical Science

Dean, School of Graduate Studies and Research

August 28, 1991
Date

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All conclusions and opinions in this study are my own. They do not necessarily represent those of the university, my thesis committee, or anyone elso who may have contributed either information or suggestions.

ABSTRACT

Author: Patrick C. Guide

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The purpose of this study was to determine whether there are any significant decreases in the safety and effectiveness of pilots by age 60. The data for this study came from records of general aviation accidents (i.e., for private pilots, commercial pilots, and air transport pilots), and airline accidents (Part 121). These accident data were acquired from many specialized aviation data banks; these include: NTSB, AOPA, FAA, and the COMSIS Research Corporation. The data were organized into groups according to the ages of the pilots-in-command responsible for the accidents. Groupings progress in five-year increments starting at 20-24, and ending with 55-59. The data were analyzed in terms of both accidents per 1,000 pilots and accidents per 100,000 annual hours flown. The results indicate that age and experience both affect safety. The magnitude of these effects and their implications on flight safety are discussed.

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LIST OF ABBREVIATIONS

ALPA	Air Line Pilots Association
AOPA	Aircraft Owners and Pilots Association
ATP	Air Transport Pilot
FAA	Federal Aviation Administration
GAO	General Accounting Office
IOM	Institute of Medicine
LOFT	Line Oriented Flight Training
NTSB	National Transportation Safety Board
PIC	Pilot-in-Command

INTRODUCTION

Aging ultimately plays a dramatic and significant role in a pilot's ability to fly an aircraft safely and efficiently. But just how early do these effects manifest? At what point in a pilot's career do they become operationally significant? Past research on the effects of aging on aviators has noted progressive deteriorations in physiological and psychological functions with increasing age. In an early study, Shriver (1953) focused on the effects of aging on aviators and found that physical abilities, motivation and the ability to improve skill and technique, and aircrew performance tend to decline with age. In the same light, Gerathewohl (1978a) noted that the aging process is characterized by progressive deteriorations in both physiological and psychological functions.

Aviators have a number of tasks to execute in their environment, especially those who operate large complex jetliners that employ the latest technologies. One report (Select Committee on Aging, 1979) noted that an aviator's ability to perform highly skilled tasks, to adapt to new and changing conditions, to process incoming information, to resist mental and physical fatigue, to maintain physical stamina, and to perform efficiently in a complex and often stressful environment begins to decline early in middle life and continues to deteriorate from that point on. However, Mohler (1981) refuted that judgment and reasoning tend to be preserved and may compensate for some of these losses. Nevertheless, these too are eventually eroded by the aging process.

The process of aging is a very complex matter. The literature indicates that there are significant variations in performance, abilities, and tolerances among individuals of the same chronological age (Braune & Wickens, 1984; Gerathewohl, 1978b; Institute of Medicine [IOM], 1981; Shriver, 1953). Hertzog (1985) noted that not all people age at the same rate or decline by the same amount. Almost all of the physiological and psychological data that we now have show an increasing variability with age, meaning that age alone progressively loses its predictive effectiveness. This finding has become one of the most distinguishing characteristics of cross-sectional studies of aging (Rodin, 1987).

Despite these variations among individuals, the Federal Aviation Administration (FAA) enforces an upper age limit of 60 years of age for U.S. airline pilots. All other pilots not flying under these particular types of operations are not affected by this regulation. One report (General Accounting Office [GAO], 1989) found that a total of 67 petitions for exemption on behalf of 418 pilots have all been denied since the implementation of this regulation. There has also been some debate as to whether or not it is fair to enforce this rule for airline pilots without the possibility of waivers or special exemptions (also known as *special issuances*).

There are both positive and negative aspects associated with this age limit rule. Some issues are not closely tied to questions of science. For example, the rule eliminates some of the most highly paid salaries to senior captains and becomes economically advantageous to an airline. In addition, it is easily enforced since it only requires the FAA and individual airlines to monitor a pilot's age. Lastly, it eliminates these so-called age decrement problems before any major deteriorations in health or performance are likely to affect flight safety.

On the other hand, enforcing this rule on the basis of age alone is clearly a form of age discrimination. But, is it economically practical to determine which pilots beyond age 60 retain their skills and capacities and which pilots do not? If all the enhanced medical screening procedures and technologies were used, the average annual cost for a first class medical exam would increase from $300 to over $1000 (Office of Technology Assessment, 1990). It should be noted that first class medical certificates are only required for those airline pilots who serve as pilot-in-command (PIC); e.g., the captain. In the same respect, the rule may aggravate the serious shortage of qualified pilots that the

U.S. airline industry is anticipating. Additionally, one must be aware of the possible inconsistencies when medical exemptions are granted to younger and less qualified pilots for problems which are potentially as threatening to safety as aging alone.

The FAA is responsible for promoting aviation safety; therefore, it is supposed to regularly re-examine the medical and scientific advancements that may affect this age regulation (GAO, 1989). Inconsistencies in the safety levels of older pilots as reported by various studies make the rule even more controversial; e.g., using the two highest experience categories, Serwer (1990) found the accident rate for older pilots (60-69 years old) to be almost three times less than those rates for younger pilots (20-29 years old); whereas Golaszewski (1983) found the accident rate for older pilots to be higher than the younger pilots' rate, suggesting that older pilots are likely to be less safe. Why? Is this because the performance capabilities of pilots decline as they grow older, or can these age-related changes be attributed to other factors? It should be apparent that this is a very complex issue with many details and requires an objective data based conclusion.

Statement of the Problem

The purpose of this study is to determine whether the available data indicate that there are any significant decreases in the safety and effectiveness of pilots by age 60; e.g., the incidence of accidents increases as a function of age. Do older pilots pose a greater risk due to either sudden incapacitation or undetected decrements in physical or mental performance? If so, at what age? Does the current arbitrary age limit for airline pilots achieve the system's purpose of maximizing safety?

Review of the Related Literature

It is clear that a better understanding of the aging process and its effects on flight safety is needed. A large proportion of the literature reviewed supports the hypothesis of a progressive decline in abilities with advancing age. However, there are some recently published reports that suggest that the data on aging needs to be reanalyzed and/or re-evaluated. For example, Labouvie-Vief (1985) noted that the very concept of aging is undergoing a shift in theoretical emphasis. Labouvie-Vief indicated that the question, "Is there decline in aging per se?" may no longer be the most useful one to pose (p. 501). Additionally, we need to recognize the myths and stereotypes typically associated with the aging process. Eisdorfer (1985) reported on the mythologies of aging and noted that the first myth of the aging process is that age brings with it a series of functional declines and decreases a person's ability to be productive. The second myth is that one's ability to perform a given task decreases as we grow older. The work of these writers suggests that it may be diseases that are more common in the elderly population that affect safety rather than age per se.

Physiological Effects of Aging

Gerontological studies prior to the 1960s were based on older subjects taken from hospitals, nursing homes, and other institutional settings (Mohler, 1981). Until recently, as reported by Rodin (1987), research on aging has only emphasized the losses associated with the aging process. However, in a break from tradition, Rodin noted that we know biological vulnerabilities associated with old age are capable of being reduced or made less severe. Likewise, Bortz (1980) found that many changes commonly attributed to aging can be retarded by an active exercise program. These findings are repeated in a number of reports that attest to the benefits of exercise in various human disease states (Bruce & Fisher, 1987; Fox & Haskell, 1968; Hellerstein, Hornsten, Goldbarg, Burlando, Friedman, Hirsch, & Marik, 1967; Mohler, 1982; The Medical Study Group, 1988).

The physiological literature indicates that there usually are physical decrements in *vision* with increasing age (Corso, 1987; Edwards, 1990; Eisdorfer, 1985; Fozard, 1990; Gault, 1990; IOM, 1981; Kline & Schieber, 1985; Sanders & McCormick, 1987; Shriver, 1953). Gault noted that the pupils tend to become smaller, especially after 60, therefore restricting the amount of light available for proper eye functioning. Likewise, Kline and Schieber found that the decline in dark adaption appears to be particularly marked after age 60. In terms of quickness, the older eye adapts to the dark the same as the younger one; however, it does not attain the high level of sensitivity (i.e., more light is needed to perform a given task). Gault also noted that a pilot of 60 might need ten times the amount of light than a 25-year-old. However, the role of eyeglasses and cockpit lighting are issues relevant to this topic, but require further study. Other research (Mohler, Bedell, Ross, & Veregge, 1967) analyzed accidents involving pilots over 60 and found that more than 51% of the accidents occurred during the landing phase of operations, where eye-sight is critical. However, Mohler et al. did not report the percentage of accidents during the landing phase for younger pilots; thus it is not possible to assess the significance of their findings on a comparative basis.

The literature also suggests that there are age-related declines in *audition* with advancing age (Corso, 1987; Edwards, 1990; Fozard, 1990; IOM, 1981; Olsho & Harkins, 1985; Ribak, Hornung, Karl, Froom, Wolfstein, & Ashkenazi, 1985; The Medical Study Group, 1988; Von Gierke & Nixon, 1971). Corso indicated that the two primary factors that produce hearing deficits are *age* and *noise*. The Medical Study Group noted that hearing impairment is inevitable with advancing age, particularly in the higher frequency range (i.e., above 1,000 Hz). These hearing changes are often characterized as progressive and irreversible. *Presbycusis* is the term most widely used to refer to age-related changes in hearing ability. Olsho and Harkins noted that presbycusis is one of the major sensory changes associated with aging in humans. Nonetheless, some compensatory devices (e.g., hearing aides, volume controlled headsets) may adequately compensate for this age-related change, but this too requires further study.

Does a hearing disability have any operational significance to pilots in a crew environment? If the loss is significant, can it slip through the recurrent Line Oriented Flight Training (LOFT) sessions and first class medical examinations? In light of the latter question, Reinhart (1991) reported that pilots intentionally seek out the easiest medical examiner to avoid learning more than they really want to know; thus, in terms of pilot health, what the public expects and what the public gets may be two different things.

The most important aspect of hearing for pilots is the ability to understand speech and to distinguish between the different types of warning signals, especially in a noisy and sometimes stressful cockpit. However, Szafran (1969) found no evidence of any discrepancy in the ability to recognize a signal from a background of white noise with subjects between 40 and 60 years of age. Although some literature suggests that declines in hearing occur at all adult age groups, not just the old, the IOM (1981) report found that 80% of people with hearing problems are over 45, and nearly 55% are 65 or older. Although these age-related declines in audition have been widely reported, the relevance of these changes to the pilots' job performance has not yet been established.

Psychological Effects of Aging

As people grow older, physiological and psychological changes inevitably take place. One of the least disputed and most pronounced findings in the gerontological literature is the slowing in cognitive processing that occurs with advancing age (Braune & Wickens, 1984; Gilbert & Levee, 1971; Hartley, Harker, & Walsh, 1980; Morrow, Leirer, & Yesavage, 1990; Reese & Rodeheaver, 1985; Salthouse, 1985; Spilich, 1983). This slowing in cognitive abilities has a number of closely related functions. The literature indicates that reaction time, attention, memory, problem solving, decision making, and intelligence, for the most part, tend to decline with increasing age, and have applications in the operational aspects of piloting an aircraft.

Several studies note that as we become older, *reaction time* has a tendency to slow down (Braune & Wickens, 1984; Braune, Wickens, Strayer, & Stokes, 1985; Cann, 1990; Craik & McDowd, 1987; Eisdorfer, 1985; Fozard, Vercruyssen, Reynolds, & Hancock, 1990; Gault, 1990; IOM, 1981; Murrell, 1970; Salthouse, 1985; Shock, Greulich, Andres, Arenberg, Costa, Lakatta, & Tobin, 1984; Simon, 1967; Vercruyssen, Carlton, & Diggles-Buckles, 1989; Wilkinson & Allison, 1989). It is probably one of the only aging effects that researchers have no disagreement over (Tsang, 1989). Gault noted that a younger person can react more quickly and strongly to urgent situations than can his older counterpart. However, older persons who retain response quickness do compete well with younger individuals. But how well? It may be true that a slower reaction time might be critical in the landing phase during which a number of tasks must be carried out rapidly. Nevertheless, Braune and Wickens suggested that a reasonable explanation for this reduction in response time could be attributable to a more conservative response, thus the responses are slower but more accurate. Additionally, Murrell found that reaction time could be improved with practice, regardless of age, but older individuals require much more practice than the younger subjects, whose performance improved immediately.

On one hand, Eisdorfer (1985) asks whether or not a few milliseconds difference in time between an older and younger pilot has any practical significance. Eisdorfer contemplated whether the small changes in speed are more or less offset by the fact that the older pilot, having experienced many different adverse situations in the cockpit, would be able to judge each situation and perhaps deal with it faster? On the other hand, the IOM (1981) report suggested that there are some situations in airline operations during which a few hundred milliseconds are operationally significant. The example cited involves a pilot who has to abort a takeoff (e.g., engine out, engine fire, blown tire). This condition requires complex decision-making and a very short reaction time; and the slightest hesitation could result in a tragedy.

It should also be asked whether an older pilot might be more easily overloaded in high workload situations where fatigue is likely to take its toll. Some research (e.g., Shriver, 1953; Schreuder, 1966) indicated that the increased susceptibility to mental fatigue is by far the most frequent type of change reported to occur with advancing age. It has also been noted (Higgins, Mertens, McKenzie, Funkhouser, White, & Milburn, 1982) that fatigue can adversely affect not only the accuracy, but also the timeliness in performance. Other research (Collins & Mertens, 1988; Mertens, Higgins, & McKenzie, 1983) has found a similar relationship—that is, at higher levels of workload, performance decreased with age.

Botwinick (1978) noted that there are two distinctive views when referring to reaction time. The first is that the general slowness in behavior is only a matter of the kinesthetics, and is thus of no importance to cognition. Therefore, the variety of tests which measure timed performance are unfair and inappropriate for testing older individuals. A contrary view offered by Braune and Wickens (1984) suggested that the speed of response is, nevertheless, a reflection of the central nervous system functioning and is most important to cognition. To this researcher's knowledge, there are no empirical data available that would conclusively support one view over the other.

Attention, like memory and intelligence, is a multifaceted concept. Some research on aging and attention (e.g., McDowd & Birren, 1990; Stankov, 1988) has subdivided attention into the following four categories: divided, switching, sustained, and selective. Of particular importance to pilots are the categories of *sustained* attention (i.e., similar to vigilance) and *selective* attention (i.e., the ability to focus on a task while ignoring irrelevant aspects). McDowd and Birren noted that sustained attention is the activity of maintaining performance on a particular task over extended time; and vigilance, as noted in Botwinick (1978), can be conceptualized as the ability to detect rarely occurring signals over a prolonged period of time, or simply the efficiency with which small but perceivable changes in the external environment are detected (Surwillo & Quilter, 1964).

There have been some reports on age-related changes in vigilance tasks that have shown somewhat mixed results (e.g., see Surwillo & Quilter, 1964; Quilter, Giambra, & Benson, 1983). Despite their contradictions, one investigator (Botwinick, 1978) conducted a thorough literature review and noted that there have been several investigations of vigilance performance in relation to age, and they all tend to suggest that vigilance behavior declines with advancing age. A study by Thompson, Opton, and Cohen (1963) tested 55 male subjects in two age groups, 18-35 and 65-75 years of age. The results show a marked decrement in vigilance performance in the older subjects; and the more complicated and demanding the task, the greater the performance decrement.

The IOM (1981) discussed selective attention and vigilance in their report and noted that an individual's inability to maintain attention would lead to a decrement in performance on many tasks, and may even lead to accidents. Additionally, McDowd and Birren (1990) conducted an exhaustive review of the literature on aging and attention and found that the overall levels of performance on vigilance tasks appear to be reduced with advancing age.

Piloting an aircraft, as reported in a letter in Select Committee on Aging (1985), often requires efficient extraction of information from a broad cluster of relevant and irrelevant stimuli in which it is embedded. It is necessary for pilots to monitor many sources of information (e.g., cockpit instruments, weather conditions) and focus their attention selectively. This selective focusing of attention is probably one of the more important functions. McDowd and Birren (1990) noted that individuals must filter out irrelevant information from their environment and select information that is task or goal oriented. Several studies were reviewed by McDowd and Birren and the prevalent findings suggest that older adults are more distracted by irrelevant information in visual search tasks than are young adults. This and other research (e.g., Rabbitt, 1977; Schonfield, 1974) suggest that older adults seem to have more difficulty discriminating relevant from irrelevant information. Despite these shortcomings, McDowd and Birren reported that some other research (e.g., Hoyer & Plude, 1982) has looked at the role of expertise in visual search tasks. They stated, "Knowing what to look for can speed search, and experts in particular domains [e.g., airline pilots] can compensate for sensory acquity problems by knowing which features of a search field are relevant and which are not" (p. 228).

Gilbert and Levee (1971) indicated that nowhere have decrements in cognitive abilities been more evident than in the area of *memory*. Memory is often characterized as a basic human function. It is interrelated with perception, attention, decision making, judgment, information processing, and many other functions (Edwards, 1990). The literature on age differences in human memory includes a number of studies comparing the performance of young and old adults on a variety of memory tests, and the prevalent view suggests that there is some decline in memory ability with increasing age (Botwinick, 1978; Craik, 1977; Craik & Byrd, 1982; Craik & McDowd, 1987; Gilbert & Levee, 1971; Gordon & Clark, 1974; Hartley, Harker, & Walsh, 1980; IOM, 1981; Moenster, 1972; Perlmutter, 1980; Perlmutter, Adams, Berry, Kaplan, Person, & Verdonik, 1987; Poon, 1985; Spilich, 1983).

Patterns of age differences in six subtests of the Guild Memory Test were presented by Gilbert and Levee (1971) and the results showed a progressive decline in scores with increasing age. The 50-59 and 60-75 year old subjects showed statistically reliable decrements as compared to the 35-49 year old group. However, Perlmutter et al. (1987) concluded that age differences in reports on memory performance have not been entirely consistent. It appears that the failing memory is both a popular stereotype and a concern about aging. Younger adults are just as likely to experience memory failures, but are less concerned than older adults by them; thus, they are not reported as frequently. Some research (e.g., Perlmutter, 1980; Poon, 1985) has speculated that age merely increases a person's sensitivity or awareness about memory problems, and may not at all be related to memory failures. In addition, Perlmutter et al. suggested that many of the memory problems that are observed later in life (e.g., recalling recent events, speed of recall) may be partially caused by factors that tend to be correlated with age, but are not inevitable consequences of aging. There is, however, a substantial amount of literature on the possible causes and theoretical paradigms of the changes in memory with advancing age, but that work is beyond the scope of this study.

Many pilot activities frequently require memory operations. Pilots are often overloaded with data in flight situations (e.g., communication frequencies, navigation frequencies, altitudes, clearances, runways) and these memory functions often influence a pilot's judgment and performance. However, Braune and Wickens (1984) noted that there are weaknesses in memory that are not realistically controllable by regulation, recurrent training, or even therapy. Can such deficits in memory result in a pilot's failure to detect a hazard or his/her inability to deal with the situation if encountered? In light of this question, Poon (1985) reviewed more than 200 reports and found that one study (Perlmutter, 1980) has suggested that although older adults probably have less efficient memory mechanisms, their rich experiences possibly allow them to perform some tasks at the same or higher level than younger adults. A similar remark was found in Hawkins (1987), who suggested that any memory deterioration which does occur may be offset by increasing experience and knowledge. Pilot experience is examined in a subsequent section of this study.

One report (Gilbert & Levee, 1971) indicated that there is evidence that the various facets of memory decline at different rates. In the same respect, Craik (1977) found that not all facets of the *working memory* are affected by the aging process. The working memory, also known as the primary memory or short-term store, is conceptualized as a limited capacity workspace that is used for temporary storage (Edwards, 1990; Leirer, Yesavage, & Morrow, 1989; Poon, 1985). No doubt, aircraft piloting is highly dependent on the working memory's capacity (e.g., different performance speeds, fuel systems, communication frequencies, navigation frequencies, emergency procedures). According to Leirer et al., many aspects of piloting are so complex that performance is limited by the working memory's speed or capacity to process rather than the availability of information for the pilot to use. Other research on the working memory was conducted by Spilich (1983) who compared young, elderly-normal, and elderly-impaired subjects whose mean ages were 21, 81, and 82 years of age respectively. The results showed a statistically significant difference in Wechsler Memory Scale scores which suggests that the older subjects are less able to maintain new information in the working memory. These findings lend evidence to the suggestion that aging could impair a pilot's ability to update his/her mental model with new information, therefore, limiting the quality of performance (Morrow, Leirer, & Yesavage, 1990).

