More than 20/20: the contrast sensitivity function

Xiaohua Zhuang

Illinois College of Optometry, Chicago, IL, USA

Correspondence to: Xiaohua Zhuang, PhD. Illinois College of Optometry, Chicago, IL 60616, USA. Email: xzhuang@ico.edu.

Comment on: Rosa C, Aleci C. Psychophysics in the ophthalmological practice—II. Contrast sensitivity. Ann Eye Sci 2022;7:35.

Keywords: Contrast sensitivity; contrast sensitivity function; visual acuity; visual pathways

Received: 07 November 2022; Accepted: 21 November 2022; Published: 15 December 2022.

doi: 10.21037/aes-22-73

View this article at: https://dx.doi.org/10.21037/aes-22-73

Contrast sensitivity assesses the ability to detect spatial or temporal contrast (e.g., achromatic luminance difference between areas or over time), which is one of the most fundamental functions of the human visual system. Many of our daily-life activities rely on this ability, such as finding an object, seeing stairs, noticing a moving car, driving, etc. The contrast sensitivity function (CSF) is the function to depict contrast sensitivity across a range of low to high spatial frequencies. The CSF provides comprehensive information about the contrast processing ability of the visual system on different sizes of objects. Contrast sensitivity deficits have been observed in older adults (1,2) and in patients with ophthalmic conditions such as amblyopia (3,4), glaucoma (5-7), diabetic retinopathy (8,9), multiple sclerosis (10), etc. It is a better predictor of daily visual performance and it correlates better with progression of ophthalmic conditions than the usual high-contrast visual acuity measurement does (11-13).

Despite its importance and relevancy, it is not yet a common clinical practice to measure contrast sensitivity, unlike the visual acuity measurement. A few barriers may have prevented a wide use of contrast sensitivity in clinic. First, although it is most informative to obtain the CSF rather than just the contrast sensitivity of a narrow range of spatial frequencies, it is time consuming to measure the whole CSF. As mentioned in the work by Rosa and Aleci [2022], there are clinical contrast sensitivity measurement tools available to obtain contrast sensitivity for only a narrow range of spatial frequencies, which is more feasible in clinic (14). However, the results from a narrow range of spatial frequencies often do not provide enough information about the patient's visual system and visual function. In addition, different ophthalmic conditions affect contrast sensitivity at different spatial frequency ranges and it is sometimes on an individual basis. It would be more helpful to obtain the whole CSF, in which case more efficient clinical tools would be needed. Second, clinical tools with high reliability and repeatability are still lacking (15). Third, the concepts of contrast threshold, contrast sensitivity, and the CSF, are found to be not easy to understand as compared to the concept of visual acuity, and not easy to explain to patients. More patient and clinician education may be needed in order for contrast sensitivity and the CSF to be measured and interpreted accurately. The work by Rosa and Aleci provides an overview and easy-to-understand summary of the concepts and several clinical psychophysical contrast sensitivity tests available on the market, which is educational and will be helpful for eye care professionals to read about. As suggested by the authors, indeed, assessing contrast sensitivity should be a more common practice in clinic.

It is also noted by Rosa and Aleci that all the currently available clinical contrast sensitivity assessment tools measure contrast sensitivity at an overall perceptual level (14). On the other hand, it is well known from anatomical and physiological studies that, the different visual pathways in the primate visual system have very distinct contrast processing characteristics (16,17). For example, the magnocellular (MC) pathway has high contrast gain, responses fast to contrast increases and shows response saturation at relatively low contrasts; whereas the parvocellular (PC) visual pathway shows linear and shallower increase of response to incremental contrast across a larger range of contrast. Pokorny and Smith [1997] developed a group of psychophysical paradigms based on physiological findings to measure contrast sensitivity at the level of the MC and PC visual pathways (18). Studies using these paradigms have reported that different ophthalmic conditions and aging have differential impacts on these two visual pathways (19-22). There are advantages to measure contrast sensitivity at the level of visual pathway than at an overall perceptual level under certain circumstances. In particular, it may be more helpful for disease diagnosis and management to measure contrast sensitivity at the visual pathway level for certain ophthalmic conditions, such as glaucoma, optic neuritis, amblyopia, etc.

As more research are on the way and more technologies are applied into the development of contrast sensitivity measurement tools (23-25), it is expected that better methodologies and clinical tools will be available in the near future for more effective and efficient measurement of contrast sensitivity and the CSF in clinical settings. Our society has a large aging population, a better assessment of this fundamental visual function will facilitate diagnosis and management of ophthalmic conditions, which will benefit not only individual patients but also the whole society collectively.

Acknowledgments

Funding: None.

Footnote

Provenance and Peer Review: This article was commissioned by the editorial office, *Annals of Eye Science*. The article did not undergo external peer review.

Conflicts of Interest: The author has completed the ICMJE uniform disclosure form (available at https://aes.amegroups.com/article/view/10.21037/aes-22-73/coif). The author has no conflicts of interest to declare.

