Acta Psychologica 48 (1981) 5–13
North-Holland Publishing Company

DETECTION AND DISCRIMINATION OF MOVING GRATINGS

Peter THOMPSON *

University of York, UK

Two techniques are described which have been used to investigate mechanisms underlying the perception of velocity. The first, subthreshold summation establishes detection thresholds of two gratings of different spatial frequencies moving at the same velocity and also the detection thresholds of combinations of these gratings. The second technique employed a detection/discrimination procedure which establishes the discriminability of two different moving gratings at detection threshold. These experiments suggest that at low velocities the detection of 2 and 6 cycle/degree gratings is mediated by independent mechanisms, this independence being diminished at higher velocities. Gratings of 2 cycles/degree but moving at different velocities are only discriminably different at detection threshold when widely separated in velocity.

Introduction

In recent years a good deal of evidence has been shed upon the nature of direction selective mechanisms in the human visual system. Levinson and Sekuler (1975), in one of the most influential papers in this field in the past decade, employed no fewer than four different psychophysical techniques in establishing that opposite directions of movement are detected by independent mechanisms at detection threshold,

More recently Watson *et al.* (1980) have examined the range of stimuli for which opposite directions are detected independently. First, as Levinson and Sekuler had done, they examined the subthreshold summation of two gratings of equal spatial frequency and contrast moving in opposite directions. Secondly, they compared the detection and discrimination thresholds for gratings moving in opposite directions. For those stimuli for which the subthreshold summation results indicated the activity of independent channels it was found that direction of movement could be discriminated at, or close to, detection threshold. Those stimuli which exhibited considerable subthreshold summation

* The research reported here is supported by a Science Research Council of Great Britain grant (No:GR/A73817). I am most grateful to Drs. Andrew B. Watson and John G. Robson for showing me their detection/discrimination data prior to their publication. I thank Professor Bob Sekuler for his comments on an earlier version of this paper.

Author's address: Peter Thompson, Dept. of Psychology, University of York, York Y01 5DD, Great Britain.

could not be discriminated at detection threshold, indicating some non-direction selective mechanism.

The success of the use of the subthreshold summation technique and the comparison of detection and identification thresholds suggested that these techniques might be used to study the mechanisms underlying the perception of velocity.

The experiments

Methods

Sine wave gratings were generated on the screen of a Joyce Electronics display with P4 phosphor by a Plessey LSI Micro-1 computer with a Motorola 6800 microprocessor embedded within a Cambridge Electronic Design 502 interface. Details of the system and software have been described elsewhere (Runciman 1981). Subjects sat 263 cm from the screen which subtended 7×5 degrees of visual angle. All gratings were shaped in space (with a gaussian profile in the X axis and a raised cosine in the Y axis) and in time (by a gaussian). This removed sharp spatial and temporal transients from the stimuli; that is only a patch grating appeared on the centre of the screen, fading to the uniform mean luminance towards the edges; the stimuli also loomed on when presented and then faded away, each presentation lasting 1.5 sec.

In both the subthreshold summation and detection/discrimination experiments described here a two interval forced choice procedure was used. In the subthreshold summation experiment *S*s had to determine which of the two intervals contained the stimulus. A staircase procedure, modelled on that described by Graham *et al.* (1978) then determined the threshold. The five different stimuli were presented in random order, each controlled by its own staircase.

In the detection/discrimination experiment the method of constant stimuli was employed, 4 contrast levels spanning the detection threshold of each of two stimuli being presented in a 2 interval forced choice procedure. *S*s here had to detect the presentation interval and identify the stimulus on each trial. This procedure is similar to that described by Nachmias and Weber (1975).

Results and Discussion

The logic of the subthreshold summation experiment is shown in fig. 1. If two gratings, detected by the same channel, are presented together in peaks-add phase then each grating need only be at half its threshold contrast in order for the channel to reach its threshold. If, however, the two gratings are detected by independent mechanisms then one or other of the gratings must reach its own independent threshold for detection to occur. These simple predictions, however, are complicated by probability summations of various kinds.

If two channels are involved in detecting the stimuli there may be probability summation between these channels (see Sachs *et al.* 1971; Graham *et al.* 1978). If only one non-selective channel detects both stimuli probability summation over space and over time must be considered (Watson *et al.* 1980; Watson 1979). These effects tend to reduce the differences predicted by the independent and non-selective channels models.

In the present study only the simplest combinations of moving gratings have been used—two gratings of spatial frequency (f) and (3f), moving in the same direction at the same velocity and always combined in peaks-add phase.