Not all research has demonstrated a clear or consistent age-linked deficit in memory. The literature reviewed gives contradictory results that may be attributed to methodological or design issues (e.g., cross-sectional versus longitudinal). Nevertheless, Hawkins (1987) concluded that the effect of aging on memory varies with the individual and it is difficult to draw generalizations from the data. Other research (e.g., Poon, 1985) has suggested that the degree of impairment in memory functions is highly related to the integrity of the biological system of the older adult. That is, the healthier the person, the less likely that person will experience memory problems. Supporting this, research over the last two decades has shown that intense physical conditioning can partially reverse some of the functional losses that typically accompany normal aging (Perlmutter et al., 1987). From this, one can reasonably suggest that the physiological improvements acquired from an active exercise program could also contribute to improvements in cognitive functioning as well. Thus, physical fitness may be an important factor to consider when evaluating the memory performance of older adults. Other factors to consider include practice and item familiarity. Poon noted that these are powerful variables in reducing age changes and improving the memory performance of older adults. Therefore, it is reasonable to speculate that these factors would put the pilot population, particularly well-practiced airline pilots, at a definite advantage compared to others within their age groups.

Based on the available information, it is logical to infer that many cognitive processes greatly overlap. For example, Reese and Rodeheaver (1985) indicated that the memory often influences performance in situations intended to assess competence in other areas, such as *problem solving.* Although memory is not in itself a problem solving ability, it can in fact be an aid to problem solving. From this, we can safely infer that any variable(s) that interfere with memory (e.g., attention, intelligence) will likely interfere with problem solving abilities. As in other areas of cognitive performance and aging, most of the problem solving research is cross-sectional in nature. In addition, Shock et al. (1984) noted that there have only been a few studies that have measured the changes in problem solving performance with age. One review (Arenberg, 1982) reported that these studies tend to show age differences with the older subjects performing less well than their younger counterparts. It is, however, recognized by gerontological investigators that age and birth cohorts (e.g., education, culture) are confounded in cross-sectional studies. This implies that age differences revealed in many of these studies may in fact represent *differences* between cohorts rather than *decrements* due to age.

Without a doubt, flying safe is a mentally demanding task. Pilots sometimes have to solve problems, divide time between difficult tasks, and exert a strong effort toward keeping mental control throughout the flight (Edwards, 1990). Reese and Rodeheaver (1985) reported that problem solving involves assessing the present state, defining the desired state, and finding ways to transform the former to the latter. It is interesting to note that Giambra and Arenberg (1980) suggested that there is a large class of problems that most individuals may not be able to solve until they have had extensive experience with such similar problems. A classic example is the Sioux City DC-10 accident, in which the aircraft lost all three hydraulic systems. There were no procedures in the emergency manual for such an event, so the 58 year old captain had to come up with a method of his own. The captain maintained the aircraft's directional stability by using differential thrust. He crash landed his crippled airplane, but his quick thinking and problem solving ability saved 186 lives (Stephens, 1989).

Decision making, somewhat related to problem solving, refers to the evaluation of the possible solutions and selecting one to carry out. Salthouse (1990a) indicated that an essential requirement for pilots is their effectiveness in high-speed decision making. Some researchers perceive accidents as being related to decisions that bring about unfortunate or inappropriate responses (Sterns, Barrett, & Alexander, 1985). Reese and Rodeheaver (1985) noted that any differences observed in decision making or problem solving performance between elderly and young adults might reflect to a large extent cohort differences that introduce confounding variables.

Intelligence, like memory and attention, is not a unitary quality. It is often categorized into dimensions such as crystallized, fluid, psychometric, and general intelligence. Of particular importance to the flying environment is that of *crystallized* and *fluid* intelligence. Sterns, Oster, and Newport (1980) noted that crystallized intelligence is presumed to reflect prior learning and experience (e.g., vocabulary knowledge, general information); whereas, fluid intelligence, according to Salthouse (1990a), reflects the efficiency of current processing (e.g., tasks that emphasize speed or accuracy of associations, decisions, or responses). Intelligence overall is a vital and essential quality of a pilot for much of his/her successful behavior. Does intelligence decline in old age or does it remain unaffected as time passes by? In many cases, the results have been interpreted as contradictory (e.g., see Baltes & Schaie, 1976; Horn & Donaldson, 1976). There are, however, some issues on which there seems to be a high level of agreement. For example, some crystallized intelligence abilities of healthy individuals can be expected to improve throughout life by increased or higher levels of education. On the other hand, fluid intelligence abilities are influenced by the physiological status of the individual; thus, any physiological degeneration will usually result in a decrement in fluid intellectual abilities. Horn and Donaldson have cautioned that decrements in intelligence, whether crystallized or fluid, are not inevitable in every person and are not an inherent aspect of the aging process.

The psychological literature on intelligence and aging over the past few decades has been dominated by a stereotypic view of decline (Baltes & Schaie, 1976). Representative of this view, Botwinick (1977) noted that the decline in *intellectual ability* is clearly a part of advancing age. However, in one of his subsequent reports Botwinick (1978) suggested that the recent literature which focuses more on longitudinal research points to small declines in intelligence with age, and in some instances, no decline whatsoever. Similar results were reported by Horn and Donaldson (1976). After presenting a thorough review of the logical and empirical evidence, they suggested that some intelligence abilities (e.g., verbal comprehension, numerical skills) improve throughout most parts of adulthood, or at least do not decline as much or as early as other abilities. They concluded that perhaps some adults manage or learn to avoid decrements which affect others. Baltes and Schaie (1974) found that on many measures of vocabulary and skills reflecting educational experience, individuals seem to maintain their levels of functioning into their sixth and seventh decade without any noticeable losses.

Whether or not aging per se alters intelligence is not an easy question to answer because of the many components of intellectual functioning and their differential relationships among one another. For example, the IOM (1981) report mentioned that an early decline in intelligence in active airline pilots (i.e., prior to 60 years of age) is very unlikely. Pilots as a group appear to have above average intelligence and there appears to be no correlation between age and intelligence. Another report (Labouvie-Vief, 1985) conducted an exhaustive literature review and found that most research on the cognitive capacities of aging adults is still performed using models that address themselves to youth rather than adulthood (e.g., testing techniques and measurement instruments). Other research (Schaie, 1974) supports the previous comment by suggesting that a presumed decline in intelligence with old adults is, at best, a methodological artifact. There appear to be large interindividual, cultural, and generational differences that are likely to influence test results. Labouvie-Vief concluded that cognitive abilities of older adults are inevitably interpreted with a regression-oriented bias. Some research (e.g., Horn & Donaldson, 1976) has suggested that our state of knowledge about intelligence and aging is not sufficient to permit authoritative assertions that there is, or that there is not, any intelligence decrement associated with aging.

Other types of cognitive processing that are occupationally relevant to a pilot's job were also reported (Glanzer & Glaser, 1959; Mertens & Collins, 1985; Salthouse, Babcock, Skovronek, Mitchell, & Palmon, 1990). Salthouse et al. conducted three separate studies in order to investigate the effects of age and experience on *spatial* *visualization abilities* among members of an occupation in which these abilities are in constant use (i.e., architects). Spatial visualization refers to the mental manipulation of spatial information (e.g., where another aircraft is or will be relative to your physical position and heading). The samples consisted of 107 men ranging in age from 21 to 78 years. They found that increased age was associated with significantly lower levels of performance, even for those subjects with extensive spatial visualization experience. They concluded that their findings suggest that age-related changes on certain aspects of cognitive functioning may be independent of the amount of occupational experience.

One of the very few studies that conducted research on pilots was done by Glanzer and Glaser (1959). They tested 544 subjects which were Air National Guard aircrewmen and/or commercial airline pilots between 20 and 50 years of age (mean age of 31.8 years). The test battery consisted of 14 psychometric tests measuring job tasks critical to pilot performance (e.g., learning and remembering, interpreting spatial patterns, mathematical reasoning, numerical calculations and approximations). In eight of the 14 tests, statistically significant age-related declines were observed on the basis of their cross-sectional data, even after flight experience was compensated for. However, the mathematical skills, which are very important to a pilot's job, did not show decrements with increased age. Other research (Mertens & Collins, 1985) examined various aviation-related tasks. They tested 30 healthy non-pilot subjects to determine the effects of stressors (e.g., sleep deprivation, altitude) on complex performance. A multiple-task battery was used to measure the performance of several flight-related tasks under varying workload conditions. The tasks included monitoring warning lights and meters, mental arithmetic, problem solving, target identification, and tracking. They found that the performance of older subjects (60-69 years old) was consistently lower than the younger subjects (30-39 years old) in all tasks.

Although there are many studies on aging in humans, Braune and Wickens (1984) suggested that since most of this research has not been conducted on pilots, the extent to which these studies can be generalized to pilots may indeed be limited. The IOM (1981) report suggested that aging effects established for general population subjects may not apply to pilots, especially airline pilots who constantly exercise well-practiced skills. Gault (1991) found that from a pilot's point of view, the effects of aging are of more interest as compared to most other groups because of the occupation's exacting demands on individual abilities and capacities. Another finding (e.g., Reinhart, 1982) indicated that most professional pilots are well informed about age-related changes and have a number of resources available to them so that they can educate themselves in health maintenance. In addition, some studies (e.g., Booze & Simcox, 1984; IOM; The Medical Study Group, 1988) found that pilots have demonstrated to be more physically fit than the general population at comparable ages, in addition to being better educated. Nevertheless, some physical components, perceptual capabilities, and sensory functions will deteriorate to a certain extent with increased age.

The psychological literature reviewed suggests that age-related changes do occur in all individuals with advancing age, and some abilities relevant to pilot performance will inevitably deteriorate. However, it would be misleading to state that these age-related changes occur by age 60, especially in healthy professional pilots. In fact, many studies have indicated that great variations in individual capabilities and tolerances exist from person to person (Braune & Wickens, 1984; Gerathewohl, 1978b; IOM; Mohler, 1981; Shriver, 1953; Szafran, 1969; The Medical Study Group; Tsang, 1989; Wentz, 1964). For example, a nonroutine event (e.g., loss of electrical power, in-flight fire) might be totally disabling to one person, but taken in stride by another. In summary, the psychological literature suggests that the status of the generally anticipated deficits in abilities associated with aging is left open to discussion, particularly with respect to healthy professional pilots.

Regulatory Background

The current procedures for regulatory control of this problem vary in the U.S., depending upon the type of flight operations. General aviation pilots can fly as long as they can maintain a current medical certificate appropriate for their type of flying duties. The same is true for commuter pilots, charter pilots, corporate pilots, and even the FAA's own pilots. However, regulatory control for airline pilots is more rigidly defined. At 60 years of age airline pilots may no longer serve as PIC. Braune and Wickens (1983) suggested that it is assumed that chronologically younger individuals are more likely to perform better in such a demanding environment; thus, chronological age limits are imposed. This age regulation is the result of a combination of several difficult-to-define variables which are believed to lead to the anticipated deterioration of the skills necessary to fly an airliner at the safety level we have come to demand (Lavin, 1989).

This anticipated deterioration of essential capabilities has been used to justify the age limitation for U.S. airline pilots. Three decades ago, the FAA mandated an upper age limit on all pilots of commercial airliners weighing more than 7500 lb and carrying more than 30 passenger seats. This regulation was issued on December 1, 1959, and implemented on March 15, 1960. It is commonly known as the *Age 60 Rule* and is administered by the U.S. government under Part 121.383(c) (Appendix A) of the Federal Aviation Regulations which prohibits individuals from serving as pilot or copilot of these commercial airliners upon reaching their 60th birthday (GAO, 1989).

Part of the rationale asserted by the FAA to support this regulation was that the risk of heart attack, stroke, or sudden incapacitation sharply increased after age 60 and that no accurate scientific means of assessing risk on an individual basis then existed. The reports and research studies in which the FAA finalized their conclusions are dated from 1938 to 1958. The studies were based on characteristics of the entire American adult male population, rather than on the healthier and better monitored pilot population (Select Committee on Aging, 1979). According to the GAO (1989), the FAA adopted the Age 60 Rule because of the large increase in the number of older pilots and the potential effects that this might have on public safety in commercial air transportation. Although not a problem at the time, the FAA concluded that accidents among older pilots could become one.

The Age 60 Rule is not considered as a mandatory retirement policy by the FAA because it does not prohibit pilots from serving in other capacities. Upon reaching their 60th birthday, pilots can contribute their knowledge and expertise by becoming flight instructors, check airmen, or flight engineers (Select Committee on Aging, 1985). Also, since this rule does not apply to the commuters (i.e., Part 135 scheduled operators), pilots 60 and over can fly smaller aircraft that weigh less than 7,500 lb and have fewer than 30 passenger seats (GAO, 1989). Why does this rule not apply to these pilots as well? No detailed explanation has ever been given for the underlying logic that allows other pilots to fly beyond age 60. One airline pilot (S. G. Broderick, personal communication, June 1, 1990) contested that commuter pilots often fly "harder time" in less equipped aircraft, and often up to eight or nine legs per day. The National Institute on Aging (1981) recommended that the Age 60 Rule should be extended to all pilots, specifically commuter pilots. By its very nature, this rule has been extremely controversial. It has frequently been scrutinized in legal challenges, public hearings, and legislative actions.

Other reports (e.g., Mohler, 1981; Mohler, 1986) found that our neighboring countries, Canada and Mexico, have no Federal upper age limit for commercial pilots. Mohler (1981) went on to note that in Great Britain, the upper age limitation of 60 years of age only applies to the captain. Additionally, Reinhart (1991) reported that British Airways requires their pilots to retire at 55; but just recently, the airline gave pilots the option to fly beyond 55 if they took additional tests. In light of this issue, several letters were written to foreign nations requesting the exact nature of their regulatory control for pilots. Many countries responded and a synopsis of the relevant statements is presented in Table 1. The actual letters are reproduced in Appendix B.

There have been other proposed alternatives and procedures to this highly debated issue. One possible technical solution suggests involving more comprehensive medical and performance tests than are currently required (Boone, 1982; National Institute on Aging, 1981; Office of Technology Assessment, 1990; Select Committee on Aging, 1979).

Table 1. Synopsis of Pilot Age Limits from Foreign Letter Responses

Country	Summary
Australia	*Non-commercial operations* — no upper age limit, provided that pilots satisfy the medical standards appropriate to the level of license held.
	Commercial and higher category license — no upper age limit, but restrictions placed upon pilots who have reached age 60. Those restrictions are: the aircraft must be equipped with dual controls and the operating crew includes another pilot who has not reached 60 years of age, and (a) if the pilot is <65 years of age, he/she must pass a flight test within the preceding 12 months, and (b) if the pilot is ≥65 years of age, he/she must pass a flight test within the previous 6 months.
Finland	*Private Pilot License* — no upper age limit.
	Commercial and Air Traffic Pilot license — upper age limit of 60.
Germany (G.D.R.)	*All pilots* — no upper age limit; only criteria for terminating an aviator's career are the medical regulations.
Mexico	*General Aviation Pilots* — no upper age limit.
	Airline Pilots — agreement between airlines and pilots' union to retire at 60.
New Zealand	*All Pilots* — no upper age limit. An aviator's career is terminated if he/she develops a medical condition for which a waiver cannot be issued.
Norway	*Private Pilot License* — no upper age limit provided that the pilot satisfy the minimum flying hours per year and have valid medical papers, or have passed a biannual Periodic Flight Training (PFT) session.
	Commercial Pilot License — upper age limit of 60 for international flights.
United Kingdom	*Private Pilot License* — no upper age limit, but an increase in frequency of medical examinations with age (see Appendix B for details).
	Professional Pilot License — upper age limit of 60 with respect to Public Transport; however, pilots may continue as Public Transport pilots until age 65, provided they are a member of a two-pilot crew aircraft with a maximum total weight authorized not to exceed 20,000 kg (43,860 lb).

Recently, political solutions have been proposed. U.S. Representative James Lightfoot introduced a bill (H.R. 3498) to the House of Representatives to increase the current age limit from 60 to 65, and Iowa Senator Charles Grassley introduced an identical bill (S. 2077) to the U.S. Senate (Cox, 1990). Both bills are currently on hold. See Appendix C for a copy of H.R. 3498.

Background of the Age 60 Rule Controversy

After the Age 60 Rule went into effect, the reaction from the airline industry was divided. Some aviation organizations supported the rule, while others called it discriminatory and strongly opposed it (GAO, 1989). Over the years, a number of pilots have legally challenged the FAA's policy of denying all requests for exemption from the Age 60 Rule. Recently, as noted in *FAA Reopens* (1989), the Federal Court of Appeals for the Seventh Circuit vacated exemption denials of 39 airline pilot petitioners. The court concluded: " . . . the FAA failed to set forth a sufficient factual or legal basis for the rejection of the petitioner's claim that older pilot's edge in experience offsets any detected physical losses" (p. 2). On October 31, 1990 the Appeals Court affirmed the FAA's denial of exemptions in a 2-1 decision. According to an aviation attorney (A. M. Serwer, personal communication, November 27, 1990), this permits the FAA to deny all exemption petitions to the Age 60 Rule.

In order to establish a basis for revocation of the Age 60 Rule, the FAA held two public hearings, one in 1970 and the other in 1977. The Aerospace Medical Association and the Committee on Aerospace Medicine of the American Medical Association both supported the rule. Furthermore, the revocation request was denied at both hearings (GAO, 1989). It is believed that these organizations supported the rule because no other acceptable alternative(s) that would offer equivalent protection to the American travelling public could be determined; and since our aviation system has operated effectively and safely within its bounds for the past 20 years, there seemed to be no need to change it.

Some who once favored the Age 60 Rule are now starting to express some concern. Former president of the Aerospace Medical Association, Dr. George Kidera, who was on the panel that originally wrote the rule was more recently quoted in Dodson (1990): "We knew it was arbitrary, but we just couldn't accurately predict which pilots were likely to fall ill and which weren't. Now we can, so there's no reason not to let a qualified pilot fly beyond age 60" (p. 194).

Pilots and other aviation enthusiasts have also challenged the Age 60 Rule by legislative means as well. In 1979, the House Select Committee on Aging, the House Subcommittee on Aviation, and the Committee on Public Works and Transportation held hearings to determine the status of the rule. The GAO (1989) found that the result of those hearings was Public Law 96-171 (see Appendix D). Briefly, this law called upon the National Institutes of Health to conduct a study to determine whether or not mandatory retirement for certain pilots at age 60 or any other age was justified. The National Institute on Aging (1981) was assigned to the project, and their report concluded " . . . that there is no convincing medical evidence to support age 60, or any other specific age, for mandatory pilot retirement" (p. 2). However, the study also suggested that if the current age limit were increased, the probability of accidents would also increase. Unfortunately, the study did not make any projections regarding the magnitude of this increase in accidents, nor how the increase would compare to other younger groups of pilots.

Exemption requests and challenges to the Age 60 Rule continue to occur. After reviewing several studies focused on gerontology, degenerative diseases, physiological and psychological changes, and the pilot population in comparison with the general population, the FAA concluded that there are no alternatives that would ensure the same level of safety as that of the Age 60 Rule. According to the GAO (1989), the FAA argues that regardless of advances made in medical diagnosis and treatment, and in primary prevention techniques, the incidences of death and disability from degenerative diseases increase with age (see Figure 1).

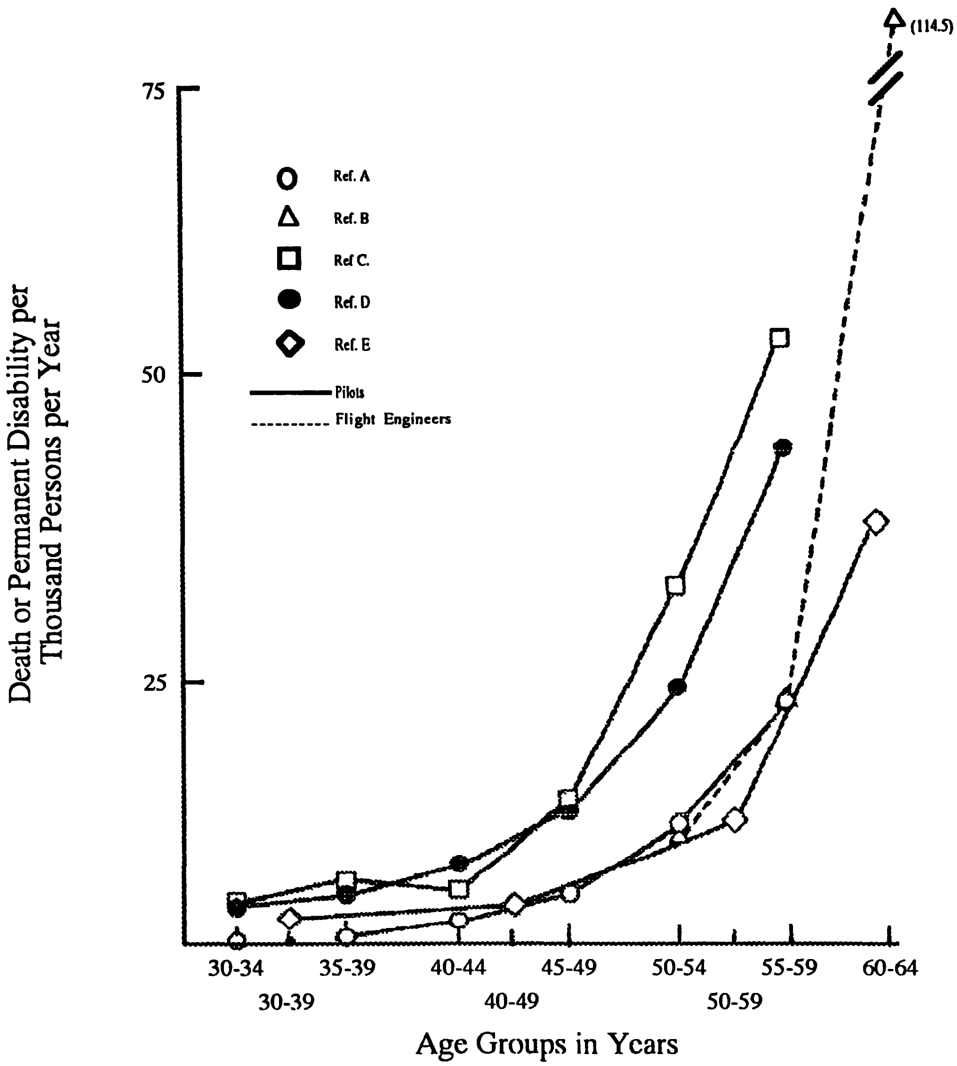

Figure 1. Death and Disability Rates in Air Carrier Pilots and Flight Engineers
From *"Report of the National Institute on Aging Panel on the Experienced Pilots Study"* by National Institute on Aging, 1981, p. 3.

