Effects of contrast, cut-off spatial frequency and phase of the otf on visual acuity and subjective image quality score

R. Legras[1], A.P. Sansot[1], G. Vandermeer[2], Y. Nochez[2], R. Navarro [3]

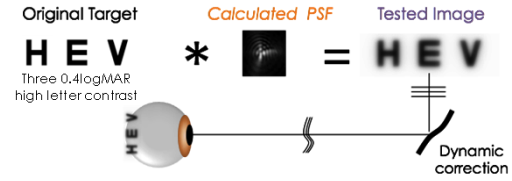
1 - Laboratoire Aimé Cotton, CNRS, Université Paris-Sud, Orsay, France
2 - Bretonneau University Hospital, Tours, France
3 - ICMA, Consejo Superior de investigaciones Científicas & Universidad de Zaragoza, Spain

INTRODUCTION

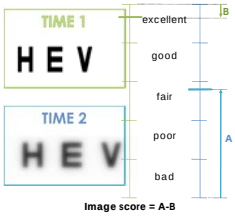
Retinal images suffer from optical blur, given by the Optical Transfer Function (OTF). Its modulus (the MTF) expresses the loss of contrast and sharpness (cut-off spatial frequency, COF), whereas its phase describes spatial shifts between frequencies (phase shift). These are the main factors affecting optical image quality, and hence they induce a loss of visual acuity and quality of vision.

The **aim of this experiment** was to evaluate the effects of these three factors (contrast, cut-off frequency and phase) separately by means of an adaptive optics simulator.

Viewing Conditions



To limit the degradation due the observer's eye optics, the simulated images were viewed through a **dynamic correction of aberrations** (CRX1™, Imagine Eyes) and **an artificial pupil of 3mm**. They were displayed on an Emagin™ micro display coupling with a colour filter ensuring a **monochromatic light** (i.e. 550 ± 50nm).

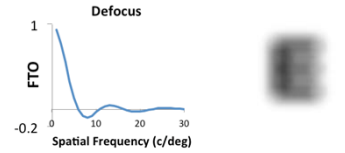


METHODS

General Method

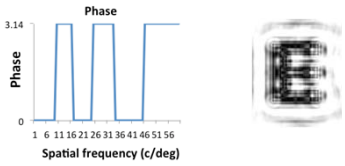
We calculated the appearance of images on 5 -mm pupil diameter, degraded either by **a loss of contrast** (i.e. 1; 0.5; 0.25; 0.12 and 0.06) or by **a lower cut-off spatial frequency** (i.e. 50; 25; 12 and 6 c/deg) or by **the phase shifts** (i.e. 0.05; 0.10; 0.25; 0.5; 0.75; 1; 1.25; 1.5 diopters of pure defocus for 5 mm pupil).

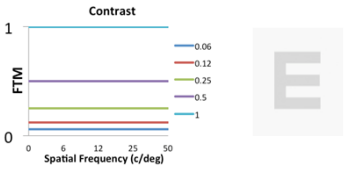
As a reference, these synthetic degradations were compared to that caused by pure defocus (modulus and phase), for the same diopters.

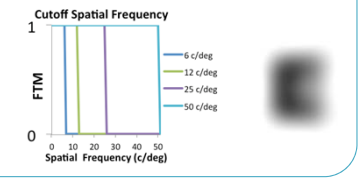


Simulated Images : manipulating the OTF

The COF is a scalar variable, but contrast and phase are 2D functions in general. To somehow convert them to scalar variables, the contrast was assumed constant within the frequency interval $0 < f < \text{COF}$; the phase of the OTF was that of a pure defocus, given in diopters. In this way a synthetic OTF was obtained combining that phase with a MTF, which was a cylinder with radius COF, and height given by the contrast (plus a delta function at $f = 0$).







Measuring the effects of these degradations

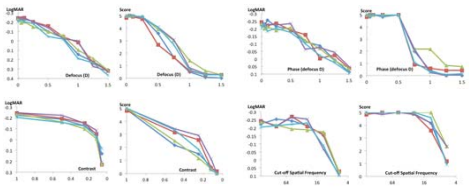
We measured these effects on **degraded high-contrast tumbling-E visual acuity** and on **subjective score**.

