

Compensation for Nicotine by Smokers of Lower Yield Cigarettes

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BACKGROUND The question has been asked whether brand-switching smokers oversmoke lower nicotine cigarettes. The Federal Trade Commission (FTC) testing method is a *per-cigarette* test and should be judged as such. (Forty truly low-calorie candy bars together could be high calorie and still, individually, be low calorie.) The FTC test cannot be blamed because smokers smoke more cigarettes when they switch to those having a lower yield. Therefore, for this review compensation data were adjusted to per-cigarette values. However, such per-cigarette adjustments only approximate what would happen if the number of cigarettes were fixed for smokers. If smokers have already compensated by smoking many more cigarettes, then presumably they would have less need to smoke more of each cigarette. In the five studies included in the authors' main review, the compensatory percentage change in cigarettes per day averaged 15 percent (± 6 , 95-percent confidence interval). No studies showed a decreased number of cigarettes smoked with a lower yield brand of cigarettes.

Experimental brand-switching studies offering measures of nicotine and cotinine were reviewed. An index of compensation was calculated using a sequence of formulas developed by Russell and colleagues (1982). Calculation of these formulas first requires information on the machine-smoked nicotine yields of cigarettes to calculate (a) the percentage change in nicotine yields. Information on the measured level of nicotine (or cotinine) in body fluids is then used to calculate (b) the percentage change in nicotine (or cotinine) intake. Finally, three consecutive formulas are used to calculate (c) the actual compensatory increase in smoke intake $[(b/a - 1) \times 100]$; (d) the increase in smoke intake necessary for complete compensation $[(1 - a)/a \times 100]$; and (e) using the values obtained in (c) and (d) above, the degree of compensation $[(c/d) - 100]$.

CIGARETTE BRAND SWITCHING IN EXPERIMENTAL RESEARCH Research on brand switching makes use of repeated-measures designs. With these designs, the same smokers get different cigarettes. This controls for individual differences in drug metabolism (Benowitz et al., 1982) and for important biases in brand selection, which usually are not controlled for in cross-sectional research. This issue has been discussed by others (e.g., Giovino et al. [this volume]; Cohen [this volume]). Wynder and coworkers (1984) explored the demographics of smokers of the low-yield cigarettes and showed that age, sex, race, education, and religion were strongly related to the selection of low-tar cigarettes. Wynder and colleagues (1984) reported that education is negatively associated with tar for males, but not for females. (Tar and

nicotine are highly correlated across the full range of tar and nicotine yields.) People who smoke low- and ultralow-yield cigarettes may be more health conscious, have better diets, and be interested in smoking less. A random sample of persons does not select ultralow-yield cigarettes.

Despite their advantages, experimental brand-switching studies have important limitations. Outside of laboratories, smokers select their own brands. There is a free market for most purchases of cigarettes. An unsatisfying brand is likely to be rejected for a satisfying brand. Persons trying an ultralow-yield cigarette may feel that they are puffing on air, so they decide not to smoke these cigarettes and probably will not buy more than one pack. Some compensatory smoking techniques (e.g., vent blocking [Kozlowski et al., 1980 and 1989]) may take time to be learned by trial and error. Short-term studies (i.e., less than 1 week of exposure on lower yield brands) do not provide an adequate indication of the nature of compensatory smoking in self-selected smokers. All reviewed studies involved brand manipulations (change of "treatment" or brand in experimental study) of more than 7 days.

Studies of brand switching also have biased samples. Who does and does not volunteer for these studies? One of the five studies reviewed (Guyatt et al., 1989) showed a dramatic number of dropouts following informed consent. Of the people who went to at least one session in this study, 81 percent dropped out. Another study on brand switching (Benowitz et al., 1986a) required that participants be hospitalized for 14 days. Some smokers, knowing that they were going to get ultralow-yield cigarettes, either might not have wanted to smoke them or spend 14 days in the hospital. One must wonder who would be available to participate in a 14-day study requiring confinement to a hospital room. Most studies of brand switching also have small samples (mean = 22 subjects). As for demographic differences, there is no way to represent the complexities of age, sex, race, and education adequately in a sample of 22 participants.

