Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FAA-AM-77-2		

4. Title and Subtitle	5. Report Date
SURVEY OF COCKPIT VISUAL PROBLEMS OF SENIOR PILOTS	
	6. Performing Organization Code
	8. Performing Organization Report No.
7. Author(s) Kenneth W. Welsh, John A. Vaughan, Paul G. Rasmussen	
9. Performing Organization Name and Address FAA Civil Aeromedical Institute P.O. Box 25082 Oklahoma City, Oklahoma 73125	10. Work Unit No. (TRAIS) 11. Contract or Grant No.
12. Sponsoring Agency Name and Address Office of Aviation Medicine Federal Aviation Administration 800 Independence Avenue, S.W. Washington, D.C. 20591	13. Type of Report and Period Covered OAM Report 14. Sponsoring Agency Code

15. Supplementary Notes

Work was performed under Task AM-D-76-PHY-91.

16. Abstract

Fifty general aviation pilots (average age 49; range 40-73) completed a questionnaire concerning cockpit visual problems. The results of the questionnaire indicated that proper interpretation of the airspeed indicator and the altimeter required the best visual acuity (48 and 39 percent of the respondents respectively). However, 33 percent reported the attitude indicator, an instrument with relatively few numerals or markings, required optimum visual acuity. Thirty-seven percent of the pilots reported that the engine instruments, usually smaller scale, are difficult to read. Light reflected from instrument cover plates caused visual problems for 32 percent of the pilots, with most difficulty occurring during daylight hours. Forty-eight percent of the pilots reported a delay in focusing from outside the cockpit to the charts and instruments, while 6 percent reported a delay of focusing from inside to outside the cockpit. More instrument readability problems were evident while flying at night than during dusk or daylight. The effects of decreasing focusing power, altered dark adaptation, and need for more lighting are discussed with respect to the older pilot. Recommendations are made to investigate the effects of instrument lighting, vision standards, and instrument design and location with respect to the limitations of the aging visual system.

17. Key Words	18. Distribution Statement
Vision, Senior Pilots, Instrument Readability	Document is available to the public through the National Technical Information Service, Springfield, Virginia 22151.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified		

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

SURVEY OF COCKPIT VISUAL PROBLEMS OF SENIOR PILOTS

I. Introduction.

It is estimated that production of general aviation aircraft will double in the next decade. Most of these aircraft will be equipped for instrument flight.[1] The population of general aviation pilots is expected to increase commensurately. We can certainly expect to see greater numbers of pilots in their sixties and seventies flying aircraft and operating other types of vehicles.

Aviation safety is partly dependent on the pilot's ability to read quickly and accurately various cockpit instruments. Table 1 lists several primary factors that may affect the readability of aircraft instruments. Each of the four primary factors is dependent on several component factors that may act singly or in combination for each individual and viewing situation.

Several well-known relationships exist between chronological age and the capabilities of the visual system. For example, the ability to focus on near objects decreases with age.[2, 3] Hofstetter determined that accommodative amplitude decreases by 0.30 diopter (D) per year up to the age of 60, after which approximately 0.50 D of accommodation remains.[4] An investigation by Diamond indicates that accommodative amplitude decreases more under dim red than under dim white lighting.[5]

Decreased accommodation causes blurred vision, with the effect beginning at the near range (30 to 51 cm) and later in life at the intermediate range (61 to 76 cm). Bifocal or trifocal lenses are then required to correct visual acuity at the near and intermediate ranges respectively. In addition, the size, shape, and height of the bifocal or trifocal segment limits the range over which the eyes may scan.

Another visual process that deteriorates with age is the capacity of the eye to adapt to dim lighting. McFarland *et al.* found that visual sensitivity to a stimulus light decreased progressively for each decade for subjects ranging in age from 16 to 89 years.[6] Guth found that individuals in their sixties required twice as much light as 20-year-olds to read printed words.[7] However, a study by Mourant and Langolf indicated that elderly individuals required 10 times more light than did young people to obtain 95-percent-correctness scores for a symbol readability task.[8] In addition, visual acuity of elderly individuals may decline because of retinal changes and clouding of the ocular media.[9, 10]

Further degradation of several visual functions occur under conditions of hypoxia. McFarland, Whiteside, and Ohlbaum found decrements in several visual functions during oxygen deprivation although the effect of age on

TABLE 1.

