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14. ABSTRACT

This report results from a contract tasking TNO Human Factors as follows: The Grantee will investigate the physiological mechanisms behind the perceived glare reduction obtained when using a yellow filter. The proposed project aims to place the reported heightened discomfort glare produced by blue light on a more scientific footing. The physiological mechanism of discomfort glare remains unclear. At least four hypotheses have been proposed:

1. Rod-cone interaction (Dr. Ian Bailey, UC Berkeley School of Optometry, personal communication)
2. Excessive iris contraction (Vos, 1999)
3. Chromatic aberration (Dr. Post, Wright-Patterson Lab, personal communication)
4. S-cone sensitivity (ophthalmological case studies)

The research consists of a re-analysis of prior collected data and a new experiment, designed to discriminate among the hypotheses.

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October 27, 2004

Yellow lessens discomfort glare: physiological mechanism(s)

F-WR-2003-0023-H Report

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Abstract

A long standing mystery is the improved visibility people report with yellow glasses. Car drivers and pilots claim reduced discomfort of oncoming head lamps at night and the blue sky during the day respectively. While people clearly benefit, scientists have not been able to pin down the causal mechanism(s). Several hypotheses have been proposed regarding the physiological origin of this “blue sensitivity” including scotopic (rod) response, excessive iris contraction, blue (S) cone response, brightness perception, and circadian receptor response. We compared the level of discomfort glare of filter pairs that discriminate between these hypotheses with 16 subjects. The results show that more S-cone stimulation corresponds to more discomfort, while more rod stimulation does not. This is consistent but does not prove a causal relation between the S-cones and discomfort glare and it is not consistent with a major role for either the pupillary constriction hypothesis or the circadian photoreceptor. The modified spectral efficiency function $V_m(\lambda)$ and large field photopic spectral sensitivity $V_{10}(\lambda)$ do not significantly change these conclusions based on the standard $V(\lambda)$. The present study has therefore been successful in eliminating several physiological mechanisms of discomfort glare, leaving the S-cones as the primary candidate.

Introduction

There is a long standing paradox regarding the effects of yellow filtering on the sensation of glare. On the one hand scientists claim it has no objective positive effect, on the other hand users claim to benefit. The USAF and many other air forces (including the RNLAF) have decided to prohibit or at least limit the use of yellow visors because of the reduction in color vision (Young et al., 2000). This, while scientifically defensible, leaves the user with an unsatisfied feeling because an apparently good thing (a yellow filter) is not allowed. In a previous project we have shown that a yellow filter does not have a positive effect on any objective measure like visual acuity or contrast sensitivity, but does turn out to greatly reduce the so-called discomfort glare (Kooi & de Vries, 2002). The yellow filter reduced the level of discomfort glare to that of a 2.3 times dimmer white light. Clearly the blue part of the spectrum is disproportionally important in causing the sensation of visual discomfort.

The spectral response of discomfort glare

The physiological mechanism of discomfort glare remains unclear. Several hypotheses have been proposed that may account for the blue importance in the experience of discomfort glare. These include (1) Scotopic (rod) response, (1b) Excessive iris contraction, (2) S-cone response, (3) Brightness perception and (4) Circadian receptor response. Blue scattering and chromatic aberration in the eye may seem a potential cause at first glance, but if anything the resulting lower contrast should *decrease* the glare sensation. From the number of hypotheses it is clear that the scientific community has a hard time to come up with the right answer. In this report we contribute to the scientific footing of discomfort glare produced by blue light making use of differences in the spectral response of three hypotheses. We have chosen to do a discomfort matching experiment aimed primarily to discriminate between the scotopic and S-cone hypotheses. The key to success in this study is the ability to find and create light sources that discriminate between the various hypotheses.

