Photostress Recovery Time Among Commercial Drivers In Nigeria

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Abstract

Photostress recovery time (PSRT) test is a simple technique used to assess the macular function. Prolonged recovery time is attributed to the delay in regeneration of visual pigments after being bleached with a bright light. In car drivers with macular degeneration, photostress effects from opposing cars may bleach retinal pigments and cause a dramatic drop in visual acuity.

The study aims to determine the prevalence of abnormal PSRT and the association of PSRT with age, visual function and driving safety among commercial drivers in Nigeria.A cross-sectional descriptive study was carried out in Ilorin metropolis, a city in north central Nigeria. Of the estimated 4,729 registered commercial drivers, 327were selected using multistage sampling methods. Structured questionnaire was administered by trained research assistants. PSRT test and visual function tests were carried out by the principal researcher and an assistant.

Subject with normal healthy macular function should be able to read the visual acuity line just above the pre-exposure visual acuity line in 50-60 seconds. Patients with a macular problem may have recovery times lasting 1.5 to 3 min or longer. The study revealed a statistically significant association between PSRT and visual acuity as well as color vision ($p<0.05$). No association existed between PSRT and age, visual field and driving safety. Majority of the respondents with normal PSRT had fair driving safety.

Regular visual screening especially during license renewals may be the most useful tool for the detection of impaired visual function and delayed photo stress recovery time among commercial drivers.

Keywords: Photostress, Macular degeneration, Commercial drivers

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Introduction

Photostress is a psychophysical process which persists after light exposure. This is because dark adaptation takes time to restore visual sensitivity to its pre-exposure level.[1] The physiologic basis for retinal photostress response is believed to be a transient state of visual insensitivity caused by bleaching of the visual pigments of the retina when exposed to intense light.[2] Return of sensitivity is dependent on re-synthesis of the visual pigments, and re-synthesis requires adequate perfusion of the photoreceptors and the retinal pigment epithelium.[3] This further depends on the integrity of the choroids especially the Bruch's membrane and relatively independent of optic nerve integrity.

Delay in photostress recovery may pose serious danger to a driver when faced by a bright headlight of an oncoming vehicle. Photostress induces an afterimage, which is in the form of a scotoma.[3] Thescotoma subsequently recedes after which normal vision is restored. The PSRT test is used mainly to estimate the functional capability and the performance reserve of the photoreceptive elements of the macular.[4] It is a simple technique used to differentiate the cause of a reduced visual acuity (VA) in an eye between a lesion in the optic nerve and a macular disease.[5] Prolonged recovery time is attributed to the delay in the regeneration of visual pigments after being bleached with a bright light.[4] If the cause of the reduced VA is optic nerve, the bleaching of the retina will have no effect on the recovery time. Apart from being used as a diagnostic tool, this test has been used to monitor the progress of disease states such as chloroquinemaculopathy, nyctalopia on vitamin A therapy, age-related macular degeneration and as a method of determining their prognosis .[6]It has also been used to monitor the progression of maculopathy in high myopia. Horiguchi*et al.*, found a significant delay of the recovery time in high myopia.[7]A prolonged PSRT or delayed adaptation was reported in glaucoma which mainly affects the ganglion cells. This suggests that a ganglion cell abnormality may delay recovery or that glaucoma may cause visual pigment abnormality.[7]The pathophysiology has however, not been established.[8]

Photostress recovery time (PSRT) varies with age. There is a difference in the recovery time for individuals over 40 years of age and younger patients. The acceptable recovery times of 50 to 60 seconds are more in line with individuals over 40 years of age. Recovery time for young healthy individuals with no macular problem can be markedly less. Individuals with macular problem may have recovery time lasting 1.5 to 3 minutes or longer.[9]

Specifically, PSRT is a measure of the time it takes for an individual to read the line just above its pretest best acuity line backwards after adequate bleaching of the photoreceptors for 10 seconds. A variety of photostress tests have been advocated and assessed including pen torches (pen light), ophthalmoscopes, Maxwellian view optical systems, pupilometers, scanning laser ophthalmoscopes, and visually evoked potentials as light source.[10,11,12] A major criticism of PSRT testing has been the lack of a standardised technique in conducting the test.[3-5]This study describes the use of alkaline powered penlight to measure objectively the recovery of central vision after photostress. The use of penlight for the PSRT test was described by Glaser[1], with the primary goal of determining the efficacy of this simple test in determining optic nerve defects from macular disease in individuals with otherwise unexplained loss of central vision.[1] The technique was kept simple so that direct clinical application would be possible without cumbersome or expensive equipment. The result obtained in Glaser's study corresponded with that of Severin et al., (1987) who used an elaborate high intensity light flash system.[13]This study however, adopted Glaser's method of PSRT testing.

