Vision Res. Vol. 26, No. 4, pp. 673–675, 1986
Printed in Great Britain. 

0042-6989/86 $3.00 + 0.00


# RESEARCH NOTE

# CONTRAST THRESHOLD ELEVATION FOLLOWING CONTINUOUS AND INTERRUPTED ADAPTATION

SVEIN MAGNUSSEN* and MARK W. GREENLEE
Neurologische Universitätsklinik mit Abteilung für Neurophysiologie, Hansastrasse 9, D-7800 Freiburg im Breisgau, F.R.G.

(*Received* 15 *October* 1985)

**Abstract**—Contrast thresholds for a 6 c/deg sinewave grating were measured following continuous and interrupted adaptation of 10 min duration to a high-contrast (0.6) sinewave grating of the same spatial frequency. Interrupted adaptation was administered as five 2-min segments, and the interadaptation interval (IAI) was varied from 10 to 180 sec. The results indicate that adaptation to spatial contrast can be described by a two-staged process, each stage having a different time constant of adaptation decay.

Psychophysics Grating adaptation Decay

The build-up and decay of spatial adaptation, as measured by tracking the changes in contrast thresholds to sinusoidal gratings following inspection of high-contrast gratings, is currently conceptualized as a fairly simple process, in terms of accumulation and dissipation of neural fatigue or inhibition among spatial frequency and orientation specific cortical channels (e.g. Dealy and Tolhurst, 1974; Braddick *et al.*, 1978; Swift and Smith, 1982; Georgeson and Harris, 1984). It seems implicitly assumed that the amount of threshold elevation at any time is a fairly straightforward measure of the state of fatigue or inhibition induced by the adaptation procedure, so that for example thresholds of equal values measured during build-up and decay are believed to be equivalent indications of the underlying physiological state. We shall call this a single process theory of adaptation.

As part of a larger study, we measured the summation of aftereffects established by continuous and interrupted adaptation to the same stimulus, keeping total adaptation time constant but varying the interval between successive adaptation segments. The results indicate that contrast thresholds measured following additional adaptation in an interrupted adaptation schedule cannot be predicted by simply determining the amount of decay occurring in the blank interval. This suggests that build-up and decay are controlled by partly independent processes.

Method and general procedure have been described in an earlier paper (Magnussen and Greenlee, 1985). Briefly, a 6.0 c/deg adapting grating of mean luminance 30 cd/m$^2$ and 0.6 contrast, subtending $11 \times 16$ degrees visual angle, was produced by back-projection on a translucent screen. During adaptation the subject scanned a 0.75 deg fixation circle in the center of the field. A test grating of the same spatial frequency and mean luminance but variable contrast, subtending $4 \times 5$ deg visual angle, was generated on a Tektronix 602 CRT by a Picasso image generator (Innisfree, Inc.). The test grating was switched on and off at a rate of 0.5 Hz. Contrast thresholds were measured by a modified method of adjustment where the experimenter varied test grating contrast via a ten-turn logarithmic potentiometer. The total adaptation time was fixed at 10 min and was administered as five 2-min adaptation segments with 0 (continuous adaptation), 10, 20, 40, 60, 120 and 180 sec interadaptation intervals (IAI); during the IAI the subject viewed a homogeneous field of the mean stimulus luminance. Beginning and end of individual adaptation segments were marked by an auditory signal. Following the last 2-min of adaptation, contrast thresholds were measured continuously during the recovery phase. The settings completed dur-

*Present address: Institute of Psychology, University of Oslo, Box 1094 Blindern, N-0317 Oslo 3, Norway.

