tvst

Article

Evaluation of Physiological Parameters on Discomfort Glare Thresholds Using LUMIZ 100 Tool

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Received: April 9, 2021
Accepted: June 18, 2021
Published: July 28, 2021

Keywords: adult; discomfort; glare; healthy population; light; pupil; iris color; biometry; skin tone; chronotype; sunglasses use

Citation: Marié S, Montés-Micó R, Martínez-Albert N, García-Marqués JV, Cerviño A. Evaluation of physiological parameters on discomfort glare thresholds using LUMIZ 100 tool. Transl Vis Sci Technol. 2021;10(8):28, https://doi.org/10.1167/tvst.10.8.28

Purpose: To assess the links between discomfort glare sensitivity and physiological factors such as eye biometry, refraction, skin phototype, age, and gender among a large sample of healthy human subjects.

Methods: A total of 489 participants who were 20 to 70 years old (241 men, 248 women) underwent discomfort glare threshold measurements via the LUMIZ 100. Eye biometry and optical quality were measured using a Zeiss IOLMaster 700 biometer and i.Profiler aberrometer. Iris color, skin tone, age, gender, eyeglasses use, chronotype, fatigue level, self-evaluation of light sensitivity, and time spent outdoors were determined. Statistical analysis was carried out using nonparametric Mann–Whitney and Kruskal–Wallis tests for categorical data and correlation coefficients for numerical data.

Results: The female subgroup had lower discomfort thresholds than the males ($P < 0.001$). There was no effect of age group, ametropia, eye biometry, iris color, skin tones, chronotype, or fatigue level on discomfort thresholds. Discomfort thresholds were related to self-assessment of light sensitivity, sunglasses ownership, and frequency of use ($P < 0.001$).

Conclusions: Exploration of easily measurable physiological parameters and questionnaire failed to provide reliable indicators of individual light sensitivity to discomfort glare.

Translational Relevance: Light sensitivity is highly subjective and variable across the population. Patients frequently complain about light bothering their daily lives. Accessible physiological factors and questionnaires are unable to predict discomfort levels due to glare. The LUMIZ 100 provides a reliable, rapid, and safe way to determine light discomfort thresholds in order to better manage light sensitivity in clinical care.

Introduction

Discomfort glare is also known as psychological glare.[1–3] Light conditions produce discomfort or pain without necessarily decreasing visual perception.[4] In a healthy population, there is a large range of discomfort thresholds and light sensitivity.[5] In the scientific literature, some physiological factors have been considered to better understand this variability within a healthy population.

Age and gender are the most studied factors of discomfort glare. In laboratory settings, no difference in discomfort thresholds between genders has been found.[3,6–9] Results on age effects vary among studies. Saur[3] found no correlation between discomfort thresholds and age, nor did Van Den Wymelenberg.[10] Verriotto et al.[7] evaluated light sensitivity by decade among subjects 10 to 60 years old and found that the group of 30 to 40 year olds was significantly less sensitive than most other age groups; there was no significance found for the group of 40 to 50 year olds.

Pupil size has been widely studied as an indicator of discomfort glare. Absolute and relative pupil sizes are linked to discomfort glare when measured with a rating scale[11–13]; however, the correlations are weak ($r^2 < 0.5$). Some studies have not found any effect of iris pigmentation,[3,11] but Bennet[14] measured higher mean discomfort thresholds for brown eyes than blue eyes. Verriotto et al.[7] measured no effect of discomfort threshold and skin color, but lower representation of darker skin in their study did not allow them to reach a definitive conclusion.

Various physiological factors of light sensitivity have been analyzed in different studies using various methodologies and light conditions. The objective of the present study was to evaluate a number of physiological factors as predictors of light sensitivity on a large population.

Methods

This prospective study was conducted between January and August 2019 at the University of Valencia.