Directly relevant literature

The literature mentiones excessive iris contraction as a possible cause for discomfort glare. The spectral sensitivity of pupil contraction is reported to be greater in the blue part of the visible spectrum than the standard photopic spectral sensitivity function V(λ), looking more like the scotopic spectral sensitivity function V'(λ). The most common explanation of this curious finding is rod contribution, also during the day (Howarth et al., 1993; Berman et al., 1996; Vos, 2003). If this is correct, the "Excessive iris contraction" hypothesis and the rod hypothesis are not discriminable. Recently Adrian (2003) questioned the rod input, attributing the heightened blue sensitivity of the iris response instead to the heightened blue sensitivity outside the fovea where the macular pigment is lacking. Adrian's hypothesis can be tested by comparing the luminance according to the 2 degree V(λ) function to the the 10 degree V(λ) function. A second potential explanation is provided by the S-cones. Surprisingly little attention is paid by the discomfort glare literature to the S-cones. Alferdinck (2000) for example has no treatment of it. A third hypothesis, stated by Dr. Post, AFRL at the start of the study, is the difference between luminance and brightness in the blue part of the spectrum. Possibly discomfort glare is directly related to brightness perception, or perhaps subjects are not able to discriminate discomfort from brightness. Berman et al (1996) treat this hypothesis and prove it to be correct for lower light levels but not for very bright lights. Fourthly the recently discovered circadian receptor provides an entirely new visual mechanism with a high sensitivity to the blue wavelengths (Berson et al., 2002; Thapan et al., 2001; Brainard et al.; 2001).

Methods

The stimulus colors

We made use of our laboratory filter set to select filter pairs to make the discrimination between the rod hypothesis and the S-cone hypothesis. The goal is to find filter pairs that differentially stimulate the one and not the other. At the same time we want to avoid highly saturated colors and prefer to stay close to the colors in the natural world and close to the color of a yellow visor. Figure 1 shows that we came quite close. It shows the rod response and the S-cone response of two light pairs. One pair differentially stimulates the rods and equally stimulates the S-cones. The other pair differentially stimulates the S-cones and equally stimulates the rods. The two yellow colored filters are made out of 5x5cm glass by Schott, type numbers GG475 and GG495. The filters with the peach color are made of gelatin. Figure 2 shows the complete spectra and the Tables show the various spectral 'descriptors' of the four lights.

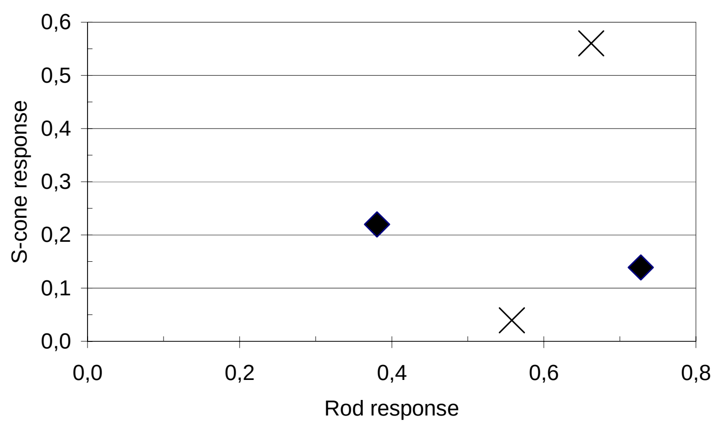


Figure 1. Spectral description of the lights used in the study, chosen to discriminate between the S-cone, rod, and brightness hypotheses. The horizontal axis shows the amount of rod stimulation (V'_{λ}) and the vertical axis shows the amount of S-cone stimulation, as the fraction of an equal energy (white) light to make the data more intuitive. The two lights labeled FILLED differ slightly in their S-cone response (0.14 versus 0.22, both low values) while the rod stimulation differs significantly (0.73 versus 0.38). The two lights labeled as a SQUARE differ greatly in their S-cone response (0.56 versus 0.04) and marginally in their rod response (0.66 versus 0.56).

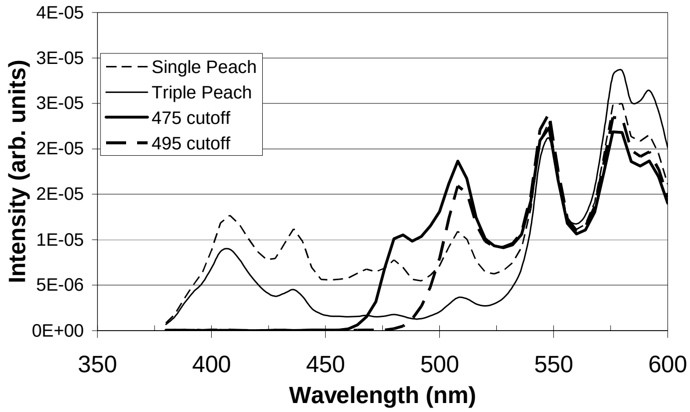


Figure 2. Spectra of the two yellow and the two peach colored lights. The peach filter transmits much more of the short wavelength light that stimulates the S-cones. The 475 cutoff filter lets the light through that maximally stimulates the rods (500nm). The spectral spikes above 500nm are caused by the spiky light source illuminating the filters.

