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Measurement in the Analysis and Treatment of Smoking Behavior

U S DEPARTMENT OF HEALTH AND HUMAN SERVICES • Public Health Service • Alcohol, Drug Abuse, and Mental Health Administration

Measurement in the Analysis and Treatment of Smoking Behavior

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Division of Clinical Research
National Institute on Drug Abuse

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Measurement in the Analysis and Treatment of Smoking Behavior

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Foreword

The causal relationship between tobacco use generally, cigarette smoking in particular, and disease is well documented in the scientific literature. In 1982, the U.S. Surgeon General noted that 350,000 excess deaths would be attributable each year to tobacco use. Despite two decades of national efforts to prevent the initiation of smoking by teenagers and other susceptible groups and to treat the behavior of those already dependent on tobacco, 53 million Americans continue to smoke cigarettes. We still have close to the highest per capita consumption of cigarettes in the world.

In the past, the National Institute on Drug Abuse has examined diverse aspects of smoking behavior (NIDA Research Monographs, No. 17--Research on Smoking Behavior; No. ES--Cigarette Smoking as a Dependence Process; No. 26--The Behavioral Aspects of Smoking). This volume adds a new dimension directing attention to issues, methodologies, and technologies in smoking research design and measurement.

The complex multifaceted aspects of smoking behavior include research on pharmacological, physiological, behavioral, and environmental determinants implicated in development, maintenance, cessation, and relapse. The diversity of subject matter and contributing factors necessitates reliance on equally varied scientific resources. This, at times, results in conflicting research strategies, designs, methodologies, and analytic techniques. The present volume provides an overview of the state of knowledge in the area and suggests general guidelines which when applied could lead to increased validity, compatibility, and hence comparability of data across studies. Attention to these factors will lead to improved intervention and prevention techniques which should eventually be reflected in reduction of tobacco-related mortality and morbidity.

Finally, it is worthy of note that this volume represents the result of collaborative efforts of two institutes, the National Institute on Drug Abuse and the National Cancer Institute, and thus emphasizes the need, desirability, and future opportunities for joint efforts in resolution of tobacco-use related health problems.

William Pollin, M.D.
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Preface

The National Institute on Drug Abuse (NIDA) and the National Cancer Institute (NCI) are devoted to contributing to disease prevention and health promotion. Basic and applied research are important to both Institutes. Each is involved in treatment and demonstration programs designed to further their respective goals in the health fields. Underlying many such efforts is the need for reliable information which emanates from field, clinical, and laboratory research supported by the Institutes.

Elucidation of the determinants of tobacco use is, of course, an interdisciplinary effort. Integrated research brings with it the weaknesses, as well as the strengths, of the respective disciplines. In addition new and innovative techniques are often required. A variety of technological advances have evolved in research concerning tobacco use. However, fundamental problems still exist concerning surveys, measurement, and topography of smoking behavior. Therefore. in August 1982. NIDA and NCI convened a group of scientists to address these issues. It was anticipated that the benefits of such a review would be twofold. First, improved techniques in survey, measurement, and topographical analysis, would significantly enhance our research programs. This will ultimately lead to improvements in treatment, prevention, and health promotion. The second major benefit would derive from the successful development of a research model in cigarette smoking with stringent criteria for outcome and evaluation variables. In turn this model might facilitate research in other areas involving interactive behavioral and physiological problems.

The present volume is a summary of that meeting. While problems in measurement still exist, careful study of and attention to the crucial methodological issues raised should significantly enhance our research activities. In addition, this volume provides a strong indication of future directions as well as an examination of many significant issues relevant to improving efforts in research devoted to health and behavior.

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Overview of Smoking Research Issues

Catherine S. Bell, M.S., and John Grabowski, Ph.D.

Historically it is evident that drug use in its varied forms has occurred in essentially all cultures. Control of use derived from social, religious, and legal sanctions. Occasionally a drug has been introduced and gained broad distribution free of governing social or legal rules, and perturbations worthy of note have followed. Thus, for example, the widespread introduction of opium to China by the British generated years of social, economic, and political problems. Concomitant efforts to eliminate use were equally noteworthy.

Similarly, tobacco was introduced to Europe from the Americas in the 16th century. Nicotine doses administered, typically by pipe, chewing, or sniffing appeared not to involve substantial direct disruptive behavioral or physiological effects. Smoking behavior in particular, however, generated great distress in some circles. Early on, King James I put forth his Counter Blaste to Tobacco (in 1604), which derogated tobacco and the user alike. Nevertheless, tobacco use spread, and while the dominant dosage form (e.g., snuff, pipe, cigarettes) was subject to change, the upward trend continued.

Efforts to terminate use and claims of dire health consequences increased over several centuries. Concurrently, introduction of an inexpensive dosage form, the machine-rolled cigarette, and new tobacco curing techniques contributed dramatically to increased use. Thus, the two forces, economic and health, pursued each other in an upward spiral to the present time when both have considerable power and notoriety. The tobacco industry reaps billions of dollars annually. In addition the Federal Government supports a substantial, although not comparable health maintenance, prevention, and research effort. In the midst of this is the basic effort to better understand the phenomena associated with tobacco use.

It is apparent that the divergent positions concerning tobacco use have an extended history. Data have only gradually accrued to strongly support the long hypothesized relationships between

tobacco use and ill health. In addition to reports from other sources, those from behavioral pharmacology laboratories have recently clarified the historically stated similarities between diverse forms of drug use and tobacco use. Thus, this perspective and current scientific wisdom now converge and point to future needs and directions.

DESIGN ISSUES

Although examination of diverse aspects of tobacco use has been a goal of government health and safety agencies, academic institutions, and voluntary health agencies, there has been little unanimity or agreement in certain areas. Thus, for example, widely varying theoretical frameworks exist, as they do in many areas of behavioral, biobehavioral, and biological science. This may well be healthy and contribute to integrative models applicable to other disorders, but only if such integration is actively pursued. In addition, comparability of methodology and identification of subject populations is often lacking. There currently exists a need to identify known discrepancies or inconsistencies in research design and analysis. Contributing to this problem are the all too frequent research reports that fail to explain how smoking behaviors are measured and verified. Interestingly, the specificity and quality of measurement appear to decline as the analysis moves from the laboratory, animal or human, to such diverse settings as clinics and classrooms or the natural environment. An even greater lack of measurement precision may emerge when survey and related community intervention techniques are employed despite increasing availability of new and appropriate technologies. There is a general sense that inherent problems in differing environments can be circumvented.

Loss of valuable information occurs when limited or no data are provided concerning determinants of smoking rate, abstinence, relapse, or shifts in tobacco dosage form used. Scientists and clinicians alike have noted that the lack of consistent application of measurement techniques has retarded progress in the acquisition of systematic knowledge which could advance understanding of smoking behavior and hence the development of effective treatment techniques. In part, this has been due to failure to draw attention to unifying or standardized approaches. Nonetheless it is particularly disturbing in those areas where laboratory research has provided tools essential to this effort.

Past problems with evaluation in smoking and tobacco research have existed in design research and validation of treatment results. More specifically, for example, there have been validation problems resulting from unverified self-report of smoking behavior. Some units of measurement have perhaps contributed to further uncertainty. For example, preference for reporting packs of cigarettes rather than number of cigarettes smoked may have led

to assumptions dictating that a difficult "breakpoint" for smoking exists at 10 cigarettes per day based on reports of half-pack increments. In other cases absence of essential measures may occur. For example, failure to obtain adequate baseline data, including brand history, and a lack of information on individual smoking styles, e.g., topography and dosimetry issues is not uncommon. The inability to clearly relate correlates of outcome to independent treatment variables may also result from other problems including: (1) lack of controls and systematic design, (2) lack of validation of programs developed in the research setting, (3) lack of longitudinal data, (4) small n samples with excessive variability in resultant data, (5) or when small n designs were appropriate, insufficient replications of measures and, (6) lack of attention to accepted theoretical guidelines or unifying conceptual premises. In brief, some research in smoking and tobacco use has perhaps in one sense suffered due to its divergent origins. Concurrently it should be clear that exceptional research of excellence has also been forthcoming. This has been particularly true in recent years, although measurements problems do exist.

THE SCIENCE BACKGROUND

In the way of background on these issues, it is interesting to note that few, if any, researchers have been trained in "cigarette smoking research." To do so would, of course, result in researchers who have little utility or scope with respect to other issues. Rather, and appropriately, scientists converged from diverse extant disciplines to contribute to a better understanding of specialized problems which have facets in biochemistry, physiology, neurological function, individual behavior, and, finally, rather complex aspects of social behavior. Inter-disciplinary efforts have thus emerged. While it is not clear that "smoking researchers," per se, are needed, it is essential to develop professionals whose skills bridge the gap of traditional disciplines. Such bridging would permit thorough analysis of biobehavioral disorders, especially those with multifaceted physiological and behavioral components.

CONVERGENCE

As the area of biobehavioral smoking research began to coalesce, it became apparent that tobacco use could on one hand be examined as another form of drug self-administration and that on the other hand it might have characteristics in common with other behaviorally based disorders. Thus, a search for similarities with other behaviors and forms of drug use might provide a useful model for analysis and for generating successful smoking prevention and cessation programs.

In turn, refinement of the view dictated that tobacco use be examined in the context of repetitive, stereotypic, habitual behaviors of all sorts, ranging from gambling, to eating behavior,

to dependence on alcohol and drugs, and even to excessive social interaction needs. Indeed, it appeared that the general features which characterized behavioral dependence were translatable across many forms of so-called habitual behaviors.

SMOKING RESEARCH AS A BEHAVIORALLY BASED INTERDISCIPLINARY ENDEAVOR

It is evident that a plethora of clearly definable disease states are correlated with and perhaps causally related to the use of tobacco. Therefore, as previously noted, numerous scientific groups became involved in the research effort from the laboratory to treatment and prevention settings. Interestingly, objective consideration suggests that even the disease states do not make the smoking issues substantially different from other behavioral problems which have often had their own associated physical ills. However, it is the occurrence of specific disease states that has generated the interest of many in what is fundamentally an issue of drug self-administration.

In any case, it is clear that smoking behavior is of interdisciplinary interest, and it is equally clear that various scientists have developed specialized, different, and often incompatible measures and have brought them to bear on the problems associated with cigarette smoking and tobacco use. Unfortunately, as has been suggested, there are areas in which standardized strategies for research have not emerged.

Overall there is a need to identify and delineate available measures and perhaps consider general principles if not guidelines <u>per se</u> for measurement in the smoking research. The guidelines for measurement of smoking behavior may also directly or indirectly have some utility in defining goals for more effective prevention and treatment strategies.

A systematic data collection strategy could provide a roughly hierarchical sequence by which data could be obtained and results defined and would also assure some equivalence in the data collected. It is therefore important to determine what the minimal level of acceptable data is in various settings or when examining particular issues. The following provides an example: it might be generally agreed that a study is of little value if it simply posits the question "Do you smoke?" What, however, is the minimal level of data to be obtained, and what makes asking any question worthwhile, if there is an interest in approximating the notion of dose effect or dose response? In brief, it is apparent that the topic of interest is one which involves biobehavioral aspects and that it is appropriate to suspect that an adequate array of biological and behavioral measures is desirable if a study is to have general utility. While it is clear that the degree of precision in measurement may vary as a function of research goals, it is equally apparent that the current level of inquiry requires

greater precision and strength than is frequently evident.

SUMMARY

Overall, the issue is deceptively simple. There is a need to list the extant techniques which include some extensive recent advances. This should be followed by a simple heirarchical systematization of the techniques and definition of the requirments of each category of study. As is evident in the present volume, problems emerge in this effort. Nevertheless, it is clear that the effort could have considerable benefit, and further that it might serve as a model for biobehavioral research efforts. The present volume and its contributors provide many, though not all, of the essential ingredients, in an effort to move in this direction.

The Use Of Biologic Fluid Samples In Assessing Tobacco Smoke Consumption

Neal L. Benowitz, M.D.

INTRODUCTION

Tobacco smoke consists of a mixture of combustion gases carrying a suspension of particulate matter. Among the many components of the gas phase arecarbon monoxide andhydrogen cyanide. Carbon monoxide and serum thiocyanate, the latter a metabolite of hydrogen cyanide, are potentially useful markers of smoke consumption. The particulate phase consists of nicotine and minor tobacco alkaloids and, the remainder, termed tar. Measurements of nicotine and its major metabolite cotinine are potentially useful markers of nicotine exposure and intake. Quantitating tar consumption is more difficult: indirect measurements such as measurement of urinary excretion of polycyclic aromatic hydrocarbons and their metabolites and of urinary mutagenic activity may prove to be useful markers but are not yet ready to be applied to large-scale smoking studies.

In this paper, I will focus on the use of carbon monoxide, thiocyanate, nicotine, and cotinine as markers of smoke consumption. Factors influencing absorption of these substances from smoke, elimination from the body, kinetic characteristics that relate to their usefulness as markers of smoke exposure, and limitations of their use are discussed.

Before discussing the individual compounds, it should be emphasized that 1) the relative intake of different pharmacologically active substances differs among different tobacco products and different smokers and 2) intake cannot be equated with exposure. With respect to the latter, both rate of intake (dose) and rate of elimination determine the average exposure level.. For these reasons, selection of biochemical measurements must be dictated by the hypotheses being tested. For example, studies of nicotine self-administration should include measurements of nicotine and/or cotinine. Studies of cardiovascular complications of smoking should include measurements of carbon monoxide as well. Studies of carcinogenesis require measurements of carcinogen exposure.

CARBON MONOXIDE

As estimated by smoking machines, approximately 10 to 20 ml of carbon monoxide is delivered to the smoker's mouth with each cigarette. Delivery to the mouth depends on the characteristics of the cigarette, particularly ventilation and moisture content, and how the cigarette is smoked. Carbon monoxide is absorbed in the lungs, where it diffuses across alveolar membranes. It is not appreciably absorbed across mucous membranes or bronchioles. Thus, depth of inhalation and the presence or absence of pulmonary disease influence the absorption of a given dose of inhaled carbon monoxide.

TABLE 1

Carbon monoxide

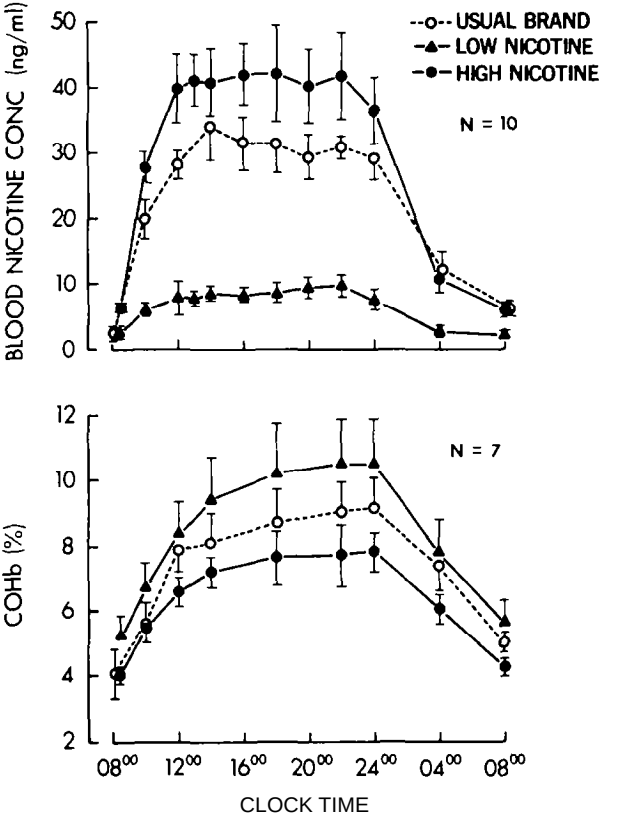
Dose	10-20 ml/cigarette Varies with ventilation and misture characteristics and how cigarette is smoked
Absorption	Pulmonary alveoli
Elimination	Respiratory Half-life 2-5 hours Ventilation (activity) dependent
Measurement	Spectrophotometric: Carboxyhemoglobin Expired carbon monoxide

Within the body, carbon monoxide is bound, as is oxygen, to hemoglobin, where it can be measured as carboxyhemoglobin. Carbon monoxide may also be bound to myoglobin and the cytochrome enzyme system, although quantitative details of binding to the latter sites are as yet poorly defined. Carbon monoxide is eliminated primarily by respiration. The rate of respiration determines the rate of elimination. Thus, the half-life of carbon monoxide during exercise may be less than 1 hour whereas during sleep it may be greater than 8 hours (Castleden and Cole 1974). With sedentary activity, the half-life is usually 3 to 4 hours.

The disposition kinetics of carbon monoxide are useful in understanding the time course of carbon monoxide in the body throughout the smoking day. With a half-life averaging 4 hours, based on pharmacokinetic principles one would predict that, with reasonably constant dosing (that is, regular smoking rate), carbon monoxide levels would plateau after 9 to 12 hours of cigarette smoking. This is what we observed in circadian studies of carboxyhemoglobin concentrations in cigarette smokers smoking on a research ward (figure 1). There is a small increment and decline in carboxyhemoglobin immediately after smoking individual

FIGURE 1

BLOOD NICOTINE AND CARBOXYHEMOGLOBIN CONCENTRATION WHILE SMOKING USUAL BRAND, LOW (0.4mg) AND HIGH (2.5mg) NICOTINE CIGARETTES



Blood nicotine and carboxyhemoglobin concentrations in subjects smoking high-nicotine (2.5 mg) and low-nicotine (0.4 mg) Kentucky reference cigarettes and their usual brand (average nicotine yield 1.2 mg) of cigarettes. Subjects smoked *on a* fixed schedule of 1 cigarette every half-hour from 8:30 A.M. to 11:00 P.M. for a total of 30 cigarettes per day. Blood samples were collected just before the next scheduled cigarette (figure taken from Benowitz et al. 1982b). © 1982, The C.V. Mosby Company. Reprinted by permission.

cigarettes (not shown in figure 1), but after several hours of smoking the magnitude of the rise and fall is small compared with the trough values. Thus, sampling carboxyhemoglobin at the end of a smoking day is a reasonably good indicator of the daily CO exposure.

Because of reduced ventilation during sleep, the rate of elimination of carbon monoxide is slower at night than during the day. With an overnight half-life of 5-9 hours (Castleden and Cole 1974), carbon monoxide persists in the body at substantial levels throughout the night &spite no further smoking (figure 1). In our subjects, carboxyhemoglobin concentrations averaged 4-5 percent before smoking the first cigarette of the day. Thus, the toxic effects of carbon monoxide in smokers are not only experienced in proximity to smoking, but also persist for 24 hours of every day. Morning carbon monoxide measurements are sensitive to cigarette smoking, but probably provide less quantitative information about the magnitude of daily exposure than do afternoon levels.

The usefulness of carbon monoxide as a measurement of tobacco smoke consumption can be considered in terms of specificity, sensitivity, and limitations. Specificity refers to the probability that a nonsmoker will be classified as a nonsmoker. Thus, a highly specific measurement has a low rate of classifying nonsmokers as smokers. In most cases, carbon monoxide levels, when measured at the end of the smoking day, are specific for cigarette smoking. There is an endogenous CO concentration (carboxyhemoglobin of about 0.7 percent) that is much lower than that observed in cigarette smokers. However, employment in areas with high ambient carbon monoxide concentrations, exposure to methylene chloride, which is metabolized to carbon monoxide (Stewart et al. 1972), or driving on busy freeways (Aronow et al. 1972) may also reduce the specificity of carbon monoxide levels, particularly when studying light smokers. Sensitivity refers to the probability that a smoker will be classified as a smoker.

The specificity and sensitivity of carboxyhemoglobin as a marker of cigarette smoking has been estimated in epidemiologic studies. Wald et al. (1981a), sampling afternoon carboxyhemoglobin levels and using a cutoff-point of 2.0 percent, found specificity to be 99 percent and sensitivity to be 81 percent for cigarette smokers and 35 percent for cigar and pipe smokers. Cohen and Bartsch (1980), measuring carboxyhemoglobin in the morning and a similar cutoff-point, found specificity to be 81 percent and sensitivity to be 83 percent.

We are also interested in measurements that yield quantitative information about the amount of a particular smoke component that is consumed. Carbon monoxide measurements do yield some dose information, particularly when sampled at the end of a smoking day.

It has been shown that for individual smokers carbon monoxide levels increase proportionately with the number of cigarettes smoked for the first few hours of smoking (Henningfield et al. 1980). Epidemiologic studies showed significant correlations between carboxyhemoglobin concentrations and the number of cigarettes smoked per day, with correlations ranging in different studies from 0.27 to 0.81 (Hawkins et al. 1976; Vogt et al. 1979; Rickert and Robinson 1981; Jaffe et al. 1981). On the average, about 25 percent of the variance in carboxyhemoglobin could be explained by the number of cigarettes smoked per day. The brand of cigarette or machine yield of carbon monoxide does not significantly predict carboxyhemoglobin levels (Rickert and Robinson 1981; Jaffe et al. 1981).

The limitations in using carbon monoxide as a measurement of tobacco smoke consumption per se are that the time of day and the length of time since smoking the last cigarette influence carbon monoxide levels and that there is considerable individual variation in carbon monoxide absorption and elimination characteristics, depending on smoking habits, disease states, and activity level.

TABLE 2

Use of carbon monoxide as a measure of smoke consumption

Specificity	Good
Sensitivity	Good at steady state (afternoons) Short term only
Cost	Inexpensive (expired CO)
Limitations	Time of day Individual variation in absorption and elimination (pulmonary disease; activity)

Measurement of carbon monoxide is straightforward and inexpensive. Because alveolar carbon monoxide pressures are proportional to the concentration of carboxyhemoglobin in blood, end-expired carbon monoxide tension accurately reflects blood carboxyhemoglobin (Jarvis et al. 1980). Expired carbon monoxide can be measured using an instrument (Ecolyzer, Energetics Science, Inc., Elmsford, NY) that measures the rate of conversion of carbon monoxide to carbon dioxide as it passes over a catalytically active electrode. Blood carboxyhemoglobin can be measured directly and quickly using a differential spectrophotometer (Co-oximeter, Instrumentation Laboratory, Inc., Lexington, MA). However, the Co-oximeter is expansive to purchase and requires considerable maintenance.

THIOCYANATE

As assessed by smoking machine delivery, approximately 30 to 200 µg of hydrogen cyanide are delivered to the mouth of the smoker with each cigarette. Hydrogen cyanide is metabolized by the liver to thiocyanate. In addition to combustion gases, certain foods, particularly leafy vegetables and some nuts, are sources of cyanide. Thus, thiocyanate is present in nonsmokers as well as smokers and may be particularly high in vegetarians. Thiocyanate is also present in beer (Bottoms et al. 1982).

TABLE 3

Thiocyanate

Source is metabolism of cyanide	
	Hydrogen cyanide in stroke
	Dietary cyanide
Absorption	Respiratory
	Ingestion
Elimination	Renal
	Half-life = 14 days
Measurement	Spectrophotometric
	Serum vs. saliva

Thiocyanate is distributed in extracellular fluid and is eliminated slowly by the kidneys. Due to the slow excretion, the half-life of thiocyanate is long (about 14 days).

The long half-life of thiocyanate means that there is little fluctuation in plasma thiocyanate concentrations within a day or from day to day. Thus, the time of sampling is not critical. On the other hand, a given level of thiocyanate reflects exposure to hydrogen cyanide in tobacco smoke over several weeks preceding the time of the sample. When a smoker stops smoking, it takes an estimated 3 to 6 weeks for thiocyanate levels to reach that individual's nonsmoking level.

Because of the presence of cyanide in foods, thiocyanate is not highly specific for cigarette smoking. There is some overlap in levels between smokers and nonsmokers. However, on the average, smokers do have levels two to four times those of nonsmokers (Cohen and Bartsch 1980; Vogt et al. 1979; Butts et al. 1974). Levels of 85-100 µmoles/L have been suggested as cutoff concentrations for smoking versus nonsmoking. Sensitivity is reasonably good in that most smokers have elevated levels: however,

because of marked variation in levels among nonsmokers, thiocyanate concentration may not be a very good quantitative indicator of smoke exposure.

Cohen and Rartsch (1980), using a cutoff-point of 100 μM/L, reported specificity of 81 percent and sensitivity of 93 percent for the use of thiocyanate in detecting cigarette smokers. Butz et al. (1974), using a cutoff-point of 85 μM/L, found 93 percent and 98 percent specificity and sensitivity, respectively. Thus, specificity and sensitivity for distinguishing smokers versus nonsmokers are reasonably good. However, in the smoker who is a light smoker or who has cut down during smoking cessation treatment, the thiocyanate level approaches levels due to dietary sources of cyanide, making documentation of smoking status increasingly more difficult.