Ethics

The ethics committee of the University of Valencia approved the study protocol, and the study was conducted in accordance with the tenets of the Declaration of Helsinki. Each participant received information about the study purpose, risks, measurements, data treatment, and their right to stop the study at any time. Informed consent was then signed by every participant.

Participants

Four hundred and eighty-nine healthy participants underwent the study. They were 20 to 70 years of age, balanced in age and gender.

Recruitment was carried out by stratified random sampling in the area of Valencia. Volunteer healthy participants underwent a complete clinical assessment to ensure that they met the requirements for enrollment. The best distance-corrected visual acuity was set at +0.10 logMAR or better in each eye. Exclusion criteria were defined as conditions that could influence vision or interfere with study assessments. For ocular health, any current or evolving pathology manifested in the eye or the appendages (e.g., age-related macular degeneration or glaucoma), any previous ocular surgery, any untreated and/or uncontrolled systemic conditions (e.g., uncontrolled diabetes or uncontrolled high blood pressure), aphakia, or presence of pseudophakic multifocal intraocular lens were exclusion criteria. Although monofocal IOLs were not considered to be an exclusion criterion during recruitment, only two male subjects within the group of participants 60 to 70 years old with an implanted monofocal intraocular lens were included in the study. With regard to general health, people undergoing certain medical treatments, taking some medications (e.g., antidepressants, tranquilizers, antipsychotics, drugs with atropinic effects), or who had a history of migraine or epilepsy were not included in the study.

Experimental Measurements

After eligibility criteria verification, each participant underwent refraction (objective and subjective), ocular biometry, and optical quality measurements, completed questionnaires, and had light sensitivity measurements taken.

Light Discomfort Thresholds

Light discomfort thresholds were determined using the LUMIZ 100 (Essilor International, Paris, France). The device is portable and provides diffuse homogeneous illumination across the entire visual field of the user. An application on a tablet monitors light illumination from 10 lux ($\log_{10}[\text{lux}] = 1$) to 10,211 lux ($\log_{10}[\text{lux}] = 4.01$) at eye level. Light discomfort thresholds are measured for two discomfort levels under three lighting conditions, which include two continuous increases and one discontinuous increase. Continuous increases start at 25 lux for 5 seconds and then increase 20% every second, between warm light (color temperature, 4000 K) and cold light (color temperature, 6500 K). Discontinuous increases start at 10 lux for 5 seconds followed by increases to 25 lux for half a second and then decreases back to 10 lux for 2 seconds, before a 44% increase from the previous flash using warm light (color temperature, 4000 K). During the light increase, participants are requested to push a button twice to indicate their discomfort levels, which are based on symptoms. The lower level occurs when a participant begins to feel "tension in the eyelids or tingling." This first level is defined as the "just perceptible" discomfort threshold. A higher level of discomfort occurs when the participant reports "requiring an effort to keep the eyes open." This second level is referred to as the "really disturbing" discomfort threshold. The acquisition protocol and reliability of measurements have been previously described in detail elsewhere.[5] Light sensitivity is computed using a mean of six logarithmic illumination thresholds.

Optics and Biometry

Optical and biometric factors were measured using the Zeiss i.Profiler aberrometer (Carl Zeiss Vision, Jena, Germany) to determine pupil size in dim light and total and high-order ocular aberrations and the Zeiss IOLMaster 700 to determine axial length. Subjective refraction was also determined. Ametropia has been defined according to the mean equivalent binocular sphere: myopic when inferior to –1 diopter (D), hyperopic when superior to +1 D, and emmetropic in between.

Eyeglasses

Participants completed questionnaires to report their use of photochromic lenses and sunglasses, as well as the frequency of their use of sunglasses.

