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RESEARCH NOTE

IS SPATIAL ADAPTATION CAUSED BY PROLONGED INHIBITION?

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Prolonged viewing of a grating raises the threshold for detecting gratings of similar orientations (Gilinsky, 1968) and spatial frequencies (Pantle and Sekuler, 1968; Blakemore and Campbell, 1969). It has been suggested that adaptation is caused by prolonged inhibition of the detection channels and not by neural fatigue (Blakemore, Carpenter and Georgeson, 1971; Tolhurst, 1972; Blakemore, Muncey and Ridley, 1973; Kulikowski and King-Smith, 1973; Kulikowski, Abadi and King-Smith, 1973; Sharpe, 1974; Dealy and Tolhurst, 1974). Two arguments have been advanced by these authors for this view.

The first maintains that the narrow bandwidths obtained with threshold summation of sine-wave gratings (Sachs, Nachmias and Robson, 1971; Kulikowski and King-Smith, 1973; Kulikowski *et al.*, 1973) reflect the range over which channels can be *excited*. The bandwidths obtained with adaptation (Blakemore and Campbell, 1969) and masking (Campbell and Kulikowski, 1966; Stromeyer and Julesz, 1972), being considerably broader, are claimed to reflect the spread of *inhibition* between channels. Recent studies on threshold facilitation (Stromeyer and Klein, 1974; Nachmias and Weber, 1975; Barfield and Tolhurst, 1975), the detectability of frequency modulated gratings (Stromeyer and Klein, 1975), and probability summation (King-Smith and Kulikowski, 1975) suggest that gratings may *not* be detected by narrow-band mechanisms. Thus, it is not clear that there is a discrepancy between bandwidths obtained with adaptation and other methods.

A second argument that adaptation is caused by inhibition between channels and not by fatigue was presented by Dealy and Tolhurst (1974) who showed that when a 4.0 c/deg adapting grating just reached its visible threshold it started to raise the threshold of a subsequently presented, 6.7 c/deg test grating (3/4 octave higher than the adapting pattern). The authors argue that the contrast of the adapting grating was below the threshold of the channel peaked at the test frequency and therefore the threshold rise was caused by prolonged inhibition of this channel by the channel directly excited by the adapting grating. The authors also observed that when the contrast of the 4.0 c/deg grating was only 3 or 10%, the threshold rise at 6.7 c/deg was *large*—the adapted threshold was about 100% higher than the unadapted threshold.

Several years ago we did experiments similar to those of Dealy and Tolhurst, but with very different results. This led us to repeat some of their experiments. Vertical sine-wave gratings were displayed on a CRT (P-4 white phosphor) that provided a field 4.5° dia of *constant* mean luminance (8.0 cd/m^2) with a dark surround. Fine diagonal cross-hairs were placed across the field to aid focusing. The gratings were presented in a repeating sequence: 5 sec exposure to the adapting grating; 3 sec test period, during which the observer pressed a button that presented the test pattern for 750 msec. Each run consisted of 100 trials with 5 min initial adaptation. For each run one test pattern was used; it was presented at four contrast values (including blanks) that occurred with equal probability according to a random schedule. The observer rated every test on a whole number scale of 1–5 as to how certain he felt that a pattern had been presented (Egan, Schulman and Greenberg, 1959). After each response, the observer was told that the test event had been a "blank", or a "low", "middle", or "high" contrast pattern. Receiver operating characteristics were fitted to the ratings by a maximum likelihood estimation to determine the detectability, d', of each test pattern (Stromeyer and Klein, 1975). Seven parameters were required to fit each run: the three values of d' for the three contrast levels, and four criterion levels separating the five response categories. Since each condition was repeated more than once we allow for possible variations in criteria between the runs, but assume that the d' values are unchanged. Thus a condition with five runs would have 5×4 criterion levels plus 3 d' values as free parameters.