Spectral filter	**475 cutoff**	**Triple Peach**	**Single Peach**	**495 cutoff**
V(λ)	**1.0**	**1.0**	**1.0**	**1.0**
Circadian receptor	1.1E-02	5.8E-03	1.7E-02	6.4E-03
V'(λ)	1.64	0.86	1.50	1.26
S-cone	0.08	0.12	0.31	0.02
V_m(λ)	1.0001	1.002	1.004	1.0001
V_{10}(λ)	1.06	1.03	1.05	1.04
CIE x	0.41	0.47	0.39	0.45
CIE y	0.50	0.43	0.39	0.53

Table 1. The various CIE spectral weighting functions of the four lights, normalized for photopic luminance, forcing the standard standard spectral sensitivity function V(λ) to be 1.0 exactly. The "circadian receptor" response was estimated from Thapan et al. (2001) and Brainard et al. (2001). V_m(λ) is the "modified V(λ)", taking the 1988 CIE correction into account. V_{10}(λ) is the large field (10 deg) V(λ), supposedly more suited to model the pupil response than the standard small field (2 deg) V(λ). In the text we examine to what extent the two light pairs are able to account for the discomfort matching data.

Filter pair ratios:	**475-Triple Peach**	**495-Single Peach**
V(λ)	1.0	1.0
Circadian receptor	1.9	0.4
V'(λ)	1.9	0.8
S-cone	0.6 (both low)	0.1
V_m(λ)	0.998	0.996
V_{10}(λ)	1.030	0.982
Discomfort match	*1.21±0.45*	*1.54±0.9*

Table 2. The relative spectral descriptors for the two light pairs. The Triple Peach–Yellow 475 pair is designed to not differentially stimulate the S-cones (i.e. isolate the rods) and the Single Peach–Yellow 455 pair is designed to isolate the S-cone activity. Note that the S-cone activity of the 475 cutoff filter and the Triple Peach filter are both very low. In short, both Cutoff filters have a more yellow appearance and both need to be increased in luminance to match the discomfort of the Peach filters. For comparison we added the psychophysical data described later on in the Results section (shown *cursive*).

The test procedure

The test procedure was adapted from Alferdinck and Theeuwes (1997) and Kooi and de Vries (2002). Subjects were instructed to indicate to the experimenter how to adjust the light level of the reference light to match the visual discomfort of the other (test) light. This is called a "method of adjustment procedure". By repeating the measurement it is possible to get a statistically meaningful measurement. In a method-of-adjustment experiment it is important to balance all factors that may influence the match. In our study these include the position of the colored lights (left & right), the viewing direction of the observer, the order of the presentations, the starting point of the luminance mismatch, and the neutrality of the experimenter. We balanced position, sequence order, and initial luminance mismatch within and across subjects. The subjects were instructed to fixate symmetrically between the two lights for 2 to 5 seconds, allowing eye movements. The subjects then indicated to the experimenter which of the two lights is more discomforting while keeping the eyes closed or while looking away. After the experimenter adjusts the relative light level, the subject repeats the visual comparison until the two light sources are judged to be equally discomforting. After four repeated measurements the subjects were asked to rate the level of discomfort glare on the 9-point rating scale of De Boer (De Boer, 1967). Next the same light pair was measured again four times with the left/right positions reversed. The experiment proceeded with the other light pair. In total each subject made 32 matches and four discomfort ratings, taking 30 to 45 min.