Materials and Methods

This cross-sectional descriptive study was carried out in Ilorin, the capital city of Kwara State, in the north central geographical zone of Nigeria. Of the estimated 4,729 commercial drivers who are registered with National Union of Road Transport Workers (NURTW), Road Transport Employers Association of Nigeria (RTEAN), State government owned transport service (Kwara Express) and other private owned motor parks in Ilorin metropolis, 327 consenting drivers participated in the study. The inclusion criteria for respondents in this study were drivers who are Nigerians by birth, who drive four wheel vehicles and convey passengers both intra and intercity, and can read the Snellen chart or understands the illiterate “E” very well. The approval for the study was obtained from the department of Epidemiology and Community Health, University of Ilorin.Informed consent was obtained from each respondent after detailed information about the study was read to them. The experimental procedures adhered to the tenets of the Declaration of Helsinki.

Participants' information and data were obtained by the use of a semi-structured interviewer administered questionnaires in each of the selected motor parks. The questionnaire elicited questions to obtain information concerning respondents' socio-demographical data, driving safety, photostress recovery time and other visual function assessment.

Visual function tests were done by the principal researcher and an assistant at designated spaces at the motor parks. The tests included distance VA testing done using the Snellen's chart and Illiterate 'E' chart for those who can read and those who cannot read respectively. The charts were placed 6 metres from the respondents and each eye was tested separately. Photostress test was done using battery energizer (AA 1.5V) pen torch with halogen bulb and a pocket electronic stop watch. The test was carried out on each respondent based on a similar procedure. The test light intensity was checked with luxmetre to ensure standardization. At 2cm, the penlight produced an illuminanceof 2,340 lumens/m^2. The batteries of the penlight were changed after being used for 15 respondents (after 150seconds). Reproducibility of PSRT value was tested in 15 respondents and there was no significant difference noted ($p>0.05$). The VA for each eye was tested first and then photostressed for ten seconds by looking at a penlight held 2 to 3 cm from the eye. The time required to read three letters on the Snellen test lines just larger than the best acuity was used as the end point.Color vision was tested using the Ishihara pseudoisochromatic plates. Visual field was tested by confrontation method using a good contrast test target. External eye examination using a pen torch and an internal eye examination using a direct ophthalmoscope was done. All findings were documented on clinical report sheet at the back of each respondent's questionnaire copy. A developed standard operating procedure (SOP) was strictly adhered to in the course of this study.

Data analysis was done using SPSS version 18.0. Appropriate test of significance was used to test statistics and the level of significance was predetermined at p-value of equal to or less than 0.05 at 95% confidence level.

Results

The age of the respondents ranged from 20 to 70years with a mean age of 46 $\pm$ 10.13 years. Majority (63.7%) of them were in the age group 40 – 59 years. The respondents were all male. Many of the respondents (44.3%) had primary education while 17.1% had no formal education. Almost three quarter (73.2%), of the respondents had no other occupation other than driving(Table 1). Majority (93.6%) of the respondents were Yoruba (Figure 1).

About one-fifth of the respondents 64 (19.5%) had been involved in RTC in the past 5 years. Only 1 driver has had RTC thrice in the last 5 years. More than half (62.5%) of the road traffic crashes were without any injury sustained. The cause of the RTC was mainly vehicular factor 49 (76.6%), Table 2.

Likert scale was used to score the respondents to determine their driving safety. A few 48 (14.7%) of the respondents had good driving safety. Majority 231 (70.3%) of the respondents were found to have fair driving safety (Figure 2). Majority of the respondents 299 (91.4%) and 305 (93.3%) had normal PSRT in the right eye and left eye respectively. The mean PSRT was 22.45± 20.07 seconds and 18.27± 18.13 seconds for the right and left eye respectively (Figure 3). The scatter diagram in figure 4 revealed a non-significant increase in PSRT with increasing age, p = 0.435 and 0.634 in the right eye and left eye respectively.