A. Pilot permanent groundings for medical reasons, U.S. air carrier. Letter communication, Walter A. Jensen, Vice President, Operations and Engineering, Air Transport Association of America, June 24 and July 16, 1981.

B. Flight engineer permanent groundings for medical reasons, same carrier as (A). Letter communication, Walter A. Jensen, Vice President, Operations and Engineering, Air Transport Association of America, June 24, 1981.

C. Medical retirements and deaths, U.S. air carrier. Orford, R. R. and Carter, E. T. ,*Aviation, Space and Environmental Medicine, 47*(2): 180-184, 1976.

D. Deaths and permanent disabilities in flight crew holding ALPA Loss of License insurance. Kulak, L. L., Wick, R. L. and Billings, C. E.,*Aerospace Medicine, 42*(6): 670-672, 1971.

E. Pilot groundings, U.S. air carrier. Jensen, W. A. In: Hearings before the Subcommittee on Aviation, U.S. House of Representatives, concerning H.R. 3948, July 18-19, 1979.

The legal and political challenges of pilots' wanting to fly as PIC beyond age 60 and the defensive position of the FAA have polarized the issue. Both sides may be expected to selectively seek and report data supportive of their positions on the issue. Consequently, the need for an objective evaluation of the age-related issues and regulatory solutions is paramount, especially with the anticipated shortage of qualified pilots that has been forecasted, along with the projected growth of the U.S. commercial airline industry.

Corroborating Reports of Age-Related Accidents

There have been recent efforts to support the Age 60 Rule with age-related accident statistics. These supporting statistics come from a seven-year-old study which covered accidents in *general aviation* from 1976 to 1980 (Golaszewski, 1983). General aviation entails the operations of U.S. civil aircraft owned and operated by persons, corporations, etc., other than those engaged in U.S. air carrier operations, like scheduled airliners or commercial operators of large aircraft (IOM, 1981). Koonce (1989) pointed out that this study suffers from a number of serious deficiencies. The study claims that as pilots age, there is an increase in the *accident rate*. The accident rate is commonly calculated as the number of accidents divided by 100,000 hours of *recent* flight time (i.e., annual flight time). The data used in Golaszewski's study represented all pilots (Class I, II, and III medical certificates) flying all types of aircraft, such as homebuilts, aircraft without copilots, and single-engine aircraft which may be less safe than commercial transport aircraft supported by large maintenance organizations. Golaszewski's study has been under much scrutiny; however, he did indicate that his research was never intended to support the Age 60 Rule. It was a preliminary research project to learn something about how experience and age relate to accidents (Stephens, 1989).

There have been other studies in the past that have looked at aviation accident statistics as a function of pilot age. Harper (1964) found that increasing age contributes significantly to accidents as well as to fatality rates. Harper also suggested that increasing age is closely associated with an increased risk of accidents. A similar report (Booze,

1977) noted that several previous studies have indicated that age is repeatedly associated with an increased risk of general aviation accidents. Supporting this, Lategola, Fiorica, Booze, and Folk (1970) analyzed civil aviation accidents and found that with the exception of the 40-49 age group, the *accident record* (accidents per 10,000 airmen) increased with age. It should be noted that the accident record tells us nothing of the pilot's risk or exposure factor (e.g., how many hours flown or the number of takeoffs and landings per pilot). According to the National Institute on Aging (1981) report, exposure is perhaps the most important factor in aviation accident statistics. One other study (Office of Technology Assessment, 1990) found that pilots between 60-69 years of age who held first and second class medical certificates, had an accident rate twice as high as similar pilots in their 50s, but a lower rate than pilots between 20 and 39 years of age.

On the other hand, Fotos (1988) reported that pilots in two age groups, between 50-59, and over 60, experienced accident rates below the average. Likewise, Mohler et al. (1967) analyzed the accident records of older general aviation pilots, over 60, and concluded that the older group had an accident record essentially comparable, and in some cases superior to that of the younger pilot group. Another study (Mohler, 1983), found a decrease in the number of accidents with increasing age for pilots flying in general aviation who have earned commercial and air transport pilot (ATP) certificates. Mohler noted that higher age groups are consistently associated with lower accident records because the older pilots' performance reflects the effects of increasing experience and judgment. Supporting that statement, Charles Caudle, a witness in Select Committee on Aging (1979) stated, "Judgment, born of knowledge and tempered with experience, is the foundation of air safety" (p. 16).

One of the more recent reports on pilot accident rates (Serwer, 1990) recalculated the data from the *Flight Time Study* (Golaszewski, 1983). Serwer found that by using the two highest experience categories in the study (>5,001 hours total flight time and >400 hours recent flight time) the accident rate per 100,000 recent flight hours decreased with age, from 9.0 for the 20-29 year age group to 3.1 for the 60-69 year olds. These results are similar to the Office of Technology Assessment (1990) findings (i.e., pilots between 60-69 years of age had a lower accident rate than those pilots between 20-39 years of age). From these results, one can reasonably say that each time an older pilot (i.e., 60-69 years old) is replaced by a younger pilot (i.e., between 20-39 years old) the safety level would decrease. Then why do we not let airline pilots fly until 65 or even 69 years of age? One could argue that the Age 60 Rule conflicts with the FAA's mandate to provide the highest standard of airline passenger safety, because safer pilots (60-69 years old) are being replaced by less safe pilots (30-39 years old).

A letter from the Air Line Pilots Association (ALPA) to the FAA (1988) indicated that older pilots may have a lower accident rate than younger pilots. However, this may be due to their greater seniority rather than their greater experience, which gives the older pilots more freedom to choose their assignments. In making that choice, older pilots tend to bid on more desirable and possibly less strenuous or less demanding assignments, and often these trips provide the greatest number of flight hours. These trips can be argued to be inherently less risky because there are fewer takeoffs and landings; and it is in these two critical stages of flight that *two-thirds* of aviation accidents occur. In contrast, others argue that while the older pilots fly the longer trips, they land their aircraft after 10-12 hours of flight, when fatigue is likely to produce some undesirable effects.

It has been shown that many studies have calculated accident rates and safety levels with general aviation data, but to this researcher's knowledge not one has focused specifically on airline operations. Why? The problem lies in acquiring the appropriate data. According to the FAA's Forecast Branch (G. Mercer, personal communication, July 26, 1990), most of the necessary data (e.g., airline pilot flight hour distribution and the number of takeoffs and landings as a function of pilot age) have not been captured anywhere. Additionally, Foushee and Helmreich (1988) stated, " . . . since accidents are so infrequent, they make terrible research criteria for judging crew performance" (p. 218).

A similar observation was made in *Baker et al. v. FAA* (1989). It was suggested that because of the extremely small number of accidents in commercial airline operations, there is simply no purpose for, nor are there data available for a broad scale statistical study of airline accidents and age.

It is obvious that the literature gives a number of mixed results. Some studies support the hypothesis of a decrease in safety with advancing age, while others report opposite findings. Koonce (1989) revealed that by utilizing different methodologies, one can get very different results. Koonce showed that differing viewpoints can be obtained from the same data, it all depends upon the goal of the researcher(s).

Experience

It has been suggested (Salthouse, 1987) that *experience* is a very important variable moderating human performance and one that should be considered when attempting to examine any type of individual differences in behavior. Salthouse noted that research in the past has convincingly demonstrated that adults of all ages benefit from experience. In a recent court case (*Baker et al. v. FAA*, 1989) it was postulated that in aviation, pilot experience enhances safety. One study on aviators (Shriver, 1953) noted that experience is undoubtedly a major factor leading to greater effectiveness in emergencies. Similar remarks were reported in *Baker et al. v. FAA* which cited airline industry experts indicating that even the best training is not always an adequate substitute for years of experience in the most demanding cockpit situations, especially those requiring knowledge and proficiency to handle an emergency. Furthermore, Dodson (1990) quoted former FAA administrator Donald D. Engen stating: "Training is important, but when everything turns to worms, experience is what counts" (p. 190).

Many things can improve with age when they are practiced often enough, particularly judgment. According to Edwards (1990), the prevalent opinion is that judgment only comes from experience. One can be taught procedures, motor skills, principles, and perhaps emotional control, but judgment comes only from performing tasks, experiencing the results and modifying the performance in future similar situations. One report, (Mohler, 1981) referring specifically to airline pilots, noted that experience enhances judgment, and that older healthy persons tend to be less impulsive, and consequently have better safety records. Does this suggest that age-related changes disappear with older individuals who have had extensive experience with such relevant activities? In light of this question, Morrow et al. (1990) noted that since older pilots usually have more flight experience, any age-related declines in motor and cognitive functions would most likely be offset by their invaluable flight experience.

It is generally felt throughout the industry that experience, whether general or specific, yields a variety of benefits. Many skills, particularly those required in today's complex airliners, are practiced over the years for hundreds and even thousands of hours, and such experience may lead to improvements in the efficiency and effectiveness of performance. Sterns et al. (1985) studied various kinds of accidents (e.g., mining, transportation, construction, manufacturing) and how they relate to aging individuals. They stated, "Older adults may maintain many highly practiced activities at a constant level even though they are subjected to age-related declines; in short, experience compensates for their loss in ability" (p. 720). Other similar remarks were made by Salthouse (1990b), who concluded that somehow increased levels of experience lead to a compensation for declining abilities. Although these reports suggest that increased experience reduces the magnitude of age-related changes, Salthouse (1990a) observed that the empirical basis for this position has not been explicitly confirmed.

Despite its importance, the effects of experience are subject to limitations. Salthouse (1987) asserted that there is an *upper threshold level* of experience relevant to performance. Once that threshold is exceeded, further increments in experience do not necessarily contribute to increases in performance. For example, a letter from the staff counsel for ALPA was cited by the FAA in *Baker et al. v. FAA* (1989): ALPA theorized that once a pilot acquires 5,000 hours of flight time, the *law of diminishing returns* comes into play; i.e., any additional flight time does not necessarily improve that pilot's performance from a safety standpoint. Although this implication derived by ALPA was based on Golaszewski's (1983) *Flight Time Study,* it was not supported by any data.

Relating flying time to experience also presents some philosophical problems; e.g., does a pilot have 10,000 hours of experience, or 10 hours of experience 1,000 times? Shriver (1953) studied the effects of aging and experience on aircrew performance. After interviewing 556 military aircrewmen (with a mean age of 29.5 and a mean number of 1,800 flying hours), Shriver noted that at some point in an aviator's career, a peak appears to be reached, after which performance begins to deteriorate. From this, Shriver hypothesized that this deterioration in performance may be due to both physical and motivational changes outweighing the positive effects of experience. In addition, Reinhart (1991) reported that we like to think that we are just as good as we once were in the good old days of our youth; in many ways, with our years of experience, we are, but not as good in others.

It has also been suggested (Edwards, 1990) that experience does not always teach correctly. For example, as pilots become more experienced, they do not necessarily become better at making decisions in all situations. They are able to make routine decisions more effectively because of the countless number of times such similar situations have arisen. Edwards added that sometimes decisions are made that work out well, but they were made for the wrong reasons (i.e., not all errors result in accidents). Consequently, the most experienced pilots may sometimes be led to make less effective decisions in infrequently occurring situations than equally well-informed novices. But, this tends to be the exception, and it is generally accepted and supported by the available data that experience contributes to better performance in most tasks and is overall beneficial.

Salthouse (1990a) noted that most of the studies designed to examine interrelations of age and experience seem to have implicitly utilized either a maintenance (i.e., experience preserves abilities that would otherwise decline) or a remediation (i.e., added experience reverses ability declines) interpretation of the role of experience. Salthouse reported that because the currently available evidence is ambiguous, there is a substantial opportunity for one's biases and prejudices to influence the nature of the conclusion regarding the possibility that experience minimizes age-related changes. Furthermore, the existing literature is still too uncertain to support firm convictions about whether age differences on familiar activities are smaller than those on new or unfamiliar activities, whether age differences can be lessened or eliminated with extensive experience, or whether performance differences at different ages are absent on continuously practiced activities associated with one's occupation.

Other Relevant Issues

The present aviation system is not flawless by any means. Pilot error remains the single greatest contributing cause of aircraft accidents. In the interest of safety, we must always look for ways to improve or supplement our current aviation system. The Age 60 Rule is intended to be part of the *margin of safety* that is built into the system to reduce the probability of accidents. Dodson (1990) quoted a National Transportation Safety Board (NTSB) official who said, "Young pilots used to learn the ropes as flight engineers. Now, with two-man cockpits, we're putting them directly into the co-pilot's seat, and that might erode a margin of safety" (p. 190). In addition to eliminating the experience gained as a flight engineer prior to moving into the co-pilot's seat, the anticipated pilot shortage in combination with the Age 60 Rule may be moving co-pilots into the captain's seat at an earlier point in their careers. This double loss of experience may cause the Age 60 Rule to be counterproductive. Thus, do we increase the likelihood of accidents by retiring some of our most seasoned and experienced pilots and replacing them with younger less experienced pilots?

The FAA has major concerns about the probability of *sudden incapacitation* and the relative inability of physicals and check rides to detect deterioration in pilot skills. The IOM (1981) report described sudden incapacitation as an immediate loss of consciousness without prior symptoms and results in the pilot's inability to control the aircraft, whether due to physiological or psychological reasons. The IOM also noted in their report that sudden incapacitation is a serious, but rare event among pilots.

Other literature (Bennett, 1972; Booze, 1987; Buley, 1969; Froom, Benbassat, Gross, Ribak, & Lewis, 1988; Mohler & Booze, 1978; Office of Technology Assessment, 1990; Rayman, 1973; Reighard & Mohler, 1967) has also cited pilot incapacitations as infrequent events. Mohler and Booze found that general aviation accidents due to sudden incapacitation are less than 1% of all documented fatal general aviation accidents. Buley studied airline pilot inflight incapacitations and found that in cases resulting in accidents, the average pilot age was 46 years old, and in cases not resulting in accidents, the average pilot age was 44 years old. In addition, Bennett found that a vast majority of inflight incapacitations are not age-related. Bennett reported that a large number of these incidents are related to food poisoning. The incapacitations by decreasing order of frequency are: nausea and vomiting associated with gastrointestinal upset, diarrhea, ear problems, faintness, headaches, and vertigo. However, despite the rarity of these events, there is still the possibility of such a classic case. Reighard and Mohler cited the catastrophic Lockheed Electra accident from 1966 as an example in which the captain, who was 59 years old, became incapacitated silently during a circling approach in instrument conditions and 83 occupants lost their lives.

Many pilots believe that special medical waivers are the only answer to this complex issue. The FAA may grant waivers if it is shown that a balanced level of safety will be provided when the waiver is granted (Glines, 1985). According to the GAO (1989) report, challengers of the rule allege that the FAA has been inconsistent in granting exemptions from certain medical requirements, but not from the Age 60 Rule (see Table 2). Bruce and Fisher (1987) argued since the FAA grants special issuances to those pilots under 60 years of age who are medically qualified despite prior myocardial infarction or bypass surgery, they should also be able to grant special issuances for pilots over 60 who are healthy and at

Table 2. Special Issuances Granted to Applicants for Class I Medical Certificates

	Number of special issuances granted						
Medical condition	1982	1983	1984	1985	1986	1987	1988
Valve replacements	0	0	0	2	3	5	2
Pacemaker	0	0	0	0	1	0	0
Coronary artery bypass surgery/coronary artery disease	9	2	3	36	26	15	20
Angioplasty	0	2	3	7	10	9	16
Myocardial infarction (w/no bypass surgery)	1	2	3	17	14	20	14
Neurological[a]	2	2	6	6	10	6	2
Psychiatric[b]	1	1	0	3	2	3	0
Drug dependence	0	1	0	3	3	0	8
Alcoholism	37	73	81	90	87	88	79
Diabetes	0	0	0	1	0	0	2
Total	50	83	96	165	156	146	143

[a]Neurological includes carotid artery conditions, stroke, disturbance of consciousness, and convulsive reactions.

[b]Psychiatric includes schizophrenia, paranoid states, psychoses, and personality disorders.

Source: FAA, Civil Aeromedical Institute, Oklahoma City.

Note. From *"Aviation Safety: Information of FAA's Age 60 Rule for Pilots"* by General Accounting Office (GAO), 1989, p. 16.

low risk for coronary events. It should also be recognized that these waivers are limited and only affect a small minority of pilots. On the other hand, the Age 60 Rule affects all pilots, and if one waiver is given, others will begin applying for the exemption. Some pilots feel that there would be too much surveillance of the pilots over 60 by both the FAA and by individual airlines, and this would burden the whole system (Hammond, 1989). However, one aviation attorney (A. M. Serwer, personal communication, January 17, 1991) speculated that a large proportion of airline pilots would like to retire at age 60. In light of this question, Reinhart (1991) conducted a survey on what individual pilots think of the Age 60 Rule. Reinhart found that 74% of the 250 responses indicated that they would accept additional and more extensive evaluations in order to fly beyond age 60. However, from the total survey results he concluded that there is not a convincing majority of pilots who want to continuing flying beyond age 60.

Some research (Downey & Dark, 1990; Mohler, 1984) found that during recent years, advances in aviation medicine and changes in FAA policies and procedures have resulted in the medical certification of pilots who, in earlier years, would have been denied. Many pilots claim that they do not understand the logic of the FAA's policy toward waivers. The FAA's application of medical knowledge to recertify these pilots with serious medical disorders demonstrates that the agency has the power and is willing to individualize its medical considerations and base judgments on the latest developments in medicine and pilot proficiency assessments. However, an FAA official indicated that medical exemptions are granted for single, specific problems, and that the Age 60 Rule is not a single-problem issue ("Federal Rule," 1989).

The Office of Technology Assessment (1990) indicated that the incidence of medical illnesses that may impair pilot performance increases with age . Supporting this, comprehensive data of airline pilots who were denied medical certification was analyzed by Downey and Dark (1990). They found that age-specific denial rates increase with age. The annual denial rate for first class medical certificates was found to be 4.3 per 1,000 active airline pilots, increasing from 1.0 per 1,000 in the 25-29 age group to 16.2 per 1,000 in the 55-59 age group (see Table 3). This demonstrates that the physical exams are detecting deterioration with age and eliminating those pilots who fall below the standard

Table 3. First Class Medical Denials (Airline Pilots)

Age Groups	Active Airline Pilots	Percent of Active Airline Pilots	Denied Airline Pilots	Percent of Total Denials	Annual Age-Specific Denial Rate*
25-29	5,698	10.2	7	1.5	1
30-34	8,809	15.8	16	3.4	1
35-39	10,005	18	20	4.2	1
40-44	9,544	17.2	52	10.9	2.7
45-49	10,288	18.5	115	24.1	5.6
50-54	7,760	13.9	150	31.5	9.7
55-59	3,576	6.4	116	24.4	16.2
TOTAL	**55,680**	**100**	**476**	**100**	**4.3**

*Annual rates per 1,000 active airline pilots.

Note. Adapted from *"Medically Disqualified Airline Pilots in Calender Years 1987 and 1988"* by L. E. Downey and S. J. Dark, 1990, DOT/FAA/AM-90/5, p. 3.

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established for safety. However, one must interpret this data with caution because there may be other factors contributing to this sharp increase in medical denials with age (e.g., economic status of the airline, management/union disagreements); this also suggests that there may be other reasons for a pilot to retire early prior to age 60 (e.g., income tax advantage).

