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An Alternative Vision Test Stimulus: Orientation-Performance Isotropy Confirmed in Central Fixation for an Angular Broken Ring Test Target

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Abstract: Ophthalmologists and optometrists use charts displaying the Landolt broken ring stimulus instead of letters when testing the vision of specific patient groups. However, a degree of performance inequality *versus* stimulus orientation has been claimed in association with the use of the classic circular broken ring design. In recent years an angular version of the stimulus has found application in several clinical and vision-related studies. The present investigation was undertaken to assess whether testing with this alternative angular optotype design has any influence on orientation-performance anisotropy in central fixation. Ten normally-sighted subjects undertook an automated four-alternative forced-choice visual discrimination task under monocular foveal viewing conditions. Their error (orientation misidentification) performance was recorded in response to a randomised sequence of high-contrast single, variously sized, four-alternative orientation angular broken ring stimuli. Having first weighted the grouped error scores to counter orientation heterogeneity in stimulus presentation, statistical analysis indicated equality of performance across the four orientations of presentation. Subsidiary analysis failed to reveal any evidence of a systematic error bias associated with stimulus angular subtense. The angular design of the broken ring optotype tested here appears to have promoted isotropic orientation performance in central fixation for this group of normally-sighted adult subjects.

Key words: Angular, circular, Landolt broken ring, orientation performance, visual acuity

INTRODUCTION

When assessing the visual acuity of pre-school children or illiterate patients in the ophthalmology clinic (and sometimes to satisfy specific criteria in vision research studies), an alternative test stimulus to the alphabet letters found on the optician's conventional chart is required. A graduated size of broken ring symbol is frequently used in these situations: The gap in the ring is randomly located either at one of the four cardinal positions (i.e., top, bottom, left or right) or sometimes in one of the four oblique directions. Rather than correctly naming the smallest letter on the chart visible to him/her at the given test distance (usually 6 m [20ft]), the patient's task becomes the accurate identification of the position of the gap in the smallest-sized ring possible.

The classic 'cercle interrompu' design of circular broken ring stimulus proposed by Landolt in 1888 continues to be the agreed international standard optotype (International Organisation for Standardisation, 1994a, b) on the grounds that it presents a notionally uniform visual acuity test stimulus in all four cardinal and/or four oblique target orientations.

Some investigators (Grimm *et al*., 1994) have indeed demonstrated orientation equi-legibility within clinically defined limits. Others have questioned the independence of visual resolution and ring orientation, advancing several bases for a perceptual/performance anisotropy. For example, lowered thresholds in the oblique as compared to the cardinal directions have been attributed to the 'oblique effect' (Appelle, 1972) similarly, acuity estimates might be unreliable in the presence of (uncorrected) astigmatism (Sloan, 1951; Taylor, 1978). A 'cultural effect' associated with familiarity with the letter "C" in English-speaking Western populations has been claimed (Prince and Fry, 1958) as the basis for a guessing bias towards a break to the right (3 o'clock position). Reduced resolution has been reported for vertical as compared to horizontal stimulus orientation (Reich and Ekabutr, 2002) and the involvement of higher (extra-striate) visual areas has been suggested (Schrauf and Stern, 2001) to explain results that showed a tendency for greater response errors associated with the break downwards (6 o'clock) stimulus orientation.

Fourier analysis of the circular Landolt ring design (Bondarko and Danilova, 1997) has suggested that a spatial frequency lower than that corresponding to the gap size may be the determinant of orientation detection with this stimulus format; i.e., the subjective response might be on the basis of perceptual asymmetry rather than actual gap resolution. A subsequent study (Reich and Ekabutr, 2002) has cast some doubt on this interpretation, however, speculating that the visual system actually uses a wide spread of spatial frequencies to resolve detail.