Factors Influencing Instrument Readability and Flying Performance

Primary Factors	Component Factors
Visual	Refractive Error Accommodation Adaptation Oculomotor Disturbance
Psychosensory	Interpretative Skills Emotional Status Reaction Time Experience Training
Biomedical	General Health Ocular Health Fatigue Drugs
Display	Digit Size Contrast Ratios Lighting View Distance Parallax
Environmental	Glare Hypoxia Vibration Toxic Products

visual performance was not investigated.[6, 11, 12] Decrements in visual performance were also noted for subjects with hypoglycemia or following inhalation of carbon monoxide in small quantities.[13, 14] Luria *et al.*, using therapeutic doses of five widely used medicinal drugs, found changes in ocular pursuit movements, pupil size, EEG, and recovery from a light flash although changes with respect to age were not evaluated.[15]

Because elderly pilots usually have known visual limitations in the near and intermediate ranges, a questionnaire was completed by, and brief visual evaluation was conducted on, 50 pilots above the age of 40 years at an Oklahoma fly-in held in the fall of 1975. Results of the study provide information needed for the establishment of priorities and guidelines for future research related to intermediate vision and aviation safety.

II. Methods.

Four women and 46 men volunteered to complete the questionnaire and to participate in a short visual evaluation. The mean age of the group was 49.2 years (range 40–73). Thirty-eight held private pilot certificates, 14 held commercial pilot certificates, and 8 had airline transport pilot certificates. Nineteen were instrument rated, 11 had flight instructor airplane (CFIA) ratings, and 8 held flight instructor instrument (CFII) ratings. The mean flying time for the group was 3,132 h (range 30–29,000 h) and all but four had some flight time the previous year (mean 77 h).

A battery of visual measurements was made on each pilot with the Titmus Vision Tester, Aeromedical Model. The tests included the subject's near and distant visual acuity, ocular muscle balance, and color vision. In addition, tests were made for intermediate visual acuity (76 cm), amplitude of accommodation (RAF Rule), and the subject's spectacle lens prescription. Data from the visual portion of the study are not included in this report but are available on request. The results were not included because the subject population was relatively small, subjects' ocular statuses varied widely, and several volunteers did not have their glasses or wore contact lenses.

