SHORT COMMUNICATION

The selective effect of optical defocus on detection and resolution acuity in peripheral vision

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Abstract

Detection and resolution acuity was measured at 30 degrees in the periphery for sinusoidal gratings under differing amounts of optical defocus. Within the range −2.0 to +2.5 diopters defocus, detection acuity was higher than resolution acuity. As defocus increased, detection acuity decreased continuously but resolution acuity was little affected until around 2.0 diopters defocus. The results indicate that resolution performance is sampling limited in peripheral vision, even for significant refractive error, and is more robust than detection acuity to the effects of optical defocus. Curr. Eye Res. 15: 351–353, 1996.

Key words: Aliasing; defocus; peripheral acuity

Since the classical study of Wertheim (1), peripheral grating acuity has been measured by many researchers in different ways. Some studies measured detection acuity where the subject had to indicate the presence of grating contrast (2, 3, 4, 5, 6, 7, 8, 9). Other studies measured resolution acuity where the subject had to indicate the orientation of the grating (1, 10, 11, 12) while others have measured both (13). Despite the fact that large refractive errors exist in the periphery, in particular oblique astigmatism (14, 15, 16, 17), the previously mentioned studies did not employ refractive correction when measuring peripheral acuity.

Recent studies have measured both detection and resolution acuity in the same subjects after correction of peripheral refractive error (18, 19, 20, 21, 22). These studies indicate that, unlike for foveal vision, detection performance is markedly higher than resolution performance in the periphery. It may be, therefore, that peripheral detection acuity is affected more by optical defocus than resolution. The study of Millodot *et al.* (23) indicated that correction of peripheral refractive error had little effect on peripheral resolution and may well be one reason why few researchers have used it. However, this is not the case for detection acuity which varies significantly with optical defocus when the control variable is both spatial frequency (24) and contrast (25).

This study seeks to examine separately the effect of differing amounts of optical refractive error on detection and resolution for sinusoidal gratings in peripheral vision, in order to determine if one is more susceptible than the other to the effects of optical defocus.

An experienced psychophysical observer (the author), who is also an emmetrope, was used as a subject. Acuity was measured at 30 degrees eccentricity in the horizontal nasal field (temporal retina) of the right eye. The subject fixated a cross at 1.5m in front while observing the stimulus on a computer monitor, also at 1.5m but placed at 30 degrees nasally. Natural pupil size (approx. 5mm) was used throughout. The eye not in use was patched. Refractive error at the eccentricity being tested was initially determined by an experienced optometrist using retinoscopy. This correction was placed in front of the eye in the form of trial lenses in line with the peripheral target. The correction was then refined subjectively using the technique described by Thibos *et al.* (21) where the spatial frequency of the target was gradually increased and the power of the lenses adjusted to maximise the contrast of the high frequency stimulus. The measured peripheral refractive error was +2.25DS −2.25DC axis 90.

A Visual Stimulus Generator VSG2/3 (Cambridge Research Systems) was used to produce 4 degree circular patches of sinewave grating on a high resolution monitor (Eizo) oriented at either 45 degrees (right oblique) or 135 degrees (left oblique). These gratings had the same mean luminance as the surround, verified by viewing the stimulus foveally through a positive lens which blurred the stripes within the patch. No difference in luminance between stimulus and surround could be discerned.

A temporal two alternative forced choice paradigm (2AFC temporal) was used to measure detection performance where the target was presented in either the first or the second interval

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Received on August 28, 1995; accepted on January 5, 1996