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For the first experiment, the adapting pattern was presented in random counterphase, viz. the grating appeared in an arbitrary phase position for 20–60 msec and then appeared for an equivalent time with contrast reversed, after which the sequence was repeated at another randomly chosen phase position [The stimulus was designed (Stromeyer, Spillman, Klein and Dawson, in preparation) to prevent local retinal adaptation or afterimages in studying spatial adaptation at very low spatial frequencies where eye movements during fixation are small relative to the spatial period of the grating.] The test stimulus in each run was either 3.6, 6.0, or 10.0 c/deg. Figure 1 shows d' values for observer SK for each of these test gratings as a function of test contrast. Open and closed circles show, respectively, results for adaptation to a blank field and a grating of 6.0 c/deg and 40% contrast. Each curve is based on 2 or 3 runs. The detectability of the 10.0 c/deg grating (3/4 octave above the adapting frequency) is unaffected by adaptation; the 3.6 c/deg grating (3/4 octave below the adapting frequency) is significantly affected. Dealy and Tolhurst found a large threshold rise for a test grating 3/4 octave above the adapting grating (adapting and test gratings of 4.0 and 6.7 c/deg), whereas the present results show no threshold change using a similar ratio. The asymmetry in our results, wherein the test grating lower than the adaptation frequency is more affected than the test grating higher than the adaptation frequency, resembles the asymmetry observed in other studies of spatial adaptation (Blakemore and Campbell, 1969) and masking (Stromeyer and Julesz, 1972; Nachmias and Weber, 1975; Henning, Hertz and Broadbent, 1975).

We also made extensive measurements with stimuli like those used by Dealy and Tolhurst, viz. a stationary 4.0 c/deg adapting grating, and test gratings of 4.0 and 6.7 c/deg. The field size was 6.2° wide and 4.5° high and the mean luminance, 7.0 cd/m^2. Other details are the same as in the previous experiment.

Figure 2 show d' values of the 4.0 c/deg test grating as a function of test contrast. Circles and squares show results for observer CES and CFS, respectively. Open symbols show the detectability of the test grating upon adapting to a blank field; closed symbols, the detectability upon adapting to a grating of 4.0 c/deg, of 10 and 30% contrast for observer CFS and CES, respectively. Figure 3 shows d' values for the 6.7 c/deg test grating under similar adaptation conditions. The 4.0 c/deg adapting grating produces a considerable change in the detectability of the 4.0 c/deg test grating and little change in the detectability of the 6.7 c/deg. For a given test spatial frequency, the runs were done in counterbalanced pairs: in one run the observer adapted to the blank field; in the other run the observer adapted to the adapting grating. For both observers, the results for the 4.0 and 6.7 c/deg test gratings are based on 2 and 5 pairs, respectively.

Figure 4 shows results when the adaptation period was increased from 5 to 20 sec. The adaptation grating was 4.0 c/deg and 10% contrast for observer CFS (solid squares) and 30% contrast for observer CES (solid circles); the testing grating was 6.7 c/deg. The results for each observer are based on 5 pairs of runs with 50 test trials per run. Again, adaptation pro-