The retirements mandated by the Age 60 Rule may have possibly contributed to the loss of our most experienced pilots, and could be forcing the airlines to lower their standards and hire less qualified pilots. Moorman (1986) found that the amount of jet-flying time required by airlines for new hirees has dropped from 2,300 hours in 1983, to

1,600 in 1984, and to 800 in 1985. New hirees are not of course, employed immediately as PIC. They often spend years in the flight engineers' seats flying sideways before they even get a chance to touch the controls. According to an airline captain (E. Soliday, personal communication, September 25, 1990), it takes a new hiree roughly 11 years for promotion to the left seat (i.e., at the time of this conversation). But that number varies from year to year and from airline to airline due to hiring trends. One must keep in mind, however, that the nature of this progression is changing. For example, new automated commercial airliners (e.g., MD-11, B-747-400) only require two pilots, rather than three. This means that new hirees of tomorrow will be hired as first officers (i.e., copilots with hands on the flight controls) rather than as flight engineers sitting sideways in the back.

It should be apparent that the Age 60 Rule is a very complex issue with many confounding details. The arguments presented by both sides (i.e., supporters and petitioners) are undoubtedly legitimate concerns. Many issues concerning the effects of age and experience on flight safety were identified in this study, and the major points are as follows:

1. Physiological and psychological changes do occur in all individuals with advancing age, and these changes are likely to influence the performance of complex tasks and critical skills.

2. Many of the studies reviewed on human performance and aging suggest progressive declines with increasing age; however, it can be argued that most of these age-related changes are attributed to one's lifestyle rather than age itself.

3. The recertification of many special issuances suggests that the FAA has the knowledge and is willing to individualize the current medical standards. If recent advances in aviation medicine can accurately predict which pilots are likely to become ill and which are not, then healthy professional pilots should be allowed to fly beyond age 60. Although, even if the FAA and the airlines allow pilots to fly beyond 60, it cannot be said for certain that safety will be enhanced.

4. Professional pilots are likely to be more aware of and may be more cautious to these age-related changes because these changes could easily affect their livelihood. Reinhart (1982) noted that most professional pilots are well informed and have a number of resources available to them so that they can educate themselves in health maintenance.

5. Years of experience in the cockpit may compensate for or reduce the magnitude of age-related changes, especially when older pilots maintain their proficiency; thus making them at least equal to if not better than their younger counterparts.

6. Since older pilots generally have more seniority, they tend to bid on more desirable and possibly less strenuous or less demanding assignments. These trips can be argued to be inherently less risky because there are fewer takeoffs and• landings, thus reducing their risk factor.

7. The current practice of putting new hirees directly into the right seat is also an area of concern because these new pilots are not getting the valuable experience as they would if they were flight engineers. The anticipated pilot shortage in combination with the Age 60 Rule may be moving these new co-pilots into the captain's seat at a much earlier point in their careers. This double loss of experience may cause the Age 60 Rule to be counterproductive.

Statement of the Hypothesis

Many feel that in older pilots, flight experience, knowledge, and judgment is irreplaceable and that these unique qualities may offset potential health risks. Consequently, the null hypothesis states that aging has no measurable effect on pilot performance as inferred from the observed-over-expected number of accidents among pilots; the alternative hypothesis argues that pilot performance deteriorates with age as inferred from a greater number of observed-over-expected accidents among older pilots.

METHOD

Data Types and Sources

The data for this study came from records of general aviation accidents (i.e., private pilots, commercial pilots, and ATPs), and airline accidents (Part 121). An *aircraft accident*, as defined by the NTSB, is an event involving substantial or greater damage to the airplane and/or serious or greater injury to an occupant of that aircraft. The most available data providing an accurate indication of our past and current aviation accident trends are contained in a number of separately maintained data banks. These data were acquired from the following specialized aviation data banks:

1. The NTSB's Accident Data Division compiled an accident data search with the following broad categories: accidents from 1982-1988 for general aviation pilots, commercial pilots, ATPs, and airline pilots. These categories contain the following data elements: age of the PIC; commercial, ATP, and airline accidents in which "pilot error" was the determined cause of the accident.

2. The Aircraft Owners and Pilots Association (AOPA) Air Safety Database provided the number of general aviation accidents that occurred between 1982-1988 independent of cause and the number of accidents in which "pilot error" was the determined cause of the accident. The Director of the AOPA Air Safety Database (J. Carson, personal communication, December 5, 1990) indicated that the AOPA has a special staff that re-evaluates the NTSB accident reports and classifies them as *pilot caused* rather than pilot error. The accidents were also separated by the type of license held (e.g., private pilot only, commercial and/or ATP). It should be noted that the pilot error accidents were used because they are a definite indicator of inadequate performance that could possibly be

associated with the aging process. It has been recognized that performance failures appear to be more closely related to pilot safety and proficiency than health or medical disabilities in flight (Gerathewohl, 1978b).

3. The FAA's Statistical Handbook on Aviation provided the distribution of pilots by age and by type of license held (i.e., private, commercial, and air transport). All data were for the years 1982 to 1988.

4. The FAA's Aeromedical Certification Statistical Handbook provided the distribution of airline pilots by age from 1982-1988. The Handbook stated that airline pilots were determined by the *combination* of Class I medical certificate issuance during the preceding 13 months and an occupation of "pilot for an airline" (see Table 4). Note that Table 4 accounts for pilots age 60 and over who claim to be airline pilots. However, the Age 60 Rule prohibits these pilots from operating as PIC (i.e., under Part 121 regulations); therefore, it was assumed that these pilots age 60 and over represent those who fly commuter aircraft and/or those who choose to be flight engineers for the airlines rather than retiring at age 60. Airline pilots are also referred to as Part 121 operators in this study.

5. The COMSIS Research Corporation provided the flight hour distribution for Class I, II, and III medical certificate holders in five-year age groups (e.g., 20-24, 25-29, 30-34) for 1982-1988 as compiled from FAA pilot medical records.

The data were stratified into categories according to the age of the PIC responsible for the accident. The categories were grouped into five-year increments starting at 20-24, and ending with 55-59. With reference to the airline data, the age groups begin with 25-29 but end with 55-59, since they are the closest to the age limits set by Part 61.151 and 121.383(c) for pilots holding an ATP rating and engaging in air carrier operations (Downey & Dark, 1990). There is, however, no upper age limit set for ATPs (i.e., an ATP can exercise his/her privileges as long as he/she can maintain the appropriate medical certificate).

Table 4. Age Distribution of Airline Pilots* (As of December 31, of that year)

Age Group	1982	1983	1984	1985	1986	1987	1988	1989
20-24	703	775	866	1,164	1,159	1,036	990	1,047
25-29	2,920	3,018	3,365	4,850	5,286	5,698	5,663	6,067
30-34	5,698	5,435	5,716	7,050	7,828	8,809	9,499	11,067
35-39	6,165	6,082	7,022	8,801	9,752	10,005	10,006	10,459
40-44	7,590	7,541	7,738	8,645	8,959	9,544	9,709	10,816
45-49	7,119	7,436	8,088	9,306	9,928	10,288	10,543	10,486
50-54	4,269	4,843	5,501	6,478	7,205	7,760	8,097	8,915
55-59	3,076	2,807	2,698	2,935	3,191	3,576	4,123	4,772
Subtotal	**37,540**	**37,937**	**40,994**	**49,229**	**53,308**	**56,716**	**58,630**	**63,629**
60-64	167	159	159	217	232	206	229	241
65-69	18	17	21	43	65	47	62	70
Total	**37,725**	**38,113**	**41,174**	**49,489**	**53,605**	**56,969**	**58,921**	**63,940**
Avg. Age	**41.5**	**41.6**	**41.5**	**41.0**	**41.0**	**41.0**	**41.2**	**43.1**

*Airline Pilots were determined by the combination of first class medical certificate issuance during the preceding 13 months and an occupation of "pilot for an airline".

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Note. From "Aeromedical Certification Statistical Handbook" by Civil Aeromedical Institute (CAMI), Aeromedical Certification Division, Statistics and Records Branch.

The data used for the analysis are the most current and reliable available. Professionally trained investigators often spend months using state-of-the-art scientific techniques to determine the primary cause of an accident, along with other essential information. According to Westrum (1987), aircraft accident investigation has now become a small branch of applied science or engineering, and these investigation procedures are more thorough than those of other transportation modes.

Design

The design of this study consisted of collecting aviation accident data containing pilot age and experience information from all available sources between 1982 and 1988. In order to analyze the data accurately and efficiently, the data were organized into tables and graphs. The accidents were analyzed in terms of: (a) the number of observed accidents versus the number of expected accidents; (b) the accident record; (c) the accident rate; and (d) the percentage of accidents classified as *pilot error*. The data were examined to determine whether there were any trends across age groups and to verify any significant differences between the different age groups.

The number of *expected accidents* was calculated by multiplying the proportion of pilots in an age group by the total number of accidents observed for all age groups. *Accident records* were calculated by dividing the number of accidents per age group by the number of pilots in that age group (e.g., accidents per 1,000 active pilots). The *accident rates* were calculated by dividing the number of accidents per age group by the number of hours flown by pilots in that age group, and were evaluated by using a common metric (e.g., accidents per 100,000 annual flight hours). The *percentage of accidents classified as pilot error* were calculated by dividing the number of "pilot error" accidents per age group by the total number of accidents in that age group. The observed-over-expected frequencies, accident records, accident rates, and percentage levels were studied for the various age groups.

This design is comparable to, but sought to avoid the bias that critics have identified in Golaszewski's (1983) study. His study included non-general aviation flight time, or air carrier hours in the accident rate equation (approximately 93 million hours) which depressed the accident rate for pilots under age 60, but not so for pilots age 60 and over. However, Golaszewski did recognize this as a potential discrepancy in his study. The primary goal of this study was to keep the data as homogeneous as possible; i.e., to keep Class III hours with private pilots, Class II hours with commercial pilots, and Class I hours with ATPs and airline pilots.

The reader should be familiar with the different details involved in each class of medical certificate. For example, Class III operators are usually private and student pilots; this class must have a physical examination every two years. Class II operators are usually commercial pilots; this class must have a physical examination every year. Class I operators are typically ATPs and/or airline pilots; this class must have a physical examination every six months. However, it should be made clear that this does not necessarily mean that all private pilots have only Class III medicals, nor does it mean that all commercial pilots have only Class II medicals, and the same goes for ATPs and airline pilots with respect to Class I medicals. These were just assumptions, and the limitations of these assumptions are discussed in a subsequent part of this study.

Procedure

The relevant information from all of the available databases was assembled into a common format which assisted the evaluation. Most of the data were obtained from 1982 to 1988 records. The data were categorized by age groups into a database on a personal computer. The categories include: pilot age groups in five-year intervals starting at 20-24, and up to 55-59; total number of active private pilots; total number of active commercial pilots; total number of active ATPs; total number of active U.S. airline pilots; number of accidents observed for a specified year by age group; number of accidents expected for a specified year by age group; the accident record; and the accident rate.

The term *active* is a minimal definition used by the FAA and refers to more than zero flight hours per year.

Limitations

There are some limitations in this study that need to be recognized. Some assumptions were made that need to be identified. An assumption, according to Gay (1987), is an important fact *presumed* to be true but not actually verified. The first assumption pertains to the reported flight hour data (i.e., the COMSIS data), in which it was *assumed* that all pilots accurately report their recent and total time when taking their flight physical, and when reporting information in an accident investigation. According to Golaszewski (1983), it is believed that most pilots do not take their logbooks with them to flight physicals; therefore, they report their recent and total time from memory. On the other hand, it is believed that the flight hours reported in accident investigations may be more precise because of the formal nature of the investigative process. Without the original pilot logbook, there is no practical means of testing the accuracy of the reported flight time. Nevertheless, it is presumed that these inaccuracies are random and will not significantly alter the results.

Another assumption was made in reference to the "pilot error" data. Some critics may argue that pilot error was the determined cause because no other relevant cause was found. This position has received some support in the literature; for example, Edwards (1990) suggested that pilot error is often listed as the cause of the accident because there is neither time nor money available for thorough investigations. These suggestions may be true to some extent, but by and large, it is assumed that they represent only a small portion of the total number of pilot error accidents.

The last assumption made in this study came about by utilizing the flight hour data (i.e., hours flown by medical class holders). In regards to general aviation, it is true that not every general aviation pilot holds a Class III certificate. In fact, some general aviation pilots are Class I holders (e.g., airline captains) who often go flying for pleasure.

Furthermore, not all airline pilots are Class I holders (see Table 5). The captain is the only one required to possess a Class I medical in an airline cockpit. It is assumed that most co-pilots (or first officers) get the Class I medical, especially the new hirees because it is normally required, but then let the medical downgrade to a Class II after six months, so they do not have to make another trip to the Medical Examiner's office. This is not only convenient, but also saves the pilot some money. Lastly, many of the hours acquired by medical class holders (particularly Class I and Class II) are not actually *hands-on* flight hours. These hours are logged by flight engineers who often "fly sideways" in the back never touching the primary flight controls.

Cross-sectional Constraints

Many studies discuss the limitations of cross-sectional studies (e.g., Hartley, Harker & Walsh, 1980; Horn & Donaldson, 1976; Reese & Rodeheaver, 1985; Shock et al., 1984; Willis & Baltes, 1980). Reese and Rodeheaver concluded that the apparent cognitive regression in old age may be an artifact of the exclusive use of cross-sectional methods. Differences in results (e.g., accident statistics) cannot be definitely interpreted as deficits in competence or a decline in abilities. Willis and Baltes indicated that in a strict sense, the cross-sectional method is never an appropriate substitute for longitudinal investigation. The cross-sectional method is characterized by measurements made at approximately the same time on a large number of subjects covering the entire adult age span. Age changes are not measured directly but are *inferred* from the differences in mean values observed in different age groups. Only average differences between age groups are identified. The primary advantage of the cross-sectional method is that the presence of age trends in a group of subjects can be detected fairly quickly. Caution is necessary in its interpretation, however, since differences between age groups include both birth cohorts as well as age effects.

Horn and Donaldson (1976) indicated that it is well known that in cross-sectional analyses, differences between generations (e.g., level of formal education, training

Table 5. Number of Pilots by Type of License and Class of Medical Certificate (1982-1988)

	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64[a]	65-69	Total
No. of Private Pilots[b]	169,345	254,111	315,427	322,102	284,601	228,723	201,167	181,523	194,079	-	2,151,078
No. of Third Class Holders[c]	157,930	215,035	245,900	243,138	216,215	177,783	159,571	118,827	122,561	47,545	1,704,505
No. of Commercial Pilots[b]	64,279	125,102	123,822	155,909	163,408	129,367	103,509	76,440	123,292	-	1,065,128
No. of Second Class Holders[c]	53,956	73,015	82,490	102,094	95,195	74,374	62,079	40,178	49,478	19,950	652,809
No. of ATPs[b]	3,757	43,706	86,841	107,338	101,536	89,229	69.930	42,884	41,561	-	586,782
No. of Airline Pilots[d]	6,693	30,800	50,035	57,833	59,726	62,708	44,153	22,406	1,369	273	335,996
No. of First Class Holders[c]	20,486	48,948	63,224	69,877	71,757	70,652	53,099	24,117	11,158	1,548	434,866

[a] *The FAA's Statistical Handbook on Aviation lists the upper age group for all pilots as 60+.*
[b] *Source: FAA's Statistical Handbook on Aviation.*
[c] *Source: COMSIS Research Corporation data for "active" medical holders (i.e., more than zero flight hours per year).*
[d] *Source: CAMI's Aeromedical Certification Statistical Handbook.*

techniques, technology) are confounded with age changes within individuals. Cultural changes (e.g., communication techniques) can occur in a decade or so, and technological changes which may also influence performance can occur almost overnight. The technological issue raises another question as to whether or not transitioning from an older aircraft (e.g., DC-9, B-727) to a new state-of-the-art airliner (e.g., the highly automatized B-767) represents a problem for the older generations' transitioning, because of the advanced computers that virtually fly the airplanes by themselves. However, Mohler (1981) strongly suggested that there is no evidence that older pilots have more trouble transitioning to new aircraft than younger pilots.

ANALYSIS

The data were separated into categories for the evaluation (e.g., Class III hours were kept with private pilots, Class II hours were kept with commercial pilots, and Class I hours were kept with ATPs). In regards to the accident statistics, an age-related trend is noticeable in a majority of the figures. This trend shows a decrease in accident statistics with increasing age, reaching minimum values between 40-49 years of age, and then increasing slightly through the 50s.

The data in the following figures represent calculated totals of pilot flight time, number of accidents, and number of active pilots as acquired from the specified aviation data banks. The source data are presented in Appendix E. Figure 2 represents the annual flight hours per pilot by class of medical certificate. The annual hours flown for first class holders reach a peak around 609 hours per year for the 25-29 year age group and maintain a level plateau through the 55-59 year age group; then, the number of reported flight hours rapidly decline for the 60-64 and 65-69 year age groups. It can reasonably be assumed that this sharp decline is a direct result of the Age 60 Rule; besides, there are not many reasons for a pilot age 60 or older to get a first class certificate, especially if he/she is not entitled to its privileges. The annual hours flown for second class holders remain relatively stable at around 190 hours per year for all age groups. In contrast, the reported flight hours for third class holders steadily increase with age; beginning with a low of 26 hours per year for the 20-24 year age group to a high of 65 hours per year for the 65-69 year age group.

The remaining figures show the accident statistics by the type of license held, and the type of operation. Figures 3 and 4 represent accident records for ATPs and commercial pilots. The accident data depicted in these figures indicate increasing safety

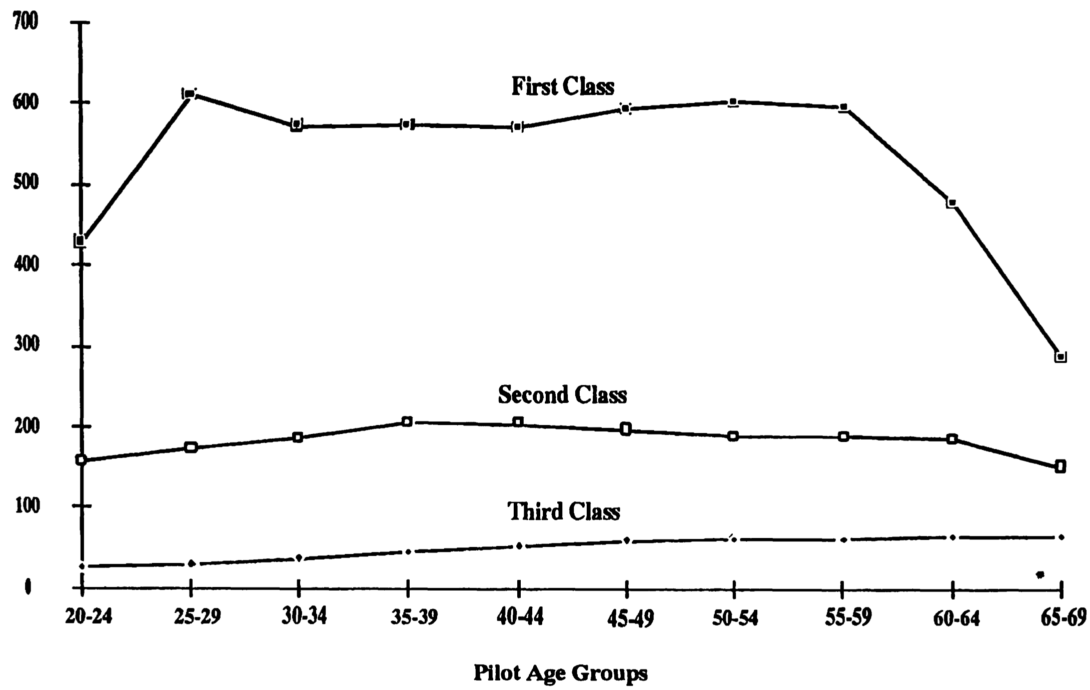

Figure 2. Annual Hours Flown per Pilot by Medical Certificate (1982-1988).
Source: COMSIS Research Corporation

through the late 40s; e.g., the accident record per 1,000 active ATPs starts from a high of 11.71 for the 20-24 year age group, declines to a low of 2.88 for the 45-49 year age group, and then climbs to 3.78 for the 55-59 year age group. The 3.78 figure for the 55-59 year age group compares favorably with the 3.77 figure for the 35-39 year age group (see Figure 3). The accident records per 1,000 active ATPs and commercial pilots both show similar patterns (see Figures 3 and 4). Accident records are highest for the youngest group (i.e., the 20-24 year age group), then progressively decline and reach a low for the 45-49 year age group, afterward there is a slight increase for the 50-54 and 55-59 year age groups. However, with both the ATP and the commercial pilot groups, the 50-59 year old pilots have lower accident records than the 30-39 year age groups.