Majority of the respondents had normal visual function as well as normal PSRT. Test of significance revealed a significant relationship between PSRT versus visual acuity and PSRT versus color vision respectively (P< 0.05). No significant association with visual field (Table 3).

Table 1: Socio-demographic Variables (N=327)

Age groups	Frequency	Percentage
20 – 29	15	4.6
30 – 39	70	21.3
40 – 49	94	28.7
50 – 59	114	35.0
60 and above	34	10.4
Educational Level		
None	56	17.1
Primary	145	44.3
Secondary	72	22.0
Tertiary	20	6.1
Quaranic	32	9.8
Vocational Training	2	0.6
Other Occupations		
None	239	73.2
Artisans	46	14.0
Trading	18	5.5
Self employed	4	1.2
Civil Servant	5	1.5
Farmers	13	4.0
Others	2	0.6

Table 2: Road Traffic Crash History among Respondents

Variables	Frequency	Percentage
Involvement in Road Traffic Crash in the Past (N=328)		
Yes	64	19.6
No	263	80.4
Number of Road Traffic Crash in the Past 5 Years (n=64)		
None	32	50.0
Once	25	39.1
Twice	6	9.4
Thrice	1	1.5
Seriousness of the Crash (n=64)		
No injury	40	62.5
Mild to serious injury	14	21.9
Fatal injury	10	15.6
Cause of crash (n=64)		
Road factor	4	6.3
Vehicular factor	49	76.6
Human factor	8	12.5
Animal	3	4.6

Table 3: Relationship between PSRT and Visual function

Visual function	PSRT Right Eye		PSRT Left Eye	
	Normal (%)	Abnormal (%)	Normal (%)	Abnormal (%)
Visual Acuity of Better Eye				
Adequate	276 (92.9)	21 (7.1)	283 (95.0)	15 (5.0)
Inadequate	23 (79.3)	6 (20.7)	23 (79.3)	6 (20.7)
	χ^2 = 6.451.	P-value = 0.011	χ^2 = 10.779.	P-value = 0.001
Visual Acuity of Second Eye				
Adequate	282 (93.7)	19 (6.3)	288 (95.7)	13 (4.3)
Inadequate	17 (68.0)	8 (32.0)	18 (69.2)	8 (30.8)
	χ^2 = 20.051.	P-value = 0.000	χ^2 = 27.862.	P-value = 0.000
Colour Vision				
Normal	275 (93.2)	20 (6.8)	282 (95.3)	14 (4.7)
Abnormal	24 (77.4)	7 (22.6)	24 (77.4)	7 (22.6)
	χ^2 = 9.220.	P-value = 0.002	χ^2 = 14.879.	P-value = 0.000
Visual Field				
Normal	244 (92.4)	20 (7.6)	240 (92.3)	20 (7.7)
Abnormal	55 (88.7)	7 (11.3)	59 (89.4)	7 (10.6)
	χ^2 = 0.912.	P-value = 0.340	χ^2 = 0.588.	P-value = 0.443

Figure 5 showed that majority of the respondents with normal PSRT had fair driving safety. Only a few (about 10%) had poor driving safety and the test of significant revealed a negative relationship between PSRT and driving safety (p > 0.05 in both eyes).

Discussion

There appears to be a wide variation in the average photostress recovery time among different studies; 10-50 seconds[3],27 ± 11seconds[1], 41.97 ± 17.34seconds[26], 5.95 ± 2.03seconds[18], 15seconds[14], 135.8 ± 63.9 seconds[15]. These variations could be

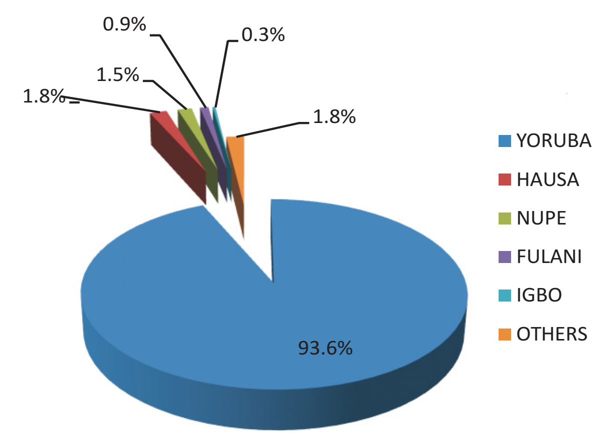

Figure 1: Ethnicity of the Respondents (N=327)