Serum or plasma levels of thiocyanate correlate significantly with the number of cigarettes per day (range of correlation 0.25-0.48) (Cohen and Bartsch 1980; Vogt et al. 1979; Rickert and Robinson 1981), but not as well as carbon monoxide. Thiocyanate levels in smokers do not correlate with machine yields of hydrogen cyanide. Salivary concentrations of thiocyanate may also be used as a noninvasive biochemical marker of smoke exposure (Luepker et al. 1981). Concentrations of thiocyanate in saliva vary as a function of salivary flow rate (Mucklow et al. 1978). Thus, a close correlation between salivary and plasma thiocyanate concentrations depends on stimulating flow of saliva. Serum or plasma thiocyanate levels can be measured fairly inexpensively using spectrophotometric methods (Butts et al. 1974; Lundguist et al. 1979).

TABLE 4

Use of thiocyanate as a measure of smoke consumption

Specificity	Good
Sensitivity	Good Long term
Cost	Moderate
Limitations	Dietary interference Overlap nonsmokers-light smokers Not useful to monitor short-term changes in smoking

In summary, the use of thiocyanate levels as a marker of smoke consumption has fairly good specificity and sensitivity in studying active smokers, has the advantage of a long half-life such that the time of sampling is not critical, and is inexpensive to measure. The limitations are that specificity and sensitivity

may be inadequate in light smokers or in smokers who have cut down on their smoking. In addition, the long half-life of thiocyanate makes it impossible to use it to assess recent smoking behavior. Due to other sources of cyanide, thiocyanate is not a good quantitative indicator of consumption of tobacco smoke.

NICOTINE

As estimated by smoking machine deliveries, between 0.05 and 2.0 mg of nicotine are delivered to the mouth with each cigarette. As is the case for carbon monoxide, nicotine delivery depends on the characteristics of the cigarette and how the cigarette is smoked. In studies by Sutton et al. (1982) and Herning et al. (1983), the increment in blood nicotine concentration after smoking a single cigarette was correlated poorly with the smoking machine yield of the cigarette and was more a function of how the cigarette is smoked.

TABLE 5

Nicotine

Dose	0.1-2.0 mg/cigarette Varies with cigarette characteristics and how cigarette is smoked
Absorption	Mucous membranes (depends on pH of smoke) Pulmonary bronchial tree and alveoli Enteroenteric
Elimination	Metabolism primary; renal secondary 4-fold individual variation in metabolic rate Renal excretion pH dependent Half-life = 2 hours
Measurement	Gas chromatography Radioimmunoassay Blood vs. urine

Unlike carbon monoxide, nicotine is absorbed through mucous membranes in the mouth, through the bronchial tree as well as in the pulmonary alveoli. The extent of mucosal absorption varies with the pH of the smoke, such that more nicotine is absorbed from relatively alkaline (cigar) smoke than from acidic (cigarette) smoke (Armitage and Turner 1970). Nicotine is distributed rapidly to body tissues and is rapidly and extensively metabolized by the liver. A relatively small fraction is excreted unchanged by the kidney. Urinary excretion may vary from 2 to 25 percent of total nicotine elimination in alkaline and acid urine, respectively (Rosenberg et al. 1980).

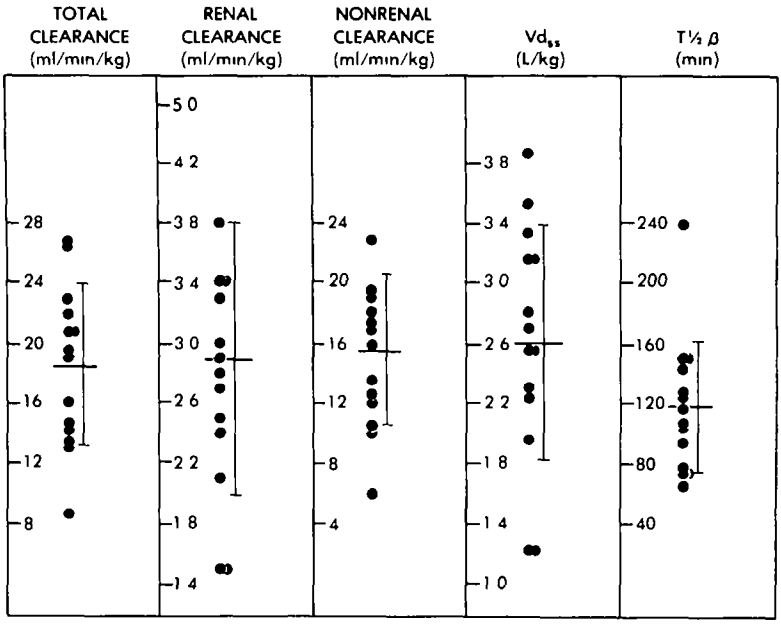
The rate of nicotine metabolism varies considerably, as much as fourfold among some people (figure 2) (Benowitz et al. 1982a). A given level of nicotine in the body reflects the balance between nicotine consumption and elimination rate. Thus, comparing two persons with the same average blood concentration of nicotine, a rapid metabolizer may be consuming four times as much nicotine as a slow metabolizer. To determine daily intake of nicotine directly, both nicotine blood concentrations and nicotine elimination rate must be measured. This procedure is feasible for small-scale studies, and is ongoing in our laboratory. However, it is not feasible for large-scale studies.

The time course of decline of blood concentrations of nicotine is multiexponential. Following a single cigarette or an intravenous injection of nicotine, blood concentrations of nicotine decline rapidly, with a half-life of 5 to 10 minutes, due to tissue uptake (figure 3). If concentrations are followed over a longer period of time or if multiple doses are consumed so that tissue stores are saturated, a longer elimination half-life of about 2 hours becomes apparent (figure 4). It should be noted that many earlier reports of nicotine half-lives of 20 to 40 minutes (Isaac and Rand 1972; Armitage et al. 1975) were based on blood concentrations from both distribution and elimination phases and were not truly measurements of the log-linear decline phase. The importance of knowing the terminal half-life is that the time course of accumulation of nicotine during the day and persistence in the body after cessation of regular smoking (such as overnight) can be predicted.

The optimal way to assess daily exposure to nicotine is to measure the blood concentrations throughout the smoking day. This can be carried out in a research ward (Benowitz et al. 1982b) but is not feasible for epidemiologic studies. Pharmacokinetic considerations are useful in planning optimal sampling of blood for measurement of nicotine concentration to estimate average exposure levels. As predicted by a 2-hour half-life, nicotine blood concentrations plateau after 6 to 8 hours of regular smoking (figure 1). At that point, the fluctuation in levels between cigarettes is relatively small compared with the trough levels. This is in contrast to sampling after the first few cigarettes of the day when there are marked fluctuations in nicotine levels between cigarettes (figure 5). Afternoon plasma levels of nicotine have been used in studies of nicotine exposure while smoking different brands of cigarettes or consuming other nicotine-containing products (Sutton et al. 1982; Herning et al. 1983; Armitage and Turner 1970; Gritz et al. 1981).

The measurement of blood concentration of nicotine is highly specific for cigarette smoking unless there is an occupational exposure to tobacco leaves (Gehlbach et al. 1975). Passive smoking may elevate blood concentrations of nicotine slightly, but not to the range seen with most smokers (Russell and Feyerabend 1975). Blood concentration of nicotine is a sensitive measurement of exposure (rather than consumption) to tobacco-smoked nicotine. Exposure rather than consumption is emphasized

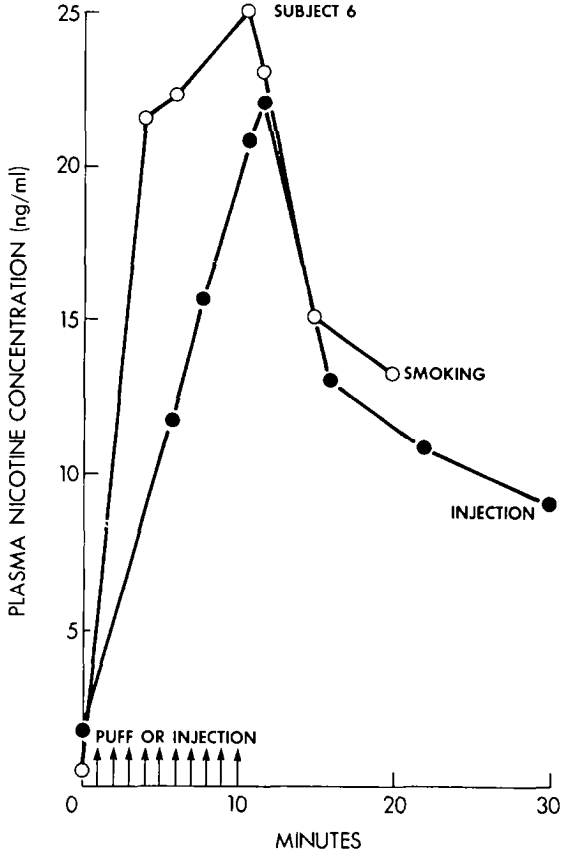
FIGURE 2



Pharmacokinetics of nicotine in 14 healthy male cigarette smokers. Pharmacokinetic analysis was performed on plasma concentration data collected during and after constant infusion of nicotine, 1-2 µg base/kg/min, for 60 minutes under conditions of urinary acidification (pH<5.5). The blood nicotine concentration-time curve is shown in figure 4. Terminal half-life was computed from plasma concentration data from 30 to 150 minutes following the end of nicotine infusion (figure taken from Benowitz et al. 1982a). © 1982, American Society for Pharmacology and Experimental Therapeutics. Reprinted by permission.

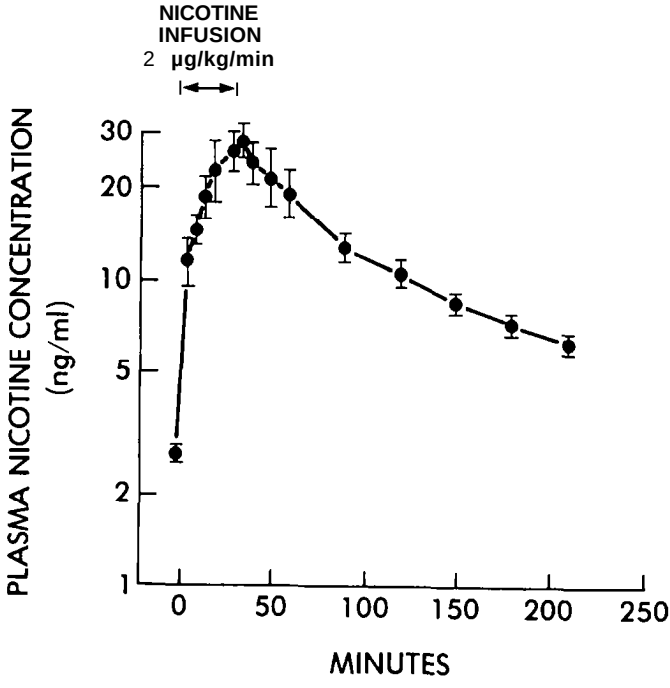
FIGURE 3

PLASMA NICOTINE.
INTRAVENOUS INJECTIONS AND CIGARETTE SMOKING



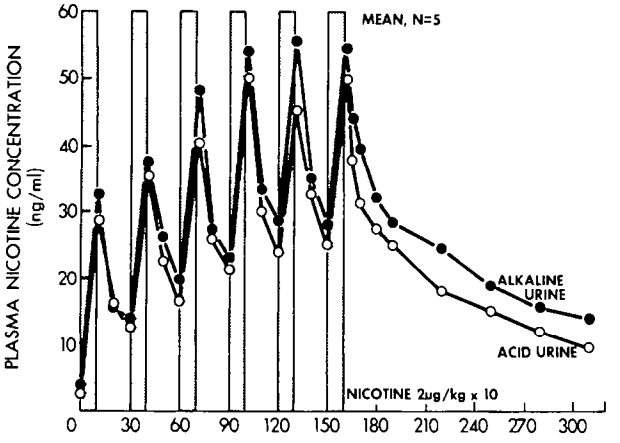
Plasma nicotine concentrations in a subject given bolus intravenous injections of nicotine, 2 µg base/kg, or inhaling from a commercial cigarette, once every minute for 10 minutes. Nicotine concentrations rise as or more rapidly while smoking compared with intravenous dosing. There is a sharp decline in concentration following the end of the series of nicotine injections or smoking, due to distribution into body tissues. The terminal half-life phase (not shown in figure), which reflects rate of drug elimination, becomes apparent 30-60 minutes following nicotine exposure.

FIGURE 4



Plasma nicotine concentrations (± S.E.M.) in five subjects during and after constant intravenous infusion of nicotine for 30 minutes. (Figure taken from Benowitz et al. 1982a.) © 1982, American Society for Pharmacology and Experimental Therapeutics. Reprinted by permission.

FIGURE 5



Mean plasma nicotine concentrations during repetitive intravenous injections of nicotine with alkaline (pH>7) and acid (pH<5) urine. Hatched area indicates 10 minute intervals during which intravenous injections of nicotine, 2 µg base/kg/min, were given. Data represent mean values for five subjects. There is considerable fluctuation in nicotine concentration following and between series of nicotine injections (or smoking cigarettes) after the first few exposures. With repetitive dosing, trough levels rise and eventually (6-8 hours) plateau.

because of the influence of individual differences in rate of metabolism of nicotine, as described previously. Measurement of the blood concentration of nicotine has a major advantage in that nicotine is the substance for which most people smoke and which may have direct toxicity. The limitations in the use of blood concentrations of nicotine are the fluctuation in nicotine concentrations between cigarettes and the considerable variation in nicotine metabolism among individual smokers. In addition, the method for measuring the low concentrations of nicotine in blood is more difficult than for other markers.

TABLE 6

Use of nicotine as a measure of smoke consumption

Specificity	Excellent
Sensitivity	Excellent Short-term only
Cost	Expensive
Limitations	Time of day Individual variation in metabolism and renal excretion

Blood concentrations of nicotine can be measured by gas chromatography (Jacob et al. 1981), radioimmunoassay (Langone et al. 1973), and possibly high performance liquid chromatography. Sample preparation is problematic in that contamination of samples with even small amounts of tobacco smoke can substantially elevate the normally low concentrations of nicotine in the blood. Thus, careful precautions against contamination during both sample collection and processing for analysis are essential. Because the concentrations are so low, measurement of nicotine in blood has been difficult for many laboratories in the past, but with currently available assays, it is feasible for large scale epidemiologic studies. Measurement of urinary levels of nicotine has been suggested as a marker for cigarette consumption (Wilcox et al. 1979). This may be qualitatively useful, but quantitatively it is limited by the fact that there is variation in renal elimination of nicotine depending on urine pH and flow rate so that it is difficult to extrapolate from urine to blood concentrations of nicotine.

COTININE

Nicotine is metabolized primarily to cotinine and nicotine-k oxide. Based on measurements of relative urinary excretion of cotinine and nicotine-N-oxide and studies of total and renal elimination of cotinine after intravenous infusion, we estimate that on the average 86 percent of nicotine is converted to cotinine. The individual variation in fractional conversion of nicotine to cotinine has not yet been determined.

TABLE 7

Cotinine

Primary metabolite of nicotine	
Elimination	Metabolism primary, renal secondary Half-life = 19 hours
Measurement	Gas chromatography Radioimmunoassay

Cotinine is distributed to body tissues to a much lesser extent than nicotine. Cotinine is eliminated primarily by metabolism with 15 to 20 percent excreted in the urine unchanged (Benowitz et al., submitted for publication). Urinary pH does affect the renal elimination of cotinine; however, the effect is not as great as for nicotine. In a small group of subjects given intravenous infusions of cotinine, interindividual variation in the rate of cotinine metabolism was considerably less than variation in rates of nicotine metabolism. The elimination half-life for cotinine in 16 subjects who stopped smoking on a research ward averaged 19.1 hours with a range of 10.9 to 37.0 hours.

Because of the relatively long half-life of cotinine, blood concentrations of cotinine are relatively stable throughout the smoking day, reaching a maximum at the end of the day. Because each cigarette adds relatively little to the overall cotinine level, sampling time with respect to smoking is not critical. A mid- or late-day concentration reasonably reflects the average concentration of cotinine throughout the day.

Using metabolic and pharmacokinetic data, blood concentrations of cotinine can be used as a measure of daily consumption of nicotine. Assuming that nicotine is 86 percent converted to cotinine and that cotinine clearance is relatively constant among people, which seems to be the case, it can be computed that a blood concentration of cotinine of 100 ng/ml represents an average 24 hour consumption of 12 mg nicotine (Benowitz et al., submitted for publication). Average concentration of cotinine in the

blood of habitual cigarette smokers is about 300 ng/ml (Langone and Van Vunakis 1975; Zeidenberg et al. 1977). Thus, I estimate that the average smoker consumes about 36 mg of nicotine/day. The range of blood concentrations of cotinine was quite wide, 5 to 900 ng/ml, presumably reflecting a wide variation in nicotine consumption among self-reported habitual smokers. Concentrations of cotinine in blood have been used to estimate nicotine consumption in several studies (Zeidenberg et al. 1977; Gritz et al. 1981; Hill and Marquardt 1980; Wald et al. 1981b).

TABLE 8

Use of cotinine as a measure of smoking consumption

Specificity	Excellent
Sensitivity	Excellent Intermediate term
Cost	Moderate
Limitations	? Individual variation in elimination rate

The specificity of cotinine as a marker for cigarette smoking is excellent. I have found no nonsmokers with blood cotinine values greater than 10 ng/ml. The sensitivity of cotinine also appears to be excellent and offers the best estimate of daily nicotine consumption. Because of its long half-life, sampling time is less critical than for nicotine or carbon monoxide.

Measurement of cotinine is moderately costly. Both radioimmunoassay (Langone et al. 1975) and gas chromatographic assays (Jacob et al. 1981) are readily available. Urinary cotinine ‘may also be measured as a qualitative indicator of smoking versus nonsmoking (Wilcox et al. 1979; Matsukura et al. 1979) but, because of individual variations in renal clearance, it is not a good quantitative predictor of blood concentration of cotinine.

SUMMARY

In summary, the source, absorption, metabolism, and disposition kinetics of several compounds that are potential markers of tobacco smoke consumption have been reviewed. Kinetic considerations have been applied to discuss specificity and sensitivity of various compounds as markers of cigarette smoking status, usefulness as quantitative indicators of tobacco smoke consumption, and optimal time for sample collection. One cannot, however, escape the conclusion that selection of a biochemical test must be linked to the hypothesis being tested. If only smoking versus nonsmoking is being assessed, then carbon monoxide and/or thio-

TABLE 9

Comparison of biochemical markers of tobacco smoke consumption

Marker	Specificity	Sensitivity	Limitations	cost	Advantages
Carbon monoxide	Good	Good short term	Time of sampling Variable absorption and elimination	Inexpensive	Direct toxin Noninvasive (Expired CO)
Thiocyanate	Good	Good long term	Dietary interference Qualitative measure	Moderate	Noninvasive (Saliva)
Nicotine	Excellent	Excellent short term	Time of sampling Variable elimination rate	Expensive	Direct measurement of reinforcer or toxin exposure
Cotinine	Excellent	Excellent inter-mediate term	? Variable elimination rate	Moderate	Measurement of nicotine consumption

cyanate are inexpensive measurements that provide adequate information. If self-administration of nicotine or toxic effects potentially related to nicotine exposure are being studied, then measurements of nicotine exposure and consumption are required. Measurement of blood concentration of nicotine per se is necessary to document nicotine exposure: blood concentration of cotinine may be a better measure of daily nicotine consumption. To study potentially carcinogenic effects of tobacco smoke, specific measurements of carcinogen consumption must be developed and validated.

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Measurement Issues in Cigarette Smoking Research: Basic Behavioral and Physiological Effects and Patterns of Nicotine Self-Administration

Jack E. Henningfield, Ph.D.

INTRODUCTION

Measurement issues in cigarette smoking research encompass a heterogeneous body of research questions and strategies. Included are investigations into the types and amounts of tobacco smoke constituents delivered by cigarettes, topographical analysis of puffing behavior, epidemiological studies of smoking behavior, health-related consequences of smoking, and investigations of cigarette smoking behavior. The primary focus of the present paper will be on studies of the dependence process in which drug self-administration strategies were used. Some of the underlying principles of such strategies are described below.

The conceptualization of drug abuse as an instance of drug self-administration, that may be studied in the laboratory, is one of the essential tenets of behavioral pharmacology (Thompson and Schuster 1968; Poling and Henningfield 1982). These strategies have now been fruitfully applied to the study of cigarette smoking (Gritz 1980; Griffiths and Henningfield 1982). The power of such strategies lies in their potential to reproduce, under rigorous laboratory conditions, the essential elements of the phenomena of drug-seeking and drug-taking behavior. A given instance of drug self-administration involves numerous elements which are of behavioral, physiologic, pharmacologic, social, and environmental nature. The drug self-administration paradigm permits the systematic manipulation of such variables so that the relative contribution of each can be assessed (cf. Griffiths, Bigelow, and Henningfield 1980).

The focus of drug self-administration studies is on operant behavior, or chains of behavior that are relatively free to occur, not to occur, or to occur in altered form, e.g., the procurement and smoking of cigarettes. The strength of operant behavior is assessed by its rate or probability of occurrence. When the maintenance of such a chain of behavior is dependent upon the delivery of a given stimulus, that stimulus is said to

be functioning as a positive reinforcer, regardless of the underlying reasons for which the stimulus holds that property, e.g., tobacco smoke inhaled from a cigarette is the reinforcer for the operant behavior entailed by cigarette smoking. Antecedent stimuli which signal conditions under which an instance of operant behavior is likely to be reinforced are termed discriminative stimuli; their power in setting the occasion for operant behavior to occur (i.e., increasing the probability of occurrence of the behavior) is dependent upon prior instances of the behavior being reinforced in their presence. The prior conditioning histories of such stimuli may be specific to the behavioral sequence at hand and may function additively, e.g., the smell of tobacco smoke and the onset of early nicotine withdrawal symptoms may each tend to set the occasion for smoking, while the contiguous occurrence of both sets of stimuli may produce an extremely high probability situation in which smoking may occur. The prior histories may also be nonspecific to the behavior at hand but equally effective at setting the occasion for the behavior to occur. Modeling the behavior of peers, obeying the instructional demands of perceived superiors or role models, and adhering to social and familial norms are generally conditioned from birth. It should come as no surprise when these kinds of discriminative stimuli function with such efficacy, e.g., when adolescents learn to smoke together, when advertising strategies use the 'Brand X Man' or the 'Brand Y Woman," and when it is discovered that smokers are not randomly distributed across the population but, rather, tend to be clustered into small social units of smokers and nonsmokers (e.g. coworkers, friends, family).

In the studies described in the present paper, two general self-administration strategies are utilized: a cigarette smoking paradigm, and an intravenous nicotine self-administration paradigm. Data collected using these paradigms provide an experimental basis for assessing the role of the multiple factors involved in cigarette smoking. Some of these factors are described below.

SOME PROBLEMS OF MEASUREMENT IN TOBACCO RESEARCH

Fundamental to any self-administration study is to provide a standard unit of the substance to be delivered, as well as to quantify intake. Typically, in drug self-administration studies, a predetermined dose of drug (e.g., mg per delivery or mg per body weight per delivery) is delivered, and the total drug intake over time is measured (e.g., mg per hour). In studies of cigarette smoking, however, this fundamental condition is confounded by the factors described in Figure 1. As shown in the figure the nature and quantity of constituents in any given puff is a function of multiple factors including cigarette constitution, puff topography, inhalation characteristics, and so forth.

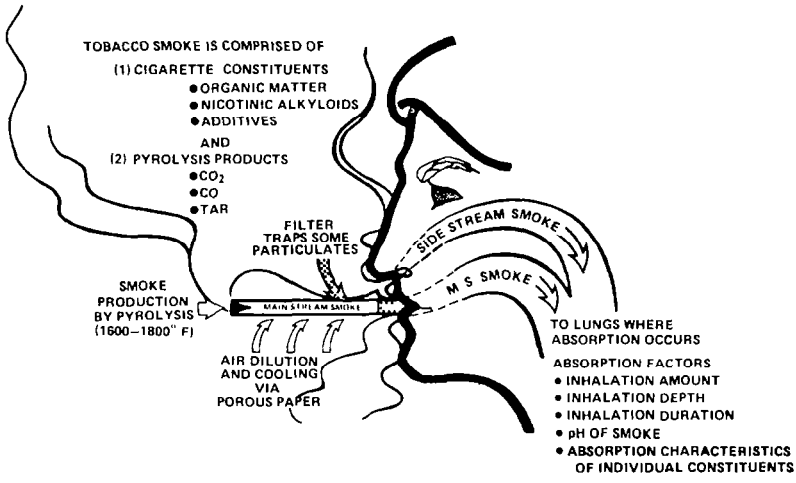

Figure 1. This illustration shows the complex sequence of events whereby a tobacco cigarette, comprised of a variety of constituents, is burned, thus yielding new constituents. The mainstream smoke is filtered and diluted as it passes through the cigarette and into the mouth. Smoke from the tip of the cigarette (side stream smoke) may be inhaled directly and thus be higher in concentration of certain constituents. Finally, a variable amount of the produced and puffed smoke is inhaled into the lungs where absorption will depend on a variety of factors.

