Solar Eye Protection Practices of Civilian Aircrew

Adrian C. Chorley; Bruce J. W. Evans; Martin J. Benwell

INTRODUCTION: There is good evidence that long term exposure to ultraviolet (UV) radiation increases the risk of cataracts. The 'blue light hazard' is considered a risk factor for retinal changes similar to those seen in macular degeneration. Previous studies ascertaining the prevalence of radiation related ocular disease in pilot cohorts have not considered use of solar eye protection. The aim of this study was to explore pilot use of sunglasses and other solar eye protection habits and to gain insight into the difficulties encountered managing sunlight on the flight deck. Additionally, the prevalence of radiation related ocular pathology in the study group was calculated.

METHODS: A web based questionnaire was developed and administered to a large population of current UK professional pilots.

RESULTS: There were 2917 respondents who completed the questionnaire, demonstrating a wide range of sunglass use during flight. A number of barriers to sunglass use were identified, the most prevalent being the requirement for corrective lenses to be used. Pilots most commonly increase sunglass use due to ocular health concerns. A high level of dissatisfaction with standard aircraft sun protection systems was reported. Long haul airline pilots were the highest users of nonstandard sunlight blocking strategies. No correlation between reported pathology and flying experience was found.

DISCUSSION: The use of sunglasses during flight is complex; however, a number of practical recommendations can be made to increase the success for those pilots who wish to use sunglasses more. Aircraft manufacturers should consider how greater control of cockpit sunlight levels can be achieved.

KEYWORDS: airline, pilots, sunlight, sunglasses.

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Professional pilots may be subject to conditions of bright sunlight during flight. The position of the sun relative to the pilot's eyes is dependent on a number of factors, including the time of day and year and the heading of the aircraft. The sun may be obscured from direct view by the aircraft structure and many aircraft types have solar protection in the form of visors for the front windshields and blinds to shield the side windows. Although visors absorb much of incident irradiance, their size is such that a large area of the windshield remains uncovered and high levels of diffuse radiation may be present on the flight deck, particularly at altitude and where radiation is reflected from cloud tops. Pilots on a long sector during daylight on a similar heading may find themselves exposed to direct solar radiation (albeit filtered by the windshield) for prolonged periods of time.

The use of sunglasses by pilots is likely to be instigated due to either a desire to gain ocular comfort in bright sunny environments or due to concern of a risk of ocular damage from overexposure to solar radiation. There is evidence that long term exposure to ultraviolet (UV) radiation is linked to an increased risk of cataract formation.[11,12,16] There is also evidence that, although the windshield material is effective at attenuating UVB radiation, significantly greater levels of UVA are transmitted through windshield types used in commercial jet aircraft.[18] The authors recently took transmittance measurements from a series of different aircraft windshields and found a marked variation in UVA transmittance affecting ocular UV dose during flight.[6] Previous research investigating the prevalence of cataract in pilots[15,19,20] has been inconclusive and, in particular, no study investigated the use of eye protection during flight in a professional pilot cohort.[7]

Retinal damage has been linked to exposure to short wavelength visible light.[1,22,23] This is known as the blue light hazard and has a peak activity spectrum around 440 nm. Although

From the Civil Aviation Authority, West Sussex, United Kingdom.

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Address correspondence to: Dr. Adrian Chorley, B.Sc. (Hons.), M.Sc., Ph.D., FCOptom., UK CAA Medical Department, Safety and Airspace Regulation Group, Aviation House, Gatwick Airport South, Sussex RH6 0YR, UK; adrian.chorley@caa.co.uk.

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acute effects have been demonstrated to high intensity artificial light sources, there is also evidence that long term exposure to a solar source may cause similar clinical signs as seen in short exposures which mimic the clinical changes seen in age related macular degeneration (AMD). There have been no previous studies investigating the prevalence of AMD in professional pilots.[7]

Anecdotal evidence gained from pilots revealed some difficulties in managing sunlight levels during flight. This prompted a series of exploratory semistructured interviews to be carried out which uncovered the prevailing conditions and stages of flight where sunlight levels were most difficult to manage, the types of standard solar protection systems installed in various commercial airline and helicopter aircraft types and the use of other strategies by pilots to cope with bright sunlight during flight.[8]

There are a number of standards[2,3,14] which stipulate minimum transmittance requirements for sunglasses and all sunglasses should be manufactured to meet one of these standards. The pilot has a wide choice of sunglasses from a large number of manufacturers. Although guidance exists[10,13] to assist pilot sunglass selection, they are not based on specific solar radiation levels likely to be encountered during flight or risk of ocular damage.

The aim of this research was to develop a web-based questionnaire to investigate the occupational eye protection habits and to ascertain the prevalence of solar radiation relevant ocular pathology within a large population of professional pilots.

METHODS

Subjects

The questionnaire was promoted through the British Airline Pilots Association (BALPA) and all participants were professional pilots and members of the Association. In order to elicit open responses, no personal individually identifiable data were collected. Participants were given study information before the start of the survey and were considered to have given informed consent by submitting their responses. The study had research ethics approval from London South Bank University and the Institute of Optometry, London.