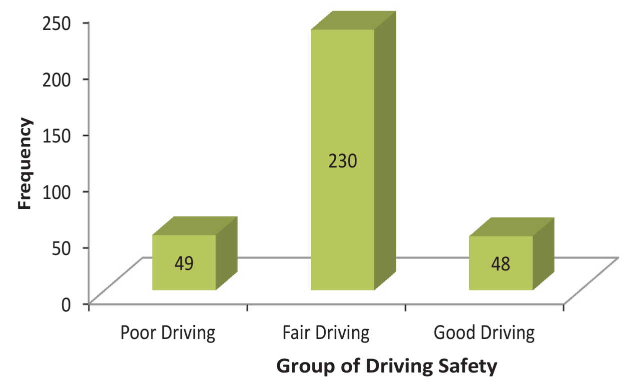

Figure 2: Outcome of Respondents' Driving Safety

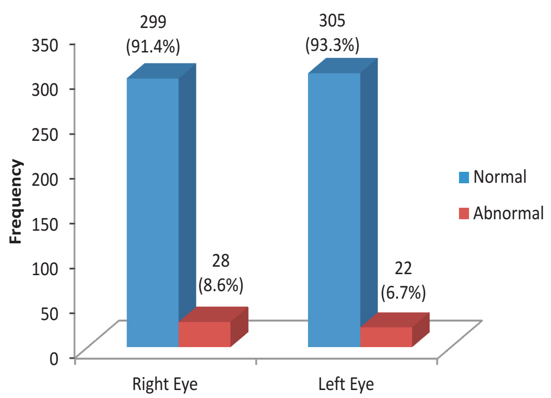

Figure 3: Outcome of Respondents' Photostress Recovery Time (N=327)