According to the boundary model of drug regulation, plasma nicotine levels are not precisely regulated (Kozlowski and Herman, 1984); there are aversive upper and lower limits or boundaries on intake for dependent smokers. At the upper limit, when people are smoking a great deal, it is difficult for them to smoke more due to overdose or toxic effects of nicotine. When they are smoking a little, it is hard for them to smoke less than the lower limit because of insufficient nicotine intake. However, within these broad limits or boundaries, psychosocial factors primarily (i.e., the presence of others smoking) determine nicotine ingestion, and dose manipulations tend to have a smaller effect on smoking behavior (Kozlowski and Herman, 1984; Kozlowski, 1989) and how smokers feel (Benowitz et al., 1986b).

RESEARCH Table 1 shows the five studies reviewed and gives a summary of their results. The following studies were not included in the review because they were either too short term or used cigarette holders, which could interfere with natural smoking behavior: Benowitz and colleagues (1986a), Kolonen

Table 1

Summary of five experimental brand-switching studies demonstrating changes in cigarette yields due to compensation

Study	Number of Subjects	% Change in Nicotine Yield in Low- vs. Usual-Yield Cigarettes (Low vs. Usual in mg)	% Change in Plasma Nicotine in Low- vs. Usual-Yield Cigarettes (Low vs. Usual in ng/mL)	% Change in Plasma Cotinine of Low- vs. Usual-Yield Cigarettes (Low vs. Usual in ng/mL)	% Compensation
Ashton et al. (1979)	6 men 6 women	43 (0.6 vs. 1.4)	71 (83.8 vs. 117.3)	—	49
Guyatt et al. (1989)	10 men 18 women	67 (0.91 vs. 1.36)	—	71 (10.8 vs. 15.2)	12
Robinson et al. (1983), Stage 1 ^a	16 treatment 6 control	67 (0.64 vs. 0.96)	—	78 (9.0 vs. 11.5)	33
Robinson et al. (1983), Stage 2 ^a	16 treatment 6 control	40 (0.38 vs. 0.96)	—	77 (8.8 vs. 11.5)	62
Russell et al. (1982)	4 men 8 women	54 (0.7 vs. 1.3)	70 (22.8 vs. 32.4)	—	35
West et al. (1984)	12 treatment 12 control	8 (0.1 vs. 1.3)	41 (9.4 vs. 22.8)	—	36

^a This is a two-part study that allows for two different comparisons.

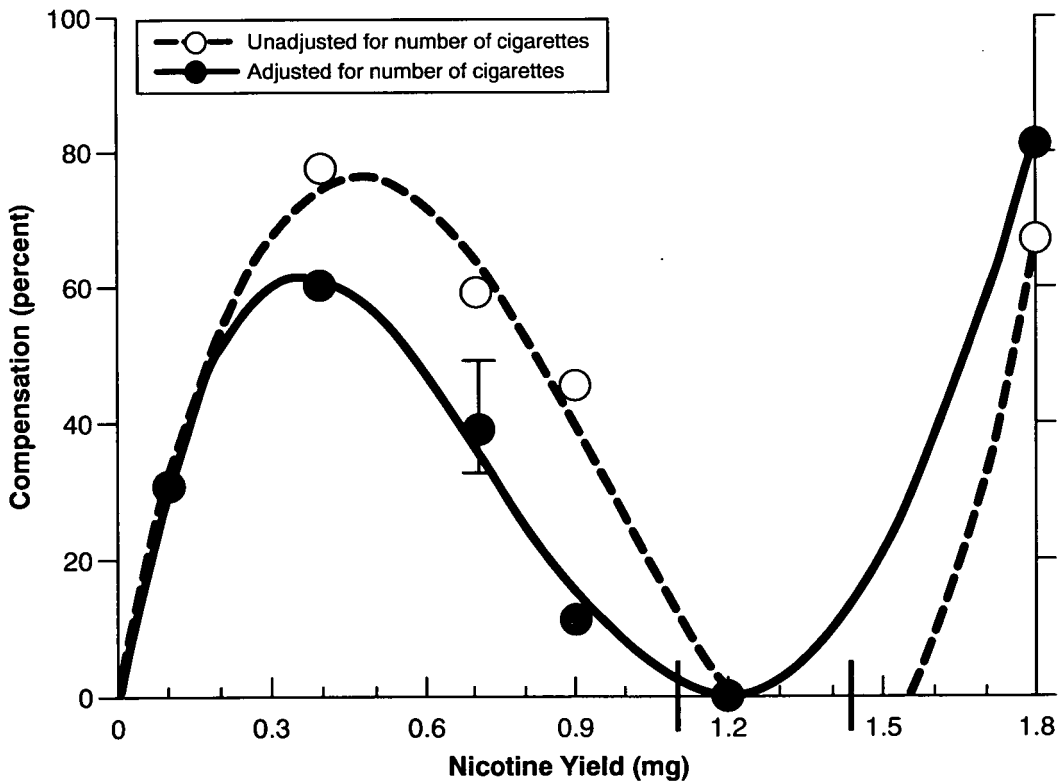
Note: Five studies gave six comparisons between low- and usual-yield cigarettes. Formulas used to calculate compensatory change in cigarette yields are reported in Russell and colleagues (1982), p. 153. Per-cigarette adjustments have been made so that all results are on the same scale.

