Notes and Comment

A reciprocal inhibitory model for monocular pattern alternation

JOSEPH THOMAS

The University of Toledo, Toledo, Ohio 43606

When two optically superimposed grating targets which differ in orientation or spatial frequency are simultaneously presented to one eye, they appear to alternate. This phenomenon is known as monocular pattern alternation (Campbell & Howell, 1972).

Several psychophysical studies have indicated that spatial frequency and orientation are processed by channels in the human visual system whose band-pass characteristics are $\pm$ an octave for spatial frequency and $\pm 10^\circ$ to 15° for orientation (e.g., Blakemore & Campbell, 1969). Since the occurrence of monocular alternation is not found until one stimulus differs from the other by $\pm$ an octave in spatial frequency or $\pm 10^\circ$ - 15° in orientation, it appears that monocular pattern alternation may reflect an antagonistic interaction (presumably involving lateral inhibition) between these channels.

Kitterle, Kaye, and Nixon (1974) found that pattern alternation was an inverted U-shaped function of spatial frequency when the spatial frequency of two orthogonal gratings were covaried over a range of frequencies. The number of alternations was maximal when both gratings were 5 c/deg. Kitterle et al. (1974) concluded that the "strength" of inhibitory interactions varied with spatial frequency. If pattern alternation reflects a reciprocal inhibitory interaction between channels which are size and orientation tuned, then pairing a 5-c/deg grating (apparently this spatial frequency results in optimal alternation rate given the Kitterle et al. contrast and luminance values) with an orthogonal grating, which differs in spatial frequency, should result in fewer alternations because of a weakened inhibitory interaction. This reciprocal inhibitory notion was tested and supported by Kitterle et al. (1974). Again, pattern alternation rate (alternations/viewing time) was described by an inverted U-shaped function of spatial frequency. The peak of this function occurred when the orthogonal gratings were of the same spatial frequency, i.e., 5 c/deg.

The results of Kitterle et al. (1974) do not clearly establish that a reciprocal inhibitory relationship exists between the channels involved in the monocular alternation phenomenon. If a reciprocal interaction underlies monocular alternation, then the grating which initiates the maximal alternation rate (from Kitterle et al. this would correspond to a 5-c/deg grating) should be responded to for a greater

number of times than orthogonal gratings of differing spatial frequencies.

A similar paradigm to the one used by Kitterle et al. (1974) was employed in the present study to test for a reciprocal interaction between spatial frequency channels in monocular pattern alternation.

METHOD

Subjects

Ten undergraduates at the University of Toledo served as observers in this experiment. All observers had 20/20 or corrected to 20/20 vision with no astigmatism and were naive about the purpose of this study.

Apparatus

The stimuli which were presented in a two-channel optical system were photographic transparencies of sine-wave gratings generated on the face of a Tektronix 561B oscilloscope with a P-31 phosphor. At a viewing distance of 76.5 cm, the spatial frequencies of the gratings were 2.74, 3.83, 4.61, 7.74, and 10.96 c/deg. The stimuli were transilluminated by the lamps of two Kodak Ectographic projectors. The gratings were seen within a circular aperture subtending 1.5° at the eye. The contrast of the gratings (maximum luminance - minimum luminance/maximum luminance + minimum luminance) was 0.6. The adapting field luminance and space average luminance of the gratings was 10 cd/m² measured with an S.E.I. photometer. The apparatus was kept in a sound-proofed and dimly lit room.

Procedure

At the beginning of the experimental session, the subject was dark adapted for 5 min and light adapted to the adapting field. During this time, the instructions were read. The subjects were told that they would view a circular aperture containing horizontal and vertical lines. They were told to report the distinctiveness of the lines by depressing one of three telegraph keys. One key would be depressed when the horizontal lines were more distinct than the vertical, another key would be depressed when the vertical lines were more distinct than the horizontal, and a third key was to be depressed when both the vertical and horizontal lines were equally as distinct (composite). They were told to change to the appropriate key whenever the distinctiveness state changed during the 60-sec viewing period.