The test setup and apparatus

The experiment took place in the TNO lighting lab, consisting of a large light-tight environment (Figure 3). The light stimulus consists of a pair of 8 cm circular lights (1.1 deg) viewed from a distance of 4.2 m. The yellow and peach filters are described above. A Pritchard Spectrascan 650 spectro-photometer was part of the experimental setup, recording all luminances and storing all spectra (spectral radiance in $W.m^{-2}.sr^{-1}.nm^{-1}$ versus wavelength in nm) from the viewing point of the subject. The high brightness lights are created by two Götschmann 67HT projectors, aimed at a black-stripe rear projection screen. The 8cm apertures are made of cardboard, attached to the rear projection screen, separated by 28cm (= 3.8 deg visual angle). The luminance levels are varied by widening and narrowing the light beams, guaranteeing a constant spectral composition and uniform light level. The average luminance level in the main experiment was $40x10^3$ cd/m^2, comparable to a weak sun reflected on a wet road. Eye safety is not an issue because of the short viewing times and the small stimulus size.

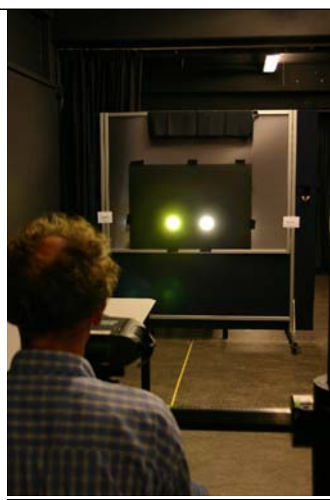
	
Subject viewing the stimulus pair	Rear view showing the optics and filters

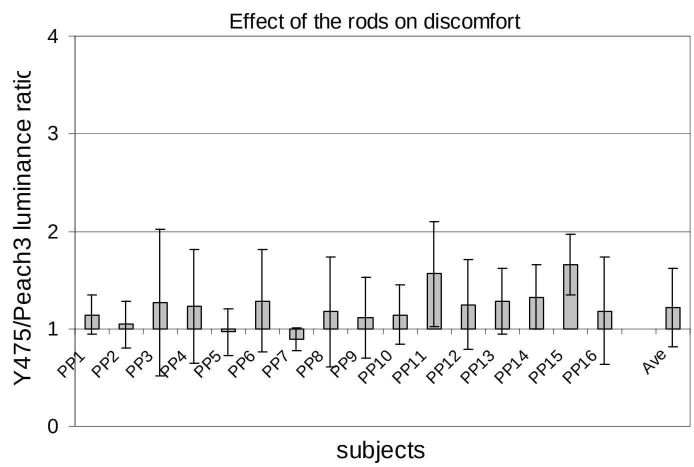
Figure 3. The setup of the experiment. The subject looks in between the two light sources.

The room was dimly lit. The amount of light reaching the subjects eyes from the surround is approximately 60 lx. While this may seem much, it is negligible compared to the ocular straylight caused by the two light discomfort glare sources.

Results

Pilot experiment
In a pilot experiment we asked five subjects to make discomfort and brightness matches between the light pair that differentially stimulates the S-cones at three light levels (3000 to 40000 cd/m^2). We verified that the highest light level is most suited for the main experiment. As reported before by Berman et al. (1996), the sensation of visual discomfort or "visual sting" diminishes at the lower light levels, leaving the brightness sensation as the dominant sensation.

Main experiment
On the de Boer scale (1967) the average score for both light pairs was between 4 and 5, close to "just acceptable". It other words, the subjects were not overly bothered by the experiment. Figure 4 shows the discomfort matches for the two light pairs per subject. All subjects on average rate the Single Peach filter as more discomforting than the yellow appearance of the 495 cutoff filter when matched for luminance. Fourteen of the sixteen subjects rate the Triple Peach filter as more discomforting than the yellow appearance of the 475 cutoff filter. Only 21 of the total 128 measurements (16 subjects times 8 repetitions) set the Single Peach light brighter than the Yellow 495 light. The asymmetry is statistically highly significant (Z=7.3, P=2.7x10^{-11}). At first sight this result suggests a role of the S-cones in causing discomfort glare. The Triple Peach–Yellow 475 asymmetry is also highly significant (Z=5.4, P=2.6x10^{-7}). Only 33 of the 128 recorded matches set the Triple Peach light brighter than the Yellow 475 light.