In marked contrast, Figures 5 and 6 show that the accident record per 1,000 active pilots, for both private pilots and airline pilots, is lowest for the youngest group, and then progressively increases up to the 55-59 year age group. For example, the accident record

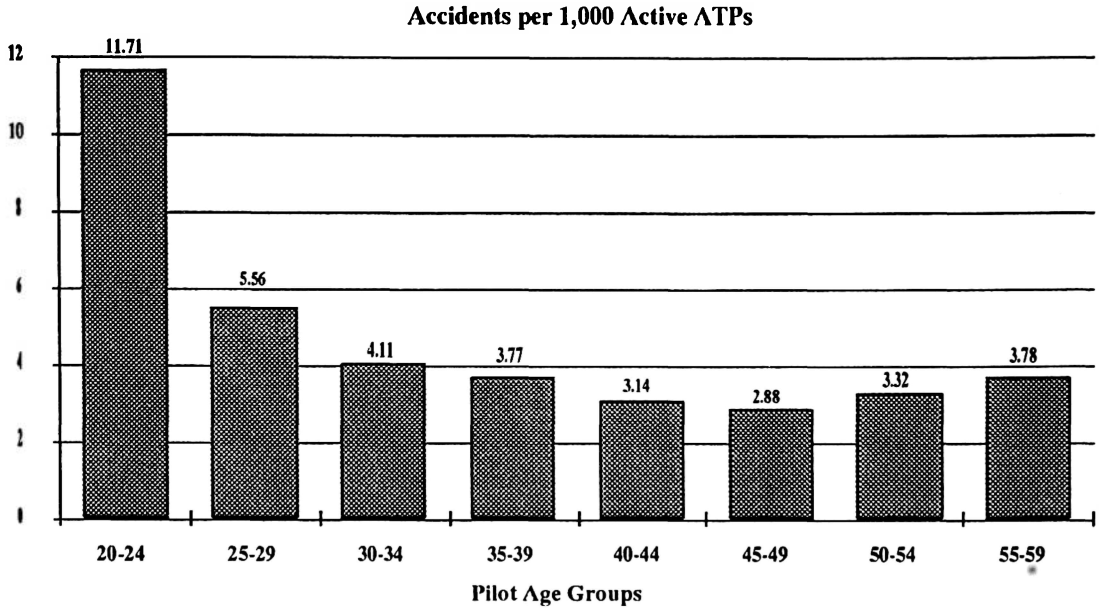

Figure 3. Accident Records for Air Transport Pilots (1982-1988). *Source: NTSB Accident Data Division & FAA's Statistical Handbook on Aviation*

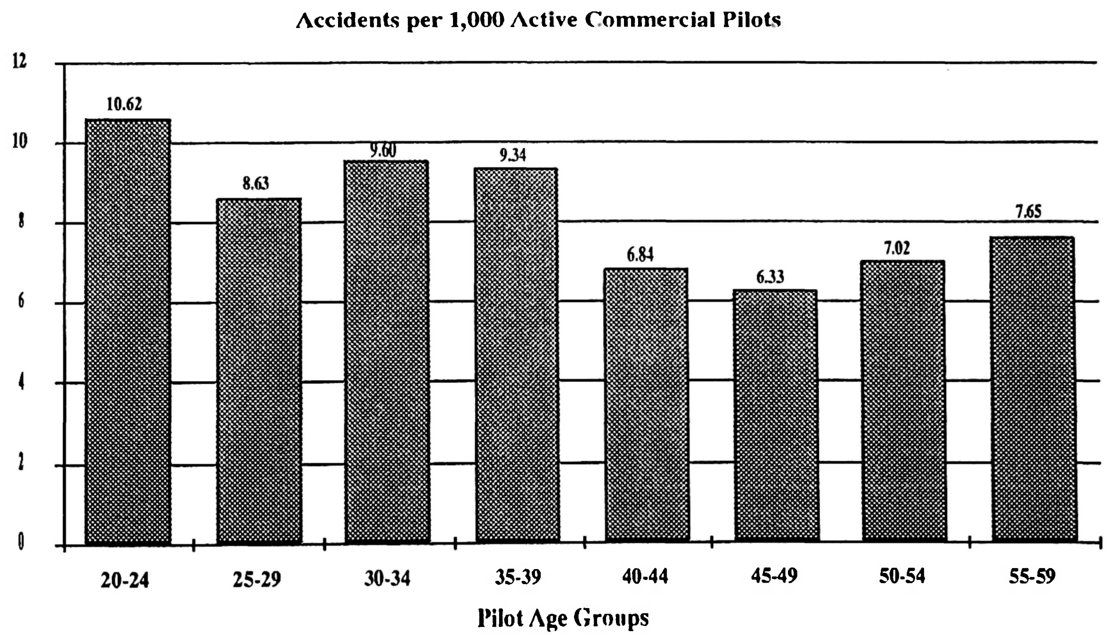

Figure 4. Accident Records for Commercial Pilots (1983-1986). *Source: NTSB Accident Data Division & FAA's Statistical Handbook on Aviation*

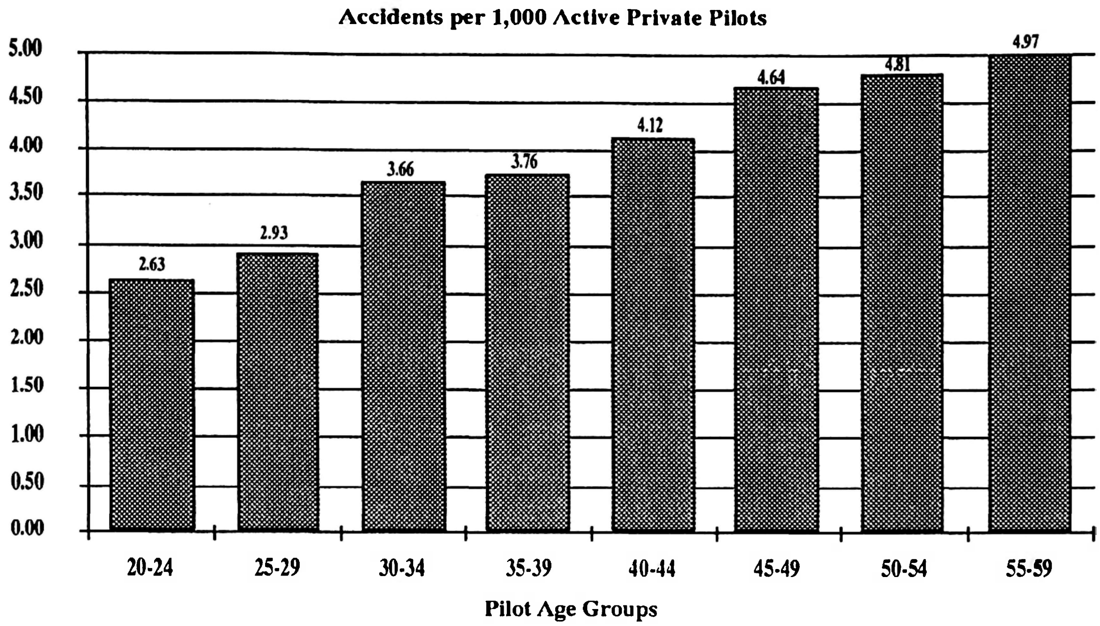

Figure 5. Accident Records for Private Pilots (1982-1987). *Source: AOPA Air Safety Database & FAA's Statistical Handbook on Aviation*

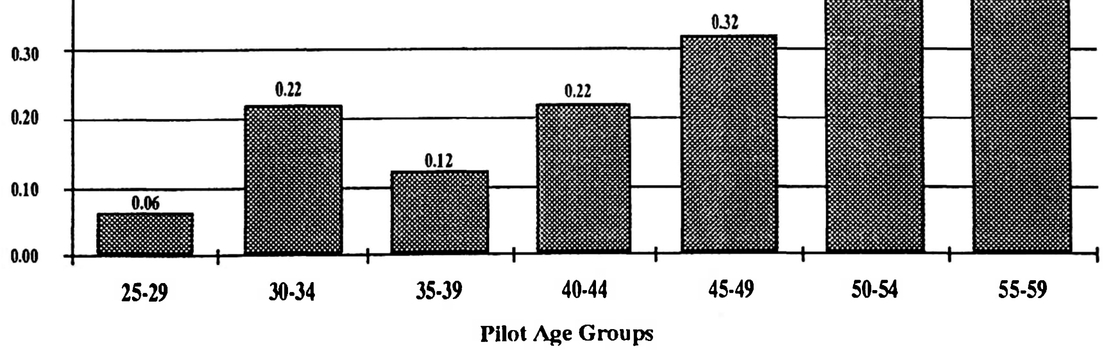

Figure 6. Accident Records for Airline Pilots (1982-1988). *Source: NTSB Accident Data Division & FAA's Aeromedical Certification Statistical Handbook*

per 1,000 active private pilots starts at a low of 2.63 for the 20-24 year age group, and increases in a linear fashion to 4.97 for the 55-59 year age group. However, the accident data in Figures 3 through 6 do not consider exposure (i.e., the number of hours flown).

Accident statistics based on exposure data (i.e., accidents per 100,000 annual hours flown) for the different pilot groups present a different picture. Figures 7, 8, and 9 represent accident rates for ATPs, commercial pilots, and private pilots. An examination and comparison of these three figures indicates the presence of a common age-related pattern: increasing safety through the 40s with a slight decrease in the late 50s; e.g., the accident rate per 100,000 annual hours flown for ATPs starts from a high of 2.74 for the 20-24 year age group, declines to a low of 0.48 for the 45-49 year age group and then climbs to 0.63 for the 55-59 year age group. The 0.63 figure for the 55-59 year age group again compares favorably with the 0.66 figure for the 35-39 year age group (see Figure 7). All three figures (ATPs, commercial pilots, and private pilots) show that active pilots in their 50s have lower accident rates than pilots in their 20s and 30s.

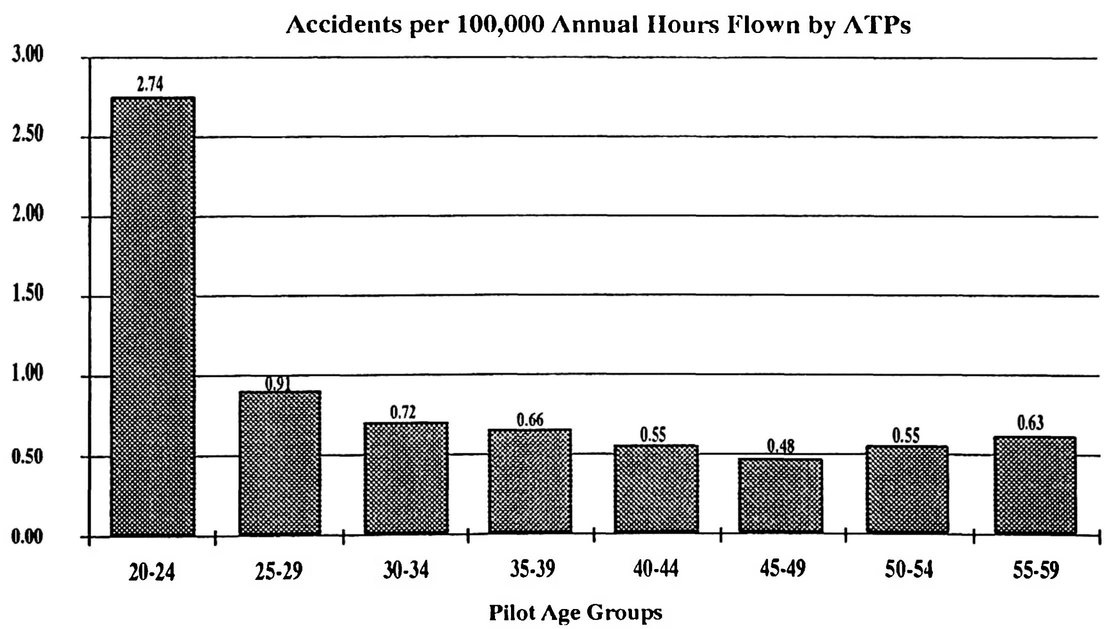

Figure 7. Accident Rates for Air Transport Pilots (ATPs) Using First Class Annual Hours (1982-1988). *Source: NTSB Accident Data Division, FAA's Statistical Handbook on Aviation, & COMSIS Research Corporation*

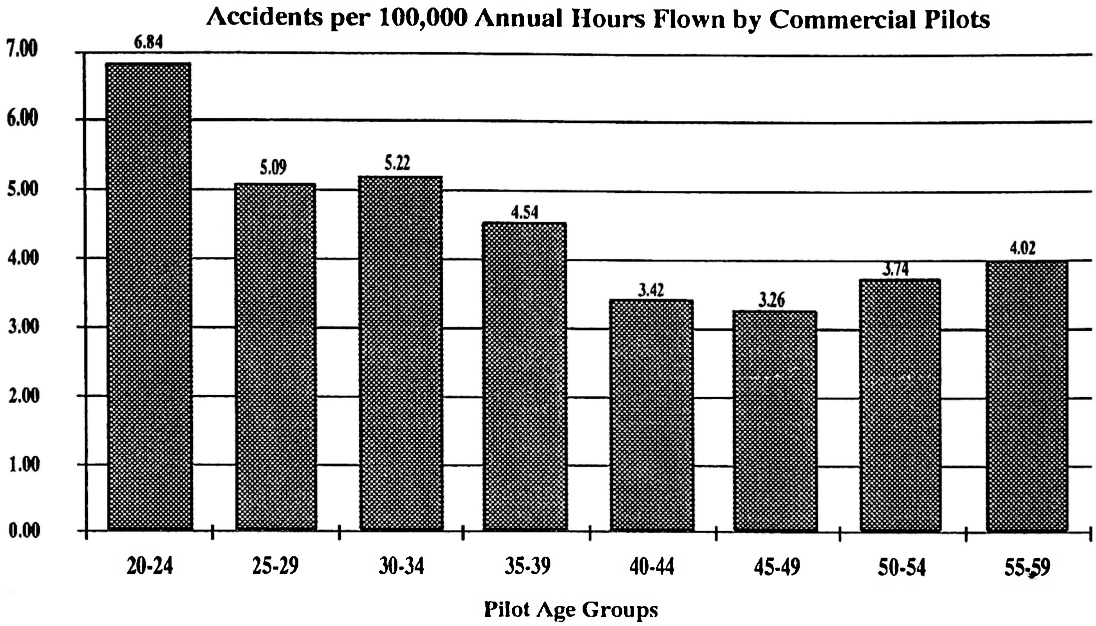

Figure 8. Accident Rates for Commercial Pilots Using Second Class Annual Hours (1983-1986). *Source: NTSB Accident Data Division, FAA's Statistical Handbook on Aviation, & COMSIS Research Corporation*

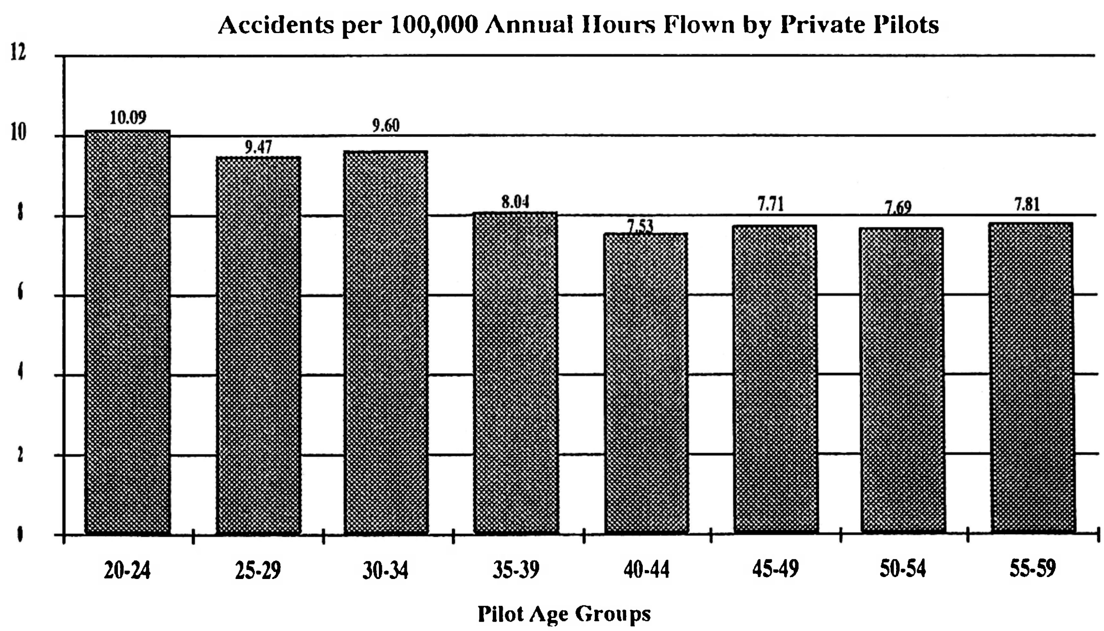

Figure 9. Accident Rates for Private Pilots Using Third Class Annual Hours (1982-1987). *Source: AOPA Air Safety Database, FAA's Statistical Handbook on Aviation, & COMSIS Research Corporation*

The relationship between the number of "pilot error" or pilot caused accidents as a percentage of the total number of accidents was also examined. This data is somewhat unique as compared to the other accident statistics because it includes pilots age 60 and over. Figures 10 and 12 show the percentage of accidents classified as pilot error for ATPs and general aviation operators. Both figures show the percentage of accidents classified as pilot error decreasing slightly with age, suggesting that pilots in their 50s and evens 60s are less likely to experience a pilot error accident, as compared to those pilots in their 20s and 30s (i.e., with the exception of the 60-64 year old ATPs and 70-79 year old general aviation pilots). However, in contrast, Figure 11 shows that the older commercial pilots are the ones more likely to experience a pilot error accident; however, the differences are quite small until pilots reach their 60s. Nevertheless, all three figures consistently illustrate the importance of experience as inferred from the type of license held; i.e., ATPs have the highest levels of flight time followed by commercial pilots and then general aviation pilots. For the time period specified, pilots possessing an ATP certificate have a 61.3% chance of an accident being classified as pilot error, as compared

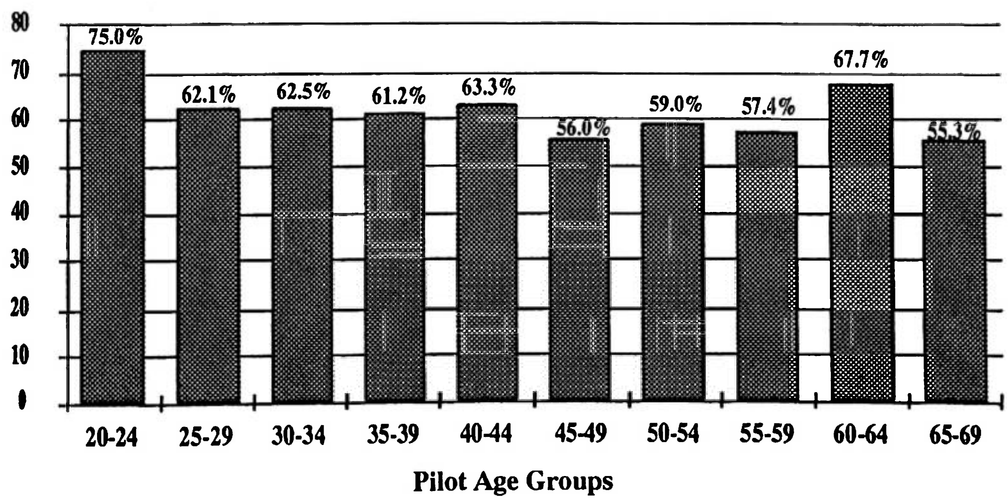

Figure 10. Percentage of Accidents Classified as Pilot Error for Air Transport Pilots (1982-1988). *Source: NTSB Accident Data Division*

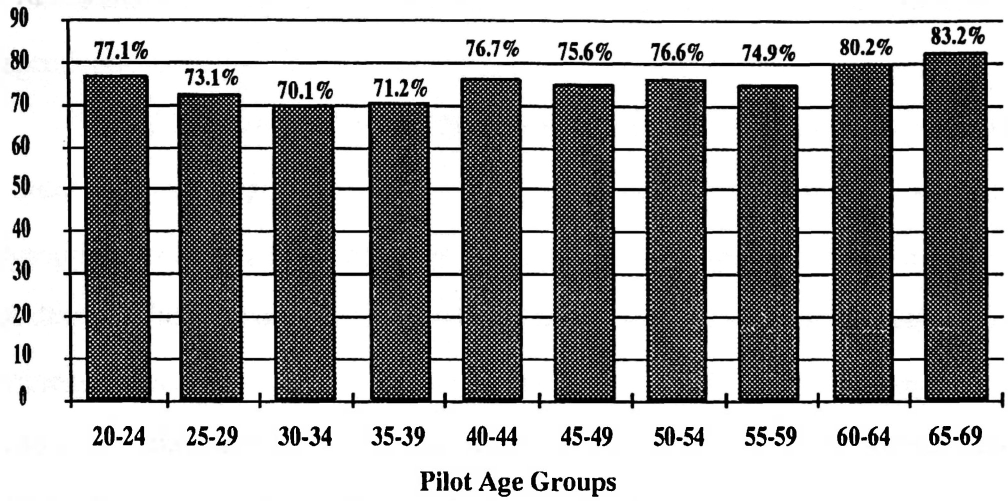

Figure 11. Percentage of Accidents Classified as Pilot Error for Commercial Pilots (1983-1986). *Source: NTSB Accident Data Division*

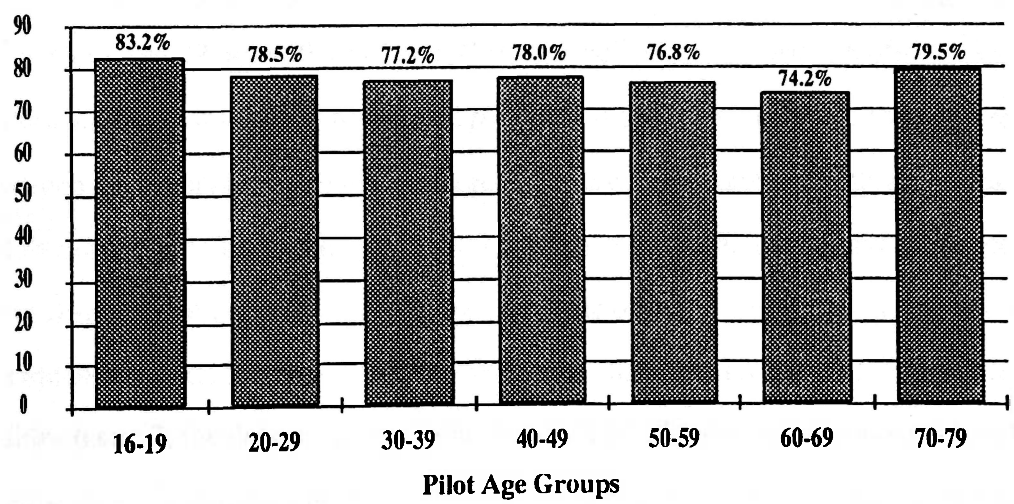

Figure 12. Percentage of Accidents Classified as Pilot Caused for General Aviation Operators (1982-1987). *Source: AOPA Air Safety Database*

to 74.4% and 77.5% chance for commercial pilots and general aviation operators, respectively.