and colleagues (1991), Russell and colleagues (1975), and Zacny and Stitzer (1988).

Figure 1 shows the pattern of results across the five studies. The solid line summarizes results from the studies after adjusting for changes in the number of cigarettes smoked. As nicotine yields go below the usual "normal" levels (1.0 to 1.4 mg nicotine), more compensation takes place until the lowest yield is reached. At this point, too much work may be required of smokers to achieve substantial compensation. This kind of dose-response pattern is consistent with that for other reinforcers. It may not be important to compensate for a 0.9-mg nicotine cigarette; it easily provides adequate levels of nicotine. The dashed line shows what happens when there is no adjustment for changes in the number of cigarettes smoked. This shows that compensation also is supported by an increase in cigarettes per day in these brand-switching studies (the 0.4-mg nicotine cigarette now shows close to 80 percent compensation).

Figure 1

Pattern of results illustrating percentage compensation across the five reviewed studies, unadjusted (dashed line) and adjusted (solid line) for number of cigarettes



The short-term study by Zacny and Stitzer (1988) (not included in our review) examined smokers who had been given three different lower yield brands (i.e., 0.1 mg, 0.4 mg, 0.7 mg nicotine). This study produced a pattern of compensation similar to that in Figure 1.

For consumers, the *average* percentage compensation may be less important than the likelihood of substantial compensation. If 1 in 2, 1 in 5, 1 in 10, 1 in 50, or even 1 in 100 smokers shows compensation of 25, 33, 55, or 75 percent, then a problem exists. If automobile brakes failed at a rate of even 1 in 1,000, this rate would be of great concern to manufacturers, consumers, and regulatory agencies.

**ONE REPEATED-
MEASURES STUDY
OF SELF-SELECTED
BRAND SWITCHING**

Lynch and Benowitz (1987) conducted a self-selected brand-switching study of participants who spontaneously switched cigarette brands. The study included 62 people who had lowered their standard yield. When they had been studied earlier, they had had plasma measures taken, and they were recontacted 3 to 6 years later. In this group, the low-yield cigarette was 62 percent of the former usual cigarette yield of nicotine (.68 mg versus 1.09 mg). Plasma cotinine per cigarette was unchanged: 10.3 ng per mL for the low-yield cigarette versus 10.2 ng per mL for the former usual cigarette. This represents a compensation of 103 percent!

**SMOKERS CAN GET
HIGH YIELDS FROM
THE LOWEST OF
THE LOW-YIELD
CIGARETTES:
MORE ON THE
ISSUE OF VENT
BLOCKING**

Some points should be made about vent blocking and the possibility of getting high yields from ultralow-yield brands. In one study, 14 people were smoking ultralow-yield cigarettes (Kozlowski et al., 1989), and half the smokers were vent blockers. Two of the seven vent blockers smoked about 25 cigarettes per day and each blocker showed carbon monoxide scores of 37 parts per million, which are very high. Salivary cotinine levels of 303 and 385 ng per mL, from a nominally .01-mg nicotine cigarette, are also very high. Therefore, there were high exposures from a very-low-yield cigarette, clear evidence that some smokers—if only two—were able to get substantial levels from the lowest of the low-yield cigarettes.

