Table 1. Characteristics of three species of Mollienesia. Averages are given, with the range in parentheses.

Sex	M. sphenops	M. formosa	M. latipinna
	Na	o. of dorsal rays	
$\mathbf{F}$	9.0 (9)	11.2 (10-12)	13.4 (13–14)
Μ	9.0 (9)	11	13.4 (13–14)
	No. of scale row	s between dorsal and occi	but
$\mathbf{F}$	12.0 (12)	10.5 (10-11)	8.6 (8-9)
М	11.5 (11-12)	9	7.1 (6-8)
	No	. of pectoral rays	
F	15.1 (14–16)	14.6 (14–15)	13.2 (13-14)
М	15.0 (14–16)	14.0 (14)	13.1 (12–14)
	Ratio of predorsal	l length to length of dorsal	base
F	4.69(4.5-5.0)	2.73(2.6-2.9)	1.88(1.8-2.1)
Μ	3.84 (3.3–4.1)	2.34	1.36 (1.2–1.7)

parents wandered many miles during its life span. We also doubt that one of its parents was released by a tropical-fish hobbyist. If this fish is an F<sub>1</sub> hybrid, it is the sole known natural hybrid of a combination thought to have resulted in the formation of M. formosa.

The male was compared with 10 females of *M. formosa* and with 10 of each sex of M. latipinna from the same collection. It was also compared with six males and 10 females of M. sphenops from the Río Pánuco system in Vera Cruz, Mexico. It resembles the females of M. formosa in traits not normally sexually dimorphic in Mollienesia (see Table 1, number of dorsal rays and pectoral rays) and differs from the females just as males of the other species differ from the females (see Table 1, scale rows between dorsal origin and occiput and ratio of predorsal length to length of base of dorsal fin).

The male also resembles females of M. formosa in color pattern (Fig. 1). Both male and female have lateral spotting intermediate between that of the spotted M. latipinna and the almost plain M. sphenops. Both have the caudal base mottled, in contrast to the clear caudal base of M. latipinna and the dusky base of M. sphenops. The dark caudal margin of the male is weak, whereas in the male of *M. latipinna* the dark margin is well developed and in males of M. sphenops the caudal margin is clear.

In body shape the male is intermediate between the robust M. latipinna males and the slenderer males of M. sphenops. Similarly the gonopodial structures of the male are intermediate between those of *M. latipinna* and those of M. sphenops. The serrae on ray 4p extend two segments beyond the tip of the spines on ray 3 in males of M. latipinna, one segment beyond in the male M. formosa, and to the tip of the spines on ray 3 in males of M. sphenops (10). The spines of the gonopodia in M. latipinna are equal in length to the basal elements and are strongly curved toward 1 MAY 1959

the fin base; in M, formosa they are slightly longer than the basal elements and are gently curved, and in M. sphe*nops* they are much longer than the basal elements and are very nearly straight. The consistently intermediate position of the M. formosa male supports a hypothesis that the species originated as a hybrid between M. sphenops and M. latipinna (2, 4). The M. formosa male is extreme with respect to the suspected parental forms only in having the largest gonopodial hood. Such extremes do occasionally occur in known hybrids (11). Its morphology bears the same position relative to that of the suspected parental forms as does the morphology of other natural fish hybrids relative to that of their suspected parental forms (4).

The effect of rare natural males on wild populations of M. formosa as well as the mechanism by which these fish developed male reproductive organs is an interesting field of study. Unfortunately this male was preserved in the field (because of the large sample and the knee-deep mud at the sampling station). It was therefore impossible to ascertain the effects of its chromatin in crosses with females of its own species and with females of related species. Microscopic examination of the gonad shows the milky white smooth texture typical of testes of related species, without any of the yellow tinge or granular texture typical of females. As the gonopodium is somewhat opaque at the tip, the male is believed to have been nearing maturity. CLARK HUBBS

GEORGE E. DREWRY

### Department of Zoology, University of Texas, Austin

BARBARA WARBURTON Texas Southmost College,

## Brownsville

#### **References** and Notes

- 1. P. Hertwig, Handbuch der Vererbungsw. 2B, 1 (1936); J. A. Moore, Advances in Genet. 7, 139 (1955).
- 2. C. L. Hubbs and L. C. Hubbs, Science 76, 628 (1932).

