of an infinite averaging time is valid in predicting an ensemble-average value for L provided that the actual animal averaging time may be presumed to be long compared with temporal details in $f(t)$.

A new Weber law. The modified Weber law may be obtained by using the approximation $\Delta L \cong dL$ for infinite averaging time. From

$$\Delta L/L = \frac{\Delta L/\Delta S}{L}\Delta S \cong \frac{dL/dS}{L}\Delta S \quad (3)$$

and using the approximation of Eq. 2, there results

$$\Delta L/L \cong \frac{(n/2)(\Delta S/N)}{1 + S/N} \quad (4)$$

Observe that $\Delta L/L$ becomes directly proportional to $\Delta S/S$ for large S as in the classic Weber law. Let $\Delta S'$ and S' apply for large S and let ΔS and S signify general values. From the modified Weber law (ΔL is independent of S) there may be formed

$$(\Delta L/L)_{\mathrm{General}\ S} = (\Delta L/L)_{\mathrm{Large}\ S} = S' \quad (5)$$

from which

$$\frac{\Delta S/S}{\Delta S'/S'} \cong 1 + \frac{1}{S/N} \quad (6)$$

Equation 6 is plotted in Fig. 1; a particular $\Delta S'/S'$ is assumed and a slight shift along the S/N axis has been made in order to account for uncertainties associated with the measurement of noise. The theoretical result compares with empirical data obtained for hearing by Miller (*5*). The corresponding result for the sine wave signal is similar.

Note in Fig. 1 that the point where the theoretical curve is 3 decibels above its large S/N plateau requires signal stimulus mean-square value S to be equal to the mean-square value of noise N. If the external signal is not corrupted by noise, this particular value for S appears to measure the noise internal to the sensory system.

The noise implied in the foregoing derivation is assumed to be intermingled with the external stimulus. If the noise is totally internal, results remain valid provided that equivalent external noise can be defined. There is evidence that neural noise is in part stimulus-dependent and hence can not be determined in terms of an externally applied equivalent; to this extent, the curve of Fig. 1 is an approximation (*6*).

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5 March 1962

Angular Displacement of the Visual Feedback of Motion

Abstract. The hypothesis is that such displacement produces no disturbance of behavior within a limited "normal" range, but that a breakdown angle can be found beyond this range which will produce disturbance in motion in proportion to the magnitude of the feedback displacement. Results with two tasks specifically support the hypothesis that limiting angles of neurogeometric control of motion and variation in performance occur with varying magnitudes of angular displacement of feedback.

Although angular displacement of vision has been studied heretofore as an example of perceptual disorientation with experimental spectacles, the significance of such study for critical behavioral theory and nervous system function has not been considered. The sensory feedback theory of the neurogeometric organization of brain function and behavior (*1*) assumes that neural detection of angular displacement of the movement-produced stimulus feedback represents a primary process in the brain's regulation of different component movements of reciprocal tremor, posture, transport, and manipulation, as well as their integration in behavior.

Figure 1*a* illustrates what we mean by angular displacement of the sensory feedback of human motions, as achieved via closed-circuit television. The subject, instead of viewing his own motions directly, views his movements, as in drawing and writing, in a television monitor. The television camera provides a substitute visual image of the subject's movements, which is transmitted to him as a normally or angularly displaced sensory feedback image. If the camera is moved to different points in space relative to the performance field, vision is, in effect, changed from its normal locus. The magnitude and direction of this angular displacement of visual feedback of any motion may be quantitatively controlled.

The particular hypothesis of neurogeometric theory under test in this study assumes that angular displacement of the locus of vision differentially affects various patterned movements of the human individual. That is, a coordination exists between vision and each movement component of the body such that there exists for each movement pattern a limited and critical angle of displacement of its sensory feedback. Within this angle patterned movement may be performed as an organized response without interference. Visual displacement beyond this critical angle causes movement (motor performance) to break down. The degree of both this disruption and the recovery of movement control with learning is assumed to be a function of the displacement angle.

The general method of angularly displacing the visual feedback of motion is described in connection with Fig. 1*a*. The figure shows how this method was applied to angular displacement of the visual feedback of two behavior patterns used in this study—drawing circles and tracing a visual gated maze.

In this experiment, 24 female subjects practiced the two experimental tasks of circle drawing and maze tracing for 9 days under four conditions: 0, 20, 40, and 60 degrees of angular visual displacement in the horizontal plane of the performance field. The vertical direction of the television camera corresponded to the normal angle of the line of sight in the vertical plane of the performance field. On the 10th day performance was measured at eight angles of horizontal visual displacement: 0, 10, 20, 30, 40, 50, 60, and 70 degrees. An appropriate design was used in order to obtain control of experimental physical variables and sequence of observations.

The instructions to the subjects in the circle drawing task were crucial. They were told to draw as "perfect" a circle as possible on the easel, regardless of what appeared on the television display, noting that what they drew and what they saw might not correspond. Thus, visual cues were pitted against kinesthetic cues. In the maze task, subjects were told to trace between the gates of the maze as accurately as possible.

