TECHNICAL NOTE

*A DEVICE FOR MEASURING CIGARETTE SMOKING
IN MONKEYS¹*

Smoking behavior has been investigated very little in humans and almost not at all in animals (Jarvik, 1967). The present paper describes a smoking device which embodies the disc-stepping principle of commercially available pellet feeders. A similar automatic machine for loading and smoking cigarettes has been produced by the American Machine and Foundry Corporation, for collection and measurement of smoking products (Lang and Moshy, 1965), but the technical requirements and cost are extremely high, and the machine was not designed for actual puffing by humans or animals. The present apparatus was built from readily available parts and offers a convenient and inexpensive way to study smoking behavior in animals. The device enables monkeys to smoke cigarettes in a manner approximating that seen in human beings, but obviates the need for human visual observation or lighting of cigarettes. In this way, the stimulus characteristics of cigarettes can be studied without introducing human experimenter stimuli.

The question being investigated was whether the sight of cigarettes and the sensations resulting from the puffing of cigarette smoke could attain in monkeys an incentive value of the same type as that found in human beings. The ultimate aim of the study was to determine whether a chemical process controls or can take control of smoking behavior.

Subjects

Four rhesus monkeys (*Macaca mulatta*), two males and two females, ranging in weight from 4 to 10 kg were used. The animals were sexually mature at the time of the experiment, and had previous experience with smoking cigarettes for approximately 2 yr. Shaping of puffing behavior was originally accomplished by supplying water from upright bottles through a tube, thereby making it necessary for the monkeys to suck on the tube in order to drink. The mouthpiece of a cigarette smoking apparatus (Jarvik, 1967) was then substituted for the water tube.

Apparatus

The smoking machine delivered lit cigarettes to monkeys at such a safe distance that they cannot handle

them directly. The apparatus enabled them to inhale the smoke from cigarettes that they could see but were not able to touch or eat. (Thus far we have not succeeded in training a rhesus monkey to smoke a cigarette like a man.) The device consisted of a disc 7.5 in. in diameter (not commercially available) which, by rotating, could present cigarettes individually to an animal. It also contained a cigarette lighter, a sensing device for measuring the movement of air, and a tubular mouthpiece through which the monkey can smoke.

The machine performed three basic functions: sequential presentation of individual cigarettes, lighting the cigarettes, and sensing pressure changes which occur when the monkey puffs. The cigarettes were held in aluminum holders taken from Whiz Mfg. Co. Type #110 cigarette holders, which had been fitted into holes in a 0.25-in. thick aluminum disc. The disc was fastened at its center to a 0.5-in. shaft driven by a pulse-operated 36-position stepping relay (Automatic Electric, series "OCS"). When the relay operated, a ratchet and pawl mechanism turned the disc exactly $\frac{1}{36}$ th of a revolution and positioned a new cigarette over the smoking tube. A seal was created by $\frac{5}{8}$ -in. round stock Delrin, sliding on the tube, which was pushed against the disc by a small steel spring.

Cigarettes were lit by the heat from an electric automotive type lighter element mounted approximately $\frac{1}{8}$ in. from the end of the cigarette. The element, which normally operates on 12 v dc, was heated with a 12.6-v ac filament transformer and drew seven amps. As soon as the cigarette was positioned for smoking, a timer allowed current to pass through the element for 15 to 20 sec. This is sufficient time to allow the element to transmit enough heat to the cigarette to start it burning.

The sensing device was a diaphragm-type vacuum switch (Herbach and Rademan, TM 12K719), which provided a contact opening whenever the pressure was reduced by a puff on the cigarette. The diaphragm constituted the blind stem of a T-tube where the other elements provided the passage for smoke from the cigarette to the monkey's mouth. The sensing device delivered a pulse output when the animal's puffing lowered the air pressure in the tube by 1 mm of mercury. The contact opening of the diaphragm switch provided an operating pulse to record the animal's puffing rate, which was monitored by appropriate instruments. The contacts were arc suppressed and rated to handle currents of 5 amps. A left-side view of the device is illustrated in Fig. 1. The Plexiglas plate constituted a portion of one wall of the cage and the tubular mouthpiece was the only portion of the ap-

¹Aided by grant #TH-1 from the American Cancer Society. Reprints may be obtained from M. E. Jarvik, Dept. of Pharmacology, Albert Einstein College of Medicine, Yeshiva University, 1300 Morris Park Ave., Bronx, N.Y. 10461.

paratus inside the cage. Six 1.75-in. holes were cut in the aluminum disc to enable the animals to view the cigarettes through the uncovered portion of the Plexiglas panel.

Fig. 1. Side view; all dimensions in inches.

The circuitry for the smoking machine was mounted on a relay rack in an adjoining room. The timing sequence is illustrated in Fig. 2. A puff on the cigarette moved the diaphragm in the sensing device, mechanically opening two contacts. One is grounded and the contact break operates a relay. Pulses were recorded on a cumulative recorder, counter, or a punched paper tape. Every few minutes, usually 8 min, a timer generated a pulse which advanced the disc. This was sufficient time for a cigarette to burn down completely. Longer time intervals may also be used but shorter time intervals will not allow the typical 85-mm cigarette to burn down. When a new cigarette was positioned, another timer allowed current to pass through the lighter for a period of 15-20 sec, sufficient to light the cigarette.

Fig. 2. Timing sequence.

Cigarette smoke produces a sticky residue which tends to adhere to the tubes and openings in the apparatus. For this reason, the entire device is made from easily washable materials: all structural members and tubes are aluminum, the seal is Delrin, and even the electric

lighter may be immersed in water without damage. The disc is removed by loosening one set screw (Fig. 1, "A"). The cigarette holders in the disc may be cleaned with a small test-tube brush. The connection between the shunt and the sensor orifice is a short piece of easily replaceable gum rubber surgical tubing. Only a small amount of residue accumulated each day, but the apparatus was checked for cleanliness daily. It was necessary to clean it thoroughly only once a week.

Results and Discussion

Figure 3 shows a partial daily record of the smoking behavior of four monkeys, obtained with an Esterline Angus recorder. The monkeys could view the cigarette loading operation and some animals emitted anticipatory puffs. At the points indicated, the cigarettes were lit and puffed on by the animals. The rates were variable, but sometimes reached over 8000 puffs per day for the heaviest smoker.

Fig. 3. Partial smoking record of four monkeys, obtained with an Esterline Angus recorder. The lighters operated in a cycle of one pulse every 2 min such that each monkey received a new cigarette every 8 min. Although the sensing mechanism and counters were sensitive enough to register every puff individually, individual puffs are not seen on this record because the paper speed was quite slow.

It should be noted that the animals were able to puff on the mouthpiece at any time, night or day, and these responses were all recorded. It is clear that the animals made a discriminative response, since the puffing rate in the presence of a lit cigarette was much

higher than in the absence of one. It may be concluded that the sight and sensations of cigarette smoking can attain incentive value in monkeys.

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