Skin and Iris Color

Skin color was objectively measured on the forearm (inferior and superior) using the RM200QC Imaging Spectrocolorimeter (X-Rite, Grand Rapids, MI). This tool allows reliable measurements of skin tone in CIELAB color space. According to lightness level (L*) and proportion of yellow color (b*), individual typology angles are computed that range from over 55° for very light skin to less than –30° for dark skin. Color segmentation (very light, light, intermediate, tan, brown, and dark) was done according to the individual typology angle limits reported by Visscher.[15]

Iris color classification was achieved based on the nine segmentation levels suggested by Mackey et al.[16]: 1, light blue; 2, darker blue; 3, blue with brown peripupillary ring; 4, green; 5, green with brown iris ring; 6, peripheral green central brown; 7, brown with some peripheral green; 8, brown; and 9, dark brown.

Other Physiological Factor and Time Factors

Questionnaires were completed by each participant regarding their self-perception of light sensitivity: Do you feel sensitive to light? 1. Yes, a lot. 2. Yes, a bit. 3. No, not really. 4. No, not at all. Note that the psychometric property of this question has not been validated. Also addressed were chronotype adapted to the Spanish population[17] and fatigue evaluation based on Samn and Perelli,[18] as well as time spent outdoors.

Statistical Analysis

According to Weber–Fechner laws,[19] brightness sensation is logarithmic to stimulus intensity; therefore, all statistics were conducted on decimal logarithms of illumination ($\log_{10}$[lux]). In those cases in which thresholds were not reached at 10,211 lux, the following level (12,253 Lux) was then arbitrarily assigned. Overall light sensitivity value was computed using the mean of six discomfort thresholds values (three light conditions per two thresholds each) in $\log_{10}$[lux].

Statistical processing of data and graphics was carried out using Dell Statistica V13 (Dell Technologies, Round Rock, TX). May produce incomprehension as after bonferroni correction, statistically significance was set at $P < 0.0025$. As normality of the six discomfort thresholds mean value was rejected ($d = 0.07309$ and $P < 0.05$, Kolmogorov–Smirnov test), categorical factors were evaluated using nonparametric tests: Mann–Whitney (MW) *U* test for two categories and Kruskal–Wallis (KW) test for three or more data categories. Links between the means of six discomfort thresholds and other numerical data were assessed using correlation coefficients. Based on 20-factor analysis (15 categorical factors and 5 numerical factors) with Bonferroni correction, statistical significance was set at $P < 0.0025$.

Results

Participants were balanced with regard to gender (241 men, 248 women) and distributed across all decades from 20 to 70 years of age. Major descriptive data are reported in Table 1 for categorical data and Table 2 for numerical data.

Sociodemographic Factors

The female subgroup had lower discomfort thresholds (mean, 2.86 $\log_{10}$[lux]) than the males (mean, 3.12 $\log_{10}$[lux]). This difference was statistically significant ($P < 0.001$, MW test), but a large dispersion within both subgroups was observed.

Participants were distributed equally across age groups, and no difference in discomfort thresholds among the age groups was identified ($P = 0.290$, KW test) (Fig. 1).

Optics and Biometry

Out of the 498 participants, 166 were considered myopic (mean equivalent binocular sphere < –1D), 251 as emmetropic, and 72 as hyperopic (mean equivalent binocular sphere > +1D). There was no effect of ametropia segmentation ($P = 0.507$, KW test).

There was no effect of equivalent binocular sphere, total and higher order aberrations, resting pupil size, or axial length effect.

