frequencies at different times were duplicated almost exactly in the other two conditions of difficulty of the reading material and were not changed by its orientation. Statistical tests showed that the differences in frequency of occurrence of the left-eye leads was significant.

The pattern of the vertical eye movements, their velocity characteristics and the difference in position between the right and left eyes are illustrated in Fig. 4. The experimental measurements consisted of time differences between the peak velocities of paired right-eye and left-eye movements, as shown in the lower two traces of the record. Results on five subjects showed that the mean time difference in ms between the two eyes favoured the left eye in tracking the vertical shifts in target position, favoured the left eye in four subjects, and the right eye in one (see Table 1). These differences between eyes were statistically reliable. Over a series of eight practice trials, the mean time between target movement and eye response was reduced significantly from a mean of 220 ms to about 200 ms. With practice, the mean time difference between the right and left eye was significantly increased from approximately 1 ms to about 9 ms.

The results of these experiments on horizontal and vertical binocular movements do not confirm the classical theory of Helmholtz that the two eyes are conjugate in binocular coordination. The finding that the left eye led the right eye in most of the measures of reading substantiates the observations of Hyde[5], who found that "outward" movements of the eye were slower than "inward" movements. The difference was 58 degrees/s (Hyde herself attributed this difference to lack of precision in her technique, and concluded that the eyes are completely conjugate).

The experiment illustrates how real-time computer systems can be used to obtain high-precision measurements in optometry and visual science. These methods, which may be extended to all fields of physiology and psychology, are based on the analogue–digital–analogue computer both as a control element in a behavioural–physiological system and as a high precision clocking and measuring device.

These findings raise questions about the validity of the claims of informational engineers[6] that the dynamics of saccadic movements in vision can be modelled adequately in terms of binary sampling processes related to sensory and neural input, which have an optimal sampling constant or response latency of 0·2 s. The results suggest that binocular visual coordination depends on several levels of continuous eye movement–retinal feedback timing and that these differ significantly for the two eyes and for each pattern of vertical and horizontal eye motion.

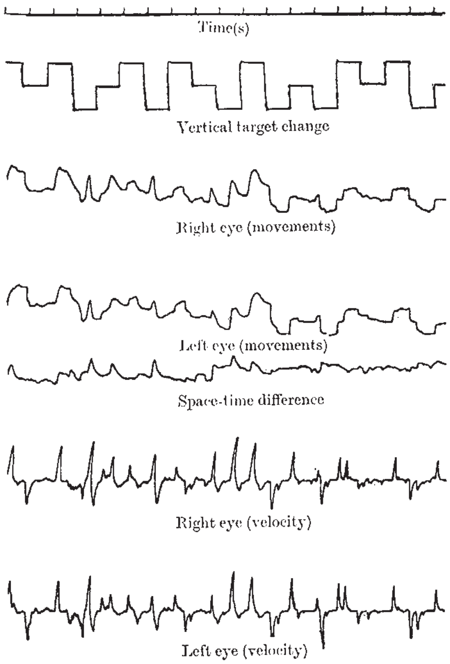

Fig. 4. Records of binocular vertical eye movements in relation to the step-wise vertical shifts in the observed target, with traces of the velocity of the eye movements.

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Effect of Blurring on Perception of a Simple Geometric Pattern

FIG. 1 is a modification of the Poggendorff illusion which has been drawn so that it is clearly visible at large distances. When viewed from a distance the central bar is perceived as being more horizontal and wider than it is drawn. This distortion increases as distance from the figure increases so that distortions of 15° can be found in most subjects. (Similar but much less striking distance and size effects have been noted in standard illusion figures[1–5].) The distortion is greater in subjects with poor visual acuity; and it can be increased by artificially increasing the blurring by optical means. The effect does not depend on accommodation, and can also be observed by placing a hair on a fine grating.

Fig. 1. A variant of the Poggendorff illusion.