Questionnaire

An online questionnaire was designed and piloted. Data collected included participant's age, type of flight currently undertaken, number of flying hours completed in the last year, previous types of flight undertaken and the number of years that the professional license had been held. The exploratory interviews revealed that the use of corrective glasses influenced the use of sunglasses.[8] Therefore, questionnaire participants were also asked whether they were required to use spectacles to correct distance vision for certificatory purposes and whether contact lenses were used.

Pilots were asked to rate their sunglasses in a series of categories including comfort and performance. Pilots were also asked to rate the importance of various factors including UV protection and brand in sunglass selection. All participants completed a series of questions on the use of other eye protection strategies such as the fitted visors and blinds within the cockpit. Exploratory interviews revealed a range of strategies used and it was found that some of these were used rarely.[8] Based on this, a Likert-type score was devised which was weighted toward more infrequent use in order to elicit optimum responses from participants of all protection strategies used. Pilots were asked to rate the instance of their subjective symptoms of discomfort glare and disability glare. Finally, all participants were asked about a positive diagnosis of cataract or AMD. The questionnaire contained a number of logic questions where the participants were asked further targeted questions depending on previous responses and used free text boxes for participants to offer further comment or explanation.

Procedure

The questionnaire was initially administered to a group of 18 professional pilots. Following feedback, some changes were made and a further group of 21 professional pilots were invited to comment in the same way on the revised questionnaire. Feedback by this second group revealed only minor suggestions, some of which were incorporated into the final version of the questionnaire accessed online. Most feedback received was very positive. The survey remained open for data collection from December 2012 to April 2013, during which time an invite and further reminder to participate were sent to all BALPA members.

Statistical Analysis

Data analysis was carried out using IBM SPSS v.19 and Microsoft Excel 2007. Data were initially subject to descriptive and frequency analysis. Where the mean age of respondents in two groups or categories was compared, the independent *t*-test was used as age data were parametric. Where the mean ages of more than two categories were compared, one-way ANOVA analysis was conducted. Pearson's Chi-square test was conducted for analysis comparing sets of categorical data. Where comparison of two independent groups of nonparametric or ordinal data was conducted, the Mann Whitney *U*-test was used and where more than two independent groups were compared, the Kruskal-Wallis test was used.

The Spearman rank-order correlation test was used to assess the association between two sets of ordinal data. Analysis of covariance (ANCOVA) was conducted in order to assess the difference in means between two groups while controlling for the effect of age. Responses in free text boxes were subject to content analysis and categorization into new variables which were in turn subject to descriptive and frequency analysis. The level of statistical significance used was $P < 0.05$.

RESULTS

A total of 2967 questionnaires were submitted which constituted a response rate around 34% (BALPA membership approximately 8800). Fifty pilots partially completed the questionnaire but omitted a required field. These incomplete records were not included in the analysis. This represents a 98.3% completion rate and the results of 2917 questionnaires were analyzed. The mean age was 42.6 yr (SD 9.7 yr) in the age range 20–66 yr and data were normally distributed (skewness 0.02). The mean length of time respondents had been professional pilots was 16.9 yr (range 1 to $>$ 40 yr) with 91.6% having a total flight time logged over 2500 h.

The majority of respondents (92.5%) operated on either airline transport short haul ($N = 1711$) or long haul ($N = 986$). A further 54 (1.9%) respondents operated helicopters off shore and 44 (1.9%) flew aeroplane cargo flights. Other categories included business jet, charter work, instructor and police/air ambulance helicopter, each of which constituted less than 1% of the respondents. The mean flying hours accrued over the previous year was 647 h and 79.7% of pilots had logged more than 500 h. Within the short haul pilot group, the mean number of hours flown in the previous 12 mo was 640 h (SD 151 h) and in the long haul pilot group, the mean was 707 h (SD 150 h). There were 546 (18.7%) pilots who had previous military experience (378 aeroplane, 116 helicopter, 52 both).

A requirement for corrective spectacles to be worn constantly during flight on the pilot's medical certificate (VDL limitation) was present in 1332 (45.7%) participants. This limitation is used by the UK CAA for all pilots unable to achieve the distance vision standards without correction and does not include presbyopic pilots with good unaided distance vision who are required to have a near vision correction available to use. For the purposes of this study, those declaring a requirement for corrective spectacles to be worn are also termed spectacle wearers. To assess any differences between various types of professional flying, the most prevalent three categories were analyzed: airline transport short haul (SH), airline transport long haul (LH) and helicopter off-shore (HOS). Assessing the prevalence of a spectacle requirement within the three main flying categories, Pearson Chi-square analysis (**Table I**) showed a significant difference with SH significantly less likely to require glasses than LH and HOS [$X^2(2, N = 2751) = 9.92, P = 0.007$].

However, one-way ANOVA analysis with multiple comparison tests showed that the mean age of SH pilots was significantly lower than both LH and HOS groups [$F(2, 2725) = 88.29, P < 0.001$]. There was no significant difference in the mean age of LH and HOS groups. It is probable that the difference in spectacle requirement between the flying categories is largely affected by the difference in age between the groups as spectacle wearers were significantly older than nonspectacle wearers [$t(2892) = 17.08, P < 0.001$].

Table I. Prevalence of a Spectacle Requirement in Different Flying Categories.