Table 1. Light Sensitivity Thresholds According to Categorical Data

Factors	*P*	*n* (%)	Mean (SD)	Median (Min/Max)
Entire population	—	489 (100)	2.99 (0.59)	3.05 (1.4/4.09)
Gender	**<0.001**[a]			
Female		248 (51)	2.86 (0.6)	2.89 (1.4/4.09)
Male		241 (49)	3.12 (0.53)	3.2 (1.81/4.09)
Age group (yr)	0.300[b]			
20–29		106 (22)	3.05 (0.54)	3.15 (1.81/3.91)
30–39		100 (20)	3 (0.51)	3.03 (1.9/4.06)
40–49		100 (20)	2.99 (0.65)	3.04 (1.4/4.09)
50–59		106 (22)	2.88 (0.6)	2.9 (1.66/4.09)
60–70		77 (16)	3.03 (0.62)	3.14 (1.61/4.09)
Ametropia	0.507[b]			
Myopic		166 (34)	2.95 (0.56)	3 (1.66/4.05)
Emmetropic		251 (51)	3 (0.58)	3.03 (1.4/4.06)
Hyperopic		72 (15)	3.03 (0.68)	3.17 (1.7/4.09)
Photochromics use	0.443[a]			
No photochromics		473 (97)	2.99 (0.59)	3.05 (1.4/4.09)
Photochromic use		16 (3)	2.88 (0.55)	2.96 (1.89/3.62)
Owner of sunglasses	**0.001**[a]			
No sunglasses		181 (37)	3.14 (0.53)	3.23 (1.87/4.09)
Sunglasses		308 (63)	2.9 (0.6)	2.97 (1.4/4.09)
Frequency of wearing sunglasses	**0.001**[b]			
Never		47 (10)	3.22 (0.6)	3.33 (1.87/4.09)
Occasionally; can do without		100 (20)	3.15 (0.5)	3.17 (1.83/4.06)
Rarely; only when in bright light		110 (22)	3.06 (0.53)	3.11 (1.87/3.93)
Regularly, when there is a bit of sun		148 (30)	2.87 (0.58)	2.89 (1.77/4.06)
Frequently, even on cloudy days		84 (17)	2.78 (0.65)	2.81 (1.4/4.09)
Forearm inferior	0.084[b]			
Very light (Fitzpatrick I)		41 (8)	2.88 (0.49)	2.86 (1.98/4.09)
Light (Fitzpatrick II)		320 (65)	2.97 (0.6)	3.01 (1.61/4.09)
Intermediate (Fitzpatrick III)		114 (23)	3.05 (0.57)	3.17 (1.4/4.09)
Tan (Fitzpatrick IV)		13 (3)	3.27 (0.59)	3.43 (2.28/4.09)
Brown (Fitzpatrick V)		1 (0)	3.46 (—)	3.46 (3.46/3.46)
Forearm superior	0.023[b]			
Light		74 (15)	2.85 (0.62)	2.9 (1.61/4.06)
Intermediate		238 (49)	2.95 (0.56)	2.97 (1.4/4.09)
Tan		148 (30)	3.08 (0.59)	3.19 (1.7/4.09)
Brown		28 (6)	3.14 (0.61)	3.21 (2.03/4.09)
Dark		1 (0)	3.46 (—)	3.46 (3.46/3.46)
Tanning	0.030[b]			
Not tanned		131 (27)	2.92 (0.62)	2.97 (1.61/4.06)
Moderately tanned		241 (49)	2.96 (0.58)	3.01 (1.4/4.09)
Very tanned		117 (24)	3.11 (0.55)	3.18 (1.9/4.09)
Iris color	0.003[b]			
Blue		45 (9)	3.08 (0.56)	3.23 (1.83/4.06)
Green		117 (24)	2.84 (0.54)	2.83 (1.4/4.06)
Brown		327 (67)	3.03 (0.6)	3.13 (1.66/4.09)
Fatigue	0.087[b]			
Fully alert and wide awake		142 (29)	3.08 (0.61)	3.23 (1.61/4.09)
Very lively and responsive, but not at peak		126 (26)	2.93 (0.55)	2.99 (1.4/4.05)
Okay, somewhat fresh		152 (31)	2.92 (0.57)	2.94 (1.66/4.06)
A little tired, less than fresh		55 (11)	3.1 (0.6)	3.19 (1.77/4.09)
Moderately tired, let down		8 (2)	3.06 (0.73)	3.05 (2.24/3.84)
Extremely tired, very difficult to concentrate		5 (1)	2.72 (0.62)	2.57 (2.03/3.68)
Completely exhausted and unable to function effectively		1 (0)	2.82 (—)	2.82 (2.82/2.82)
Self-perception of light sensitivity	**0.001**[b]			
Yes, a lot		87 (18)	2.7 (0.62)	2.63 (1.4/3.79)
Yes, a bit		224 (46)	2.97 (0.57)	3.04 (1.7/4.09)