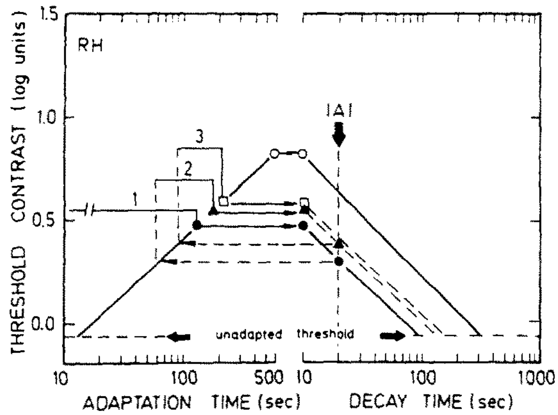


Fig. 1. Diagram illustrating the theoretical build-up of the threshold elevation aftereffect in repeated 2-min adaptation segments with 20 sec inter-adaptation intervals (IAI), as predicted by a single-process theory of adaptation. Solid gradients are regression lines fitted to the build-up data during 10-min adaptation (left panel) and the subsequent decay (right panel) (○), and decay following a single 2-min adaptation (●). The logic of the diagram is simple: the decay during the 20-sec IAI following the first 2-min adaptation phase brings the threshold down to a value corresponding to that reached after approximately 1 min adaptation, the second adaptation phase adds a 2 min (here, 0.48 log unit in time sec) effect to this value (▲, left panel), the subsequent decay occuring during the 20-sec interval reduced the threshold to a value corresponding to approximately 1.5 min adaptation (▲, right panel), the third adaptation segments adds another 2-min (here, however, only 0.37 log unit in time sec) increase to this value (□, left panel), etc. Thus, with increasing adaptation time the increment in threshold elevation caused by an additional 2-min of adaptation decreases in magnitude, although the amount of decay elicited by the 20-sec decay interval remains constant.

ing the first 10 sec after termination of adaptation define the initial threshold elevation. Each IAI condition was tested four times in random order. Each run was preceded by 10 preadaptation baseline settings of the contrast threshold.

Consider first Fig. 1 which illustrates the build-up of the aftereffect during repeated 2-min adaptation phases according to the logic of a single-process model of adaptation: if adaptation is resumed after a short decay interval, the growth of the aftereffect elicited by additional adaptation should depend upon the amount of residual adaptation there is following the decay interval. It follows that even very short IAIs would seriously slow down the growth process. Solid lines in Fig. 1 are regression lines fitted by least-squares method to observed data for subject R.H. (Fig. 3). The exponent of the power function describing the build-up and decay is invariant of adaptation time (Magnussen and Greenlee, 1985), for R.H. mean absolute exponent $= 0.55 \pm 0.01$. Shown here are the decay functions for a single 2-min adaptation and for 10 min continuous adaptation (●, ○) taken from Fig. 3. The diagram shows how the aftereffect should develop after the first (●), second (▲) and third (□) 2-min phase of adaptation assuming a 20-sec IAI. Additional adaptation has a rapidly diminishing effect, and a stable level should be attained when the amount of threshold rise during the 2-min adaptation phase equals the decay during the 20-sec IAI.

The diminishing effect of additional adaptation is due to the fact that adapting time is effective in a logarithmic fashion (e.g. Magnussen and Greenlee, 1985). It follows that after 300 sec of adaptation (i.e. 2.48 log units), an additional 600 sec ($0.3 + 2.48 = 2.78$ log units $= 900$ sec) of adaptation would be needed to compensate for the decrease occurring during a 20-sec decay interval (0.3 log units; 10 sec being the first value that can be measured with our methods). Irrespective of the number of readaptation phases the aftereffect in the 20-sec IAI condition should therefore not exceed a value of approx. 5 min continuous adaptation because 2 min adaptation segments can no longer compensate for the decay during the IAI.

Figure 2 shows for subject R.H. the magnitude of the initial threshold elevation as a function of IAI. The speckled horizontal columns indicate the threshold elevation $\pm 1$ SE following a single 2 min and 10 min continuous adaptation period, respectively; the diagonal

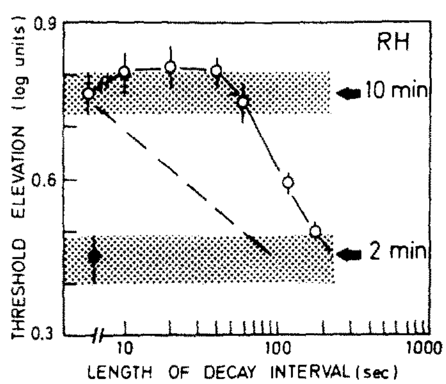


Fig. 2. Contrast threshold elevation following interrupted adaptation as a function of the length of the interadaptation interval ($n = 4$, vertical bars indicate $\pm 1$ SE). Horizontal arrows and shaded areas indicate the aftereffect of 2-min and 10-min continuous adaptation $\pm 1$ SE. Diagonal dashed line is a theoretical curve derived from a single-process theory of adaptation discussed in the text and depicted in Fig. 1. Results for subject R.H.

