serotonin reaches a peak around 4 weeks postnatally in cats [W. A. Himwich, in *Sleep and the Maturing Nervous System*, C. D. Clemente, D. P. Purpura, F. E. Mayer, Eds. (Academic Press, New York, 1972), p. 125]. This approximately coincides with the start of the critical period for consolidation of binocularity in kitten visual cortex [see (*3*)]. Furthermore, the mean frequency of PGO waves in kitten geniculate nucleus (in REM sleep) increases sharply during the third and fourth weeks. No PGO waves are observed before postnatal day 15 [C. Bowe-Anders, J. Adrien, H. P. Roffwarg, *Exp. Neurol.* **43**, 242 (1974)].

8. U. Ungerstedt, *Eur. J. Pharmacol.* **5**, 107 (1968); F. E. Bloom, S. Algeri, A. Groppetti, A. Revuelta, E. Costa, *Science* **166**, 1284 (1969); U. Ungerstedt, in *6-Hydroxydopamine and Catecholamine Neurons*, T. Malmfors and H. Thoenen, Eds. (North-Holland, Amsterdam, 1971), p. 101; N. J. Uretsky and L. L. Iversen, *J. Neurochem.* **17**, 269 (1970); G. R. Breese and T. D. Traylor, *J. Pharm. Exp. Ther.* **174**, 413 (1970); J. D. Champlain and R. Nadeau, *Fed. Proc. Fed. Am. Soc. Exp. Biol.* **30**, 877 (1971).
9. Eight milligrams of 6-OHDA · HBr (Sigma) was dissolved in 0.5 ml of Ringer solution containing 250 to 500 $\mu$g of ascorbic acid to give a final concentration of 16 $\mu$g/$\mu$l of 6-OHDA. The *p*H was about 6.0. The low *p*H and presence of ascorbic acid prevent the auto-oxidation of 6-OHDA which turns the color of the solution reddish-brown on contact with air. The solution was kept frozen at −20°C.
10. B. Singh and J. De Champlain, *Brain Res.* **48**, 432 (1972); I. Creese and S. D. Iversen, *ibid.* **55**, 369 (1973); F. Petitjean *et al.*, *ibid.* **48**, 281 (1972); R. Laguzzi, F. Petitjean, J. F. Pujol, M. Jouvet, *ibid.*, p. 295; C. Sachs and G. Jonsson, *ibid.* **99**, 277 (1975).
11. The first sign of drug effects began 2 days after the start of 6-OHDA injection for TJ9. This was a sham rage reaction to the sudden presentation of any sort of sensory stimulus [K. Nakamura and H. Thoenen, *Psychopharmacologia* **24**, 359 (1972); L. J. Poirier, P. Langelier, A. Roberge, R. Boucher, A. Kitsikis, *J. Neurol. Sci.* **16**, 401 (1972)]. This reaction may be due to the acute release of catecholamines from degenerating catecholamine terminals since it is prevented by prior treatment with $\alpha$-methyl-*p*-tyrosine, a specific inhibitor of the rate-limiting enzyme in catecholamine synthesis, tyrosine hydroxylase [K. Nakamura and H. Thoenen, *Psychopharmacologia* **24**, 359 (1972)]. On day 4 after injecting 6-OHDA, we noted pupillary constriction of both eyes and a poor light reflex. On the next day, there was a compulsive rotation of the body toward the left (the side opposite injection), after the injection of 6-OHDA. It was very fast (40 rotations per minute, if the rotation took place on the same spot) and lasted for 30 minutes or so with a regular break every 0.5 to 1 minute. This rotation may be explained as an effect of 6-OHDA on the dopamine receptors in the caudate nucleus at the floor of the lateral ventricle near our injection site [U. Ungerstedt, in *The Neurosciences, Third Study Program*, F. O. Schmitt and F. G. Worden, Eds. (MIT Press, Cambridge, Mass., 1974), p. 695]. When the animal was held during rotation he showed large amplitude nystagmus whose quick phase was in the same direction as body rotation. This rotation response to injection of 6-OHDA started as early as the third day in some kittens. Gross behavioral manifestations such as compulsive rotation and the prodromata of seizures (twitching of ear tips, whiskers, and eyelids) were confined to the time of injection. In between injections, the 6-OHDA–treated kittens showed normal visual placing and following reactions, and both the experimental and control kittens spent comparable periods of time alert, awake, and interacting with the environment. While it was sometimes possible for one of us to distinguish the experimental from the control animal between injections, on the basis of his more sluggish pupillary response or a tendency to be "jumpy," there were no gross differences in behavior which might alter the amount of visual experience obtained by the experimental kittens. In other words there were no indications that 6-OHDA–treated kittens suffered from a decreased visual input.
