Baker's stain, and their capacity to retain auramine-rhodamine stain. As was reported earlier (*6*), *M. lepraemurium* and BCG retained their staining capabilities after treatment with pyridine.

2) Competence in clearing bacilli (CCB) test: This is a test that was developed in our laboratories and in which an antigen similar to the Mitsuda antigen is used (*6*). It differs from the Mitsuda antigen in that it contains a much larger number of heat-killed *M. leprae*, so that it produces a macroscopic nodule in lepromatous patients 30 days after intradermal inoculation. Biopsy of the nodule shows typical lepra cell granulomas composed of macrophages containing large numbers of acid-fast bacilli. For this test, antigens were prepared from each of the armadillo tissues along with *M. leprae* obtained from human lepromatous tissue. Each preparation contained 6.4×10^8 organisms and was injected intradermally into 20 lepromatous patients. Some of these patients were bacteriologically negative after several years of sulfone therapy while others were sultone-treated patients with active lesions.

The two antigens prepared from armadillo tissues gave the same responses in these individuals as the antigen prepared from human lepromatous tissue; that is, a nodule had formed at the injection site of each patient 30 days after inoculation. Biopsy of all three nodules in each patient showed large numbers of macrophages containing numerous acid-fast bacilli.

3) Mitsuda test: Antigens were prepared with material from armadillo 5 and from human material taken from lepromatous patients. The inoculums were adjusted to a concentration of 4.0×10^7 organisms per milliliter. This material was injected into the same 20 patients used for the CCB test, as well as into 7 patients with diagnosed tuberculoid leprosy. Each patient was inoculated with 0.1 ml intradermally on the surfaces of the forearm. At 30 days, the lepromatous patients showed no reaction to either the antigen from the human lepromatous patients or the antigen prepared from the injected armadillo tissue. The tuberculoid patients, however, gave positive reactions to both preparations. Thus, the Mitsuda response with armadillo antigen as compared to human antigen was the same in both lepromatous and tuberculoid patients. This is an important finding since leprologists are in general agreement that one of the primary proofs for the identification of *M. leprae* is that the organism in question produces the same response as *M. leprae* from human leprosy when inoculated into lepromatous and tuberculoid patients.

The results of these tests provide definite proof that the acid-fast organisms isolated from armadillos after experimental inoculation with *M. leprae* are identical to *M. leprae* isolated directly from human lepromatous patients.

In addition, we have recently transmitted leprosy to another species of armadillo. The details of this will be reported elsewhere (*7*).

J. CONVIT
M. E. PINARDI
Instituto Nacional de Dermatología,
Apartado Postal 4043 (Carmelitas),
Caracas 101, Venezuela

References and Notes

1. E. E. Storrs, *Int. J. Lepr.* **39**, 703 (1971).
2. W. F. Kirchheimer and E. E. Storrs, *ibid.*, p. 692.
3. W. F. Kirchheimer, E. E. Storrs, C. H. Binford, *ibid.* **40**, 229 (1972). See also the following abstracts (*ibid.*, in press) from 10th International Leprosy Congress, Bergen, Norway, 13 to 18 August 1973: S. L. Issar and C. H. Binford, "Infection of armadillo (*Dasypus novemcinctus*, Linn.) with *M. leprae*: General pathology"; C. H. Binford and S. L. Issar, "Cell-mediated immunity in armadillos (*Dasypus novemcinctus*, Linn.) with *M. leprae*: Ultrastructural study of skin and liver"; J. D. Balentine, S. C. Chang, S. L. Issar, "Infection of armadillo (*Dasypus novemcinctus*, Linn.) with *M. leprae*: Ultrastructural studies of peripheral nerves."
4. The tissue was obtained from Dr. Eleanor Storrs, Gulf South Research Institute, P.O. Box 1177, New Iberia, Louisiana 70560.
5. I. Campo-Aasen and J. Convit, *Int. J. Lepr.* **36**, 166 (1968); C. A. Fisher and L. Barksdale, *J. Bacteriol.* **113**, 1389 (1973); J. Convit and M. E. Pinardi, *Int. J. Lepr.* **40**, 130 (1972).
6. J. Convit, J. L. Avila, M. Goihman, M. E. Pinardi, *Bull. WHO* **46**, 821 (1972).
7. J. Convit and M. E. Pinardi, in preparation.
8. This work was done at the WHO International Reference Centre for Histological Identification and Classification of Leprosy with funds obtained through grant DF-S1-0278 of the Consejo Nacional de Investigaciones Científicas y Tecnológicas, Caracas, Venezuela.

