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Irrelevance of local position information in visual adaptation to random arrays of small geometric elements

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Abstract. Experiments were carried out to test whether spatial relationships between local pattern features are important in the production of pattern-specific visual adaptation effects. Evidence was found for sensitivity to the shape of local pattern features, but not to their relative positions. These findings are contrasted with recent results for texture discrimination where the visual system can make use of local position information.

1 Introduction

In a recent report in this journal, Julesz and Caelli (1979) discussed the role of Fourier decomposition in visual texture perception. The authors point out that there is agreement between the early measurements of texture discrimination (Julesz 1962, 1975; Julesz et al 1973) and some measurements of grating adaptation effects (Pantle and Sekuler 1968; Blakemore and Campbell 1969; Graham and Nachmias, 1971) in that the visual system appears to show insensitivity to phase ('spatial position') information in the stimulus patterns. The authors go on to cite later texture discrimination experiments (Caelli and Julesz 1978; Caelli et al 1978) for which this result does not hold. They conclude that "... the visual system for the relatively simple task of preattentive texture perception *can* utilize the phase (position) information, but most likely *not* in the form of *global* Fourier phase spectra in which the conspicuous local spatial information is submerged. Instead, it seems more likely that the positional information is evaluated by averaging the output of many local, nonlinear analyzers tuned to specific geometrical features" (Julesz and Caelli 1979, p 72).

Whereas we do not disagree with the conclusions of Julesz and Caelli concerning the nature of the processes underlying texture discrimination, we suggest that an analogous conclusion for the mechanisms subserving form-adaptation effects is unlikely to be true. We have performed pattern-adaptation experiments with random arrays of small geometric figures somewhat similar to those used by Caelli et al (1978) and we find that, although there is adaptational sensitivity to the *shape* of local pattern features, there is no such sensitivity to the *relative positions* of these pattern features. Beck has also argued that, in the peripheral discrimination of line figures, there is a diminished sensitivity to local position information (Beck 1972; Beck and Ambler 1973).

2 Method

The test and adaptation stimuli used in these experiments are illustrated in figure 1. (The figure contrast is reversed: the stimuli were brighter than their backgrounds.) Figure 1a shows the test stimulus, a single T-shaped figure composed of two $20' \times 3'$ orthogonal bars on a uniform 15° diameter background. The four fixation marks formed a $3\cdot5^\circ \times 3\cdot5^\circ$ square. Figures 1b and 1c show the two main patterned adaptation fields. In figure 1b copies of the T-shaped test figure are distributed over the 15° diameter field with coordinates determined by a randon-number generator such that the centres of any two copies were not closer than 40′. In figure 1c the component bars of the T-shaped test figure are independently distributed over the 15° diameter field under a similar regime. The total numbers of bars of each orientation in figures 1b and 1c are the same. In figure 1d the area and position of each dot coincides with that of the corresponding T-shaped figure in figure 1b. A 15° diameter uniform field was used as a control. The mean spatial luminances of the patterned adaptation fields and the test-stimulus background field were each photometrically equated to the uniform adaptation field.

The main experiment concerned the threshold-elevation effect for detection of the T-shaped test figure after the observer has adapted to the connected-bar pattern of figure 1b or to the disconnected-bar pattern of figure 1c. The rationale of the comparison of these effects is this. Figure 1b has the same local pattern features and the same local position information relating these features as the test figure; figure 1c has the same local features as the test figure, but, because none of the bars are connected and because their positions are completely randomised with respect to each other, the average local position information, to a good approximation, is zero. The experiment thus determines the relevance of local position information by testing whether its *removal*, as distinct from merely a change in its *value*, affects threshold.

The stimulus patterns were drawn by a computer-controlled plotter and photographed onto high-contrast Kodalith film. These film masks were viewed by means of a conventional four-channel Maxwellian-view optical system. The first channel provided the test stimulus, the second the test-stimulus background field, the third the adaptation field, and the fourth a reference channel for light-level monitoring. The single light source was a tungsten–halogen lamp run from a stabilised DC power supply. The intensities of the channels were controlled by neutral-density filters and a compensated neutral-density wedge. The retinal illumination of the uniform field was set at 4·0 log td; that of each of the elements of each of the patterned adaptation

