Straylight literature overview for C-Quant. March 2006

INTRODUCTIONS

This and other documents are prepared by TJTP van den Berg and coworkers for users of the C-Quant by Oculus GmbH.
Dr van den Berg will be pleased to answer questions on these documents, or any other queries you may have with respect to retinal straylight and its measurement.

A first introduction into the phenomenon of straylight at the human retina can be found in the accompanying document “Introduction to retinal straylight”

An introduction into the psychophysical approach to assess retinal straylight with the C-Quant can be found in a further document “Compensation Comparison”

An extensive scientific paper on the C-Quant basics appeared in February 2006 in IOVS, another is in press in the Journal of Biomedical Optics, and others are submitted or in preparation. In short the principles have been published as
Van den Berg TJTP, Coppens JE, Franssen L. New Approach for Retinal Straylight Assessment: Compensation Comparison. Invest Ophthalmol Vis Sci. 2005 ;46 :ARVO Eabstract 4315

BACKGROUND SUMMARY and LITERATURE REFERENCES

Originally, the insight in retinal straylight developed from studies on the phenomenon of glare. It was found that disability glare could fully be understood on the basis of the optical phenomenon of straylight at the retina, quantified by means of the psychophysically measurable value L_{eq}/E_{bl} [1,2] Consequently, the CIE (Commission International d’Eclairage) has *defined* disability glare as retinal straylight. This is precisely what the C-Quant Straylight Meter assesses.[3] The Straylight Meter is the only device that assesses retinal straylight. On the other hand more than a dozen so called glare testers have been defined. These instruments do not assess straylight nor disability glare, but a more or less loosely related score.[4,5] The chairman of the CIE committee on disability glare TC1-18 Dr Vos together with Dr van den Berg developed a Standard Glare Observer,[6] accepted as CIE standard. Today it is realized however that retinal straylight constitutes a visual handicap of a much more general nature than glare alone. Patient complaints may include problems of “hazy vision”, contrast and color loss, difficulty with against-the light face recognition, halos around bright lights, etc.

Straylight measurement as it is done in the C-Quant is based on a flickering annular source of straylight. This flickering annulus causes a perceptible straylight flicker in the center. In the first realization of straylight measurement, the psychophysical approach of *direct compensation* was used. This implied silencing of this flicker phenomenon in the center by giving counterphase light. The first publication was in 1986.[7] Since then many studies on retinal straylight appeared using this approach, such as on normal population aging effects,[8] on the use of red(yellow) glasses,[9] on

diaphany of the ocular wall,[10,11] on the effects of ocular pigmentation differences,[12] on populations with different kinds of cataracts,[13] etc.

A small instrument was made to accommodate fellow researchers, described in publications in 1991 and 1992.[3,14,15] Publications appeared using these instruments notably by Elliott and coworkers on a variety of subjects,[16-22] by others on refractive surgery,[23-26] and more recently on driver licensing questions.[27-29] etc.

In 2003 a new psychophysical approach was defined, called *Compensation Comparison*, now implemented in the C-Quant. The essential difference was that this new approach is suitable for random subjects and for routine clinical use. The previous approach had shown to be too difficult for routine use. Moreover, the new approach enabled control over the reliability of the assessment. It was no longer possible to influence the measurement outcome, and quality control factors could be defined. A large study took place in 2003-2004. More than 2400 subjects were measured in 5 centers in Europe (Amsterdam, Barcelona, Tübingen, Salzburg and Antwerp). So a reference database is already established, showing this approach to work very well. The measurement values closely correspond to the earlier comparative studies, so that the full set of data accumulated over the past 15 years can serve as reference. An important finding in the European study was that straylight increase occurs frequently in the population, but can not be detected by a visual acuity or other measurement. The amount of increase is often considerable. If one realizes that glare hindrance is already a problem for young eyes, it is clear that a straylight increase by a factor of 4 constitutes a serious handicap. Yet such increase was often found. In terms of the “straylight parameter” s: its value should be limited to $\log(s)<1.45$. Papers are under way, but for now please refer to the accompanying documents or to www.glare.be for the EU study.

