CONCURRENT MEASUREMENT OF HEART RATE AND INSTRUMENTAL AVOIDANCE BEHAVIOR IN THE RHESUS MONKEY

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A graphical method has been developed for the concurrent recording of heart beats and lever responses during behavioral experiments. The EKG signal fed into any DC amplifier goes to a fixed level trigger circuit and relay driver with its own power supply. The signal from this drives any standard cumulative recorder. Lever response rates are recorded concurrently on an additional cumulative recorder using the same paper speed.

This paper describes a method for the simultaneous cumulative recording of heart beats and lever responses during psychophysiological experiments involving autonomic measurements and instrumental behavior performance. In addition, it illustrates changes in heart rate related to performance on a shock-avoidance schedule in laboratory primates.

METHOD

Three Rhesus monkeys restrained in Foringer primate chairs (Mason, 1958) and enclosed in sound-attenuating booths were trained on a conditional avoidance procedure (Sidman, 1953). Brief electric shocks (6 ma., 60-cycle AC, for 0.5 sec) were delivered to the feet every 20 sec unless a lever response during the interval delayed the shock another 20 sec. The training procedure involved the use of a short 2-sec interval between shocks in the absence of a lever response (the "shock-shock" or "S-S" interval) and a 20-sec interval between lever responses and shocks (the "response-shock" or "R-S" interval). The avoidance behavior was brought under stimulus control by pairing the presentation of a continuous red light with the programming of the shock-avoidance requirement. The experimental procedure was programmed and the behavior and autonomic activity were recorded automatically by timers, counters, cumulative recorders, and associated physiological monitoring instruments.

The EKG was obtained through chronically implanted subcutaneous tantalum electrodes placed on the right and left arms and brought

out to a fixed pedestal secured to the animals skull (Sheatz, 1960). The EKG input was obtained through a shielded cable from this pedestal and the EKG output signal was fed from a DC amplifier (Grass model 5P) into a fixed level trigger circuit and relay driver with its own power supply and AC filter. Figure 1 illustrates the circuit diagram of the fixed level trigger unit. The modified EKG pulse activated the stepper of a Gerbrands cumulative recorder with a paper speed of 11 in. per hr and a step range of 950 responses. A second Gerbrands cumulative recorder with a paper speed of 11 in. per hr and a step range of 450 responses recorded lever responses.

RESULTS

Figures 2 and 3 are presented as illustrative data reflecting sensitivity of method for recording concurrently cumulative heart beats and lever responses under different experimental conditions for two of the animals. Comparative visual estimates of both lever responses and heart beats can be derived by counting complete excursions of the pen across the paper, measuring distance between peaks of these excursions, and/or measuring the slope of the curves per unit time.

Part A and B of Fig. 2 show control concurrent tracings for both lever responses and heart beats in the absence of the avoidance stimulus and shock programming for monkey M-1. Sections C and D of Fig. 2 illustrate concurrent lever responses and heart beat recordings during a 2½-hr experimental session in the presence of the red light but with the

Fig. 1. Circuit diagram of fixed level trigger unit.

Index for Figure 1

R1 91 ohms, 1 watt
 R2 51 ohms, $\frac{1}{2}$ watt
 R3 10K ohms, $\frac{1}{2}$ watt
 R4 47K ohms, $\frac{1}{2}$ watt
 R5 470K ohms, $\frac{1}{2}$ watt
 R6 100K ohms, $\frac{1}{2}$ watt
 R7 5.1K ohms, $\frac{1}{2}$ watt
 R8 1K ohm, $\frac{1}{2}$ watt
 P1 1 megohm potentiometer, 2 watts
 C1 20 mf., 450 v.
 C2 40 mf., 450 v.
 C3 0.1 mf., 200 v.
 C4 0.33 mf., 200 v.

Potter & Brumfield KCP 11 relay
 TR1 Power Transformer, Stancor PS 8416
 c.t. center tap (0 to 125 volts)
 A.C. line 117 volts a.c., 60 cps
 T1 one-half 12 AT7 tube
 T2 one-half 12 AT7 tube
 PNP 2N 414 transistor
 D1 diode M 150
 D2 diode IN 625
 D3 diode IN 754
 S1 manual switch, SPDT
 OUT output

shock turned off (avoidance extinction). During the initial 10 to 20 min of this extinction session the monkey maintained a high lever pressing response rate and the heart beat rate showed a correlated elevation over control levels. As the lever pressing rate declined following the initial 20-min exposure the heart rate also declined. Subsequent oscillations in the two measures tended to follow closely except for the terminal phases of the session during which heart beat rate showed a marked increase while lever responding dropped to its lowest level.