The *Chi-squared* (χ^2) statistical technique was selected to evaluate particular data in order to test the hypothesis advanced. The χ^2 is a nonparametric test of significance appropriate when data are in the form of frequency measures (e.g., number of observed accidents). The χ^2 goodness-of-fit test determines whether a statistically significant difference exists between the proportions observed and the proportions expected. As can be seen from the formula, the χ^2 value dramatically increases as the difference between the the observed and expected frequencies increase.

Formula: $$\chi^2 = \sum \frac{(O-E)^2}{E}$$

Where: O is the number of accidents observed, and
E is the expected number of accidents based on the pilot population.

The calculated results of χ^2 can be seen in Tables 6, 7, and 8. Using p=.001 the χ^2 = 24.32 and 22.46, with *df*=7 and *df*=6, respectively. Because the observed χ^2 values are larger than is required at the p=.001 level, it is concluded that the differences between the observed and expected frequencies ***are significant*** across three groups of pilots beyond the .001 level; therefore, the null hypothesis that aging has no effect on pilot performance capabilities as inferred from the observed-over-expected frequency of accidents is rejected. However, the trends across the three groups were inconsistent. In Tables 6 and 7, the data for commercial pilots and ATPs shows that the significant χ^2's are because the younger pilots age 20-39 experienced more accidents than expected, and the older pilots age 40-59 generally had fewer accidents than expected. However, in Table 8, the older airline pilots age 45-59 appear to have had a significantly greater

Table 6. Chi-Squared Test Results Using Commercial Pilot Data (1983-1986)

Pilot Age Groups	Number of Pilots	Observed Accidents (O)	Expected Accidents (E)	(O-E)	$(O-E)^2/E$
20-24	35,773	380	290.71	89.29	27.43
25-29	71,012	613	577.08	35.92	2.24
30-34	69,993	672	568.80	103.20	18.73
35-39	93,920	877	763.24	113.76	16.96
40-44	95,444	653	775.62	-122.62	19.39
45-49	73,759	467	599.40	-132.40	29.25
50-54	60,785	427	493.97	-66.97	9.08
55-59	42,230	323	343.18	-20.18	1.19
Total	542,916	4,412	4,412	0.00	124.24

Source: NTSB Accident Data Division & FAA's Statistical Handbook on Aviation

Table 7. Chi-Squared Test Results Using Air Transport Pilot (ATP) Data (1982-1988)

Pilot Age Groups	Number of Pilots	Observed Accidents (O)	Expected Accidents (E)	(O-E)	$(O-E)^2/E$
20-24	3,757	44	13.91	30.09	65.07
25-29	43,706	243	161.85	81.15	40.69
30-34	86,841	357	321.58	35.42	3.90
35-39	107,338	405	397.48	7.52	0.14
40-44	101,536	319	376.00	-57.00	8.64
45-49	89,229	257	330.42	-73.42	16.32
50-54	69,930	232	258.96	-26.96	2.81
55-59	42,884	162	158.80	3.20	0.06
Total	545,221	2,019	2,019	0.00	137.63

Source: NTSB Accident Data Division & FAA's Statistical Handbook on Aviation

Table 8. Chi-Squared Test Results Using Part 121 (Airline Pilot) Data (1982-1988)

Pilot Age Groups	Number of Pilots	Observed Accidents (O)	Expected Accidents (E)	(O-E)	$(O-E)^2/E$
25-29	30,800	2	8.18	-6.18	4.67
30-34	50,035	11	13.29	-2.29	0.39
35-39	57,833	7	15.36	-8.36	4.55
40-44	59,726	13	15.86	-2.86	0.52
45-49	62,708	20	16.65	3.35	0.67
50-54	44,153	19	11.72	7.28	4.52
55-59	22,406	15	5.95	9.05	13.77
Total	327,661	87	87	0.00	29.08

Source: NTSB Accident Data Division & FAA's Aeromedical Certification Statistical Handbook number of accidents. This result should be interpreted with great caution, since only one out of the three sets of comparisons yielded this result and the airline pilots have an extremely low accident rate.

CONCLUSION

The results of this study support the rejection of the null hypothesis that aging has no measurable effect on pilot performance as inferred from the number of accidents among pilots. The χ^2 analysis indicated that the observed frequency of accidents was significantly different than the expected frequency among active pilots. However, the analysis for airline pilots showed the older pilots age 45-59 had significantly more accidents than expected. It may be that the PIC factor contributes to this increase in accidents (e.g., it is likely that there are many more older airline captains than there are younger ones, and in an accident report, it is the PIC who gets charged with the accident whether he/she was flying the airplane or not). On the basis of the data presented, it was determined that there may in fact be some point in a pilot's career (e.g., a threshold level) after which performance gradually declines. The data presented herein consistently suggests that this decline occurs in the fifth decade for the majority of pilots.

Current medical screening procedures seem to be quite effective in eliminating those pilots who fall below the accepted medical standards. Pilots with medical problems are screened out of the active population at an increasing rate in association with the more advanced age groups. However, the validity of this data can be argued to be ambiguous because the very high number of medical denials of struggling airlines suggests that these denials could be a result of other factors than aging per se (e.g., management/union disagreements, political issues). Although much of the physiological and psychological literature would predict that performance decrements should begin in the late 20s and early 30s, the accident data indicate that the pilot safety records continue to improve through the 40s. This improvement probably indicates that the benefits of experience exceed any of the initial effects of aging; however, the effects of age and experience are more complex and difficult to evaluate and require further study.

The high accident statistics observed for younger pilots 20-24 years old, particularly among ATPs and commercial pilots, could be a result of other factors rather than their limited flight experience. These younger pilots, particularly those who work for commuter airlines, usually get the least desireable and most hazardous routes from the airline bidding process because of their low seniority. This bidding process also limits these pilots to the type of aircraft they fly (i.e., new and automated versus old and antiquated), thus increasing their risk and exposure factors considerably. However, some of these well-trained younger pilots may be just as safe as the older pilots; but, because the way our system is set up, the issue as to whether younger pilots are less safe than older pilots becomes more confounding.

The slight increase in the number of accident statistics involving pilots age 50 and over suggests that the benefits of experience may have an upper threshold limit. After this upper limit is reached or exceeded, the effects of age-related decrements appear to impact the safety record. In contrast, the accident record per 1,000 active private pilots, who as a group have significantly less flying experience than ATPs and commercial pilots, shows the type of progressive increase in accidents that would be predicted by the physiological and psychological literature. It could be that this progressive increase in accidents is a result of the very limited amount of hours flown by private pilots (i.e., third class holders). Their recent exposure rate is just too low to really get proficient in their flying skills. However, when the data for private pilots are adjusted by the number of hours flown, the safety level increases through the early 40s and then remains relatively stable with a slight decrease in safety in the late 50s.

The accident data suggest that there is a decrease in the safety and effectiveness of pilots by age 60. Whether this decrease in the older pilots' safety records is critical or not is difficult to establish. In comparing the records of the older groups of pilots with the younger groups who will be replacing them, the effectiveness of the Age 60 Rule would appear to be open to question. Compared to pilots in their 40s, the older pilots are slightly less safe, but compared to the younger pilots who would replace them, they seem to be slightly better. However, it is difficult to speculate how well the accident statistics would compare if older pilots were allowed to fly beyond age 60.

The debate as to whether or not older pilots are more at risk because of sudden incapacitation does not seem to be a major issue. Sudden incapacitation does not appear to be an age-related problem; it is more frequently associated with food poisoning. It is interesting to note that the age group most likely to suffer from sudden incapacitation (i.e., 45-49 year olds) is also the age group with the safest accident statistics. However, whether older pilots are more at risk because of undetected decrements in physical or mental performance has yet to be determined. The age trends within the data presented suggest that there are some noticeable changes with increasing age, especially after age 50. Although the literature suggests that there are a variety of tests which could be used to determine a pilot's reaction time and cognitive skills, there is very little information available which relates these measures to actual piloting skills. It is clear from the literature presented, that progressively fewer older pilots are able to meet the first class medical standards. Reinhart (1991) stated, " . . . we become less tolerant to the extremes of life, especially in the flight environment, and we become unable to maintain the fine tuning of our skills like we had in the good old days of our youth" (p. 13).

Despite the limitations addressed in this study, the evidence herein raises at least one point of general importance—the effects of experience may be greater than the effects of age for pilots between 20 and 49 years of age. Although the amount of recent experience is perhaps more important to flight safety than age alone, it was not addressed in this study because of the complexities in the databases. In addition, the consistent differences among pilot groups in the accident statistics by age 50 may be partly a result of factors other than aging alone. Such factors include cohort effects, attitude, motivation to fly, the fact that accidents are attributed to the PIC who may not necessarily be the one at the controls, and especially the cross-sectional nature of the study itself.

Summary

The objective of this study was to identify and report the issues relevant to the Age 60 Rule. This study as a whole lends support to the hypothesis advanced that pilot safety decreases for the most senior age groups (50-59 years old). It was generally observed that accident rates declined from the 20s through the late 40s, and then gradually increased in the 50s. There are also some striking similarities between the accident statistics and the medical issues presented herein; i.e., both show an age-related trend in the fifth decade. In general, the results show that pilots in their 40s experience the lowest accident rates. The data suggest that aging effects may outweigh the positive effects of experience in a pilot's fifth decade.

To this day, the Age 60 Rule remains to be a controversial topic. The medical issues, as they relate to piloting an aircraft, clearly impact the situation and obviously favor younger pilots. We must always seek ways to improve aviation safety. In comparing the records of the older groups of pilots with the younger groups who will be replacing them, the Age 60 Rule appears to diminish the overall safety level. However, it is again difficult to fully predict what would happen to the safety level if the current age limit for airline pilots was increased into the 60s—perhaps the Age 60 Rule would be supported. We must keep in mind that individual abilities and capacities vary dramatically. Professionally trained pilots with high levels of experience may in fact be able to cope with some of their selective sensory and cognitive losses and may also be capable of maintaining an acceptable safety record even into their sixth or seventh decade.

If the Age 60 Rule were to be changed, what are the alternative options available? More comprehensive and costly medical exams? More detailed and monitored LOFT sessions? Even though the results of this study support the notion that older and experienced pilots are safer than those who will replace them, Reinhart (1991) offered some interesting philosophical questions that we should consider. Reinhart queried whether airline pilots would really want the responsibility of the added burden of more costly and comprehensive testing and monitoring merely to fly for just a few more years, keeping in mind the ever present possibility of not meeting new standards at some unexpected point in time. "Or is it more prudent to plan for a stated age, continue to accept the present standards, and have more control of when to expect retirement for pilot and company?" (p. 17). At the present time, the Age 60 Rule remains to be a conservative approach to the aging and safety issues; however, the rule could very well be counterproductive by retiring our most seasoned and experienced pilots and replacing them with much younger and less qualified pilots. Nevertheless, it is presumed that until more advanced cognitive screening techniques are developed and validated, the rule will most likely remain unchanged.

Recommendations

The accident statistics for pilots age 60 and over could not be calculated as initially expected. These pilots are not specifically represented in the FAA's database. For example, the FAA's Statistical Handbook on Aviation lists the *upper age group* for license holders (i.e., private, commercial, and ATPs) as *60+*. Since there are many more older active pilots today, as compared to previous years (Mohler, 1986), it should be recommended that these pilots be accounted for until at least 65-69. This will allow future studies to benefit and utilize this data in order to get accurate statistics for these pilots as well, and to see if the trends increase even more beyond age 60.

Additional research with improved methodology (e.g., actual flying hours rather than medical class hours) is necessary before authoritative conclusions can be reached concerning the effects of age and experience on flight safety. The optimal means of determining whether there are any significant age decrements among older pilots is to conduct a longitudinal study; although very costy, a longitudinal study utilizing state-of-the-art technologies and appropriate measures of pilot performance would provide very beneficial information, therefore it is strongly recommended. It is also suggested that future studies use a recent time interval (e.g., just those pilots with >600 annual hours) in order to study the effects of recency and age on accident rates. For example, many of the ATPs and airline pilots involved in accidents often had more than 600 hours per year, as compared to some private pilots with only 30 hours per year.

Furthermore, there are highly advanced modern simulators that can duplicate real-life conditions along with the aircraft characteristics. These training devices should be able to screen out or at least identify pilot performance decrements objectively provided that standardized test and evaluation procedures can be agreed upon. Sterns et al. (1985) found that psychological tests designed to identify subtle changes in cognitive functioning have not been systematically administered to pilots. It would be useful to design future studies utilizing these psychological tests in order to help assess pilot performance involving complex tasks. Additionally, Salthouse (1987) stated, "Since accident avoidance behaviors often demand maximum response, tests should include demanding as well as moderate tasks" (p. 720). Future studies should also attempt to validate the use of LOFT and other assessment techniques on subjects that are current and proficient in their flying skills, particularly airline pilots where a high level of knowledge and skill is essential. Although, some literature (e.g., Salthouse) has already supported the development of screening and assessment approaches for airline pilots over 60 in order to identify those individuals who may be experiencing or who have already experienced some age-related changes that may reduce their functional level of skills.

The physiological and psychological literature adequately documents the evidence that human cognitive and sensory capabilities begin to decline in the late 20s. The accident data indicate that pilot safety continues to improve into the late 40s. Just how these age-related effects and experience alter pilot capacities is not well understood. This area is fruitful with opportunities for future research topics which should attempt to get a better understanding of these age-related effects on the pilot population.

REFERENCES

Arenberg, D. (1982). Changes with age in problem solving. In F. I. M. Craik & S. Trehub (Eds.), *Aging and cognitive processes, 8,* 221-235. NY: Plenum.

Baker et al. v. FAA, United States Court of Appeals for the Seventh Circuit (No. 89-2524; 1989).

Baltes, P. B., & Schaie, K. W. (1974, March). Aging and IQ the myth of the twilight years. *Psychology Today,* *7*(10), pp. 35-40.

Baltes, P. B., & Schaie, K. W. (1976). On the plasticity of intelligence in adulthood and old age. *American Psychologist, 31*(10), 720-725.

Bennett, G. (1972, October 26). Pilot incapacitation. *Flight International,* pp. 569-571.

Boone, J. O. (1982). *Functional aging in pilots: An examination of a mathematical model based on medical data on general aviation pilots* (Rep. No. FAA-AM-82-18). Washington, DC: Office of Aviation Medicine.

Booze, C. F., Jr., (1977). *An epidemiologic investigation of occupation, age, and exposure in general aviation accidents* (Rep. No. FAA-AM-77-10). Washington, DC: Office of Aviation Medicine.

Booze, C. F., Jr., & Simcox, L. S. (1984). *Blood pressure levels of active pilots compared with those of air traffic controllers* (Rep. No. FAA-AM-84-3). Washington, DC: Office of Aviation Medicine.

Booze, C. F., Jr., (1987). *Sudden inflight incapacitation in general aviation* (Rep. No. DOT-FAA-AM-87-7). Washington, DC: Office of Aviation Medicine.

Bortz, W. M., II (1980). Effect of exercise on aging-Effect of aging on exercise. *American Geriatrics Society, 28*(2), 49-51.

Botwinick, J. (1977). Intellectual abilities. In J. E. Birren & K. W. Schaie (Eds.), *Handbook of the psychology of aging* (pp. 580-605). New York: Van Nostrand Reinhold.

Botwinick, J. (1978). *Aging and behavior* (2nd ed.). New York: Springer.

Braune, R., & Wickens, C. D. (1983). The functional age profile: An objective decision criterion for the assessment of pilot performance capacities and capabilities. In R. S. Jensen (Ed.), *Proceedings of the second symposium on aviation psychology* (pp. 437-444). Columbus, OH: Ohio State University.

Braune, R., & Wickens, C. D. (1984). *Individual differences and age-related performance assessment in aviators. Part I: Battery development and assessment* (Tech. Rep. No. NAMRL 83-1/EPL-83-4). Champaign: University of Illinois at Urbana-Champaign, Dept. of Psychology.

Braune, R., Wickens, C. D., Strayer, D., & Stokes, A. F. (1985). Age-dependent changes in information processsing abilities between 20 and 60 years. *Proceedings of the Human Factors Society 29th Annual Meeting,* 226-230.

Bruce, R. A., & Fisher, L. D. (1987). Exercise-enhanced risk factors for coronary heart disease vs. age as criteria for mandatory retirement of healthy pilots. *Aviation, Space, and Environmental Medicine, 58*(8), 792-798.

Buley, L. E. (1969). Incidence, causes and results of airline pilot incapacitation while on duty. *Aerospace Medicine, 40*(1), 64-70.

Cann, M. T. (1990). Causes and correlates of age-related cognitive slowing: Effects of task loading and CNS arousal. *Proceedings of the Human Factors Society 34th Annual Meeting, 1*, 149-153.

Collins, W. E., & Mertens, H. W. (1988). *Age, alcohol, and simulated altitude: Effects on performance and breathalyzer scores* (Rep. No. DOT-FAA-AM-88-2). Washington, DC: Office of Aviation Medicine.

Corso, J. F. (1987). Sensory-perceptual processes and aging. In K. W. Schaie & C. Eisdorfer (Eds.), *Annual review of gerontology and geriatrics, 7* (pp. 29-55). New York: Springer.

Cox, J. (1990, January). Bill to change age 60 rule introduced in Congress. *Sport Aviation,* p. 8.

Craik, F. I. M. (1977). Age differences in human memory. In J. E. Birren & K. W. Schaie (Eds.), *Handbook of the psychology of aging* (pp. 384-420). New York: Van Nostrand Reinhold.

Craik, F. I. M., & Byrd, M. (1982). Aging and cognitive deficits: The role of attentional resources. In F. I. M. Craik & S. Trehub (Eds.), *Aging and cognitive processes* (pp. 191-211). New York: Plenum Press.

Craik, F. I. M., & McDowd, J. M. (1987). Age differences in recall and recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 13*(3), 474-479.

Dodson, R. (1990, November). Why are we grounding our best pilots? *Reader's Digest,* pp. 189-196.

Downey, L. E., & Dark, S. J. (1990). *Medically disqualified airline pilots in calender years 1987 and 1988* (Rep. No. DOT-FAA-AM-90-5). Washington, DC: Office of Aviation Medicine.

Edwards, D. C. (1990). *Pilot mental and physical performance.* Ames, IA: Iowa State University.

Eisdorfer, C. (Ed.). (1985, December). *Research on aging.* Paper presented at the Science and Public Policy Seminar. (Available from [The Federation of Behavioral, Psychological, and Cognitive Sciences, 1200 Seventeenth Street, N.W., Washington, DC 20036]).

FAA reopens age-60 file. (1989, February). *Aviation International News,* p. 2.

Federal rule forcing airline pilots to retire at 60 under fire again. (1989, December 3). *Daytona Beach Sunday News-Journal,* p. 10A.

Fotos, C. P. (1988, November 28). FAA weighs response to age-60 challenge. *Aviation Week & Space Technology*, pp. 98-99.

Foushee, H. C., & Helmreich, R. L. (1988). Group interaction and flight crew performance. In E. L. Wiener & D. C. Nagel (Eds.), *Human factors in aviation* (pp. 187-227). San Diego: Academic Press.

Fox, S. M., III, & Haskell, W. L. (1968). Physical activity and the prevention of coronary heart disease. *Bulletin of New York Academy Medicine, 44*(8), 950-967.