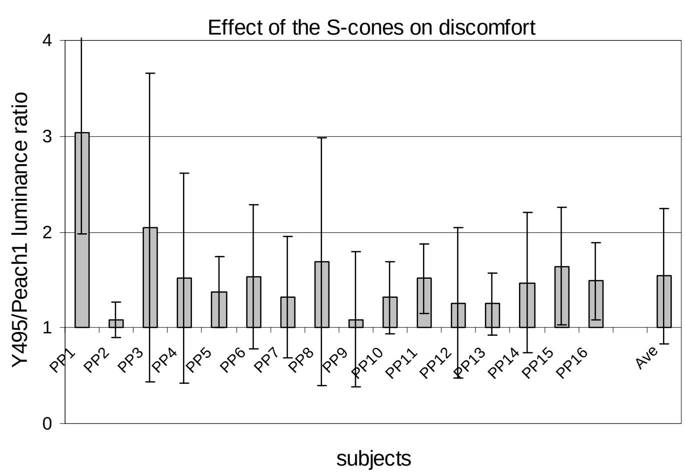


Figure 4. The discomfort glare matches set by the 16 subjects for the two light pairs. The bluer light (the peach filter) is seen as more glaring in both cases. This result is consistent with a role for the S-cones in visual discomfort but not consistent with a role for the rods.
This discomfort asymmetry is not as expected however: the light source with more rod stimulation causes *less* discomfort, suggesting the absence of a causal relationship between rod stimulation and discomfort

glare. A possible cause for this (small) reversed effect may be the small difference in S-cone stimulation as shown in Figure 1.

Discussion

S-cone and rod role in visual discomfort
From a statistical significance point of view it is clear that more S-cone stimulation corresponds to more discomfort glare. This does not prove a causal relationship, but does make it more likely. The data strongly suggest the absence of a causal relationship between rod stimulation and discomfort glare.

We tested various other theories that have been suggested as potential candidates to contribute to discomfort glare. Table 2 shows the calculated values for the filter pairs, here we discuss them.

Judging discomfort versus brightness
In the pilot experiment the matches were made on the basis of discomfort glare as well as brightness. It quickly became apparent that the distinction was not meaningful to the subjects, in particular at the medium and lower light levels. This is an interesting finding in its own right. The judgements of visual discomfort and brightness can be hard to discern. In a previous study comparing very bright simulated white and saturated yellow headlights, the subjects had little difficulty making the distinction however (Kooi & de Vries, 2002). We conclude that this type of discomfort glare experiment indeed requires high light levels with substantial discomfort to avoid settings based on brightness.

Circadian photoreceptor component in visual discomfort?
Dr. Berman of the Lawrence Berkeley Lab has given the suggestion that the supposed "circadian receptor" might be responsible for the blue dominance of discomfort glare, given its high sensitivity to blue wavelengths (Thapan et al., 2001; Brainard et al., 2001). The circadian spectral sensitivity falls in between the S-cone and rod spectral sensitivity (Figure 5). We have tested this hypothesis by convoluting the circadian spectral response with our four light stimuli. Table 2 shows the result which is in between the S-cone ratio and the rod ratio for the Single Peach-495 Cutoff pair, and virtually identical to the Rod ratio for the Triple Peach - 475 Cutoff pair. Just as the rod hypothesis can be discounted (475 Cutoff stimulates the rods more than the Triple Peach filter but the Triple Peach filter causes more discomfort), the Circadian receptor hypothesis can be discounted: 475 Cutoff stimulates the Circadian receptor more but causes *less* discomfort. The preliminary conclusion therefore is that the hypothesized Circadian receptor cannot be responsible for discomfort glare, at least not fully. We suggest the spectral calculation should be repeated once the Circadian spectrum is pinned down more accurately. This will be easy to do since it will not require collecting more data.

Modified spectral efficiency function $V_m(\lambda)$
We verified the impact of the 1990 CIE luminance correction on the the discrepancy between luminance and discomfort; it should decrease it slightly. The *Modified* V(λ) is based on the Judd-Vos correction and described in CIE (1990). Table 1 indeed shows a small effect in the right direction. It is too small to impact the conclusions based on the standard spectral sensitivity function V(λ) however.