The data of the measures of performance at the eight angles of displacement during the test period are summarized in Fig. 1, *b* and *c*. The curve for maze tracing (Fig. 1*b*) shows that

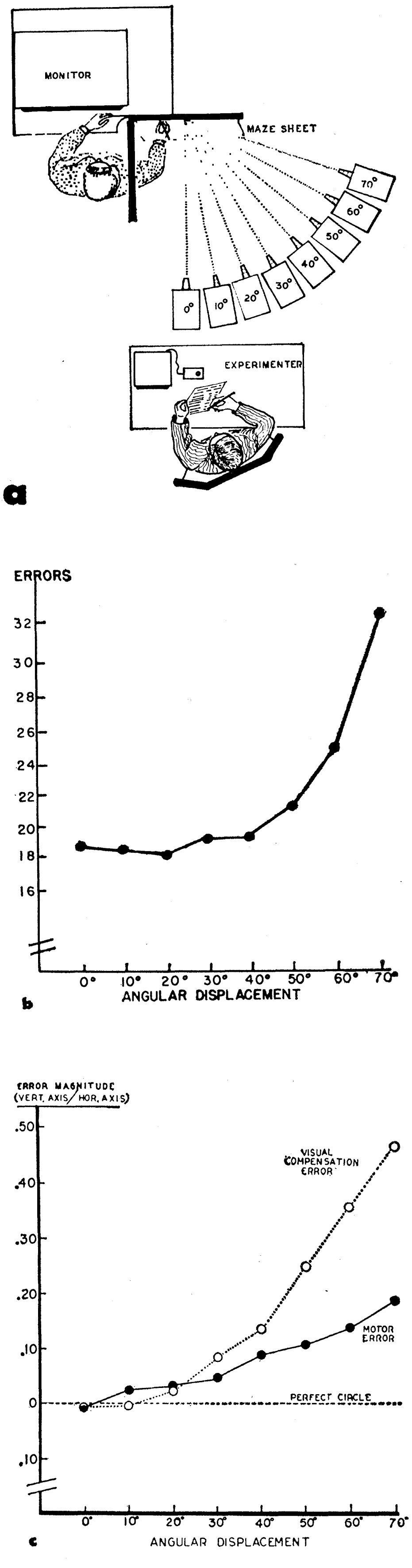

Fig. 1. *a*, Method of angular displacement of the visual feedback of motion. *b*, Errors in maze tracing. *c*, Motor error and visual compensatory error.

accuracy of performance in tracing, as measured in terms of maze errors, was maintained at angles up to 40 degrees at which point performance broke down. Beyond this point, errors are typically a direct function of angle of displacement.

To follow instructions in the circle drawing task, the subject had to compensate accurately for the distorted visual feedback of her drawings that appeared on the monitor in order to make a true circle. Two types of discrepancies or errors from a "perfect" circle were thus possible: *direct motor error* and *visual compensatory error.* Motor error is defined as the difference between actual performance and the ideal or "perfect" circle. Visual compensatory error is based upon the sine function that describes the increasing ellipticity of a "circle," subtended at the lens of the television camera, as the angle of horizontal displacement increases. The use of this sine function as the reference to the magnitude of the angular displacement distortion effect gives the visual compensatory error.

The fact that the two types of errors are of significant magnitude means that the subject neither drew true circles accurately through direct motor adjustment as instructed, nor tended to completely compensate visually for the distortion. The differential magnitude of the two curves for circle drawing (Fig. 1*c*) means that the subject was directed less by the feedback effects of the visual distortion than by the kinesthetic effects denoting true circularity. Although both curves show an increasing magnitude of error as a function of angular displacement, the visual compensatory error increases relatively more.

The results of this experiment specifically uphold two main assumptions, in terms of which the experiment was designed. These are that the neurogeometric detector mechanisms governing particular motions have definite breakdown angular thresholds, beyond which integration of movement is disturbed, and that the degree of disturbance beyond this breakdown threshold is a function of the angle of displacement. It may be noted also that the results indicate that the degree and rate of learning involved in adaptation to the different conditions of space-displaced feedback are also related to the magnitude of the angle of displacement. Accordingly, the findings add to a body behavioral and neural evidence which supports the view that the brain regulates the pattern of motion by means of internuncial neurogeometric detector systems, which record the spatial differences between a movement and its sensory feedback effects (*2*).

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Relationship of Erythrocyte to Leukocyte Antigens in Chickens

Abstract. Tests with blood typing antisera revealed that antigens of the *A, D,* and *L* blood group systems are erythrocyte specific, while antigens of the *B* and *C* systems are common to lymphocytes and erythrocytes. Injection of day-old chicks with erythrocytes inhibited production of agglutinins for lymphocytes as well as erythrocytes when subsequent immunizations were attempted.

Leukocyte antigens are of special significance in tissue transplantation work. Antigens that cause transplantation immunity are believed to be fully represented in lymphoid cells but not in red cells (*1*). Antibodies having the power to agglutinate leukocytes but not erythrocytes have been produced in humans and some laboratory animals (*2*). Little is known concerning the reverse situation, that is, that antibodies may agglutinate the erythrocytes but not the leukocytes of an individual. That this may occur, however, has recently been suggested from work with chickens (*3*).

This report (*4*) presents the findings from a study of the selectivity of isoantibodies for erythrocyte and leukocyte antigens in chickens.

Agglutination tests were made with lymphocytes and red cells of 18 White Leghorn fowls, by using 15 iso-immune reagents specific for antigens of five blood group systems. These systems correspond to those designated by other workers (*5*). Suspensions of essentially