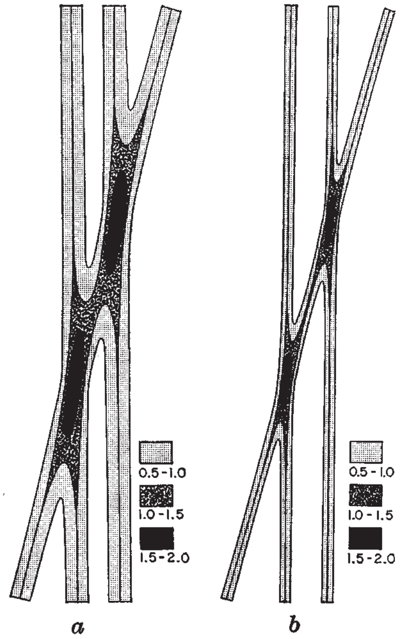

Fig. 2. *a*, The contour map of intensity which results when a line pattern, formed by two parallel lines crossed by a third at a 15° angle, is convolved (blurred) with a Gaussian of unit height. The distance between the parallel lines is twice the half-width of the Gaussian; *b*, the same as *a*, but with the distance between the parallel lines four times the half-width of the Gaussian.

The illusion seems to be caused by the faulty interpretation by the visual system of an image blurred by any combination of optical, motor or neural processes[6]. Here, however, I consider the effects of blurring in foveal vision, for which the blur function has been experimentally determined and may be approximated by a Gaussian whose half-width depends on the pupil size (the half-width is about 1·2 min for a 3·8 mm pupil)[7,8]. The retinal intensity pattern for foveal viewing of a luminous line pattern formed by two parallel lines crossed by a third at a 15° angle, can be computed, and is illustrated for distances between the parallel lines of twice the half-width of the Gaussian (Fig. 2*a*) and four times the half-width (Fig. 2*b*). Away from the points of intersection in Fig. 2, the extent of the blurring is about equal to the visual acuity and we perceive a straight sharp edge (perhaps as a result of neural inhibitive processes in the visual system)[9]. In the vertex of the acute angle, however, there is a plateau of rather slowly changing illumination several times larger than that at the limit of visual acuity. Although it is not easy, it is possible, looking carefully at Fig. 1, to see this blurred region in the vertex of the angle (see ref. 1, Fig. 29). Ordinarily, however, we do not notice these fine details and at large distances we perceive a tilted bar whose boundaries appear to be a "best fit" to a contour of constant intensity (Fig. 2).

In the past, many investigators have proposed that the inability to resolve the vertices of acute angles may lead to their perceptual enlargement, and consequently to many of the geometric illusions (Poggendorff, Zöllner, Hering, Orbison)[1–5,10–13]. Among the many demonstrations which support this hypothesis are the disappearance of the Poggendorff illusion when the ends of the oblique lines meeting the verticals are bent slightly outward near the point of contact[14]; the necessity of acute angles for the Hering illusion[4]; the enhancement of illusions by artificial increases of blurring[10,15]; persistence of illusions in haptic presentation[13]. Although these demonstrations provide evidence that distortions induced by acute angles are important in causing the illusions, many have persuasively argued that other factors must also be involved[1,15–18]. Certainly this is so. Even for such simple patterns as the geometric illusions, it is necessary to consider how information reaching the higher visual system simultaneously through parallel channels, or sequentially because of eye movements: is integrated to yield a single percept. The state of attention of the subject to fine details as well as expectations concerning what the stimulation pattern is will certainly affect this integration.

I have here presented a visual distortion which seems to be caused by the erroneous interpretation of a blurred image. Although only optical blurring has been discussed, "neural blurring" of the visual image at higher levels of the visual system will enhance the optical blurring which is already present at the retinal level. The partial persistence of the geometric illusions in binocular presentation[19] would therefore be expected. Study of the size and distance effect observed here should be useful in determining the rules by which people extract information from visual patterns, and may indicate that the comparatively small regions distorted by blurring in large figures have a large effect on the final percept.

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Relation of Age and Mongolism to Lateral Preferences in Severely Subnormal Subjects

HILDRETH[1] estimated the incidence of left-handedness in very young children to be about twice as high as in the adult population. This is consistent both with an effect of social training and also with maturation in lateral dominance, but in either case one might expect a subnormal population to show, at least up to a certain age, a greater incidence of left-handedness. Burt[2] and Gordon[3], relying partly on the observations of teachers, both found this; Clausen[4], however, using three objective tests, found no differences between retardate and normal groups aged