	REQUIREMENT FOR OPTICAL CORRECTION		
TYPE OF FLYING	**YES *N* (%)**	**NO *N* (%)**	**TOTAL**
Airline long haul (LH)	486 (49.3)	500 (50.7)	986 (100.0)
Airline short haul (SH)	737 (43.1)	974 (56.9)	1711 (100.0)
Helicopter off-shore (HOS)	26 (48.1)	28 (51.9)	54 (100.0)
Total	**1249 (45.4)**	**1502 (54.6)**	**2751**

Of the spectacle wearers, 24 (0.8%) used clip-on shades over their prescription glasses; 355 (26.6%) wore contact lenses during flight and of this group, 110 (30.9%) wore contact lenses with a UV block, 101 (28.4%) had no UV block and 144 (40.6%) did not know whether their contact lenses included a UV block.

Pilots described conditions where they need to look outside through the cockpit windshield and where the azimuth of the sun is such that it is near their line of sight as being particularly problematic. Discomfort glare (visual discomfort caused by direct or reflected sunlight) was reported 'sometimes' or 'generally' by 74.9% of respondents. Disability glare (preventing pilot from visualizing aircraft instruments) was reported 'rarely' or 'sometimes' by 83% of respondents and was mainly reported during critical stages of flight (takeoff, approach and landing).

There was no significant difference in the reporting of discomfort or disability glare between LH-SH-HOS pilots (Pearson Chi-square). There was a significant positive correlation between reported discomfort glare and disability glare (Spearman's Rho $r_s(2915) = 0.431, P < 0.001$); however, there was no significant relationship between levels of discomfort or disability glare and age (one-way ANOVA) or total number of flying hours (Kruskal-Wallis). There was a significant increase in sunglass use with increasing reported levels of discomfort glare ($P < 0.001$ Kruskal-Wallis) and disability glare ($P < 0.001$ Kruskal-Wallis).

There were 26 (0.9%) pilots who independently reported in free text boxes symptoms of headache or asthenopia in bright light conditions, 14 (0.5%) who reported sensitivity to light, and 3 (0.1%) who reported symptoms of 'eyes watering'. A further 8 pilots (0.3%) stated that bright sun caused sneezing. During instances of disability glare, pilots independently reported that aircraft instruments were not sufficiently visible ($N = 40$, 1.4%), that the use of sunglasses dimmed the view of the aircraft instruments, making them hard to interpret ($N = 27$, 0.9%), or that contamination (dust, finger marks) became more apparent, making displays hard to interpret ($N = 9$, 0.3%).

The use of sunglasses by spectacle and nonspectacle wearers is shown in **Fig. 1**. A total of 727 (24.6%) participants never use sunglasses or use them less than 10% of the time during flight. Of the 413 (14.2%) pilots who never use sunglasses during flight, significantly more required corrective spectacles (VDL) compared to those who did not [Pearson Chi-square, $X^2(1, N = 2917) = 69.64, P < 0.001$]. The reason for not using sunglasses was explored within this group of pilots (**Table II**).

It can be seen that eight respondents who did not require spectacles gave a reason for not using sunglasses in flight due to wearing untinted prescription spectacles. This group is likely to consist of pilots with low optical prescriptions who are able to meet the vision standards without their spectacles but who use them in flight for optimum visual acuity or visual comfort.

Ex-military pilots used sunglasses significantly less than those pilots without a military flying history (Mann-Whitney U, $P < 0.001$), however, this group was also significantly more likely to be spectacle wearers (Mann-Whitney U, $P < 0.001$)

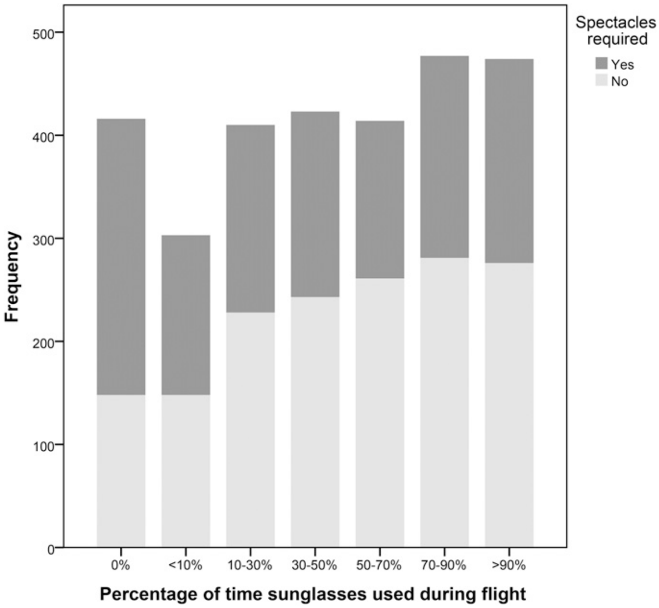

Fig. 1. Distribution of amount of sunglass use during daytime flight for spectacle and nonspectacle wearers.

and to be older (independent *t*-test with variances not equal, $t(1155) = 26.13$, $P < 0.001$). Both of these factors cause a significant decrease in sunglass use.

