switch is "off"—is directly dependent upon the resistance of the P-R element in the "on" and "off" states. To maximize this ratio, the extremes of applied voltage should be used, subject to the limitation of damage to the light source.

Figure 3 shows a schematic drawing of an audio switch employing a P-R element in combination with a light source (a Raytheon CK1123 "Raysistor") used in our laboratory. Usually in psychophysical studies in which it is necessary to control the intensity of audio stimuli, an attenuator is inserted in the circuit immediately following the switching device. In such cases it is desirable to match impedances between adjacent devices for the "switch on" condition. This is accomplished by choosing the proper value for R_1 (if the "on" resistance of the Raysistor is 60 ohms and the source and load resistance is 500 ohms, then R_1 should equal 3.6 kilohms). The device in Fig. 3 has an on-off ratio in excess of 85 dB and insertion loss of 3 dB when working with a 500-ohm source and load resistance. If in Fig. 1 the resistance of the P-R device is represented as R_R and that of the loudspeaker as R_L , then the on-off ratio is given by

$$\frac{R_R \text{ "on"} + R_L}{R_R \text{ "off"} + R_L}$$

If $R_L = 10$, $R_R \text{ "on"} = 60$, and $R_R \text{ "off"} = 10^7$ ohms, the on-off ratio is 103 dB.

Figure 4 shows a schematic drawing of a control device to provide the input to the Raysistor light source. It consists of a unijunction transistor operating as an astable multivibrator driving a bistable multivibrator that in turn supplies the current to the Raysistor light source through an isolating emitter follower. The circuit provides independent control of on- and

off-time when cycling repetitively and of on-time when operating under "one-shot" conditions. Circuit Elements C_4 , C_5 , and R_{12} provide the necessary shaping of the current onset and offset to provide equal rise and decay times for the audio signal. Figure 5 illustrates the form of a typical sine wave burst. The cost of the Raysistor used here was less than \$4.00; the cost of the parts contained in the light driver shown in Fig. 4 was under \$15.00.

DISCUSSION

In summary, the minimization of the click associated with the onset and termination of an auditory stimulus is important for almost any experiment employing such a stimulus. This click is basically a function of the spectral energy spread associated with abrupt changes in the signal. By controlling the rate of change of signal amplitude at onset and offset, the energy spread is minimized and the perception of the click eliminated. A simple device for accomplishing this consists of a light source and a resistive element whose resistance is a function of the light intensity falling upon it. The variable resistance functions as a graded switching device whose temporal characteristics depend largely upon those of the light source (and its driving current). The advantages of such a switch over commercially available electronic switches are: low cost, low noise level, absence of harmonic distortion, high on-off ratio, high reliability, and uniform frequency response from dc to the megahertz range.

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An automated multi-channel programming, data collection, and printout system for avoidance and stress conditioning of monkeys¹

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A multichannel programming, data collection, and printout system is described for the investigation of avoidance and stress conditioning of monkeys, individually or yoked.

An automated system was developed for simultaneous avoidance or stress conditioning of several yoked pairs or of individual monkeys. During testing each monkey is housed in a primate restraining chair instrumented with a joy-stick lever for avoidance electric shock and a stimulus light panel indicating conditioning treatments. Three treatments may be programmed singly or in all possible combinations: (a) a relatively intense body shock ($\frac{1}{2}$ -20 mA) for $\frac{1}{2}$ -2 sec duration, delivered periodically (every 5-100 sec) unless the S resets the interval timer by a lever pull; (b) a relatively low-intensity shock (1/10-5 mA) to the body and hand, for the duration of a lever pull, each time the

animal pulls the lever; and (c) an occasional aperiodic unavoidable body shock, recurring every 8 min on the average, of relatively high intensity ($\frac{1}{2}$ -20 mA) for $\frac{1}{2}$ -2 sec duration. For the initial training, the first treatment may be controlled manually to inhibit programmed shock or deliver unprogrammed shock.

For Treatments (a) and (c) the shock is delivered to the body of the S between a neck-chain and metal neck contact-plate and either the buttocks or feet so that the S cannot avoid the shock by any positioning effort. For Treatment (b) the lever, when pulled, is also in the shock circuit, i.e., the S receives the shock at the hand as well as the body, or only the body depending upon the position of a switch. The three treatments, and combinations thereof, are indicated by the illumination of three 6-W lights with a red, green, and white frosted jewel, respectively, in the stimulus light panel mounted on the primate restraining chair. No illumination of the lights indicates a rest period, i.e., no treatments, and is programmed by having the programmer "on" with no treatment scheduled.

Fig. 1. Simplified system block diagram of automated, multichannel avoidance-conditioning equipment.

