gas. In order to prevent the thrombus from floating in the plasma, the lumen of the tube was constricted at one point by an outside metal clip. Aseptic sterile technique was used throughout the experiment.

A total of 165 experiments were performed on the plasma of blood obtained from adult patients of the outpatient clinic of the Eugene Talmadge Memorial Hospital of the Medical College of Georgia. Samples were taken from most of the patients before and after an operation or delivery. Several variations in the experiment were tried initially. Sixty-seven experiments were done as described above, and lipophages were identified in 28 of 45 thrombi that were stained for fat. All thrombi were examined histologically.

Human in vivo thrombi in the early stages of degeneration and organization also contained lipophages similar to those in atherosclerotic plaques. Phagocytosis of platelets was observed in 58 of 134 venous and arterial thrombi that were obtained at autopsy and varied in estimated age from a few hours to several weeks (Fig. 1*c*). Phagocytosis was most pronounced in the first 2 weeks. In some thrombi transitional cells containing both fat and platelets were observed.

The concept that some atherosclerotic plaques are mural thrombi altered by degeneration and organization is supported by many investigators who have traced the conversion of fibrin to fibrous intimal plaques in both human and experimental thrombi (*4*). Since fibrin is a fibrous protein that contains no lipid (*5*), it does not account for fat in plaques. However, platelets are rich in lipids, including cholesterol (*6*), and are a principal constituent of arterial thrombi (*7*).

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7. This work was supported in part by a grant (H-3973) from the U.S. Public Health Service. We wish to thank Marion Hutson, Teresa Klett, and Mrs. David Fulghum for their technical assistance.

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Continuous Compensatory Tracking by a Cebus Monkey

Abstract. A cebus monkey was trained to hold a continuously moving voltmeter needle on-target for 60 seconds to obtain a food-pellet reinforcement. The task confronting the animal was relatively complex in that the high-frequency error voltage fed to the voltmeter needle was nulled by the animal by means of a joystick physically separated from the stimulus display.

The investigation reported here was designed to determine whether a cebus monkey could be trained to perform continuous compensatory tracking in one dimension with (i) food reward as a positive reinforcement, (ii) a relatively complex tracking task, and (iii) a control stick physically separated from the stimulus display. Such a response would be invaluable for providing precision monitoring of animal behavior in studies where conditions such as drug states, space flights, and so forth, would preclude the use of human subjects.

The apparatus as seen by the monkey is shown in Fig. 1. A potentiometer attached to the bottom of the self-centering control stick (*A*) provided a voltage change proportional to stick position. A ½-inch target zone (*D*), in the center of the milliammeter (*B*), was illuminated by a red 6-volt bulb any time the needle (*C*) entered the zone.

A cam-generated forcing function produced an irregular needle deflection of ±1 inch, and had a frequency of approximately 10 cy/min. The potentiometer attached to the stick enabled the animal to null the cam-generated error voltage and receive a reinforcement (food pellet). The error voltage drove a pen on a multichannel recorder, and, when reduced by the monkey to a sufficiently low magnitude, started a synchronous timer and actuated the on-target light in the center of the meter face. When the animal held the needle on target for the length of time set into the synchronous timer, a 0.67-g pellet of whole-diet food was delivered to the food cup by a mechanized food dispenser (see *E* in Fig. 1).

To prevent the monkey from obtaining free food pellets during early training stages as the needle passed through the target zone, the needle was set to fluctuate about a point 2 inches to the right or left of the target zone (see trace *A* in Fig. 2).

Although the animal was unrestrained and free to move the stick at any time, the food delivery equipment was energized only 1 hour in the morning, 1 hour at noon, and 1 hour at night. Since the monkey was not fed at any other time, it was under 16 hours of food deprivation in the morning, and under 4 hours of deprivation before each of the other two sessions. At feeding times (which were controlled automatically by a 24-hour timer), the room lights were shut off, the small light behind the face of the meter was turned on, and the multichannel graphic recorder was started. If the stage of practice required it, the forcing-function cam was also started at this time. After 1 hour, the apparatus was automatically turned off and the room lights were automatically turned on.

With the exclusion of delays due to apparatus failures and experimenter error, it is estimated that the training lasted approximately 30 days, or 90 experimental hours. In the first phase of training the monkey was taught to compensate for a discrete deflection of the display needle. Initially, any deflection by the control stick that caused the needle to cross the target zone was rewarded no matter how small an amount of time it remained in the target zone. The delivery of the food pellet was accompanied by an audible click of a relay and the illumination of the red

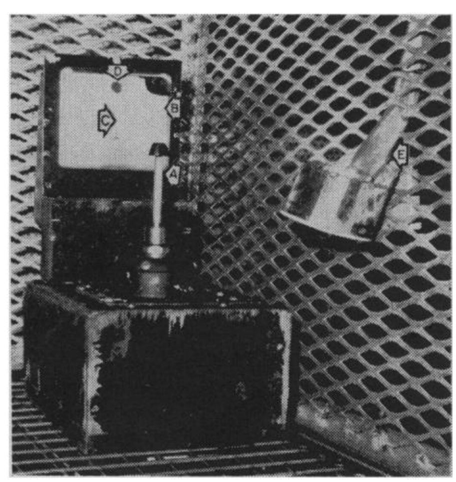

Fig. 1. Apparatus as seen by the monkey (*A*, control stick; *B*, meter; *C*, needle; *D*, target zone; *E*, food dispenser).

