Reports

Cat's Ability to Discriminate Oblique Rectangles

Abstract. *Cats were trained to discriminate either between a horizontal and vertical rectangle or between two oblique rectangles, one at 45°, the other at 135° to horizontal. All animals were first trained with both shapes (one in each orientation) presented together, and then retrained with only one shape shown at a time. Throughout the experiment the animals being trained with oblique rectangles performed as well as those being trained with horizontal and vertical rectangles. This finding is in marked contrast with results obtained from other species. The results suggest that the ability of a species to discriminate between rectangles in different orientations may depend upon the relative numbers of cells in the visual system having receptive fields in each orientation.*

Hubel and Wiesel (*1*) have found that in the cat striate cortex there are neurons with long, narrow receptive field centers. Each of these neurons responds maximally to a rectangular shape projected on the retina in a particular orientation. Other neurons respond maximally to appropriately oriented boundaries between light and darkness. In the cat, different neurons have receptive fields in different orientations. Hubel and Wiesel found "no indication that any one orientation was more common than the others" (*1*). Young (*2*) has found that the dendritic fields of neurons picking up from incoming fibres in the optic lobe of octopuses are predominantly elliptical in shape. This may be the anatomical substratum for a similar type of coding device to that which Hubel and Wiesel have demonstrated in the cat. However, Young presents evidence which suggests that in the octopus there are more dendritic fields with orientations corresponding to the visual horizontal or vertical than with intermediate (oblique) orientations. Sutherland (*3*) has suggested that this type of coding arrangement in the octopus brain would satisfactorily account for much of the behavioral evidence on how shapes are classified by *Octopus*. In particular, octopuses have great difficulty in discriminating between two oblique rectangles set at 45° and 135° to horizontal, whereas they discriminate very readily between a horizontal and vertical rectangle (*4*).

The explanation of the octopus's difficulty with the oblique rectangles may lie partially in the relative scarcity of dendritic fields in orientations corresponding to oblique orientations on the retina. If this account of shape discrimination in the octopus is correct, it should follow that if cats have about as many oblique fields as vertical and horizontal, they should discriminate between two oblique rectangles as readily as between a vertical and horizontal. My experiment was designed to test this prediction.

Four cats were trained to discriminate between a horizontal and vertical rectangle, and four between two oblique rectangles at 45° and 135° to horizontal. The rectangles were black, measured 3.5 by 0.7 inches, and were exposed against a white circular background 3.5 inches in diameter. The apparatus used was designed by Sperry, Miner, and Myers (*5*). The stimuli were presented on doors to the left and right of a partition. The door bearing the positive stimulus was unlocked and the cats could obtain food by pushing against it. The door bearing the negative stimulus was locked and subjects running to it were pushed back into a start chamber and rerun. The interior of the apparatus was dark, and the stimuli were translucent and illuminated from the outside. The position of the positive and negative stimuli (to left or right) was determined by semirandom Gellermann type orders. Twenty trials a day were run in close succession, each trial concluded when the animal made the correct choice. All animals had been previously trained to push open the doors for food reward. The experiment was run in two stages.

Stage I. The two stimuli (a vertical and a horizontal rectangle for one group, two oblique rectangles in opposite orientations for the other) were presented simultaneously, and animals were run until they achieved a criterion of 38 correct choices out of 40 over a 2-day training period. The animals trained with vertical and horizontal rectangles averaged 11.0 days to reach criterion, (range 9 to 14 days); those trained with oblique rectangles averaged 10.75 days (range 8 to 13 days). The learning curves for the two groups are not shown since they were almost identical. Thus both groups learned equally fast to discriminate between the shapes presented simultaneously.

Stage II. The question arises whether the oblique group may have learned to discriminate in terms of the total pattern made by the shapes rather than in terms of the orientations of the two oblique rectangles. For example, they might have learned to run left when the tops of the oblique rectangles faced inward, and to run right when the bottoms faced inward. To control against this possibility both groups were retrained with one shape presented at a time. On half the trials the positive shape only was presented with a blank door on the other side, on half the negative shape only was presented. When the positive shape was shown, animals were rewarded for pushing the door on which it was exposed; when the negative shape was shown, they were rewarded for running to the door on the other side of the apparatus. All animals showed immediate transfer to this situation.

Thus on the first day of retraining with single shapes, animals trained with the horizontal and vertical rectangles ran correctly in 73 percent of the trials and those trained with the two obliques ran correctly in 78 percent of the trials. Training was continued in this way for 4 days, and although all animals ran consistently above chance their scores showed little sign of improvement. Thus on the fourth day animals trained with vertical and horizontal rectangles averaged 75 percent correct responses, and the other group 78 percent correct. The immediate transfer to the new situation strongly suggests that neither group had learned the original discrimination in terms of the total pattern made by the two shapes, but that they had learned independently the orientation of the positive and negative shapes. The fact that, when only one stimulus was presented at a time, the animals still discriminated as accurately between the oblique rectangles as between the horizontal and vertical rectangles was in marked contrast to my own powers of discrimination in relation to these shapes. In setting up the single oblique rectangles in the correct sequence, I had to proceed slowly and to double check every setting for fear of making an error. No such difficulty was experienced with the horizontal and vertical rectangles.