3.

- 4. 5.
- ....., Aquarium J. 17, No. 8, 3 (1946). C. L. Hubbs, Systematic Zool. 4, 1 (1955). H. Meyer, J. Genet. 36, 329 (1938). Among the many experimental broods about 6. which data are as yet unpublished are a few which are bisexual and intermediate between the parental phenotypes. Efforts to repeat these results are now under way; however, none of these broods include males of the M. formosa phenotype. (C. P. Haskins, personal communication, 1958.)
- A. Krumholtz, Ecol. Monographs 18, 1 7. L. (1948).
- C. L. Hubbs, personal communication, 1958; C. P. Haskins, C. L. Hubbs, R. R. Miller agree that this fish is of the *M. formosa* 8. phenotype.
- 9. C. P. Haskins and E. F. Haskins, Proc. Natl. Acad. Sci. U.S. 40, 627 (1954); C. Hubbs, Ecology 40, 154 (1959); C. Hubbs, Evolution,
- in press. We follow the gonopodial nomenclature used by C. Hubbs and V. G. Springer, *Texas J. Sci.* 9, 279 (1957).
- Hubbs and K. Strawn, Evolution 11, 1 11. C. Hul (1957).

13 November 1958

# An Approach to Quantifying Various Types of **Spontaneous Activity**

Abstract. The output of an activitymeasuring device is fed into low- and high-gain cumulative recorder channels which are reset to zero after different time periods. The records, inscribed at various paper speeds, are easily quantified. The tracing patterns can be identified with specific activities of undisturbed animals. The activities are monitored by means of closed-circuit television.

The quantity and quality of spontaneous behavior, simultaneously measured, should be sensitive indicators of the effects of physiological, psychological, and pharmacological procedures. Unfortunately, the techniques generally used to ascertain the random activity of animals yield either a single number or a kymographic record of the pattern of activity (1) which is difficult to quantify. A start toward solution of the problem of obtaining precise information on both parameters simultaneously has been made by combining a specially designed cumulative recorder that indicates the interruption of a light beam across the animal's cage (2) with closed-circuit television.

The recorder, a modification of Skinner's design (3), has several distinctive features. (i) The same input feeds simultaneously into a low-gain channel and into a channel with a gain which is 10 to 50 times that of the other. To obtain the records shown in Fig. 1, the low-gain channel was set at 500 light-beam interruptions, full scale, and the high-gain channel at 50 interruptions, full scale. (ii) Reset to zero is based on elapsed time rather than on accumulated number; the low-gain channel is reset every 15 minutes and the high-gain channel, every 0.5 minute. As a result of this feature, the height of the line gives a number per unit of time without further calculation. Connecting the tops of the lines gives a curve representing the first derivative, rate of change. (iii) A variablespeed paper drive is used so that measurement of the interresponse interval may be as fine as is needed for various purposes. The paper speed used for the charts shown in Fig. 1 was 0.25 mm per second. As may be seen in Fig. 1, certain rates or slopes of line recur on records for specific animals. Through the use of closedcircuit television, operated simultaneously with the cumulative recorder, particular types of behavior have been identified with particular rates or slopes of line (especially on the high-gain channel). Observation by television, of course, has the advantage that the animal's en-



Fig. 1. Rates and patterns of activity of three monkeys as recorded on the low-gain (15minute reset) and the high-gain (30-second reset) channel. The numbers below the tracings refer to patterns of activity. 1, Unidirectional circular pacing typical of rhesus monkeys subjected to prefrontal lobotomy; 2, very rhythmic leaping-pacing behavior typical of mangabeys; 3, random changes of position in the cage; 4, either sitting at rear of cage doing nothing or lying on back on the floor of the cage. The downward deflections on the low-gain channel result from the noise of the recorder.

vironment is not disturbed. Once the records and behavior of an animal have been correlated, television need be used only periodically, since a considerable portion of the total activity can then be *qualitatively* identified from the slope of the line. Moreover, this behavior can be easily and accurately *quantified* on the basis of the absolute height of the line.