The programmer is designed for a maximum of 24 different programs in a 24-h period. A single program may be as short as 5 min or as long as 24 h. Each programmer encompasses either one experimental S or a yoked pair, i.e., an experimental and a control. The programming for the yoked animals is identical and the integrity of their lever pulls maintained, but the experimental S's lever is functional whereas the control S's lever is not. The control monkey receives the same shocks at the same time as the experimental S but has no control over shock occurrence or postponement. The programming, data collection, and printout system is capable of handling successive periods of conditioning and rest for weeks on end. Details of the system are described below.

The block diagram in Fig. 1 shows that system timing is determined by a Digital Clock with a separate time matrix connected to each of several Program Channels. A programmer provides two functions: a pulse to initiate a printout sequence and the gates that turn on the programmed treatments generated by each Shock Timer and Data Acquisition Unit (STADA). Data accumulated by STADA units are sequentially selected for printout by the Data Selector. After completion of a printout sequence, the Data Selector resets the data counters and steps the Programmer.

Visual readout of the data is available from BCD (binary coded decimal) neon lights. A stored number is easily read as the sum of the lighted neons having a weighting of 1, 2, 4, and 8, Fig. 2, bottom.

Basic Printed Circuit Boards

All of the electronic counting, switching logic, and pulse

Fig. 2. One of several identical programmers in automated, multichannel avoidance-conditioning equipment.

generation are accomplished with six basic building-block printed circuit boards: (a) DCU (decade counting unit); (b) quadruple AND gate; (c) octuple neon light driver; (d) dual relay-power driver; (e) dual multipurpose multivibrator; and (f) dual Schmitt trigger.

DCU. The decade counting unit (commercially available³) is a conventional scaler using four flip-flops and the required feedback gates to achieve counting by radix 10. The BCD output is a four-line 1-2-4-8 code having a logical "0" level of less than minus 0.3 V and a logical "1" level of greater than minus 6.0 V. These output levels were adopted for the entire system to yield considerable noise immunity.

Quadruple AND gates. The AND gates (Walston & Miller, 1963) are converted with a minor wiring change to perform the OR function. The complementary functions, NAND and NOR, are available with reduced fan-out (output loading) capability.

Neon light drivers. Eight inverting drivers using high-voltage transistors were constructed on each board.

Dual relay-power driver. This circuit handles general-purpose power control such as relay operation, high-current reset pulses to multidecade counters or any situation where the fan-out ability of the standard logic gates is exceeded. The printed circuit wiring permits multiple wiring schemes for the many different power functions.

Dual multipurpose multivibrator. This board (Cleary, 1964) consists basically of a unijunction transistor timing circuit that triggers a flip-flop. By altering the connections to the circuit of a resistor-capacitor timing network, the circuit will perform as an astable, monostable, or asymmetrical astable multivibrator with excellent stability. Because of the high input impedance of the unijunction transistor, the circuit can easily produce long periods, 50 microsec to 100 min. Risettime of the output waveforms is less than 2 microsec and it is easily triggered at three separate points.

Schmitt trigger. This conventional regenerative trigger circuit (Walston & Miller, 1963), used whenever exceedingly short risetimes are required, is employed here to trigger the first decade of each counter and as a conditioner to eliminate multiple pulses whenever a pulse is required from a switch closure.

Discrete components were used in the construction of the logic circuits described above. Substantial cost savings may now be achieved by employing the new low-cost plastic encapsulated integrated logic circuits.⁴

Digital Clock

The time base, a 60-Hz synchronous motor cam timer with a momentary switch closure once per minute, is used to step a rotary solenoid switch counter. Rotary solenoid switches are used in place of transistor logic to maintain the integrity of the clock time and program placement after momentary power failures. The switch closure steps a 10-position "minutes" switch, every fifth position of which steps a 12-position "five-minute" switch, every twelfth position of which steps a 24-position "hour" switch. The use of an unconventional counting system permits program changes at 5-min intervals while maintaining a conventional clock readout.

One pole of each switch is used to develop a BCD output for printing clocktime at the start of each printout sequence. A second pole is used to switch NIXIE decimal readout tubes. The remaining poles of the "five-minute" and "hour" switch are connected to the individual programmers.

Programmer

There are two sections to the Programmer: the first determines the time of a program change and the second determines which treatments of a program are to be on. To allow changes in program sequence, the front panel contains a separate pinboard

matrix⁵ for time and programs (Fig. 2, top). The time matrix is arranged with "hour" columns and "five-minute" rows. To select the time of a printout and program change, a diode pin is inserted in the hole at the intersection of the desired time. Figure 2 shows diode pins installed for 6:15, 6:35, 8:05, and 8:30. While printout is normally required at the end of a program, subtotal printouts may be obtained by inserting a resistor diode pin in place of the diode pin, thus inhibiting the reset and stepping pulse.