Large field spectral efficiency function $V_{10}(\lambda)$
The same holds for the 10 degree field V(λ). The calculated ratios shift by 3% the most while the psychophysical effect amounts to 51% and 22%.

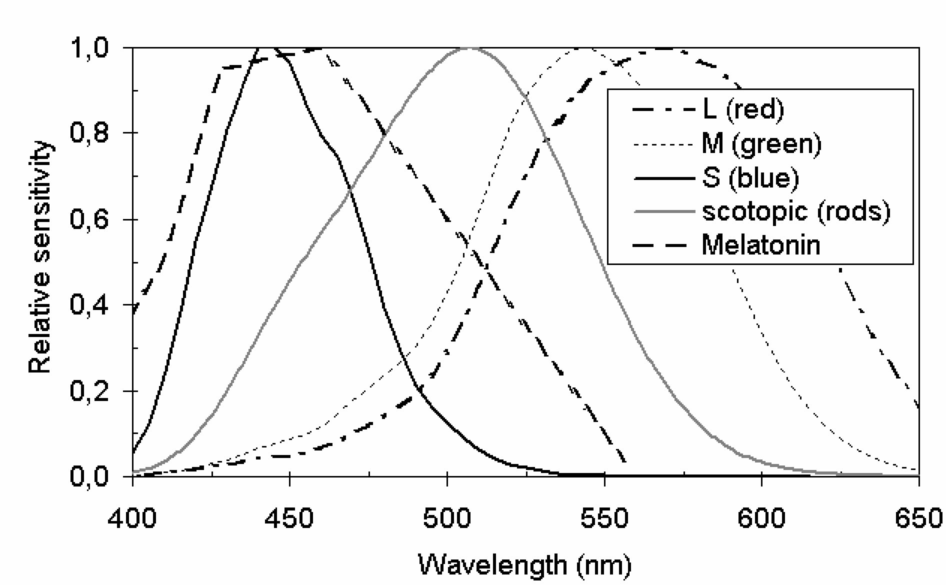


Figure 5. A comparison of the spectral sensitivity of the rods, the three cones and the hypothesized receptor responsible for the Circadian (day/night) rhythm. The spectrum of the 'Circadian receptor' falls between the S-cone and the rod spectra, making it a potential candidate to account for blue effects.

Conclusions

S-cones

It turned out to be possible to find filters suitable to discriminate between the S-cone and rod hypotheses. The results show that more S-cone stimulation corresponds to more discomfort. This was no surprise given the well known blue glare effect.

Rods

More rod stimulation surprisingly corresponds to *less* discomfort, suggesting that the rods do not contribute. This conclusion is consistent with Berman et al. (1996) who also showed a "high scotopic light source" to be less discomforting at high light levels, undermining not only the rod but also the pupillary contraction hypothesis for discomfort glare.

Perceived brightness

Perceived brightness measured in this study appears closely related to visual discomfort. It cannot however be consistent with the brightness matching spectral sensitivity found in the literature (CIE 1978; Wyszecki & Stiles, 1982). This is one of the aspects that merits more thought and model effort.

Other factors

Other factors like the hypothesized circadian photoreceptor, the modified spectral efficiency function $V_m(\lambda)$, and the large field spectral efficiency function $V_{10}(\lambda)$ all affect the calculations but not enough to affect the conclusions based on the standard $V(\lambda)$ spectral efficiency function.

Summary

The present study has been successful in undermining several potential physiological mechanisms of discomfort glare. The S-cones come out of the study as the most likely source, but the data do not prove a causal relationship.

Remaining research issues

The present study has contributed to the understanding of the discomfort glare mechanism. One interesting next step is to get a quantitative grip on the importance of the S-cone contribution; does it account for all or part of the yellow glare reduction? Secondly, it is intriguing that a 1.5 times luminance reduction is sufficient to compensate for a 15 times S-cone increase. A 1.5 times reduction in luminance is minimal compared to the effect of sunglasses, which typically darken by a factor of 10 to 100. We conclude that the two other perceptual phenomena, the increased perceived contrast and brightness with yellow glasses (Rabin & Wiley, 1996), are worth closer investigation. The results of this study will be useful to develop a yellow filter that simultaneously maximizes viewing comfort and color vision.