Figure 1A is the record for a monkey (Macaca mulatta) which was hyperactive after a prefrontal lobectomy (4). This animal's activity consisted almost entirely of circular pacing, and the uniformity in the amount of this activity in successive half-minute periods is very striking. Figure 1B is a record for a normal mangabey (Cercocebus torquatus atys) that was engaging in a certain amount of rhythmic behavior, reflected in a characteristic slope, and then in nonspecific cage ramblings, which also produced a characteristic pattern. The terminal portion of the record indicates a period of inactivity. Figure 1C illustrates the pattern of activity of a monkey (Cercopithecus mona) not indulging in any rhythmic or recurrent action at all-an animal that is, in fact, exceptionally inactive.

Obviously, the records most easily analyzed are those from animals showing some rhythmic or cyclic activity, since such activity can be identified with great confidence. Even the more heterogeneous tracings without constant slopes can, however, be associated with at least a general category of behavior, which may be peculiar to an individual animal. To what extent a particular slope of line may be used to specify a type of behavior for any animal rather than for a particular animal has not yet been determined. At present the technique is being used only for analysis of the behavior of individuals, both normal animals and those with surgically produced neural lesions.

When, as in the experiments currently being conducted, interruption of a beam of light is used as a means of determining activity, only actions involving gross motor movements are measured. Perhaps use of a cage with a suspended floor which is easily disturbed (that is, a very sensitive jiggle cage) would make it possible to record and identify small-amplitude movements such as scratching. It is estimated that records obtained with the apparatus described in this report (5) account for roughly 80 to 90 percent of the total energy expended by an animal in somatic muscle activity.

> ORVILLE A. SMITH, JR. JUNE L. DEVITO

Departments of Anatomy and Physiology and Biophysics, University of Washington School of Medicine, Seattle

SCIENCE, VOL. 129

#### **References and Notes**

- 1. T. C. Ruch and H. A. Shenkin, J. Neurophys-
- iol. 6, 349 (1943). W. Isaac and T. C. Ruch, Science 123, 1170 2.
- (1956). 3.
- (1956). B. F. Skinner, *The Behavior of Organisms* (Appleton-Century, New York, 1938). This study was aided by a contract (N113-150) between the Office of Naval Research, De-partment of the Navy, and the University of Washington
- We are indebted to Edmund H. Brand for the 5. design of most of the equipment utilized in the study and to Dennis Meadows for the construction and maintenance of the equipment.

28 November 1958

## Factors Involved in the Effect of Serotonin on Evoked **Electrocortical Potentials**

Serotonin, when it is injected into the common carotid artery, causes a transitory inhibition of the (ipsilateral) transcallosal response (Marrazzi et al., 1, 2). Marrazzi et al. conclude that serotonin inhibits the ipsilateral cortical synapses. However, the question arises whether serotonin may not exert its inhibiting effect upon the cortical synapses indirectly-that is, via subcortical or even extracerebral receptors such as the carotid sinus receptors. Bonvallet et al. (3) have demonstrated that an increase in excitation in the pressoreceptors leads to an inhibitory picture in the electroencephalogram, and Heymans et al. (4) have shown that serotonin has an excitatory effect upon the pressoreceptors in the sinus.

In cats anesthetized with dial-urethane (0.45 ml/kg), the right carotid sinus was denervated. Fine metal canulae were inserted into the common carotid artery on both sides, approximately 1 inch below the carotid sinus. Optically evoked potentials were recorded in the conventional manner from both visual areas. A short light flash was applied every 6.3 seconds. The standard procedure was to give ten control stimuli and then to inject the serotonin and to record another 50 responses. Injections into the innervated (left, I) artery and into the denervated (right, D) artery were alternated at intervals of not less than 30 minutes. Each injection yielded two sets of records, an ipsilateral (with respect to site of injection, I) one and a contralateral one (C). Thus four sets of records were available from each pair of injections, referred to as II, (innervated, ipsilateral), IC (innervated, contralateral); DI (denervated, ipsilateral); and DC(denervated, contralateral). We averaged the results in each of these four groups after we had converted the measured values to ratios with respect to unity, and we calculated the area between the curve connecting the (averaged) peaks of the responses and the straight line representing the mean of the (preinjection) control values for the four experimental situations. Areas below the control were designated as "minus," indicating inhibition, those above as "plus," indicating facilitation. Our results are based on 27 experiments with 1.25, 5.0, and 10.0 µg of serotonin per animal.