5 March 1974; revised 10 April 1974 ■

Perception of Letters in Words: Seek Not and Ye Shall Find

Abstract. *Subjects perceive a letter in a briefly presented word more accurately when they attend to the whole word than when they focus their attention on just the letter they want to see.*

Until recently, most accounts of visual information processing have dealt primarily with isolated stimuli (such as single letters) or arrays of unrelated stimuli (such as random letter strings) (*1*). Outside of the perception laboratory, however, stimuli are usually related to one another; in particular, they often fit together to form larger, coherent wholes.

It has been demonstrated that belonging to a larger whole can have an important effect on perceptual processing. The letters in a word are perceived more accurately than a single letter alone, even when perception is tested by a forced-choice procedure that eliminates any guessing advantage for words (*2, 3*). For instance, subjects are more accurate in deciding whether a brief exposure of the word COIN was COIN or JOIN than whether a brief exposure of C was C or J.

This finding rules out the possibility that what we see when we perceive a word is a set of independently identified letters. Letters in a word are simply perceived too accurately for this to be the case (*4*). The processing of any given stimulus letter must depend critically on the larger stimulus of which it is a part.

Previous demonstrations of this word-letter phenomenon leave open an important question. Is it due simply to the nature of the stimulus? Or must the subject actively attend to the whole stimulus word for perception of a letter to be enhanced? If attention to the whole is necessary, we reasoned that the word-letter phenomenon could be obtained using the same stimulus under two different instructions: to look at just one letter position in the word, or to look at the whole word. Looking at just the first letter in COIN as an individual letter should reduce perceptibility of the C compared to looking at the whole word COIN. This seemingly paradoxical result is exactly what we found.

Sixteen subjects (University of Pennsylvania students) viewed very brief exposures of four-letter words. Each word was typed in capital letters with a half space between letters (*5*) and subtended 1.90° by 0.42° of visual angle. Stimuli were presented in a two-field tachistoscope with a random contour mask as a pre- and postexposure field. The position in which each letter would appear was clearly indicated in the mask. After each exposure, the subject looked outside of the tachistoscope, where he saw two alternative words that differed by only one letter. Each of the four letter positions contained the critical letter equally often in random sequence (*6*).

On half of the trials (whole word condition), we instructed the subject to fixate the middle of the stimulus and try to see a whole word. We explained that if he saw the whole word, he would be able to make a correct forced choice regardless of which position was critical. On the other half of the trials (letter condition) we told the subject before each trial which letter position contained the critical letter. We instructed him to fixate this position and try to see only the letter that appeared there, since the other letters in the word would be irrelevant to the forced choice.

Each subject viewed 224 different words, which were grouped together into alternating blocks under whole word and letter instructions (order of presentation was counterbalanced over subjects). The first two pairs of blocks (20 trials per block) were used for practice and the determination of approximate threshold exposure durations by a modified staircase procedure (the median subject required a 35-msec exposure). Each subsequent pair of whole word and letter blocks (18 trials per block) was presented at a constant exposure duration. Adjustments were made between pairs of blocks if performance deviated much above or below 75 percent correct choices. Data retained for analysis consisted of the last 16 trials from four whole word blocks and four letter blocks.