12. Nissl-stained slides did not show any gross changes in the visual cortex of 6-OHDA–treated kittens.
13. One indirect measure of the activity of the catecholamine pathway may be the frequency of PGO waves [see (*6*)]. When 6-OHDA is administered, we have found that the frequency of PGO waves in rapid-eye-movement sleep drops sharply. However, high doses are required to maintain the suppression and PGO wave frequency returns to control levels 1 week after stopping the 6-OHDA injections. Further evidence for rapid recovery of catecholamine terminals may be found in a recent review [R. Y. Moore, A. Björklund, U. Stenevi, in *The Neurosciences, Third Study Program*, F. O. Schmitt and F. G. Worden, Eds. (MIT Press, Cambridge, Mass., 1974), p. 961].
14. The total amount of 6-OHDA given to TJ9 was 12.4 mg. After the accumulated dose attained 11.0 mg on the tenth day, the kitten started to show some signs of seizure such as hypersalivation, widely dilated pupils, twitches of whiskers, and blinks and jaw movements which were followed finally by mewing. Another dose of 1.0 mg on the next day made the situation worse resulting in a fit of the grand mal type involving the whole body [G. Chen, C. R. Ensor, B. Bohner, *Proc. Soc. Exp. Biol. Med.* **86**, 507 (1954); A. Lehmann, *Life Sci.* **6**, 1423 (1967); K. Schlesinger, W. Boggan, D. X. Freedman, *ibid.* **7**, 437 (1968)]. As shown by a sudden drop of body weight, the general condition of TJ9 deteriorated, but he recovered on cessation of drug treatment. This seizure occurred in several episodes after the injection. Seizures were not observed in any of the other 6-OHDA–treated kittens in this report, although we have since observed them after high doses of 6-OHDA in another study (*15*).
15. J. D. Pettigrew and T. Kasamatsu, in preparation.
16. H. G. Baumgarten, A. Björklund, L. Lachenmayer, A. Nobin, U. Stenevi, *Acta Physiol. Scand. Suppl.* **373**, 1 (1971); H. G. Baumgarten, L. Lachenmayer, H. G. Schlossberger, *Z. Zellforsch. Mikrosk. Anat.* **126**, 553 (1972); H. G. Baumgarten, A. Björklund, A. F. Holstein, A. Nobin, *ibid.* **129**, 256 (1972); E. Costa, J. Daly, H. Lefevre, J. Meek, A. Revuelta, F. Sparro, S. Strada, *Brain Res.* **44**, 304 (1972); H. G. Baumgarten and L. Lachenmayer, *Z. Zellforsch. Mikrosk. Anat.* **135**, 399 (1972).
17. Briefly, the kitten was anesthetized ($N_2O$, $O_2$, $CO_2$; 75 : 27.5 : 2.5 by volume, respectively) and immobilized (Flaxedil, 5 mg/hour). A small amount of dexamethasone (0.5 mg/hour) was added to the infusion solution. Body temperature and the rate of heartbeats were monitored continuously. The cornea was covered by contact lenses of zero power. The background illumination was kept at the photopic level and the brightness of visual stimuli was at about 1 to 2 log units above it. The pupil was dilated by topical application of Cyclogyl (1 percent). Visual stimuli were presented on a tangent screen at 57 cm from the animal's eye by a specially designed rear projection system. A joystick controlled the movement of images in the *X* and *Y* axes as well as their rotation.
18. W. R. Levick, *Med. Electron. Biol. Eng.* **10**, 510 (1972).
19. D. H. Hubel and T. N. Wiesel, *J. Physiol. (London)* **160**, 106 (1962).
20. J. D. Pettigrew, *ibid.* **237**, 49 (1974); C. Blakemore and R. C. Van Sluyters, *ibid.* **248**, 663 (1975).
21. We have also tested the effects of short- and long-term administration of 6-OHDA on the visual response properties of neurons in normal kittens and adults (*15*). 6-OHDA had little effect on the few neurons we studied both before and after injection. Long-term administration in normal visually experienced animals (in contrast to very young kittens) has little effect on binocularity and appears to have subtle effects which include a general increase in the sharpness of orientation tuning. This latter effect is difficult to understand but it at least supports our interpretation that the direct effects of 6-OHDA on neuron response properties play a minor role in comparison to its effects in reducing the sensitivity of the cortex to monocular deprivation.
22. Supported by NIMH grant MH25852 and by the Spencer Foundation. We thank Lederle Laboratories for providing us with Flaxedil.