A trial consisted of a ready period followed by the offset of the adapting field and the presentation of the pattern for 60 sec, after which the pattern was extinguished and the adapting field was turned on again. Fifteen seconds intervened before the next trial. Each subject judged the pattern for five trials. The spatial frequency of the horizontal grating was held constant at 4.61 c/deg and the orthogonal grating had the same spatial frequency or differed in spatial frequency.¹ The spatial frequencies were 2.74, 3.83, 7.74, or 10.96 c/deg in this case. Wratten filters No. 33 and No. 61 were used to produce the colors of red and green. Gratings of different color were used to maximize the pattern alternation effect (Rauschecker, Campbell, & Atkinson, 1973).

The total number of responses made to each distinctiveness state (alternation rate) was the dependent measured used in the subsequent analyses.

RESULTS

A 5 by 3 ANOVA (Spatial Frequency by Component Response) was conducted upon the

Figure 1. Pattern alternation rate (number of keypresses/minute) as a function of the spatial frequency of the vertical grating. The parameter of this figure is component response, i.e., horizontal, composite, and vertical.

alternation rate data. The interaction between Spatial Frequency and Component Response was significant [$F(8.64) = 3.10$, $p < .01$]. These results are presented in Figure 1, where the number of keypresses is plotted as a function of the spatial frequency of the varied grating (i.e., vertical). The parameter of this figure is component response.

The function relating number of keypresses and spatial frequency is that of an inverted U [$F(4,32) = 8.97$, $p < .001$], supporting Kitterle et al. (1974). Of particular importance, in Figure 1, is the distribution of keypresses as a function of spatial frequency. When the pattern components differed in spatial frequency, the horizontal grating was responded to for a greater number of times than the vertical. However, when the pattern components were of similar spatial frequency, both the horizontal and vertical gratings were responded to for the same number of times.

DISCUSSION

In the present study, it was shown that the distribution of component responses during monocular pattern alternation was differentially affected by the spatial frequency of the individual gratings comprising the pattern. Moreover, the nature of the response distribution fits nicely within a reciprocal inhibitory model.

It seems intuitively consistent with a reciprocal model that component response magnitude should be

a positive function of stimulus strength. This direct relationship between stimulus and response 'strength' would be predicted from two aspects of the monocular alternation rate data. First, alternation rate should be optimal when the pattern consists of components which are of equal and maximal strength. Alternation rate, in the present study, peaked when both gratings were of similar spatial frequency. The second relationship which must exist for a reciprocal model to be in operation concerns the component responses when the pattern is comprised of gratings of different spatial frequency and therefore of different stimulus "strength." If a reciprocal inhibition model is to provide an adequate account of the alternation process, then the vertical grating response magnitude should decrease as a function of the spatial frequency difference from the horizontal grating. Figure 1 of the present study indicates that, indeed, this is the case.

Monocular pattern alternation provides another method of investigating the organization of human visual channels. The alternation paradigm allows for the examination of interactions between spatial frequency and orientation channels. An important application of this alternation phenomenon might be in the evaluation of the visual channel interaction in an amblyopic system. Amblyopia (reduction in visual resolution capabilities) accompanies such disorders as strabismus and anisometropia. It might be expected that the "effective strength" of spatial frequency differences, between the alternation components, would differ between an amblyopic and an emmetropic visual system. Thomas (Note 1) has found that this is, indeed, the case. Amblyopes of a high degree (e.g., 20/100 or 20/200) display a low-frequency "bias." That is, the peak of the inverted-U function occurs at a lower frequency for the amblyopic eye when compared to the emmetropic.

REFERENCE NOTE

1. Thomas, J. *Monocular pattern alternation in strabismic amblyopes*. Unpublished manuscript, 1976.

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- effects which might arise due to nonconjugate eye movements. Wade (1974) has suggested that horizontal nonconjugate eye movements enhance the detectability of vertical gratings by displacing the vertical contours onto new retinal areas.

NOTE

1. The horizontal, rather than the vertical, grating was chosen to be held constant so as to eliminate any possible interactive

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