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ADAPTATION TO GRATINGS: NO COMPENSATORY ADVANTAGES FOUND

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Abstract—Psychophysical measurements were made following adaptation to gratings in order to test the hypothesis that adaptation to patterned features of visual stimulation serves a function analogous to the changes in retinal function during light and dark adaptation. No improvements in detecting changes of spatial frequency, orientation or contrast were found.

What is the functional significance of adaptation to gratings? The neural changes that occur in the retina when the eye adapts to higher or lower luminances of steady background have two advantageous functional effects that are quite readily understood. First, the maintained discharge does not rise unduly with adapting luminance in on-centre units, nor fall unduly in off-centre units, and its variability stays rather constant (Barlow and Levick, 1969); thus the dynamic range of the system is well centred on the mean luminance of the adapting scene at all levels. Secondly, the development of lateral inhibition at higher backgrounds results in the accentuation of high spatial frequencies relative to low, and the temporal contrast sensitivity function is also transformed from a low-pass, high-cut characteristic to a band-pass characteristic; improved contrast sensitivity at high spatial and temporal frequencies clearly increases the total amount of information signalled centrally from the image.

Adaptation occurs to pattern features of the visual image as well as to the mean luminance, and the effects of adapting to gratings are particularly striking (Gilinsky, 1968; Pantle and Sekuler, 1968; Blakemore and Campbell, 1969). Since the after-effects of adaptation transfer readily from one eye to the other the mechanisms giving rise to them are probably in the visual cortex. The question naturally arises whether they confer any advantages comparable to those of retinal adaptation to luminance. A grating can be defined by three parameters, spatial frequency F, orientation O, and contrast C; the phase varies with fixation position of the eye and hence cannot usually be specified. By analogy with the retina it was thought possible that adaptation would improve discrimination between test gratings with parameters close to those of the adapting grating. Some support for this derives from the fact that the apparent frequency and orientation of a test grating are shifted away from the frequency and orientation of a previously exposed adapting grating (Blakemore, Nachmias and Sutton, 1970), so that the scales of apparent frequency and orientation are expanded or magnified in the neighbourhood of the adaptation parameters. Similarly, although the threshold contrast sensitivity is depressed at the adapting frequency and orientation, it seemed possible that changes of contrast are better detected following adaptation. Discriminations of contrast (ΔC), frequency (ΔF), and orientation (ΔO) were therefore measured. We found no improvement, and the purpose of this note is to report briefly the conditions for these negative results in the hope that this will provoke others to look for and report any beneficial consequences of cortical adaptation.

(I) CONTRAST DISCRIMINATION

Blakemore, Muncey and Ridley (1973) demonstrated that the threshold elevation following adaptation to a high contrast grating is continued above threshold as a suppression of apparent contrast. The authors remarked that contrast discrimination might be improved in this way by grating adaptation. This effect might be substantial if, analogous to the shifts in orientation and spatial frequency mentioned above, a corresponding *enhancement* of test contrasts higher than the adapting contrast could be found. This possibility was ruled out, however, by repeating Blakemore *et al.*'s (1973) experiment with lower adapting contrasts, so that the observations could be extended to test contrasts above the adaptation level; no enhancement was found.

Actual contrast discrimination was measured both by presenting two contrasts side-by-side as well as by alternating their presentation in time. In the first experiment a vertical test grating (6 c/deg) was vertically split; its left and right halves could differ slightly in contrast from each other and from the adapting field. It was presented in flashes of duration 0.6 sec. The phase of the adapting grating was reversed at 1 sec intervals as an insurance against afterimages and the grating was exposed continuously except for the brief test exposures, which occurred every 7 sec. To help the subject distinguish the test grating from the adapting one, and to eliminate unwanted cues or masking effects produced by transients, we found it

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useful to interpolate a uniform (zero contrast) field of 0.3 sec duration between the adaptation and test gratings.

For subject MMH the split-field contrast difference threshold (75% correct, method of constant stimuli) obtained under adaptation to the grating did not differ significantly from the value obtained with prolonged adaptation to a uniform field. For AVM there was a statistically significant detrimental effect of adaptation: exposure to the adapting grating increased his contrast difference threshold by about 20%.