As is shown in Fig. 1, denervation of the carotid sinus does not abolish the effect of intracarotid injection of serotonin. However, quantitative differences between II and DI indicate that part of the cortical effect is induced from the carotid sinus and conveyed to the cortex via nervous pathways. Since effects are obtained from the denervated carotid on the ipsilateral (DI), as well as on the contralateral cortex (DC), the drug evidently excites receptor sites which have a bilateral modulating effect upon the optic cortex (5). Such receptors are in all probability located in the reticular core. Finally, differences between the ispi- and contralateral records point toward participation of a cortical receptor site sensitive to serotonin. From this evidence we conclude that the following three factors play a part in bringing about the cortical effect: (x) a nervous influence induced by stimulation of carotid sinus receptors, conveyed from there to the brain stem and from there via ascending unspecific diffuse systems to the ipsilateral and the contralateral cortex (5); (y) a bilateral nervous influence via ascending unspecific systems, activated by the drug at receptor elements located in the brain stem; (z) a direct influence of the drug in question on the cortical (5) synapses on the side of the injection. We further assume that the effects of these components add algebraically to bring about the cortical effect. The following equations indicate the way in which these factors are combined in the four experimental situations:

$$II: x + y + z \tag{1}$$

$$IC: x + y$$
 (2)

$$DI: y + z \qquad (3)$$
$$DC: y \qquad (4)$$

$$IC + DI - DC = II \tag{5}$$

· • .

The values obtained indicate that Eq. 5 is well satisfied by our experiments, although there is a residue of positive or negative sign. On the basis of Eqs. 2, 3, and 4, the time course of factors x, y, and z as f(t) was calculated from the



Fig. 1. Effect of serotonin (10, 5 and 1.25  $\mu g)$  on optic potentials. The numbers at the top of each curve indicate the areas between preinjection values (dashed horizontal lines) and the peak-to-peak distance of the primary positive and negative response (solid lines). The abbreviations II, IC, DI, and DC indicate the different experimental situations described in the text; x, y, and z are the factors calculated on the basis of Eqs. 2, 3, and 4. All curves are smoothed averages (10 values) from mean values of 10 (10  $\mu$ g), 9 (5  $\mu$ g), and 8 (1.25 µg) experiments. The heavy line in the top section is  $II_t$ ; the thin line is (x+y+z) t. Note the good coincidence. Abscissa: time; ordinate: one-tenth relative amplitude.

values of IC, DI, and DC at any time t. Figure 1 shows the result in smoothed average curves (ten values each). Furthermore, Fig. 1 shows that the curve  $\Sigma$   $(xyz)_t$  follows closely curve  $II_t$ . This is another indication that our assumptions and equations are valid.

The method described here thus allows one to "fractionate" drug effects and to gain insight into the intimate mechanisms involved in the action of "centrally active" chemicals.

W. P. Koella

J. R. Smythies

D. M. Bull

Laboratory of Neurophysiology, Worcester Foundation for Experimental Biology, Shrewsbury, Massachusetts

#### **References and Notes**

- 1. A. S. Marrazzi and E. R. Hart, Science 121, 365 (1955). M. I. Gluckman, E R. Hart, A. S. Marrazzi,
- 2. ibid. 126, 448 (1957)
- 3.
- M. Bonvallet, P. Dell, G. Hiebel, *Electroencephalog, and Clin. Neurophysiol.* 6, 119 (1954). C. Heymans and Van den Huevel-Heymans, 4.
- Arch, intern. pharmacodynamie 93, 95 (1953). Cortical here may be taken to mean "cortical or geniculate body, or both." 5.
- This work was aided by grants from the U.S. Public Health Service (MY-2211), the Ford Foundation, and the Scottish Rite Fund for Dementia Praecox Research through the Na-6. tional Association for Mental Health.

10 December 1958