There were 1706 (58.9%) pilots who used sunglasses between 10–90% of the time. All sunglass users were questioned as to what phase of flight (walk around, taxi, takeoff, cruise, approach, landing) or conditions (when tired, when flying toward direct sun, when it feels too bright) under which sunglasses were worn. The stage of flight where sunglasses were most likely to be used was during cruise (mode: 'usually', $N = 1070$, 43.1%), however, the use of sunglasses was driven more by perceived bright light conditions rather than a particular phase of flight (when flying toward the sun, mode: 'always', $N = 1326$, 53.4%, when it feels too bright, mode: 'always', $N = 1381$, 55.7%).

A total of 110 (4.4%) respondents used a second pair of sunglasses. These were used less in all categories, but showed a similar pattern in that they were used most during cruise and in bright light conditions. LH pilots were more likely to use 2 pairs than SH or HOS pilots [$X^2(2, N = 2366) = 27.00$, $P < 0.001$]. Kruskal-Wallis analysis revealed no significant difference between those using one or two pairs of sunglasses and the use of any other eye protection strategy (such as aircraft visor). The most common differences reported between the first and second pair of sunglasses was that one pair of sunglasses were prescription (40%), that there was a difference in tint depth (29%) or a difference in frame style (16%).

Respondents were also questioned whether their sunglass use had altered over the past year (**Table III**). This was to gain insight as to external factors which may influence the use of sunglasses. The most common cause of reduction in sunglass use was a change to prescription. Through coding of a free text comments box, this group was mainly emmetropes who had become presbyopic and required near correction.

Participants were asked a series of questions regarding the primary sunglasses used during flight. Those with a VDL had significantly newer sunglasses [Mann-Whitney U, $P = 0.002$]. Of those respondents using sunglasses, 1903 (76.1%) had a fixed nongraduated tint, 278 (11.1%) had a graduated tint, 162 (6.5%) had polarized lenses and 73 (2.9%) had photochromatic lenses. A further 84 (3.4%) did not know what type of tint their sunglasses had. Pearson Chi-square analysis revealed that LH pilots were significantly more likely to have a fixed nongraduated tint compared to SH pilots [$X^2(4, N = 2322) = 18.82$, $P = 0.001$].

Pilots most commonly described their sunglasses as having a gray (957, 38.3%) or brown (921, 36.8%) tint, 292 (11.7%) described a green tint, 40 (1.4%) yellow, 35 (1.2%) black, and 46 (1.6%) blue. Other color tints described (each less than 0.3%) included red, silver, gold, pink, purple, amber, and orange.

The most prevalent types of frame style were wrap-around (939, 37.6%), aviator (840, 33.6%), and rectangular (18.5%). There were 155 (6.2%) respondents who had rimless sunglasses and 104 (4.2%) had oval or round frames. All sunglasses users were asked how long ago the fit of their sunglasses had been assessed or adjusted; 1861 (63.8%) had never had them fitted and 106 (3.7%) had the fit checked within the previous 6 months. Spectacle wearers were significantly more likely to have had their sunglass fit checked ($X^2(4, N = 2500) = 527.97$, $P < 0.001$).

Respondents were asked to rate the overall performance of their sunglasses. There were 132 (5.2%) respondents who rated

Table II. Reasons Given as to Why Sunglasses Are Not Used.*

	SPECTACLES REQUIRED ($N = 269$)		NO SPECTACLES REQUIRED ($N = 148$)	
REASON GIVEN	**NUMBER**	**% WITHIN GROUP**	**NUMBER**	**% WITHIN GROUP**
Aircraft has adequate protection offered with visors	102	37.9	57	38.5
I forget to carry them with me	17	6.3	20	13.5
I wear clear prescription glasses instead	115	42.8	8	5.4
Sunglasses too expensive	18	6.7	12	8.1
Sunglasses uncomfortable	36	13.4	53	35.8
Sunlight doesn't bother me	60	22.3	48	32.4
Too much hassle to put on during flight	44	16.4	41	27.7
Instruments too dark through sunglasses	37	13.8	21	14.2
Sunglasses not used for other reasons	26	9.7	6	4.1

* Participants can give multiple responses.

Table III. Reasons Given as to a Change in Sunglass Use.*

REASONS FOR CHANGE IN SUNGLASS USE	DECLARED USE INCREASE	DECREASE	SAME	TOTAL
Sunglass tint	3	2	3	8
Sunglass comfort	7	9	0	16
Change of operating environment	20	18	2	40
Change of prescription	10	26	10	46
Increase awareness of potential impact to vision	23	1	4	28
Eye contact with other pilot	1	0	1	2
Lost / damaged sunglasses	1	4	1	6
Use other strategies instead	0	3	1	4
Visual fatigue	6	3	3	12
Other	0	2	1	3
Change to light sensitivity	6	3	1	10
Total	**77**	**71**	**27**	**175**

* Participants who declared a change in use of sunglasses over the previous year were asked to state the previous amount of use and, in a free text box, describe the reason (if any) for the change of use.

their sunglasses 'very poor' or 'poor,' while 1759 (70.4%) rated their sunglasses 'good' or 'excellent.' There was no significant relationship between overall sunglass rating and flying experience (Kruskal-Wallis) but a significant difference was seen with age with younger pilots rating overall performance higher than older pilots [one way ANOVA, F(4, 2475) = 4.60, $P = 0.001$]. There was no significant relationship between the overall sunglass rating and sunglass age, type, or color of tint (Kruskal-Wallis). Additionally, there was no significant relationship between overall sunglass rating, sunglass age, or color of tint between LH-SH-HOS pilot groups (Kruskal-Wallis).