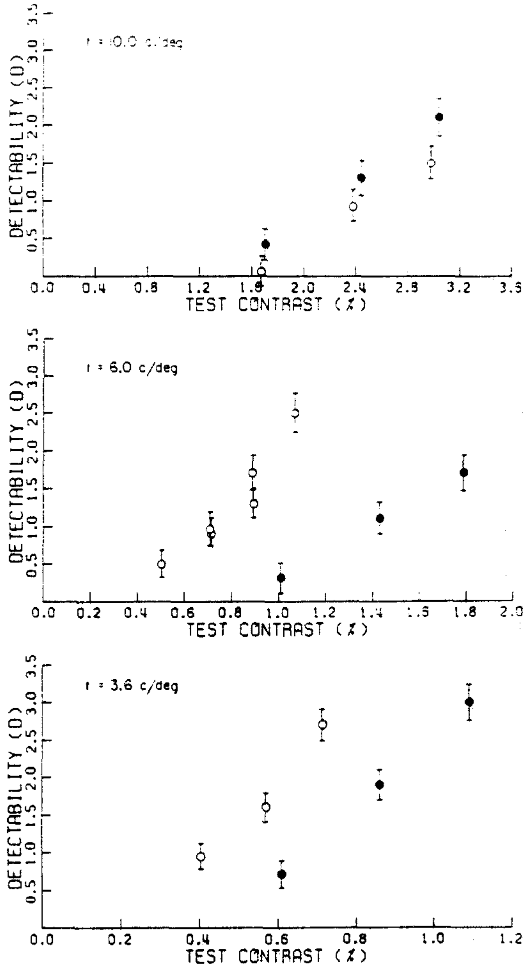

Fig. 1. The d' values for test gratings of different spatial frequencies (t) as a function of test grating contrast. Open circles, adaptation to a blank field; closed circles, adaptation to a random counterphase grating of 6.0 c/deg and 40% contrast. Bars are ±1.0 S.E. of mean. Observer SK.

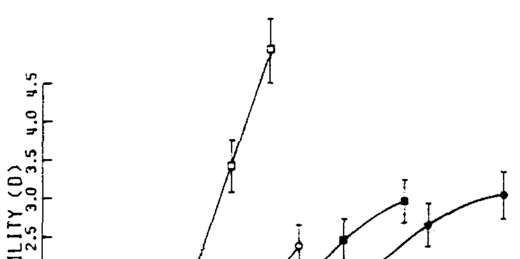

Fig. 2. The d' values (and ±1.0 S.E. of mean) for a test grating of 4.0 c/deg as a function of the test grating contrast. Circles and squares are data for observers CES and CFS, respectively. Open symbols, adaptation to a blank field; closed symbols, adaptation to a grating of 4.0 c/deg and 10 and 30% contrast for CFS and CES, respectively.

duced little threshold elevation at the 6.7 c/deg test frequency.

Dealy and Tolhurst used a field whose luminance was 150 cd/m^2. Our field was 7.0 cd/m^2. Figure 5 shows results for observer CFS when the luminance was increased to 70 cd/m^2. The adapting and test periods were 10 and 3 sec, respectively; the adaptation pattern was 4.0 c/deg and 20% contrast; the test pattern was 6.7 c/deg. The results are based on 3 pairs of runs with 100 trials per run. Again adaptation produced little threshold elevation at the 6.7 c/deg test frequency.

Dealy and Tolhurst used the method of adjustment. We have also used this method. Stimuli were presented in a sequence: 20 sec adaptation period, 10 sec test period during which the observer adjusted a potentiometer so that the test pattern was just visible. For each run, the adapting pattern was a blank field (7.0 cd/m^2) or a 4.0 c/deg grating of 10% contrast for CFS, or 30% contrast, CES. The test pattern was 6.7 c/deg. There was 5 min initial adaptation to this sequence, after which 10 threshold settings were made. The threshold rise is expressed as the percentage increase in the test contrast settings caused by the adapting grating (relative to settings made while adapting to the blank field). The threshold rise for CFS was 19% (based on 4 counterbalanced pairs); for CES, it was 8% (2 pairs).

Our results show that adapting to a grating of 4.0 or 6.0 c/deg produces very little change in the visibility of a grating that is 3/4 octave higher in spatial frequency. Dealy and Tolhurst, in contrast, found a large threshold rise for gratings separated by this ratio. Our results, however, appear to be quite similar to the results obtained in other studies, as summarized in Table 1. In these studies the spatial frequency of the adapting pattern was held constant and the test pattern was varied in spatial frequency, or vice versa. The adapting contrast is given in the middle column. For studies in which the *test* frequency, F_T, was held constant, denoted by *, we have tabulated (right column) the ratio of the threshold elevation (given by per cent increase in threshold contrast) produced by an adapting pattern 3/4 octave lower than F_T relative to the threshold elevation produced by an adapting pattern at F_T. Since the patterns did not always have an exact 3/4 octave separation, we interpolated values for this separation. Alternatively, for studies in which the *adapting* spatial frequency was held constant, the threshold elevation at F_T (left column) was tabulated (right column) relative to the threshold elevation for a test pattern at the same spatial frequency as the adapting pattern—3/4 octave below F_T. Except for the studies by Graham (1972) and Dealy and Tolhurst (1974) the results tabulated in Table 1 show that a pattern at F_T is little affected by an adapting pattern 3/4 octave lower.