Next we arranged a temporal contrast discrimination experiment. A 6 c/deg grating was presented over the whole 5° field and its contrast was changed once/sec from 0.50 $(1 + m)$ to 0.50 $(1 - m)$; the subject's task was to detect the alternation. This test-grating was presented periodically for 5 sec followed by a 25 sec adapting interval during which either a uniform field was presented, or the grating was presented continuously but m was set to zero. The threshold value of m proved to be slightly higher, rather than lower, in the adapted condition for two observers (HBB and AVM).

Finally it was thinkable that adaptation to a grating might be advantageous for the detection of superimposed stimuli of quite different types. One might wonder, for instance, whether the detection of a grating with spatial frequency w_1 superimposed over a high contrast grating with spatial frequency w_2 is improved by preadaptation to the latter grating. We found that adaptation to a 5 c/deg grating with a contrast of 0.50 did not significantly reduce the masking effect caused by this grating upon the detection of a 13.5 c/deg grating (observers HBB and AVM, method of adjustments). Similarly, adaptation to a 9.5 c/deg grating did not alter the masking effect upon the detection of a 3 c/deg grating (observer AVM). Also, the detection of a 0.9° wide vertical bar, masked by a 13.5 c/deg vertical grating, was not improved by preadaptation to that grating (observers HBB and AVM).

In summary, we found no evidence that grating adaptation improves the detection or discrimination of contrast of test targets either when they resemble the adapting target, or when they do not.

(2) FREQUENCY DISCRIMINATION

The split-field technique described above was applied to frequency discrimination by arranging a grating of frequency 6 $(1 + m)$ c/deg on the left hand side of the test field and one of 6 $(1 - m)$ c/deg on the right; m could be positive or negative. The contrast was 0.5 on both sides. Four subjects gave forced-choice frequency-difference thresholds of roughly $m = 0.02$, with or without adaptation to a 6 c/deg grating. Once again the slight and statistically insignificant differences found tend to suggest that adaptation was deleterious rather than beneficial.

In other experiments designed to see whether adaptation produces any benefits too subtle to reveal themselves in threshold measurements, the adapting grating filled only the upper (or sometimes the lower) half of the centrally fixated field and the other half was uniform. Both in frequency and in contrast discrimination, the four subjects found that discrimination between left and right halves of the test field was at least as difficult (and often more difficult) in the adapted region as in the unadapted region.

(3) ORIENTATION DISCRIMINATION

The subject inspected a 6 c/deg sine wave grating of contrast 50% for 3–4 min, then started a computer program that delivered the following sequence of stimuli: a dot flashed as a signal for the subject to fixate the screen, then two lines appeared on the screen either nearly parallel to the grating lines, or orthogonal to them, in alternation. The lines were 50 min long and separated by 1/6 deg, and their divergence assumed one of five values, selected at random with the constraint that exactly 20 of each divergence were presented. These lines were displayed for 1 sec, then the subject indicated which end was diverging, or if he thought they were parallel, and then looked back at the adapting grating for 10 sec, when the next signal dot flashed on. The cycle was repeated until 100 or 200 test flashes had been presented. If the subject failed to fixate, or blinked, he could omit a trial. The proportions judged diverging in the two directions were subjected to probit analysis (Finney, 1971), and the reciprocal of the slopes of the regression lines taken as estimates of the standard deviations of the judgements "diverging to left", or "diverging to right". In addition the standard deviation of the divergences judged to be parallel was calculated. No significant change of orientation acuity was found.

CONCLUSIONS

In spite of the expanded scale of subjective frequency and orientation following adaptation to a grating we were unable to find any corresponding improvement of discrimination. Similarly we found no evidence for improved detectability of contrast change. Our conclusion is that, if there are any beneficial results of adaptation on discrimination, they are very small or occur under conditions we have not tested.

Adaptation could reduce the distracting effect of a stimulus that is constantly present, thereby giving greater prominence to a novel or changed stimulus. A more promising suggestion is that of Georgeson and Sullivan (1975), who propose that adaptation equalizes the suprathreshold apparent contrast of different spatial frequencies. Thus it is supposed to compensate for the unequal demodulation of different frequencies caused by optical and neural factors, and it would be a nice example of the error-correcting perceptual mechanisms postulated by Andrews (1964). But they have not found a task which can actually be shown to be performed better as a result of adaptation. Can anyone do so? There are in the literature a few data points suggesting improved performance, but is this improvement consistently attainable? Is it large enough and does it occur under such conditions as to have significant survival value? If not, we may be forced to conclude that adaptation to patterned stimuli is a deleterious result of processes such as ionic depletion, transmitter exhaustion, or "fatigue", with no advantageous consequences.

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