Some submissions from the cigarette industry have indicated that vent blocking is not a substantial problem. In contrast, four laboratories have produced eight peer-reviewed studies that found evidence of vent blocking (Hofer et al., 1991; Kozlowski et al., 1982a, 1988, 1989, and 1994; Lombardo et al., 1983; Robinson et al., 1983; Zacny and Stitzer, 1988). In these studies, the prevalence of “extreme” vent blocking ranged from 1 to 210 per 1,000 (median = 19 percent), and the prevalence of “at least some blocking” ranged from 61 to 580 per 1,000 (median = 50 percent).

One submission from the cigarette industry notes that ventilation has changed a great deal recently. However, invisible laser ventilation has been available for at least a decade. From a consumer’s point of view, it is unclear why invisible ventilation techniques should be viewed as appropriate.

Smokers can block the vents inadvertently if they do not know where the vents are and what they do. If smokers know where the vents are located, they can decide to avoid blocking the vents. There are real questions about who is most advantaged by laser techniques and invisible perforations.

Marlboro Lights, Winston Lights, Camel Lights, and Newport Lights ("lights" in general) are ventilated-filter cigarettes. Much of the focus of research has been on the ultralight cigarettes of 5 mg of tar or less. Unlike the ultralights, these light cigarettes are best sellers, but like the ultralights, they are ventilated-filter cigarettes. Therefore, the principle of informing the consumer that these are ventilated cigarettes, discussing how the vents work, and warning about blocking the vents with the fingers or lips is relevant to lights as well as ultralights.

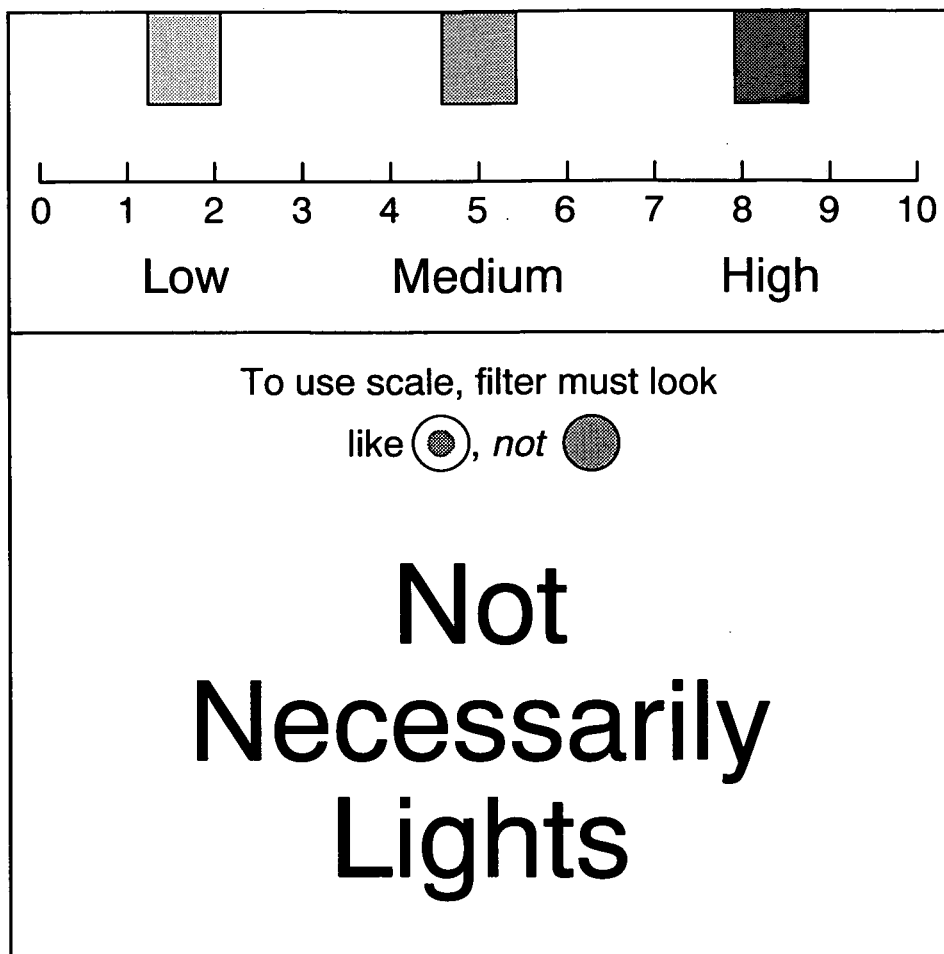
Anyone who is skeptical about vent blocking of ultralow-yield cigarettes should take the lowest tar challenge: Light a 1-mg tar cigarette, placing your lips on the filter as close to the smoker end as possible. Keep your fingers off the filter so your fingers do not get in the way (i.e., do not block the vents with your fingers) and take a puff. Consider its taste, temperature, and feel. Now put your lips at least three-quarters of the way to the tobacco column (i.e., block the vents with your lips) and take another puff of similar size. (In our butt collection studies [Kozlowski et al., 1988 and 1994], we regularly have found lipstick stains beyond the filter vents, on the filter end of the cigarette, showing how far the cigarette had been put into the mouth.) Compare the second puff to the first. See for yourself how easy it is to block the vents and how much difference it makes to real tobacco pleasure by doing this. Those onlookers who prefer not to take a puff of cigarette smoke can usually see the difference in the smoke that is exhaled by someone else because blocked vents produce a "juicy" mouthful of smoke that billows out from a noninhaled puff of smoke. With unblocked vents, onlookers will see only a little smoke exhaled.