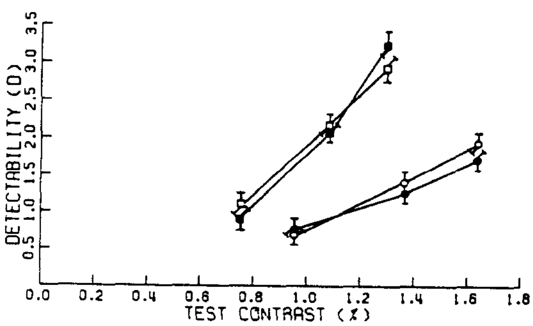

Fig. 3. Conditions similar to Fig. 2 but with the test grating spatial frequency raised from 4.0 to 6.7 c/deg.

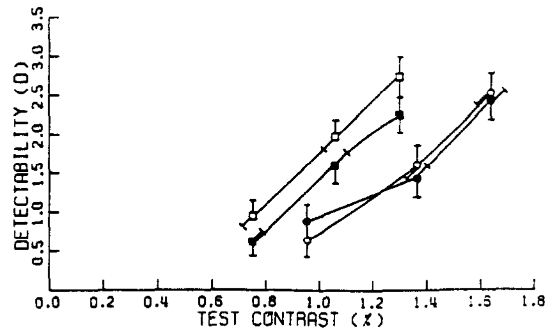

Fig. 4. Conditions similar to Fig. 3 (adaptation 4.0 c/deg; test 6.7 c/deg) but with the adaptation period lengthened to 20 sec and the test period maintained at 3 sec.

Even if near-threshold adapting gratings were to slightly increase the threshold for detecting gratings at a different spatial frequency, this would not necessarily support the view that adaptation is caused by inhibition between channels. A simpler model could also explain such a result, as suggested by Stecher, Sigel and Lange (1973). Perhaps the detection of a grating is based upon the response of a range of spatial frequency mechanisms (not by just the mechanisms peaked at the adapting frequency); some of these mechanisms may be fatigued by adaptation, thus causing the threshold rise. It would be most surprising to find strong inhibition between channels that are being stimulated near threshold.

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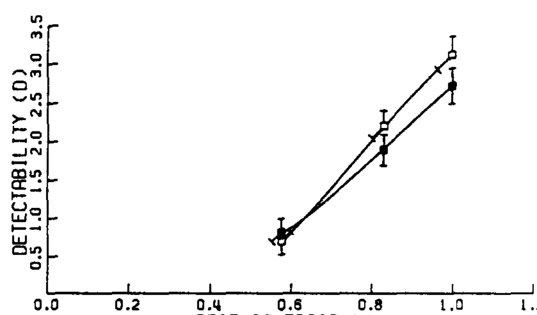

Fig. 5. The d' values for a test grating of 6.7 c/deg as a function of the test grating contrast. Open squares, adaptation to a blank field; closed squares, adaptation to a grating of 4.0 c/deg and 20% contrast. Adaptation period, 10 sec; test period, 3 sec. Mean luminance, 70 cd/m^2. Observer CFS.

Table 1.

		F_T (c/deg)	C_A (%)	Threshold elevation ratio (see text)
Blakemore and Campbell (1969, Fig. 7, adapt. 3.5 c/deg)		5.9	15	0.15
Dealy and Tolhurst (1974)		6.7	10–30	0.5
*Graham (1972, Fig. 2)		5.5	80	0.4
		7.5	80	0.3
*Maudarbocus and Ruddock	O AYM	6.1	100	0.15
(1974)	O SN	6.1	100	0.15
*Maudarbocus and Ruddock	O AYM	6.0	100	0.15
(1973a, dichoptic)	O SN	6.0	100	0.25
*Maudarbocus and Ruddock		6.1	100	0.15
(1973b, dichoptic)		12.2	100	0.15
Nachmias *et al.* (1973)	O RS	5.4	41	0.2
	O AV	5.4	41	0.2
*Stecher *et al.* (1973)		13.3	3–30	<0.2
Tolhurst (1973, Fig. 5)		6.7	31	0.15
This study		6.7	10 or 30	0.1

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