Table 1. Continued

Factors	*P*	*n* (%)	Mean (SD)	Median (Min/Max)
No, not really		152 (31)	3.12 (0.53)	3.21 (1.81/4.09)
No, not at all		26 (5)	3.31 (0.59)	3.41 (1.97/4.09)
Chronotype	0.889[b]			
Evening type		10 (2)	3.09 (0.61)	3.11 (2.12/3.93)
Moderate evening type		22 (4)	2.92 (0.55)	3.09 (1.95/3.6)
Moderate morning type		212 (43)	2.98 (0.6)	3.03 (1.61/4.09)
Morning type		243 (50)	2.99 (0.58)	3.06 (1.4/4.09)
Missing data		2 (0)	3.8 (0.04)	3.8 (3.77/3.83)
Time of day	0.130[b]			
Morning		200 (41)	3.04 (0.61)	3.17 (1.66/4.09)
Mid-day		205 (42)	2.98 (0.54)	3.01 (1.77/4.09)
Evening		84 (17)	2.89 (0.61)	2.84 (1.4/4.09)
Month	0.808[b]			
January		1 (0)	3.35 (—)	3.35 (3.35/3.35)
February		173 (35)	3.03 (0.55)	3.08 (1.66/4.06)
March		144 (29)	2.92 (0.61)	2.96 (1.61/4.09)
April		89 (18)	3 (0.61)	3.15 (1.4/4.09)
May		58 (12)	2.99 (0.65)	3.07 (1.83/4.06)
June		22 (4)	3.01 (0.38)	3.04 (2.1/3.68)
July		2 (0)	2.97 (0.35)	2.97 (2.73/3.22)

Bold indicates a statistically significant factor ($P < 0.0025$) based on Bonferroni correction of the 20-factor analysis.

[a] Mann–Whitney *U* test.

[b] Kruskal–Wallis test.

Table 2. Light Sensitivity Thresholds According to Numerical Data

Light Sensitivity Thresholds Versus	Valid *n*	Spearman's *R*	*t*(*N*–2)	*P*
Binocular mean equivalent sphere	489	0.034	0.748	0.455
Pupil size in dim light	489	0.015	0.338	0.735
Total ocular aberrations	476	–0.009	–0.201	0.841
High-order ocular aberrations	476	–0.042	–0.915	0.361
Eye axial length	489	0.050	1.108	0.268

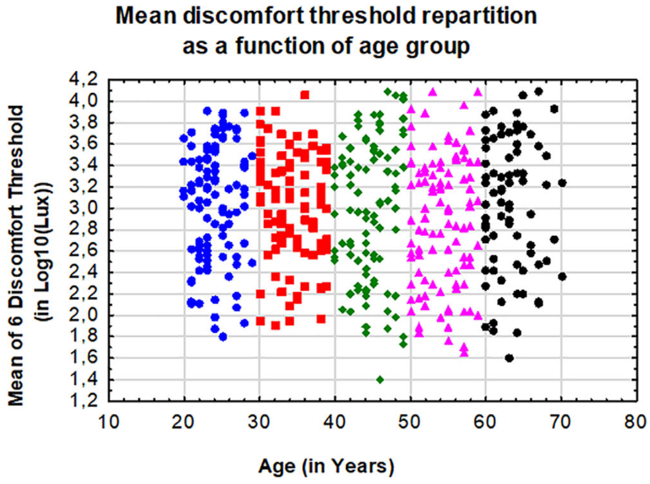

Figure 1. Scatterplot of light sensitivity thresholds according to age. Repartition of mean discomfort thresholds across all levels and all ages revealed no correlation between age and light sensitivity thresholds.