**GRAPHIC
INFORMATION
ON TAR AND
NICOTINE YIELDS:
THE COLOR-
MATCHING
TECHNIQUE**

In 1982, a study was published on a color-matching technique to provide better information on tar and nicotine yields to smokers (Kozlowski et al., 1982b). The color-matching technique can be used to estimate the number of puffs taken on a cigarette, and thus tar and nicotine yields, by comparing the color intensity of the end of a spent cigarette filter with a color scale. The study demonstrated a strong relationship between the "darkness" of color of the filter and the tar and nicotine yield of the cigarette. Figure 2 illustrates a modified version of the color-matching scale that the authors incorporated on a cigarette package. Three different color papers (meant to represent tar stains of low, standard, and high yields) developed by the authors from the Pantone by Letraset Color-Matching System are used to compare the filter stain colors from spent cigarettes. The low (Pantone 127U), standard (Pantone 117U), and high (Pantone 139U) colors are mounted on the scale at points 2, 5, and 8, respectively. Smokers rated the filter stain color on the 0-to-10 scale, moving from the lower to the higher intensity color blocks. They decided "whether the filter looked lighter,

Figure 2

The color-matching technique scale shown on a cigarette package. (Pantone-colored papers representing low, standard, and high yields at scale locations 2, 5, and 8, respectively.) The appearance of an unblocked vented filter is shown in the bull's-eye stain; the uniform stain on the filter end indicates extreme vent blocking.



darker, or about the same as each of the colored blocks, and then selected the most appropriate scale number" (Kozlowski et al., 1982b).

Figure 2 also shows how stain patterns on spent filters can be used to indicate whether vent blocking has taken place on a conventional ventilated filter cigarette (Kozlowski et al., 1980). The bull's-eye tar stain on the left indicates no vent blocking. (Diluting air rather than smoke has been drawn through the periphery of the filter.) The uniform tar stain on the right indicates extreme vent blocking. On ventilated-filter cigarettes, vent blocking decreases filter efficiency so that the amount of stain left in the filter *underestimates* the amount of smoke that has gone through the filter;

in other words, the color-matching technique requires the assumption that vents remain unblocked. Because vent blocking alters yields dramatically, the graphic reminder not to block vents also may be useful in its own right.