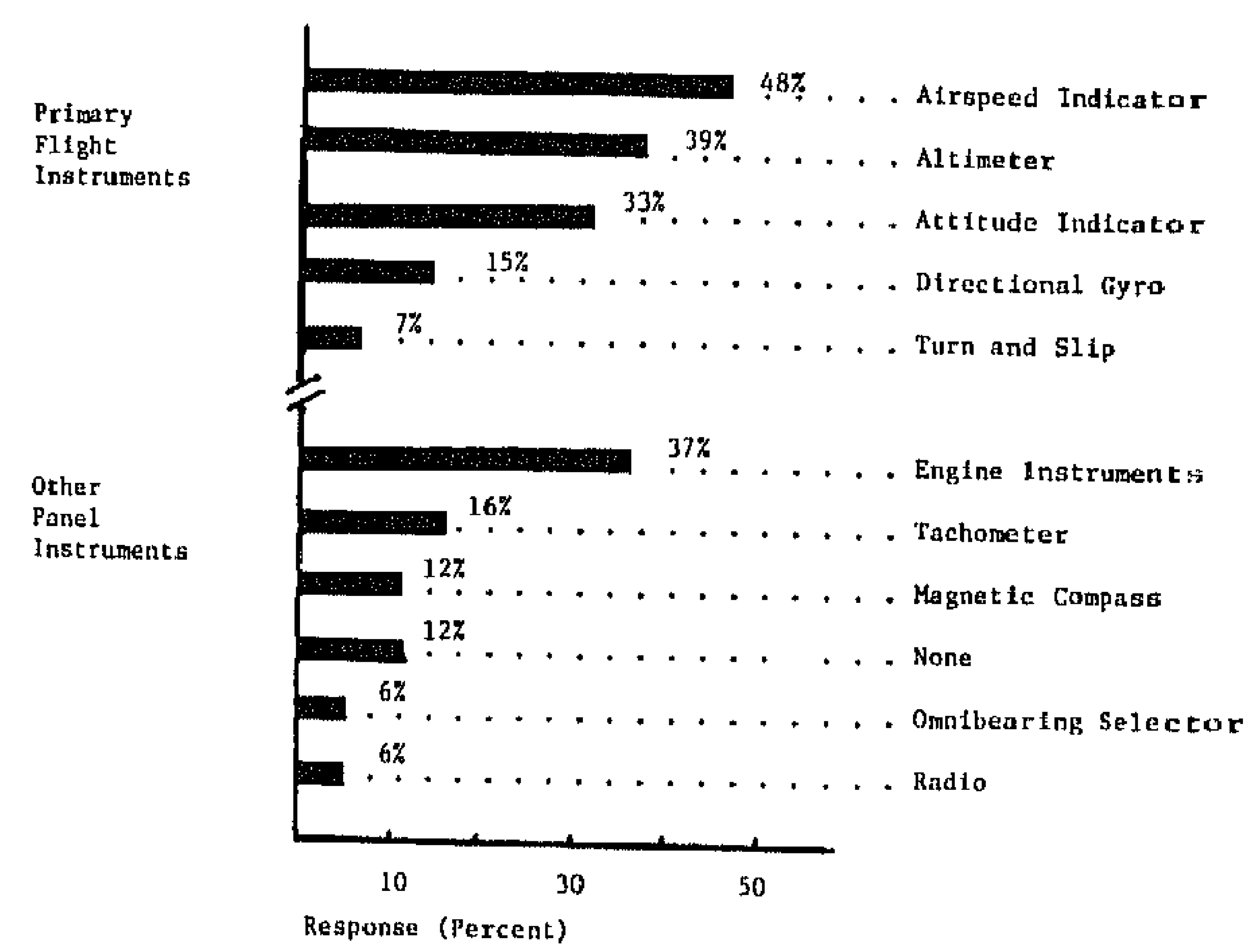
III. Results.

Most of the questions were multiple choice, and several allowed the subjects to select more than one response. The remaining questions required a short written statement.

Specific Visual Problems. Table 2 shows the various responses given to the question concerning the primary flight instruments (altimeter, airspeed, attitude) requiring optimum visual acuity for proper interpretation. Several subjects noted more than one cockpit instrument. Also given in Table 2 are the subjects' responses to other panel instruments that, in their opinion, require optimum visual acuity.

TABLE 2.

Subject Response (%) as to the Instruments Requiring the Best Visual Acuity for Proper Interpretation



When asked whether reflections from the glass plates covering the instruments hampered vision, 68 percent responded "no" and 32 percent responded "yes." As to other factors that adversely affected the readability of aircraft instruments, 13 of 20 pilots responded that instruments having small numerals were difficult to read, while 7 of 20 indicated that visual parallax was a problem for instruments in the central portion of the panel. To observe the instruments in the central portion of the panel, the pilot in the left seat must look to his right at an oblique angle.