Ethical Statement: The author is accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

References

1. Glass JM. Visual function and cognitive aging: differential role of contrast sensitivity in verbal versus spatial tasks. Psychol Aging 2007;22:233-8.
2. Owsley C. Vision and Aging. Annu Rev Vis Sci 2016;2:255-71.
3. Mohammadi A, Hashemi H, Mirzajani A, et al. Contrast and spatial frequency modulation for diagnosis of amblyopia: An electrophysiological approach. J Curr Ophthalmol 2018;31:72-9.
4. Dorr M, Kwon M, Lesmes LA, et al. Binocular Summation and Suppression of Contrast Sensitivity in Strabismus, Fusion and Amblyopia. Front Hum Neurosci 2019;13:234.
5. Thakur S, Ichhpujani P, Kumar S, et al. Assessment of contrast sensitivity by Spaeth Richman Contrast Sensitivity Test and Pelli Robson Chart Test in patients with varying severity of glaucoma. Eye (Lond) 2018;32:1392-400.
6. Jammal AA, Ferreira BG, Zangalli CS, et al. Evaluation of contrast sensitivity in patients with advanced glaucoma: comparison of two tests. Br J Ophthalmol 2020;104:1418-22.
7. Ichhpujani P, Thakur S, Spaeth GL. Contrast Sensitivity and Glaucoma. J Glaucoma 2020;29:71-5.
8. Pramanik S, Chowdhury S, Ganguly U, et al. Visual contrast sensitivity could be an early marker of diabetic retinopathy. Heliyon 2020;6:e05336.
9. McAnany JJ, Park JC, Liu K, et al. Contrast sensitivity is associated with outer-retina thickness in early-stage diabetic retinopathy. Acta Ophthalmol 2020;98:e224-31.
10. Balcer LJ, Raynowska J, Nolan R, et al. Validity of low-contrast letter acuity as a visual performance outcome measure for multiple sclerosis. Mult Scler 2017;23:734-47.
11. Owsley C. Contrast sensitivity. Ophthalmol Clin North Am 2003;16:171-7.
12. Cole SR, Beck RW, Moke PS, et al. The National Eye Institute Visual Function Questionnaire: experience of the ONTT. Optic Neuritis Treatment Trial. Invest Ophthalmol Vis Sci 2000;41:1017-21.
13. Ridder A, Müller ML, Kotagal V, et al. Impaired contrast sensitivity is associated with more severe cognitive impairment in Parkinson disease. Parkinsonism Relat Disord 2017;34:15-9.
14. Rosa C, Aleci C. Psychophysics in the ophthalmological

practice—II. Contrast sensitivity. Ann Eye Sci 2022;7:35.
15. Kalia A, Lesmes LA, Dorr M, et al. Development of pattern vision following early and extended blindness. Proc Natl Acad Sci U S A 2014;111:2035-9.
16. Kaplan E, Shapley RM. The primate retina contains two types of ganglion cells, with high and low contrast sensitivity. Proc Natl Acad Sci U S A 1986;83:2755-7.
17. Solomon SG, Peirce JW, Dhruv NT, et al. Profound contrast adaptation early in the visual pathway. Neuron 2004;42:155-62.
18. Pokorny J, Smith VC. Psychophysical signatures associated with magnocellular and parvocellular pathway contrast gain. J Opt Soc Am A Opt Image Sci Vis 1997;14:2477-86.
19. Elliott SL, Werner JS. Age-related changes in contrast gain related to the M and P pathways. J Vis 2010;10:4.1-15.
20. McKendrick AM, Sampson GP, Walland MJ, et al. Contrast sensitivity changes due to glaucoma and normal aging: low-spatial-frequency losses in both magnocellular and parvocellular pathways. Invest Ophthalmol Vis Sci 2007;48:2115-22.
21. Pokorny J. Review: steady and pulsed pedestals, the how and why of post-receptoral pathway separation. J Vis 2011;11:1-23.
22. Zele AJ, Pokorny J, Lee DY, et al. Anisometropic amblyopia: spatial contrast sensitivity deficits in inferred magnocellular and parvocellular vision. Invest Ophthalmol Vis Sci 2007;48:3622-31.
23. Zhuang X, Tran T, Jin D, et al. Aging effects on contrast sensitivity in visual pathways: A pilot study on flicker adaptation. PLoS One 2021;16:e0261927.
24. Hall CM, McAnany JJ. Luminance noise as a novel approach for measuring contrast sensitivity within the magnocellular and parvocellular pathways. J Vis 2017;17:5.
25. Rosenkranz SC, Kaulen B, Zimmermann HG, et al. Validation of Computer-Adaptive Contrast Sensitivity as a Tool to Assess Visual Impairment in Multiple Sclerosis Patients. Front Neurosci 2021;15:591302.

doi: 10.21037/aes-22-73
Cite this article as: Zhuang X. More than 20/20: the contrast sensitivity function. Ann Eye Sci 2022;7:32.