A 24-position rotary solenoid switch that is connected to the columns of the program matrix is used to select the program. The position of the switch and, therefore, the program in progress is indicated by a small light at the top of each column. The individual treatments in a program appear as rows in the matrix. Each program is selected by inserting a diode pin in the hole at the intersection of the desired treatment row and program column. Shown in Fig. 2 is Treatment C for Program 1 and Treatments A and B for Program 3. The treatments were described earlier. In the event that fewer than 24 programs are required for a complete cycle, a reset row appears in the matrix. A diode pin placed in any hole along the reset row will, when the rotary solenoid switch steps to that intersecting program column, cause the rotary solenoid switch to seek its home position which is Program No. 1.

Shock Timer and Data Acquisition Unit

The number of lever pulls of each monkey is totaled by separate five-decade counters. Each decade of the counters consists of a DCU, quadruple two-input AND gate, and one-half of an octuple neon light driver. The AND gates provide the means to select sequentially the DCU's four-line BCD output for printout while front panel visual readout is continuously provided by the neon lights (described earlier) from gates supplied by the neon light drivers. Decade positions on a printout line not used to display a DCU output are used to code information. For this purpose, the AND gates and neon light drivers are utilized without a DCU.

The shock, a 60-Hz constant-current sine wave, generated from the 500-V rms secondary of a transformer by a relay contact closure, operates in three modes, singly or in any combination, providing for the three conditioning treatments.

The first mode triggers a shock-duration timer after an interval variable between 5 and 100 sec unless reset by the experimental S's lever; the second delivers a continuous shock while the animal's lever is operated; and the third delivers to a shock-duration timer, triggers with asymmetric intervals having a cycle period of 100 min. The particular sequence of the

intervals are programmed via a plug-in-circuit board.

The number of shocks received by the S pair in Modes 1 and 3 is counted by a two- and one-decade counter, respectively. The number of shocks received in Mode 2 is the same as the number of lever pulls of the experimental animal. To avoid the possibility of the monkeys being subjected to an undesirable number of shocks due to malfunction of the shock circuit, a latching preset shock inhibit AND gate is connected to the counter. When the preset number of shocks during any one treatment program is delivered to the Ss, the gate inhibits all further shocks and provides a visual alarm.

Data Selector

The Data Selector, upon receipt of a readout command from a Programmer, produces the following sequence of events in rapid succession (2.7 sec total): Printer ac power is turned on; combinations of a readout gate and print command are sequentially sent to, respectively, the data counters and the printer; a reset pulse is sent to the counters; a stepping pulse is sent to the Programmer to initiate the next program; and Printer ac power is turned off. A 52-position telephone step-selector switch wired for self-stepped operation is used to select and generate the required gates and pulses for the readout sequence.

Printer and Printout Format

The printer is a medium-speed digital unit⁶ equipped for a 6-digit line capacity. Clock time occurs on the first line of the 21-line printout followed by three data lines and a blank line per programmer channel. The data lines contain the subject code, treatment code, number of paddle pulls, and number of shocks per treatment of each monkey.

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NOTES

1. This project was supported by NIH Grants NB 04053 and MH 02895.
2. The authors wish to acknowledge the assistance of Mr. Charles Dreyer in the completion of this project.
3. Computer Measurements Company, Model 90-512. Division of Pacific Industries, Inc., San Fernando, California.
4. A DCU costs approximately \$30. The equipment common to all channels using plastic ICs costs about \$2500, with each channel an additional \$1000. Although our original cost was \$7000, an equivalent unit consisting of three channels can be constructed for approximately \$5500.
5. Sealectro Company, 225 Hoyt Avenue, Mamaroneck, N.Y. 10543.
6. Computer Measurements Company, Model 410A. Division of Pacific Industries, Inc., San Fernando, California.

A runway for chicks

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Problems associated with using chicks in a runway are discussed. Acquisition and extinction data are presented from a sample of 12 Australorp chicks.

Chicks have been used previously as Ss in runway experiments but only with the aid of special pretraining methods that have

made interspecies comparisons difficult. Grindley (1929), for example, used a prolonged successive approximation procedure and the social facilitation of a group of chicks tethered adjacent to the goal box to develop running and eating responses. These methods were necessary to overcome two major problems in the use of these animals as Ss: the length of time it takes chicks to begin eating when they are alone and their immobility when they are alone.

The feeding problem can be solved by placing chicks in groups