Given the complexity of the physical and behavioral processes involved in the production and eventual intake of tobacco smoke constituents, it would seem that dose assessment could only result from a profile of the various measurable parameters. These include (1) puffing parameters (e.g., rate and volume), (2) inhalation parameters (e.g., rate and volume), (3) physiologic intake parameters (e.g., CO level and plasma nicotine), and (4) subjective effects parameters (e.g., self-reported strength of cigarette). All of these factors may bear complex and dependent relationships to one another, and may be most meaningfully addressed as elements of a profile.

Multiple variable measurement, yielding a profile of effects, provides one solution to the issues raised above. Figure 2 shows the profile of effects determined in a study of the effects of d-amphetamine on cigarette smoking in normal volunteers (Henningfield and Griffiths 1981). As shown in the figure, a variety of measures showed dose-related changes. The collection of several variables permits a more meaningful analysis of the results. For instance, the CO measure confirmed

that subjects were not simply puffing more, but were actually inhaling more smoke. Another approach to addressing the problem in measurement concerning delivered and obtained doses is to present known quantities of a pure form of the substance under study, for instance, to deliver intravenous doses of nicotine. However, such an approach assumes that intravenous nicotine is functionally equivalent to nicotine delivered via inhaled tobacco smoke.

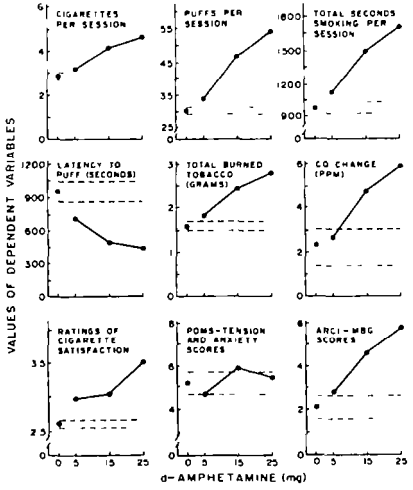

Figure 2. For each dependent variable, the overall man value (n = 40, 8 subjects x 5 sessions) is shown as a function of d-amphetamine dose. The dashed line indicates the 95% confidence interval for placebo. The y axis shows the units of measurement appropriate to the dependent variables indicated in individual graphs. (© The c. v. Mosby Company. From Clinical Pharmacology and Therapeutics, Vol. 30, No. 4, 1981. Reprinted with permission.)

EQUIVALENCE OF IV NICOTINE TO TOBACCO SMOKE

Before studies of nicotine self-administration were conducted, some of the effects of nicotine given intravenously or in the form of research cigarette smoke were compared using biological assay procedures (cf. Finney 1962). Subjects were given a range of doses of nicotine, intravenously and in the form of inhaled

tobacco smoke. Drug dosing was double-blind, following an initial "dose run-up" study done with each subject to verify the safety of the doses. Before, during, and after drug administration, a variety of subjective and physiologic variables were measured. The research staff also made behavioral observations about the subjects (the procedures used and the results obtained have been described in greater detail elsewhere: Henningfield et al. 1983a).

The main findings of this study were that nicotine produced similar profiles of effects given via the intravenous route or in the form of inhaled tobacco smoke: Dose-related increases in scores on scales of drug dose strength, drug liking, and euphoria (MEG scale of the Addiction Research Center Inventory), decreases in desire to smoke, increased heart rate and blood pressure (the high iv dose produced an initial bradycardia), and decreased skin temperature. Peak subjective effects occurred within the first minute of administration of nicotine (or completion of the cigarette) and declined to negligible levels within a few minutes. There were some differences between iv and inhaled nicotine: Inhaled nicotine was more effective at decreasing the desire to Smoke, and intravenous nicotine was identified as a euphoriant producing a "rush" similar to that produced by cocaine or morphine (though of much shorter action). A subsequent study (Henningfield et al. 1983b) showed that nicotine produced early effects on other physiologic measures that corresponded with the changes in heart rate and subjective response observed in the former study. For instance, pupil diameter first increased, then decreased, and returned to saline levels within a few minutes of injection. The more recent study also showed that mecamylamine pretreatment blocked physiologic responses to nicotine and attenuated subjective effects of nicotine (mecamylamine is a ganglionic blocker used as an antihypertensive medication).

This series of studies confirmed findings from earlier studies that nicotine produces many of the effects of cigarette smoking (cf. review by Gritz 1980), and the findings showed that nicotine's profile would contribute to its role as a pharmacologic mediator of compulsive cigarette smoking, i.e., by reinforcing the behavior of tobacco smoke self-administration. Further, these findings support the validity of using intravenous nicotine self-administration as a model to study pharmacologic aspects of cigarette smoking.

SELF-ADMINISTRATION OF INTRAVENOUS NICOTINE BY HUMAN SUBJECTS

The findings of the study summarized above were consistent with those of other investigators (cf. reviews by Gritz, 1980; Griffiths and Henningfield, 1982) suggesting that nicotine is the critical pharmacologic mediator of the behavior of cigarette smoking. To further study the role of nicotine in the

dependence process of cigarette smoking, a series of studies was conducted in which intravenous nicotine was available in place of cigarettes. Some of the issues of scientific importance that can be addressed by the self-administration approach include the following: (1) Can nicotine, in the absence of the vast array of stimuli involved in cigarette smoking, serve as a positive reinforcer and thereby maintain self-administration? (2) How does nicotine compare to other psychoactive drugs which have been studied in self-administration paradigms? (3) How do patterns of nicotine self-administration compare to patterns maintained by cigarette smoke? (4) How is the behavior of nicotine self-administration affected by pharmacologic manipulations?

General Methods

Subjects resided on the research ward for the 6- to 12- week duration of studies. Experimental sessions were 3 hours and were scheduled 1 to 3 days apart. Prior to a session, the subject was catheterized in a forearm vein using a standard intravenous infusion set. Automatically activated syringe pumps were used for injections. Dose volume and infusion duration were 1 ml and 10 sec, respectively. During sessions the subjects sat in a reclining chair in isolation and had access to a radio and magazines. Cigarette smoking was not permitted for 1 hour prior to or during sessions.

Before and after each session, basic vital signs were collected by the research staff. Subjects then also completed three questionnaires: (1) A short form (40 items) of the Addiction Research Center Inventory (ARCI) which contains empirically derived scales sensitive to the effects of several classes of psychoactive drugs. (2) The Single Dose Questionnaire (SDQ) which contains a scale of drug liking and a drug identification list with the street names of 10 common psychoactive drugs. (3) A newly developed form with rating scales of drug dose strength, and desire to smoke a cigarette. Additionally, 1 minute after each injection the liked and disliked effects of the injection were rated by the subject on 100 nun line visual analogue scales. An operant test panel with two levers and attendant stimulus lights were located near the subject’s reclining chair.

Prior to the study, the safety of the nicotine dose levels was verified by injecting the subjects with each of the possible doses at 1 hour intervals in an ascending sequence. They were told that only doses from among this sequence, or placebo, would be available during the self-administration study, but they were given no information regarding the specific nicotine dose available during any session nor the schedule of its availability. In some studies, sessions were preceded by oral administration of mecamylamine. Subjects were told that any lever pressing or drug taking was voluntary; they were not asked OK encouraged to take injections.

Studies were conducted following review and approval of the study plan by the Institutional Review Board. To further ensure the safety of subjects, (a) a one-minute time-out followed each injection, (b) there was a programmed maximum limit on the number of injections available during successive thirty minute intervals, (c) a research nurse observed the subject and the subject's continuous electrocardiogram display and was free to abort the session at his or her discretion, and (d) the subject was free to abort the session at any time.

RESULTS

In the initial study of nicotine self-administration, subjects were presented with one dose of nicotine or saline during sessions; ten responses on one lever produced drug, while responding on the other lever had no programmed consequence (Henningfield et al. 1983c). Figure 3 shows patterns of nicotine injections taken under such conditions. All of the six subjects tested self-administered both nicotine and saline; however, nicotine injections occurred in regular patterns, whereas saline injections occurred with wide variablility in pattern and frequency, both within and across subjects. Patterns of nicotine self-administration were similar to those of humans smoking cigarettes and to animals self-administering psychomotor stimulants (Griffiths et al. 1980). In some of the subjects, comparison of nicotine- to saline-maintained lever pressing suggested that nicotine was serving as a positive reinforcer, while in other subjects it appeared that nicotine was serving as an aversive stimulus relative to saline. Unlike the study of single dose nicotine administration in which desire to smoke was decreased in dose-related fashion, desire to smoke was not reliably decreased in this study. However, the behavior of smoking (cigarettes smoked and puffs taken) was decreased following sessions in which nicotine was self-administered as compared to sessions in which saline was available.

A subsequent study examined the effects of systematic within-subject manipulations of nicotine dose in human and squirrel monkey subjects when ten lever presses were required per intravenous nicotine injection (Goldberg and Henningfield 1983). With the human subjects nicotine and saline were presented concurrently, while with the animal subjects saline and nicotine were presented across sessions. The results of the study were similar in both species.

In the Goldberg and Henningfield study, all subjects self-administered both nicotine and saline. Nicotine injections exceeded saline injections in three of the four humans and three of the four monkeys tested, indicating that nicotine was serving as a positive reinforcer for these subjects. The highest dose of nicotine decreased injection rates, though amount of nicotine

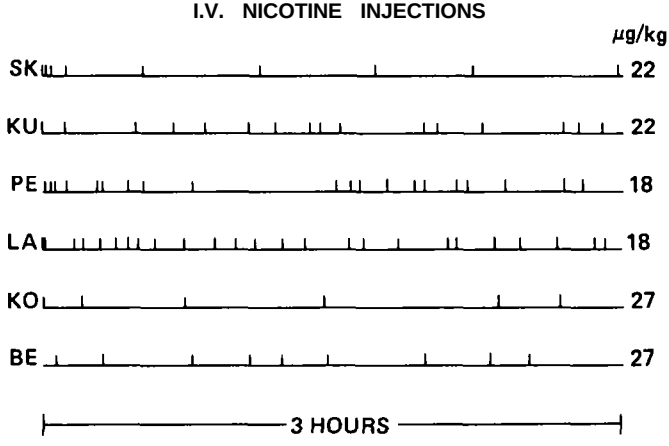

Figure 3. Intravenous nicotine self-administration by cigarette smokers. The vertical marks indicate injections obtained by each subject during a 3-hr session. For subjects BE, KO and LA, the data shown are those from a representative session at the 1.5 mg per injection dose: for subjects SK, KU and PE, the data are from the only session in which the 1.5 mg dose was available. The actual unit dose for each subject , expressed as ug nicotine per kg body weight, is indicated on the right side of each record.

obtained per session was relatively unchanged. With the human subjects, as injection dose increased from 0.75 to 1.5 mg, there was little change in number of injections taken per 3 hour session. However, when dose was increased to 3.0 mg, number of injections per session decreased. This is interesting since studies of the effects of nicotine yield in cigarettes on cigarette smoking behavior have shown little effect on rate of cigarette consumption except when nicotine yield of the cigarettes was in excess of 2 mg per cigarette (Griffiths et al. 1980).

Self-administration studies in animals and humans with opioid agonists (e.g., morphine) have shown that pretreatment with antagonist drugs (e.g., naltrexone) decreases the reinforcing efficacy of the opioid, relative to placebo (Griffiths et al. 1980). These results suggest that nicotine self-administration might also be reduced by pretreatment with an antagonist. Studies of intravenous nicotine self-administration by animals have shown that the reinforcing efficacy of nicotine is reduced by pretreatment of the animals with mecamylamine (e.g., Spealman and Goldberg 1982).

To assess the effects of mecamylamine on nicotine self-administration behavior, a subject was pretreated with mecamylamine or placebo, 1 hour before 3-hour sessions. Nicotine, in 3 mg doses (IV) and saline were concurrently available by pressing either of two levers (the nicotine and saline levers were alternated each day, and the subject was told that pressing on either lever could produce any of a previously given range of doses of nicotine or placebo).

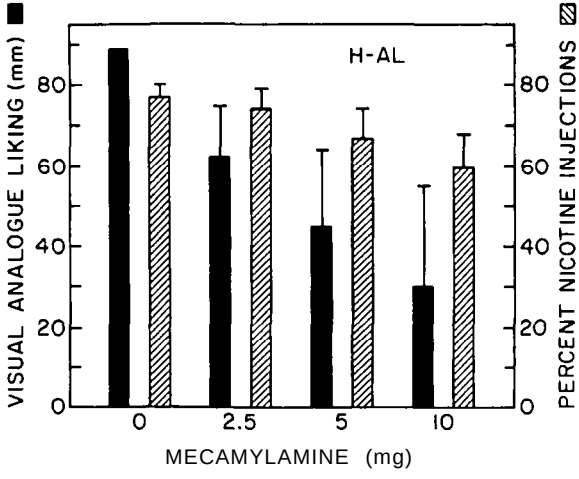

Figure 4. Mean values (n = 3 sessions) and S.E.M. of dependent variables when the available nicotine dose was constant across sessions (3.0 mg) and the presession mecamylamine dose was varied from 0 to 10 mg. The shaded bars indicate the mean visual line analogue scores obtained 1 minute following each of the first three injections of a session. The striped bars indicate the percent of total number of injections during a session that were nicotine injections.

Figure 4 shows that mecamylamine pretreatment produced a dose-related blockade of the subjectively liked effects and of the reinforcing effects of nicotine. Liking scores on a 100 mm visual line analogue scale were decreased by nicotine (0 mm = no effect and 100 mm = very strong positive effect). The preference for nicotine, as compared to saline, was decreased by mecamylamine administration.

IMPLICATIONS

These studies suggest that measurement issues can be surmounted by systematically applying the methods of behavioral pharmacology and biological assay procedures. Use of multiple measures helped to resolve issues arising from any single measure (e.g., the relationship between nicotine's effects on desire to smoke versus the behavior of smoking). Studies with intravenous nicotine showed that nicotine, in its own right, is an abusable drug, and that nicotine produces physiologic, subjective, and behavioral effects which are generally similar whether nicotine is delivered intravenously or via tobacco smoke inhalation. Subjective effects are qualitatively similar to those produced by abused drugs such as cocaine. Certain effects onset within seconds and offset within minutes. Mecamylamine selectively attenuates interoceptive effects, though higher doses block physiologic responses to nicotine. The fundamental implication of the self-administration study is that nicotine was voluntarily taken in place of cigarettes, in the absence of the vast array of stimuli (social, taste, etc.) normally concommitant to nicotine taking by cigarette smoking, thereby indicating that nicotine may function as a positive reinforcer.

Taken together, these results show that cigarette smoking is appropriately categorized as an instance of drug dependence in which nicotine is the key pharmacologic mediator of the behavior. A caveat, applicable to all forms of drug dependence, is that the pharmacologic mediator is only one of many components involved in the acquisition, maintenance, and elimination of the dependence proccess. However, knowlege concerning the role of a pharmacologic mediator provides a rational basis for pharmacologic aids for the treatment of the behavior. For instance, a nicotine substitution treatment (e.g., nicotine containing chewing gum) or a nicotine blocking treatment (e.g., mecamylamine) may be of use.

The emerging conceptualization of cigarette smoking is that cigarette smoking may be regarded as an instance of voluntary toxin self-administration. Unlike other forms of toxin self-administration, however, in which knowledge of the toxic effects of the substance (e.g., dioxin in drinking water, or asbestos in air) is frequently sufficient for the behavior to change, in the case of cigarette smoking, the toxins (specifically, tar, CO and particulate matter) are accompanied by a psychoactive compound that reinforces the behavior of self-administration. It is clear that any serious attempt to reduce the disease and suffering caused by cigarette smoking will need to consider these issues (U. S. Department of Health and Human Services, 1983).

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Analysis of Reinforcement by Varying Smoke Component Concentrations

Jed E. Rose, Ph.D.

Since nicotine is thought to be one of the principal reinforcing constituents in tobacco, a logical way to classify smokers may be to distinguish those who are dependent on nicotine from those who smoke for other reasons, e.g., other components of tobacco, sensory/motor aspects of the habit, or social reasons (Russell et al. 1974). The role of nicotine in cigarette smoking has been studied by examining smokers' reactions to cigarettes of different nicotine deliveries or to nicotine preload. By observing compensatory charges in smoking behavior in response to variable nicotine delivery (titration) it was hoped that the reinforcing role of nicotine would be highlighted. The empirical findings have typically demonstrated statistically significant, but often slight, compensatory changes in response to varying nicotine yields (Ashton and Stepney 1982; Gritz 1980).

The methodology about to be described was designed to study the reinforcing actions of nicotine in smokers in a way that would overcome two conceptual problem inherent in most nicotine titration studies. The first problem is that if nicotine is a reinforcer for smoking, smokers would not be expected to like low-nicotine cigarettes, and in that case it would not be reasonable to expect them to smoke for example, 10 times more of a 0.1 mg nicotine cigarette than of a 1.0 mg nicotine cigarette (which would be required for complete titration of nicotine intake).

The second problem is that even if titration does occur, it would be consistent with the view that nicotine is aversive rather than reinforcing and that smokers are obtaining other reinforcers from the cigarette (Russell 1979). Although the titration paradigm may be useful from a practical standpoint for investigating smokers' responses to altered yield cigarettes, it is not an appropriate methodology for the study of nicotine's reinforcing value.

METHOD

The new methodology to be described here explores variations in nicotine preference In which the concentration of nicotine in each puff of smoke is under the subject's control. In this choice procedure, subjects utilize a smoke-mixing apparatus to adjust the nicotine concentration in cigarette smoke on a puff-by-puff basis

and select an optimal nicotine delivery. The rewarding and/or aversive properties of nicotine at a specific time can be inferred by the nicotine level chosen.

The smoke-mixing device (figure 1)[1] consists of a two-barreled, glass cigarette holder, constructed from a three-way stopcock, that blends smoke from two, sources: a high- and a low-nicotine cigarette, roughly equivalent in other respects (e.g., tar delivery, carbon monoxide). For this purpose, we have employed the University of Kentucky Reference cigarettes: 2A1, 0.45 mg nicotine, 36.4 mg tar; 2R1, 2.45 mg nicotine, 35.8 mg tar. As in blending hot and cold water with a faucet, subjects may turn a knob and vary the ratio of smoke drawn from the two cigarettes and, hence, the nicotine concentration of the smoke inhaled. The mixing of smoke takes place within the modified Teflon stopcock, also shown in figure 1. The center core of the stopcock was first drilled out, and then three slits were cut to allow the inside to communicate with the exterior. One of these slits, the largest (approximately 3 mm wide), connects to the mouthpiece and allows smoke to travel unimpeded into the smoker's mouth. The other two slits, located on the opposite side of the stopcock, are much narrower (approximately 1.2 mm wide). These two smaller slits are offset with respect to each other, so) that when one is perfectly aligned with one channel of the cigarette holder, the other is not, and vice versa. Intermediate rotations of the stopcock cause partial aligment of each slit with the corresponding channel in varying degrees. At a given setting, same smoke is drawn through each side of the mixer. The precise ratio depends on the alignment of the slits, which is controlled in turn by the adjuster (vernier) knob operated by the subject. The overall draw resistance present& by both slits is negligible compared to that of a cigarette.

The flow of smoke through each side of the holder is measured by differential pressure transducers (Statham Model PM6TC±2.5-350), which sense the pressure difference across the restriction tuba in each barrel. The diameter of this tube (1.6 mm) is sufficient to prevent accumulation of smoke residue and presents a small, fixed draw resistance. The use of differential pressure. measurements across a constant resistance is necessary so that variations in the length of the cigarette as it burns do not affect the relationship between flow and pressure measured by the transducer. This system is similar to those used previously in studies of smoking topography (Creighton et al. 1978; Rawbone et al. 1978). The output from the transducers leads to a polygraph to be recorded, and measuring the height of the puff profile on each channel yields the flow through that side. Two additional polygraph channels record the volume of smoke taken in through each channel, after intermediate circuitry has linearized and integrated the signals from the pressure transducers. Calibration records were produced by independent determination of flows using a vacuum pump and Gilmont spherical float flow meters. The estimate of nicotine delivery (Nic) of the smoke mixture is computed as follows:

SMOKE MIXING DEVICE

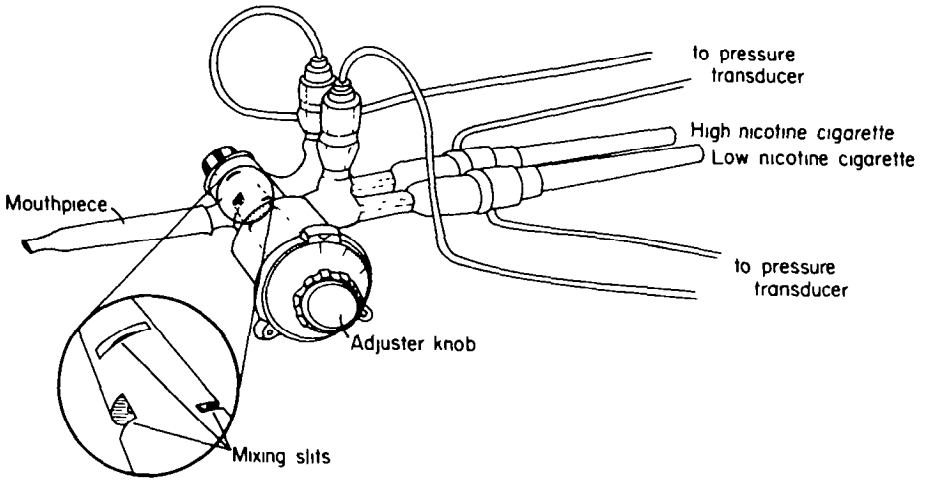

Figure 1

Smoke-mixing device used to assess smokers' nicotine preference. The knob controls the positions of mixing slits which blend high and low nicotine smoke to achieve intermediate nicotine deliveries. Tar delivery is held constant with the research cigarettes employed. The mixture setting chosen with each puff is measured with pressure transducers that monitor the flow of smoke through each barrel of the mixer.

$$\text{Nic (mixture)} = \frac{\text{Volume (Side 1)Nic 1} + \text{Volume (Side 2)Nic 2}}{\text{Volume (Side 1)} + \text{Volume (Side 2)}}$$

Nic 1 and Nic 2 are the nicotine deliveries for the two types of cigarettes employed.

There are two main sources of error to be considered in this measurement. The first is random variations in nicotine delivery between puffs from cigarettes of a given type. This error includes variations in nicotine concentration accompanying changes in the rate of puffing or volume (Creighton and Lewis 1978). The magnitude of this error is probably Less than ±10% in the range of puff parameters commonly encountered; however, observed puff volumes and interpuff intervals could be used in a retrospective analysis to improve the estimates of per-puff nicotine deliveries. The second source of error is the systematic increase in the concentration of smoke products across puffs from a single cigarette due to the rod filtration effect (Russell et al. 1979; Wiley and Wickham 1974: Young et al. 1991). This factor can be corrected, for it is known precisely how nicotine deliveries vary across the length of the particular cigarettes employed, and it can be minimized by restricting smoking to the distal halves of the cigarettes used. The burn rates of the two types of University of Kentucky research cigarettes are very similar over a wide range of mixture settings, so that the lengths and relative contributions of each cigarette to total nicotine delivery remain nearly constant across the length of the cigarettes.

A simpler measure of nicotine preference may also be employed: the relative ratio of smoke drawn through the high nicotine side. This latter measure more clearly reflects the behavior of the subject (in adjusting the knob position) and is less sensitive to inaccuracies in determining absolute nicotine deliveries per puff. Positively reinforcing aspects of nicotine would be unambiguously demonstrated by the choice of a mixture delivering more than 50% smoke from the high nicotine side, and, conversely, an aversion to nicotine would be clearly evidenced by a selection of the lowest nicotine delivery. Selection of a 50-50 mixture would indicate either indifference to nicotine or a positive preference for that intermediate nicotine level. Selection of mixtures delivering between 0 and 50% from the high nicotine side are similarly ambiguous in that they would be consistent either with a mild aversion to nicotine or simply a preference for a positiveliy reinforcing, but lower concentration, of that substance.

Inasmuch as smoking abstinence has been shown to be a potent variable influencing subsequent smoking (Kumar et al. 1977; Henningfield and Griffiths 1973), our first goal in the behavioral application of the smoke mixer was to measure variations in nicotine preference resulting from smoking abstinence and satiation. In analogy to the work of Gabanac (1971), who showed that food-deprived subjects preferred more concentrated sugar solutions than satiated subjects, it was predicted that if cigarette deprivation produced a nicotine "hunger," subsequent preference for nicotine should likewise increase.