Eyeglasses

A small proportion of the population reported the use of photochromic lenses (16 participants, 3%). Discomfort thresholds did not differ between photochromic users and the rest of the population ($P = 0.443$, MW test). Owners of sunglasses were much more greatly represented in the studied population (63%) and demonstrated statistically lower discomfort thresholds (median, 2.97 vs. 3.23 $\log_{10}$[lux]; $P < 0.001$, MW test).

Reported frequency of use of sunglasses (Fig. 2) and discomfort thresholds were linked ($P < 0.001$, KW test); however, the distribution of discomfort thresholds for all subgroups greatly overlapped each other, which did not allow evaluating the discomfort thresholds of an individual according to his or her reported frequency of use of sunglasses.

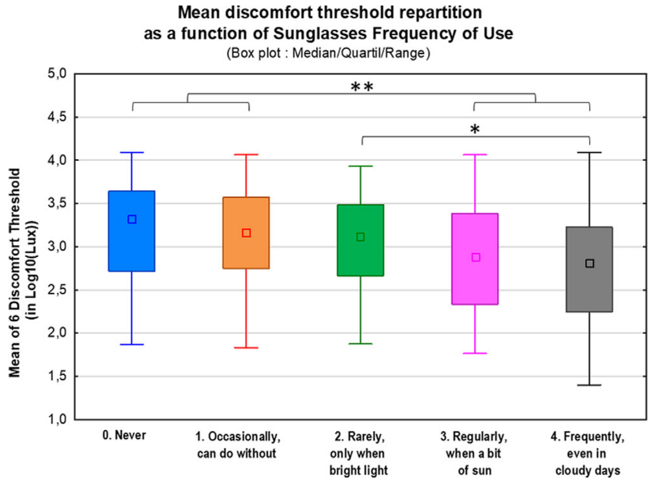

Figure 2. Boxplot of light sensitivity thresholds according to reported frequency of use of sunglasses. Populations that reported higher frequency of use of sunglasses had, on average, lower discomfort thresholds.

Skin and Iris Color

Skin color was classified according to individual typology angles on the anterior forearm and posterior forearm, as well as tanning of the forearm. None of theses factors was significant after Bonferroni correction.

Based on the Mackey et al.[16] classification diagram, iris color classification was rearranged into three subgroups: blue (45 participants, 9%), green (117, 24%), and brown (327, 67%). This factor was not statistically significant after Bonferroni correction ($P = 0.003$, KW test).

Other Physiological Factors

Reported levels of participant fatigue ranged from 1 (“fully alert, wide awake”) to 7 (“completely exhausted, unable to function effectively”). No major effect of fatigue level on light discomfort was observed ($P = 0.087$, KW test).

Participants rated their self-perception of light sensitivity on a four-point scale from 1 (“yes, a lot”) to 4 (“no, not at all”). Discomfort thresholds and self-perception were in agreement ($P < 0.001$, KW test). All self-perception subgroups had different mean thresholds ($P < 0.001$, post hoc multiple comparisons) except for the 3 (“no, not really”) sensitive subgroup with 2 (“yes, a bit”) and with 4 (“no, not at all”) ($P > 0.05$, post hoc multiple comparison).

According to chronotype segmentation, the majority of the population was of the morning type (243, 50%) and moderate morning type (212, 43%). No effect of this factor on discomfort thresholds was observed ($P = 0.889$, KW test).

Time Factors

No effect of time of the day (morning, mid-day, evening) was seen on discomfort thresholds ($P = 0.130$, KW test). Month of measurement (from January to July) did not affect discomfort thresholds ($P = 0.808$, KW test).