The results (Fig. 1) were clear-cut: performance was better with whole word instructions. The 6.7 percent difference was significant at the .001 level [by Kincaid's method of pooling contingency tables (*7*)], reliable across subjects [13 out of 16 did better in the whole word condition with one tie ($P < .005$ by sign test)], and reliable across stimuli ($P < .005$ by sign test).

At least three factors are working against the difference we found. In the whole word condition the critical letter (i) had a less predictable absolute location in the field, (ii) had a less predictable position relative to the other stimulus letters, and (iii) fell further away from the center of the fovea (*8*). As far as we know, this is the only case ever reported in which knowing what part of an array contains the relevant stimulus makes that stimulus harder to see.

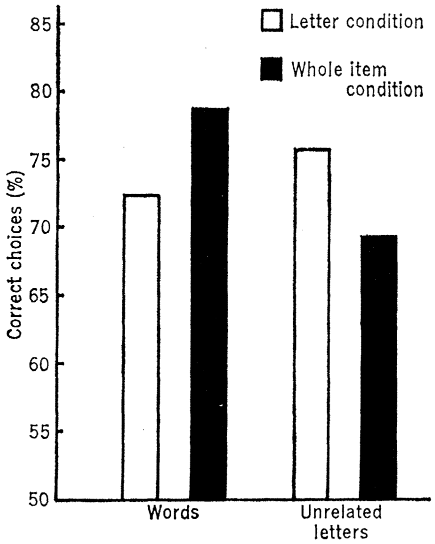

Fig. 1. Mean percentage of correct critical letter choices when subjects looked at the whole item compared to just the critical letter itself (1024 trials per bar). Stimuli were words for one group of 16 subjects and unrelated letters for the other. Absolute performance levels cannot be compared between word and unrelated-letter groups since subjects were tested at threshold stimulus-exposure settings determined on the basis of the kind of material they were viewing.

We wondered whether superior performance in the whole word condition might be due to some artifact. Perhaps, for instance, subjects had to devote so much attention to fixating the appropriate position on each letter trial that processing capacity available for perceiving the stimulus was reduced. To rule out such artifacts, we repeated the experiment on a new group of 16 subjects exactly as before, except that the stimuli used were unrelated letters (meaningless and unpronounceable quadrigrams). Stimulus and choice letters for the critical position were retained from the word stimuli (for instance, CPRD-JPRD retained the critical letters from COIN-JOIN).

The results with unrelated letters (Fig. 1) were almost exactly the reverse of the results with words. Looking for just the critical letter improved performance by 6.5 percent. The difference was again significant at the .001 level by Kincaid's method, reliable across subjects [12 out of 16 did better in the letter condition ($P < .05$)], and reliable across stimuli ($P < .005$). The interaction of material type used (words versus unrelated letters) with instruction condition was highly significant ($P < .001$ in separate χ^2 tests over subjects and over stimuli).

Our results indicate that for the whole to facilitate perception of a part, the subject must attend to the whole. It remains to be determined what kind of attention to the whole is critical.

The nature of the stimulus clearly plays a role in determining what can be seen as a whole in a way that facilitates perception of a part; instructions to attend to a whole string of unrelated letters did not facilitate perception of a part. The present data do not tell us what stimulus property is critical. It might be some property peculiar to words, or it might be some more general property shared by other kinds of wholistic stimuli (*9*). It will be important to determine whether the method developed here yields analogous whole-part facilitation effects when it is applied to such stimuli as faces, geometric forms, and common objects.

