

of activation from odorant to odorant and irritant to irritant, not necessarily revealed best by simple reaction time, may govern any contribution from peripheral factors. Irrespective of the mechanism of the interaction, our results suggest a need for special attention to odorous and irritating contaminants in the workplace. An irritating gas may mask the presence of useful olfactory signals (such as, warning agents) and an odorant may mask the possibly corrosive vapours (for example, inorganic acids) that often form the stimulus for the trigeminal nerve.

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1. Tucker, D. in *Handbook of Sensory Physiology* Vol. VI, pt 1 (ed. Beidler, L. M.) 151-181 (Springer, Berlin, 1971).
2. Cain, W. S. *Ann. N.Y. Acad. Sci.* **237**, 28-34 (1974).
3. Stone, H., Carregal, E. J. & Williams, B. *Life Sci.* **5**, 2195-2201 (1966).
4. Stone, H., Williams, B. & Carregal, J. A. *Expl Neurol.* **21**, 11-19 (1968).
5. Stone, H. in *Olfaction and Taste III* (ed. Pfaffmann, C.) 216-220 (Rockefeller University Press, New York, 1969).
6. Stone, H. & Rebert, C. S. *Brain Res.* **21**, 138-142 (1970).
7. Katz, S. H. & Talbert, E. J. *Tech. Pap.* 480 (Bureau of Mines, US Department of Commerce, 1930).
8. Bain, A. *The Senses and the Intellect*, 152 (Longmans Green, London, 1868).
9. Cain, W. S. & Moskowitz, H. R. in *Human Responses to Environmental Odors* (eds Turk, A., Johnston, J. W. Jr & Moulton, D. G.) 1-32 (Academic, New York, 1974).
10. Cain, W. S. *Nature* **268**, 50-52 (1977).
11. Tucker, D. in *Olfaction and Taste* (ed. Zotterman, Y.) 45-69 (Pergamon, London, 1963).
12. Cain, W. S. *Sensory Processes* **1**, 57-67 (1976).
13. Hughes, J. R. & Mazurowski, J. A. *Electroenceph. clin. Neurophysiol.* **14**, 646-653 (1962).
14. Sem-Jacobsen, C. W. *et al. Am. J. med. Sci.* **232**, 243-251 (1956).
15. Walsh, R. R. *Am. J. Physiol.* **186**, 255-257 (1956).

Illusory reversal of extrafoveally perceived displacement

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It has long been known that the temporal characteristics of human peripheral vision differ markedly from those of foveal vision. Slowly moving peripheral stimuli, for example, can give rise to dramatically exaggerated estimates of their displacement^{1,2}. More recently, Thorson *et al.*^{3,4} have shown that where two spots are flashed in sequence to peripheral vision with an interflash interval of 50 ms, a sensation of movement can be induced even when the spatial separation of the spots is below the static acuity threshold. These observations fit with several others^{5,6}, suggesting that the visual system uses separate channels for signalling 'motion' as distinct from 'change of location', and that in some circumstances the integration of motion signals may make a dominant contribution to the perception of displacement. I now report a striking illusion which seems to reinforce and extend this conclusion.

This illusion is easily demonstrated and quantified using a double-beam cathode-ray oscilloscope with a non-persistent screen in a normally lit room. If one spot (or line) on the screen is deflected instantaneously through 1° or 2° and allowed to return more slowly to its original position, for example by alternate (1 s⁻¹) exponential-spike waveforms of 25 ms time constant and opposite polarity (Fig. 1a), then in foveal vision its motion is perceived more or less veridically. Viewed 3° or 4° extrafoveally, however, the appearance is surprisingly different. The displacement perceived is actually in the opposite direction to the real, the apparent motion being as shown in Fig. 1b. The illusion is readily quantified⁷ by imposing an RC-filtered step deflection of this form on the second cathode-ray tube beam, and adjusting its amplitude and time constant until the motion of the second

spot or line, when viewed foveally, seems to match that of the first (perceived extrafoveally). Detailed measurements are still in progress and will be reported elsewhere, but for photopic stimuli viewed at retinal eccentricities of a few degrees, the motion perceived is just as if the rapid displacements had not occurred. Furthermore, if fixation is changed so that both stimuli are viewed extrafoveally, their perceived motions still seem to match.

It thus seems that in these conditions only the slow phases of the image motion are signalled by the extrafoveal system to the centres that mediate motion perception. As the resting position of the spot (between spikes) remains physically unchanged (Fig. 1a), but is perceived as displaced alternately by an amount $\pm y$ (Fig. 1b), extrafoveally perceived location seems here to be computed entirely by integration from motion signals, rather as in an 'inertial navigation' system. (The rising phase of the spike, which takes only a few microseconds, is presumably too rapid to stimulate any physiological 'motion detectors' (ref. 8).)

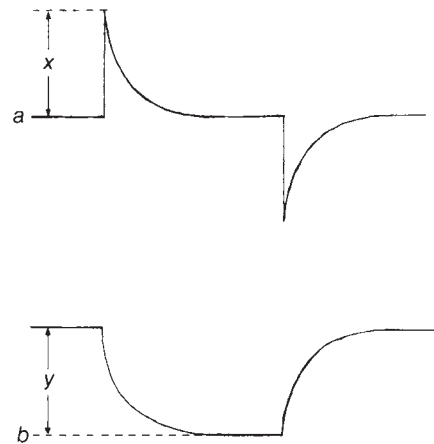


Fig. 1 a, Waveform of deflection of extrafoveally viewed spot (spike deflections $\sim 1^\circ$, 1 s⁻¹). b, Waveform of perceptually matching deflection of foveally viewed spot. For perceptual match, $y = x$ and time constants are equal.

Note that the displacement x (Fig. 1a) was here much larger than the static acuity threshold for the extrafoveal region stimulated. When a square wave of the same amplitude was substituted for a , the spot motion was clearly perceptible. The present illusion is thus distinct from, and in a sense complementary to, the Thorson effect^{3,4} described above.

Further experiments have shown that at scotopic light levels (with only the retinal rods active) the perceptual match between the foveal and extrafoveal stimuli of Fig. 1 breaks down. This suggests that the computation of extrafoveal displacement on the basis of motion signals is primarily a function of the cone system. In this connection it may be significant that it is normally only at scotopic light levels (when the cone system is inactive) that illusory instability of the perceived world is seen during saccadic eye movements. The findings reported here suggest that at photopic levels the processing of extrafoveal information may be undisturbed by the image displacements produced by normal saccadic exploratory movements.

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1. Exner, S. *Pflügers Arch. ges. Physiol.* **11**, 403-432 (1875).
2. Kries, J. Von in *Handbuch der Physiologischen Optik* Vol. III, 3rd edn (ed. Southall, J. P. C., English edn) 275-276 (Optical Society of America, 1925).
3. Thorson, J., Lange, G. D. & Biederman-Thorson, M. *Science* **164**, 1087-1088 (1969).
4. Biederman-Thorson, M., Thorson, J. & Lange, G. D. *Vision Res.* **11**, 889-903 (1971).
5. MacKay, D. M. *Nature* **181**, 507-508 (1958).
6. MacKay, D. M. in *Handbook of Sensory Physiology* Vol. VII/3A (ed. Jung, R.) 307-331 (Springer, Heidelberg, 1973).
7. MacKay, D. M. *Proc. physiol. Soc.* September, 14P (1979).
8. Grüsser, O. -J. & Grüsser-Cornehls, U. in *Handbook of Sensory Physiology* Vol. VII/3A (ed. Jung, R.) 333-429 (Springer, Heidelberg, 1973).