Subjects

Twenty smokers, who regularly consumed at least a pack a day, and whose customary brand of cigarette delivered (by FTC method) over 0.5 mg, were recruited for the study. Subjects included 12 males and 3 females, with an average age of 38 years.

Procedure

Subjects' nicotine preference was assessed under two, conditions: Deprivation, in which subjects abstained from smoking for approximately 2 hours (1 hour before entering the laboratory and an additional 50 minutes after arriving): and Satiation, in which subjects smoked two cigarettes of their own brand in the 20 minutes immediately prior to the nicotine preference test.

During the nicotine preference test, subjects were instructed simply to find their preferred nicotine concentration, using the mixing device to blend smoke with each puff from the high and low nicotine research cigarettes. They were free to use any cues for finding their optimal nicotine mixture, including the immediate sensory impact of nicotine (Cain 1980), or the pharmacologic effects which occur within seconds of inhalation (Russell and Feyerabend 1979). To the extent subjects desired the higher nicotine smoke, they could adjust the mixture to as high as 2.45 mg. (Mean nicotine delivery of subjects' habitual brands was 1.60 mg.) For half of the subjects, the high-nicotine cigarette was placed in the left barrel of the mixer, and for the other half the positions of the high- and low-nicotine cigarettes were reversed.

A replication of each condition was presented (an a different day), and since the results from the days within a condition did not differ, the data were averaged across replications. Two behavioral measures of smoking were compared between Deprivation and Satiation conditions: 1) average nicotine preference (averaged across all puffs taken in the preference test); and 2) number of puffs taken during the test. Additionally, after each puff subjects used two ten-pint scales to rate the perceived "strength" and "desirability" of the smoke.

RESULTS AND DISCUSSION

Figure 2 depicts the results, which show subjects' preference for significantly higher nicotine concentrations in the Deprivation condition than in Satiation ($t=2.23$, $p<.04$). Further, subjects who selected consistently higher nicotine levels in Deprivation than Station in both replications ($n=9$), chose a mixture in Deprivation that was not only greater than the low-nicotine extreme but also significantly higher than the 50-50 indifference point ($t=2.42$, $p<.05$). This constitutes direct evidence confirming nicotine's role as a desired ingredient in cigarette smoke. Ingesting high-nicotine smoke was more reinforcing after A period of cigarette deprivation, when nicotine levels ware presumably low. Smoking abstinence indeed seems to evoke a hunger for nicotine in

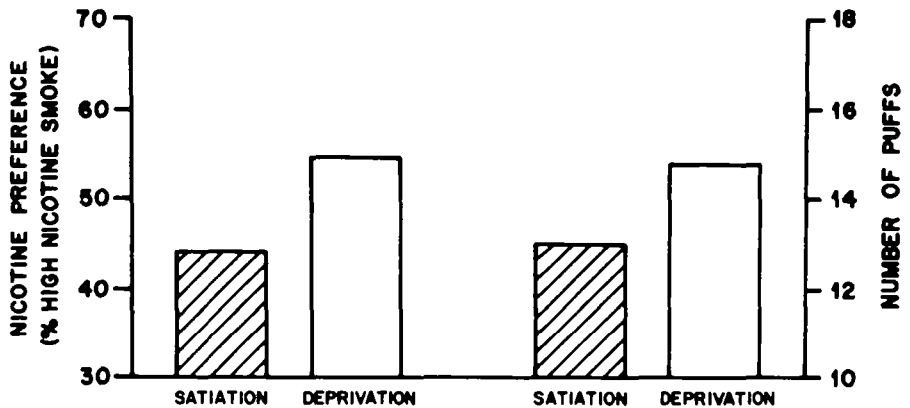

Figure 2

Mean nicotine preference and number of puffs taken during test smoking period after two hours' smoking abstinence (Deprivation) and after smoking two cigarettes (Satiation). Significant elevations in both smoking parameters occurred after cigarette deprivation.

at least some smokers. For the same subjects, the level of nicotine selected during Satiation was marginally lower than the indifference point (t=2.22, p=.06), suggesting that nicotine aversion may have influenced preference in Satiation (see figure 3). The assessment of nicotine's aversive qualities depends in part upon whether the criterion for aversion is the choice of a mixture below the indifference point or selection of the lowest nicotine level possible. Subjects also took significantly more puffs after a period of cigarette deprivation than when satiated (t=2.73, p<.02). Subjects thus increased nicotine intake after smoking abstinence in two ways: taking more puffs as well as increasing the nicotine {mixture of each puff. The increase in puffing was, of course, not a specific measure of nicotine-seeking (unlike the mixture adjusment) and may have reflected deprivation for non-nicotine factors in the smoking habit, such as oral or manipulative reinforcement.

In the Satiation condition suppression of smoking was not complete. This may have been due to the fact that the two cigarettes presented in Satiation were insufficient to reverse the effects of almost 2 hours' Deprivation, during which many subjects would have smoked as many as three or four cigarettes. Alternatively, there may be an extremely rapid recovery from the satiating effects of cigarette smoking, storming from the very short distributional half life of nicotine (Benowitz et al. 1982).

In order to identify characteristics of smokers who were more responsive to the Deprivation manipulation, additional statistical analyses were conducted. The magnitude of increase in nicotine preference with Deprivation was found to be positively correlated (r=.61, p<.O1) with the subject's age. In contrast, subjects whose puffing behavior was most affected by the experimental maniplation tended to report smoking most in social situations (r=.63, p<.01). The fact that puffing and nicotine preference were correlated with different subject characteristics suggests that these two factors may represent different types of reinforcement gained from smoking.

The subjective judgments of strength and desirability also differed between experimental conditions. Puffs were rated as significantly Less strong (t=2.25, p<.04) and more desirable (t=2.38, p<.03) following Deprivation. Desirability ratings from each subject did not correlate with nicotine delivery (t=0 and .05 for Deprivation and Satiation, respectively, p>.5), suggesting that many other factors affect the subjective enjoyment of smoking, or, alternatively, that each subject's ratings varied nonlinearly with nicotine delivery. Goldfarb et al. (1976) and Pose (1983) also reported the absence of a correlation between satisfaction ratings and nicotine delivery, whereas strength ratings were positively correlated with nicotine. In the present study, subjects generally displayed a positive correlation between nicotine content of each puff and perceived strength (t=4.36 and 6.23 for Deprivation and Satiation, respectively, p<.001). me fact that subjects rated puffs as weaker in Deprivation, even though the nicotine levels chosen were higher than in Satiation, suggests that smoking deprivation induces a substantial downward shift in the sensitivity

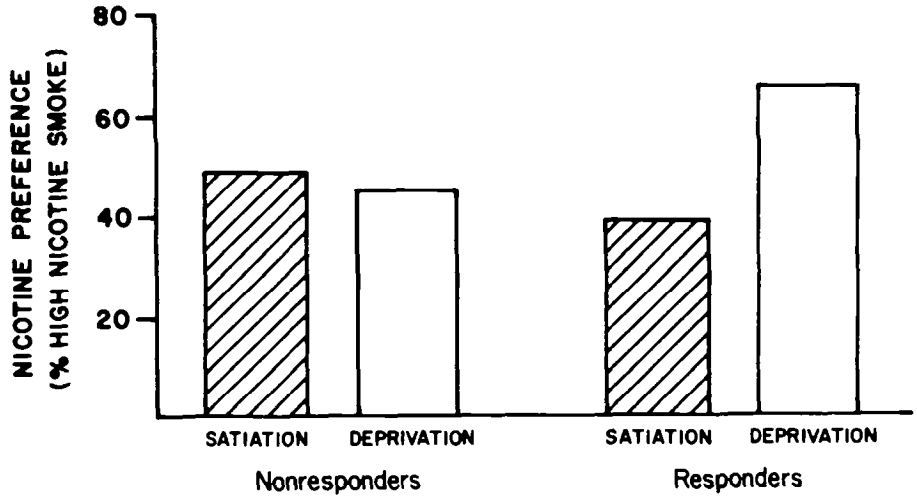

Figure 3

Nicotine preference of subjects who consistently chose higher nicotine levels after cigarette deprivation (responders) and those who were unaffected by this manipulation (nonresponders). After deprivation, responders selected smoke mixtures containing significantly more than SO% high nicotine smoke, which demonstrates the positively reinforcing qualities of nicotine in this condition.

to nicotine. The slopes of regression lines relating perceived strength and nicotine content did not differ across conditions ($t=.98$, $p>.3$), so the shift in strength ratings represents a uniform bias rather than a change in discriminability per se. Perhaps this shift reflects a comparison between the perceived qualities of the smoke and the desired level of nicotine as determined by internal cues. Also involved may be the responsiveness of receptors mediating the common chemical sense, located in the pharynx and sublaryngeal regions (Cain 1980), or the sensitivity of CNS receptors for nicotine (Abood et al. 1979). The relative importance of central versus peripheral stimulation in discriminating nicotine's reinforcing effects has not as yet been firmly established. Further studies which identify the factors affecting nicotine preference and satiation should significantly clarify the psychopharmologic basis of cigarette smoking.

Although primarily designed to study nicotine preference, the smoke mixing methodology can be applied to the investigation of other factors important in smoking reinforcement. For example, "tar" has been suggested to play an important role in modulating the sensory and pharmacologic effects of inhaled nicotine, and conceivably contains additional constituents important in their own right (Goldfarb et al. 1975). By placing in the smoke mixer cigarettes of equal nicotine delivery but high and low in tar delivery, preference for tar concentration may be measured. Technical refinements will allow the construction of cigarettes with alterations in the delivery of more specific ingredients. Preference for any constituent of tobacco smoke may thus be explored with the present methodology, if cigarettes are available with high and low yields for that particular component.

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FOOTNOTE

1. This paragraph, the following two paragraphs which describe the smoke-mixing device, and figure 1 are reprinted from Rose, J.E.; Lafer, R.L.; and Jarvik, M.E. A smoke-mixing device for measuring nicotine preference. Behavior Research Methods & Instrumentation 14(6), 501-503, 1982.

Physical Indicators of Actual Tar and Nicotine Yields of Cigarettes

Lynn T. Kozlowski, Ph.D.

By the late 1960s, cigarette tar was becoming officially dangerous to the health of smokers (e.g., USPHS 1964). Those who refused to stop smoking were encouraged to smoke lower tar and nicotine cigarettes. In 1967, the Federal Trade Commission (FTC) established a laboratory to conduct standardized assays of the tar and nicotine yields of cigarettes. This standard smoking-machine procedure provided the yardstick by which all cigarettes were to be measured. Lower tar cigarettes, by definition, deliver lower tar when smoked in the standard fashion of one 2 second long, 35 ml puff each minute until a fixed butt length IS reached. Except for small differences in rules for butt length, this machine procedure is the internationally standard way to smoke cigarettes in the analytical laboratory (Coresta 1969; ISO 1977). Whenever and wherever (world-wide), one sees official tar and nicotine yields, whether in a United States Surgeon General's Report or on a billboard, one can assume that the brand in question has undergone this exact smoking regimen.

THE CRADLE OF THE STANDARDIZED SMOKING MACHINE TEST

Interestingly, the origin of the 2 sec, 35 ml puff/mm regimen IS generally not known. Although my research has explored limitations of standard smoking-machine assays (Kozlowski et al. 1980b; Kozlowski 1981a; Kozlowski 1981b; Kozlowski et al. 1982b), I had not tried to trace the origins of the puffing regimen. It has been assumed that average human smoking behavior somehow provided the basis for the procedure. Further, it has been assumed that the standards derived from the smoking of the stronger, shorter, and less-filtered cigarettes of 20 to 30 years ago.

The standard regimen appears to have been born in the laboratory of the American Tobacco Company (ATC), Richmond, Virginia, in the 1930s (Bradford et al. 1936). AT the time, ATC dominated the manufacture of cigarettes in the United States (Overton 1981). The Bradford et al. article proposed to create a standardized smoking machine procedure "in the interest of economy of research, and harmony among the various investigators" (p. 836).

In a book published to promote an ATC brand at the 1939 New York World's Fair, Flannagen (1938) describes a tour of the ATC analytical laboratory. The author appears to have seen the Bradford et al. equipment in action: "Fascinated, I soon learned [from his guides] some interesting facts about smoking cigarettes. The average puff, for

instance, contains 35 cubic centimeters of smoke, and the smoke moves through the cigarette at the rate of 17 cubic centimeters per second. The normal time between puffs is 60 seconds.... All of these human phenomena and others were reproduced faithfully by the machine" (p. 78).

Inspecting the original Bradford et al. paper, however, one finds the empirical basis for these "average" and "normal" values of smoking behavior lies in a study by Pfyl (1933). In 7 subjects, Pfyl had found puff volumes of from 29 to 61 ml (Mean = 42.3, SD = 10.4). (Though commonly described as puff volumes, Pfyl's values were for air intake into the cigarette during a puff; Schur and Rickards (1957) found that an air intake of 35 ml was equivalent to a smoke gas phase volume, i.e., the modern smoking machine's puff volume, of 42 ml--a 20% difference.) Pfyl set his own smoking machine to take a 2 sec, 40 ml puff twice a minute. Bradford et al. commented that Pfyl's smokers probably smoked more vigorously than normal because of the experimental setting, and the authors close their article by stating "The present writers' arbitrarily selected rate IS a 35-cc. puff of 2-second duration taken once a minute" [emphasis added] (p. 839). Earlier in their article, the authors do give some rationale for the selection of their machine settings: 1) a puff should not be larger than the capacity of the mouth, but "should be large enough to produce a generous smoke," (p. 838), 2) the time between puffs should be long enough to allow the coal to return to a free-burning condition, and 3) the puff should neither be too rapid nor too slow.

For those Interested in smoking behavior, the standard assay lacks the empirical, objective pedigree that has been assumed. Standard tar and nicotine assays were born in the tobacco science laboratory out of a need to precisely quantify cigarette smoke. Bradford et al. (1936) and their colleagues in tobacco science should not be faulted for devising a procedure to meet their own special needs. It has long been clear that smoke yields depend on the exact manner in which a cigarette is smoked. To do analytical research on cigarette smoke, an agreed upon standard smoking procedure was mandatory so that conditions could be reproducible from laboratory to laboratory and from experiment to experiment. The idea, then, was not to come up with a model of average human smoking behavior, but rather to arrive at a reasonable, fixed and reproducible way of putting cigarettes through their paces so that chemical and physical properties could be examined (see Wynder and Hoffmann 1967).

Note that the standard procedure was created primarily to compare quite similar cigarettes when smoked in exactly the same way. Between the 1930s and the 1950s, most cigarettes were 70 mm long. The modern cigarette market has all but forgotten the early best-sellers and includes mainly filter cigarettes (both ventilated and unventilated) that are 80 mm (in boxes), 85 mm (in softpack), 100, or even 120 mm long. The complex issues of varying smoking habits, the behavioral pharmacology and behavioural toxicology of smoking, and reduced-risk smoking were not salient at the outset of the standard assays. The smoking and health industry had not attained the prestige and Influence of the present day.

AVERAGE SMOKING BEHAVIOR AND STANDARD YIELDS

The writings on smoking machine tests before 1960 show that little effort was made to determine "average" puffing values for a representative sample of smokers. Puffing measures were mainly taken on convenient samples (e.g., Schur and Rickards 1957). A detailed review of measurements of average human smoking behavior will not be attempted. Moody (1980) provides a brief review of earlier findings, and his own study employs the largest sample of smokers (517 adult medical patients). HIS laboratory procedures find average puff durations of 2.12 sec (SD = 0.881, puff volumes of 43.5 ml (SD = 21.91, puff intervals of 25.8 sec (SD = 17.1). One can estimate from this research that the standard puff IS 20% smaller, 6% faster, and 133% less frequent than that of the "average" smoker in the laboratory. Of course, as noted by Bradford et al. (1936), the behavioral laboratory does appear to lead to more intensive smoking than do more natural smoking conditions (e.g., Russell et al. 1982). There are probably as many "average" smoking behaviors as there are distinct psychological settings for smoking. For example, poorer, older male smokers are more intense smokers per cigarette than are richer, younger males (Moody 1980).

Even if a valid or accurate estimate of average smoking behavior IS attainable, it does not follow that it would be sufficiently reliable or precise to give many smokers information about their own idiosyncratic tar and nicotine yields from a given brand. The ideal average smoker may always be an inadequate stand-m for individual smokers; an average value tells you about the behavior of other members of the population to the extent that the other members of the population cluster in close proximity to the average. From Moody (1980), one can estimate that 68% of smokers have puff volumes that are between 21.6 and 65.4 ml; the coefficients of variation are substantial: 41.5% for puff duration, 50.3% for puff volume, and 66.2% for puff interval. The variability of human smoking behavior IS large enough that standard yields do not, on their own, provide a good indication of actual yields to individual smokers (Green 1978; Kozlowski 1981b). A valid average tar and nicotine yield might, however, be useful for epidemiological studies on dose-disease relationships in large samples of smokers (Kozlowski et al. 1982c).

OTHER PROBLEMS WITH THE STANDARD SMOKING MACHINE

To understand the deficiencies of standard tar and nicotine assays, it helps to understand the strategies involved in the construction of lower-yield cigarettes. The standard procedure, one discovers, provides the hurdles, while design variants provide ways around the hurdles. For the most part, standard tar and nicotine yields are altered in only two ways. Cigarettes are constructed to either a) burn faster and therefore have fewer puffs taken during the standard one puff per minute procedure or b) produce lower concentration smoke per puff. Table 1 outlines some common manufacturing techniques for reducing standard tar and nicotine yields.

Number of Puffs

Remember that the standard procedure does not specify a number of puffs to be taken on the cigarette, but rather a puffing-rate. Changes in total burn-time seem to have been a major strategy responsible for yield reductions between 1967 and 1975 (Kozlowski et al. 1980b). Dropping just one puff from a 20 mg tar cigarette can reduce the yield by 2 to 3 mg.

Tobacco manufacturers, themselves, argued that the FTC cigarette tests should make systematic use of information about puff variations from brand to brand: "...the failure to report results both on an average per puff and average per cigarette basis would create bias and have unwarranted adverse competitive effects." (American Tobacco Company, Brown & Williamson Tobacco Corporation, Liggett and Myers Tobacco Company, Philip Morris Incorporated, and R.J. Reynolds Tobacco Company, December 20, 1966, p. 10). (See also Keith and Newsome 1958). When one appreciates that a standard procedure caused 6.9 puffs to be taken on one filter king size (85 mm) cigarette and 11.5 puffs on another filter king size (85 mm) cigarette (a difference of 66.6%, Jenkins et al. 1979), it IS unfortunate that the warning by the tobacco companies was not heeded. If 120 mm cigarettes are considered, machine puffs ranged from 6.9 to 16.3 (a difference of 136%) (Jenkins et al. 1979): This means that a pack-a-day, puff-per-minute smoker of the 16.3 puff cigarette would be taking 136% more puffs per day than would the same kind of smoker of the 6.9 puff cigarette, yet nominally they would both be pack-a-day smokers.

TABLE 1
REDUCING STANDARD TAR AND NICOTINE YIELDS

A. REDUCE NUMBER OF PUFFS PER CIGARETTE BY

1. decreasing length of available tobacco column with
    a. longer overwraps
    b. longer filters
2. increasing the burn-rate of column with
    a. chemical additives
    b. higher porosity paper
    c. less tobacco (wt/vol)

B. REDUCE CONCENTRATION PER PUFF BY

1. increasing filter-efficiency with
    a. ventilated-filters
    b. longer filters
    c. denser filters
2. increasing porosity of cigarette paper
3. decreasing tobacco leaf (wt/vol) with
    a. reconstituted sheet tobacco
    b. puffed tobaccos
    c. flavorings and additives
4. increasing the use of lower-yields tobacco strains

The Behavioral Problem of Vent-Blocking

Unquestionably, the most dramatic yield reductions in recent cigarettes are due to the effects of filter ventilation. The modern ultra-low-yield cigarette (< 6 mg tar) IS a ventilated-filter cigarette. On a 1 mg tar cigarette a vented filter can cause each puff to be diluted by about 80% with ambient air (Kozlowski 1981c). In addition to affording all the traditional opportunities for compensatory smoking (e.g., more cigarettes, larger puffs, more frequent puffs), vented-filter cigarettes can have the air intake holes on the filters blocked by smokers' lips or fingers (Kozlowski 1983). Kozlowski et al. (1982b) found that about 40% of them sample of long-term smokers of vented cigarettes blocked the vents to a substantial degree. Table 2 shows how dramatically hole-blocking, coupled with somewhat larger and more frequent puffs, can increase tar, nicotine, and carbon monoxide yields on selected "lowest" yield cigarettes from three countries. Whereas smokers are free to block filter vents, smoking-machine rules rigidly specify the amount of filter inserted into the holder: Air intake holes can not be blocked by the "smoker" in the course of a standard assay.

TABLE 2
EFFECTS OF INTENSIVE SMOKING ON LOWEST YIELDS

COUNTRY	STANDARD ASSAY			INTENSIVE ASSAY		
	TAR	NIC	CO	TAR	NIC	CO
U.K.	1	0.1	1	29	2.2	21
CANADA	1	0.1	2	15	1.1	24
U.S.	1	0.1	2	12	0.8	18

The intensive procedure was a 2.4 sec, 47 ml puff every 44 sec; all values are in mg; for more data and details about brands, see Kozlowski et al. (1982b). © 1982, British Journal of Addiction. Reprinted by permission.

GOING BEYOND THE STANDARD ASSAY

The standard tar and nicotine numbers result from an artificial and unsatisfying "method of convenience." Standard ratings offer more to the tobacco scientist than the behavioral scientist, yet they are often taken at face value by behavioral scientists, as i they were almost perfect predictors of actual yields achieved by a given smoker of a given cigarette (e.g., Foxx and Brown 1979).

Armed with reasonable standards, the tobacco science field over the years has become invested in maintaining the settings of a 2 sec, 35 ml puff, once a minute. Tampering with the standard puffing procedure, it has been argued, would disrupt the continuity and historical comparability of much of tobacco science. Despite the weaknesses of such arguments, it might be more realistic to propose that an improved

procedure should be added alongside the sanctified standard, rather than to urge the complete abandonment of the standard. The spent cigarette butt of a filter cigarette is in a unique position to supply information about the actual yield of tar and nicotine from that cigarette "Yield" here refers essentially to mainstream smoke, or, in other words, the smoke drawn through the filter as a result of puffing.

The study of tar and nicotine deliveries should not be mistaken for the study of the burden of tar and nicotine in the smoker's body. Exposure at critical tissue sites IS dependent on myriad factors (e.g., inhalation, levels of drug-metabolizing enzymes), and it is unrealistic to expect that any measure of how much smoke has issued from the smoker end of a cigarette can be anything but a rough indicator of pharmacologically or toxicologically significant exposure.

USING PHYSICAL EVIDENCE TO DETECT ACTUAL YIELDS

The remainder of this paper focuses on what can be learned from the tracks of smoke (tar stains) left behind in cigarette filters. Even a novice can read these tracks, to get an idea of the actual tar and nicotine yields of cigarettes. A skilled reader of sign, using a camera or equipment for chemical analysis, can achieve a more objective, yet still unobstrusive, measure of what has been delivered through the smoker end of a cigarette. Cigarette filters can provide useful information about how an individual cigarette has been smoked, and the physical evidence of these filters can help in the estimate of the actual tar and nicotine deliveries of cigarettes. The resultant measures are approximate indicators of behaviors and yields that are difficult to estimate in any more practical and less expensive way. Filter analyses can provide a summary indication of the puffing behavior that has occurred, but these analyses may say little about how the smoke was used after the puffs were taken.

USING STAIN PATTERN TO DETECT HOLE-BLOCKING

About 40% of current hole blockers seemed to be unaware that they did block the vents (Kozlowski et al. 1982b). Those who were aware of blocking the holes appeared to think their actions served mostly to make the cigarette easier to light and more flavorful, and these smokers (and many researchers) were ignorant of the powerful effects on tar, nicotine, and carbon monoxide yields (see Table 2).

Most ventilated filters have air-intake holes that feed the diluting air directly into the cellulose acetate filter. In these cigarettes, when the holes are blocked, a bull's-eye tar stain pattern will be seen in the smoker end the filter, surrounded by a ring of unstained filter (see Figure 1). Insofar as the vents are blocked, the tar stain extends to the edge of the filter and, in the extreme, forms a uniform field of tar stain on the end of the filter. If the filter vents were blocked by a pinch of the fingers that occluded the same opposing set of holes on each puff, the tar stain would form a band between the blocked holes. Blocking on a few puffs would likely cause a somewhat irregular tar stain, with a darker central region. Incidentally, lipstick stains over the vent holes also give physical evidence of hole-blocking.