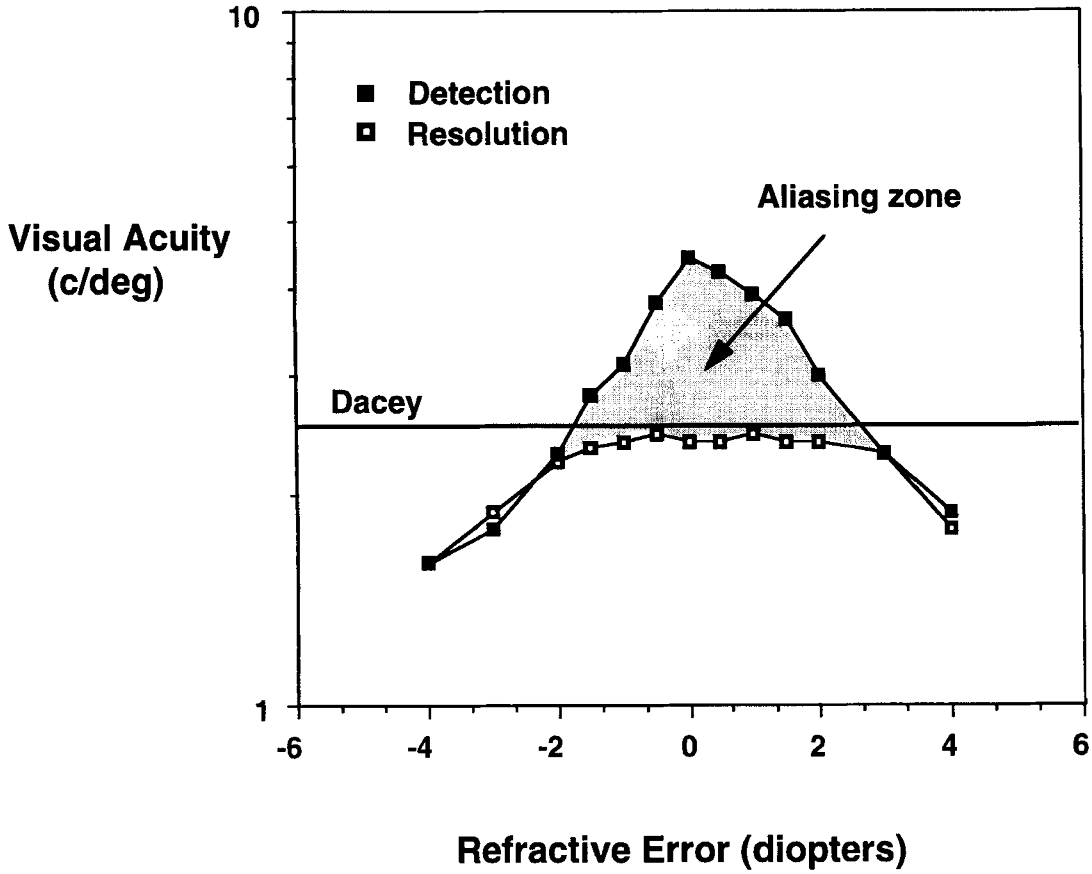

Figure 1. Detection acuity (filled symbols) and resolution acuity (open symbols) for varying amounts of optical defocus at 30 degrees eccentricity. Horizontal line represents predicted resolution performance from anatomical data of Dacey.

and the other interval contained a blank screen. Each presentation was for one second and was separated by one second. Grating orientation was randomly right or left oblique and the subject was required to indicate which interval contained the stimulus by pressing one of two buttons which triggered the next presentation. Three correct responses led to an increase in spatial frequency at the next stimulus presentation and one incorrect response led to a decrease in spatial frequency at the next stimulus presentation. Fifty pairs of presentations were made in each session and threshold was calculated as the mean of the reversals. This gave on average 5-6 reversals per session.

For the resolution part a spatial two alternative forced choice paradigm (2AFC spatial) was used where the subject was required to indicate whether the orientation of the grating was left or right oblique by pressing one of two buttons which triggered the next stimulus. Each presentation lasted one second and, as for detection, three correct responses caused an increase in spatial frequency and one incorrect response caused a decrease in spatial frequency. Threshold was again determined as the mean of the reversal values.

Detection and resolution acuity was measured after different amounts of refractive error were placed in the trial lens holder in line with the peripheral target (Meniscus reduced aperture trial lenses). These refractive errors were −4, −3, −2, −1.5, −1.0, −0.5, 0, +0.5, +1.0, +1.5, +2, +3, and +4 diopters added to the previously determined peripheral optical correction already in place.

Figure 1 is a plot of threshold spatial frequency versus refractive error for detection and resolution acuity at 30 degrees eccentricity. The standard deviation of the reversal values for each data point represented less than 10% of the mean.

Detection acuity is significantly higher than resolution acuity between about −2.0 diopters and +2.5 diopters. This superiority of detection acuity over resolution acuity in peripheral vision occurs because the two tasks are mediated by different mechanisms [19] and is strong evidence that resolution is sampling limited. Indeed, the observer could clearly observe the presence of *aliasing* over most of this range of refractive errors. Aliasing occurs when a stimulus is under-sampled by the underlying sampling array and causes high spatial frequencies to masquerade as lower spatial frequencies of different orientation. It is a strong indicator that a task is sampling limited. The aliasing zone is represented by the shaded area.

For detection acuity, as refractive error increases, there is an immediate and continuous fall in performance for both positive and negative errors. The deterioration is slightly greater for negative errors than positive errors, probably because the magnification differences alter the effective spatial frequency.

This pattern of performance is not observed for resolution however. Interestingly, resolution performance remains quite flat between the range −2.0 diopters and +2.5 diopters, the range over which aliasing occurs. Thibos *et al.* (21) measured grating detection and resolution for gratings of different contrast and found that increases in contrast above 10% produced a large improvement in detection performance but no improvement in resolution performance. They proposed that this again is a good sign that performance is sampling limited in that as long as there is a minimum amount of contrast the effective sampling density does not change significantly over this range. The present data show a similar pattern to those of Thibos *et al.* in that any reduction in contrast of the stimulus caused by optical defocus affects detection acuity significantly but has little effect on resolution over a certain range until the resolution changes from being sampling limited to contrast limited, at which point performance is very similar to that for detection. The horizontal line indicates the resolution performance predicted for this eccentricity from the anatomical data of Dacey (26) for midget ganglion cells. This shows good agreement with the measured resolution performance in this sampling limited region.

In conclusion, this study indicates that optical defocus has a greater effect on detection acuity than resolution acuity in peripheral vision, meaning that correction of peripheral refractive error is important for peripheral acuity experiments, in particular for detection acuity. Peripheral resolution acuity appears to be sampling limited even for defocus up to 2 diopters.

Acknowledgements

This research is supported by a Research Fellowship from the Royal National Institute for the Blind.

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