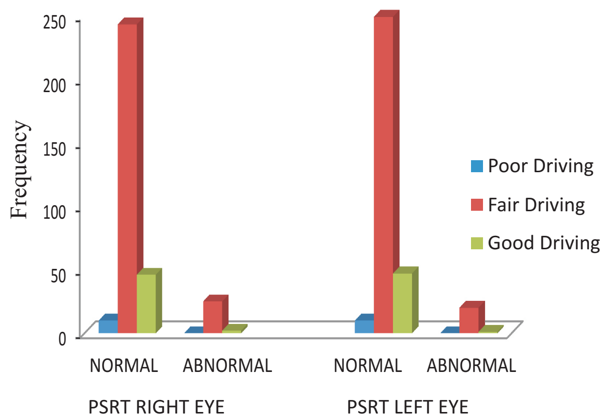

Figure 5: Relationship between PSRT and Driving Safety

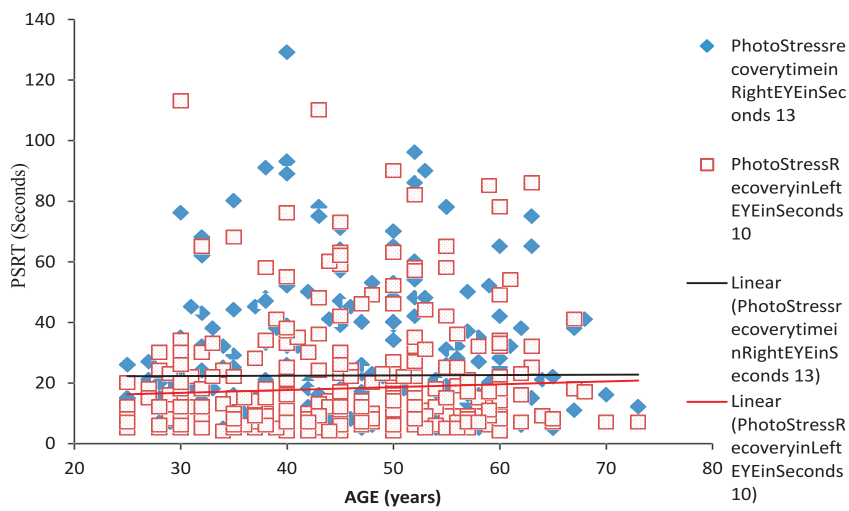

Figure 4: Relationship between PSRT and Age of respondents

attributable to non-uniform light intensity employed by the different studies for dazzling.[1, 3, 10-15, 18, 26] The mean PSRT for this study was 22.45± 20.07 seconds. This study adopted the method by Glaser et al.,[1] which is the use of pentorch. The choice of this method was because it was more readily available and easy to use. The average PSRT in our study was similar to that found in previous studies using similar short exposure flash like Ophthalmoscope, MAP, Eger macular stressometer(EMS) which tend to be more sophisticated.[3, 13, 14] The mean PSRT is generally lower than that obtained with other technique,[10–12, 15] which suggests the device does not bleach sufficient photopigment to challenge outer retinal physiology. The amount of photopigment bleached is dependent on the intensity and duration of the flash.[16] In addition; pupil size and eccentricity of viewing will affect the result. Elderly patients tend to have smaller pupils and majority (35%) of the respondents in this study was in this category. Therefore may need longer exposure to the light source for the photoreceptors to be fully bleached. Bleaching the photoreceptors with a direct ophthalmoscope for 30 seconds has been suggested to be the most reliable test of photostress as more photopigment is bleached and the effect of pupil size is limited.[4] As such, redesign of the test with a longer flash duration of greater visual angle may be appropriate.

PSRT in relation to Age

Photostress recovery time increases with photostress source luminance.[7, 17] It also increases with ageing, although different rates of increase are reported for different testing methods.[4, 17] Macular degeneration and other retinal disorders markedly prolong recovery times.[18]

The PSRT of 50 healthy subjects were measured in a study, using three clinically applicable techniques and a reference technique designed to bleach a consistent amount of photopigment and their ages ranged from 21 to 69. The agreement between each clinical technique and the reference technique was determined. Mean photostress recovery time differed for each of the techniques studied. Analysis of the data obtained with the reference and the best clinical technique showed that age was the only factor that had a significant effect on PSRT.[4] Increasing participant age was shown to result in a lengthening of the recovery time constant, of a magnitude comparable to previously published psychophysical data.[19]

This study revealed non-significant increase in the association between PSRT and increasing age (Figure 4). The revelation is contrary to the findings of a study done in Edo state, Nigeria.[20] The difference in the two reports despite applying the same method may be due to the marginal difference in the mean age of the participants in both studies (mean age: 46±10.13 and 33±12.74 for this study and the Edo state study respectively). Majority, 148 (45.5%) of the participants in this study were above 50 years of age and therefore more at risk of aging retinal degenerations that can affect PSRT when compared to the other study with a wide age range between 11 – 70years.[20] The increase in PSRT between age groups of 51-60 years and 61-70years and the decrease in PSRT between the age groups of 11-20 years to 21-30 years could be responsible for the positive relationship between age and PSRT as found in that study. It has previously been shown that PSRT is adversely affected by conditions affecting the macula, including central serous retinopathy,[7] age-related macular degeneration,[21] and diabetic maculopathy.[21–23] Disruption of the retinal pigment epithelium–retina relationship, because of serous retinal detachment or macular edema for example, has been shown to be an important factor in the prolongation of PSRT in such macular disease.[24] Importantly, PSRT deficits have been observed in asymptomatic subjects where visual acuity is relatively preserved, indicating that a suitably designed test might provide an effective indicator of early disease or disease progression.[25]

PSRT in relation to Visual function

The PSRT has been widely reported as a helpful screening clinical tool. PSRT has been proven by previous studies as a strong tool in determining the cause of reduced visual function as a problem in the macular or in the optic nerve. If the vision loss is owing to macular disease, the PSRT will be too long in contrast to when the cause of vision loss is attributed to optic nerve. This study revealed a positive relationship between PSRT and visual acuity as well as color vision. The relationship with visual field is not significant. Visual acuity is one of the best tests of macular function. If the macula is diseased, acuity falls. Color vision testing is also a good macular test because color is sensed in the cones which reside in the macular. This study therefore revealed an association with visual acuity and color vision because most of the respondents are above 50years of age and are therefore more predisposed to macula disorders. Some of the respondents on examination were also found to have some disorders that can affect macular function.

In a study to test the PSRT in 30 eyes from 15 patients with chronic open angle glaucoma, and 30 eyes from 15 individuals of a similar age group with no eye disorder, no association was found between visual acuity and recovery time for either group.[26] There was a relatively small significant association between age and recovery time in the control population and none in the glaucoma group. The reason for no significant association between PSRT and visual acuity could be attributed to the fact that glaucoma is a disease of the optic nerve head and optic nerve lesion does not affect the PSRT.[2,3] Likewise the control group was without any visual disorder which could affect PSRT except for age which revealed a little association.