Acknowledgement

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References

Adrian W. (2003). Spectral sensitivity of the pupillary system. Clin. Exp. Optom. 86 (4), 235-238.

Alferdinck, J. W. A. M. (2000). Glare and distraction by bluish car headlamps; a literature survey (TNO-report TM-00-C018). Soesterberg, The Netherlands: TNO Human Factors.

Alferdinck, J. W. A. M. & Theeuwes, J. (1997). The relation between discomfort glare and driving behaviour. In: Proceedings symposium PAL-congress 1997 (pp. 24-32). Darmstadt, Germany: University of Darmstadt.

Berman S.M., Bullimore M.A., Bailey I.L. and Jacobs R.J. (1996). The influence of spectral composition on discomfort glare for large-size sources. Journal of the Illuminating Engineering Society, Winter 1996, 34-41.

Berson D.M., Dunn F.A., Takao M. (2002). Phototransduction by retinal ganglion cells that set the circadian clock. Science 295.

Brainard G.C., Hanifin J.P., Greeson J.M., Byrne B., Glickman G., Gerner E. and Rollag M.D. (2001). Action spectrum for melatonin regulation in humans: evidence for a novel circadian photoreceptor. The Journal of Neuroscience 21(16), 6405-6412.

CIE (1978). Light as a true visual quantity: principles of measurement. Publication CIE no 41, 1978.

CIE (1990). CIE 1988 2^0 spectral luminous efficiency function for photopic vision. (CIE Publication No. 86). Vienna: Author.

Boer, J.B. de (1967). Public lighting. Eindhoven, The Netherlands: Philips Technical Library.

Flannagan, M., Sivak, M., & Traube, E. C. (1994). Discomfort glare and brightness as functions of wavelength (Report No. UMTRI-94-29). Ann Arbor, Michigan, U.S.A.: The University of Michigan, Transportation Research Institute.

Howarth P.A.; G. Heron G., Greenhouse D.G.; Bailey I.L. and Berman S.M. (1993). Discomfort from glare: The role of pupillary hippus. International journal of lighting research and technology 25, 37-42.

Kooi F.L. & de Vries G. (2002). Een subjectieve beoordeling van optische hulpmiddelen bij het autorijden in het donker [The influence of optical aids on driving comfort at night]. (TNO-report TM-02-C028, in Dutch). Soesterberg, The Netherlands: TNO Human Factors.

Rabin J. & Wiley R. (1996). Differences in apparent contrast in yellow and white light. Opthalmic and Physiological Optics, 16, 68-72.

Thapan K., Arendt J. and Skene D.J. (2001). An action spectrum for melatonin suppression: evidence for a novel non-rod, non-cone photoreceptor system in humans. The Journal of Physiology 535(1), 261-267.

Vos J.J. (2003). Reflections on glare. Lighting Res. Technol. 35 (2), 163-176.

Wyszecki G. & Stiles W.S. (1982). *Color science: concepts and methods, quantitative data and formulae*. 2nd Edition, New York: John Wiley & Sons.

Young P.A., Perez-Becerra J. & Ivan D. (2000). Aircrew visors and color vision performance: A comparative and preliminary pilot study analysis. Aviation, Space, and Environmental Medicine 71, 1081-1092.

Wednesday, September 08, 2004

Improved viewing comfort resulting from yellow filters

F-WR-2003-0023-H Report

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(1) In accordance with Defense Federal Acquisition Regulation 252.227-7036, Declaration of Technical Data Conformity (Jan 1997),

"The Contractor, TNO Human Factors, hereby declares that, to the best of its knowledge and belief, the technical data delivered herewith under Contract No. FA8655-03-1-3043 is complete, accurate, and complies with all requirements of the contract.

DATE: 8 Sept 2004

Name and Title of Authorized Official:

DR. F.L. Kooi

(2) In accordance with the requirements in Federal Acquisition Regulation 52.227-13, Patent Rights-Acquisition by the U.S. Government (Jun 1989),

"I certify that there were no subject inventions to declare as defined in FAR 52.227-13, during the performance of this contract."

DATE: 8 Sept 2004

Name and Title of Authorized Official:

DR. F.L. Kooi

The referenced Federal Acquisition Regulations can be found at http://farsite.hill.af.mil or http://www.arnet.gov/far/