Discussion

Sociodemographic Factors

Among the participants, the females subgroup demonstrated lower discomfort thresholds than did the males. This is not in agreement with previous studies that have measured discomfort thresholds.[3,6,7] The main differences reported by these studies include lighting conditions (reduced size source vs. full field) and population size. Saur[3] included 35 participants, whereas Vanagaite et al.[6] recruited 67 persons in the control group and Verriotto et al.[7] evaluated 12 men and 23 women. The mean difference measured between the genders in this study was relatively low (0.27 $\log_{10}$[lux]), and there was high superposition of distribution in the two groups. The significance of the difference could be due to a large sample (over 240 participants per subgroup), but another hypothesis could be that it could be attributed to factors not considered in the inclusion/exclusion criteria, such as undiagnosed or misdiagnosed migraine in women. Cultural factors may also produce a difference; for example, Bennet[14] found a “youth effect” and hypothesized that younger participants may have tested their limits. The cultural effects of gender may produce a small measured difference, and further assessment of gender effects in different cultures would be relevant.

Eye transparency[20] and pupil size[21] changes with aging result in a reduction of light reaching the retina. However, no age effect on discomfort thresholds has been demonstrated in populations from 20 to 70 years old, in agreement with the literature.[6,22] Bennet[14] measured higher discomfort levels among participants who were less than 20 years old. It would be of interest to further examine discomfort thresholds in the youngest (below 20 years old) and the oldest (over 70 years old) populations, particularly in light of the accelerated decrease in visual acuity after 70 years of age.[23]

Optics and Biometry

In this study, ametropia did not have a significant effect on discomfort glare. This is in agreement with previous review of Pierson et al.[22] Discomfort glare is not influenced by axial length or high-order aberrations, unlike disability glare which is known to be. This may be due to the stimulus used to measure discomfort thresholds that is uniform across the field of view without any contrasted stimulus.

In previous studies exploring pupil size as an indicator of discomfort glare (reviewed by Hamedani et al.[24]), correlations between absolute pupil size[11,12] or relative pupil size[25] and discomfort ratings are significant but weak ($r^2 < 0.5$). In our study, there was no correlation between dim light pupil size and discomfort thresholds ($r^2 < 0.001$). Pupil size during light exposure is a better predictor of discomfort.

Eyeglasses

The low representation of photochromic users does not allow us to reach a conclusion regarding the potential effect of light protection produced by this type of lenses discomfort threshold. The use of sunglasses use addresses various needs, ranging from fashion to protection from ultraviolet light and protection from discomfort. The fact that sunglasses' owners have lower light discomfort thresholds than non-owners demonstrates that people with lower discomfort thresholds require more protection. This observation is reinforced by reported sunglasses frequency of use. Further investigation would be relevant to evaluate light protection needs according to the discomfort threshold.

Skin and Iris Color

Skin tone or tanning is not a significant effect, in agreement with Verriotto et al.[7] However, in both of our studies, darker skin tone were less represented, which may reduce the analysis reliability. Additional studies would be relevant to further examine skin tone, taking into account theses parameters in the recruitment of the population.

No significant effect of iris color has been demonstrated in this study, in agreement with previous studies that classified iris color into two categories—clear or dark—and found either no effect[3,6] or low effect.[14]

Other Physiological Factors

In order to compare results, we used the same Samn–Perelli seven-point fatigue scale[18] that was used by Kent et al.[9] to score fatigue levels and found similar results: no effect of fatigue level on discomfort threshold. However, a large majority of the population reported no fatigue, and only 11% reported being "a little tired, less than fresh." Fatigue may have an effect only for the highest fatigue level, but that level was not sufficiently represented in our population (five participants) to reach a conclusion.

Even if there were overlaps among discomfort thresholds among the self-evaluated sensitivity subgroups, the self-perception of light sensitivity was strongly associated with the measured discomfort threshold. Bennet[14] found similar results after asking about susceptibility to day-driving discomfort glare (yes/no). Using glare sensation vote and yes/no self-evaluation of sensitivity could mitigate results. Rodriguez et al.[26] found no difference, although they did in a previous study.[27] Van Den Wymelenberg[10] measured self-reported sensitivity on a seven-point scale and found low correlation ($r^2 = 0{,}04$) with measured sensitivity to brightness but noted that those who are very sensitive tend to select dimmer conditions compared with those who are least sensitive. The questions asked in self-report studies and the various statistics used can explain the different findings among studies. However, even if some studies demonstrate a trend between self-evaluation and discomfort threshold or glare sensation vote, the link is not strong enough, and measurement is relevant to assess light sensitivity.

