Does binocular disparity impact the contrast sensitivity function?

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Rationale

In order to ensure successful and reliable diagnosis, accurate calibration of medical displays is required. Typically, knowledge of the contrast sensitivity function (CSF) describing human eye ability to detect a low contrast pattern stimulus is crucial to develop calibration algorithms. Over the last decades the 2D CSF and its dependence to parameters such as the mean luminance, the stimulus size, and eye disorders have been intensively studied. Although 2D imaging remains more widespread than 3D imaging in diagnostic applications, 3D imaging systems are already being used and studies reveal that they could improve diagnostic performance. Nevertheless, very few studies have examined the CSF in stereoscopic viewing (hereafter 3D CSF). To know whether binocular disparities may impact the CSF, we investigated the relationship between the well-known 2D CSF and the 3D CSF.

Methods

Seventeen human observers tested for their normal visual acuity and stereovision participated into subjective experiments following a 3-down 1-up staircase. In the staircase experiment, the contrast of the stimulus was either decreased or increased depending on the observer's response to the preceding stimulus: target visible or target invisible. The stimuli were computer-generated stereoscopic images comprising a vertically oriented 2D Gabor patch as the target. The experiment was performed for seven different frequencies (0.4; 1; 1.8; 3; 4; 6.4; 10) expressed in cycles per degree (cpd), and two depth planes (the plane of the display, DP:0, and the depth plane lying 171 mm behind the display plane, DP:171). At DP:171 the spatial frequency was adapted to account for the increase in perceived viewing distance, and therefore to have constant spatial frequency across DPs. The stimuli were 1920x1200 pixel large images displayed on a 24 inch full HD stereoscopic surgical monitor using a patterned retarder. The experiments were conducted in a controlled environment with an ambient light of 0.8 lux.

Results

Computed medians and first and third quartiles as well as results of Friedman significant testing suggest that at low frequencies ($f \leq 1.8$ cpd) the CSF is significantly lower for DP:171 (3D CSF) than for DP:0 (2D CSF). However, at a frequency of 10 cpd the analysis indicated a significant improvement of the 2D contrast sensitivity (CS) compared to the 3D CS. For all the other spatial frequencies, the CS is not affected by the introduction of binocular disparities.

Conclusions

Differences in location of elements between the retinal images are likely to induce a loss in CS at low frequencies. As a consequence the suggested difference between the 2D CSF and the 3D CSF may have important implication in medical display market in the sense that new calibration algorithms would have to be developed for medical displays based on binocular disparity.