Evidence for a Neurological Zoom System in Vision from Angular Changes in Some Receptive Fields of Single Neurons with Changes in Fixation Distance in the Human Visual Cortex

The response of single cells to spatially discrete stimuli in the visual field was obtained by means of microelectrodes indwelling in the human occipital cortex. These electrodes were inserted concurrently with macroelectrodes implanted through the same burr hole into the posterior hippocampus for the diagnosis and therapy of medically intractable, temporal-lobe epilepsy, with the informed consent of the patients. Receptive fields in the shape of bars and discs were plotted and their various other characteristics noted.

Methods. The method of plotting has been described[1-3]. Briefly, a large, flat sheet of cardboard with an ink-dot fixation or viewing point was placed 1 m from the supine patient's eyes and various-sized wands displaying a disc or bar were presented. So stimulated, increased firing of the unit could be heard, superimposed upon the unit's 'bursty' or irregular spontaneous rhythm. Once the position of the receptive field was established, it was rapidly delineated and lightly outlined on the cardboard for subsequent measurement.

Single units could be distinguished by the usual criteria: amplitude, polarity, wave-form and receptive field. No shift from one unit to another was seen during the recording.

Early results and discussion. To increase the accuracy of plotting we increased the viewing distance. At first we were unable to find the receptive fields at the greater distance although they were still recordable at 1 m.

Ultimately, a receptive field was found at a greater distance, but its size and position could not have been predicted by the laws of geometrical optics. The 10 cm diameter of the receptive field of this binocular unit at a distance of 1 m was expected to be almost 3 times larger at a distance of 2.7 m, but, instead, was found to be approximately the same linear size with its geometric center displaced up and medially. This finding raised the questions: Is there a change in size and position of the receptive field with viewing distance? If so, could it be the neurological basis for a constancy or zoom mechanism?

There are a number of psychophysical experiments that can be explained only by postulating some sort of neurological zoom or scaling mechanism. The history of size constancy has been treated by BORING[4]. A number of other phenomena occurring with changes of fixation distance, also discussed by BORING, appear to be associated with such a mechanism, for example, a change of angular acuity (Aubert-Foerster phenomenon) and changes in angular size of after-images (Emmert's law). More recent measurements of size constancy have been made by HOLWAY and BORING[5], LEIBOWTZ et al.[6] and others. HARVEY[7] has shown changes in critical flicker fusion with fixation distance. A rotatory plasticity by vestibular influence on receptive fields from cells in cat visual cortex has been demonstrated by HORN and HILL[8].

The time available with these few patients was extremely limited but in 2 we plotted receptive fields at several viewing distances to see if the angular size and position relative to the fixation point of the visual fields did indeed change with different viewing distances. The order of binocular viewing distances with the first unit was 1, 2, 4, 1, 0.4 and 4 diopters and with the second 1.4, 1.4, 2, 1, 0.3 and 1.25 diopters. Fixation was no problem since the patients were cooperative and the receptive field could be quickly outlined several times at each fixation distance.

Later results and discussion. Two theoretical models of 2 receptive fields are presented in Figures 1 and 2 in the form of dashed lines and solid curves (which are practically straight lines). Figures 1a and 2a represent the diameters and Figures 1b and 2b the positions. The horizontal dashed lines represent the slope of a receptive field diameter or the slope of the distance from the fixation point, assuming a constant angular size with changes in viewing distance, in accordance with optical laws. The solid lines in Figures 1a and 2a represent theoretical curves whose slopes are drawn for a constant

[1] E. MARG and J. E. ADAMS, EEG clin. Neurophysiol. *23*, 277 (1967).
[2] E. MARG, J. E. ADAMS and B. RUTKIN, Experientia *24*, 348 (1968).
[3] E. MARG, Proc. First Int. Cong. Visual Sci., Bloomington, Indiana, April 1968 (Indiana University Press, Bloomington, Indiana 1970), in press.
[4] E. G. BORING, *Sensation and Perception in the History of Experimental Psychology* (D. Appelton-Century Co., New York 1942).
[5] A. H. HOLWAY and E. G. BORING, Am. J. Psychol. *54*, 21 (1941).
[6] L. O. HARVEY JR. and H. W. LEIBOWITZ, J. Optical Soc. Am. *57*, 249 (1967).
[7] L. O. HARVEY JR., Thesis, Doctoral Dissertation, The Pennsylvania State University (1968). Vision Researsch, in press.
[8] G. HORN and R. M. HILL, Nature *22*, 186 (1969).

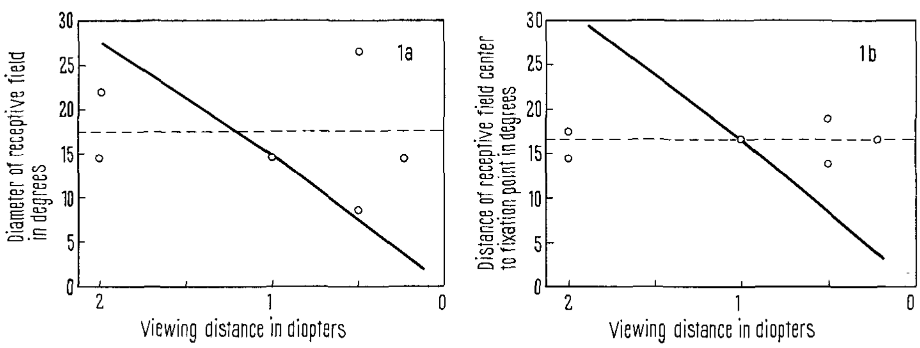

Fig. 1. One receptive field measurement as a function of the dioptric viewing distance. The dashed horizontal lines represent the slope of a constant angular size. The solid lines represent the slope of a constant linear diameter of the receptive field (1a) or perfect size constancy relative to the fixation point (1b). All lines are arbitrarily positioned.