A total of 91 different sunglass brands were reported in addition to prescription sunglasses, nonbrand sunglasses and store own brand sunglasses. Aside from the three major brands (**Table IV**), other sunglasses reported were recategorized into either 'aviation specific' where the manufacturer intended the sunglasses to be used specifically for aviation, 'marked for solar protection,' 'marketed for sports use' (usually cycling or skiing), or 'fashion marketed' sunglasses including designer labeled sunglasses. Silhouette was the fourth most prevalent brand worn by 1.8% of respondents. RayBan sunglasses were used more commonly within the HOS pilot group (42.5%) compared to SH (34.9%) and LH (26.5%) pilot groups.

Table IV. Summary of the Distribution of Sunglass Make with Recategorization of Those Sunglasses Not Within the Most Prevalent Three Brands into Generic Groups Due to the Wide Variety of Sunglass Types Declared.

SUNGLASS CATEGORY	FREQUENCY	PERCENTAGE
Prescription	402	16.8
Ray Ban	768	32.1
Oakley	458	19.1
Serengeti	205	8.6
Aviation specific	41	1.7
Marketed for solar protection	116	4.8
Marketed for sports use	52	2.2
Fashion marketed	207	8.6
Store own or nonbrand	141	5.9
Other	4	0.2
Total	**2394**	**100.0**

Respondents were asked to rate the importance of a series of factors when selecting sunglasses (**Fig. 2**). The mode score for comfort of frame, UV protection, and comfort of tint was 'very important' (72.6%, 65.9%, and 54.6%, respectively). Sunglass brand was considered least important (mode: 'not important,' 35.7%) and was significantly less important for spectacle wearers [Pearson Chi-square, $X^2(3, N = 2470) = 38.91, P < 0.001$].

Frame style, UV protection and frame comfort were also significantly less important factors for spectacle wearers [$X^2(3, N = 2490) = 18.04, P < 0.001$; $X^2(3, N = 2494) = 11.41, P = 0.010$, and $X^2(3, N = 2481) = 7.99, P = 0.046$, respectively]. There was no significant difference in the rating of tint color, comfort of tint, or protection from oblique or peripheral light between spectacle and nonspectacle wearers (Pearson Chi-square). There was no significant difference for any ratings between LH-SH-HOS pilots (Pearson Chi-square).

Respondents were questioned regarding other eye protection practices employed during flight. Using the standard fitted aircraft visors was the most common strategy employed. The other strategies decreased in popularity score from use of newspaper or chart against windshield or visor, adjusting seat to move head position out of direct sunlight, using hand to block direct sunlight, using tray-liners against windshield and use of a peak (baseball) cap. There was no significant difference in the use of visors between ex-military and non ex-military pilots (Pearson Chi-square); however, there was a significantly lower overall use of eye protection strategies other than sunglasses in ex-military pilots having allowed for age [ANCOVA, F(1, 2127) = 12.1, $P = 0.001$].

There was a significantly higher use of baseball caps by spectacle wearers (Mann Whitney U, $P = 0.015$); however, no significant differences were found for the use of other eye protection strategies between spectacle and nonspectacle wearers. The use of a baseball cap, seat adjustment, newspapers, and plastic sheets were all significantly higher in LH than SH pilots (Mann Whitney U, $P < 0.001$ in each category).

Comparing LH, SH, and HOS pilots, the use of aircraft visors (Kruskal-Wallis, $P < 0.001$), hand to block sun (Kruskal-Wallis, $P = 0.007$), seat adjustment (Kruskal-Wallis, $P < 0.001$), newspapers (Kruskal-Wallis, $P < 0.001$), and plastic sheets (Kruskal-Wallis, $P < 0.001$) were all significantly lower in HOS pilots. The use of a baseball cap was significantly higher (Kruskal-Wallis, $P < 0.001$) among HOS pilots.

A further 146 pilots declared other strategies used. These included the use of suction or stick on car side window blinds ($N = 39$), aircraft checklists against windshield or attached to visor ($N = 34$), and other items including paper, cardboard, or envelopes against windshield or attached to visor. Fifteen pilots