The existence of these various possibilities and detractors has prompted consideration of alternative designs to the classic circular broken ring format (Pointer *et al*., 1980). An angular (square) version, although limiting tests timulus orientation to the four primary directions, does remove oblique testing uncertainty and appears to overcome the claimed 'cultural' (3 o'clock) guessing bias (Pointer, 1986). This angular test stimulus has been used successfully for vision assessment in several clinical studies (Pointer *et al*., 1985) and acuity-related investigations (Leat *et al*., 1999). The square configuration has also been identified as a precise and stable stimulus format in conjunction with Cathode-Ray Tube (CRT)-based visual acuity tests, especially when a compensation is implemented to counter pixel non-linearity associated with orientation of the stimulus break relative to that of the CRT raster scan (Liu and Cho, 2002).

In the light of the reported acceptance and application of this angular variation on the classic circular (Landolt) broken ring it is perhaps surprising that, with the possible exception of Pointer (1986) apparently no study has assessed subjective performance versus stimulus orientation for this alternative design. The present short report attempts to rectify this omission: In brief, can orientation-performance isotropy be demonstrated in central fixation for this angular configuration of the broken ring vision test stimulus?

MATERIALS AND METHODS

Ten young adult male postgraduate students (group mean age = 22.7±2.6 years) in good general and ocular health were recruited for participation in this investigation. All subjects were experienced psychophysical observers but were naïve to the aims of the experiment. Each subject habitually wore spectacles to correct a low myopic/astigmatic refractive error. Clinically all recorded a monocular (right eye) visual acuity of 6/4 [20/13] with their optimum distance correction; this was worn during testing in the form of accurately centred full-aperture trial case lenses (with an opaque occluder before the left eye).

All measurements were made under photopic conditions, using natural pupil size. Although not specifically assessed during the course of data collection, given the stability of ambient illumination in the test room (which received solely artificial illumination) and the uniformity of the subject group, any variation in pupil diameter would have been negligible and should have exerted no influence on the results obtained (Walsh and Charman, 1988).

The subjects undertook an automated 4-alternative forced-choice visual discrimination task (Pointer, 1986) whereby individual threshold acuity estimates were determined. The psychophysical test procedure was arranged such that the subject was presented in central fixation with a randomised sequence of single, variously sized, four-alternative orientation angular broken ring stimuli on a calibrated monochrome monitor screen. Stimulus appearance can be visualised from the insets on Fig. 1. The space-averaged luminance of the screen was 45 cdm^{-2} throughout this work (Spectra "Mini-Spot" photometer with accessories). The display was surrounded by an evenly illuminated uniform light grey field and, as stated above, the test room was solely artificially illuminated. Stimulus position was randomised at each presentation but always fell within the central screen area, masked down to a square aperture of side 1 deg angular subtense. The stimuli adhered to the conventional figure:Detail ratio of 5:1 and comprised 10 gap sizes across a 3.5 octave range spanning 0.35 - 4.15 min arc at the test distance of 9.7 m (Snellen equivalent range 6/2 [20/7]-6/25 [20/83]). Figure-ground contrast was -85% (Michelson ratio; dark stimulus on a light ground).

At each trial (indicated by an auditory tone) the subject was required to indicate where he perceived the position of the break to lie in the square stimulus (i.e., in the top/bottom/left/right side) by pressing only one of four buttons on a hand-held response box, guessing being required in the event of uncertainty: Feedback was not given. The electronics that governed all aspects of

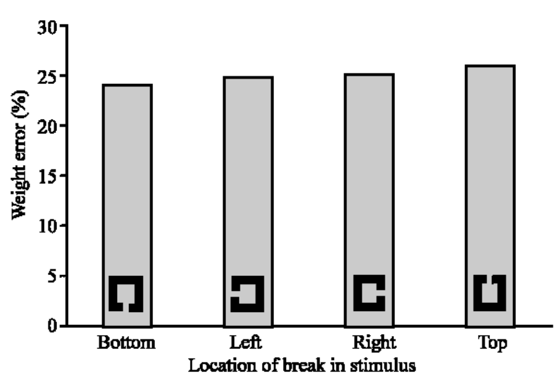

Fig. 1: The percentage of weighted errors for each of the 4 primary orientations of the angular broken ring stimulus (N = 10 subjects and data pool of N = 1,666 weighted errors)

stimulus presentation and monitored a subject's response were contained in a ventilated instrument cabinet; aside from a small cooling fan, operation of the equipment was completely silent, providing no auditory cues to stimulus presentation or test response.