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## Responses of Infants to Visually Presented Objects

Abstract. *The reaching behavior of some 60 infants between 7 and 23 days of age was studied. Contrary to some other reports, the infants did not respond differently to a visually presented, graspable, solid object than to its two-dimensional representation.*

Recent advances in the study of perception of very young infants have revealed abilities undreamed of 10 years ago (*1*). It has been claimed, with some justification, that the more sophisticated the methods of investigation have become, the more the infant's perceptual capacities have apparently grown (*2*). The study of infant perception is not a new phenomenon, but earlier evidence on perceptual development (*3*) generally supported the view that the initial stages of perceptual activity are diffuse and poorly articulated, and that intersensory coordination, particularly between vision and touch, develops slowly over time.

Table 1. Comparison of Bower's results (*4*) with those of experiment 1. Infants 7 to 23 days old were exposed for 4 minutes each to either an object (O) or its two-dimensional representation (picture) (P). Entries are the mean number of responses per infant in each observation period for each target.

| Experiment | Contacts | | Reaches | |
|---|---|---|---|---|
| | O | P | O | P |
| Bower | 12.0 | 0.0 | 53.0 | 0.5 |
| This report | 0.46 | 0.39 | 2.2 | 1.9 |

Bower (*4*) has pointed out that demonstrating an infant's ability to make visual discriminations does not necessarily tell us anything about its apprehension of the nature of the distal (physical) stimulus, for example, whether it is a real object. He argues that investigating an ecologically valid response—one that has utility for the organism, such as grasping at small objects presented visually and not too far from the body—would give more information about the infant's actual perceptual world. He reported that infants less than 2 weeks old do differentiate with an appropriate gesture between graspable and nongraspable objects presented visually (*4*). This finding is so revolutionary and goes against such a well-established tradition in perceptual psychology that it should be validated. We therefore planned to replicate Bower's experiment and then to investigate the conditions under which visually guided reaching develops with respect to speed and precision.

Table 2. Mean number of responses per child (in 4 minutes) and mean duration (in 240 seconds) of looking at an object or the picture of the object. The infant's average state (5) is also reported. Numbers in parentheses are the correlation coefficients for the two independent ratings on each measure. Definitions: reach, an extension of the arm exceeding half the distance to the target; looking-reach, one that occurs when the infant is judged to be looking at the target area; visual orientations, turns of the head or eyes to the target area; duration of staring (out of 4 minutes), number of seconds spent fixating on the target; duration of scanning, number of seconds spent scanning the target; and total duration of looking, the sum of staring and scanning.

| Exposure condition | Number | | | Duration (seconds) | | | Average state (5) |
|---|---|---|---|---|---|---|---|
| | Reach | Looking-reach | Orientation* | Staring | Scanning | Looking | |
| Object | 6.4 (.88) | 3.3 (.90) | 7.6 (.94) | 36.1 (.78) | 66.3 (.85) | 102.4 (.95) | 4.2 (.98) |
| Picture | 5.6 (.92) | 4.1 (.83) | 6.4 (.91) | 22.2 (.48) | 64.5 (.86) | 86.7 (.93) | 4.4 (.99) |

*$P < .05$ [Sandler's $A$-test for correlated measures (8)].

