Monoptic, dichoptic and binocular masking in strabismic amblyopia

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1. Introduction - deficits in amblyopic contrast vision

Contrast vision in strabismic amblyopia is characterised by:

i) threshold elevation in the amblyopic eye (Hess \& Howell, 1977)

ii) poor binocular summation at threshold (Levi et al, 1979)

iii) abnormal dichoptic masking (Harrad \& Hess, 1992)

Here, we explore contrast masking functions in greater detail than reported previously, and use a model of interocular contrast vision to describe our results.

2. Method - interocular pedestal masking

Three masking conditions:

• Monoptic (pedestal and test to same eye)

• Dichoptic (pedestal and test to opposite eyes)

• Binocular (pedestal and test to both eyes)

Run monoptic and dichoptic for each eye, hence 5 masking functions:

- Previous studies used mirror stereoscopes, and vertical stimuli
- Could lead to artifacts because of phase misalignment of stimuli
- We used stereo goggles and horizontal gratings
- We also corrected any strabismus using prisms

Test stimuli

4. Analysis part I: binocular summation at threshold

It is common in the clinical literature to calculate binocular summation ratios relative to the good eye only. The left panel shows this analysis for our subjects.

Amblyopes all show < 2 \times \text{binocular summation ratio}

However, it is conceivable that the summation process is normal, but appears to be absent because of low sensitivity in the bad eye. This is illustrated by the case of the normal subject with an ND filter (*). Neural summation is presumably constant, but ratios appear to decrease with the filter present.

5. Masking functions for normal subject

Normal subject data replicate Meese et al. (2006) and are well described by the Two Stage model, using the parameters from that paper (see table).

Parameters 5 and 6 were allowed to vary to describe variations in sensitivity and dipper placement.

- Binocular: normal for all amblyopes
- Dichoptic: facilitation absent for other 3 (right)
- Monoptic: facilitation present for all 3 (left)

6. Analysis part II: masking functions for amblyopes

- Thresholds in amblyopic eye always elevated
- Dichoptic facilitation present for 3 subjects (left)
- Dichoptic facilitation absent for other 3 (right)
- Masking functions steep in dichoptic condition

Two subjects (left column) show behaviour very similar to that of a normal subject with an ND filter in one eye. Both dichoptic facilitation and binocular masking (see Box 4) are preserved.

The other three subjects (right column) do not show normal binocular summation (Box 4) or clear evidence of dichoptic facilitation.

In contrast to Harrad \& Hess (1992), the slope of dichoptic masking is similar to that in normals on threshold normalized axes (below, red line).

7. Two different model architectures

Early attenuator

For the other three amblyopes, who show no signs of dichoptic facilitation, and abnormally low binocular summation at threshold, a model with independent channels provides a better description of the data. As for the other model, threshold elevation is caused by an early attenuator, but all binocular interactions, including interocular suppression and binocular summation, are absent (lesioned).

Performance is now determined by a peak picket at the output stage, implemented using Minkowski summation with a large exponent (\(k=20\)).

8. Conclusions

- Dichoptic facilitation is not always absent in amblyopia, and the process of binocular summation at threshold may be intact in some subjects

- Dichoptic masking is typically normal for our amblyopes

- The largest losses in binocularity (tan shading) occur in the subjects with the greatest acuity losses or greatest angular strabismus

- Subjects fall into two groups, indicating two types of strabismic amblyopia

- Lesions and attenuators in the Two Stage model give a reasonable account of many of our findings, but not a complete description

References