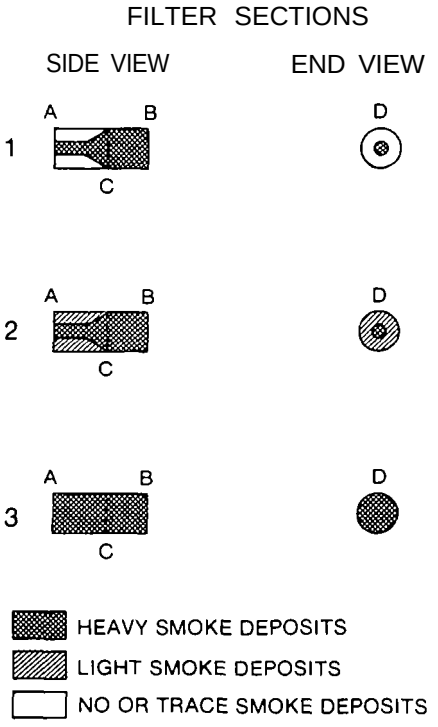

FIGURE 1 - shows the progressive staining of the proximal end (A & D) of the filter downstream from the perforation line (C) as the number of holes blocked increases from one in filter 1, to a partial block in filter 2, and a complete block in filter 3. B is the distal end of the filter. Kozlouski et al. 1980a.

Photographic records can be made of the stain patterns, to aid in scoring the spent filters. At the present time, it is best to try to sort a smoking episode into one of three categories: 1) the holes were extensively blocked, 2) the holes were not at all blocked, 3) the holes were partially or occasionally blocked. The discrimination is most reliable between the first and second categories; avoiding the approaching coal can cause finger-blocking on the last few puffs and, hence, an intermediate stain pattern (Lombardo et al. 1983). More precise quantification will have to await the development of techniques for scanning and scoring carefully-controlled photographs of butts.

Knowledge of hole-blocking can inform smokers and researchers of egregious misuse of a low-yield cigarette If the vents have not been blocked, it does not ensure that the cigarette was not oversmoked in some more traditional manner. A pamphlet (Kozlowski 1982) has been prepared, to explain to consumers some of the complex risks involved with switching to low-yield cigarettes.

USING STAIN INTENSITY TO DETECT ACTUAL YIELDS

Chemical assays for residual nicotine in spent filters have been used to provide estimates of "mouth level exposure" or yields (e.g., Forbes et al. 1976; Kozlowski 1976). These estimates depend on the assumption of a constant filter efficiency. Filter efficiency refers roughly to the percentage of smoke ingredient presented to the filter that is trapped in the filter. Knowing the filter efficiency and the amount of nicotine (or other marking ingredient) trapped in the filter, one can calculate the amount of nicotine that passed through the filter. Unfortunately, filter efficiency can be altered, especially by factors that Influence puff velocity (e.g., Creighton and Lewis 1978). The faster the puff velocity, the less efficient the filter. (Note that the Moody 1980, study would have a puff velocity of 20.5 ml/sec, whereas the standard assay has a 17.5 ml/sec puff velocity--a 17% difference.) Since blocking vent holes causes an increase in puff velocity through the filter and a resultant and substantial drop in filter efficiency, evidence of hole-blocking should disqualify a butt from this method of estimating yields.

A color-matching technique (called the CMT scale) IS being developed, employing the same general principles as the butt-nicotine estimates of mouth-level exposure. The CMT scale IS also dependent on the assumption of constant filter efficiency, and, because of this intrinsic limitation, it is likely, at best, to provide ballpark estimates of tar and nicotine yields, rather than pinpoint figures. Tar stains are visible and the intensity of the "color" of a tar stain Increases as the amount of tar Increases.

Kozlowski (1981b) proposed that visible differences in tar stains could be used to detect how much a smoker had puffed on a given cigarette, and showed that individuals could tell faultlessly that a 12-puff butt was darker than a 6-puff. Kozlowski et al. (1982a) showed that individuals can make even finer discriminations of tar variations, if they rate "lightness or darkness in color" by comparing butts to a scale made up of colored papers.

The original CMT scale was created by matching specially smoked butts with colored papers from the Pantone by Letraset Color-matching System. Three prototype butts were prepared: one resulting from a light smoke (a 2 sec, 25 ml puff/120 sec), one from a standard smoke, and one from a heavy smoke (a 2.5 sec, 45 ml puff/20 sec). A best-selling filter cigarette (standard yield: 0.9 mg nicotine, 16 mg tar, in about 10 puffs) was used in all phases of this project. The optimal, though not perfect, matches were, respectively, a pale yellow (Pantone 127 U), a greenish brown (Pantone 117 U), and a brown (Pantone 139 U). The "light," "standard," and "heavy" colors were mounted at points designated as 2, 5, and 8 on a 0 to 10 scale (see Kozlowski et al. 1982a, for details and a picture of the instrument).

To supply filters for rating, 5 to 16 approximately standard puffs were taken on cigarettes of the same brand. This puff manipulation was designed to produce a substantial, but reasonable, manipulation of tar yields. The difference in yields from 5 to 16 puffs was estimated to be 18 mg tar and 1 mg nicotine. Eleven adults gave each filter a score on

the CMT scale. Table 3 shows a summary of the results (the data have been smoothed somewhat by averaging scores across subjects and across adjacent pairs of puff numbers). The raters were clearly able to do the task (Linear regression, Puffs = 3.1 (Rating) -6.0; r = .996). Correlations between numbers of puffs and CMT score for the individual participants were .99, .98, .97, .96, (N : 4), .90, .83, .82 (Ps < .05, 2 tailed) and .73 (p < .10).

TABLE 3
EFFECT OF NUMBER OF PUFFS TAKEN ON CMT SCORES

	STANDARD PUFFS TAKEN					
CMT SCORE	5-6	7-8	9-10	11-12	13-14	15-16
MEAN	3.6	4.5	4.9	5.5	6.2	6.9
S.D.	1.0	1.0	0.8	1.0	0.8	0.7

Kozlowski et al. 1982a. © 1982, American Public Health Association. Reprinted by permission.

Hopefully, the CMT scale can be developed to provide smokers with, in effect, a speedometer and an odometer to aid them in monitoring their own tar and nicotine yields. The CMT scale can be combined with information about the range of possible yields from a brand and, at the same time, give smokers some means of gauging where they fall within that range.

Since this scale IS based on a printer's color-matching system, it could be practically applied as part of cigarette packaging, match-book covers, or supplementary pamphlets on tar and nicotine yields. Apart from giving the consumer some information on actual yields, there may be additional benefits in avoiding a presentation of yields that gives only one rating number per brand. The mode of presenting tar information using a CMT system shows graphically that actual yields depend on amount smoked.

A FINAL COMMENT

For anyone Interested in human smoking behavior, the standard smoking-machine tests for tar and nicotine yields are so Inadequate that it is easy to propose improvements. It is not easy, however, to know how much these improvements might actually help cigarette consumers and smoking researchers; and, in the long run, it is even harder to know how these new hurdles might be gotten round by future changes in either cigarettes construction or smoking-machine procedures.

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Measurement of Some Topographical Aspects of Smoking in the Natural Environment

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A major problem in smoking research has been measurement of the behavior. Instead of a simple response as originally assumed, smoking appears to be a relatively complex behavior. It is composed of a number of different responses, which include frequency (number of cigarettes smoked per day, number of puffs per cigarette), durational (puff duration, cigarette duration, interpuff interval, intercigarette interval), and volumetric (puff volume, inhalation volume) components. Together these components comprise a topography that determines the individual's actual smoke exposure (Frederiksen et al. 1977).

In smoking research it is important to employ as many measures of smoking topography as possible in estimating smoke exposure (Griffiths and Henningfield 1982). Measurement of a single aspect of smoking will not suffice for most research studies. Different individuals may have identical values on certain topographical measures but differ widely on others and therefore have different levels of actual smoke exposure. It is also important to employ multiple topographical measures in studies of factors controlling smoking behavior, because at least some of the responses comprising smoking behavior appear to be functionally interrelated. When one component of smoking behavior is experimentally manipulated, changes occurring in that component may be partially offset by compensatory changes in other components of the behavior (Gust et al. in press). Precise measurement of smoking topography is therefore essential to any scientific study of smoking behavior.

For this reason previous studies of smoking topography have been confined largely to the experimental laboratory. This has been due primarily to lack of suitable recording devices for measurement of multiple components of smoking topography in the natural environment (Frederiksen et al. 1979). Previous studies of smoking topography in the natural environment have been limited almost entirely to single measures of smoking behavior collected by self-report records, or to a limited number of multiple measures of smoking behavior determined by direct observation. For the experimental analysis of smoking behavior, however, self-report records are not

sufficiently precise and direct observation is impractical. While attempts to determine the effects of experimental manipulations on smoking behavior in the natural environment have also employed biochemical measures to track smoking behavior (Moss and Prue 1982), such measures have lacked the sensitivity and specificity that is required to measure cigarette-to-cigarette changes in smoking behavior. In addition, such measures have shown considerable variability between subjects and consequently have not proven reliable in predicting individual smoking rates.

We have recently developed a small, portable, solid-state device that can be used in the natural environment to obtain several measures of smoking topography. This device is about the size and weight of a small transistor radio and can be easily clipped onto a belt or carried in a coat pocket or purse. It will measure and record individual puff durations, interpuff intervals, cigarette durations, and intercigarette intervals, and will also count both cigarettes/day and puffs/cigarette. The device employs microelectronic technology and can measure time intervals as short as 0.1 sec and as long as 18.1 hours in each of its 2048 memory cells. Assuming 10 puffs per cigarette, the device has the capacity for precisely measuring all frequency and durational aspects of smoking topography for over 100 individual cigarettes over a two-day period. This report describes the operation of the device and computer software that has been developed to facilitate its use. Studies on accuracy and reliability of the device will also be reported.

AMBULATORY SMOKING RECORDER

The recorder is an electronic device that precisely measures the duration of consecutive puffs and pauses that occur in cigarette smoking. Short pauses separate puffs occurring during the smoking of a single cigarette, while longer pauses separate puffs into individual cigarettes. By measuring the duration of these puffs and pauses, it is possible to obtain all of the topographical measures of smoking described above. In brief, the device functions as follows. Constant-rate pulses from a time-base generator are counted until onset of a puff. When the puff begins, the number of pulses accumulated in the counter is stored in a memory cell, the counter is reset, and counting of pulses from the time-base generator resumes. When the puff ends, the number of counts accumulated in the counter since the start of the puff is stored in another memory cell, the counter is reset, and counting resumes. This continues until onset of the next puff, when the number of counts accumulated is stored in yet another memory cell, etc. Thus, both the onset and termination of a puff cause accumulated counts to be stored in memory cells, with the number of counts appearing in each cell corresponding to the duration of the smoking event. Timing continues in this fashion until the battery supplying power to the device is exhausted (56 hrs minimum) or all memory cells have been utilized (2048).

Specifically, the recorder consists of a standard cigarette holder that is connected via plastic tubing to a small metal box (1 x 4 x

5 in) which the subject carries either in hand or attached to a waist belt. The weight of the device is approximately one pound. The cigarette holder (Tar Gard, #1274, Venturi Corp.) is screwed into one end of a 7/8-in length of 3/8-in diameter brass tubing, with the other end of the brass tubing holding the cigarette that is to be smoked. A 1/4-in length of stainless steel tubing is soldered into a hole drilled into the side of the brass tubing. One end of a 24-in length of plastic tubing (1/16-in I.D., 1/8-in O.D., 1/32-in wall) is attached to the stainless steel tubing, and the other end of the plastic tubing is attached to a pressure switch (Model 505-3, 0.5-in pressure to activate, Coventry Corp.) located inside the metal box. In addition to the pressure switch, the metal box contains a rechargeable nickel-cadmium battery (4.8 volts, .75 amp hrs, Gould Battery Corp.), and printed circuit boards containing microelectronic hardware necessary for measurement and storage of the durations of the successive smoking events.

To obtain the time measurements, the output of a 3.58 MHz quartz crystal (ECG 358) is fed through oscillator/dividers (FM5369) into counters (CD4040) to yield a 1/4 Hz (slow) and 10 Hz (fast) time base. A separate counter controls a series of multiplexers (74C1571 which direct the time-base output to sequential memory cells. The memory cells are 16 x 2048 bits of random access low-power CMOS memory (6514B5261). Initially, only the output from the fast time base (10 counts/sec) is directed into the memory cells; however, after 409.6 sec the output from the slow time base (1/4 counts/set) is directed into the memory cells. Thus, during the first 6 min, 50 sec of an interval, the resolution of the device is .1 sec, while after this time the resolution is 4 sec. Of each 16-bit data word, the upper 2 bits serve as flags to indicate whether the event was a puff or pause, and whether the time base was in the fast or slow mode. The remaining 14 bits of the 16-bit word are reserved for interval timing function. Initialization of the memory cells and retrieval of data from the device is under software control through interface with an Apple II Plus microcomputer via a 6522 Parallel Interface board (John Bell Engineering, Inc., Part No. 79-295) and ribbon cable.

SOFTWARE SUPPORTING RECORDER

The software is written in Pascal programming language and requires an Apple microcomputer with 64K of RAM memory, a Thunderclock Plus card for time-keeping function, and two disk drives for data storage and program execution.

The primary software program has three functions: (1) to establish and maintain data files for individual research subjects; (2) to initialize and retrieve data from memory cells of the device; and (3) to display and analyze data obtained. In the first function, the program allows for Pascal-formatted diskettes to be initialized for use in data recording, subject names to be added and deleted to a master directory file, and diskette numbers to be assigned to subjects for data recording. In the second function, the program initializes (sets to zero) the memory cells of the device prior to

subject issue and records the time of initialization in the subject's file. When the recorder is returned by the subject, the program writes the collected data to a diskette file and writes the time of the data collection in the subject's file. In the third function, the program displays data from a diskette file to a screen monitor or printer, allows the experimenter to designate memory cells that are to be interpreted by the computer as the start and end of individual cigarettes, and performs a summary analysis of the data (see below). Since a certain amount of pressure switch chatter will occasionally occur with such a system (usually towards the end of a puff), the program allows a minimum pause value to be specified which will result in pauses less than a given value being combined with adjoining puff values. For example, we have found that pause cutoff values of 0.5 sec will accurately eliminate most problems associated with switch chatter, giving a more accurate number of puffs per cigarette and a more accurate measure of puff time. Presently, the program is undergoing a revision to permit the automatic delineation of cigarettes from raw puff/pause data, with pauses longer than a given value being considered by the computer as intercigarette intervals.

A sample of the summarized data obtained from one subject is shown in figure 1. The subject's name has been removed for anonymity. The raw data collected was stored as Record 1 on Disk 002A. The recorder was initialized at 16:44 (4:44 pm) on May 15, 1983, and the minimum pause duration for data analysis was set at 1.0 sec. The first column shows cigarette number; the second column shows the starting time of the cigarette; the third column shows the seconds spent in smoking the cigarette (cigarette interval); the fourth and fifth columns show the memory cells that delineate the cigarette event based on data entered earlier by the experimenter after inspection of a printout of the raw data (not shown); the sixth column shows number of puffs per cigarette; the seventh column shows the total duration in seconds of all puffs taken on the cigarette (total puffing time); the eighth column shows total pause duration in seconds for the cigarette; the ninth and tenth columns show the mean puff and pause durations, respectively, in seconds for each cigarette; the eleventh and twelfth columns show intercigarette times in seconds and minutes, respectively. Following the individual cigarette data, mean values for the entire session (in this case 48 hrs) are given along with standard errors.

Other software has been developed for testing the timing accuracy of the device and for determining the status of memory cells in the device.

00--83 00:00:00
Subject :
Disk : 002A:
Record : 1
Data starts at 15-May-83 16:44:01
Pause cutoff : 1.0 (secs)

cig #	start time	event dur.	strt evt#	end evt#	# of puffs	tot puff dur	tot pse dur.	mean puff dur	mean pse dur	initial following	time/ ICI
										10272.0*	(171.20')
1	07:35	496.3	1	23	12	13.2	483 1	1 10	43.92	2628 0*	(43.80)
2	08:27	601 7	25	45	11	12 6	589 1	1 15	58 91	1656 0*	(27.60')
3	09:04	490.3	47	73	12	12 0	478.3	1.00	43.48	3516 0*	(58 60')
4	10:11	439 8	75	93	9	10.0	429.8	1 11	53.72	24608.0*	(410 13')
5	05:09	451 3	95	115	10	10 7	440 6	1 07	48.96	8348 0*	(139 13')
6	07:35	484 9	117	137	10	10.2	474 7	1 02	52.74	1832.0*	(30.53)
7	08.14	510 2	139	153	8	8.9	501 3	1.11	71.61	4208 0*	(70.13')
8	09:33	311.7	155	175	11	12.1	299 6	1 10	29 96	2400 0*	(40.00')
9	10 18	437.0	177	189	7	6 7	430 3	0 96	71 72	2384 0*	(39.73')
10	11:05	432.9	191	207	8	9 7	423 2	1 21	60 46	7808.0*	(130 13')
11	01:22	416.9	209	227	10	10 7	406 2	1 07	45 13	664 0*	(11 07)
12	01:40	568.7	229	249	11	11 4	557 3	1 04	55 73	1268 0*	(21 13')
MEAN:		472.72			9 56	10 41	462.31	1 09	55 77		
S.E :		119 38			2 42	2 64	116 80	0 27	14 30		

Mean inter-cigarette interval: 4533 33 (75.56 mins)
Total # of cigs: 16
Total smoke exposure/session: 166 50 (2 78 mins)

FIGURE 1. Printout of summarized topographical data from subject using the Ambulatory Smoking Recorder. (See text for description of record.)

TESTING OF THE DEVICE

Timing Accuracy of Device

To determine the timing accuracy of the device, electronic programming equipment was programmed to input electronic pulses of known duration to the device for comparison with data output from the device. The duration of intervals fed into the recording device was of the range that is typical of smokers' puff durations. A precision time-base in conjunction with a predetermining counter (Coulbourn Instruments S51-10 and S43-30, respectively), opened and closed a switch connected to the digital memory unit of the recording device at intervals set by the experimenter. When the timer was set at 1.0 second, the switch closure changed every second, resulting in intervals of 1 second "on" and 1 second "off" which the recording device interpreted as "puff" and "interpuff" intervals, respectively. The digital memory unit's accuracy was tested by recording a minimum of 50 consecutive time intervals at the following timer settings: 3.0, 2.0, 1.0, 0.9, 0.8, 0.7, 0.6, 0.5, 0.4, 0.3, 0.2, and 0.1 seconds. In addition, the device was tested with 30 consecutive 20.0-second intervals. No differences were found between input and output values. (Steven Morgan, personal communication).

Validity of Device

To determine if the device was yielding results representative of the subject's actual smoking behavior, a study was conducted comparing the topograhical data collected by the smoking recorder with similar data collected simultaneously by trained observers. Eight paid volunteers? all patients on the Clinical Investigations Unit, University of Minnesota Hospitals? served as subjects. Subjects were observed while smoking one cigarette twice each day for eight days. The morning session took place at approximately 9:30, the afternoon session at approximately 2:30. Subjects were observed through a one-way mirror while they smoked in a sound-attenuating, ventilated test chamber. An observer was present during all 16 observation sessions. A total of four observers were employed, each monitoring at least two subjects while they each smoked at least two cigarettes. During each test session the observer electronically timed the duration of the cigarette interval (measured from the time a flame was held to the end of the cigarette until the time the cigarette was extinguished). The observer also manually closed a pushbutton switch for the duration that the cigarette was laced in the subject's mouth and observed to glow (puff duration).

For eight of the 16 observation sessions, the subjects used the smoking recorder in smoking (once each day, either in the morning or afternoon). Whether or not the recorder was used in the morning or afternoon was determined by a counterbalanced design. During observation sessions a chart recorder (Esterline Angus Corp.) with a chart speed of 12-in/min was used to record smoking topography. One channel of the recorder was connected to the pushbutton switch

operated by the observer. A second channel, used only during observations in which the subject used the smoking recorder, was connected to the pressure switch of the smoking recorder.

There was no significant difference between the simultaneously collected measures. There was 100% agreement between observer and smoking recorder data for number of cigarettes smoked and mean number of puffs per cigarette. However, across subjects, the durations measured by the observers for puff interval were slightly larger than those measured by the smoking recorder (1.66 sec vs. 1.54 sec, respectively). The durations of interpuff intervals were also longer for observers than for the recorder (19.17 sec vs. 18.72 sec, respectively). Across the eight subjects, the mean discrepancy per puff between the recorder and the observational data was 0.12 seconds. Therefore, the puff durations measured by the observers were on the average 8% larger. For interpuff intervals, the mean discrepancy was 0.45 seconds. Therefore, the interpuff intervals measured by the observers were on the average 2% larger.

To analyze further the discrepancies obtained between observer and recorder data, observers were asked to monitor a more discrete stimulus than the glow of a cigarette tip. Three observers monitored the duration of illumination of a small, red stimulus light (.75-in diameter red dome covering a #327 lamp located atop a 2 x 3 x S-in metal box in the subject chamber). The observers closed a switch when the light was illuminated and released the switch when the light was extinguished. The on-off pattern of the light was programmed to replicate a typical smoking pattern. One channel of an event recorder charted the on-off pattern of the stimulus light; another channel recorded the on-off pattern of the observers' switch.

Absolute discrepancies between channels were calculated for each on-off data pair. The mean discrepancy for light-on was .09 seconds (relative to .14 seconds for puffs in the previous study) and the mean discrepancy per light-off was .12 seconds (relative to .34 seconds for pauses in the previous study). Thus, even on a simple observational task, significant rater error was found. Rater error could be expected to increase as the discrimination between "on" and "off" became more difficult, as in observing the glowing tip in cigarette smoking (Steven Morgan, personal communication).

Effects of Use of the Recorder on Smoking Behavior

To determine the effects of using the smoking recorder on the subjects' smoking behavior, the smoking pattern of eight subjects was monitored over eight consecutive days while they lived as inpatients on the Clinical Investigations Unit of University of Minnesota Hospitals. Subjects were required to record to the nearest minute the exact time when each cigarette was lit, using forms provided. On four of the eight days, the subject used the smoking recorder in smoking all cigarettes. The order of the days using the device was counterbalanced across subjects. Twice each day the subjects were observed while smoking a cigarette in the test cham-

ber (described above). An observer recorded the time and duration of each cigarette and manually closed an electrical switch for the duration of each puff, recording the event on an event recorder.

Using the smoking recorder resulted in a small, but statistically significant decrease in the number of cigarettes smoked per day. When using the recording device, subjects smoked an average of 21.33 cigarettes per day; without the device, subjects smoked an average of 25.72 cigarettes per day ($t = 3.93$. $df = 62$, $p < 0.001$). Furthermore, this trend was consistent across subjects, with each subject smoking more cigarettes on non-use days. Observations made in the laboratory on days with and without the recorder were compared to determine the effect of the smoking recorder on smoking topography. There was a statistically significant main effect of recorder use on number of puffs per cigarette and mean total puffing time per cigarette. When using the smoking recorder subjects tended to take slightly more puffs per cigarette (15.8 vs. 13.3) and to have a slightly longer mean total puffing time per cigarette (26.2 seconds vs. 22.1). While use of the recorder was expected to reduce number of cigarettes smoked (as almost all such procedures have been found to do in behavioral research), the increase in number of puffs per cigarette and mean total puffing time may reflect a titration effect, in which reduction in number of cigarettes per day is compensated for by an increase in the number of puffs taken per cigarette and by an increase in total puffing time per cigarette. This is supported by the finding that use of the recorder had no significant effect on total daily smoke exposure (derived by multiplying number of cigarettes per day by number of puffs per cigarette by mean puff duration).

Self-Report/Recorder Agreement in the Natural Environment

In previous studies the accuracy and reliability of the smoking recorder was tested in a hospital environment. In the present study, testing of the device was extended to the natural environment. Subjects were issued the smoking recorder on Monday evening and instructed to use the recorder in smoking all cigarettes until returning to the laboratory at the same time two days later. Subjects were asked to keep a written record of the time each cigarette was smoked. The record was kept on a bright blue 3 X S-in card that was folded and inserted beneath the cellophane wrapper of the subject's cigarette pack. Subjects were asked to record the time to the nearest minute that each cigarette was lit.