In a pilot study we observed 40 infants between 6 and 23 days old under conditions approximating those described by Bower (4). They were normal, full term babies born with little or no anesthetic; they were observed when in a quiet but alert state, as determined by the mother and the experimenter. They were propped up comfortably in a semisupine position with pillows or in an infant seat, so that the head and arms were free to move. The graspable object was an orange ball, 3 cm in diameter, attached by a spring 1 cm long to a dark blue rectangular background, 11 cm by 19 cm; the nongraspable object was a colored picture of the ball and its background, placed at the distance of the object background. Each target was presented approximately 15 cm from the infant's body and along its midline, so that both the ball and the picture were within reach when an arm was fullly extended. During target presentation the infant's behavior was recorded on videotape with a camera placed almost 1 m to the side. Babies varied considerably in their state of activity, and, although there were some arm movements and visual scanning of the targets, they did not exhibit behavior that could be regarded as intentional reaching or coordinated visual and tactual/kinesthetic activity. Thus, we failed to obtain evidence that visually guided reaching behavior can readily be elicited in very young infants.

In order to replicate Bower's experiment as closely as possible, we observed 13 new infants, drawn from the same population as the original 40, for periods of 8 minutes each. The infants were made comfortable in an infant seat (General Motors LUV seat), which was padded so that their heads and arms were free to move. They were observed during two 2-minute presentations of each of the targets (object and picture). In each pair of presentations, each target appeared once, the order being randomly determined. As in the pilot study, a videotape recording of the infant was made. Two experimenters viewed the tapes and independently scored them for the number of reaches each child made under each experimental condition and for the number of contacts with either target (Table 1). We defined a reach as an extension of the arm, exceeding half the distance to target and in its direction. This is comparable to Bower's "hand raised to centre line," but our recorded frequency for reaching is only about 5 percent of the rate he reports; this is also true for contact frequency. There is no significant difference between the number of reaches to, or of contacts with, the different targets.

We report the means of the numbers of reaches and contacts recorded independently by two raters. Agreement between the raters was good: For the object condition, $r = .88$, and for the picture condition, $r = .89$. Recording this specific behavior during periods of quiet alertness was fairly successful. The state of each baby was also recorded by the raters in each separate 2-minute segment according to Brazelton's scheme, in which state 4 is "Alert, with bright look; seems to focus attention on source of stimulation . . . motor activity is at a minimum," and state 5 is "Eyes open; considerable motor activity, but discrete reaction difficult to distinguish because of general high activity level" (5). During object presentation the approximate mean state was 4.50 ($r = .71$) and during picture presentation it was 4.69 ($r = .64$). State behavior was variable and rarely failed to change within a 2-minute segment. The state for each child was found by averaging the numbers for each state observed within a segment; no account was taken of the duration of each state or the number of state changes. The low reliabilities indicate that judgment of state was difficult, perhaps because only a profile view was available. But, since states 4 and 5 span the behavior from quiet alertness to extensive motor activity, we think that these infants were, in the main, in an appropriate state to show the desired behavior and that the state did not differ markedly between the two experimental conditions.

There are several possible reasons for our failure to replicate Bower's results. We did not deliberately manipulate the state of the infants in order to optimize conditions for directed reaching. The babies may not have been positioned correctly in an appropriate apparatus. Also, our single profile view of the subject may have militated against the proper detection of directed reaching. To attempt to make the conditions more favorable for observing the desired behavior, in a second experiment, infants were manipulated into the appropriate state of alertness before observation started and were positioned in a seat designed for the study of directed reaching (6) or in the LUV seat if the other caused crying. A split screen videotape system was used, with a profile and a full front view of the infant recorded simultaneously.

Twenty infants between 11 and 23 days of age served as subjects. Except for the changes noted, the design and procedure were the same as for the first experiment and a more complete behavioral repertoire was recorded. The question of interest is not just whether infants display directed reaching toward graspable objects, but the more general questions: (i) What visual and motor responses do infants make when visual targets are presented? (ii) Do infants show either visual or motoric evidence of differentiating between targets and two-dimensional pictures of targets? (iii) Do they grasp and look simultaneously?