Other studies not mentioned above include: effects of straylight on the PERG,[30] ocular lubricants and straylight,[31] mathematics and modeling of the straylight function,[32-34] corneal disease and straylight,[35] in vitro study on light scattering of the human eye lens and straylight,[36-39] cataract straylight modeling[40], wavelength dependence of straylight,[41] the ciliary corona,[42] etc.

Reference List

1. Vos J.J. Disability glare - a state of the art report. *Commission International de l'Eclairage Journal*. 1984;3/2:39-53.

2. van den Berg, T. J. T. P. and IJspeert, J. K. Intraocular straylight, studied using the direct compensation technique. 22nd session(division 1), 83-84. 1991. CIE Proceedings.

3. van den Berg TJTP, IJspeert JK. Clinical assessment of intraocular straylight. *Applied Optics*. 1992;31:3694-3696.

4. van den Berg TJTP. On the relation between glare and straylight. *Doc Ophthalmol*. 1991;78:177-181.

5. van den Berg TJTP. On the relation between intraocular straylight and visual function parameters. *Invest Ophthalmol Vis Sci*. 1994;35:2659-2661.

6. Vos JJ, van den Berg TJTP. Report on disability glare. *CIE collection*. 1999;135:1-9.

7. van den Berg TJTP. Importance of pathological intraocular light scatter for visual disability. *Doc Ophthalmol.* 1986;61:327-333.

8. IJspeert JK, de Waard PW, van den Berg TJTP, de Jong PT. The intraocular straylight function in 129 healthy volunteers; dependence on angle, age and pigmentation. *Vision Res.* 1990;30:699-707.

9. van den Berg TJTP. Red glasses and visual function in retinitis pigmentosa. *Doc Ophthalmol*. 1989;73:255-274.

10. van den Berg TJTP, IJspeert JK, de Waard PW, Meire F. Functional quantification of diaphany. *Doc Ophthalmol*. 1990;75:239-246.

11. La Hey E, IJspeert JK, van den Berg TJ, Kijlstra A. Quantitative analysis of iris translucency in Fuchs' heterochromic cyclitis. *Invest Ophthalmol Vis Sci.* 1993;34:2931-2942.

12. van den Berg TJTP, IJspeert JK, de Waard PW. Dependence of intraocular straylight on pigmentation and light transmission through the ocular wall. *Vision Res.* 1991;31:1361-1367.

13. de Waard PW, IJspeert JK, van den Berg TJTP, de Jong PT. Intraocular light scattering in age-related cataracts. *Invest Ophthalmol Vis Sci.* 1992;33:618-625.

14. van den Berg, T. J. T. P. and IJspeert, J. K. Straylight Meter. 1, 256-259. 1991. Technical Digest on noninvasive assessment of the visual system.

15. IJspeert, J. K. and van den Berg, T. J. T. P. Design of a portable Straylight Meter. Proceedings 14th IEEE-EMBS, 1592-1594. 1992.

16. Elliott DB, Hurst MA, Weatherill J. Comparing clinical tests of visual loss in cataract patients using a quantification of forward light scatter. *Eye*. 1991;5 (Pt 5):601-606.

17. Elliott DB, Mitchell S, Whitaker D. Factors affecting light scatter in contact lens wearers. *Optom Vis Sci*. 1991;68:629-633.

18. Elliott DB, Bullimore MA. Assessing the reliability, discriminative ability, and validity of disability glare tests. *Invest Ophthalmol Vis Sci.* 1993;34:108-119.

19. Elliott DB. Evaluating visual function in cataract. *Optom Vis Sci*. 1993;70:896-902.

20. Elliott DB, Fonn D, Flanagan J, Doughty M. Relative sensitivity of clinical tests to hydrophilic lens-induced corneal thickness changes. *Optom Vis Sci.* 1993;70:1044-1048.

21. Whitaker D, Steen R, Elliott DB. Light scatter in the normal young, elderly, and cataractous eye demonstrates little wavelength dependency. *Optom Vis Sci.* 1993;70:963-968.