The color-matching technique is a tool that can be used in future studies on compensation. Figure 2 also demonstrates how the color-matching technique and the stain-pattern technique could be included on cigarette packaging for consumer use. Color-matching information may better reflect the actual cigarette yields to smokers than the alternative FTC method. The FTC machine estimates of tar and nicotine yields can be unreliable given the variability among smokers and the various methods of compensation.

Further developmental work is needed on this color-matching technique. In the land of a largely blind FTC testing method, even a one-eyed color-matching technique could be king (Kozlowski and Rickert, 1984). It is not necessary to be perfect in providing the consumer with better information about the tar and nicotine yields of cigarettes to improve on the current standard method. A color scale attached to cigarettes can emphasize to the consumer that the yields from a cigarette depend on how the cigarette is smoked. Graphically, a color scale helps smokers see that yields are not captured by any one tar or nicotine number, and thus smokers can get a sense of where they stand in relation to the standard.

SUMMARY Our review of brand-switching studies indicated that smokers increase nicotine intake from lower yield cigarettes by compensatory behavior, including filter-vent blocking. This behavior is a neglected issue for smokers of light and ultralight cigarettes. The current FTC testing method used to estimate average tar and nicotine yields of cigarettes is compromised by compensatory smoking behavior and individual variability among smokers. Graphic techniques (e.g., the color-matching technique and the stain-pattern technique) also need to be explored as ways to provide estimates of tar and nicotine yields to smokers of lower yield cigarettes. Simple graphic materials may help these smokers realize that a low-yield cigarette can provide high yields when smoked in certain ways.

QUESTION-AND-ANSWER SESSION

DR. BENOWITZ: Lynn, you said that in one study about half the people were vent blockers. My work and the Gori study suggest that people are taking in, on average, about .7 mg of nicotine per cigarette, which is tremendously more than would be possible taking more puffs. So, I think virtually everyone who smokes ultralow-tar cigarettes must be blocking. And how many of the holes do these ultralow-tar cigarette smokers block?

DR. KOZLOWSKI: The story I like is the student of mine in class who said his aunt, who smokes an ultralow-tar cigarette, keeps a roll of transparent tape on her coffee table. When offering a cigarette to a friend she will say, "Do you want that taped or untaped?" Bizarre as that might be; it happens.

It illustrates that people do not understand what ventilation does to their cigarette. I had a call years ago from an angry executive as a result of

some media exposure about the results of some of these studies. He said, "I have a 1-mg tar cigarette, and yes, I block the vents on that cigarette, and yes, it makes it taste better and it is easier to light, but I thought it was a 1-mg tar cigarette; it says so right on the pack."

Ventilation is not the only manufacturing technique that contributes to an ultralow-yield cigarette. There can be other differences that mean that, even with blocking, the smoker will not necessarily get the same really high levels that you might with some other cigarettes. But it is clear that it is a major factor; it is clear that smokers can subvert it completely or even partially.

Lombardo did a study years ago with people staining their fingers with printer's ink. And he found that, as the cigarette coal burns down, and your fingers are getting away from it, they start to get in the way of the vent holes. It is also interesting that those last few puffs are the richest, and if you were to block those holes, that would be a particularly good time to do that to get higher yields.

DR. TOWNSEND: Dr. Kozlowski, how did you measure the vent blockage?

DR. KOZLOWSKI: We have done it a few ways. Most of the time it is a stain pattern method.

DR. TOWNSEND: On the mouth end of the filter?

DR. KOZLOWSKI: Yes.

DR. TOWNSEND: What I do not understand about something you just said is that people will purposefully tape holes closed. I think my experience with consumers is that they clearly know the tradeoffs between tar delivery of a cigarette and taste characteristics.

It would really surprise me that consumers would make that purposeful change to the design of a cigarette and not understand that they are increasing tar. Besides, they have the choice to go out into the market and buy a higher tar product if that is what they choose; so I do not understand the rationale or the psychology here.

DR. KOZLOWSKI: I think it is something to be surprised about.

DR. TOWNSEND: About the compensation issue, there is another answer that I do not completely understand.