The finding that cats discriminate between two oblique rectangles as readily as between horizontal and vertical rectangles confirms the hypothesis that the relative ease with which animals discriminate rectangles in different orientations may depend at least partially on the number of neurons with receptive fields in particular orientations. The result is particularly striking when it is borne in mind that octopuses (*4*) and children under four (*6*) seem unable to solve the oblique discrimination at least with the training techniques so far used, while goldfish need about three times as many trials to learn to discriminate between two opposite oblique rectangles as they require to master the vertical-horizontal discrimination (*7*). From an evolutionary standpoint it is difficult to say why the cat should differ from the other three species in this way. Accurate recognition of oblique orientations may be of special importance to an animal jumping from branch to branch (*8*).

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References and Notes

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8. The experiments were performed at California Institute of Technology, where I received support from grants made to R. W. Sperry by the National Institutes of Health and the Frank P. Hixon fund of the California Institute of Technology. The work forms part of a project on "Stimulus analyzing mechanisms" financed by the Office of Naval Research (contract N62558-2453). I also acknowledge a travel grant from the Wellcome Trust and thank Gene Mercer for assistance in running the experiment.

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Neurogenic Component of Chronic Renal Hypertension

Abstract. *Infusion of angiotensin or renin in small quantities affects the sympathetic nervous system so that responses are increased to either drugs or reflexes that cause release of norepinephrine at nerve endings. Response to injected norepinephrine is relatively unchanged. This action of angiotensin is dependent upon an intact sympathetic nervous system. The direct vasoconstrictor action of angiotensin is not an essential part of the enhanced response. The phenomenon was shown to have relevance to acute and chronic experimental renal hypertension in dogs by the fact that in both the pressor response to tyramine was enhanced. We believe that the ability of angiotensin to intensify the effect of normal neurogenic vasomotor activity, along with an upward reset of the carotid sinus buffer mechanism, might account importantly for the neurogenic component of renal hypertension.*

Much evidence suggests that chronic hypertension, elicited by application of a clamp to a renal artery or by enclosing the renal parenchyma in a Cellophane-induced hull, is associated with the liberation of renin and the formation of angiotensin. There has been no reason to believe that the autonomic nervous system had concurrently ceased to participate in the maintenance of cardiovascular tone; but whether to a greater or lesser degree than in a normotensive animal was not known.

Participation of the autonomic nervous system might be increased if there was increased sensitivity to the neurohumoral mediator at the myoneural junction, but published observations on the pressor response of chronic renal hypertensives to several vasoactive drugs are contradictory. The most that can be said is that the responses are either normal or slightly increased. This applies in particular to the two key substances, angiotensin and norepinephrine. In the case of norepinephrine, response to injected, or exogenous, material has been studied. A possible change in response to endogenous norepinephrine liberated at the myoneural junction after stimulation has not been explored. The widely accepted view that some drugs, such as tyramine, act indirectly on blood vessels by causing liberation of norepinephrine, suggests the possibility to study the endogenously produced neuroeffector and to associate it with the known vasoactive humoral agent of renal origin, angiotensin.

We observed that when tyramine was injected during the hypertension elicited by crude renin in dogs anesthetized with pentobarbital the pressor response was considerably elevated above the control levels. The same response occurred when synthetic valyl^5-angiotensin was infused. It was then shown that ephedrine behaves similarly and that the ganglion stimulating agent, DMPP (1, 1′-dimethyl-4-phenyl piperazinium iodide), caused a greatly enhanced pressor response when it was given during the infusion of angiotensin. It appeared that angiotensin caused an increase of the pressor response to any drug which depends for its action on the release of norepinephrine at the myoneural junction. At the same time the response to injected norepinephrine was unchanged or only slightly increased.

The enhancing effect was not related to the vasopressor action of angiotensin for it occurred even when tachyphylaxis to angiotensin had been produced. The sensitizing action of angiotensin must be at receptor sites different from those concerned with its own vasoconstrictor activity.

If this newly observed phenomenon was to be related to the mechanism of renal hypertension, it was necessary to show in animals made hypertensive, and in which it is presumed that the kidneys provide a slow infusion of angiotensin, that increased responsiveness to tyramine is demonstrable. A Goldblatt clamp was tightened on a renal artery after removal of the opposite kidney. The systemic arterial pressure rose moderately and responses to tyramine and DMPP were augmented within from 15 to 30 minutes while those to norepinephrine were unchanged (Fig. 1, top).

Responses to tyramine were also enhanced in dogs several days after application of a Goldblatt clamp and contralateral nephrectomy (Fig. 1, bottom). In experiments performed with Y. Kaneko's aid, values of measured responses to tyramine were on the average 2½ times those of the values on controls after placement of the clamps and when hypertension had developed. During control tests, infusion of angiotensin caused the usual increase in response to tyramine. When the animals had de-