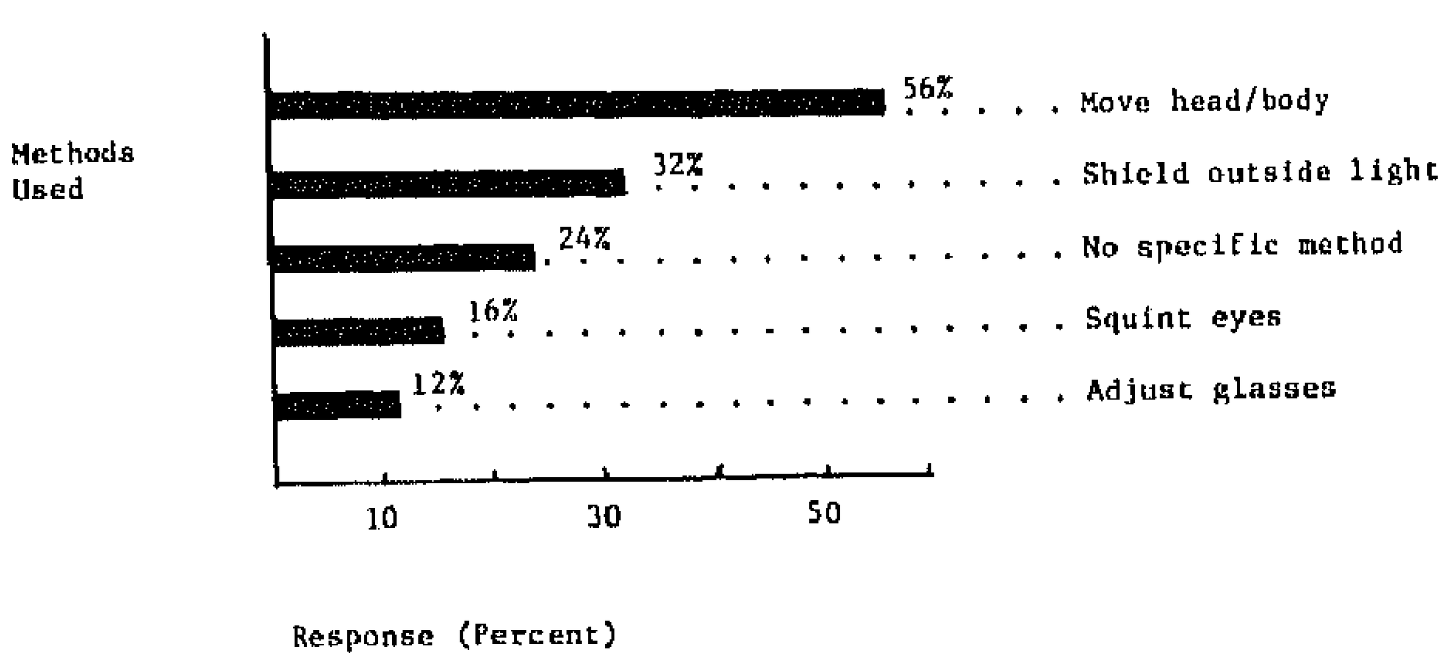
When the pilots were asked whether they had noticed over the years any alteration of time required to change visual focus, 31 percent said they had noticed an increase in focusing time from outside the cockpit to charts and 17 percent had noticed an increase in focusing time from outside to the instruments. Few pilots (6 percent) reported a delay in focusing from maps or instruments to outside the aircraft.

Frequency of Problems. When the pilots were asked if they had noted any difficulty in reading aircraft instruments, 56 percent reported none, 38 percent said "occasionally," and 6 percent reported frequent visual problems. When questioned as to when the instruments are most difficult to read, 48 percent indicated "nighttime," 28 percent said "dawn and dusk," 22 percent replied "never difficult," and 6 percent reported "equally difficult at all times." Of the 16 pilots reporting visual difficulty from reflective glare off the instrument cover plates, 69 percent indicated more problems during the day while 31 percent had more problems at night.

Individual Solutions. Table 3 lists the subjects' responses concerning various methods used to improve the readability of the cockpit instruments.

TABLE 3.

Methods Used by Pilots
to Improve Instrument Readability



When asked what specific steps were taken to reduce reflections from the glass cover plates, 43 percent stated they employed head movements and 26 percent shielded the instruments; the remaining subjects gave no response.

Of 44 pilots responding to the question concerning the level of instrument brightness preferred during night flying, 66 percent preferred the medium intensity level, 23 percent liked the brightest level, and 16 percent preferred the dim level. Thirty percent of those responding stated they occasionally used a flashlight to read the instruments when flying at night. When asked to recommend changes to improve the readability of aircraft instruments, 36 percent recommended lighting changes, 28 percent indicated changes in the dial design, and 30 percent said no changes were needed.