In a study to distinguish optic nerve conduction defects from macular disease in patients with otherwise unexplained loss of central vision, prolonged PSRT was found in 63 eyes with maculopathy and was not in 20 patients who had optic nerve disease.[1]

In a similar study which adopted the use of an eger macular stressometer (EMS), a different instrument from past studies, to determine association between PSRT with other measures of visual function. There was no evidence from results that EMS PSRT is affected by age related macular degeneration (AMD), contrary to this study report and previous reports using other photostress techniques.[1, 27, 28] Those patients with a central visual field defect or distortion had a similar EMS photostress recovery time as those with an intact central visual field in exudative ($p = 0.56$), atrophic ($p = 0.38$), or mixed AMD ($p = 0.10$). However the average EMS recovery time was similar to that found in previous studies using similar short exposure flash in healthy patients.[29]

In another study by Antonio et al., PSRT was found to be delayed by age. Cataract and primary open angle glaucoma groups did not affect the PSRT significantly.[30] There was no report on PSRT association with visual function in the previous study in Nigeria to compare this finding. The previous study[20] was carried out on healthy adult Nigerians (ie. without any visual disorder that can affect PSRT) with the aim of determining the influence of age on PSRT.

PSRT in relation to Drivingsafety

The test of the correlation between PSRT and driving safety(involvement in road traffic crash) is a test of the sensitivity of the drivers to glaring light sources such as a setting sun or the headlights of approaching cars. Subjects with increased glare sensitivity (i.e. tendency for delayed PSRT) may be more easily blinded in such conditions. Studies on accident statistics of subjects with increased glare sensitivity revealed high relative road traffic crash (RTC) risk values.[31]

In an on-road simulation study, Theeuwes*et al.*,[32] found that headlight glare caused decreased recognition of objects along the roads, especially by elderly drivers. Skaar*et al.*[33] found that increased glare sensitivity correlated with decreased visual attention especially in elderly drivers. According to Higgins, Wood and Tait, onset of senile cataract, leading only to a mild decrease in visual acuity and selectively affecting glare appears much more detrimental for driving safety than decreased visual acuity produced by optical blur.[34]

Several visual functions including visual acuity, visual field, contrast sensitivity and glare recovery can be distinguished. These functions are basically independent of each other although many disorders and diseases of the eye cause impairments in more than one function. For example: cataract leads to decreased visual acuity but also to decrease contrast sensitivity and glare recovery (delayed PSRT). Loss of these visual functions is related to the presence of eye disorders and is best described in terms of visual disability such as loss of night driving ability.

This study revealed no significant association between PSRT and driving safety [$p = 0.307$ right eye and 0.266 left eye]. This could be explained by the fact that most people drive considerably fewer miles during the hours of darkness.[35] Another study revealed that more than half of RTC fatalities occur after dark.[36] This finding may be explained in part by changes in driver behavior associated with nightfall, such as increased alcohol consumption, increased driver fatigue and increased driving speeds due to lower traffic density. However, a number of authors have found an association between reduced illumination and driver safety that may contribute to reduced driving safety.[37]

In low illumination, physiological changes occur within the visual system resulting in degradation of both spatial and temporal resolution, a reduction in contrast sensitivity and poorer color discrimination. These changes are somewhat moderated during night driving by the presence of headlights, street lighting and reflective road markings, but visual processing still remains impaired compared with daytime illumination.[38] Drivers are generally unaware of the visual limitations of driving at night as this extrinsic lighting permits them to continue to see road signs and steer their vehicles effectively.[39] However, they will have more difficulty in detecting the low contrast and poorly illuminated objects due to delayed PSRT, and as such exhibit longer reaction times, resulting in longer stopping distances.[36,40]

The visual standards for licensure are based solely on performance in photopic conditions, although photopic visual acuity has been shown to be a poor predictor of the ability to recognize road signs at night.[41] Studies have also shown that the disparity between daytime and nighttime visual acuity levels increases with advancing age, with daytime levels becoming increasingly worse predictors of vision at night.[42] Low-contrast acuity in mesopic conditions, in the presence and absence of glare, is only tested in Germany prior to private or commercial driver licensing.[37]

Conclusion

The photostress test has been limited by a lack of standardization. There is tremendous variability in PSRT going by the available findings.