A high degree of agreement was found between the subjects' self-report records and data obtained from the smoking recorder. Figure 2 shows the difference in minutes between self-report and recorder data for a representative subject in the study. The bar graph shows the magnitude and direction of the difference between self-report and recorder measures. For each cigarette, specific values obtained by self-report and recorder are shown above and below each graph point. Values obtained with the smoking recorder were rounded to the nearest minute. As shown in the figure, there was close agreement between smoking times indicated on the self-report form

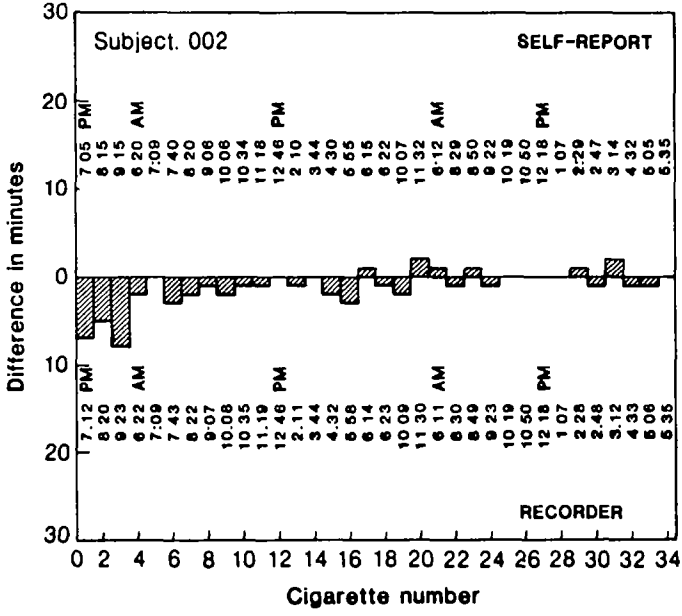

FIGURE 2 Comparison of self-report and recorder values for cigarette starting times.

and smoking times indicated by analysis of the data from the smoking recorder over the entire 48-hr period of the study. At least some of the discrepancy could be related to the subject's tendency to round the self-report value to the nearest 5-min period, although the subject was specifically instructed not to do so.

While smoking recorder and self-report data agreed closely concerning the starting time of each cigarette, the smoking recorder data can also be analyzed to provide additional information about cigarette smoking. For example, all of the data shown in Figure 1 were obtained as part of the present study. Thus, in addition to information on number of cigarettes smoked and cigarette starting time, which both self-report and smoking recorder can provide, the smoking recorder can provide topographical data on cigarette duration, number of puffs per cigarette, total puff time per cigarette, intercigarette interval, etc.

SOME PRELIMINARY FINDINGS

Recent research from our laboratory suggests that situational and mood factors may affect smoking topography in the natural environment. Subjects were issued the Ambulatory Smoking Recorder and asked to use the device in smoking all cigarettes in the natural environment over a 10-day period. (Subjects returned to the laboratory every two days for data retrieval and to obtain a recharged battery.) Subjects were also asked to record the time, situation, and internal state associated with each cigarette. When smoking topography was compared for the most frequently occurring situations and mood states, large differences were found. Figure 3 shows total smoke exposure (total puffing time) for a single subject smoking the same brand of cigarette in different situations/activities. Each data point represents the mean value for one cigarette. Horizontal lines indicate the mean value for all cigarettes in each situation. As can be seen, rather consistent effects were found within each situation, and total smoke exposure (total puffing time) differed widely across situations. Similar effects have been found for subjects smoking under different mood states. These results suggest that situation as well as mood may influence smoking pattern in the natural environment (Steven Morgan, personal communication).

APPLICATIONS OF THE DEVICE

The need for methodology to study smoking topography in the natural environment is particularly acute for a number of reasons. Firstly, smoking appears to be controlled by a number of situational and internal factors not readily amenable to laboratory control. With availability of the proper technology, the natural environment would afford the ideal site for such studies. Secondly, the validity of results from laboratory studies of smoking behavior needs to be ascertained. Attempts should be made to determine if findings from laboratory studies will generalize to the natural environment. Thirdly, the analysis of smoking topography in the natural environment may shed light on factors related to smoking treatment suc-

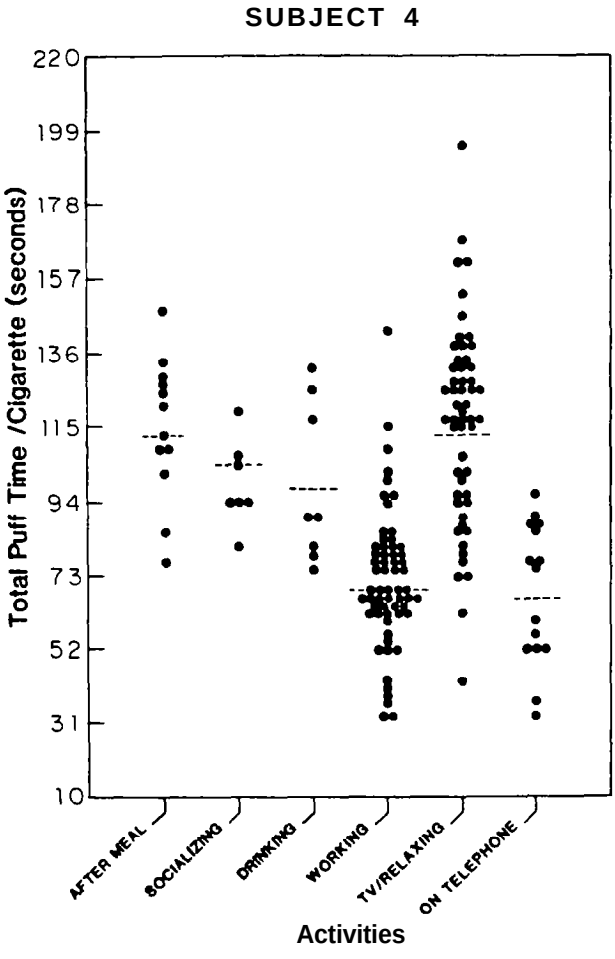

FIGURE 3. Total puff time per cigarette for subject when smoking in various situations (activities). Each dot represents the mean value for a single cigarette. Dashed lines represent mean value for all cigarettes smoked under each condition.

cess. Differences in smoking topography may explain why various groups of smokers have different rates of treatment success. Fourthly, such measures could provide a sensitive and inexpensive estimate of smoke exposure, thereby providing a useful adjunct to biochemical and other measures in estimating exposure to the toxins in cigarette smoke. Finally, since smoking appears to be a form of drug dependence, the study of smoking behavior in the natural environment may provide data relevant to other drug dependencies, where studies in the natural environment are more difficult to conduct.

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Data Collection and Questionnaire Design: Smoking Cessation in Adults

Harry A. Lando, Ph.D.

Data collection and questionnaire design are significant to both researchers and clinical practitioners in the field of adult smoking cessation. Unfortunately, minimal standards for data collection are typically neglected by public service and proprietary programs and all too often are neglected by researchers as well. The purpose of the current paper is not to recommend new standards in this area. Instead, discussion will focus upon some existing standards that profitably can be applied in research and public service settings. Unfortunately, extensive recommendations have been made in the past (e.g., International Union Against Cancer 1976; National Interagency Council on Smoking and Health 1974) with little apparent effect upon actual practice.

A major reason for failure to adhere to recommended standards may be the fact that it is inconvenient to do so, especially for public service and proprietary programs. One possibility would be to develop a uniform one- to two-page questionnaire that could be used by both researchers and practitioners. This questionnaire would solicit information that is considered essential in both contexts. Construction of such a uniform questionnaire would in no way preclude collection of additional information (as will be discussed below). It would, however, provide commonalities in comparing subjects across both settings and types of programs.

Previous standards may have provided relatively little incentive for implementation, especially in public service settings. The standards may in fact have been seen as somewhat coercive (e.g., these are the appropriate criteria, and any deviations from these criteria are indicative of unsound methodology). The standards may also have been viewed as overly extensive (the NICSH recommendations required approximately 35 pages of text).

One possible approach in encouraging sound principles of data collection might be to construct a simple and convenient questionnaire with adequate reliability and validity. The questionnaire should solicit minimal information that is considered essential in both laboratory and field contexts. The appeal of such a questionnaire might be considerably enhanced by

including a brief interpretive section that would allow smokers to score their own responses. The continued popularity of the Smoker's Self-Testing Kit (Ikard et al. 1969), despite limited evidence for validity, is testimony to the attractiveness of this type of approach.

NATIONAL CENTER FOR HEALTH EDUCATION GUIDELINES

The National Center for Health Education Code of Practice and Standards for the Evaluation of Group Smoking Cessation Program provide an excellent starting point in formulating recommendations for data collection. These guidelines have been adopted by such major public service and proprietary agencies as the American Cancer Society, the American Health Foundation, the American Heart Association, the Five-Day Plan to Stop Smoking, and SmokEnders. However, at present it is unclear that these guidelines are being followed in practice.

The NCHE guidelines are surprisingly stringent in a number of respects. The criterion for success is complete abstention from all forms of tobacco for a period of 1 year following treatment. The Code of Practice notes that common definitions are needed to provide both protection and assurance for smokers seeking assistance in quitting. Almost all previous interventions, both research and public service, have subscribed to a less rigorous criterion in defining success.

The NCHE code of Practice also calls for conscientious record-keeping. All smokers who are unavailable to followup must be listed as smoking for purposes of evaluation. Furthermore, participants include all of those smokers who attend at least the first treatment session following orientation. This is a very important point. Proprietary programs, in advertising extravagant claims of success, appear in many cases to include only those who complete treatment.

The NCHE guidelines assert that not only criteria for success, but also accounting for program participants, followup, and method of reporting outcome must all be standard. Definitions are provided for terms, including in-term quitter, attrition rate, long-term quitter, and recidivist. Although other outcome measures may be reported in addition to complete abstention for at least 1 year (e.g., abstinence for less than 1 year, switching to pipes or cigars), the term "success" is not to be to be used in conjunction with such measures.

Evaluation is to include: number of participants, number and/or percentage who quit at the end of the intervention, and number and/or percentage completing treatment who do not relapse. It is also appropriate to state number and/or percentage of participants entering the program who quit and did not relapse during a 12-month period thereafter.

Because all participants who cannot be located at followup must be counted as failures for purposes of data analysis, this

provides a strong incentive to reach as many participants as possible. The guidelines call for collection of sufficient identifying characteristics for each participant to permit contacting them at all followup intervals. Name, address, and telephone number should be recorded, and employment address and telephone number should also be noted where applicable. Although not part of the NCHE standards, it is strongly recommended that names, addresses, and telephone numbers of close friends or relatives be solicited as well. These individuals can be contacted to confirm self-reported abstinence and can provide information on the whereabouts of participants who might otherwise be lost to followup. Lando and McGovern (1982) found these additional sources extremely helpful in locating participants at long-term followups.

The NCHE standards permit followup by either mailed questionnaires or telephone interviews. No provision is included for independent validation of self-reported abstinence. Records are to note data on tobacco use in any form for all participants at beginning and termination of treatment and at l-year followup. At this latter point, it should also be determined whether participants smoked during the past year.

Detailed instructions are provided for calculating long-term success rates. Participants who relapse, who refuse to respond, or who are not located at followup are all counted as smoking. Programs that do not report on their total enrollment are to collect and report data for no fewer than 500 participants per year. These should be all participants entering treatment starting at a given point and continuing until the minimum total (or some larger number) has been attained.

Basic identifying data are to be collected prior to the first treatment session as part of registration to insure inclusion of all participants. Dates of sessions and participants' attendance are to be recorded. Information regarding smoking rate and use of tobacco in any other form is also to be collected at registration. Each case record must include identifying information needed for purposes of followup.

American Lung Association Questionnaire

The American Lung Association in its Guide for Clinic Leaders provides standardized forms and questionnaires for data collection. Local chapters of the American Lung Association are to maintain records for all clinics including name of association, starting date of clinic, number of participants, and name of clinic leader. An intake questionnaire, end of clinic questionnaire, and 12-month followup questionnaire are also provided, A sample letter is included for participants who cannot be reached by telephone for followup. In addition, a cumulative tally form is enclosed for recording information on all participants through 12-month followup.

At intake, participants are asked current brand of cigarettes and

level of smoking. They report identifying characteristics of their brand (e.g., length, filtered vs. unfiltered, mentholated vs. unmentholated). Information is solicited concerning age of smoking onset, heaviest smoking consumption, and number and method of previous attempts to quit. Use of tobacco in other forms is also examined.

Participants report their longest period without smoking since they began regular tobacco use. Furthermore, in addition to information relating directly to smoking, participants are asked about supportiveness of spouse, children, friends, and coworkers as well as about prevalence of smoking among these categories of individuals. They are asked about their own perceived readiness to quit and about the number of clinic sessions they plan to attend. Finally, they list basic demographic information including age, sex, race, level of education, occupation, and marital status.

Questionnaires administered at the end of treatment *require* participants to report most and least helpful elements in treatment. Current cigarette consumption is assessed, together with use of tobacco in other forms. Evaluations of clinic leaders and recommendations for improving the program are solicited.

Twelve-month followup interviews are limited to minimum essential data (projected time per interview is approximately 3 minutes). Participants are asked whether they have smoked in the previous month and if so about level of smoking. They are asked about cigarette use since the termination of the clinic. Smokers are to indicate cigarette consumption, brand, and brand characteristics. All participants indicate date of last cigarette. Use of other forms of tobacco is again assessed. Finally, participants are asked to recall any elements from the clinic that may have been especially helpful.

Evaluation

The NCHE guidelines and American Lung Association questionnaires provide an excellent beginning in formulating recommendations for data collection and questionnaire design. Especially encouraging is the emphasis upon including all participants in reporting outcomes (dropouts and participants who are not located must be counted in computing abstinence rates) and upon l-year followup as a minimum period for evaluating success. Conscientious implementation of NCHE guidelines should be a major factor in increasing the meaningfulness and comparability of data reported.

The guidelines are realistic and do not appear to impose an excessive response burden upon public service or proprietary organizations. As noted above, the requirement that nonrespondents be counted as treatment failures provides a strong incentive for careful recordkeeping and concerted efforts to locate all participants. The major criticism of the guidelines is that they fail to provide for independent validation of self-

reported smoking. Although this could be a touchy issue outside of the laboratory, it seems most unfortunate to prescribe rigorous standards for data collection and evaluation and yet to overlook obvious questions concerning the validity of such data.

A minimum step might be to obtain permission of participants to contact close friends and/or relatives for confirmation of reported smoking status. Although the accuracy of informant data is by no means certain, such data would allow at least some measure of independent validation of self-reports. More attractive would be the use of biochemical validation, although admittedly this level of assessment may be problematic outside the research setting.

Biochemical validation would be appropriate for those organizations that seek acceptance of their reported outcomes by the scientific community. Such validation would not be required for all participants, nor would it be required for all clinics. A representative sampling of clinics in varying locations should provide a meaningful estimate of the accuracy of self-reports. There are laboratories that are equipped to perform biochemical analyses for outside organizations. The cost of such analyses would be relatively modest (especially if limited to a random sample of those participants reporting abstinence at follow-up) and easily could be defrayed by a small charge for treatment to all participants. Comments on biochemical validation procedures are contained elsewhere in this monograph (e.g., Benowitz, this volume).

BASIC MEASUREMENT ISSUES

At first glance, the assessment of smoking behavior appears to be a very simple matter. Smoking is readily observable and occurs in discrete units. But what is the best unit of measurement? Tallies can be kept of cigarettes, of actual puffs, or of amount of tar and nicotine ingested (McFall 1978). Furthermore, these records can be kept on an hourly basis, a daily basis, or even a monthly basis. Most investigators have emphasized number of cigarettes smoked per day. As McFall points out, there is nothing magical about this particular measure. Certainly it overlooks a great deal of important information. However, it does have the advantage of providing a common standard of comparison.

Discussion of assessment issues in smoking has focused primarily on determining the outcome of structured interventions. Two fundamental indices have been used: rate, using days as the unit of time and typically expressed in percentage of baseline smoking; and abstinence, the number or percentage of subjects abstaining altogether (Lichtenstein and Danaher 1976). Despite the fact that abstinence is a nominal scale datum which necessitates less powerful, nonparametric statistical procedures, it does have several important advantages over rate. It is less susceptible to reactivity effects of self-monitoring, less likely to require transformations in the data due to a marked skewness

in the distribution of outcome, and it is a better indicator of clinically significant, as opposed to statistically significant, treatment effects.

Reactivity is likely when subjects in treatment self-monitor their smoking rates because of the implicit assumption that these rates will decrease (Lando 1981). Self-monitored smoking rates tend to be lower than subjects' prior estimates of their smoking behavior. Smoking rates are also likely to be susceptible to changes in self-monitoring procedures. It is obviously desirable that data collection procedures remain constant. Otherwise, changes in rate may be partly a reflection of changes in measurement. On the other hand, the major concern with abstinence data is not how the self-report data are obtained, but the possibility that subjects might not be telling the truth.

A crucial issue relates to the selection of a method or methods of assessment. This issue is addressed by McFall (1978) in a comprehensive and useful discussion. Possible measures include self-reports, controlled laboratory observations, unobtrusive naturalistic measurements, collaborator reports, and correlates of smoking behavior. Each of these methods has potential advantages and disadvantages.

The most cons-only used measure has been self-report. The obvious advantage is that the subject is in a better position than anyone else to observe his or her own smoking behavior continually. Unfortunately, there is no assurance that the subject will be accurate or even honest. False reporting has been documented in a number of studies. Self-reports can also be reactive, as noted previously. The fact that many Studies have relied solely upon unverified self-reports as a measure of outcome is therefore a cause for concern.

Observing smoking under controlled laboratory conditions is a more precise method, but it also presents significant problems. Smoking behavior observed in the laboratory may be quite different from smoking that occurs under more natural conditions. Unobtrusive naturalistic measurement presents another possibility. McFall (1978) suggests the monitoring of samples of cigarette butts as one example. The butts could be collected in several locations and would provide both an indirect check upon self-reported smoking and some indication of within-subject changes in smoking over time. One of the few studies to use cigarette butts as a measure of smoking was that of Auger et al. (1972). Unobtrusive measurement procedures suffer from several shortcomings, including difficulty, expense, impracticality in many situations, and potential invasion of privacy.

Collaborator reports have been used increasingly in recent years. Investigators sometimes ask subjects to provide the names of close friends or relatives who are in a position to observe their smoking and can be contacted periodically for reports (cf. Lando 1981). This strategy was recommended both as a check upon self-reports and as an additional means of locating subjects at

followup. Again, however, the use of collaborators is no guarantee of accuracy. Recruitment of friends as observers can lead to increased reactivity. Cooperation may be very difficult to obtain, performance many be sloppy, and there may be obvious bias. Because the collaborators are often close friends of the subjects, their reports my be no more objective than those of the subjects themselves. McFall (1978) suggests that the extremely high correlations often obtained between subjects and collaborators may be a reflection of collusion more than accuracy. Because there is no simple means of ascertaining the validity of collaborator reports, additional checks upon the accuracy of subjects' self-reports are highly desirable.

Correlates of smoking behavior are a very promising possibility. Investigators have attempted to establish valid indirect measures of smoking for a number of years, and such measures receive considerable attention in this volume.

QUESTIONNAIRE DESIGN

The American Lung Association intake and followup questionnaires provide a useful starting point in considering issues of questionnaire design. They constitute a package that can be conveniently used by local associations and that allows collection of appropriate minimal information. A standardized form such as the American Lung Association intake questionnaire would represent a substantial improvement over current practice in that clinics could report a common data set. The American Lung Association materials are also attractive in their brevity and ease of administration.

A major difficulty at this point in recommending questionnaire design is that it is by no means clear what kinds of information are crucial. Furthermore, questionnaire content my differ according to the purpose of the user. Researchers may be interested in issues that are of minimal concern to clinical practitioners and vice versa. The current paper will not attempt to specify the final form of a questionnaire for either research or clinical use. However, suggestions will be drawn from the literature for types of items that might be included.

Essential information relating to subject characteristics could prove extremely valuable in comparing smokers who enroll in various types of programs. Obviously, two treatments each of which produce 30 percent long-term abstinence my not be equivalent in effectiveness if smoking history characteristics of enrollees in the two program are radically different. A consensus at this point might be that information should be obtained concerning age, sex, number of years as a smoker, current daily rate of smoking, previous quit attempts and duration of abstinence, and brand smoked (NICSH 1974).

Data on occupation, education, and income may also be useful in characterizing subject samples and in comparing smokers who enroll in various programs. The vast majority of formal smoking

cessation treatments have been strongly weighted toward participation from middle and upper middle socioeconomic strata. Assessment of socioeconomic indicators is likely to focus additional attention on the need to reach underserved populations. It is also possible that systematic differences exist in the types of participants recruited by various programs. An obvious example would be that a commercial clinic requiring an investment of several hundred dollars is extremely unlikely to enroll subjects from lower class backgrounds.

An important concern is related to inclusion of potential predictor variables. A minimal questionnaire might be limited to a few items assessing subject and smoking history characteristics. Such a questionnaire could be standardized along the lines of the intake measure construct&i by the American Lung Association. Researchers (and practitioners) who are interested in predicting outcome could solicit additional information.

What are some likely predictor variables? The answer to this question may be important not only in anticipating probable outcome, but also in assigning individuals to particular treatments. Standardized data collection over numerous programs and a substantial subject pool should provide considerable information. This in turn might facilitate effective tailoring of treatments to the needs of the individual.

Predictor variables that have been identified to date are generally based upon relatively small numbers of subjects. With this limitation in mind, a number of such variables can be suggested. Repeated use of a standardized questionnaire containing these items would allow much more confidence in their validity. It appears quite likely that certain categories of items will prove highly related and that factor analyses will provide more streamlined predictive measures.

Even the minimal information obtained through the American Lung Association questionnaire should allow some prediction of outcome. Roth subjects' age and smoking rates have sometimes correlated with reduced consumption in previous studies. Furthermore, number and duration of previous quit attempts appear to be predictive as well. Supportiveness of others and prevalence of smoking in home and work environments might also be important. Other predictor variables contained in the American Lung Association questionnaire may include subjects' age, sex, race, marital status, level of education, and occupation. Perceived readiness to quit is another questionnaire item that could correlate significantly with outcome.

The predictive power of the American Lung Association measure might be improved, however, if on some items subjects were allowed a greater range of choices. Thus, as one example, rather than simply indicating whether individuals in the environment are either supportive or nonsupportive of quit attempts, it might be more useful to allow subjects to report varying levels of support.

Many other potential predictor variables have been identified in the literature. An especially useful indicator might be perceived ability to resist smoking urges in specific situations. Condiotte and Lichtenstein (1981) have published a very promising instrument. Preliminary data suggest clearly that subjects are quite capable of anticipating situations in which they are likely to experience difficulty. This type of measure could provide an important link between assessment and treatment intervention. Knowledge of circumstances under which subjects are apt to experience difficulty may facilitate tailoring of treatment programs to the needs of individual participants. It should be noted that the Condiotte and Lichtenstein questionnaire is somewhat lengthy (47 items). Preliminary data suggest that a substantial reduction in the number of items would be quite feasible.

A simple eight-item questionnaire developed by Fagerstrom (1978) to assess physiological correlates and dependence might also be of considerable interest. Preliminary validity data are encouraging. It might be especially interesting to assess the correlations between this paper-and-pencil instrument and both topographical and biochemical indicators of smoking exposure. The single item assessing time from awakening to first cigarette could provide a rough indication of dependency.

Other questions that might be included appear almost infinite. Several studies have found that negative affect smokers (those who smoke in response to tension, anger, depression, or other negative emotions) are less likely to remain abstinent (cf. Pomerleau et al. 1978). Items indicative of Type A behaviors (impatience, overwork, competitiveness, aggressiveness) might also be predictive of unsuccessful outcome. Subjects who are able to state only limited tangible expected benefits from quitting may be poor candidates for abstinence.

Life events measures (e.g., what types of stressful circumstances are present either currently or in the recent past) may correlate with abstinence. Relevant stressors could include such events as a recent move, a divorce, a change in job status, or the loss of a close friend or relative. Attributions for previous unsuccessful abstinence attempts could also be quite important. obviously, subjects who attribute a previous failure to a particular set of conditions should have a plan of attack for coping with similar conditions in the future. A consideration of prior withdrawal symptoms may provide an additional indicator of both expected outcome and of types of problems in remaining abstinent. A measure published by Shiffman and Jarvik (1976) contains a number of items that might be used in assessing withdrawal.

Attention might also focus specifically upon actual relapse episodes. Issues to be considered might include the course of relapse, where the episode occurred, and the subject's emotional

and physical states at the time. Information relating to presence of other people, interpersonal conflict, social pressure, stress, and withdrawal symptoms all could be of value in predicting and preparing for future crisis situations. Alcohol consumption associated with a relapse could be especially significant (cf. Marlatt and Gordon 1980; Shiffman 1981).

There are other miscellaneous predictive items suggested by the literature. For example, use of alcohol and other drugs, caffeine intake, and participation in psychotherapy may all be associated with outcome. General health status may be important, as well as physician advice to quit. Presence of young children in the home has been identified as another possible factor related to abstinence. Number of driving accidents has correlated negatively with outcome. Success in changing another major personal habit could be a positive indicator.

Current or anticipated pregnancy appears to be an obvious item to include for female smokers. Information on prior attendance at formal cessation programs may be important. Concerns with weight gain could suggest problems in remaining abstinent. Moderate to high physical activity levels, on the other hand, might be a positive factor. Subjects' "want/should" ratio (Marlatt and Gordon 1980) and perceived pressure from others to quit might be other important points to consider.