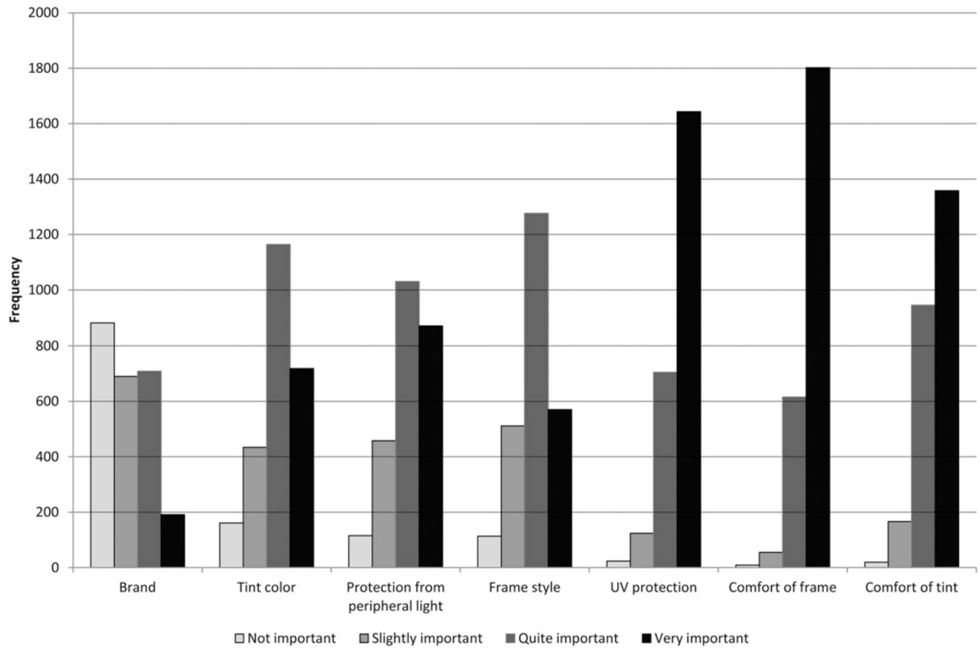

Fig. 2. Subjective ratings of importance given by the pilots to various considerations for sunglass selection. Key: light grey outlined bar = not important; medium grey outlined bar = slightly important; medium grey bar = Quite important; black bar = very important.

were flying in operations where a flying helmet with integrated visor was used. LH pilots were the highest users of other strategies and HOS were the lowest users (Kruskal-Wallis, $P < 0.001$). The following shows examples of the ingenuity of pilots to adapt the standard aircraft systems to give more effective sunlight protection:

480: 'slip an A5 sized duty free bag over the visor, I split in down one side to the mid- point and then it slips beautifully over the standard Boeing clip on visor'.

676: 'One or more sheets of paper can be stuck to the windshield by rubbing against the back of the paper until it stays in place'.

734: 'clipboard clipped to sun visor, plastic checklist jammed into window frame, plastic checklist attached with rubber bands to visor'.

1039: 'Cusions (sic.) from the aircraft jumpseat'.

1041: 'Flight envelope from visor and trapped by standby compass housing Airbus'.

1125: 'The soft HUD visor cover'.

1275: 'I carry 2 self expanding mesh sun shades (of the type used in cars) with center suckers, usually doubled up, either stuck onto the windshield directly or onto the sun visor or between side sun visors to reduce light leakage in the gaps not covered by sun screens'.

1823: 'I use a lightweight A3 size aluminised [sic] envelope slotted over the sun visor to block the sun'.

1944: 'Napkin plus sun visor'

2397: 'have a roll of car window tint film that sticks with static electricity to the window'.

When questioned about the presence of exposure related ocular pathology, 41 (1.4%) pilots had been told that they were developing or had been diagnosed with cataracts and 18 (0.6%) had undergone cataract surgery; 43 (1.5%) had been told that they were developing or had been diagnosed with macular degeneration. There was no significant difference between any health question and the amount of time that sunglasses were used during flight (Kruskal-Wallis).

There was no reported pathology from HOS pilots. Of the SH pilots, 0.8% reported as being diagnosed with cataract, 0.5% had undergone cataract surgery, and 1.3% had been told that they were developing or had been diagnosed with macular degeneration. Within the LH pilot group, 2.1% reported as being diagnosed with cataract, 0.8% had undergone cataract surgery, and 1.6% had been told that they were developing or had been diagnosed with macular degeneration. Pearson Chi-square analysis revealed that flying category was not significantly associated with declarations of cataract, intraocular lens implants or macular degeneration. There was no significant difference in prevalence of UV related ocular pathology between ex-military and non ex-military pilots (Pearson Chi-square).

Independent t-test analysis revealed that those declaring ocular pathology were significantly older for cataract [$t(2892) = 7.77$, $P < 0.001$), cataract surgery ($t(2892) = 3.20$, $P = 0.001$] and macular degeneration [$t(2892) = 4.03$, $P < 0.001$]. However, ANCOVA analysis showed no significant relationship between flight time logged and cataract [$F(1, 2891) = 0.01$, $P = 0.93$], flight time logged and macular degeneration [$F(1, 2891) = 0.05$, $P = 0.82$] or flight time logged and intraocular lens implant [$F(1, 2891) = 0.33$, $P = 0.57$] once allowing for age.

Respondents were able to add free text comments to elaborate or comment on a number of their responses. Additionally, a general comments box for "any other" remarks was placed at the end of the questionnaire. A total of 731 comment boxes were assessed, coded and analyzed (**Fig. 3**). The most prevalent theme from the free text comments box was a perceived inadequacy of solar protection, particularly visors, fitted to aircraft. There were significantly more negative comments received regarding Boeing visors (65 negative, 5 positive) compared to Airbus (16 negative, 10 positive) [Pearson Chi-square, $X^2(1, N = 96) = 14.11$, $P < 0.001$]. More negative comments were received regarding the brightness of Airbus instrument displays (19 negative, 1 positive for Airbus, 3 negative, no positive for Boeing), however, Pearson Chi-square analysis showed no significant difference between comments on Airbus and Boeing instrument displays.