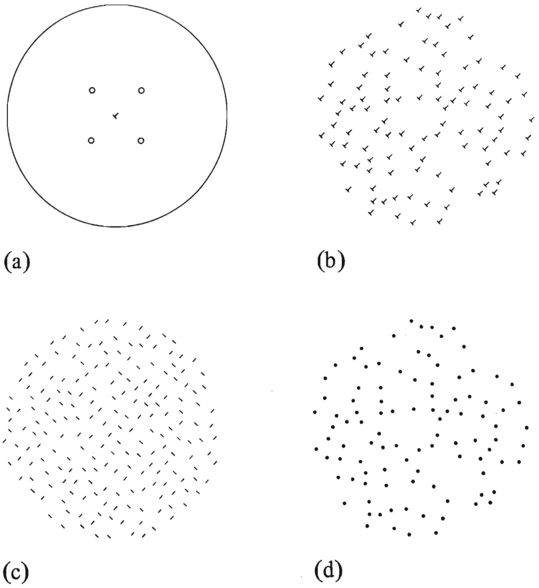

Figure 1. Test and adaptation patterns: (a) T-shaped test figure surrounded by four fixation marks; (b) connected-bar adaptation pattern; (c) disconnected-bar adaptation pattern; (d) dot adaptation pattern. The dimensions of each bar in (a), (b), and (c) were 20′ × 3′; the diameter of each dot in (d) was 13′. The stimuli were brighter than their backgrounds.

fields was 5·7 log td. The colour temperature was 3500 K. The time course of the stimuli was determined by electronically controlled electromagnetic shutters which interrupted the beams at intermediate foci. The rise and fall times of the stimuli were each not more than 3 ms. The timing of the channel changeovers was adjusted so that any transient fluctuations in the total luminous flux measured at the eyepiece were less than 1% of the mean. A dental bitebar was used to steady the subject's head. The stimuli were viewed monocularly through a 2 mm artificial pupil with the right eye.

To minimise localised retinal adaptation by the adaptation field (Smith 1977), an irregular saccade-like displacement of the field was introduced by a rotating cam that moved a small negative lens at the eyepiece. The profile of the cam was engineered so that as it performed one full rotation lasting 2 s, the adaptation stimulus occupied twelve distinct positions in the visual field. The mean displacement magnitude was set at either 0·7° or 1·1°. The mean duration of each stationary phase was 138 ms and of each motion between stationary phases 29 ms. These rapid displacements of the adaptation stimulus could not be visually tracked by the subject. The test stimulus was at all times stationary.

The experimental procedure was as follows. At the beginning of each session the subject dark-adapted for 10 min. The subject viewed the selected adaptation field (either patterned or uniform) for an initial 2 min period (Blakemore and Campbell 1969). The test stimulus and adaptation field were then presented in an alternating sequence in which the test figure was exposed for 2 s, and the adaptation field for 20 s. Subjects moved their gaze randomly over the adaptation field. The luminance of the test stimulus was adjusted by the subject so that it was just detectable and the final threshold setting was approached from subthreshold values. Each threshold setting involving a patterned adaptation field was preceded and followed by a similar measurement made with the uniform adaptation field. The elevation in test stimulus threshold (in log units) due to a patterned adaptation field was expressed as the difference between the threshold level obtained with the patterned adaptation field and the mean of the two threshold levels obtained with the uniform adaptation field(1). The order of testing of the two patterned adaptation fields, e.g. figures 1b and 1c, was adjusted to form a crossover design balanced for order and carryover effects (Finney 1960). Each subject made, in all, twelve determinations of the effect of each patterned adaptation field on test-stimulus threshold.

There were three subjects: ATS, and the authors DHF and RJM. Each was experienced at making psychophysical measurements. ATS was unaware of the purpose of the experiment.

3 Results

Figure 2 shows the effect of adaptation to the connected-bar and disconnected-bar patterns of figures 1b and 1c. Threshold of the test stimulus is raised by about 0·2 to 0·3 log units, depending on the subject. There is no significant difference between the effects of the two types of adaptation field (for each subject, $p > 0\cdot 1$).

It might be suggested that the results of figure 2 are an artifact of the particular adaptation paradigm used here, and that any spatially nonuniform adaptation fields of the same mean luminance would give the same threshold elevation. We accordingly performed a control experiment in which the effect of the connected-bar adaptation pattern of figure 1b was compared with the effect of the dot adaptation pattern of figure 1d. Results are shown in figure 3. For each subject, the dot adaptation

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(1) This procedure was found necessary as test-stimulus thresholds measured for the uniform adaptation field condition were observed to drift by an average of 0·2 log units in each run. Some discussion of the temporal variability of thresholds is given by Wertheimer (1953) and Home (1978).

pattern has significantly less effect in elevating test-stimulus threshold than does the connected-bar adaptation pattern ($p < 0{\cdot}01$)(2). Evidently, the present adaptation paradigm does reveal adaptational sensitivity to the shape of local pattern features.