Miscellaneous Data. Prescription spectacle lenses were worn by 68 percent of the subjects while flying. Of those wearing glasses, 67 percent wore bifocal lenses, 27 percent wore trifocal lenses, and 7 percent wore half-eye reading glasses. When viewing the instruments, 65 percent of those wearing bifocal lenses used the bifocal (lower) portion rather than the distance portion of the lens. Sixty-two percent of the trifocal wearers used the trifocal (middle) portion of the lens to view the instruments. Of those pilots wearing glasses, 44 percent carried an extra pair while flying.

Information from the Aeromedical Certification Branch showed that 32 percent of all pilots are required to wear glasses while flying. An additional 8.2 percent of the pilots must have glasses (usually the reading type) available while flying. Although the information was not available, the percentage of pilots wearing glasses would be expected to increase with age.

In response to the question concerning the color of instrument lighting available, 52 percent of the subjects stated they flew aircraft equipped with red panel lighting, 24 percent said white lighting, while 22 percent said selectable red or white lighting.

IV. Discussion.

Because of the limited pilot population surveyed (N=50) and the large number of ocular refractive and instrumentation variables, no statistical correlations could be made between the visual measurements and questionnaire data. However, in a laboratory study now in progress at the FAA Civil Aeromedical Institute, visual acuity of older subjects will be determined through the distance and near portions of their spectacle lenses at 51, 76, and 102 cm during photopic viewing conditions. The questionnaire data, however, indicate several common instrument-readability problems among older pilots. Although not investigated in this study, many of the same problems may also occur among younger pilots when flying under similar conditions.

The results of the questionnaire indicate that aircraft instruments with many numerals and markings (airspeed indicator and altimeter) require optimum visual acuity for proper interpretation. However, one-third of the pilots reported that an instrument with few numerals or markings (attitude indicator) required optimum visual acuity for proper interpretation. The apparent dichotomy of opinions indicates that interpretative difficulties associated with dial design may influence the pilot's opinions. In addition, we believe that the pilot's training and experience influence his opinion about the instruments that require optimum vision for correct dial interpretation.

The readability for electro-optical displays (cathode ray, light-emitting diode, etc.) was not covered in the questionnaire. Because of increasing use of these displays in aircraft instruments, further research is recommended in this area with respect to older pilots.

To isolate visual performance from the pilots' subjective judgment, we recommend a study to evaluate readability of aircraft instruments under various visual acuity levels and flying conditions. Information concerning the visual, cognitive, and design aspects of instrument readability is found in several sources.[16, 17, 18]

Another visual problem noted by one-third of the pilots was reflective glare from the glass plates covering the panel instruments. Reflective glare is presumed to occur without respect to the pilot's age or visual status. At least two aspects of cover plate reflections require further investigation. First, research should be conducted to quantitate visual impairment caused by reflections during various flight conditions. Second, we need data on the effectiveness of shielding, lighting, polarizing, and/or convexing the glass cover plates.

Instrument-readability problems caused by oblique observation angles (parallax) also merit investigation as to their significance and possible remedies by design modification.

Nearly half the respondents indicated that instrument readability was a problem when flying at night. We believe that further research is necessary concerning the effects of instrument lighting intensity, spectral color of lighting, dial markings, hypoxia, fatigue, and drugs with respect to night vision in older pilots. Several papers direct attention to the visual problems of presbyopic pilots.[19, 20, 21]

The trifocal portion of a spectacle lens is designed to improve visual acuity at the intermediate (instrument panel) range. The necessity for trifocal lenses increases with age and is considered essential to provide good intermediate vision for those with less than 2.00 D of accommodation. Data show that individuals 53 years of age or older have less than 2.00 D of accommodation and may benefit from trifocal lenses, especially under dim luminance conditions.[4, 5] However, of the 14 pilots more than 53 years of age surveyed in our study, only two pilots wore trifocal lenses. Harper and Kidera also reported that many senior pilots flying large commercial aircraft do not wear trifocal lenses.[20] They stated that natural human reluctance to wearing multifocal lenses and unawareness of reduced intermediate visual acuity were contributing factors.

This survey revealed several potential visual problems common to older general aviation pilots. We feel that these visual problems merit further attention with respect to medical standards, accident statistics, human factors, and cockpit design.

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