Fig. 2 shows the subthreshold summation results for gratings of 2 cycles/degree and 6 cycles/degree for 2 subjects. In fig. 2(a) both components are stationary. This condition is similar to those investigated by Graham and Nachmias (1971) and Graham *et al.* (1978). Figs. 2(b, c and d) show the data for gratings moving at 1, 3 and 4 degs/second. Bars represent ± 1 standard deviation. Bearing in mind the size of these standard deviations and the assumptions involved in calculating the various effects of probability summation it seems unwise to read more into these data than that there appears to be a trend from independent channels towards a non-selective channel as velocity increases.

The second experiment used a detection/discrimination procedure to investigate the conditions under which two moving stimuli are detected by

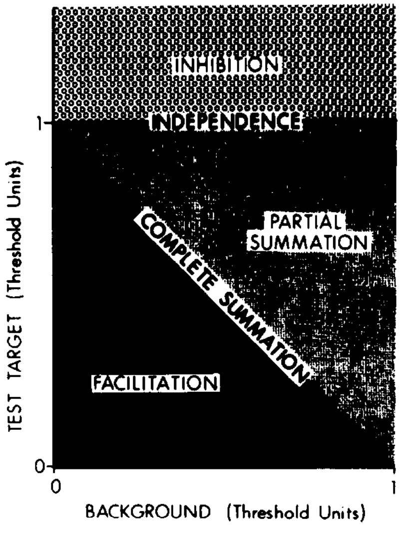
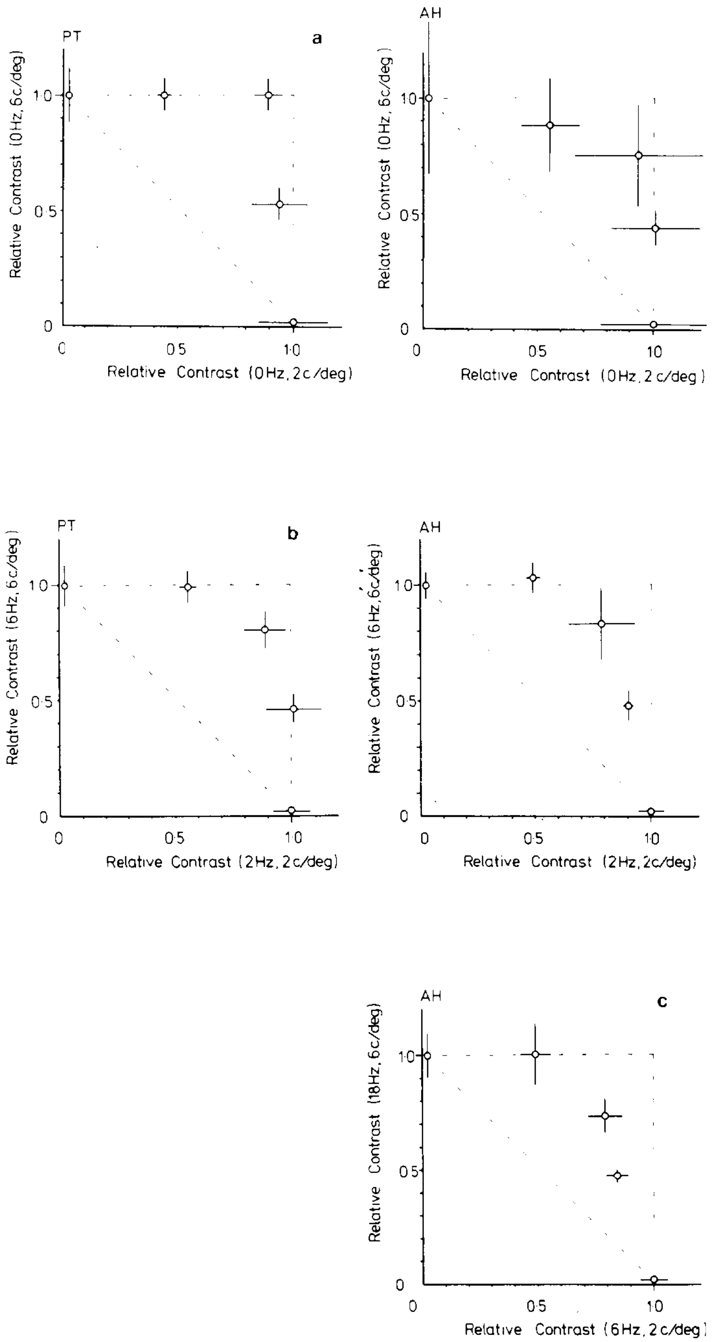


Fig. 1. Logic of the Subthreshold summation experiment. Path of points for complete summation between background and test targets is shown by oblique line. Path of points for independence between background and test targets is shown by horizontal line. (From R. Sekuler, Visual motion perception. In: Handbook of Perception; Vol 5, Seeing. E.C. Carterette and M.P. Friedman (eds). Academic Press (1975).)