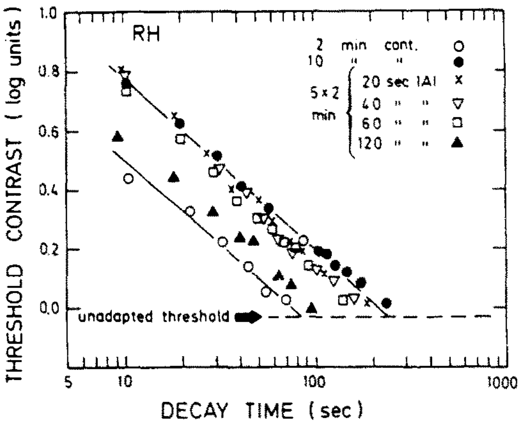


Fig. 3. Decay of the threshold elevation aftereffect (plotted on log–log axes) following continuous and interrupted adaptation as indicated in the figure. Parameter is the interadaptation interval (IAI). Results for subject R.H.

dashed line indicates the results expected on the basis of the single process theory as described in Fig. 1. The results (shown by open circles) do not conform to this prediction as no reduction in magnitude is observed until the IAI exceeds 60 sec. A plot of the complete decay functions for the various IAI conditions (Fig. 3) shows that in the interrupted-adaptation condition the aftereffects of IAI adaptation with a $<60$ sec IAI approach but do not significantly exceed the effects of 10 min continuous adaptation. An earlier experiment (Magnussen and Greenlee, 1985) shows that under identical conditions saturation of the aftereffect is first attained after 30–60 min continuous adaptation. As we are well below this figure, no ceiling effect is involved here.

In any case, it is clear that the results are very different from those expected on the basis of the single-process concept of spatial adaptation. Following a brief decay the aftereffect grows more rapidly during the next 2-min adaptation segment than would be expected if the same 2-min segment occupied the corresponding time position in the normal course of continuous adaptation. Thus additional build-up in adaptation produced in the course of continuous adaptation is not equivalent to the build-up caused by equal amounts of stimulus exposure following brief interruptions in adaptation. This must further mean that growth and recovery are controlled by at least partly independent mechanisms having different time-constants, indicating that a single process model of adaptation is inadequate. The results are, however, consistent with a two-process model of adaptation analogous to that proposed recently by Magnussen and Johnsen (1985) for the tilt aftereffect. This model assumes that adaptation occurs at two stages, serially connected; a first stage where recovery is very quick, and a second stage which recovers fairly slowly. The second stage provides output to spatial frequency and orientation detection, and controls the decay of the aftereffect. The effect of short rest pauses may thus be understood in terms of repeated gain adjustments, or resetting of the sensitivity of the first stage of adaptation.

*Acknowledgements*—S.M. was supported by the Alexander von Humboldt Foundation and the Norwegian Research Council for Science and the Humanities, and M.W.G. by the Deutsche Forschungsgemeinschaft (SFB 70, A6). The authors would like to thank L. Spillmann for providing laboratory facilities and for comments on the paper, and Rainer Hessenkamp for serving as a subject.

## REFERENCES


Braddick O., Campbell F. W. and Atkinson J. (1978) Channels in vision: Basic aspects. In *Handbook of Sensory Physiology* (Edited by Held R., Leibowitz H. W. and Teuber H.-L.), Vol. VIII, pp. 3–38. Springer, Berlin.

Dealy R. S. and Tolhurst D. J. (1974) Is spatial adaptation an after-effect of prolonged inhibition? *J. Physiol.* **241**, 261–270.

Georgeson M. A. and Harris M. G. (1984) Spatial selectivity of contrast adaptation: models and data. *Vision Res.* **24**, 729–741.

Magnussen S. and Greenlee M. W. (1985) Marathon-adaptation to spatial contrast: saturation in sight. *Vision Res.* **25**, 1409–1411.

Magnussen S. and Johnsen T. (1986) Temporal aspects of spatial adaptation. A study of the tilt aftereffect. *Vision Res.* **26**, 661–671.

Swift D. J. and Smith R. A. (1982) An action spectrum for spatial-frequency adaptation. *Vision Res.* **22**, 235–246.