Monocular (right eye) subjective responses were recorded over six successive runs, each individual run comprising 100 trials (i.e., ten repetitions of a ten-stimulus cycle). Data from the first run was discarded, analysis being undertaken upon material generated in the remaining five runs. All data collection was completed at a single experimental session of approximately 50 min duration.

RESULTS

No statistically significant difference ($p>0.10$) was revealed in these data between the performance of each of the ten subjects: Consequently, all analysis was undertaken upon overall group data, the latter comprising (Schrauf and Stern, 2001) the error scores.

Tabulation of the entire stimulus/response data set (i.e., [10×10 variously-sized stimuli per run] ×5 repetitions ×10 subjects = 5,000 stimulus/response pairings) revealed that while the distribution of the gap location across the four cardinal meridians was heterogeneous (Pointer, 1986) this variation was independent of stimulus size. The error (orientation misidentification) scores were accordingly weighted with their likelihood of occurrence for each orientation at each stimulus size level before any statistical analysis was undertaken.

A data pool of 1,666 weighted errors was obtained: not surprisingly, the proportion of errors was greatest for the broken ring stimuli of smallest subtense and least for the largest stimuli.

The results are summarised in Fig. 1 for each of the four test orientations (appearance indicated on the results columns) the percentage of weighted errors for the angular broken ring stimuli are shown. *Prima facie* the error material appears approximately equally distributed across the four cardinal directions of presentation. Non-parametric (X^2) testing confirmed that irrespective of stimulus orientation no statistically significant difference

Table 1: Non-parametric X^2 statistical test results (weighted error data): Paired comparisons of the gap orientations for the angular broken ring stimuli

Compared direction of break			X^2 value	p (≤)
Top	*vs*	Right	0.3490	0.55
		Bottom	1.9606	0.16
		Left	0.6446	0.42
Right	*vs*	Bottom	0.6555	0.42
		Left	0.0450	0.83
Bottom	*vs*	Left	0.3570	0.55

in overall error scores was present in this material (Table 1). In addition, subsequent X^2 testing of the weighted error data at the level of stimulus size failed to reveal any evidence of a systematic error bias.

DISCUSSION

The experimental protocols adopted for this work were aimed at maintaining steady and invariable stimulus test conditions and control of subjective factors (including optimum refractive correction).

The use here of an angular rather than the classic circular broken ring test stimulus appears to have minimised the influence of any subjective guessing bias founded on 'cultural' cues: This outcome corroborates the result of an earlier investigation which also used the alternative angular ring configuration (Pointer, 1986). In addition, single presentation of the luminance contrast defined stimuli has eliminated the confounding ('crowding') effects of contour interaction, a detractor in several earlier published investigations in the area of orientation performance (Schrauf and Stern, 2001).

A circularly-symmetric functional visual field is assumed in central fixation for normally-sighted human subjects. Indeed, a consideration of the underlying neuro-anatomy (Curcio and Allen, 1990) would predict isotropic sensitivity, especially for orthogonally-oriented (as distinct from obliquely-oriented) stimuli.

Whilst a broad range of stimulus angular subtense above, below and around the spatial visual threshold was tested, the question as to whether subjects relied upon relatively higher (corresponding to the stimulus break) or lower (the entire stimulus configuration) spatial frequency discrimination to make their response (Bondarko and Danilova, 1997) remains unresolved. All testing was undertaken in foveal fixation, within which specific projection a broad range of spatial frequency-tuned cells are to be found. It is a possibility that discrete testing at eccentric visual field loci (i.e., where the population densities of high spatial frequency-tuned cells are reduced) might aid clarification of this issue.

CONCLUSION

This alternative angular version of the broken ring vision test stimulus appears to have promoted isotropic orientation performance in central fixation for this group of normally-sighted adult subjects.

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