PT
a
Relative Contrast (0Hz, 6c/deg)
Relative Contrast (0Hz, 2c/deg)
AH
Relative Contrast (0Hz, 6c/deg)
Relative Contrast (0Hz, 2c/deg)
PT
b
Relative Contrast (6Hz, 6c/deg)
Relative Contrast (2Hz, 2c/deg)
AH
Relative Contrast (6Hz, 6c/deg)
Relative Contrast (2Hz, 2c/deg)
AH
c
Relative Contrast (18Hz, 6c/deg)
Relative Contrast (6Hz, 2c/deg)

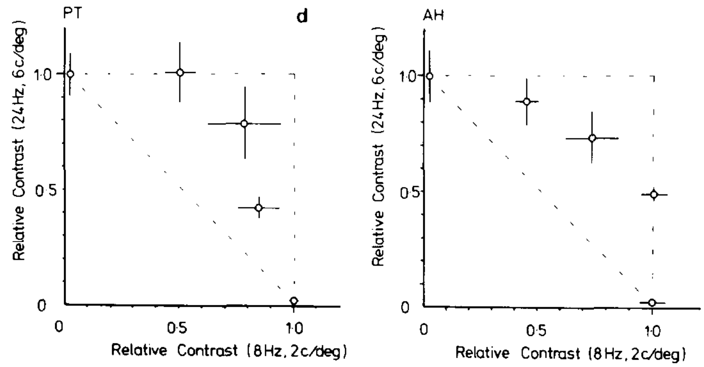


Fig. 2. Subthreshold summation of 2 cycles/degree and 6 cycles/degree gratings moving at: (a) 0 degrees/sec (stationary gratings); (b) 1 degrees/sec; (c) 3 degrees/sec; (d) 4 degrees/sec. Further details in the text.

independent mechanisms. This procedure relies upon the following logic. At detection threshold a stimulus is detected by the single most sensitive detector, or channel, for that stimulus. If an observer's different channels are labelled in some way so that he knows when one rather than another is active, then two different stimuli will be discriminable at detection threshold when they have been detected by different channels. Stimuli which are confused at detection threshold may be detected by some common channel, or perhaps by unlabelled channels. This technique has been used in the past to examine colour channels (Krauskopf and Srebro 1965), spatial frequency channels (Nachmias and Weber 1975; Furchner *et al.* 1977) and directional mechanisms (Watson *et al.* 1980; Lennie 1980).

In the present experiment detection and discrimination thresholds were collected simultaneously for two gratings moving in the same direction. Each trial consisted of two intervals, one of which contained a stimulus. The task was to detect the interval which contained the stimulus and to identify the stimulus as one of the two presented within any session. Four contrast levels of each stimulus, in 2 decibel steps embracing detection threshold were presented 33 times in each session. The results of several sessions were pooled to establish psychometric functions for detection and for identification of each stimulus. The data were fitted with a Weibull function using Watson's (1979) 'Quick' curve fitting program. From this detection and identification thresholds were obtained for each stimulus, the difference between these two thresholds being a measure of the subject's ability to identify each stimulus at threshold. Fig. 3 shows some of the psychometric functions for subject PT; pairs of gratings, one of 2 cycles/degree, the other of 6 cycles/degree were presented either stationary or moving at equal velocity. Fig. 4 shows the difference between the detection and identification thresholds for two subjects. The large individual