The raters were highly consistent in their judgments of the infants' states (Table 2), which indicates that the behaviors (perhaps with the exception of staring duration) can be reliably observed and can thus serve as indices of visual response. Few target contacts (approximately 3 percent of the reaches) were observed in either condition.

The results have four important features. (i) "Appropriate behavior" (that which seems to indicate an active attention to, and exploration of, targets) occurs in the presence of visual targets. (ii) The appropriate behavior is predominantly visual; about 70 percent consists of scanning. (iii) Although the infants were active, relatively little of their motor activity was directed toward the targets; of this only about half seemed to be coordinated with visual response to the target. (iv) There is virtually no evidence that the behavior toward graspable and nongraspable objects differs in any way. The observed rates of responding in our first experiment were so low that differences for the two target conditions could scarcely have been detected. But in the second experiment higher frequencies of relevant behavior were observed, so that real differences should have been detectable. Only one of the six differences tested was statistically significant, and was small.

Our findings are consonant with an earlier report on the development of visually elicited reaching (*7*). We conclude that, although infants show definite interest when visual targets are displayed, they express their interest primarily through visual exploration; these experiments thus do not support the hypothesis of some form of advanced or higher-order processing of the properties of a distal stimulus. In particular the experiments do not allow the interpretation that infants in the first 2 weeks of life readily differentiate visually presented objects from their representations.

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### References and Notes

1. D. R. Peebles and D. Y. Teller, *Science* **189**, 1102 (1975); B. E. McKenzie and R. H. Day, *ibid.* **170**, 1108 (1972); W. E. Jeffrey and L. B. Cohen, in *Advances in Child Development and Behavior*, H. W. Reece, Ed. (Academic Press, New York, 1971); T. G. Bower, *Sci. Am.* **225**, 30 (April 1971); R. L. Fantz, in *Early Behavior: Comparative and Developmental Approaches*, H. W. Stevenson, E. H. Hess, H. L. Rheingold, Eds. (Wiley, New York, 1967), pp. 181–224.
2. E. K. Bond, *Psychol. Bull.* **77**, 225 (1972).
3. J. Piaget, *The Origins of Intelligence in Children* (Norton, New York, 1963), pp. 88–143; A. Gesell and C. S. Amatruda, *Developmental Diagnosis* (Harper & Row, New York, 1947), pp. 32–33; W. James, *The Principles of Psychology* (Dover, New York, 1950), vol. 2, pp. 31–43; J. B. Watson, *Behaviorism* (Univ. of Chicago Press, Chicago, 1930), pp. 7–8.

→ T. G. R. Bower, *Perception* **1**, 15 (1972).

5. T. B. Brazelton, *Neonatal Behavioral Assessment Scale* (Lippincott, Philadelphia, 1973), p. 5.

→ J. S. Bruner and B. Koslowski, *Perception* **1**, 3 (1972).

7. B. L. White and R. Held, in *The Causes of Behavior: Readings in Child Development and Educational Psychology*, J. Rosenblith and W. Allinsmith, Eds. (Allyn & Bacon, Rockleigh, N.J., ed. 2, 1966).
8. J. Sandler, *Br. J. Psychol.* **46**, 225 (1955).
9. We thank S. Smallman and N. Smith for help in collecting preliminary data. Supported by National Research Council of Canada grant AOA 44 to P.C.D.

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## Sexual Dimorphism in Vocal Control Areas of the Songbird Brain

Abstract. *In canaries and zebra finches, three vocal control areas in the brain are strikingly larger in males than in females. A fourth, area X of the lobus parolfactorius, is well developed in males of both species, less well developed in female canaries, and absent or not recognizable in female zebra finches. These size differences correlate well with differences in singing behavior. Males of both species learn song by reference to auditory information, and females do not normally sing. Exogenous testosterone induces singing in female canaries but not in female zebra finches. This is believed to be the first report of such gross sexual dimorphism in a vertebrate brain.*

In many species of animals, males and females exhibit different patterns of behavior, especially in contexts related to courtship and reproduction (*1*). Recent evidence suggests that structural differences in male and female central nervous systems may contribute to these differences in behavior (*2*). We have discovered a striking sexual dimorphism in song control areas of the brain of the canary (*Serinus canarius*) and the zebra finch (*Poephila guttata*), which can be related to behavioral differences between the two sexes.