Van Den Wymelenberg[10] measured differences between summer and fall in an office environment. On average, participants were more sensitive in fall. In this study, we did not detect an effect of month or time of the day on the discomfort thresholds, indicating that the effect of season or time of day would be small in magnitude. Further study using repeated measurements on the same population as done by Kent et al.[9,28] would be interesting to measure more precisely these factors.

According to chronotypes, we have not found higher discomfort thresholds for morning people, but Kent et al.[9] did. This may be partly due to the use of different questionnaires. As the study was conducted in Spain, we used an adapted morningness questionnaire. Based on this questionnaire, our population was mostly of the morning type. Because the representation of eveningness type was low, this could affect the results. Moreover, the methodology used by Kent et al.,[9] which repeated discomfort threshold measurements throughout the day, is better for evaluating chronotype effect.

Factors Combination and Unmeasured Factors

Significant factors were found to be linked to the self-perception of light sensitivity and the use of sunglasses, confirming that the LUMIZ 100 can accurately identify the need for protection, thus allowing for more precise evaluation of light sensitivity, which would be of value for light sensitivity management in clinical care. No other studied physiological factor has been found to be significant. As a sensation, discomfort glare is mainly a cortical process. Bargary et al.[29] explored cortical hyperexcitability in the presence of contrast glare and reported that more sensitive participants had greater neuronal response in the visual cortex area regardless of the light intensity level. Still related to the brain, literature has shown that some brain conditions are associated with photophobia (e.g., migraine,[6] blepharospasm,[30] traumatic brain injuries[31]). In a healthy population, we observe large variations in light sensitivity that are not correlated with or explained by the accessible physiological factors studied so far. Exploration of cortical processes would be a relevant approach to investigating light sensitivity.

Conclusions

Across a large population ranging in age from 20 to 70 years and balanced in gender, various physiological factors of light sensitivity were studied, and we observed the following findings:

- The female population had lower discomfort thresholds than men, but there was a large superposition of discomfort threshold distributions.
- No age factor was found for the 20 to 70 year olds who participated in the study.
- No ametropia or biometry factor was identified to explain light sensitivity levels.
- The frequency of use of sunglasses was consistent with light sensitivity even if it was not the only reason for using sunglasses.
- Skin tone, tanning level, and iris color had no effect on discomfort thresholds.
- Among the population reporting no or moderate fatigue levels, fatigue level did not demonstrate an effect on discomfort thresholds.
- Self-reported light sensitivity and discomfort thresholds were related, but the correlation was not strong enough to reduce the relevance of LUMIZ 100 measurements.

Exploration of easily measurable physiological parameters failed to provide reliable indicators of individual light sensitivity.

It must be noted that the results reported here were obtained in a very sunny region during the end of winter and all of spring, which must be taken into account when drawing conclusions. Additional studies on populations exposed to different light conditions in their daily lives are necessary to further explore the effects of location, season, and skin tones and to confirm the conclusions of the present study.

Acknowledgments

The authors thank Anne-Catherine Scherlen and Pascale Lacan for their help in study definition and analysis, as well as Stephane Perrot, Amandine Debieuvre, Sylvain Van Luchenne, and David Tan for LUMIZ 100 tool development.

Funded by an Essilor International research grant to the University of Valencia.

Disclosure: **S. Marié**, Essilor International (E, P); **R. Montés-Micó**, None; **N. Martínez-Albert**, None; **J.V. García-Marqués**, None; **A. Cerviño**, Essilor International (C)

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