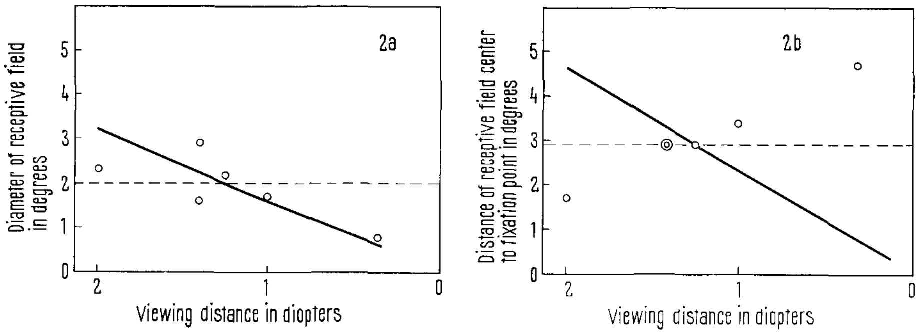

Fig. 2. Another receptive field. Dashed and solid lines as in Figure 1. The receptive field, which was to the right of the fixation point, moved out laterally with greater viewing distance.

linear size of the diameter of the receptive fields regardless of viewing distance. Those in Figures 1b and 2b are theoretical curves whose slopes are drawn to provide perfect size constancy. If this curve were followed, as the target approaches the eye and one end of the target were considered to fall on the fovea, then the increase in optical image size on the retina would be perfectly compensated for by a minifying neurological system, providing perfect size constancy.

The scatter of points in Figure 1a was too great to determine whether the shape of the dashed or of the solid line represented the points, but there was little doubt that the data in Figure 1b were better represented by the horizontal dashed line (optical law). The geometric center of this receptive field thus appeared to maintain a constant angle relative to the fixation point, following optical principles. Figure 2a seemed better described by the slope of the solid line, which points to a neurologically maintained constancy of visual grain size.

In Figure 2b, the solid line indicates a 2.3°/D minification (the receptive field moves away from the fixation point) as an object of regard comes closer to the eyes, which, theoretically, would give perfect size constancy. The data points fit neither this curve nor the horizontal dashed line. They would more accurately fit a curve with 2.3°/D magnification.

The linear diameter of the receptive field (Figure 2a) fits a constancy model reasonably well, but the change of the angular position of the receptive field (Figure 2b) did not fit a simple size constancy model. In fact, the graph showed the reverse – a magnification superimposed on the optical magnification as an object approached the eyes.

In an interpretation of psychophysical findings, RICHARDS[9,10] placed a scaling (zoom) mechanism in the lateral geniculate body, and pointed out that this phenomenon is rapidly lost in the peripheral visual field. This proposal would be consistent with the results of Figure 1, which shows that no neurological size phenomena are seen in the large receptive field which is 15° from the fixation point while on the other hand a neurological effect is seen in the smaller parafoveal receptive field described by Figure 2.

It is difficult to account for a neurological size-changing mechanism that would emphasize rather than compensate for the lack of size constancy in simple optics. One possibility is an intermediate zone between central-field size constancy and peripheral-field lack of constancy. The intermediate-field zone, then, would have to show a negative constancy in order to cover the entire visual field. This might be the case in the 2° to 5° range.

Another possibility is that, according to RICHARDS'[9,10] scaling theory, the disparity detectors must adjust their receptive field positions with changes of fixation distance to maintain the depth constancy that we experience perceptually. These adjustments in receptive field positions need not necessarily change in the same manner that sizes of the fields change.

Conclusions. Regardless of the exact mechanism, from measurements of 2 of the 3 receptive fields for single units in the human visual cortex, a neurological substrate for a zoom or constancy mechanism in or peripheral to the occipital cortex appears to be required in order to explain the behavior of 2 of the 3 disc-shaped receptive fields for single units we have measured in the human visual cortex. Further studies as patients become available may clarify the operations responsible for the plastic behavior of our cortical receptive fields. In the meantime, it is necessary to be cautious in interpreting these phenomena. Finding neurological magnification where minification was expected demonstrates the complexity of the system[11].

Résumé. Dans le cortex visuel humain de 3 champs réceptifs de neurones individuels 2 présentent des changements d'angle correspondant aux changements de perception à distance. Ces changements peuvent être la base neurologique du système perceptif de stabilité, de «zoom» ou de graduation de la vision.

E. MARG and J. E. ADAMS

School of Optometry, University of California, Berkeley (California 94720, USA), and Division of Neurological Surgery, University of California Medical Center, San Francisco (California, USA), 16 June 1969.

[9] W. RICHARDS, Neuropsychology *5*, 63 (1967).
[10] W. RICHARDS, Kybernetik *4*, 146 (1968).
[11] We thank Miss NANCY KUWADA for making the microelectrodes. This work was supported in part by the National Science Foundation Grant No. GB 7301 and in part by a research professorship (EM) from the Miller Institute for Basic Research in Science from the University of California, Berkeley.