Contour integration in adults with a history of amblyopia.

E. C. Hall, E. A. Bauer, & L. Kiorpes. Visual Neuroscience Laboratory, Center for Neural Science, New York University, NY.

Purpose. Our aim was to investigate how abnormal early visual experience in humans affects the relationship between local and global visual processing. We assessed contour integration, a global visual processing ability, and contrast sensitivity, which depends on local spatial processing, in adult humans. Our participants had a history of amblyopia, an eye condition that is usually molecular and/or structural in nature, caused by early visual experience.

Several studies have investigated contour integration in humans or monkeys with abnormal early visual experience; however, the results have been inconsistent (see, e.g., Hevi, Molloy, & Field, 1997; Hevi & Dembrowski, 1996; Rouw et al., 2008; Chabane et al., 2011; Kime & Kiorpes, 2009). The lack of agreement across studies could be accounted for by methodological differences, rather than, for example, the presence of amblyopia. Nonetheless, these studies suggest that some aspects of abnormal early visual experience may result in a global processing deficit, whereas other aspects may result in a local processing deficit. In the context of abnormal visual experience, the severity of the deficit and its relation to global processing may depend on the specific type of visual experience. However, to our knowledge, the role of abnormal early visual experience in global processing ability in human amblyopes relates to basic spatial visual codes, such as study or contrast sensitivity.

In our contour integration task (CI), the observer identified the location of a 6 deg diameter ring of Gabor patches imbedded in a field of randomly arrayed noise patches. Data were gathered monocularly, with best correction, interleaving eyes. Feedback followed each response. Spatial 2AFC, Method of constant stimuli, 4 stimulus levels per condition.

Methods.

Subjects. There were 9 adult participants: 4 with a history of anisometropic amblyopia, 2 with a history of strabismic amblyopia, and 3 with a history of bilateral amblyopia. The participants had normal visual history, normal visual acuity, and normal visual fields.

Psychophysics.

Spatial SART. Method of constant stimuli. 4 stimulus levels per condition.

Feedback followed each response.

Data were gathered monocularly, with best correction, interleaving eyes.

Contour integration stimuli.

A 6 deg diameter ring of Gabor patches was imbedded in a field of randomly arrayed noise patches. Gabor patches were 3 radian standard deviation multiplied by 0.5 deg SD Gaussian, in sine phase.

Stimuli were generated and displayed using an SGI computer/server configuration.

The display subtended 27 x 17 deg of visual arc.

The range of background noise density was 0.3 - 3.0 patches/sq. degree.

A feedback follow-up was given, with a feedback level of the contour.

Our measure of contour integration performance was ‘noise tolerance’; the maximum noise density yielding 75% correct performance.

Contrast Sensitivity.

Static sine wave gratings of 1.5, 3, 6 and 12 cycles/deg matched in space-average luminance density. In addition, we measured contrast sensitivity (CS) for comparison with CI deficits. We varied both contour element co-circularity and background noise density. In addition, we measured contrast sensitivity (CS) for comparison with CI deficits. We varied both contour element co-circularity and background noise density.

Figure 1. Contour integration stimuli. The task is to locate the target contour. Examples of contour conditions, right eye: receive stimulation from target contour.

Figure 2. Noise tolerance for the co-circular contour element condition (orientation jitter = 0). The filled symbols represent data from affected eyes and left eye data from scotopic conditions: the open symbols represent fellow eye data and right eye data from control. Each data point describes the noise tolerance and its standard error of estimate. Quadratic fits were computed for each participant. We considered the worse-performing eye to have a deficit if the standard error of the noise tolerance estimate did not overlap that of the other eye. Three of the individuals with a history of amblyopia had a larger range of interocular noise tolerance difference compared with controls. Also, some individuals showed CS deficits with both the affected and the fellow eye (e.g., SP, ST). (Note: data symbols denote anisometropic amblyopic participants).

Figure 3. Examples of noise tolerance as a function of orientation jitter of the elements in the contour. Data are shown from control participant EB (top left), recovered anisometropic amblyopia (top right), amblyopic amblyopia (GM) (bottom left), and recovered strabismic amblyopia (ER) (bottom right). All had a reduced CI deficit, noise apparent at the intermediate orientation jitter levels. The CI deficit of shown by GM was substantial, and was relatively consistent with change in jitter level. ER showed a CI deficit, either intensity or in comparison to control data.

Figure 4. The interocular ratio (fellow/affected) eye for CS plotted against the interocular ratio for CI. In calculating the interocular ratio for CI, we used noise tolerance for the co-circular condition. For CS, we used performance measured at 3 cpd (the spatial frequency of the Gabor patches). The figure shows human data from the present study, along with data from the prior study of non-human primates. Data from 3 strabismic and 3 anisometropic amblyopic monkeys have been included for comparison. In strabismic amblyopic monkeys, it is possible to have a deficit in the deviated eye, but not the tested eye. All monkeys except for 1 had a CI deficit, except for the one that was strabismic and 1 monkey had CS deficits. Our data for control subjects largely lay along the unity line, as expected.

Conclusions.

1. Amblyopes are poorer at contour integration than those successfully treated for amblyopia or than controls.

2. Some amblyopes show CI deficits in both eyes.

3. Contrast sensitivity at 3cpd, the spatial frequency of the Gabor patches, predicted CI deficits in human recovered amblyopes and anisometropic amblyopic monkeys, but not in strabismic amblyopes of either species.

4. These results suggest that global visual processing is more affected by abnormal early visual experience in amblyopes than controls.

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References.


Table 1. Clinical data.

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