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An Inexpensive Portable Device for Measuring Puffing Behavior by Cigarette Smokers[1,2]

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HENNINGFIELD, J. E., J. YINGLING, R. R. GRIFFITHS AND R. PICKENS. *An inexpensive portable device for measuring puffing behavior by cigarette smokers.* PHARMAC. BIOCHEM. BEHAV. 12(5) 811–813, 1980.—A device for counting discrete puffs by cigarette smokers is inexpensive, easily constructed, and fully portable. The device consists of a plastic cigarette holder which is connected to a miniature pressure sensor via 18 gauge polyvinyl tubing. The pressure sensor has two electrical terminals which provide access to a normally open circuit which is closed following a pressure drop produced by puffing on the cigarette holder. The pressure sensor is wired to a common pocket calculator in such a way that each puff is counted by the calculator. The device has been shown to be reliable, and the puff measure is sensitive to a variety of experimental manipulations. The device may serve in either the laboratory setting or may be carried by a smoker to monitor his behavior in his natural environment.

Cigarette smoking Puffing behavior Puff monitor Interbout interval Puff rate Human research

AN important parameter in the experimental analysis and assessment of smoking behavior is rate of puffing [5, 6, 9]. Puff rate is an interesting variable since it may be one of the primary mechanisms of compensation when the delivery of tobacco products is diminished by the use of weaker cigarettes [1,8], or ventilated holders [7,10]. Additionally, rate of puffing is a quantitative measure which is more sensitive than many of the more commonly used measures such as self-reported number of cigarettes smoked or cigarette butt weight [6]. Three techniques have been used for counting cigarette puffs: (1) visual observation of smoking (e.g., [2,3]), (2) smoking cigarettes through a cigarette holder which is connected to a pressure transducer, (e.g., [4,6]), or (3) smoking cigarettes through a cigarette holder which is connected to a temperature sensitive thermister (e.g., [6,8]). These systems are reliable and objective, but are expensive and best adapted to studying smoking in the laboratory environment. The present device is inexpensive and easily constructed, being comprised of a cigarette holder, a miniature pressure sensitive switch and a pocket calculator. Additionally, since the device is fully portable and is not inconvenient to use, it may serve in either the laboratory or the nonlaboratory environment.

CONSTRUCTION

Figure 1 shows a diagram of the puff monitoring device. The filtration material is removed from a commercially available plastic cigarette holder (e.g., Aqua Filter Corp., Opa Locka, FL). The holder is cut to a 35 mm length and the tapered portion of the holder is discarded. A 2 cm length of an 18 ga needle is inserted perpendicularly through one wall of the holder at the point midway between the two ends and is attached to an appropriate length of black, 18 ga, polyvinyl tubing. The distal end of the tubing is connected to a 2 cm, 18 ga, hypodermic needle which is pressed over the male pressure port of the pressure sensitive switch (No. MPL-502-V-5 mmHg Micro Pneumatic Logic, Inc., North Miami Beach, FL). If desired, the connection points can be glued and the pressure sensor can be glued to the calculator. Two quick disconnect electrical terminals on the pressure sensitive switch provide access to a closed circuit for the duration of a pressure drop of 5 mmHg and greater. The pressure sensitive switch is interfaced with a common portable calculator (e.g., Unisonic® No. 840 or Radio Shack Model EC-257). One terminal of the pressure sensitive switch is wired to the electrical ground of the calculator, and the other terminal is wired to the contact point of the summation key or the con-

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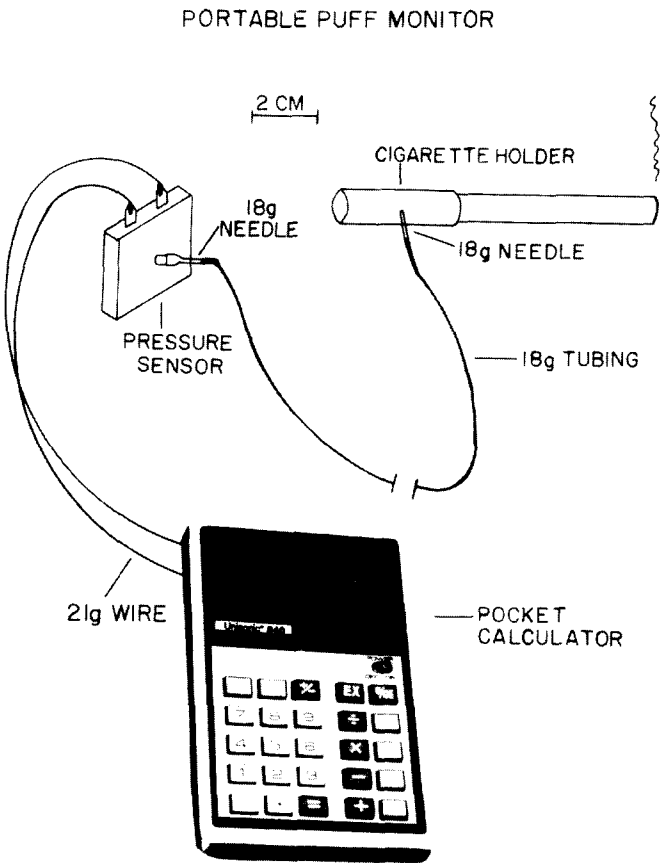

FIG. 1. The cigarette holder and the pressure sensor are drawn to the indicated scale. A variety of different sizes and types of pocket calculators (e.g., small and ultra-thin models) may substitute for the one shown.

