Fig. 3. A continuous record of the drug self-administration and free operant response made by a monkey for a period of 90 days.

responding obtained with one channel.

The dependent variable is the distribution of responses in time. Identifying legends attached to the left of the graph permits ready comparison of saline and drug effects. Drugs were identified by code number as part of a blind control condition.

It is apparent that the graph presented yields information about response distributions that would not be evident from daily response totals and that could not be conveniently obtained by most other methods of data presentation.

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An inexpensive, low-frequency function generator*

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In research on visual tracking, it is sometimes necessary to present a target that moves with varying velocities in a complex and erratic fashion (e.g., Steinbach, 1969). Complex analog equipment can provide the necessary voltages (Young, 1962, for example, used the sum of four sinusoids in his technique), but the simple technique described below is adequate for many studies and provides a function generator that produces repeatable, slowly varying voltages in any waveform the investigator chooses.

The apparatus is schematically illustrated in Fig. 1. It requires a light-dependent resistor (LDR, silicon, or cadmium sulfide cell)¹ with a mask over the LDR that has a narrow slit cut in it. A cardboard disk with the opaque function in polar coordinates cut on it is rotated by a motor (not shown in the figure).² A dc source of illumination is also required. The items are arranged so that the amount of light falling on the LDR is determined by the opening in the narrow slit which is not occluded by the opaque portion of the disk. The

LDR requires a separate dc source (a 6-V battery is usually sufficient); the amount of light falling on the LDR causes its resistance to be altered proportionally, and the potential changes can be read across the leads of the LDR.

The maximum height and depth of the cutout function are determined by the maximum diameter of the photosensitive surface of the LDR. The masking slit should be of the same length. It is usually necessary to experiment somewhat to find an orientation of the LDR under the slit that produces a response linear with respect to the amount of light passing through the slit. In my application, the generated potential changes were displayed as a moving spot on an oscilloscope that had the horizontal sweep disabled, and this provided the target to be tracked.

If an irregular waveform is used, cycle time or repetition rate will be determined by the rpm of the motor. The motor used rotated at 0.6 rpm; thus, it was 100 sec before the function repeated. The waveform was sufficiently irregular, however, so that the S was unaware of repeating cycles even after several minutes of observation. The top illustration in Fig. 2 shows the waveform resulting from the irregularly cut cardboard disk to the left of the function. It is possible to use any repeatable waveform (sine, square, triangle, sawtooth,

Fig. 1. Exploded view of the low-frequency function generator components.

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Fig. 2. Top record shows the output of the irregularly shaped function disk. The time record represents 1-sec intervals. The waveform repeats after 100 sec. Bottom record shows a sine wave output generated when a circular function disk is mounted eccentrically in the apparatus.

etc.) and to alter the frequency by using a variable-speed motor to rotate the disk. Amplitude can be varied by altering the peak-to-trough distance on the function disk or by varying the voltage applied to the LDR. The bottom illustration of Fig. 2 shows a sine function that can be approximated by mounting a circular function disk eccentrically.

A useful extension of the technique described above allows for the development of a variable phase generator.³ A second light-slit-LDR unit mounted radially and modulated by the same function disk provides a second voltage that is phase-shifted from the first by an amount equal to the angular separation between the two LDRs. Thus, if a sine function were being generated and the second LDR was rotated 90 deg (the reference axis is the spindle of the motor driving the disk), two sine waves would result, with a phase angle of 90 deg. Adjustment of the second LDR's position would provide phase variations.

REFERENCES

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- Young, L. R. A sampled data model for eye tracking movements. Doctoral dissertation, M.I.T., 1962.

NOTES

1. Suitable LDRs are readily available from electronics supply houses or other sources, e.g., Edmund Scientific Co., Model 41,108.
2. The function can be cut out of opaque adhesive plastic sheet ("Mac-Tac" or "Con-tact") and attached to a Plexiglas disk or simply painted on the disk.
3. I thank Stuart Anstis for this and other helpful suggestions.
4. A sophisticated version of this instrument, the Advance Electronics SG-88 VLF generator, was available commercially, but the item has been withdrawn from the market.

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