Fozard, J. L. (1990). Vision and hearing in aging. In J. E. Birren & K. W. Schaie (Eds.), *Handbook of the psychology of aging* (3rd ed.), (pp. 150-170). San Diego: Academic Press.

Fozard, J. L., Vercruyssen, M., Reynolds, S. L., & Hancock, P. A. (1990). Longitudinal analysis of age-related slowing: BLSA reaction time data. *Proceedings of the Human Factors Society 34th Annual Meeting, 1*, 163-167.

Froom, P., Benbassat, J., Gross, M., Ribak, J., & Lewis, B. S. (1988). Air accidents, pilot experience, and disease-related inflight sudden incapacitation. *Aviation, Space, and Environmental Medicine, 59*(1), 278-281.

Gault, O. (1990, June). When is it time to quit? *Air Progress*, pp. 20-21.

Gay, L. R. (1987). *Educational research competencies for analysis and application* (3rd ed.). Columbus, OH: Merrill.

General Accounting Office. (1989). *Aviation safety: Information on FAA's age 60 rule for pilots* (GAO-RCED-90-45FS).

Gerathewohl, S. J. (1978a). *Psychophysiological effects of aging - developing a functional age index for pilots: II. Taxonomy of psychological factors* (Rep. No. FAA-AM-78-16). Washington, DC: Office of Aviation Medicine.

Gerathewohl, S. J. (1978b). *Psychophysiological effects of aging - developing a functional age index for pilots: III. Measurement of pilot performance* (Rep. No. FAA-AM-78-27). Washington, DC: Office of Aviation Medicine.

Giambra, L. M., & Arenberg, D. (1980). Problem solving, concept learning, and aging. In L. W. Poon (Ed.), *Aging in the 1980s* (pp. 253-259). Washington, DC: APA.

Gilbert, J. G., & Levee, R. F. (1971). Patterns of declining memory. *Journal of Gerontology, 26*(1), 70-75.

Glanzer, M., & Glaser, R. (1959). Cross-sectional and longitudinal results in a study of age-related changes. *Educational and Psychological Measurement, 19*(2), 89-101.

Glines, C. V. (1985, August). Exemptions and waivers: Stretching airline safety? *Air Line Pilot*, pp. 20, 41.

Golaszewski, R. (1983). Acumenics Research and Technology, Incorporated. *The influence of total flight time, recent flight time and age on pilot accident rates* (Order No. DTRS57-83-P-80750). Unpublished manuscript.

Gordon, S. K., & Clark, W. C. (1974). Application of signal detection theory to prose recall and recognition in elderly and young adults. *Journal of Gerontology, 29*(1), 64-72.

Hammond, P. (1989, April 16). Mandatory retirement 'senseless,' pilots say. *New Hampshire Sunday News* [Manchester], Transportation, 1989, fiche 21, grid E8-9.

Harper, C. R. (1964). Physical defects of civilian pilots related to aircraft accidents. *Aerospace Medicine, 35*(9), 851-856.

Hartley, J. T., Harker, J. O., & Walsh, D. A. (1980). Contemporary issues and new directions in adult development of learning and memory. In L. W. Poon (Ed.), *Aging in the 1980s* (pp. 239-252). Washington, DC: APA.

Hawkins, F. W. (1987). *Human factors in flight.* Brookfield, VT: Gower.

Hellerstein, H. K., Hornsten, T. R., Goldbarg, A., Burlando, A. G., Friedman, E. H., Hirsch, E. Z., & Marik, S. (1967). The influence of active conditioning upon subjects with coronary artery disease. *Canadian Medical Association Journal, 96,* 758-759.

Hertzog, C. (1985). An individual differences perspective. *Research on Aging, 7*(1), 7-45.

Higgins, E. A., Mertens, H. W., McKenzie, J. M., Funkhouser, G. E., White, M. A., & Milburn, N. J. (1982). *The effects of physical fatigue and altitude on physiological, biochemical, and performance responses* (Rep. No. FAA-AM-82-10). Washington, DC: Office of Aviation Medicine.

Horn, J. L., & Donaldson, G. (1976). On the myth of intellectual decline in adulthood. *American Psychologist, 31*(10), 701-709.

Hoyer, W. J., & Plude, D. J. (1982). Aging and the allocation of attentional resources in visual information processing. In R. Sekuler, D. Kline, & K. Dismukes (Eds.), *Aging and human visual function* (pp. 245-263). New York: Liss.

Institute of Medicine, National Academy of Sciences. (1981). *Airline pilot age, health, and performance.* Washington, DC: National Academy Press.

Kline, D. W., & Schieber, F. (1985). Vision and aging. In J. E. Birren & K. W. Schaie (Eds.), *Handbook of the psychology of aging* (2nd ed.), (pp. 296-331). New York: Van Nostrand Reinhold.

Koonce, J. M. (1989). Another look at aircraft accident statistics. In R. S. Jensen (Ed.), *Proceedings of the 5th Symposium on Aviation Psychology, 2,* 866-871.

Labouvie-Vief, G. (1985). Intelligence and cognition. In J. E. Birren & K. W. Schaie (Eds.), *Handbook of the psychology of aging* (2nd ed.), (pp. 500-530). New York: Van Nostrand Reinhold.

Lategola, M. T., Fiorica, V., Booze, C. F., Jr., & Folk, E. D. (1970). *Comparison of status variables among accident and non-accident airmen from the active airman population* (Rep. No. AM-70-18A). Washington, DC: Office of Aviation Medicine.

Lavin, C. H. (1989, April 4). Older pilots challenge a rule that closes careers after 60. *The New York Times*, pp. A1, B8.

Leirer, V. O., Yesavage, J. A., & Morrow, D. G. (1989). Marijuana, aging, and task difficulty effects on pilot performance. *Aviation, Space, and Environmental Medicine, 60*(12), 1145-1152.

McDowd, J. M., & J. E. Birren (1990). Aging and attentional processes. In J. E. Birren & K. W. Schaie (Eds.), *Handbook of the psychology of aging* (3rd ed.), (pp. 222-233). San Diego: Academic Press.

Mertens, H. W., Higgins, E. A., & McKenzie, J. M. (1983). *Age, altitude, and workload effects on complex performance* (Rep. No. FAA-AM-83-15). Washington, DC: Office of Aviation Medicine.

Mertens, H. W., & Collins, W. E. (1985). *The effects of age, sleep deprivation, and altitude on complex performance* (Rep. No. FAA-AM-85-3). Washington, DC: Office of Aviation Medicine.

Moenster, P. (1972). Learning and memory in relation to age. *Journal of Gerontology, 27*(3), 361-363.

Mohler, S. R., Bedell, R. H. S., Ross, A., & Veregge, E. J. (1967). *Aircraft accidents by older persons* (Rep. No. AM 67-22). Washington, DC: Office of Aviation Medicine.

Mohler, S. R., & Booze, C. F. (1978). U.S. fatal general aviation accidents due to cardiovascular incapacitation: 1974-75. *Aviation, Space, and Environmental Medicine, 49*(10), 1225-1228.

Mohler, S. R. (1981). Reasons for eliminating the "Age 60" regulation for airline pilots. *Aviation, Space, and Environmental Medicine, 52*(8), 445-454.

Mohler, S. R. (1982, March/April). Lifestyle and longevity: New findings for pilots. *Human Factors Bulletin, 28*(2).

Mohler, S. R. (1983, September/December). Civil pilot taxonomy: Implications for flight safety. *Human Factors Bulletin, 29*(5).

Mohler, S. R. (1984, January/April). Aircrew physical status and career longevity. *Human Factors Bulletin, 31*(1).

Mohler, S. R. (1986, May/June). Special issuances to pilots who do not meet basic medical standards. *Human Factors Bulletin, 33*(3).

Moorman, R. (1986, August). Where have all the pilots gone? *Airline Pilot*, pp. 24-27.

Morrow, D., Leirer, V., & Yesavage, J. (1990). The influence of alcohol and aging on radio communication during flight. *Aviation, Space, and Environmental Medicine, 61*(1), 12-20.

Murrell, F. H. (1970). The effects of extensive practice on age differences in reaction time. *Journal of Gerontology, 25*(3), 268-274.

National Institute on Aging. (1981). *Report of the National Institute on Aging Panel on the experienced pilots study.* Bethesda, MD.

Office of Technology Assessment. (1990). *Technical analysis: Medical risk assessment and the age 60 rule for airline pilots,* pp. 1-12.

Olsho, L. W., & Harkins, S. W. (1985). Aging and the auditory system. In J. E. Birren & K. W. Schaie (Eds.), *Handbook of the psychology of aging* (2nd ed.), (pp. 332-377). New York: Van Nostrand Reinhold.

Perlmutter, M. (1980). An apparent paradox about memory aging. In L. W. Poon, J. L. Fozard, L. S. Cermak, D. Arenberg, & L. W. Thompson (Eds.), *New directions in memory and aging: Proceedings of the George A. Talland memorial conference* (pp. 345-353). Hillsdale, NJ: Lawrence Erlbaum Assoc.

Perlmutter, M., Adams, C., Berry, J., Kaplan, M., Person, D., & Verdonik, F. (1987). Aging and memory. In K. W. Schaie & C. Eisdorfer (Eds.), *Annual review of gerontology and geriatrics, 7* (pp. 57-92). New York: Springer.

Poon, L. W. (1985). Differences in human memory with aging: Nature, causes, and clinical implications. In J. E. Birren & K. W. Schaie (Eds.), *Handbook of the psychology of aging* (2nd ed.), (pp. 427-462). New York: Van Nostrand Reinhold.

Quilter, R. E., Giambra, L. M., & Benson, P. E. (1983). Longitudinal age changes in vigilance over an eighteen year interval. *Journal of Gerontology, 38*(1), 51-54.

Rabbitt, P. M. A. (1977). Changes in problem solving ability in old age. In J. E. Birren & K. W. Schaie (Eds.), *Handbook of the psychology of aging,* (pp. 606-622). New York: Van Nostrand Reinhold.

Rayman, R. B. (1973). Sudden incapacitation in flight, 1 Jan. 1966 - 30 Nov. 1971. *Aerospace Medicine, 44*(8), 953-955.

Reese, H. W., & Rodeheaver, D. (1985). Problem solving and complex decision making. In J. E. Birren & K. W. Schaie (Eds.), *Handbook of the psychology of aging* (2nd ed.), (pp. 474-499). New York: Van Nostrand Reinhold.

Reighard, H. L., & Mohler, S. R. (1967). Some aspects of sudden incapacitation in airmen due to cardiovascular disease. *Aerospace Medicine, 38*(12), 1273-1275.

Reinhart, R. O. (1982). *The pilot's manual of medical certification and health maintenance.* Osceola, WI: Specialty Press Publishers & Wholesalers.

Reinhart, R. O. (1991). Age 60 rule compulsory retirement at age 60. *Aviation Safety Journal, 1*(1), 12-17.

Ribak, J., Hornung, S., Karl, J., Froom, P., Wolfstein, A., & Ashkenazi, I. E. (1985). The association of age, flying time, and aircraft type with hearing loss of aircrew in the Israeli Air Force. *Aviation, Space, and Environmental Medicine, 56*(4), 322-327.

Rodin, J. (Ed.). (1987, October). *The determinants of successful aging.* Paper presented at the Science and Public Policy Seminar. (Available from [The Federation of Behavioral, Psychological, and Cognitive Sciences, 1200 Seventeenth Street, N.W., Washington, DC 20036]).

Salthouse, T. A. (1985). Speed of behavior and its implications for cognition. In J. E. Birren & K. W. Schaie (Eds.), *Handbook of the psychology of aging* (2nd ed.), (pp. 400-426). New York: Van Nostrand Reinhold.

Salthouse, T. A. (1987). The role of experience in cognitive aging. In K. W. Schaie & C. Eisdorfer (Eds.), *Annual review of gerontology and geriatrics, 7* (pp. 135-158). New York: Springer.

Salthouse, T. A. (1990a). Influence of experience on age differences in cognitive functioning. *Human Factors Journal, 32*(5), 551-569.

Salthouse, T. A. (1990b). Cognitive competence and expertise in aging. In J. E. Birren & K. W. Schaie (Eds.), *Handbook of the psychology of aging* (3rd ed.), (pp. 310-319). San Diego: Academic Press.

Salthouse, T. A., Babcock, R. L., Skovronek, E., Mitchell, D. R. D., & Palmon, R. (1990). Age and experience effects in spatial visualization. *Developmental Psychology, 26*(1), 128-136.

Sanders, M. S., & McCormick, E. J. (1987). Visual displays of static information. In J. Anker & J. Morriss (Eds.), *Human factors in engineering and design* (pp. 79-116). New York: McGraw-Hill.

Schaie, K. W. (1974). Translations in gerontology—from lab to life: Intellectual functioning. *American Psychologist, 29*(11), 802-807.

Schonfield, D. (1974). Translations in gerontology—from lab to life: Utilizing information. *American Psychologist, 29*(11), 796-801.

Schreuder, O. B. (1966). Medical considerations in civil jet operations. *Aerospace Medicine, 31*(7), 578-583.

Select Committee on Aging, House of Representatives Ninety-Sixth Congress. (1979). *Age discrimination against airline pilots* (Comm. Pub. No. 96-183). Washington, DC: U.S. Government Printing Office.

Select Committee on Aging, House of Representatives Ninety-Ninth Congress. (1985). *Age discrimination and the FAA age 60 rule* (Comm. Pub. No. 99-533). Washington, DC: U.S. Government Printing Office.

Serwer, A. M. (1990). Compulsory retirement at age 60—II. *Proceedings of the 35th Annual Corporate Aviation Safety Seminar,* 18-26.

Shriver, B. M. (1953, February). *Age and behavior* (Research Project No.21-0202-0005). Randolph Field, TX: USAF School of Aviation Medicine.

Shock, N. W., Greulich, R. C., Andres, R., Arenberg, D., Costa, P. T., Jr., Lakatta, E. G., & Tobin, J. D. (1984). *Normal human aging: The Baltimore longitudinal study of aging* (NIH Publication No. 84-2450). Washington, DC: U.S. Government Printing Office.

Simon, J. R. (1967). Choice reaction time as a function of auditory S-R correspondence, age and sex. *Ergonomics, 10*(6), 659-664.

Spilich, G. J. (1983). Life-span components of text processing: Structural and procedural differences. *Journal of Verbal Learning and Verbal Behavior, 22,* 231-244.

Stankov, L. (1988). Aging, attention, and intelligence. *Psychology and Aging, 3*(1), 59-74.

Stephens, R. (1989, October). FAA: It's flying blind. *AARP Bulletin*, pp. 1, 9.

Sterns, J. A., Oster, P. J., & Newport, K. (1980). Reaction time measures, hemispheric specialization, and age. In L. W. Poon (Ed.), *Aging in the 1980s* (pp. 309-326). Washington, DC: APA.

Sterns, H. L., Barrett, G. V., & Alexander, R. A. (1985). Accidents and the aging individual. In J. E. Birren & K. W. Schaie (Eds.), *Handbook of the psychology of aging* (2nd ed.), (pp. 703-724). New York: Van Nostrand Reinhold.

Surwillo, W. W., & Quilter, R. E. (1964). Vigilance, age, and response-time. *American Journal of Psychology, 77,* 614-620.

Szafran, J. (1969). Psychological studies of aging in pilots. *Aerospace Medicine, 40*(5), 543-553.

The Medical Study Group, British Air Line Pilots Association. (1988). *Fit to fly* (2nd ed.). Great Britain: Granada.

Thompson, L. W., Opton, E., Jr., & Cohen, L. D. (1963). Effects of age, presentation speed, and sensory modality on performance of a "vigilance" task. *Journal of Gerontology, 18,* 366-369.

Tsang, P. S. (1989). A reappraisal of aging and pilot performance. In R. S. Jensen (Ed.), *Proceedings of the fifth international symposium of aviation psychology, 2,* 521-526.

Vercruyssen, M., Carlton, B. L, & Diggles-Buckles, V. (1989). Aging, reaction time, and stages of information processing. *Proceedings of the Human Factors Society 33rd Annual Meeting, 1,* 174-178.

Von Gierke, H. E., & Nixon, C. W. (1971). Noise effects and speech communication in aerospace environments. In H. W. Randel (Ed.), *Aerospace Medicine* (2nd ed.), (pp. 224-253). Baltimore: Williams & Wilkins.

Wentz, A. E. (1964). *Studies on aging in aviation personnel* (Rep. No. AM 64-1). Washington, DC: Office of Aviation Medicine.

Westrum, R. (1987). Management strategies and information failure. In J. A. Wise & A. Debons (Eds.), *Information systems: Failure analysis* (pp. 109-127). Berlin: Springer-Verlag.

Wilkinson, R. T., & Allison, S. (1989). Age and simple reaction time: Decade differences for 5,325 subjects. *Journal of gerontology: Psychological sciences, 44*(2), 29-35.

Willis, S. L., & Baltes, P. B. (1980). Intelligence in adulthood and aging: Contemporary issues. In L. W. Poon & A. D. Smith (Eds.), *Aging in the 1980s* (pp. 260-272). Washington, DC: APA.

APPENDIX A

F.A.R. PART 121.383(c)

Subpart M—Airman and Crewmember Requirements

SOURCE: Docket No. 6258, 29 FR 19212, Dec. 31, 1964, unless otherwise noted.

§ 121.381 Applicability.

This subpart prescribes airman and crewmember requirements for all certificate holders.

§ 121.383 Airman: Limitations on use of services.

(a) No certificate holder may use any person as an airman nor may any person serve as an airman unless that person—

(1) Holds an appropriate current airman certificate issued by the FAA;

(2) Has any required appropriate current airman and medical certificates in his possession while engaged in operations under this part; and

(3) Is otherwise qualified for the operation for which he is to be used.

(b) Each airman covered by paragraph (a)(2) of this section shall present either or both certificates for inspection upon the request of the Administrator.

(c) No certificate holder may use the services of any person as a pilot on an airplane engaged in operations under this part if that person has reached his 60th birthday. No person may serve as a pilot on an airplane engaged in operations under this part if that person has reached his 60th birthday.

[Doc. No. 6258, 29 FR 19212, Dec. 31, 1964, as amended by Amdt. 121-144, 43 FR 22646, May 25, 1978]

Note. From *Code of Federal Regulations, Title 14* (p. 436), 1990, Washington, DC: U.S. Government Printing Office.

APPENDIX B

LETTERS FROM FOREIGN NATIONS ON PILOT AGE LIMITATIONS

(AUSTRALIA, FINLAND, GERMANY, MEXICO, NEW ZEALAND, NORWAY, UNITED KINGDOM)

Civil Aviation Authority

G.P.O Box 367
Canberra
ACT 2601
Australia
Telephone: (062) 684111
Telex: 62221
FAX: (062) 485239

Mr Patrick C Guide
Box 1391
Embry-Riddle Aeronautical University
DAYTONA BEACH FLORIDA 32114-3900

Dear Mr Guide

Your letter of 16 August 1990 to Senator the Hon Bob Collins, Minister for Shipping and Aviation Support, has been referred to the Civil Aviation Authority for reply.

You sought information on upper age limits for pilots in Australia. In respect of non-commercial operations, I can advise that there is no upper age limit applied to pilots, provided they satisfy the medical standards appropriate to the level of licence held.

For commercial and higher category licences there is also no upper age limit, but there are limitations placed upon pilots who have attained the age of 60 years. I have enclosed copies of the relevant Civil Aviation Orders which set out these limitations.

I trust this information will be of some assistance to you.

A E HEGGEN
Group General Manager
Safety Regulation

4 October 1990

FINNAIR

Flight Department/U. Koskela/tm *14 December 1990*

Patrick C. Guide
Embry-Riddle Aeronautical University
Box 1391
Daytona Beach, FL 32114-3900
USA

Your letter of 27 August 1990

UPPER AGE LIMITS

I am sorry for our late reply.

The upper age limits are as follows:

Type of licence	upper age limit
Private pilot's licence	no age limit
Commercial pilot's licence	60 years
Air Trafffic pilot's licence	60 years

These limits are valid if there is no medical reasons to cancel the pilot's licence earlier.

With best regards,

FINNAIR
Flight Department

Urpo Koskela
Chief Pilot

Finnair 840/1 A - VRL/SDF

Postilokero

Helsinki-Vantaan Lentoasema
PL 68-69
01531 VANTAA

Helsinki Airport
PL 68-69
01531 VANTAA
FINLAND

Puhelin - Telephone
Keskus - Exchange (90) 818 51
Ohivalinta - Direct Line (90) 818..

Telex
124396

Telefax
(90) 818 6700

Luftfahrt-Bundesamt
Außenstelle Berlin
Referat Flugmedizin

Luftfahrt-Bundesamt Außenstelle Berlin
Flughafen . 0-1189 Berlin-Schönefeld

Mr. Patrick C. Guide
170 Iron Gate Circle
Port Orange, FL 32119
USA

Ihre Zeichen und Nachricht vom	(Bitte bei Antwort angeben) Unsere Zeichen	Unsere Durchwahl	Berlin-Schönefeld
07. 09. 1990	B 2317dr.do-gr Tgb.-Nr. 149	672 4027	06. 11. 1990

Dear Mr. Guide,

Please excuse my late response.
Mr. Krupper handed me your letter dated Sep. 7th 1990 regarding your study relating changes in flying safety as a function of pilot age.