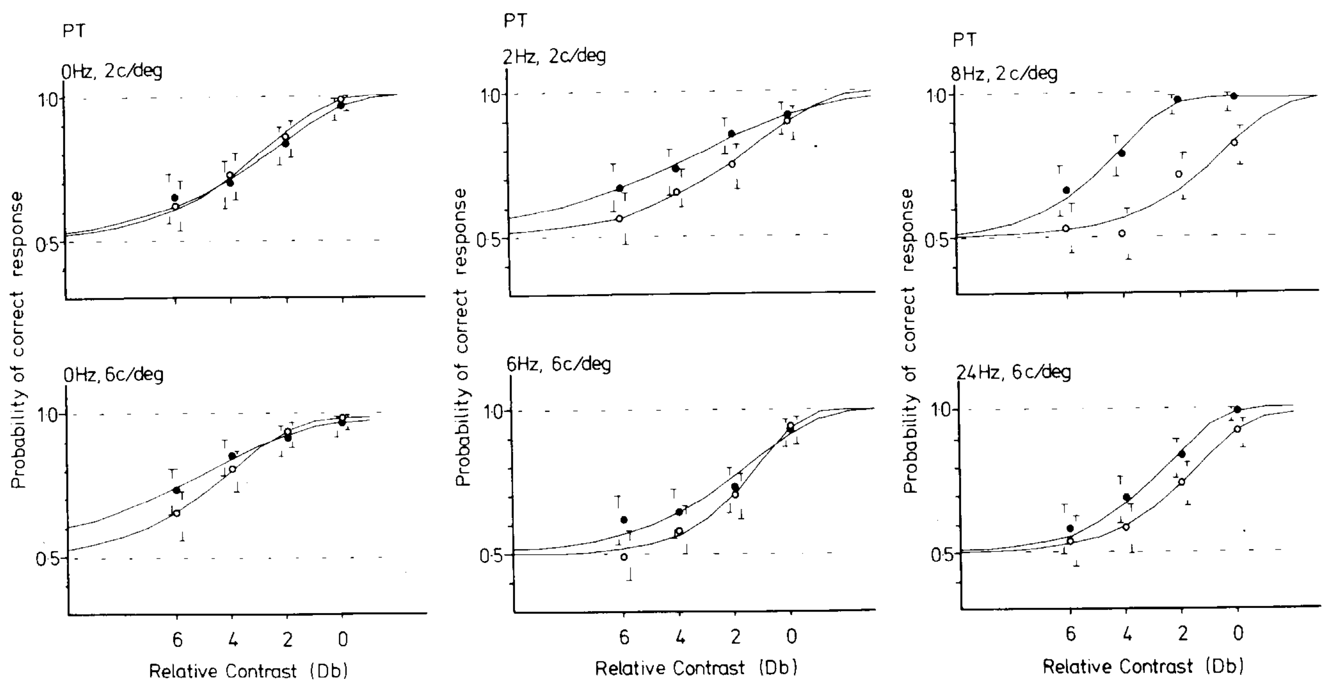
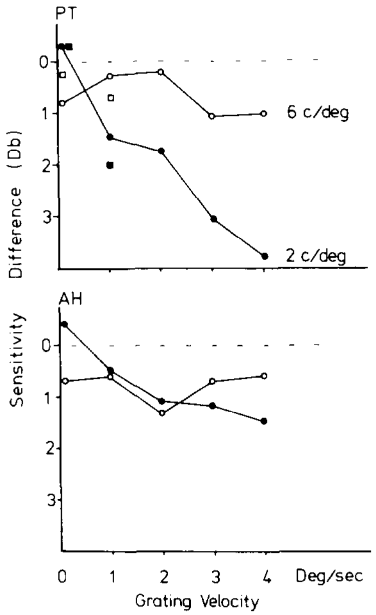


Fig. 3. Examples of psychometric functions for detection and identification of 2 cycles/degree and 6 cycles/degree gratings. Curves fitted by Watson's 'QUICK' program, Watson (1979). Further details in text.



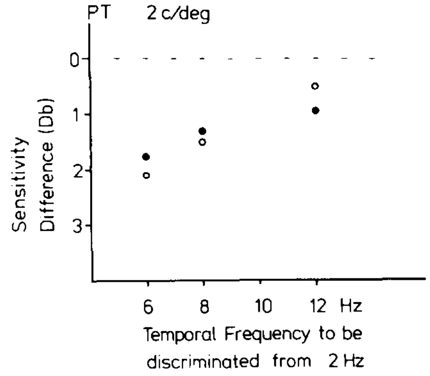


Fig. 4 (left). Difference between detection thresholds and identification thresholds as a function of the velocity of the 2 and 6 cycles/degree gratings. Sensitivity differences of less than about 1 dB may be regarded as indicating independent channels (Watson and Robson 1981). Squares denote replications of the data.

Fig. 5 (right). Difference between detection and identification thresholds for 2 cycles/degree gratings moving at different rates. Filled symbols are for 2 Hz, 2 cycles/degree grating; open symbols are for stimulus denoted on the abscissa.

differences between subjects P.T. and A.H. are puzzling. On some detection/discrimination conditions, not reported in the present paper, A.H. does show the short of asymmetry shown by P.T. here. The data of fig. 4 also show that the performance of A.H. seems less affected by the velocity of the gratings than P.T. This appears to be a genuine individual difference between the subjects although experiments are now in process to investigate the possibility that inadequate fixation of the display screen might be the cause of this difference.