Future Directions

Public service clinics may limit themselves to relatively minimal intake data provided by questionnaires such as that currently employed by the American Lung Association. Researchers may adopt instruments that are considerably more involved. At the level of both research and clinical application, use of standardized questionnaires could contribute much to our knowledge.

It would be especially valuable if self-report measures were shown to correlate with other dimensions including topography and biochemical exposure. An obvious strategy would be to include questionnaire items assessing these other dimensions. Unfortunately, there is little evidence that subjects can accurately report topography, much less biochemical intake. Even so, it is possible that a paper-and-pencil measure could provide a rough indicator of the other dimensions. Future research might provide a useful formula for estimating topography and biological exposure from self-report data.

If questionnaire measures can eventually receive son-e validation at the levels of topography and physiological assessment, an important element of convergent validation will have been attained. One strategy might be to train subjects to be better observers of their own smoking behavior. Frederiksen and his colleagues (e.g., Frederiksen et al. 1976) have successfully taught smokers to monitor a number of topographical factors and even to discriminate differing levels of carton monoxide uptake. Promising instruments designed to supplement self-report are

discussed elsewhere in this monograph. Pickens (this volume) has constructed a device that can measure important components of smoking topography in the natural environment. Kozlowski and his colleagues (Kozlowski 1981; Kozlowski et al. 1982) describe an innovative technique which enables smokers to estimate their actual tar and nicotine intake by examining the appearance of spent cigarette filters. All of these methods should contribute significantly to more precise measurement.

ADDITIONAL ISSUES IN DATA COLLECTION AND CLINIC EVALUATION

The National Center for Health Education guidelines provide a sound basis for evaluating smoking cessation treatments, as was discussed previously. These guidelines are not complete, however, and additional information should be obtained to allow optimal assessment of interventions. Clinics should routinely note numbers of smokers who inquire about treatment, as well as those participants actually attending an initial orientation session. Requirements for participation also should be those smokers who make preliminary inquiries or that impose highly stringent screening criteria could report very high abstinence rates and yet still be quite limited in generalizability.

Both practitioners and researchers should maintain cumulative records of all participants in treatment. Maintenance of cumulative data sets could provide vital information in evaluating trends in outcome. In the author's own research, computer records have been established for all smokers who have entered treatment during the previous 6 years. The need for cumulative records is underscored by the fact that it often has been difficult to secure adequate subject samples for evaluation of treatments. This problem has been compounded by the use of group treatment formats in which group process variables sometimes outweigh specific treatment effects (Lando 1978).

Not only would cumulative data sets be useful in evaluating overall effectiveness of interventions, they may also serve to help isolate potential predictor variables (large-scale subject samples might be of considerable benefit in validating proposed assessment devices). In addition, this would facilitate analysis of subject characteristics for purposes of assigning participants to appropriate treatment conditions. Thus far, most work related to tailoring interventions to the needs of individual smokers has been disappointing. This may be due in part to assignment criteria that are either totally intuitive or that are based upon very limited subject samples.

Minimal statistical power is lacking in many published studies, especially when the major criterion is a dichotomous abstinence-nonabstinence outcome. One means of compensating for unsatisfactory power in individual studies may be to replicate promising interventions in successive program. Thus, in the author's research, an apparently effective broad-spectrum treatment encompassing oversmoking and maintenance has become a standard against which to compare other interventions. It

thereby has been possible to compute both average effectiveness and variability in outcome for this method. Results to date with this broad-spectrum intervention have consistently reached or slightly exceeded 40 percent abstinence at 12-month followup. Confidence in the validity and generalizability of these results is enhanced by numerous replications in both research and public service settings.

Collection of long-term followup data is obviously essential. Although a 12-month followup period now appears generally accepted as a minimum standard, soliciting of additional data beyond this point is relatively inexpensive and may prove extremely useful. Subject addresses and telephone numbers (together with those of informants) should be kept up-to-date. This should enable contact with a minimum of 90 percent of initial subjects even after a period of several years (cf. Lando and McGovern 1982).

Long-term data collection in public service settings might be facilitated by construction of simple followup assessment kits containing appropriate questionnaires and a schedule for their distribution (it was previously recommended that an attractive and convenient intake measure be developed for public service use. Ideally, this measure could be self-scoring to increase subjects' interest.) Such a followup assessment kit could substantially increase the likelihood of adequate data being reported by public service programs. In addition to followup questionnaires, the kits would contain detailed instructions for contacting nonrespondents.

Long-term followups could address several key questions that have received little attention. One issue might be the subsequent smoking history of subjects who fail to achieve abstinence in cessation programs. Might such participants be more resistant to subsequent change attempts? Is it possible that future smoking history for nonabstinent subjects could differ systematically as a function of the initial treatment? At this point, we simply do not know. Two programs could conceivably achieve identical short-term outcomes and yet differ dramatically in later abstinence attempts initiated by unsuccessful participants.

Schachter (1982) has argued that cumulative success rates are high both for people desiring to lose weight and to quit smoking. If the net effect of a treatment is to discourage future abstinence efforts for the majority of participants, the value of that treatment must be subject to serious question. This may be a particular concern for programs reporting 10 to 20 percent 12-month abstinence. Conceivably, these programs could produce a negative overall impact. Long-term followup assessment should focus not only on incidence of smoking but also upon change attempts among nonabstinent participants. Paradoxically, treatments that are viewed most favorably could be more likely to discourage further quit &tempts on the part of continuing smokers who come to view themselves as confirmed failures.

Self-efficacy measures (Bandura 1977; Condiotte and Lichtenstein 1981) might also be useful at followup as well as during treatment. Such measures could be informative both in camparing clinics and in predicting subsequent (successful) abstinence attempts. Clinics that place their sole emphasis upon abstinence may risk greater reductions in self-efficacy among nonabstinent participants than do clinics that appear to allow for intermediate results. In this context, it is possible that nicotine fading procedures may be recommended even if research definitively indicates that switching to low tar and nicotine cigarettes is ineffective in reducing risk. Nonabstinent nicotine fading subjects may see themselves as having achieved tangible progress in overcoming their smoking habit. This perception might in turn predict future efforts to abstain (of course, the reverse is also possible: nonabstinent participants may be more prone simply to continue what they perceive to be a safer style of smoking).

In addition to collecting data on subsequent smoking history and self-efficacy, investigators might do well to monitor relapse episodes in subjects who achieve initial abstinence. Such monitoring could improve understanding of major risk factors. This improved understanding could in turn facilitate the development of stronger inoculation strategies. Of particular interest might be any reported coping strategies by subjects who are successful in dealing with stressful situations and by those who are unsuccessful.

CONCLUSIONS AND ADDITIONAL RECOMMENDATIONS

Bernstein (1978) has argued that service providers as well as researchers should see careful data collection and description of treatment techniques as a fundamental part of their responsibility. Lichtenstein (personal communication) has suggested that interventions be required to meet specific standards for accreditation. This possibility may merit further attention. In the meantime, better dissemination of existing standards for evaluating treatments (e.g., definitions of long-term abstinence rates) might be of value in helping the general public to make more informed choices among available treatment programs. Unfortunately, although several major providers have endorsed the NCHE guidelines, it is not generally clear that they are following these guidelines in practice.

If both practitioners and researchers adopt certain standardized practices in data collection and questionnaire design, it may even be possible to pool data sets for purposes of some analyses. Perhaps the Office on Smoking and Health or some other central resource could serve as a depository or referral source for data that meet specific guidelines. These data sets would be available to researchers and would provide a much larger cumulative subject pool than would otherwise be possible. The requirement that guidelines be met for inclusion of data might serve as a further incentive to adhere to rigorous standards. These data Sets could represent a rich archival source for

investigators in dealing with such issues as isolation of predictor variables and tailoring of treatment to invidual smokers.

An obvious starting point would be to adopt a standardized minimal intake questionnaire. The questionnaire could be developed along the lines of that currently used by the American Lung Association (again, this would in no way preclude collection of additional information). The adoption of a questionnaire, together with adherence to NCHE guidelines in tabulating and reporting outcome, would provide considerable information. It would be possible to compare characteristics of smokers who tend to enroll in various types of interventions. It would also be possible to achieve much more meaningful comparisons of outcomes for different treatments.

Numerous suggestions have been presented for data collection and questionnaire design. These suggestions should be considered in the context of procedures discussed elsewhere in this volume for both topographical and physiological assessment. It now appears possible to achieve relatively sophisticated assessment of smoking patterns at fairly minimal cost. Inexpensive and unobtrusive monitoring devices have been described that are capable of measuring tobacco intake in the natural environment. Precise laboratory procedures are available for observation of smoking topography. These procedures can be supplemented by training subjects to be much more sensitive observers of their own smoking in the natural environment.

Future questionnaires are likely to be considerably more sophisticated than those currently available. Self-report items may provide information relevant to dimensions of both topography and physiological exposure. A combination of self-report, topographical, and physiological indices might allow more accurate estimation of the extent to which individual smokers are "at risk." Such information potentially could be used by smokers who are either unable or unwilling to abstain in achieving clinically significant reductions in exposure. As noted above, accurate guidelines for defining categories of smokers (e.g., "light smoker," "moderate smoker," "heavy smoker") must consider far more than just average number of cigarettes smoked per day.

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Evaluation of Smoking Risk: Some Proposed Minimum Standards

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The topic of this paper is the assessment of smoking in organizational settings. While the assessment of smoking in such settings (e.g., worksite) is not fundamentally different from assessment in other settings (e.g., treatment clinics or classrooms), this perspective, as well as the special characteristics of the research environment, serves as the background for discussion.

This discussion will concentrate on minimum standards. What are the requirements on the smoking researcher, if he or she wants to meet minimum scientific standards of acceptability? Development of innovative programs does not necessarily require extensive measurement considerations initially, but if replicable and reliable efforts are to be undertaken, minimum standards are clearly desirable.

Assessment in organizational settings is primarily concerned with reduction of health risks. This concern often, but not always, translates into some level of smoking cessation. These are similar concerns to those existing in any treatment situation. whether it be a hospital clinic, a classroom, or a self-help project.

These concerns are, however, somewhat different from those of researchers interested strictly in a laboratory analysis of behavior and pertinent physiological and pharmacological research. Some of the standards that are appropriate in treatment interventions are not necessarily appropriate for all laboratory studies. However, it is clear that a variety of measures developed in the laboratory should be applied in the natural environment.

ASSUMPTIONS

Two fundamental assumptions provide starting points for developing minimal standards for assessment/evaluation. One of those starting points involves the issue of why we are interested in smoking

behavior. The other assumption is that the reason for scientific study of smoking behavior is the potential health risk related to tobacco use. This is contrasted to a view that would characterize smoking as wrong on moral, political, religious, or any other grounds. In short, in the organizational setting the primary criterion is smoking risk and not smoking behavior per se.

As has been stated by a number of researchers, the reason for their initial interest in smoking behavior is that it was a behavior consisting of a simple, innocuous response for which a frequency measure was appropriate. Smoking is, of course, an interesting behavior from a whole range of perspectives, but in the organizational setting the concern must be with both the behavior and the associated health and safety risks. There are design and analysis implications when it comes to measurement criteria and the significance of research outcomes in organizational settings.

Those who are involved in risk reduction and smoking cessation in organizational settings have taken a view that emphasizes this aspect of the issue. An example of the level and areas of concern may be useful: Individual A has never used tobacco products in any form. Individual B has a long history of smoking; he has smoked one cigar a week for 20 years (after Sunday dinner) which was not inhaled. Individual C is also a smoker, consuming 2 1/2 packs of high tar, high nicotine, high CO cigarettes each day. From a smoking versus nonsmoking distinction, Individual A is clearly different from Individuals B and C. However, from a purely health risk standpoint, it is likely that A and B are more similar and markedly different from Individual C. It is clear that simple binary distinctions between smoking and nonsmoking do not capture the full range of risk and are consequently of little value by themselves.

The second starting point is our view of smoking behavior. In times past, many of us working in smoking research tended to view it as a relatively simple, straightforward behavior: either the individual smoked or didn't smoke. Smoking rate (number of cigarettes per unit time) was considered to be an adequate descriptor of smoking behavior. A few investigators did examine and discuss the substance used; however, even this was extremely rare (cf. Frederiksen et al. 1979).

In recent years, it has become increasingly clear that this is a far too simplistic picture. Considerable variation exists among products and the manner in which they are consumed. While it has long been assumed that situational factors could affect smoking rate, the evidence of recent years has also demonstrated that smoking topography can be affected by a host of variables such as physical characteristics of the cigarette, perhaps pharmacological interaction with other substances such as alcohol and coffee, cigarette deprivation, social factors, and instruction given to the smoker (cf. Frederiksen et al. 1981). The picture that has emerged is of a complex multiply determined behavior sensitive to a variety of environmental and pharmacological variables.

Overall it becomes apparent that while our concern is "risk," an adequate description of smoking must involve the assessment of what is smoked, the rate or temporal pattern of that consumption, and smoking topography (puff rate, puff size, interpuff interval, puff volume, etc.) (Frederiksen et al. 1979; Frederiksen and Martin 1979). While details of this argument are not reviewed here, it has received some recent empirical support. In a recent study, designed to predict alveolar carbon monoxide levels, it was found that the best predictor was a combination of three variables. Using a stepwise multiple regression procedure, the predictors (accounting for 36% of the total variance) included one topographical variable (interpuff interval), one variable describing substance smoked (carbon monoxide yield), and one variable describing smoking rate (Burling et al. 1983).

It is apparent that we have delineated numerous specific variables which might provide an adequate description of smoking behavior. However, no single variable provides an adequate description. The interrelationships among the variables are not clear. Further, we do not understand all the factors affecting any particular variable. This suggests a need for caution and puts a premium on comprehensive assessment under known, standardized conditions.

With this background, minimum standards for the adequate assessment of smoking behavior in organizational settings can be examined.

MINIMUM STANDARDS OF MEASUREMENT

Basic standards of scientific research must be applied to laboratory, treatment, and prevention efforts regardless of the setting in which they are implemented. Thus, for example, in organizational settings it is essential that the methods used for assessment of smoking behavior be held constant across experimental conditions. The rationale for this view is fairly evident. Since different smoking assessment procedures have been demonstrated to be differentially reliable and yield different results (e.g., Frederiksen et al. 1975), it behooves the investigator to hold them constant across assessment. This point may be sufficiently obvious, but investigators do not adhere to this simple requirement. It is not uncommon for some reports to include retrospective baselines or self-monitored smoking rates during baseline and treatment conditions, with telephone followup on the proportion of smokers abstinent (Frederiksen et al. 1979). Clearly these are not directly comparable measures. If the investigators are changing measures from phase to phase, they are systematically biasing their data across conditions.

Another issue of importance is that there should be some analysis of measurement reliability at each assessment point. Here, again, the rationale seems simple and straightforward. Yet, with surprising frequency, studies make no attempt to validate a smoker's self-report. While historically there may have been practical reasons making such validation difficult, the advent of biochemical measures seems to have made such validation more simple.

In a review of treatment and behavioral research studies (Frederiksen et al. 1979), it was noted that only 20 percent of the studies reviewed took measurement reliability at more than one point. For example, measurement reliability might only be undertaken during followup. or only during baseline, but not regularly and consistently throughout the study. Given the inherent method variance in smoking measurement, changing measures in mid-study necessarily provides distorted and essentially unusable data.

Techniques presented by investigators in other chapters In this volume describe useful, reliable, and important tools for obtaining information which will assist in changing tobacco use behavior and yield concomitant reductions in risk. Thus, for example, given the ready availability of carbon monoxide measurement! reliability assessments from a confederate, or automatic smoking machines, it seems incomprehensible that reliability checks should not be conducted at each assessment period.

A basic requirement is that data should be reported to identify the proportion of individuals who are currently not smoking. Not smoking is defined as a smoking rate of zero for a specified period of time (probably a minimum of one week). Further, the length of time that individuals have not been smoking should also be determined. This recommendation recognizes abstinence as total absence of smoking behavior over a specified period of time. It reflects the common practice of lumping smokers with nonsmokers to get an "average smoking rate" and also suggests that there be a minimum time of nonsmoking to be calculated as abstinence.

It is relatively clear that smoking is a continuum. A person who smokes two and a half packs of high-nicotine/high-tar cigarettes is not the same as someone who smokes three low-nicotine/low-tar cigarettes a week. These behaviors constitute different patterns with different levels of risk. However, it appears obvious that at some point on that continuum the smoker moves over into a different kind of category, and that is total abstinence. Therefore it is tremendously important that at the point of abstinence the individuals be examined separately. Shifts in data emerge for subjects as a function of individual behavioral change, but these data may not be reflected in group data. Thus the goal is to track individual patterns, not aggregate percentages.

Finally, total abstinence is meant to be <u>total.</u> Some investigators have used abstinence criteria of less than one cigarette in a week or less than one in a month. It is suggested that the best course for use is to set a minimum period of time (for example, at least one week) and if the person is not smoking <u>at all</u> they are abstinent at that point. In any case, the length of time that is used for abstinence criteria must be specified. It should, of course, be noted that the "one week" requirement is indeed a minimum standard and should not be associated with sustained abstinence.

An essential measurement issue is that data for current smokers should be presented in a way that allows for a determination of smoking rate (episodes per unit time) and the substance used (cigarette brand, etc.). This recommendation is to indicate the minimum level of data. These data should not be presented as an index that obscures the independent determination of these two variables, although such an index could be presented in addition to the individualized variables. It is not immediately apparent that there is a need to further standardize the time interval over which rate should be determined nor what data should be presented about the substance. However, as more data are collected in various research efforts it may become clear that considerable refinement is necessary.

In a review of published smoking research, Frederiksen et al. (1979) found only 20 percent of the studies were sufficiently detailed to permit determination of not only the rate at which people were smoking, but also what tobacco products they were smoking. While it is becoming more common for investigators to report these data, they are, unfortunately, often reported as an index. For example the cigarette pack yield of tar or nicotine or carbon monoxide is multiplied by the average rate to produce indices. The disadvantage is that it is not clear what these indices represent.

Further research is also required to permit precise specification of the time periods over which rates should be integrated. That is, it is necessary to determine whether the time base for rate measures should be hourly, daily, weekly, etc. Similarly the minimum number of units necessary for calculation of rate, i.e., how long the behavior should be recorded, is not readily apparent. Continued effort in delineating the measurement parameters is essential, and a precise statement on this dimension at present is impractical.

An important issue is that, whenever possible, a description of current smokers should also include an assessment of smoking topography. Here again, it is not possible to specify exactly under which conditions topography assessment should be made or which topographical variables should be recorded (cf. Ossip-Klein et al. 1983). Experimental study is essential, but at this point it is evident that at least some topographical variables should be assessed. Further these should be presented in a way that allows for the separation of topography from the variables of rate and substance. While the topography may also be combined with these other variables into an index, the measures should, when reported, be separable so that comparison with other studies is feasible.

COMMENT

It is suspected that these suggested criteria may be unsatisfying to some, since they don't clearly delineate categories of smokers and do not provide closure on which specific measures to use. Rather, they put an emphasis on two points. One is the quality of

the data that we are collecting on smoking cessation. Are there reliable, consistent data that that can be interpreted, broken down, separated out, and looked at in other ways? In many cases it is evident that the data are not reliable. and improvement in this area is essential. Researchers, clinicians, or health educators must comply with the minimum requirements of measurement. The second point concerns the detail of the information. It should be obvious that an aggregate smoking and nonsmoking distinction is far too gross, as is smoking rate or simple reports of substance smoked. Therefore the essential element is a need for more detailed analysis or more detail in analysis. The extent to which this occurs will determine the extent to which treatment efforts will move forward.

Despite the critical comments contained herein, there is an optimistic note in this proposal. That is, it does give us a criterion or a direction in which to look if clear and comparable measures of smoking are to evolve.

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Survey and Evaluation Methods: Smoking Prevention Among Children and Adolescents

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There has in recent years been a marked increase in survey and evaluative research on tobacco smoking among children and adolescents in the United States. Scientists and lay persons alike may wonder why these populations are of interest since children and adolescents are not supposed to smoke tobacco. Youths under the age of 16 are ostensibly banned from buying tobacco products nearly everywhere. Yet never before have so many children and adolescents smoked cigarettes; and the average age at which they begin gets younger each year (United States Public Health Service, 1982). The main reason for studying youths in regard to tobacco use is that even during childhood girls and boys experiment with cigarettes. Worse yet and adding grist to the cause for smoking-related survey and evaluative research is that experimental adolescent smokers grow up to be tobacco-dependent individuals (Lichtenstein and Brown 1980). As such, young persons risk the disease consequences associated with long-term tobacco use. Another just as disquieting reason for studying children and adolescents is that tobacco smoking has immediate and untoward physical consequences for young people per se. All these reasons are valid and equally compelling stimuli for empirical research with youthful populations at risk for tobacco smoking.

Still, and in spite of a growing body of data, exactly what constitutes smoking or "being a smoker" during childhood and adolescence is unclear. The vagaries of youth together with impediments to assessing this socially disapproved act yield several definitions of tobacco use. A chapter on tobacco smoking among children and adolescents in the 1979 Surgeon General's Report notes, "Such terms as 'regular smoker,' 'occasional smoker,' 'experimental smoker,' and 'nonsmoker' vary from one study to the next" (Evans et al. 1979, p. 7). The lack of correspondence between studies is exacerbated by ill-defined criteria for placing youth in each category of tobacco use. Many reports do not operationalize and specify the labels used (O'Rourke 1980). Common and uniform definitions of tobacco consumption categories are needed.

Studying children and adolescents with respect to tobacco use is a formidable task. Childhood and especially adolescence in America are not well demarked. Societal sanctions against precocious tobacco use cause young persons to engage in patterns of smoking that greatly differ from adult usage. For adolescents, more than for older cohorts in this country, smoking may for some groups represent a "rite de passage." The practice gets confused with values that have nothing to do with tobacco dependence. Finally, girls and boys show wide variability in attitudes and practices involving tobacco.

This paper considers such issues in conducting tobacco use surveys and in evaluating smoking prevention and intervention research with American youth. The authors review what is known about the peculiarities of nonadults who smoke. They compare and contrast methods to determine tobacco consumption among members of the target age groups. These tasks are accomplished in three major sections. The following sections cover issues of defining childhood and adolescence, disparate smoking patterns, and weaknesses of self-reported data. Discussion of each issue includes recommendations for future surveys and evaluations of young persons' smoking. Taken as a whole, these recommendations should provide direction toward more precise and homogeneous research on tobacco smoking among American children and adolescents and, of particular importance, provide comparability of results across research reports.

DEFINING CHILDHOOD AND ADOLESCENCE

The first issue faced in survey and evaluative research with children and adolescents is defining the age group to study. Who is a child? Common and anecdotal definitions of childhood are fairly in agreement that children are small and infantile people, primarily dependent on adults. Indeed, legal terminology calls anyone under the age of majority--18 to 21 years in most regions--a child since she or he is still under her or his parents' care and responsibility (Gilchrist and Schinke, in press). A theoretical treatise on child development lately indicated the generic notion of childhood as not helpful for research purposes. Irving Sigel, a developmental psychologist, observed a "growing trend toward eschewing the term child, which is an age-based concept" (1980, p. 348) The present authors concur. Childhood is best expressed as a developmental epoch, such as might be identified with school grade.

Deciding who is an adolescent in the United States is more difficult. Elsewhere the authors suggest adolescence ought not be equated with "teenage" (Schinke 1981; Schinke and Gilchrist, in press-b). Physiological, social, and psychological changes occurring in the transition from childhood to adulthood far exceed the 13th and 19th years. Again. school grade is a more reliable indicator of developmental maturity than age (Radius et al. 1980; Revill and Drury 19801. The developmental literature (Flavell 1977; Greenberg& et al. 1975; Mussen et al. 1979) depicts adolescence as three stages: early adolescence (school grades 6

through 8), middle adolescence (school grades 9 through 12), and late adolescence (college and employment). Smoking behavior at each stage differs. Surveys document that off-and-on experimentation is characteristic of early adolescence (Pederson et al. 1981). Habitual smoking does not typically emerge until middle adolescence (Evans 1976). Late adolescent smokers are not unlike adults (Bosse et al. 1980).

An overview of the literature and the work of the authors suggest that for tobacco smoking research, childhood should be defined as beginning with birth and extending until a point prior to middle school, generally through the end of fifth grade. Examples of contemporary tobacco smoking research with such populations would be the examinations of the effects of ambient or sidestream smoke on preschool children who spend considerable time with their parents.

Another example would be primary prevention research with school children before the high-risk middle-school years. Regarding research on adolescent tobacco smoking, young people beyond high school should be considered adults. Younger subjects are best described in terms of school grade. Cognitive and behavioral capacities that differentiate early adolescence from middle adolescence warrant consideration when designing surveys and evaluations aimed at American youth.