Figure 3 shows concurrent recordings of heart beats and lever responses for monkey M-2 during an experimental session involving avoidance plus "free-shock". Monkey M-2 was already well trained by the time the data of Fig. 3 was taken. Following a 1-hr control

period during which heart beats and lever responses were recorded in the absence of the shock-avoidance requirement, the red light was presented and the shock-avoidance contingency programmed along with intermittent "free-shocks" which the monkey could not avoid. The pips on the two tracings indicate the frequency and distribution of the "free-shocks". These conditions were in effect for 50 min during which a dramatic increase in both lever responses and heart beats showed a noticeable decline although elevations above control levels continued to be apparent for at least the first post-avoidance hour.

DISCUSSION

The results of these experiments demonstrate the feasibility of obtaining concurrent

Fig. 2. Concurrent cumulative lever responses and heart beat recordings during a 2 1/2-hr avoidance extinction session.

Fig. 3. Concurrent cumulative lever responses and heart beat recordings during an experimental session involving avoidance plus "free-shock". A. lever responses and B. heart beats. Pips on the two tracings indicate the frequency and distribution of the "free-shocks".

cumulative recordings of heart beats and lever responses for rapid visual inspection in the course of psychophysiological studies with laboratory primates. The relationship of this method for recording autonomic changes during behavioral performance to other more conventional measures of cardiovascular function must, of course, be reliably assessed. In the present analysis such reliability checks were accomplished using three channels of the Grass polygraph (model 5P). Inputs to these three polygraph channels provided simultaneous recordings of the EKG in more conventional form as well as temporally correlated recordings of lever responses and relay driver firings. Figure 4, for example, illustrates typical polygraph tracings obtained during avoidance and control sessions recorded simultaneously with the cumulative records shown in Fig. 2. The relay driver firing followed every R wave deflection of the EKG (lead II) and the mean heart rate change from the control (138 beats

per min) to avoidance (177 beats per min) is clearly apparent.

Previous reports have described autonomic (Gantt and Hoffmann, 1940; Wenzel, 1960) and neurophysiological (Hearst, Beer, Sheatz, and Galambos, 1960; Anliker, 1959) changes related to instrumental behavior performance in laboratory animal subjects. In humans, Peters and Gantt (1951); Notterman, Schoenfeld, and Bersh (1952) have shown heart rate conditioning. For the most part, however, the analysis of such relationships has not emphasized longitudinal concurrent cumulative measurements. In monkeys, movement artifacts and unfavorable signal-to-noise ratios have made it difficult to develop readily comparable recording techniques for such psychophysiological correlation studies. The use of 60-cycle filters, fixed chronic electrode implants, and fixed pick-up devices in the present method tends to materially reduce such artifact interference.

Fig. 4. Polygraph tracings indicating relay driver firing, EKG, and lever responses. Upper tracing was obtained before avoidance behavior. Lower tracing was obtained during avoidance behavior.

REFERENCES

- Anliker, J. Brain waves and operant behavior. *J. exp. Anal. Behav.* 1959, **2**: 252.
- Gantt, W. H., and Hoffmann, W. C. Conditioned cardio-respiratory changes accompanying conditioned food reflexes. *Am. J. Physiol.*, 1940, **129**: 360.
- Hearst, E., Beer, B., Sheatz, G., and Galambos, R. Some electrophysiological correlates of conditioning in the monkey. *J. EEG and Clin. Neurophysiol.*, 1960, **12**: 137-152.
- Mason, J. Restraining chair for the experimental study of primates. *J. appl. Physiol.*, 1958, **12**: 130-133.
- Notterman, J. M., Schoenfeld, W. N., and Bersh, P. J. Conditioned heart rate response in human beings during experimental anxiety. *J. Comp. and Physiol. Psychol.*, 1952, **45**: 1.
- Peters, J. E., and Gantt, W. H. Conditioning of human heart rate to graded degrees of muscular tension. *Fed. Proc.*, 1951, **10**: 104.
- Sheatz, G. Multilead electrode holder in chronic preparations. *Symposium on Brain Stimulation*. University of Texas Press, 1960.
- Sidman, M. Avoidance conditioning with brief shocks and no exteroceptive warning signal. *Science*, 1953, **118**: 157-158.
- Wenzel, B. M. Changes in heart rate associated with responses based on positive and negative reinforcements. *J. Comp. and Physiol. Psychol.* (In press).

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