In the former GDR there was no regulation concerning a upper age limit of 60 years however we only know about two pilots of this age.

The age - criteria which terminated an aviators career were the medical regulations for Licensing only.

A study performed by INTERFLUG has indicated, that older pilots were not involved in more accidents, failures or inflight - incapacitations then younger pilots.

Further indepth information could possitly be received from INTERFLUG.

Many greetings

Dr. Dollny

FORMA CG.1A

SECRETARIA DE COMUNICACIONES
Y
TRANSPORTES

DIRECCION GENERAL DE AERONAUTICA CIVIL
DIRECCION TECNICA Y DE SUPERVISION
101.204.-237 36232

CORREO AEREO REGISTRADO

TRANSLATION ON NEXT PAGE

México, D.F., 3 de octubre de 1990.

PATRICK C. GUIDE
Embry-Riddle Aeronautical University
Box 1391
Daytona Beach, FL 32114-3900
U.S.A.

En relación a su atenta de fecha 27 de agosto próximo pasado, me permito informarle que en nuestro País no existe restricción legal por edad a ningún piloto para volar en la aviación general, el único requisito es que pasen los exámenes médicos establecidos por la Dirección General de Medicina Preventiva en el Transporte a través de la Subdirección de Medicina de Aviación, los cuales son más rigurosos en ciertos aspectos que los normales de otro País, sin embargo algunos empleadores no aceptan pilotos mayores de 60 años. Por otra parte en convenios contractuales celebrados entre la Asociación Sindical de Pilotos Aviadores de México, Mexicana de Aviación, Aerovías de México y otras pequeñas compañías de líneas aéreas, se ha fijado la fecha máxima para prestar servicios hasta la edad de 60 años a los cuales deberán retirarse protegidos con programas de retiro o jubilación.

Los pilotos eliminados por causas médicas son indemnizados de acuerdo a los Contratos firmados con la Asociación Sindical de Pilotos y sumadas a las señaladas por la Ley Federal del Trabajo de nuestro País.

Esperando que la información sea de utilidad.

Atentamente.
SUFRAGIO EFECTIVO. NO REELECCION.
EL DIRECTOR GENERAL.

ENRIQUE ZAPATA B.

S.C.T.
... DE AERONAUTICA CIVIL
ENTRADA

S.C.T.
DIRECCION GENERAL ...
OCT 15 1990
OFICINA: ... Y ARCHIVO
SALIDA

CAP. FBT*ahp.

TCN

General Direction of Civil Aeronautic
Technical and Supervisory Direction

Mexico, D.F., October 3, 1990

In relation to your courteous letter dated August 27, may I inform you that in our country there are no legal restrictions due to age for pilots in order to fly in general aviation, the only requirement is that they pass the medical exams established by the General Office of Preventative Medicine in Transportation through the subdivision of Aviation Medicine. These exams are more rigorous in certain aspects than the regular exams from other countries, notwithstanding some companies do not accept pilots older than 60 years of age. On the other hand, in negotiations between the Pilots Association of Mexico and the two largest air carriers of Mexico, along with the other smaller airlines, it has been established that the latest date to fly will be at the age of 60 at which time the pilot should retire with a pension program.

Those pilots that are eliminated for medical reasons are paid in accordance with the contracts signed by the Pilots Association and in accordance to the pertaining Federal Labor Regulations of our country.

I hope this information will be useful for you.

Sincerely.

General Director
Enrique Zapata B.

OFFICE OF AIR ACCIDENTS INVESTIGATION

IF REPLYING QUOTE 25/1/13

31 August 1990

Embry-Riddle Aeronautical University
Daytona Beach, FL 32114-3900
UNITED STATES OF AMERICA

Dear Mr Guide

Reference your letter of 16 August.

Herewith the data re age and experience of pilots involved in accidents to fixed wing powered aircraft from 1983 - 1987.

There is no upper age limit for pilots in New Zealand.

An aviator's career is terminated if he develops a medical condition for which a waiver cannot be issued.

The cost of the enclosed printout, time and postage is US$36.

Yours faithfully

R Chippindale
Chief Inspector of Air Accidents

Encl

14TH FLOOR, INVESTMENT HOUSE, CNR BALLANCE & FEATHERSTON ST, WELLINGTON

PO Box 1210 Wellington Telephone (04) 733-112 Fax (04) 499-1510 Telex NZ 30630

KIRKVAAGbehandler

LUFTFARTSVERKET
HOVEDADMINISTRASJONEN
AVDELING FOR LUFTFARTSINSPEKSJON

Patrick C. Guide,
170 Iron Gate Circle
Port Orange, FL 32119,
USA.

24th Sept 1990	Vår referanse	Deres dato	Deres referanse
	90/06109 741	900829	Letter

STATISTICS IN REGARDS TO AIRCRAFT ACCIDENTS IN NORWAY.

Thank you for your letter about the above mentioned statistics.
We are sorry to inform you that we do not have any information about changes in flying status as a function of pilot age.

All private pilots are able to fly as long as they have valid medical papers and satisfy our minimum flying hours per year, or have passed a two-yearly PFT (Periodic Flight Training).

Commercial pilots have to stop flying internationally when they reach the age of 60 years.
Certainly, pilots may also end their career if they have any kind of serious illness that prohibit further flying.
This is according to international rules and regulationes.

This is also an answer of your letter to SAS about the same subject.

Yours sincerely

Tor B. Kirkvaag,
Chief Inspector.

Postadresse	Kontoradresse	Telefon	Telefax	AFTN	Telex	Telegram
Postboks 18	Gamle Snarøyveien 47	Nasjonalt (02) 59 33 40	Nasjonalt (02) 59 34 69		21568	CIVILAIR
1330 OSLO LUFTHAVN	Fornebu Nord	Internasj. +47 2 59 33 40	Internasj. +47 2 59 34 69	ENCAYEYX	enyen n	OSLO

Civil Aviation Authority
Safety Regulation Group
Aviation House 3W
South Area
Gatwick Airport
Gatwick
West Sussex RH6 0YR
Tel: Switchboard 0293 567171
Telex: 878753 Fax: 0293 573999

Mr Patrick C Guide
Embry-Riddle Aeronautical University
Daytona Beach
FL 32114-3900

Our Ref: 10MG/03/01/10
WP:JH725

23 August, 1990

Dear Mr Guide

Thank you for your further letter dated 16 August 1990, regarding upper age limits for pilots and aviators careers.

There is no upper age limit for the holders of Private Pilots Licences (PPL). However, there is an increase in the frequency of medical examination:

Under 40	-	60 months
40 - 50	-	24 months
50 - 70	-	12 months
Over 70	-	6 months

The privileges of Professional Pilot Licence holders are restricted in respect of Public Transport at 60 years of age to require him/her to fly as a member of a crew of 2-pilots or more and then only in aircraft with a Maximum Total Weight Authorised not exceedidng 20,000 kg. A Professional Pilot Licence holder cannot fly for Public Transport when aged 65 years or more. A Professional Pilot Licence holder can otherwise fly any aircraft included in his licence up to any age provided he remains fit and can qualify for a medical certificate.

The Authority has no say in the employment of pilots or their career structure.

I hope this information is sufficient, please do not hesitate to write to me again.

Yours sincerely

J Harris

Miss J Harris
Management Support Unit

APPENDIX C

H.R. 3498

I

101st CONGRESS
1st Session

H. R. 3498

To amend the Federal Aviation Act of 1958 to limit the age restrictions imposed upon aircraft pilots.

IN THE HOUSE OF REPRESENTATIVES

OCTOBER 19, 1989

Mr. LIGHTFOOT (for himself, Mr. BALLENGER, Mr. CHAPMAN, Mr. DUNCAN, Mr. EMERSON, Mr. HANCOCK, Mr. HAYES of Illinois, Mr. INHOFE, Mr. LAUGHLIN, Mr. PACKARD, Mr. DENNY SMITH, Mr. HASTERT, Mr. GRANT, Mr. JONES of Georgia, and Mr. PAYNE of Virginia) introduced the following bill; which was referred to the Committee on Public Works and Transportation

---

A BILL

To amend the Federal Aviation Act of 1958 to limit the age restrictions imposed upon aircraft pilots.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SECTION 1. LIMITATION ON AGE RESTRICTIONS IMPOSED UPON AIRCRAFT PILOTS.

Section 602(b) of the Federal Aviation Act of 1958 (49 U.S.C. 1422(b)) is amended by adding at the end thereof the following new paragraph:

"(3) LIMITATION ON AGE RESTRICTIONS.—The Administrator shall not, solely by reason of the age of a person, if such person is less than 65 years of age—

"(A) refuse to issue an airman certificate to, or refuse to renew such certificate for, such person, if such person is applying for the issuance or renewal of such certificate in order to serve or continue to serve as a pilot of an aircraft; or

"(B) require an air carrier to terminate the employment of, or refuse to employ, such person as a pilot on an aircraft of such air carrier.".

○

APPENDIX D

PUBLIC LAW 96-171

Public Law 96-171
96th Congress

An Act

To require a study of the desirability of mandatory age retirement for certain pilots, and for other purposes.

Dec. 29, 1979
[H.R. 3948]

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the Director of the National Institutes of Health, in consultation with the Secretary of Transportation, shall conduct a study to determine—

Pilots, study of mandatory age retirement. 49 USC 1421 note.

(1) whether an age limitation which prohibits all individuals who are sixty years of age or older from serving as pilots is medically warranted;

(2) whether an age limitation which prohibits all individuals who are older than a particular age from serving as pilots is medically warranted;

(3) whether rules governing eligibility for first- and second-class medical certification, as set forth in part 67 of title 14 of the Code of Federal Regulations (as in effect on the date of enactment of this Act), are adequate to determine an individual's physical condition in light of existing medical technology;

14 CFR Part 67.

(4) whether rules governing the frequency of first- and second-class medical examinations, as set forth in part 67 of title 14 of the Code of Federal Regulations (as in effect on the date of enactment of this Act), are adequate to assure that an individual's physical condition is being satisfactorily monitored; and

(5) the effect of aging on the ability of individuals to perform the duties of pilots with the highest level of safety.

The Director shall complete such study and submit a report of the results thereof to Congress within one year after the date of enactment of this Act. In conducting such study the Director shall utilize all available studies and data which are relevant to such study.

Report to Congress.

SEC. 2. No funds are authorized to be appropriated for the fiscal year commencing October 1, 1979, in addition to funds otherwise available to carry out the study described in section 1 of this Act.

Appropriation authorization.

Approved December 29, 1979.

LEGISLATIVE HISTORY:

HOUSE REPORT No. 96-474 (Comm. on Public Works and Transportation).
CONGRESSIONAL RECORD, Vol. 125 (1979):
Dec. 5, considered and passed House.
Dec. 18, considered and passed Senate, amended.
Dec. 19, House concurred in Senate amendment.

O

59-139 O - 80 (213)

APPENDIX E

ACCIDENT STATISTICS FOR AIR TRANSPORT PILOTS (ATPs), COMMERCIAL PILOTS, PRIVATE PILOTS, PART 121 OPERATORS, AND GENERAL AVIATION OPERATORS

Table E-1. Accident Statistics for Air Transport Pilots (1982-1988)

	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60+	TOTAL
No. of ATPs[a]	3,757	43,706	86,841	107,338	101,536	89,229	69,930	42,884	41,561	586,782
% of ATPs	0.64	7.45	14.80	18.29	17.30	15.21	11.92	7.31	7.08	100
1,000s of ATPs	3.76	43.71	86.84	107.34	101.54	89.23	69.93	42.88	41.56	586.78
ATP Accidents Observed[b]	44	243	357	405	319	257	232	162	162	2,181
ATP Accidents Expected	13.96	162.45	322.78	398.96	377.40	331.65	259.92	159.39	154.48	2,181
Avg. Flight Hours/Pilot (Class I holders)[c]	427.1	608.7	572.3	575.9	571.0	594.4	606.2	598.9	383.0	575.7
100,000 Annual Flight Hours	16.0	266.0	497.0	618.2	579.8	530.4	423.9	256.8	198.7	2,953.0
Observed/Expected	3.15	1.50	1.11	1.02	0.85	0.77	0.89	1.02	1.05	1.00
Accident Record (accidents per 1,000 pilots)	11.71	5.56	4.11	3.77	3.14	2.88	3.32	3.78	3.90	3.72
Accident Rate (accidents per 100,000 hours)	2.74	0.91	0.72	0.66	0.55	0.48	0.55	0.63	0.82	0.74

[a] *FAA's Statistical Handbook on Aviation*
[b] *NTSB Accident Data Division*
[c] *COMSIS Research Corporation data for "active" first class holders*

Table E-2. Accident Statistics for Commercial Pilots (1983-1986)

	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60+	TOTAL
No. of Commercial Pilots[a]	35,773	71,012	69,993	93,920	95,444	73,759	60,785	42,230	71,238	614,154
% of Commercial Pilots	5.82	11.56	11.40	15.29	15.54	12.01	9.90	6.88	11.60	100
1,000s of Commercial Pilots	35.77	71.01	69.99	93.92	95.44	73.76	60.79	42.23	71.24	614.15
Commercial Pilot Accidents Observed[b]	380	613	672	877	653	467	427	323	358	4,770
Commercial Pilot Accidents Expected	277.84	551.53	543.62	729.46	741.29	572.87	472.10	327.99	553.29	4,770
Avg. Flight Hours/Pilot (Class II holders)[c]	155.3	169.5	184.1	205.5	200.3	194.3	187.8	190.4	183.1	167.0
100,000 Annual Flight Hours	55.5	120.4	128.8	193.0	191.1	143.3	114.2	80.4	130.4	1,025.7
Observed/Expected	1.37	1.11	1.24	1.20	0.88	0.82	0.90	0.98	0.65	1.00
Accident Record (accidents per 1,000 pilots)	10.62	8.63	9.60	9.34	6.84	6.33	7.02	7.65	5.03	7.77
Accident Rate (accidents per 100,000 hours)	6.84	5.09	5.22	4.54	3.42	3.26	3.74	4.02	2.74	4.65

[a]*FAA's Statistical Handbook on Aviation*
[b]*NTSB Accident Data Division*
[c]*COMSIS Research Corporation data for "active" second class holders*

Table E-3. Accident Statistics for Private Pilots (1982-1987)

	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	TOTAL
No. of Private pilots[a]	148,521	222,803	274,569	277,461	242,969	194,650	175,205	158,070	1,694,248
% of Private pilots	8.77	13.15	16.21	16.38	14.34	11.49	10.34	9.33	100
1,000s of Private pilots	148.52	222.80	274.57	277.46	242.97	194.65	175.21	158.07	1694.25
Private Pilot Accidents Observed[b]	391	652	1,004	1,042	1,001	904	843	786	6,623
Private Pilot Accidents Expected	580.58	870.96	1,073.32	1,084.63	949.79	760.91	684.90	617.91	6,623
Avg. Flight Hours/Pilot (Class III holders)[c]	26.1	30.9	38.1	46.7	54.7	60.2	62.6	63.7	48.3
100,000 Annual Flight Hours	38.8	68.8	104.6	129.6	132.9	117.2	109.7	100.6	817.8
Observed/Expected	0.67	0.75	0.94	0.96	1.05	1.19	1.23	1.27	1.00
Accident Record (accidents per 1,000 pilots)	2.63	2.93	3.66	3.76	4.12	4.64	4.81	4.97	3.91
Accident Rate (accidents per 100,000 hours)	10.09	9.47	9.60	8.04	7.53	7.71	7.69	7.81	8.10

[a]*FAA's Statistical Handbook on Aviation*
[b]*AOPA Air Safety Database*
[c]*COMSIS Research Corporation data for "active" third class holders*

Table E-4. Accident Statistics for Airline Pilots (1982-1988)

	25-29	30-34	35-39	40-44	45-49	50-54	55-59	TOTAL
No. of Airline Pilots[a]	30,800	50,035	57,833	59,726	62,708	44,153	22,406	327,661
% of Airline Pilots	9.40	15.27	17.65	18.23	19.14	13.48	6.84	100
1,000s of Airline Pilots	30.80	50.04	57.83	59.73	62.71	44.15	22.41	327.66
Airline Pilot Accidents Observed[b]	2	11	7	13	20	19	15	87
Airline Pilot Accidents Expected	8.18	13.29	15.36	15.86	16.65	11.72	5.95	87
Avg. Flight Hours/Pilot (Class I holders)[c]	608.7	572.3	575.9	571.0	594.4	606.2	598.9	589.6
100,000 Annual Flight Hours	187.5	286.4	333.1	341.0	372.7	267.7	134.2	1,932.0
Observed/Expected	0.24	0.83	0.46	0.82	1.20	1.62	2.52	1.00
Accident Record (accidents per 1,000 pilots)	0.06	0.22	0.12	0.22	0.32	0.43	0.67	0.27
Accident Rate (accidents per 100,000 hours)	0.011	0.038	0.021	0.038	0.054	0.071	0.112	0.045

[a]*CAMI's Aeromedical Certification Statistical Handbook*
[b]*NTSB Accident Data Division*
[c]*COMSIS Research Corporation data for "active" first class holders*

Table E-5. Air Transport Pilot (ATP) Accidents Classified as Pilot Error (1982-1988)

Pilot Age Groups	Number of ATP Accidents	Number of "Pilot Error" Accidents	Percent of Accidents Classified as "Pilot Error"
20-24	44	33	75.0
25-29	243	151	62.1
30-34	357	223	62.5
35-39	405	248	61.2
40-44	319	202	63.3
45-49	257	144	56.0
50-54	232	137	59.1
55-59	162	93	57.4
60-64	124	84	67.7
65-69	38	21	55.3
TOTAL	2,181	1,336	61.3

Source: NTSB Accident Data Division

Table E-6. Commercial Pilot Accidents Classified as Pilot Error (1983-1986)

Pilot Age Groups	Number of Commercial Pilot Accidents	Number of "Pilot Error" Accidents	Percent of Accidents Classified as "Pilot Error"
20-24	380	293	77.1
25-29	613	448	73.1
30-34	672	471	70.1
35-39	877	624	71.2
40-44	653	501	76.7
45-49	467	353	75.6
50-54	427	327	76.6
55-59	323	242	74.9
60-64	257	206	80.2
65-69	101	84	83.2
TOTAL	4,770	3,549	74.4

Source: NTSB Accident Data Division

Table E-7. General Aviation Accidents Classified as Pilot Caused (1982-1987)

Pilot Age Groups	Number of General Aviation Accidents	Number of "Pilot Caused" Accidents	Percent of Accidents Classified as "Pilot Caused"
16-19	214	178	83.2
20-29	2,793	2,193	78.5
30-39	4,358	3,366	77.2
40-49	3,630	2,833	78.0
50-59	2,819	2,165	76.8
60-69	1,206	895	74.2
70-79	200	159	79.5
TOTAL	**15,220**	**11,789**	**77.5**

Source: AOPA Air Safety Database

Table E-8. Flight Hour Distribution by Medical Certificate (1982-1988)

Pilot Age Groups	Number of First Class Holders	First Class Total Flight Hours	Annual Hours per First Class Holder	Number of Second Class Holders	Second Class Total Flight Hours	Annual Hours per Second Class Holder	Number of Third Class Holders	Third Class Total Flight Hours	Annual Hours per Third Class Holder
20-24	20,486	8,749,648	427.1	53,956	8,461,349	156.8	157,930	4,134,468	26.2
25-29	48,948	29,793,969	608.7	73,015	12,723,406	174.3	215,035	6,653,354	30.9
30-34	63,224	36,181,346	572.3	82,490	15,479,632	187.7	245,900	9,394,306	38.2
35-39	69,877	40,244,200	575.9	102,094	21,199,709	207.6	243,138	11,370,428	46.8
40-44	71,757	40,972,145	571.0	95,195	19,646,455	206.4	216,215	11,835,156	54.7
45-49	70,652	41,998,712	594.4	74,374	14,776,983	198.7	177,783	10,740,408	60.4
50-54	53,099	32,186,136	606.2	62,079	11,878,318	191.3	159,571	10,005,544	62.7
55-59	24,117	14,444,590	598.9	40,178	7,736,850	192.6	118,827	7,571,636	63.7
Subtotal	**422,160**	**244,570,746**	**579.3**	**583,381**	**111,902,702**	**191.8**	**1,534,399**	**71,705,300**	**46.7**
60-64	11,158	5,333,372	478.0	49,478	9,196,933	185.9	122,561	7,869,178	64.2
65-69	1,548	445,639	287.9	19,950	3,062,826	153.5	47,545	3,067,876	64.5
TOTAL	**434,866**	**250,349,757**	**575.7**	**652,809**	**124,162,461**	**190.2**	**1,704,505**	**82,642,354**	**48.5**

Source: COMSIS Research Corporation for active airmen with >0 hours per year