Five subjects, aged between 22 and 40 years, scored three times the quality of each simulated image (three 0.4 logMar letters) using a continuous 5-items grading scale according to the ITU recommendations [1]

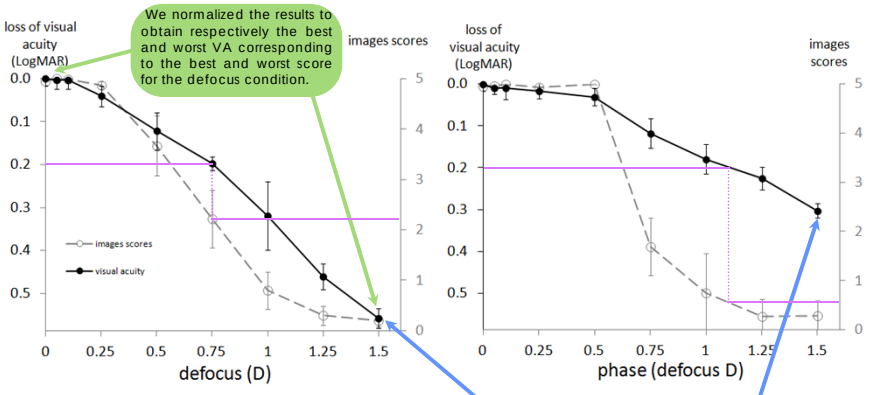
Their visual acuities under the various conditions were also measured three times.

RESULTS

The averaged **intra-individual** standard deviation (SD) was **0.03 logMar** and **0.15 grade**, the larger difference of SD between subjects and type of degradation was observed with image quality score. The averaged **inter-individual** SD was **0.03 logMar** and **0.27 grade**. These SD were largely under clinical significant difference (i.e. 0.1 logMar and a difference of grade of 1).



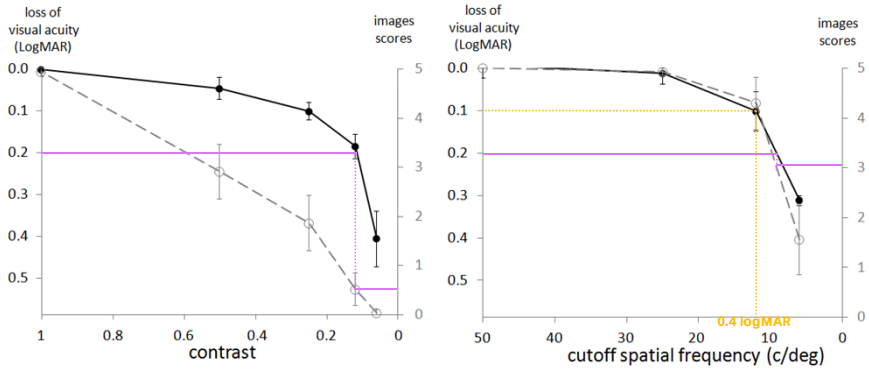
Effects of Defocus, Phase, Contrast and COF on the 5 subjects



When reducing the VA by 2 lines, in the same time the sujective score is reduced to 2.3, 0.6, 0.6 and 3 due to respectively a pure defocus, phase shift, a loss of contrast and a lower cutoff spatial frequency.

Half of the VA loss caused by a pure defocus is due to phase shift.

A cut-off SF of 12 c/deg should led to a VA of 0.4 logMAR. We measured, in this condition a higher VA (i.e. 0.1 logMAR). The low spatial frequencies included in the E letter give cue to detect the orientation of the letter inducing an «overestimated» visual acuity.



CONCLUSION

The cut-off frequency induces a comparable loss of VA and subjective score. However, a loss of contrast or phase shift appeared to have a less detrimental effect on VA than on subjective score. Considering a given loss of VA, we are subjectively more affected by a phase shift or loss of contrast than by a loss of sharpness (lower COF) or a pure defocus error.

REFERENCES

[1] ITU-R, Methodology for the subjective assessment of the quality of television pictures, Recommendation ITU-R BT, 500-506, 1974-2002.

CONTACT

richard.legras@u-psud.fr