JAMES C. JOHNSTON
JAMES L. MCCLELLAND
Department of Psychology,
University of Pennsylvania,
Philadelphia 19174

References and Notes

→ G. Sperling, *Acta Psychol.* **27**, 285 (1967); C. W. Eriksen and T. Spencer, *J. Exp. Psychol. Monogr.* **79**, No. 2, part 2 (1969); D. E. Rummelhart, *J. Math. Psychol.* **7**, 191 (1970); W. K. Estes, *Percept. Psychophys.* **12**, 285 (1972); G. T. Gardner, *Cogn. Psychol.* **4**, 130 (1973). A recent exception is N. Weisstein, C. S. Harris, M. E. Ruddy, *Bull. Psychon. Soc.* **2**, 324 (1973).

→ G. Reicher, *J. Exp. Psychol.* **81**, 274 (1969);
→ D. D. Wheeler, *Cogn. Psychol.* **1**, 59 (1970);
→ M. Thompson and D. Massaro, *J. Exp. Psychol.* **98**, 49 (1973). Thompson and Massaro claim to have shown that the word-letter phenomenon is an artifact of the greater redundancy in words, since when they used a restricted stimulus list (ACE, AGE, APE, and ARE compared to C, G, P, and R) the phenomenon disappeared. The present results suggest a different interpretation: the phenomenon disappeared with the restricted stimulus list because subjects stopped looking at whole words and looked at just the critical middle letter.

3. J. C. Johnston and J. L. McClelland, *Percept. Psychophys.* **14**, 365 (1973).
4. This argument depends on the assumption that a letter in a word is not perceptually enhanced merely by the presence of adjacent contours per se, which would invalidate any comparison to a single letter alone. A single letter embedded in a string of dummy elements ("#" signs) is no easier to see than a better control for adjacent visual contours: the produce a strong word-letter phenomenon (*3*). The present experiment provides an even better control for adjacent visual contours: the letters in a word themselves.
5. There were half spaces between letters to minimize any possibility that, in the letter

condition, subjects would have trouble focusing their attention in the right place. Subjects read a brief sample of prose in half-space type shortly before the experiment to become accustomed to words printed in this style. A pilot experiment with normally spaced type and no reading sample produced virtually identical results.

6. Details of a very similar procedure and a replica of the type of mask used are given in (*3*).
7. W. M. Kincaid, *Biometrics* **19**, 224 (1962).
8. The degree of facilitation produced by position cueing with unrelated letter stimuli (6.5 percent) may provide a rough estimate of the strength of the factors working against the word-letter difference in this experiment. The factors mentioned may explain why the word-letter difference obtained is smaller than that reported under similar visual conditions comparing a word to a single letter alone (*3*).
9. I. Biederman [*Science* **177**, 77 (1972)] found that although items in "real world scenes" (for instance, objects arrayed along a street) are perceived better in their normal arrangement than when scrambled, a particular item is perceived still more accurately when subjects are told where to look for it. Biederman's evidence may mean that the phenomenon reported here does not hold when stimuli are related to one another, but not so strongly as to form a single coherent whole. Alternatively, our results may not be obtainable with stimuli as large as Biederman's (3.5° by 5° of visual angle).
10. Supported by NSF predoctoral fellowships to J.C.J. and J.L.M. and by a grant from the Spencer Foundation. We thank L. Paris and E. Moynihan for their assistance and H. Feldman, L. Johnston, J. Jonides, J. Nachmias, and P. Rozin for their helpful comments.

19 December 1973; revised 20 February 1974 ■

Operant Conditioning of Single-Unit Response Patterns in Visual Cortex

Abstract. *Unit responses to photic stimuli were studied in cat visual cortex. After the baseline response pattern of a cell was determined, conditioning trials were given during which reinforcement was contingent upon increased firing during a selected segment of the poststimulus interval. Density of reinforcement increased substantially in about half the cells studied; significant increases in firing occurred within, but not outside, the criterion segment.*

One promising approach to studying neural mechanisms of conditioning and learning treats neural occurrences as conditionable responses, rather than simply as neural correlates of behavioral conditioning. Thus, classical conditioning of both electroencephalographic rhythms and evoked patterns of unit activity has been demonstrated, and a variety of neural events—including theta waves, spontaneous discharge rates of single units, and gross visual evoked potentials—have been brought under operant or reinforcement control (*1*).