Adult male canaries have a complex song repertoire learned by reference to auditory information (*3, 4*). Female canaries do not normally sing, although they will produce a song similar to that of the males when administered testosterone (*5, 6*); the song, however, is considerably less varied than that of males (*6*). Female canaries also produce a variety of other calls (*7*), and, as in the case of other carduelines (*8*), some of these calls may be learned.

Male zebra finches have a single song type, which, as in the canary, is devel-

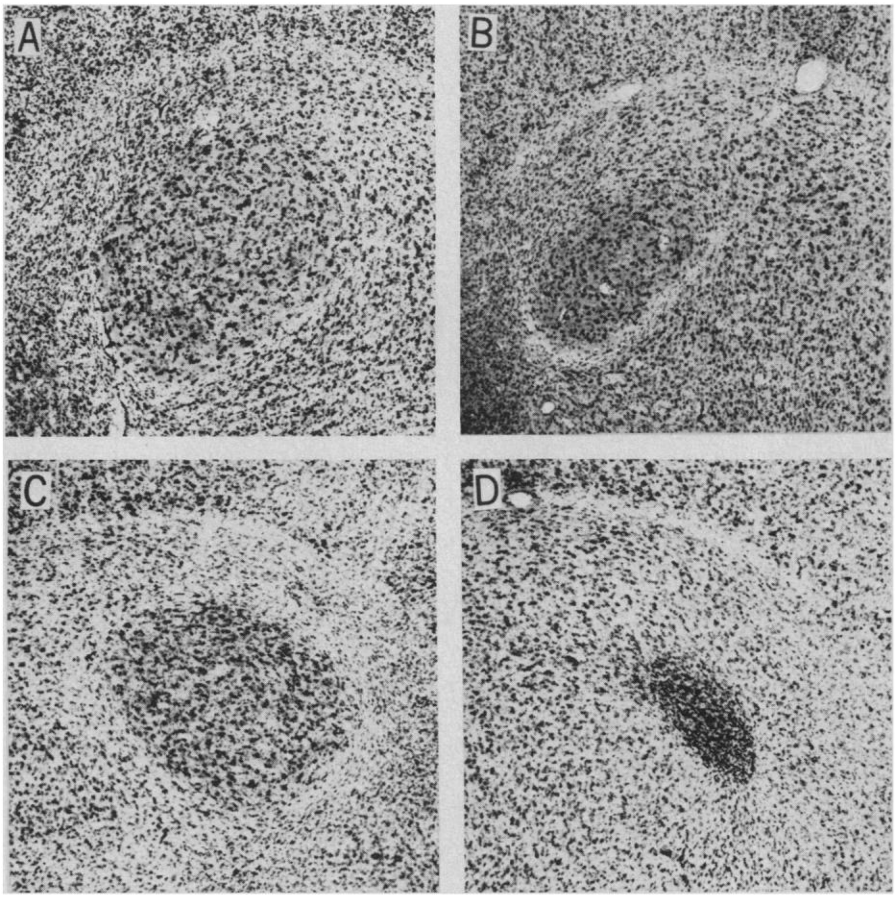

Fig. 1. Frontal sections through the robust nucleus of the archistriatum (RA) in a male (A) and female canary (B) and a male (C) and female zebra finch (D). The canary photographs are from the left hemisphere, and those of zebra finch are from the right. For each of the four birds shown, the rostro-caudal level corresponds to the largest area of RA seen in this plane of section. The relatively unstained eyebrow-shaped structure is the lamina archistriatalis dorsalis, which separates the neostriatum (dorsal) from the archistriatum (ventral). The prominent ellipsoidal nucleus is RA. Cresyl violet–stained sections, 50 μm thick (×42).