DISPARATE SMOKING PATTERNS

Because of negative social sanctions on smoking and because children and adolescents in this country have limited access to cigarettes, youthful smoking patterns are uneven. Among fifth-grade children and eighth-grade adolescents. the authors have learned that many youths will smoke eight to ten cigarettes in an evening, then not smoke again for several days running (Schinke and Gilchrist, in press-a). Some adolescents will smoke two packs a week, with the bulk of cigarettes consumed during 24 to 36 hours over the weekend. Can these youths be defined in the same way as young people who smoke a consistent four or five cigarettes a day? One approach to the question is to examine the physiological consequences of each consumption pattern. At present, little research has been done on the consequences or the disease risk associated with disparate patterns of tobacco use among children and adolescents (Office on Smoking and Health 1982).

Clearly, more investigations need to examine the physiological implications of massed doses of tobacco smoking on young people's still maturing bodies (Frederiksen and Martin 1979). An impediment to such work is that the topography of tobacco use widely differs between adults and nonadults. Standard topographical analyses for adult smokers are: number of puffs per cigarette, puff duration, length of time from first puff to last, total intake volume, ratio of intake volume to number of puffs, and interpuff interval (Epstein et al. 1981). Whether or not children and adolescent smokers inhale as deeply as and frequently as adult smokers is not known. If regularity is used to distinguish smokers from

experimenters, a problem arises. Presumably, youths who smoke without inhaling suffer fewer physiological consequences than those who smoke more sporadically but inhale deepy. Some analogues can be derived from research with adult populations, but the generalizability of such findings is limited.

For children and adolescents more than for adults, demographic factors influence smoking habits and tobacco consumption. Variations in the tobacco smoking of youthful subgroups and cultures necessitate highly specific samples (Clausen 1968). The smoker's gender warrants special consideration. Nationally, cigarette consumption has risen among young women while decreasing among young men (Bachman et al. 1981). Ethnicity too affects childhood and adolescent tobacco use. Hunter et al. (1980) found white 16- to 17-year-olds smoked twice as much as black youths the same age. Geographic differences also come into play. As an example, Hunter et al. (1980) learned that one in four adolescent subjects in southern Louisiana reported regular tobacco chewing. In all likelihood, these youths would be expected to evidence spuriously low rates of tobacco smoking when compared with youths from areas where tobacco chewing is uncommon.

Several approaches may be taken to resolving problems of analysis which reside in differences emanating from the sources and factors mentioned above. Less weight should be given to the quantity (i.e., absolute number) of cigarettes young people smoke. Instead, more attention ought to be put on the timing and situational patterns of youths' tobacco consumption. Researchers must a priori sketch the features that clearly identify their child and adolescent subject samples. Every report that springs from research with nonadults ought to carefully delimit the generality of findings on what was perhaps a sui generic sample of young persons. Key descriptive features that should be detailed are the youths' developmental profiles in terms of their cognitive and physical maturation and their racial characteristics and family backgrounds.

Investigators should grow acquainted with previous research done with their youthful sample. Earlier surveys and interventive programs may dramatically skew children's and adolescents' responses to current assessments and evaluative research (Glasgow et al. 1981). Effects of attention, placebo, and experimenter expectancy are particularly acute with children and adolescents (Schinke et al. in press). Taking into account the idiosyncracies of every youthful sample demands extra care. Far from burdensome, such preliminary steps have manifold payoffs by focusing subsequent research and by controlling factors which may confound the external validity of whatever results from the research.

WEAKNESSES OF SELF-REPORT

The bulk of survey and evaluative investigations with children and adolescents have exclusively relied on self-reported tobacco use and abstinence. Lack of honesty, poor recall, and desirable response bias, however, plague self-reports and can yield inchoate data. The flaws of self-reported smoking are magnified with

children and adolescents. O'Rourke (1980) speaks to the issue: "In the light of the possible negative implications to individuals, especially to youth by their parents, different studies using similar groups may find different rates of smoking behavior but which may, in fact, be a function of how well the confidentiality of the respondent was protected" (p. 163).

Fear of discovery is not the only trouble with self-reports of children's and adolescents' smoking. For largely developmental reasons, young people may not know how to classify their own smoking behavior. As an illustration, self-report criteria from Pederson et al. (1981) in research with fourth and sixth graders would have been inadequate for fifth and sixth graders in the present investigators' sample. Pederson et al. considered their respondents "regular smokers" if the young persons said they "usually" smoked cigarettes "just about every day." Youths were called "occasional smokers" if they reported smoking cigarettes "once in a while but not every day" (Pederson et al. 1981, p. 143). Qualifiers of "usually," "just about," and "once in a while" permit too much leeway for children and adolescents who must relate the terms to their own behavior. Youths under age 15 are vulnerable to misinterpreting imprecise language (Duke et al. 1980). Cognitive operations of abstract thinking are generally not mastered until late adolescence (Gilchrist 1981). Before that time, young people have difficulty pairing overt actions with symbolic words. Moreover, children's and adolescents' ability to recall patterns of recent behavior is notoriously poor (Schinke et al., in press-b).

To better separate indistinct categories of tobacco use, researchers have lumped young persons into fewer, self-defined groups. Thirteen- to 17-year-olds in a national household survey done by Yankelovich et al. (1977) were thus grossly grouped as smokers or nonsmokers regardless of patterns of cigarette use. Lotecka et al. (1981) asked high school students "to identify themselves as a Smoker, Non-Smoker, or Ex-Smoker" (p. 524). Not surprisingly, the team found their third group to be quite heterogeneous and noted, "The definitions with Ex-smokers (sic) were blurred at times with some individuals unsure about their status" (Lotecka et al. 1981, p. 524).

For the sake of unified and compatible research on childhood and adolescent tobacco smoking, objective definitions are needed. The definitions ought to be specific enough for direct translation into survey and evaluation protocols. Definitions of youthful smoking must nonetheless apply to diverse and varied research on the incidence, effects, concomitants, prevention, and cessation of tobacco use among children and adolescents. These ends can be served neither by simple bipolar categories nor by elaborate nosologies of youths' tobacco smoking. Rather, researchers must strike a balance between the two poles.

In search of a harmonious yet broadly applicable definition of tobacco use by children and adolescents, the authors drew from the literature and from their own evaluative research. Most

influential were definitions from the Bogalusa Heart Study (Hunter et al. 1980) and those from the authors' primary prevention efforts with fifth- and sixth-grade boys and girls (Schinke and Gilchrist, in press-a; Schinke et al., in press). Combined, the young samples from these projects total about 3,500 8- to 17-year-olds of both sexes. Definitions produced by interdigitation of the survey and evaluative research cover seven nonexlusive categories of youthful tobacco smoking. These are:

Nonsmoker. A child or an adolescent who has never intentionally puffed on a cigarette.

Experimenter. A child or an adolescent who on at least one occasion but less then once weekly during the most recent month lit, held, puffed, or inhaled any form of tobacco.

Ex-experimenter. A child or an adolescent experimenter in a prior month who did not intentionally puff on any form of tobacco in the most recent month.

Adopter. A child or an adolescent who once or more a week during the most recent month intentionally inhaled tobacco smoke.

Increased adopter. An adopter who previously smoked less often than during the most recent month.

Decreased adopter. An adopter who previously smoked more often than during the most recent month.

Ex-adopter. An adopter in a prior month who has not lit, held, puffed, or inhaled any form of tobacco in the most recent month.

Figure 1 lays out a schematic presentation of these definitional categories plotted across the life span with respect to tobacco consumption and disease risk.

The seven categories defined above offer distinct advantages to tobacco smoking research with children and adolescents. The definitions are responsive to any youthful age group and tobacco substance. They permit investigators to move young persons from one category to another as their smoking behavior shifts. The categories can be assigned on the basis of self-reported, observational, and biochemical data. As depicted in figure 1, the definitions have implications for theory building. The graphed categories reveal how young people maintain, decrease, and increase one facet of cancer disease risk by altering their tobacco use. The definitions allow survey and evaluative researchers to specify and delineate a homogenous study sample. In all likelihood such homogeneity will make data gathering more focused and will presage improved surveys, prevention programs, and treatment efforts. Last, the seven inclusive definitions will foster better communications among smoking investigators. When a number of scientists adopt the seven groupings of childhood and adolescent tobacco users and nonusers, normative data can be amassed and exchanged.

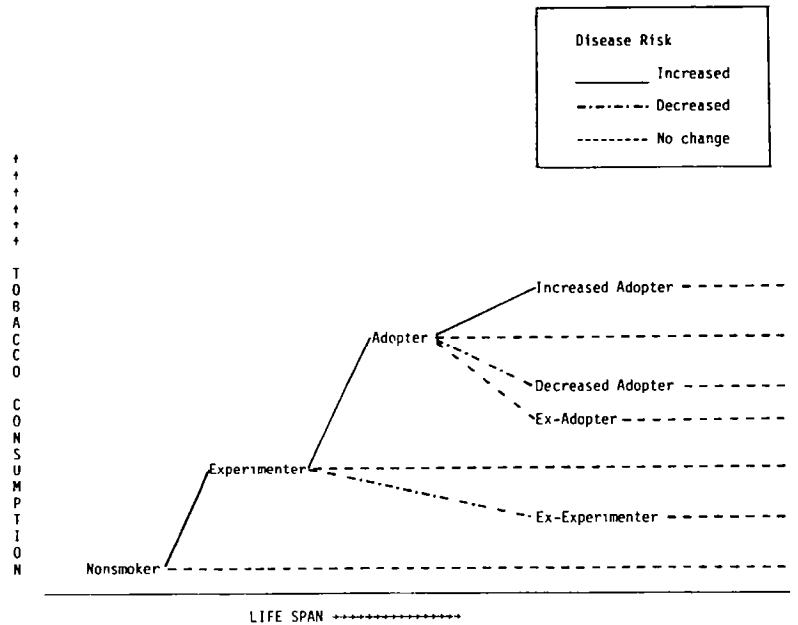

FIGURE 1. Schematic presentation of seven categorical definitions of children and adolescent tobacco users and nonusers.

SUMMARY

Past behavioral research on the special characteristics of tobacco smoking among children and adolescents is fraught with definitional ambiguities. More precise benchmarks of these age groups will facilitate mutually advantageous investigations. Researchers ought to agree on their target age cohorts. Too, investigators should account for the peculiar tobacco smoking patterns of children and adolescents who are research subjects. Finally, researchers should reach a consensus on how they categorize various kinds of young nonsmokers, smokers, and exsmokers. Recommendations put forth here are an attempt toward common parameters for researching tobacco use among American children and adolescents.

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Issues in the Measurement of Smoking: Summary and Discussion

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Investigators were attracted to the experimental analysis of smoking behavior for diverse reasons. The perceived simplicity of measurement appealed to some clinical investigators who had been dealing with less quantifiable phenomena. For others, smoking behavior and related or pharmacological issues provided a logical area for examination of related problems. From a clinical perspective, the goal was to eliminate or reduce tobacco use, and it appeared that the behavior could be measured by simply asking smokers how many cigarettes they smoked per day. Other scientists and clinicians were interested in aspects of tobacco use or nicotine effects insofar as a model existed for examining a commonly administered and well understood pharmacological agent. Analysis of tobacco use provides an opportunity for researchers to examine behavioral pharmacological mechanisms and perhaps contribute to the basis for therapeutic intervention.

A substantial data base reflects the fact that smoking behavior, despite its seeming simplicity, is as varied and as difficult an analysis problem as most human activities. As this volume attests, smoking is a complex biobehavioral process and can not be adequately delineated by any single question or indicator. It has become apparent that behavioral, physical, and biochemical indicators must be considered when developing research protocols. One goal of this discussion will be to further delineate the issues that must be considered by investigators with diverse goals.

Clinicians and researchers are necessarily consumers of smoking measurement technology. Depending on the specific areas of study, much interest lies in evaluating the effectiveness of preventive and cessation interventions; studying the acquisition and maintenance processes involved in smoking behavior; or examining physiological and behavioral correlates of pharmacochemical effects. The investigator who is implementing intervention programs attempts to assure that subjects who say they are not smoking are being truthful. Other investigators are interested in issues which include the effects of shifts to a lower tar/nicotine cigarette, the relative reinforcing effectiveness of nicotine,

individual differences among smokers with respect to disease states, topography, frequency, metabolism, or other characteristics. Different questions require emphasis on different measures, although similarities in requirements do exist.

Much of the material presented in this volume can be organized around three major questions or areas that concern various segments of the smoking research community. The first area involves determination of current smoking or abstinence. This simple question is for some purposes the most critical issue. The second issue is related to dosage or exposure to tobacco (nicotine), its metabolites and tobacco combustion products. This involves the measurement of tobacco use, including rate, topography, and chemical intake. The third area involves identifying characteristics of tobacco users, for example those of the "dependent smoker." This entails examining physiological and pharmacological correlates of behavioral patterns and delineating relationships.

DETERMINING SMOKING AND NONSMOKING

Measuring nonsmoking is the major concern of intervention programs, be they cessation or prevention. Most have an abstinence focus. The key dependent variable for evaluation of the intervention procedure is the proportion of subjects not smoking at a specified time. Clearly it is equally important to attend to individual data and assure that they coincide with group differences or similarities.

Self-report has been a major tool for determining nonsmoking in intervention studies. Issues of some importance for analysis of the behavior are those related to patterns and topography. Obtaining systematic and reliable data can be difficult, but it is useful for the researcher to determine, for example, whether the subject's cigarette is smoked "half-way" or to the filter. Similarly, it is helpful to determine whether cigarette smoking occurs in bouts or is spaced evenly throughout the day. When smoking has ceased the appropriate questions must be carefully stated and the focus of the response must be clearly determined. Thus, for example, the period of time during which no smoking has occurred is important whether it be one day, one week, or one year. Whether a shift from one to another tobacco product has occurred must be determined. Technical issues in the process can be resolved if questions are properly devised and if the procedures for collecting information are carefully implemented.

Truthfulness is a major issue concerning self-reports of both smoking rates and nonsmoking. Demand characteristics, social pressure, or incentives for abstinence (Goeckner 1979) may lead adolescents or adults to deception about their smoking status and aspects of rate or topography. Objective, chemical measures are sought to rule out this possibility. Especially useful in this regard would be a table of the various chemical measures and the state-of-the-art consensus as to their relative strengths and weaknesses. Fortunately Benowitz advances toward this goal by

providing a useful formulation which considers the sensitivity, costs, and limitations for each of four biological fluids. The invasiveness of each procedure should be considered as another comparison dimension. Expired air (carbon monoxide) and saliva (thiocyanate, nicotine) are easily obtained even in classroom and nonclinical settings. Urine and blood may be difficult or impossible to obtain in many field studies. The need for more invasive procedures differs as a function of the focus of the study. Clearly no study should be undertaken for which highly invasive measures are necessary. However, studies should not preclude use of procedures because of inconvenience or additional analytical tasks. If appropriate measures are not possible, the investigators should modify the research question so that appropriate measures are at their disposal. As was noted in presentations and discussion, various factors including the need for medical oversight, the existence of stringent criteria governing human subject involvement, and increasing budgetary requirements must be evaluated. Further it must be considered that one or another study may not be feasible if appropriate measures can not be obtained.

A relatively simple and inexpensive technique for determining abstinence is the use of significant others to record data. The use of others to augment self-report may contribute an extra measure of validity (e.g., Lichtenstein et al. 1973) but should not be relied on as infallible, and potential risks of the procedure must be recognized. Another technique, the so-called "bogus pipe line," has been reported to increase accuracy of self-report among adolescents (Evans et al. 1981), but it suffers from potential ethical problems, as well as confounding of results from a number of sources.

It is clear, overall, that techniques exist to measure current rates of smoking and subsequently of abstinence for individuals involved in smoking research projects. The critical issue is whether or not the consuming scientist properly uses the available technology. In this vein, it is equally apparent that even at the level of abstinence there is a need to utilize the available chemical analysis techniques if data are to be accepted as valid and/or reliable.

MEASURING SMOKING OR DOSAGE

The measurement of actual tobacco use as well as the transition to abstinence can be extremely important for studies intended to examine diverse issues. Thus, for example, the focus of analysis might be the behavior of smoking as a case of drug self-administration, the examination of the physiologic state of patients with cardiovascular problems, or the effectiveness of a cessation program. Whatever the purpose, precision in measurement is an essential adjunct to the study's primary goal. As previously noted, necessary data can not be ignored simply because they are difficult to obtain. The question that arises is which data are necessary or of interest. As indicated in the previous section, questionnaires can be used to obtain essential data.

Critical questions concerning type and numbers of cigarettes, patterns of smoking, and the like must be asked. These questions should, whenever possible, be derived from other sources (rather than being developed anew for each study) and should be compatible with measures used by other researchers. Chemical measures have clear advantages in verifying gross discrepancies between the verbal report and actual use levels. The purpose ultimately is to determine the exposure to products of combustion as well as the nicotine dosage and their levels in the body in relation to reported tobacco use. The specific combination of measures may vary, but breadth of data appears necessary from a health risk perspective. In addition, it is useful to determine exposure to those compounds or gases known or believed to be toxic, such as tars, nicotine, carbon monoxide, and hydrogen cyanide. It is worth noting that tars seem the most difficult to measure in standard smoking studies and there is little available information, although crude physical indicators of tar intake may be used.

The papers in this volume indicate that much progress has been made in measuring nicotine, cotinine, carbon monoxide, and saliva thiocyanate, although the task remains complex, On one hand analysis of obtained fluids reflects levels at a given point. On the other hand appropriate measures can provide a strong indication of recent use, and these data can be examined in terms of self-report measures. Individual differences in rates of intake and elimination must be considered in estimating overall exposure levels as well as matters of frequency or recency. Questionnaire-based smoking rates are the self-report approximation of exposure or dosage but have the clear disadvantage of unreliability if they are not linked to objective chemical measures. However, self-reported rates are convenient for descriptive or statistical purposes. For example, they permit the use of more powerful parametric statistical analysis (Lichtenstein and Danaher 1976). Unfortunately, compared to reports of abstinence, they are subject to more reporting biases (Pechachek 1979). Self-reported smoking rates tend to be only moderately correlated with biochemical indicators. This may in part be due to differences in intake and elimination but also may reside in erroneous reporting. Nevertheless, it must be remembered that self-reported rates have been useful in establishing rough dose-response relationships between smoking and disease. Concurrently, it must be recalled that further opportunities for efforts of the magnitude required to establish such statistical relationships are unlikely to occur.

One major interest in obtaining precise measures of dosage or intake is to test hypotheses about the nature of smoking behavior patterns including analysis of titration, or so-called "nicotine regulation," and the relative reinforcing and aversive properties of nicotine. Dosage issues may also be of considerable practical importance in determining aspects of exposure and perhaps in developing treatment strategies. Plasma cotinine appears to be the dosage measure of choice for nicotine intake if precision is required, and it is useful as a marker due to its longer half life.

Experimental analysis of nicotine regulation and associated physiological effects requires the capability of manipulating as well as measuring nicotine intake. The capability to measure successive puffs or cigarettes in the laboratory provides different levels of precision for different purposes. Comparison with standardized nicotine doses administered intravenously indicates the equivalence of intravenous nicotine to tobacco smoke. This permits special parallel laboratory studies and provides a basis for comparison with other drugs. Thus, at this level, the analysis of smoking serves to verify basic premises about the behavior, the "product," and the relation to other similarly administered or similar drugs. Topographical measurement using portable devices in the natural environment extends the opportunities for further understanding of smoking and its determinants. Topography measures can serve as indirect indicators and thus, for example, puff rate, puff duration, and especially puff volume can contribute to estimating nicotine intake. Perhaps more important is that these behavioral measures can serve in examining questions about social variables and other environmental determinants modulating smoking behavior. An interesting and possibly useful application for the new measurement techniques may be in the maintenance of controlled smoking which has been described as an alternative to abstinence (Frederiksen and Simon 1978; Foxx and Brown 1979). In these cases chemical measures of dosage can serve to measure compensation which maintains nicotine or CD levels in the face of reduced cigarette consumption. Some (e.g., Frederiksen and Simon) but not all (Foxx and Brown 1979) controlled smoking studies have included appropriate measures. Another group for which precision of topographical measurement is essentially nonexistent is that of adolescents. The measuring devices could be used to further our understanding of the intermittent or "unusual" non-chronic patterns of smoking which often characterize members of this and other groups. More generally, any studies which report reduction in smoking rates as a positive outcome should provide chemical measures of dosage.

Another neglected issue in examining dosage is, of course, the measurement of smokeless tobacco use. Adult and adolescent use of these less traditional forms of tobacco is on the rise and an increasing source of concern (Christen 1980). Plasma nicotine or cotinine, and probably urinary cotinine, could index use of chewing or dipping tobacco (Gritz et al. 1981). For adolescents in school settings,-however, a noninvasive procedure is needed, but none is currently available. If a subject both smokes cigarettes and uses chewing tobacco, biochemical measurement of one or the other becomes very difficult. This is a particular problem for young adolescents who may be experimenting with both routes of administration. It also becomes an issue in treatment programs when alternative routes of use occur after smoking ceases.

MEASURING CHARACTERISTICS OF SMOKERS

Characteristics of smokers may be of interest for several reasons. The need arises in part to permit comparison of data from different studies. One of the problems that plagues the field is the

difficulty of comparing results from different programs since the comparability of subjects cannot be ascertained. Inherent in this effort is the need to identify functional subsets of smokers as defined by smoking patterns and individual characteristics. This might permit prediction of differential response to different kinds of interventions.

Considerable disagreement exists concerning the role of personality or attitudinal variables as determinants of smoking. However, there is implicit agreement among investigators that smokers vary in the extent of dependence on pharmacological reinforcing properties and related behavioral dependence. There has been little effort to measure this dimension via psychometric or questionnaire instruments. One possible exception, noted by Lando, is Fagerstrom's Tolerance Scale (Fagerstrom 1578). This eight-item measure is fairly crude from a psychometric point of view, but it appears to have considerable construct validity. The basic idea of scaling the dependence dimension is worth pursuing, and Fagerstrom's scale identifies key behaviors that may reflect the degree of dependence. It should be noted, however, that an unpublished study by Lichtenstein and his coinvestigators suggests the scale has weak internal consistency and modest concurrent validity.

In general, characteristics of smokers can be measured by combinations of questionnaire instruments and biochemical or behavioral (topography) measures. Plasma cotinine may be the best measure of tobacco use although nicotine may reflect acute changes most accurately. Topographical data, including indicants of overall patterns (e.g. daily), combined with chemical measures to validate questionnaire data would likely generate useful information.

COST-BENEFIT CONSIDERATIONS

The three major questions on areas under discussion may be viewed as having different measurement requirements. Indeed it might be argued that each potential hypothesis requires choices with respect to measurement and the precision required. A cost-benefit dimension is also involved in the choice of measure. Given the necessary conceptual and technical base, precision can usually be obtained, but the cost may be substantial. For example, it is often a critical measurement goal to assess nicotine dosage. There is widespread recognition that the number of cigarettes smoked (assuming that is validly measured) is an imprecise measure. Knowledge of official nicotine yields of the cigarette smoked provides little additional information of actual dosage self-administered.

Although cotinine provides the most precise, valid measure of nicotine dosage, it is very expensive and moderately invasive since it requires blood or urine samples. Many investigators, depending on their hypotheses, may require less precision or may trade some degree of precision and validity for a less costly or less invasive measure, such as alveolar carbon monoxide or saliva thiocyanate.

Similarly some topographical measures are more difficult or more costly than others, and choices concerning precision will be necessary. However, it is evident that some effort to verify questionnaire data through use of chemical and topographical measures is extremely useful, if not essential.

Problems concerning validation using chemical and topographical measures exist in many areas of smoking research, but they are particularly evident in studies of adolescent smoking. Adolescents present some difficult measurement issues. They tend to smoke episodically, sometimes trying a few cigarettes, then not smoking for weeks or months. They also tend to smoke less frequently. In addition adolescents tend to be less reliable when providing self-report data. As a group, adolescents thus provide an excellent example of a case where data collected without verification may be of limited value.

Unfortunately, biochemical indicators are less sensitive to lower dosage levels likely to be self-administered by adolescents. It is not clear that carbon monoxide or thiocyanate levels are useful in experimental or occasional adolescent smokers except perhaps to verify infrequent smoking. It is clear that precise noninvasive techniques are essential for this population and it would be useful for those engaged in developing biochemical measures to follow patterns other than those characterized by chronic tobacco use. Arguments that a chemical measure, despite its insensitivity, might serve to produce a bogus pipeline effect (Evans et al. 1977) are not particularly convincing. The bogus pipeline effect may reassure the investigator, but is probably too fragile and in any case invokes ethical reservations. In addition its utility will be reduced as general knowledge of the phenomenon evolves.

In summary, the chapters in this volume provide a useful overview of strategies and methods for measurement of smoking behavior. Both the laboratory investigator and the field researcher should profit from the material herein. It is important to remember that it was not very long ago that self-report was the only measure of smoking behavior appearing in the literature. Progress in measurement has been very substantial and surely will continue. Both the experimental analysis of smoking behavior and the evaluation of intervention efforts will profit from such progress.

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