To our knowledge, the present report is the first to show that the operant paradigm can be applied also to modify the temporal pattern of activity evoked in a single unit by a sensory stimulus. We recorded the response patterns of cortical neurons to a visual stimulus in temporarily immobilized cats, and then attempted to produce specified changes in these patterns by using electrical stimulation of lateral hypothalamus as a reinforcer.

Adult cats were implanted under surgical anesthesia with bilateral tripolar stimulating electrodes aimed at the lateral hypothalamus. A U-shaped aluminum frame with slotted sides was also cemented to the skull so that the cat could be returned later to the stereotaxic instrument and held firmly in place without pressure and with a clear visual field. After recovery, each cat was tested in a standard operant chamber for self-stimulation on each of the hypothalamic probes, and preferred points and the optimal current for reinforcing intracranial stimulation (ICS) were determined. To maximize the effectiveness of ICS as a reinforcer in the subsequent recording sessions, a relatively stringent behavioral requirement was imposed: Of a large number of implanted subjects, 13 that made more than 200 bar presses in an 8-minute test were used in the remainder of the experiment. Cats that were used repeatedly in two or more recording sessions received additional tests for behavioral self-stimulation interspersed with the recording sessions.

For recording, subjects were placed in the stereotaxic instrument on a circulating warm water coil and prepared under ether anesthesia. Pupils were dilated with Isopto atropine (1 percent), and nictitating membranes were retracted by using ophthalmic Neo-Synephrine hydrochloride (10 percent). All wound margins were infiltrated with a long-lasting local anesthetic (Zyljectin), and proparacaine hydrochloride (Ophthetic) (0.5 percent) was applied topically on the corneal surfaces. Ether was then discontinued, and the subject was immobilized with intravenous gallamine triethiodide (Flaxedil) (20 mg/ml) and artificially respired. Each eye was focused on a tangent screen by appropriate corneal contact lenses. The optic disk and area centralis were projected onto the tangent screen and mapped separately for each eye. During the remainder of the session, Flaxedil was administered (about 1 ml/hr), and heart rate and rectal temperature were monitored and kept at about 200 beats per minute and 38°C. After ether was discontinued, at least 3 hours elapsed before recording began.

Extracellular unit action potentials were recorded from the visual cortex with tungsten microelectrodes and sent to an amplitude discriminator that pulsed a computer of average transients (Mnemotron CAT 400B); the computer generated a 1- or 2-second peristimulus time histogram (PSTH) of the cell's response to a stimulus. Visual stimuli were back-projected onto the translucent gray tangent screen 50 cm from the subject. The eye ipsilateral to the cell being studied was covered, and stimuli were presented to the contralateral eye. For many cells, a 15° spot centered on the area centralis was effective in producing a clear, patterned response; other cells were activated by using smaller spots or slits of various widths centered on the cell's receptive field.

During recording from a cell, trials were generated every 5 seconds by pulses that synchronized the occurrence of the computer sweep and a 25-msec presentation of the visual stimulus 200 msec after sweep onset. For each cell, trials without reinforcement (baseline trials) were first given; PSTH's showing the baseline response pattern were made and the number of spikes during a selected time segment (the criterion period) was recorded and printed for each trial. A criterion spike count that was exceeded on about one-fourth of the trials was selected. Then conditioning trials were given during which the reinforcement contingency was in effect: On each trial, a comparator circuit counted the number of spikes during the criterion period; if the criterion had been exceeded, a 500-msec train of ICS was delivered starting 300 msec after the end of the criterion period. The criterion period began 300 msec after presentation of the visual stimulus and lasted 500 msec (other values were occasionally chosen).

Baseline or conditioning PSTH's were made for 75 cortical cells. Some cells were studied for an insufficient time to complete conditioning trials,