From previous work, for example that of Graham (1972), there is evidence that spatial frequency channels broaden as temporal frequency, or velocity, increases. In the present experiment this would be reflected by an increasing difference between detection and identification thresholds with increased velocity. This result is found. However far more striking is the asymmetry between the discriminability of the two stimuli, particularly for subject P.T. at the faster rates of movement.

The subject is asked to detect and identify 2 gratings, one of 2 cycles/degree, the other of 6 cycles/degree. When the 6 cycles/degree gratings is presented he can identify it very close to his detection threshold. However when the 2 cycles/degree grating is presented he cannot make the identification at threshold. One possible cause of this asymmetry might be a bias in the responding of the subject—perhaps any stimulus he is unsure of he labels 6 cycles/degree. However there is little evidence of this type of bias in the raw data, and certainly no more in the case of P.T. than A.H.. There is a more plausible and intriguing possibility. Suppose that the 2 cycles/degree grating is detected by some channel 'Y' at threshold whilst the 6 cycles/degree grating is detected by channels 'X' and/or 'Y', both being equally sensitive to the stimulus. Now, if at threshold channel 'Y' detects the grating the subject correctly identifies the stimulus as 6 cycles/degree. If channel 'X' detects the stimulus however, the subject guesses the identity of the stimulus, presumably with some bias determined by his knowledge that equal numbers of each stimulus are presented in a session.

In the present experiment one possibility is that whereas the 2 cycles/degree stimuli are detected by movement channels, the 6 cycles/degree gratings excite both movement and pattern channels (Kulikowski and Tolhurst 1973).

The previous experiment held the velocity of the two stimuli to be discriminated constant, leaving the subject the task of identifying the stimuli on the basis of their temporal frequency difference, or, more probably, their spatial frequency difference. Consider now two moving gratings of equal spatial frequency, 2 cycles/degree, to be discriminated on the basis of their different temporal frequencies, or velocities. Clearly if the rates of movement of the two gratings are very similar they will not be discriminated at threshold. Indeed the results, shown in fig. 5, suggest that a 2 Hz, 2 cycles/degree grating can only just be discriminated from a 12 Hz, 2 cycles/degree grating. This very broad tuning is in agreement with the findings of Watson and Robson (1981) who have suggested that just two temporal frequency channels are sufficient to describe their detection/discrimination data which were collected for gratings whose contrast was sinusoidally modulated in time.

Experiments are currently in progress to determine whether the two temporal channels are best described as 'temporal frequency' or 'velocity' channels.

References

Furcher, C.S., J.P. Thomas and F.W. Campbell, 1977. Detection and discrimination of simple and complex patterns at low spatial frequencies. Vision Research 17, 827–836.

Graham, N., 1972. Spatial frequency channels in the human visual system: effects of luminance and pattern drift rate. Vision Research 12, 53–68.

Graham, N. and J. Nachmias, 1971. Detection of grating patterns containing two spatial frequencies: a comparison of single and multiple channels models. Vision Research 11, 251–259.

Graham, N., J.G. Robson and J. Nachmias, 1978. Grating summation in fovea and periphery. Vision Research 18, 815–825.

Krauskopf, J. and R. Srebro, 1965. Spectral sensitivity of color mechanisms: derivation from fluctuations of color appearance near threshold. Science 150, 1477–1479.

Kulikowski, J.J. and D.J. Tolhurst, 1973. Psychophysical evidence for sustained and transient mechanisms in human vision. Journal of Physiology 232, 149–163.

Lennie, P., 1980. Perceptual signs of parallel pathways. Philosophical Transactions of the Royal Society, London. Series B, 290, 23–37.

Levinson, E. and R. Sekuler, 1975. The independence of channels in human vision selective for direction of movement. Journal of Physiology 250, 34–667.

Nachmias, J. and A. Weber, 1975. Discrimination of simple and complex gratings. Vision Research 15, 217–223.

Runciman, C., 1981. Modula and a vision laboratory. International Journal of Man Machine Studies (in press).

Sachs, M., J. Nachmias and J.G. Robson, 1971. Spatial frequency detectors in human vision. Optical Society of America 61, 117–1186.

Watson, A.B., 1979. Probability summation over time. Vision Research 19, 515–522.

Watson, A.B. and J.G. Robson, 1981. Discrimination at threshold: labelled detectors in human vision. Vision Research (in press).

Watson, A.B., P.G. Thompson, B.J. Murphy and J. Nachmias, 1980. Summation and discrimination of gratings moving in opposite directions. Vision Research 20, 341–347.