Although comments were received regarding the perceived importance of using sunglasses during flight or details of

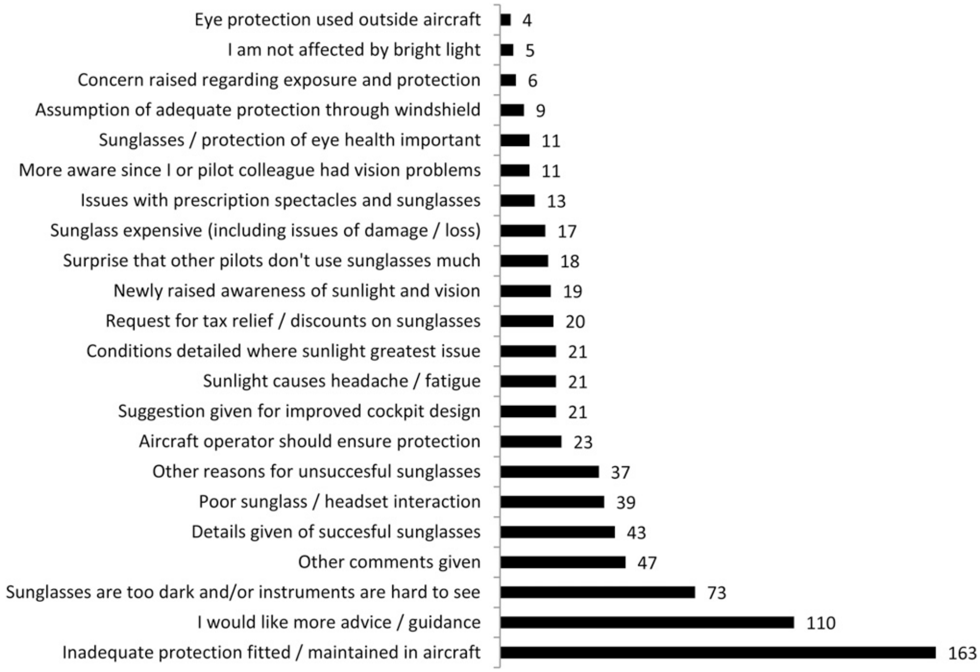

Fig. 3. Summary of coding completed on free text boxes covering other comments made by respondents.

successful sunglasses used, there were 179 comments highlighting the barriers to successful sunglass use including comfort, cost, and issues with using corrective spectacles. The most commonly reported barrier to sunglass use was that it made the instruments too dark to visualize clearly. Respondents showed engagement with the questionnaire as the second most prevalent theme within the free text boxes was for more guidance and advice to be published for pilots.

DISCUSSION

There is an expected rise in the requirement for the use of spectacles with age. This is most commonly due to the onset of presbyopia[5] and a shift toward hypermetropia[4] which causes a reduction in the level of unaided vision. The results show that there was a wide variation between pilots in the use of sunglasses. There are a number of possible explanations for this. It can be seen from the results that pilot sunglass use is strongly driven by prevailing conditions rather than by a particular stage of flight. There is likely to be a wide population variation in personal threshold of tolerance to bright light conditions due to a number of physiological and ocular factors including degree of ocular pigmentation, facial anatomy (e.g., prominent eyebrows, deep-set eyes), age, and pupil size.

Normal age related ocular changes including lens and other media changes, increase in scatter and fluorescence of lens and cornea, reduced dark adaptation and glare recovery[21] are all likely to increase glare sensitivity with age yet the older spectacle wearing pilot is less likely to use sunglasses. The most common reason for reduction in sunglass use with time is due to the onset of requiring corrective spectacles. It is interesting to see that younger pilots rate their sunglass performance higher. This could be due to the normal ageing ocular changes in older pilots impacting on visual performance in ways that are not fully ameliorated by sunglasses.

The overall prevalence of pilots using contact lenses during flight was 12.2% which was higher than the 3.1% found among U.S. civilian pilots back in 1997.[17] Due to the continued expansion of the contact lens industry, improvements in lens technology, and range of lenses available, it would be expected that current prevalence of contact lens use in U.S. pilots would now be significantly higher. It is estimated that in the U.K. population age 15–65 yr, the prevalence of contact lens use in those requiring optical correction is approximately 18% compared with 26.6% found in the study. This higher prevalence of contact lens use in the study group is surprising as it would be expected that prolonged contact lens use in the low humidity cockpit environment would cause discomfort in some wearers. The higher contact lens use in the study group may be due to pilots being of a higher socio-economic group than the overall U.K. population but may also be influenced by a pilot preference to be spectacle free when undertaking aviation visual tasks. There is likely to be a number of factors influencing this decision, however, the ease of using one pair of non-prescription sunglasses when needed is likely to be a consideration. Contact lens wearers were found to use sunglasses significantly more than spectacle wearers (Mann Whitney U, $P < 0.001$).

The use of aviator style sunglasses is significantly higher in helicopter pilots while airline pilots are more likely to be using wrap around style sunglasses. These are likely to offer superior protection from peripheral radiation and the long haul pilot in particular may be subject to long periods of flight with the sun in a similar relative position within their field of view. This also offers an explanation for the long haul pilot being more likely to have two pairs of sunglasses. An aviator frame is likely to have a more compatible thin side for use with close fitting noise attenuating headsets used by the helicopter pilot.