Thus, in contrast to the findings of Caelli and Julesz (1978) and Caelli et al (1978) for texture discrimination, the results of the present study indicate that in the present paradigm the visual system is *not* adaptationally sensitive to local spatial information relating the position of one local pattern feature to another local pattern feature. It is of course possible that other more complex juxtapositions of pattern elements may reveal adaptational sensitivity to spatial relationships. We have, however, found results similar to those reported here for L-shaped figures and for obtuse-angled chevrons. It is also possible that the mechanisms adapted by pattern fields undergoing saccade-like displacements are not the same as those adapted by stationary pattern fields viewed with freely moving gaze. In preliminary experiments with stationary versions of the adaptation fields used in the present work, we did find evidence of a differential effect of connected-bar and disconnected-bar stimuli. But, because of the high localised retinal illumination, it seems plausible that this differential effect originates

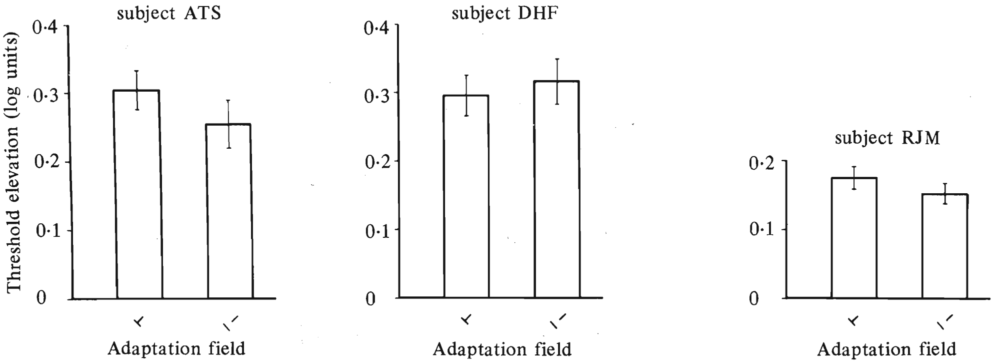

Figure 2. Threshold elevation of T-shaped test stimulus after adaptation to the connected-bar pattern of figure 1b and to the disconnected-bar pattern of figure 1c. The adaptation field is indicated in each case by a typical element. Each reading is the mean of twelve determinations and the vertical bars correspond to ±1 S.E.M.

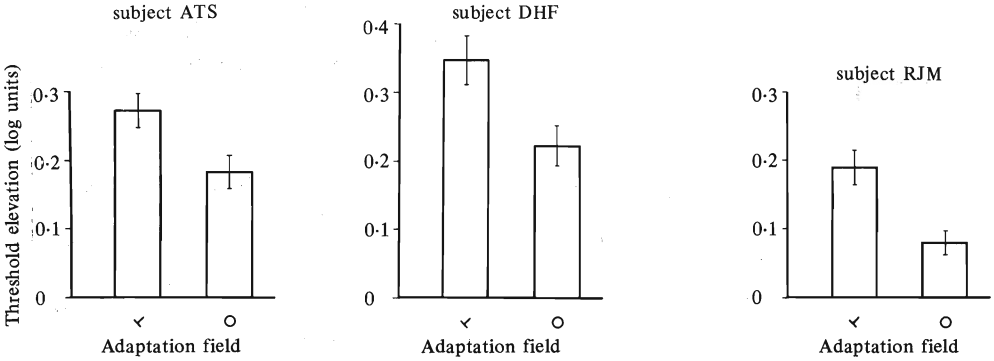

Figure 3. Threshold elevation of T-shaped test stimulus after adaptation to the connected-bar pattern of figure 1b and to the dot pattern of figure 1d. The adaptation field is indicated in each case by a typical element. Each reading is the mean of twelve determinations and the vertical bars correspond to ±1 S.E.M.

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(2) The fact that the dot adaptation field produces an adaptation effect for the T-shaped test stimulus may be attributable to a residual edge or area factor common to the two figures. This result does not affect the conclusions of the study.

in purely retinal adaptation that is not countered by the voluntary movement of the subject's fixation. (In this stationary-pattern paradigm prolonged afterimages were apparent on some occasions.) The other standard method of reducing retinal adaptation, namely counterphase modulation, is unlikely to be useful here, since Virsu and Laurinen (1977) have shown that this procedure can also give rise to long-lasting afterimages.

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