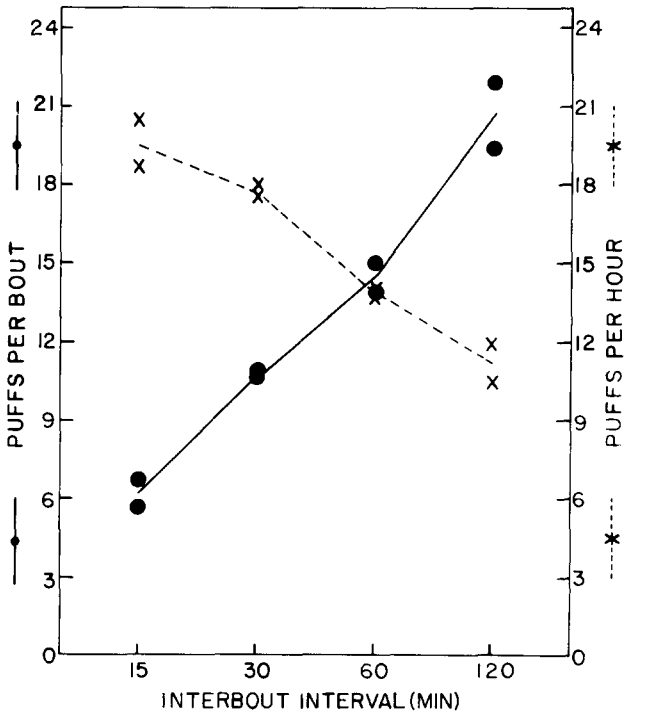

FIG. 2. Mean puffs per smoking bout and mean puffs per hour as measured by the portable puff monitor in one subject. Each point represents data from one experimental session. The interbout intervals, shown on the X axis were randomly presented across days.

stant key of the calculator. To operate the system the calculator should be preset by the appropriate button operations for the calculator to add "1" each time the pressure switch is closed. For example, the Radio Shack Model EC-257 is "cleared" then press "1"; when the data are desired, press the "memory recall".

This device is sensitive to discrete pressure changes, and the mechanical nature of the pressure switch and the circuitry of the calculator prevent artifactual switch "bounce". For portable use, the calculator and pressure sensor can be housed in a calculator carrying case (which prevents visual access to the data) and hung from the subject's belt, or carried in a purse or shirt pocket. The entire system may be constructed for less than $30.00 and the pressure sensor is rated to be reliable for 100×10^6 cycles. For portable use, calculators with LCD displays (e.g., Radio Shack No. EC-257) are preferred to those with LED displays since the former may operate continuously, on one set of batteries, for several thousand hours. Black tubing is preferred to a translucent tubing since the inside of the tubing will become discolored from the cigarette smoke. If the system is used in the laboratory with different cigarette smokers, the holder can be quickly cleaned by rinsing it in ethanol. The tubing should be cut to a correct length for the particular application. We have used lengths ranging from 0.5 m to 3 m without any effect on the sensitivity or reliability of the device.

APPLICATION AND RELIABILITY

The reliability of this device has been assessed by two different procedures. First, the device was compared to our expensive, pressure transducer-type, laboratory puff monitor [6]. Both systems were simultaneously connected to a plastic cigarette holder by separate 18 ga needles. Each of five different subjects was tested in at least 20 daily smoking sessions which were 1.5 to 3 hr in duration. Puff counts on the 2 systems are generally within 5% of one another. Furthermore, the two systems were equally effective in tracking changes in puff rate due to manipulation of experimental variables including administration of drugs and cigarettes with varying nicotine content. The second procedure by which the reliability of the device was assessed was to compare it to self-monitored puff counts by a subject in a study on our inpatient behavioral pharmacology research ward. In that study, cigarettes were smoked at a nurse's station using a uniform puff protocol in which puffs were spaced at 30 sec intervals and each puff was inhaled and held for 5 sec. The number of puffs during any bout of smoking was regulated by the subject but each bout of smoking was scheduled by the staff at intervals of 15, 30, 60, or 120 min. The same interbout interval was used throughout a session (12 hr) and the sequence of intervals, across days was determined randomly. Figure 2 shows mean puffs per smoking bouts and puffs per hour during the 12 hr daily sessions as a function of the interbout interval length. Puffs per smoking bout as measured by the puff monitor showed a 0.998 correlation with data generated by the subject using a hand held counter and reported to the staff. Absolute values of the puffs per bout

were an average of 1.59 greater for the puff monitor since the puff monitor counted pressure changes which occurred during the lighting of cigarettes which were not counted as puffs by the subject. These applications have shown that the portable puff monitor is reliable and provides a useful dependent variable for the study of cigarette smoking behavior.

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