The results show that a major factor in the comfort of sunglasses, and as a consequence, the amount that they are used, is the compatibility with the headsets. Not only were symptoms of discomfort around the ears reported independently by 39 participants, 3 pilots declared comfort as the reason for carrying a second pair of sunglasses during flight, and sunglass discomfort was reported by 89 non-sunglass wearing participants as their reason for not using sunglasses. It is likely that those pilots who require a prescription are more adapted to wearing frames on a full time basis. They are also more likely to have had their glasses professionally adjusted for optimum fit (although 63.8% of sunglass users questioned had never had a fitting) than those pilots who have purchased nonprescription sunglasses from a retail outlet.

The majority of sunglass tint color was described as gray, brown, or green. These are unlikely to cause significant changes to perception of color; however, it is recognized that perceived tint color may not correlate well to the sunglass lens transmittance properties. For example, those describing a silver tint may have had a neutral gray tint and a mirrored reflective coating on the front surface of the lens. Some tints described as green or purple may have multi-antireflection coating on the lens and those describing their sunglasses as blue or black may have a dark (higher absorption) neutral gray tint.

A number of pilots reported difficulty with the aircraft instruments appearing too dark when wearing sunglasses (73 reported independently and 58 non sunglass wearing pilots gave this as their reason for not using sunglasses). The obvious solution to counter this would be the use of a graduated tint which is darker at the top and lighter at the bottom of the lens. However, only 11.1% of sunglass wearing pilots had this type of tint with the majority having a fixed, equal density tint. This disparity is surprising and could be due to a number of causes. Graduated tints in nonprescription sunglasses may be less prevalent or be under-reported by participants if the degree of graduation is subtle. It may also be that graduated tints are not used as they are perceived as offering a lower level of solar protection compared to an equal density tint. Finally, it may be that graduated tints are less commonly available in the showroom frames that are typically found in sunglass outlets or magazines.

Overall, the majority of pilots questioned rated their sunglass as 'good' or 'excellent', although this did not include the pilots who never used sunglasses and who would have more likely had a poor previous experience. This positive rating is in spite of only 1.7% of sunglass wearers using aviation specific sunglasses. This may be due to a low awareness that these sunglasses are available, the perception of a greater expense to purchase, skepticism about the claimed benefits, or that pilots perceived sunglass comfort to be satisfactory with their current sunglasses.

It is clear that bright sunlight conditions can be problematic in the flight deck. The standard visors and blinds were consistently reported as not offering adequate comfort to the pilot throughout normal operations. The range of other practices declared shows how pilots often use whatever is to hand within the cockpit to block glare from direct sunlight. A number of pilots have anticipated the potential in-flight issues of sunlight and carry some form of glare protection in their flight bag, such as a stick on vehicle window blind marketed for glare protection for children. It is interesting to note that there is no significant difference in the use of strategies between spectacle wears and nonspectacle wearers with the exception of using sunglasses (lower among spectacle wearers) and using a baseball cap (higher among spectacle wearers). It would seem that the additional barriers to sunglass use by spectacle wearers result in the use of a peak cap being a more practical option for this group.

The highest users of sunlight protection strategies are the long haul airline transport group where the aircraft is likely to be operating in controlled airways, on auto-pilot and on a similar heading for potentially many hours at a time, and where the requirement for spotting other traffic is reduced. The lowest users of the three most prevalent flying categories were the helicopter off-shore pilots. This would be expected for these operations which are lower altitude, short duration with more frequent changes of heading and a greater safety requirement for look out and spotting other traffic. It is also logical that the use of a peaked baseball cap is higher in this group as the windshield blocking strategies used in other flight operations could affect flight safety.

It is of interest that ex-military pilots used eye protection strategies less frequently. This may be due to differences in initial pilot training and the availability of sun protection systems in military aircraft but also apparent is a lower use of nonstandard sun protection practices by ex-military pilots.

There have been a number of studies reporting a poor understanding within the general public of the hazards of UV exposure to ocular health.[9] This, together with the assumption made by some pilots that aircraft windshields offer adequate protection (in turn, possibly due to the lack of skin effects noticed by the pilot) may offer some explanation as to the large number of pilots using sunglasses very little or not at all. Additionally, the most common reason for a pilot to increase their sunglass use is through awareness of potential impact to eye health.

Conclusions

A number of barriers have been uncovered in the use of sunglasses by professional pilots. The need for corrective spectacles is a large factor and it would be wise for practitioners to promote prescription lens materials which offer good UV protection properties. Similarly, a UV blocking lens should be offered to the contact lens wearing pilot. The advantages of a graduated tint in order to optimize the visibility of the instrument display should be promoted. All sunglasses should be light, strong and professionally fitted to ensure optimum comfort and compatibility with a headset. Finally, the widespread use of improvised and nonstandard methods found to reduce solar illuminance in the cockpit should prompt aircraft manufacturers to consider what improvements can be made to ensure that visors and blinds offer more flexibility and have the facility for covering a greater area of the cockpit windshield.

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Authors and affiliations: Adrian C. Chorley, M.Sc., Ph.D., Civil Aviation Authority, UK CAA Medical Department, Safety and Airspace Regulation Group, West Sussex; Bruce J. W. Evans, B.Sc.(Hons.), Ph.D., Institute of Optometry, London; and Bruce J. Benwell, B.Sc.(Hons.), Ph.D., Faculty of Health and Social Care, London South Bank University, London, UK.

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