Having discussed the relationship between PSRT and driving safety as well as various visual functions, and having discussed the problems of the cut-off values, the next question is whether drivers should be periodically screened for impairments of vision and, if so, at what intervals. In the European Council Directive 91/439/EEC, there are no guidelines regarding periodic testing of drivers. In most member states, however, some form of visual evaluation takes place upon driving-licence renewal. An individual with progressive eye condition such as cataracts, glaucoma, etc., may be asked to provide vision reports from a specialist before license renewal. There may be need to issue a restricted license depending on the outcome of vision report in relation to recommended visual requirements for driving in Nigeria.

Positive associations between PSRT in relation to visual acuity and color vision were found in this study. If redesign and further development of the PSRT test could produce associations with driving safety especially at night, as well as with the severity and progression of macular degeneration, it may be an attractive test in clinical practice.

References

1. Glaser JS, Savino PJ, Sumers KD,McDonald SA, Knighton RW. The photostress recovery test in the clinical assessment of visual function. *Am J Ophthalmol* 1977; 83:255–260.
2. Keeffe JE, Jin CF, Weih LM, McCarty CA, Taylor HR. Vision impairment and older drivers: who's drivingfi*Br J Opthalmol* 2002;86:1118-21.
3. Hackenlively JR, Pearlman JT, Shaver L, Brickman M and Henkind P. Macular recovery from dazzle (photostress) in normal women. *Doc. Ophthalmol. Proc. Ser*. 1998;15:313-6
4. Margrain TH, Thomson D. Sources of variability in the clinical photostress test. *OphthalPhysiol Opt* 2002, 2261–67.67
5. Millodot M. Photstress testing. Dictionary of Optometry and Visual Sci. Butterworth Heinemann,London. 2004; 6th eds. pp.347
6. Ernst W, Kemp M. Retinal processing of visual information in clinical ophthalmology. *Am. J. Ophthalmol*. 1987; 20:115 – 7
7. Horiguchi M, Ito Y, Miyake Y. Extrafovealphotostress recovery test in glaucoma and idiopathic central serous chorioretinopathy. *Br. J. Ophthalmol*. 1998; 82 (9): 1007 – 1012.
8. Lewibrock CS, Reuter J, Lamb TD. Molecular basis of dark adaptation in rod photostress. *Eye*. 1998; 12:511 – 20
9. Brown B, Tobin C, Roche N. *et al* Cone adaptation in age-related maculopathy. *Am J OptomPhysiol Opt* 1986; 63450–454.454
10. Lovasik J V. An electrophysiological investigation of the macular photostress test. *Invest Ophthalmol Vis Sci* 1983; 24437–441.441
11. Zabriskie N A, Kardon R H. The pupil photostress test. *Ophthalmology* 1994; 1011122–1130.1130
12. Ito Y, Horiguchi M, Miyake Y. *et al*Extrafovealphotostress recovery testing with a scanning laser ophthalmoscope. *Jap J Ophthalmol* 1997; 41255–259.259
13. Severin SL, Tour RL, Kershaw RH. Macular function and the photostress test 2. *Arch Ophthalmol*. 1987; 77: 163
14. Dhalla MS, Fantin A. Macular photostress testing: Sensitivity and recovery with an automated perimeter. *Retina,* 2005; 25 (2),189–192
15. Loughman J, Mukunda CA, Stephen B, Grainne S, Peter AD, O'Dwyer V, et al. The relationship between macular pigment and visual performance. *Vision Research*. 2010; 50:13, 1249–1256
16. Hollins M, Alpern M. Dark adaptation and visual pigment regeneration in human cones. *J Gen Physiol* 1973; 62430–447.447
17. Mainster MA, Timberlake GT. Why HID headlights bother older drivers.*Br J Ophthalmol.* 2003; 87(1): 113–117.
18. Sandberg MA,Gaudio AR. Slow photostress recovery and disease severity in age-related macular degeneration. *Retina* 1995;15:407–12.
19. Wood A, Margrain T, Binns AM. The effect of bleach duration and age on the ERG photostress test. *Graefe's Archive for Clinical and Experimental Ophthalmology*, 2011; 249(9), pp. 1359-1365. doi: 10.1007/s00417-011-1627-7
20. Omokhua PO, George OG. Photostress recovery time among Nigerians. *JNOA*. 2010, 16: 16 – 20.
21. Newsome DA, Negreiro M. Reproducible measurement of macular light flash recovery time using a novel device can indicate the presence and worsening of macular disease. *Curr Eye Res* 2009;34:162–170
22. Frost-Larsen K, Larsen HW. Macular recovery time recorded by nyctometry—a screening method for selection of patients who are at risk of developing proliferative diabetic retinopathy. *Arch Ophthalmol* 1985;63:39–47.
23. Midena E, Segato C, Giuliano M, et al. Macular recovery function (nyctometry) in diabetics with and without retinopathy. *Br J Ophthalmol*

1990;74:106–108.