Let's assume that compensation occurs to a very large degree, and people get essentially the same deliveries from a low-tar cigarette that they get from a higher tar cigarette. Then, why do consumers complain to us that the taste of low-tar cigarettes is weaker, milder, less strong, and less acceptable?

Again, their perception is that tar and taste go together. As a smoker, I can fairly accurately estimate the tar yield of a cigarette by smoking it, and I can get within a couple of milligrams.

I think many smokers, while they may not be as accurate in estimating FTC tar yields, still can rank cigarettes by tar. Now, how could they possibly do that if compensation were extensive?

DR. KOZLOWSKI: I think you do not want to think of compensation as something that influences everybody's smoking behavior. What we found in the *Pharmacology, Biochemistry and Behavior* study, half of the people block vents quite a lot, and the other half did not block them at all.

And if you looked further at those who did not block, you found that they did not smoke as many cigarettes per day. If you did taste ratings and how they liked the taste of the cigarette, they seemed to be consumers who were after a really low-yield smoke. They weren't blocking the holes. Not everybody smoking a low-yield cigarette blocks the vents. But this gets back to the issue of subject self-selection biases. We have to expect that there are individual differences in how much nicotine a person might want and also to the extent that a person is smoking for nicotine.

So, half of those subjects who were smoking ultralow-yield cigarettes in the long term were not blocking vent holes; they did not smoke many cigarettes per day; and they had low CO levels. The other half smoked a lot more cigarettes a day, smoked earlier in the morning, and got higher nicotine levels. You average them, and you get the kind of figures that are commonly described as "intermediate." Some people were showing a lot of compensation; some were showing very little; and that figure of mean compensation can be misleading.

DR. DEBETHIZY: I think you have pointed out an important fact: No machine-smoking method can predict individual behavior. This method was never intended to predict individual behavior, and it does not. I think people use different strategies when they smoke cigarettes, and it is rather obvious in the data you presented today.

DR. COHEN: Is it your intuition that a great many people who compensate are just following classic learning theory and do not even know they are doing it?

DR. KOZLOWSKI: Some people are not aware they are doing it; that is clear. They are not aware they are blocking the holes. I think that some people find the cigarettes relatively difficult to light. You push it a bit further in your mouth and it is a lot easier to light. Blocking could get started in a number of ways.

DR. SHIFFMAN: We have all been struggling with the issue of variability within a given product or products of equal FTC yield, I think, in talking about compensation and in the difference between the machine yield and the human biological exposure.

Now, with this issue of color matching, you are introducing something that I think has to do with true exposure rather than FTC yield. I wonder what you could tell us about the prospects of using a system like this to

estimate exposure, the differences that might be due to things other than number of puffs, and all the kinds of things we think a compensating smoker might do.

DR. KOZLOWSKI: I think Dr. Rickert might be able to comment intelligently on that.

DR. RICKERT: One of the things that we have done is to look at the yield of a cigarette in relationship to the color of the filter itself. We have established that there is an extremely good regression between the measured color characteristic of the filter and the FTC yield. We have done that on the smoking machine and for the actual filter on cigarettes. We have looked at yields under 87 different conditions to cover a wide range of potential behavioral conditions. And we have looked at the yields under those conditions and have looked at the relationship between that and color. And color of the filter is a very good predictor of yields under a wide variety of conditions.

DR. HENNINGFIELD: I would just like to point out that the kinds of compensation that you see are consistent with what Dr. Zacny was talking about, the dynamic smoker, what I was talking about, the addicted and behavior-modified smoker. But it is also very similar to what you see in the animal laboratory, with addictive drugs like alcohol, sedatives, and opiates.

What you see is that as you push the dose up, you get some downward compensation. As you decrease the dose, you get some upward. But it is within a boundary. It is rarely perfect, because as you increase the dose, the animals tend to get a little more drug. If you decrease the dose to a certain point, the behavior can kind of just fall apart and get very erratic. It just struck me how similar it was, what we see with animals and addictive drugs, and what you are seeing.

DR. KOZLOWSKI: I agree.

DR. HENNINGFIELD: It looks like a basic biological phenomenon, in other words.

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