22. Butuner Z, Elliott DB, Gimbel HV, Slimmon S. Visual function one year after excimer laser photorefractive keratectomy. *J Refract Corneal Surg*. 1994;10:625-630.

23. Veraart HG, van den Berg TJ, IJspeert JK, Cardozo OL. Stray light in radial keratotomy and the influence of pupil size and straylight angle. *Am J Ophthalmol*. 1992;114:424-428.

24. Veraart HG, van den Berg TJ, Hennekes R, Adank AM. Stray light in photorefractive keratectomy for myopia. *Bull Soc Belge Ophtalmol*. 1993;249:57-62.

25. Veraart HG, van den Berg TJ, Hennekes R, Adank AM. Stray light in photorefractive keratectomy for myopia. *Doc Ophthalmol*. 1995;90:35-42.

26. Harrison JM, Tennant TB, Gwin MC, Applegate RA, Tennant JL, van den Berg TJ, Lohmann CP. Forward light scatter at one month after photorefractive keratectomy. *J Refract Surg*. 1995;11:83-88.

27. van den Berg TJTP, van Rijn LJ. Assessment of visual function of driving licence holders. Final report EU project I-TREN E3 200/7/SI2.282826. 2003.

28. van den Berg, T. J. T. P. and van Rijn L.J. Entoptic straylight measurement using the direct compensation method in relation to driver licensing application. X. 2004. Vision in Vehicles press. Vision in Vehicles. Gale, A.

29. van Rijn L.J., Nischler C, Gamer D, Franssen L, de Wit G, Kaper R, Vonhof D, Grabner G, Wilhelm H, Volker-Dieben H, van den Berg TJTP. Measurement of straylight and glare: comparison of Nyktotest, mesotets, Straylight Meter and computer implemented Straylight meter. *Br J Ophthalmol*. 2005;89:345-51.

30. van den Berg TJTP, Boltjes B. The point-spread function of the eye from 0 degrees to 100 degrees and the pattern electroretinogram. *Doc Ophthalmol*. 1987;67:347-354.

31. Veraart HG, van den Berg TJ. Ocular lubricants and intraocular stray light. *Doc Ophthalmol*. 1992;82:29-31.

32. IJspeert JK, van den Berg TJTP, Spekreijse H. An improved mathematical description of the foveal visual point spread function with parameters for age, pupil size and pigmentation. *Vision Res*. 1993;33:15-20.

33. Vos JJ, van den Berg TJTP. The large angle course of the disability glare function and its attribution to components of intraocular scatter. *CIE collection.* 1997;124:11-29.

34. van den Berg TJTP. Analysis of intraocular straylight, especially in relation to age. *Optom Vis Sci*. 1995;72:52-59.

35. van den Berg TJTP, Hwan BS, Delleman JW. The intraocular straylight function in some hereditary corneal dystrophies. *Doc Ophthalmol*. 1993;85:13-19.

36. van den Berg TJTP, IJspeert JK. Light scattering in donor lenses. *Vision Res*. 1995;35:169-177.

37. van den Berg TJTP. Depth-dependent forward light scattering by donor lenses. *Invest Ophthalmol Vis Sci*. 1996;37:1157-1166.

38. van den Berg TJTP. Light scattering by donor lenses as a function of depth and wavelength. *Invest Ophthalmol Vis Sci*. 1997;38:1321-1332.

39. van den Berg TJTP, Spekreijse H. Light scattering model for donor lenses as a function of depth. *Vision Res*. 1999;39:1437-1445.

40. de Wit G, Franssen L, Coppens JE, van den Berg TJTP. Straylight contribution of cataract and its simulation. *J Cataract Refract Surg*. in press 2005.

41. Coppens JE, Franssen L, van den Berg TJTP. Wavelength dependence of intraocular straylight. *Exp Eye Res*. in press 2005.

42. van den Berg TJTP, Hagenouw MP, Coppens JE. The ciliary corona: physical model and simulation of the fine needles radiating from point light sources. *Invest Ophthalmol Vis Sci*. 2005;46:2627-2632.