24. Krastel H, Alexandridis E. Recovery from macular photostress and slow retinal potentials in cured retinal detachment. *Ophthalmologica*1980;181:47–52.

25. Newsome DA. A randomized, prospective, placebo-controlled clinical trial of novel zinc-monocysteine compound in age related macular degeneration. *Curr Eye Res* 2008;33:591–598.

26. Sherman MD, Henkind P. Photostress recovery in chronic open angle glaucoma. *British Journal of Ophthalmology*. 1988, 72(9):641-5. DOI: 10.1136/bjo.72.9.641 ·

27. Midena E, Angeli C D, Blarzino M C. *et al* Macular function impairment in eyes with early age-related macular degeneration. *Invest Ophthalmol Vis Sci* 1997; 38: 469–477.

28. Wu G, Weiter J J, Santos S. *et al* The macular photostress test in diabetic retinopathy and age-related macular degeneration. *Arch Ophthalmol* 1990; 108: 1556–1558.

29. Barlett H, Davies L N, Eperjesi F. Reliability, normative data , and the effect of age-related macular disease on the Eger Macular Stressometerphotostress recovery time. *OphthalPhysiol Opt* 2004; 24:594–599.

30. Antonio MG, Filomena AS, Paula SF, Antonio FM. The macular photostress test in diabetes, glaucoma, and cataract. *Proc. SPIE* 8785, 8th Iberoamerican Optics Meeting and 11th Latin American Meeting on Optics, Lasers, and Applications, 8785FW (November 18, 2013); doi:10.1117/12.2026235; http://dx.doi.org/10.1117/12.2026235

31. Lachenmayr, B.; Berger, J.; Buser, A., and Keller, O. (Institut fur Mathematik und Datenverarbeitung, UniversitatskrankenhausEppendorf, Hamburg). ReziertesSehvermögenführtzuerhöhtemUnfallrisikoimStrassenverkehr. Ophthalmologe. 1998 Jan; 95(1):44-50; ISSN: 0941-293X.

32. Theeuwes, J.; Alferdinck, J. W., and Perel, M. Relation between glare and driving performance. *Hum Factors*. 2002;44(1):95-107.

33. Skaar, N. Rizzo M. &Stierman L. 2003 Glare disability with attention impairment *Abstract Journal of Vision* 3 9719a http://www.journalofvision.org/3/9/719/.

34. Higgins, K. E.; Wood, J., and Tait, A. Vision and driving: selective effect of optical blur on different driving tasks. *Hum Factors*. 1998; 40(2):224-32.

35. Owsley C, Stalvey BT, Wells J, et al. *Visual risk factors for crash involvement in older drivers with cataract. Arch Ophthalmol 2001;119(6):881-887.*

36. PlainisS, MurrayIJ, PallikarisIG. *Road traffic casualties: understanding the night-time death toll. InjPrev2006;12(2):125-128.*

37. Aachal K, Alexander S, Ananth V. Visual function and fitness to drive. *Br Med Bull (2008) 87 (1): 163-174.* doi: *10.1093/bmb/ldn028*

38. StockmanA, SharpeLT. *Into the twilight zone: the complexities of mesopic vision and luminous efficiency. Ophthalmic Physiol Opt 2006;26(3):225-239.*

39. LeibowitzHW, OwensDA. *Nighttime driving accidents and selective visual degradation. Science 1977;197(4302):422-423.*

40. EloholmaM, KetomakiJ, OrrevetelainenP, et al. *Visual performance in night-time driving conditions. Ophthalmic Physiol Opt 2006;26(3):254-263.*

41. WoodJM, OwensDA. *Standard measures of visual acuity do not predict drivers' recognition performance under day or night conditions. Optom Vis Sci2005;82(8):698-705.*

42. SturrJF, KlineGE, TaubHA. *Performance of young and older drivers on a static acuity test under photopic and mesopic luminance conditions. Hum Factors 1990;32(1):1-8.*