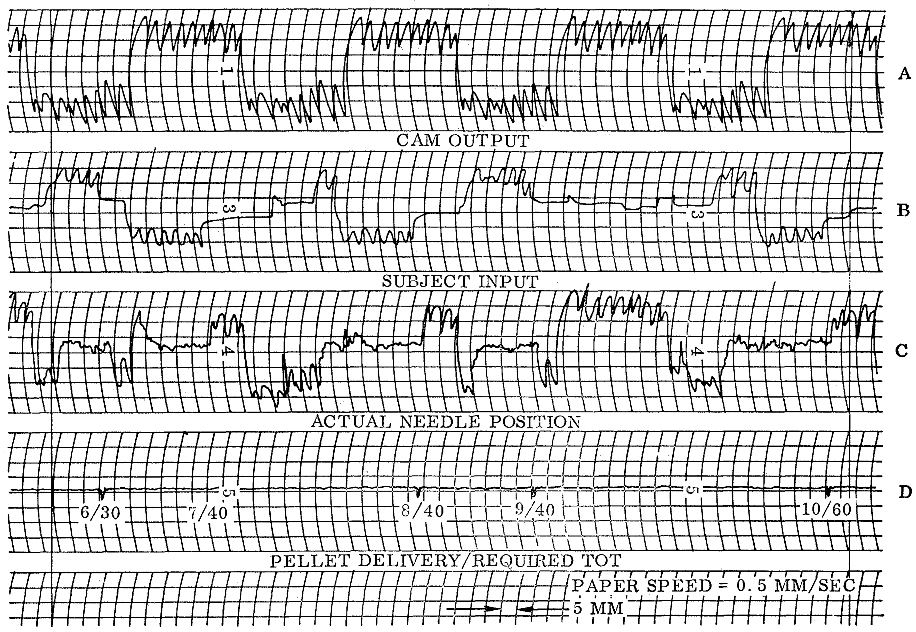

Fig. 2. Graphic record of a 7-min tracking run obtained at termination of monkey's training.

light behind the target aperture. The necessary time-on-target was gradually increased until the monkey had learned to hold a corrective stick deflection for as long as 10 sec. A 10-sec maximum was used since it was felt that forcing the animal to maintain a discrete stick deflection for a longer period of time would be a difficult response to extinguish when the needle was eventually switched to continuous motion.

The last phase of training involved the transition from discrete to continuous tracking, and the development of the continuous tracking response to a high level of proficiency. The transition was accomplished by turning on the error generator and reducing the required time-on-target to an interval still large enough (0.5 sec) to prevent the monkey from obtaining "free" pellets when the needle passed through the target zone on its way to the other side. Although the needle now moved continuously, the animal continued making more or less appropriate control stick responses, indicating that it had mastered the association between the centering of the needle (as a result of its manipulation of the control stick) and the food reward. During the initial stages of the transition from discrete to continuous tracking, the monkey was awarded a pellet by the experimenter if the needle remained in the target zone for as short a period as 0.25 sec (if the time-on-target was not caused by the periodic cam-induced movement of the needle through the target zone). When the monkey was able to obtain 25 to 30 food pellets per session, the required time-on-target was increased by a small amount until the animal was able to track continuously up to 60 sec at a time without letting the needle get off-target.

A graphic record of a 7-min tracking run obtained at the termination of the training is shown in Fig. 2. The upper trace (*A*) portrays the cam-induced forcing function which served as the input to the display needle. Trace *B* is a record of the monkey's input; a straight line down the middle of the recording space indicates no input at all. Trace *C* is a combination of traces and represents the actual needle position as a function of both the cam input and the monkey's input. A straight line down the middle of the recording space on trace *C* would indicate that the monkey had been compensating perfectly for fluctuations induced by the cam. Trace *D* depicts when the subject performs well enough to obtain a food reward; the numbers 30, 40, and 60 to the right of the slash indicate the number of seconds on-target necessary for the pellet to be delivered. The numbers to the left of the slash indicate cumulatively the number of pellets the monkey had obtained at successive points during the 7-min tracking run.

The precision of the monkey's response is indicated by the relatively small fluctuations in the needle during the 60-sec tracking run in trace *C* (Fig. 2). The tracking performance exhibited on this and other runs is quite precise, since the full width of the recording space corresponds roughly to 4½ inches on the meter face. Further, even during the rapid cross-over period to the opposite side of the meter, the needle was kept within the error tolerance zone.

From these results, it appears possible to train subhuman primates to perform continuous compensatory tracking tasks that are not unlike those faced by human trackers. This finding suggests the possibility of using animal subjects as substitutes for humans in many more types of behavioral research situations.

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