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Self-Selected Blocking of Vents on Low-Yield Cigarettes

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KOZLOWSKI, L. T., T. F. HEATHERTON, R. C. FRECKER AND H. E. NOLTE. *Self-selected blocking of vents on low-yield cigarettes*. PHARMACOL BIOCHEM BEHAV 33(4) 815–819, 1989.—Blockers of vents in ultra-low-yield cigarettes had higher levels of carbon monoxide (CO) and salivary cotinine than did nonblockers. None of the blockers reported that they blocked vents. Exposure differences seemed not to be due simply to vent blocking, but also to be the result of syndromes of heavier (blocking, more cigarettes per day, and starting earlier in the morning) or lighter smoking (not blocking, fewer cigarettes per day, and starting later in the morning). The results are interpreted in light of the boundary model. Cigarette smoking and brand selection should be studied as they occur naturally, as well as in experimentally contrived studies.

Cigarettes Smoking Tobacco Smoking topography Hole blocking Nicotine dependence Filter ventilation Low-yield cigarettes Boundary model

COMMERCIAL ultra-low-yield cigarettes (≤4 mg tar, 0.4 mg nicotine) depend upon ventilated filters to reduce tar and nicotine yields (12). Blockade of filter vents—typically with lips or fingers—is one way in which smokers *can* compensate for the low yields (15, 17, 18, 20), but it is still unresolved how vent blocking contributes to actual exposures to cigarette smoke in the natural environment.

In the laboratory, complete blockade of cigarettes yielding 4 mg of tar in "standard" assays increases machine-simulated yields to 13 mg (15). Experimentally forced ventblocking greatly increases the carbon monoxide (CO) exposure in smokers (26). Although these subjects took more puffs and larger inhalations from unblocked than from blocked filters (i.e., showed compensation), alveolar CO levels were more than twice as high with the fully-blocked filter (26). Thus, the effects of hole blocking overrode the opposing effects of other changes in smoking behavior. These experiments, however, do not demonstrate how *self-selected* smokers of low-yield cigarettes smoke these cigarettes.

Some researchers have used experiments to study the effects of low-yield cigarettes on tar and nicotine exposure [e.g., (2,25)], but the public health relevance of this experimentation is questionable, given the freedom that smokers have to pick and choose cigarette brands when not influenced by specific research or treatment demands (11). Examining intake in smokers who have chosen low-yield cigarettes is important because cigarette brands are selected—often after trial-and-error—for many reasons, both psychosocial (such as advertising, risk perception, modelling) and biochemical (such as standard tar or nicotine yield). The boundary model (16) predicts that smokers will select brands and derive drug doses from these brands in response to both psychosocial and biological factors. Smokers who have chosen cigarettes which are insufficient to meet their biological needs are likely to oversmoke their cigarettes, whereas systematic undersmoking is likely to occur when a brand is chosen which is too strong (16). Thus, hole blocking is more likely to occur among those smoking cigarettes which are too weak for them.

We asked a group of cigarette smokers who already smoked ultra-low-tar cigarettes to complete a questionnaire on their smoking, collected biological measures of smoke exposure, and examined cigarette butts to assess the degree to which filter vents had been blocked. These data were interpreted in light of the boundary model.

METHOD

Procedure

Our subjects were visitors to the Ontario Science Centre in Toronto, who volunteered to participate after seeing a poster advertising a study of smoking habits. Subjects (N = 180) filled out an extensive questionnaire about their smoking habits [including questions about average daily consumption of cigarettes and

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average time to the first cigarette of the day—a good index of heaviness of smoking (8,14)]. They supplied a forced, end-expiratory breath sample (after a 20-sec breath-holding procedure) for alveolar carbon monoxide testing (CO; using an Ecolyzer, Energetics Science, Elmsford, NY) [cf. (26)], and provided a saliva sample for nicotine and cotinine [a stable metabolite of nicotine (1)] analysis. Saliva was collected by having subjects place a sterile cotton roll in their mouths while completing the questionnaire. The sample was placed in a sealed vacutainer and frozen until laboratory analysis. The frozen rolls were thawed, and individually mixed with known volumes of solvent. The rolls were later compressed to yield a maximal volume of liquid (saliva plus solvent), and by using sociometric techniques the original volume of saliva was determined. Knowing the total mass of nicotine and cotinine in the expressed saliva/solvent mixture and knowing the residual roll volumes, the concentrations of nicotine and cotinine were calculated. The salivary extracts were analyzed in a pressurized clean air laboratory, using capillary-column gas chromatography (9).

As expected from data on cigarette sales (12), few smokers of ultra-low-yield cigarettes were found. All 23 smokers of ultra-low-yield cigarettes (less than 4 mg tar) were invited to smoke one of their own cigarettes, and fourteen agreed to do so. After finishing the cigarette, subjects filled out a questionnaire about the way they smoked their low-yield cigarettes, including the extent to which they blocked the filters vents. The smoked cigarette filters were placed in sealed vacutainers and frozen until rated.

Scoring Procedure

Filters were scored by three independent raters on a 3-level scale: 1 = Little if any stain at the outside edge of the filter; 2 = Light to moderate stain around the outside with a noticeably darker center stain; and 3 = Uniform stain from inside to outside (consistent with complete blockage). Interrater correlations (.957, .957, and 1.0; 93.75% agreement) were excellent and comparable to previous findings in our own (17) and in an independent laboratory (26).

Statistical Analyses

Linear regression analyses, reliability coefficients (intraclass correlation coefficients), and *t*-tests were used. For contingency tables, chi-square without the continuity correction was used (3).

Subjects

The final group consisted of 8 females and 6 males, aged from 25 to 60 [mean = 37 ± 2.8 (SEM)]. This group smoked 22 ± 2.1 cigarettes per day (range 6–40) and had been smoking for 16 ± 2.6 years (range 3–38). Standard tar ratings ranged from 0.4 to 4 mg (mean = 3 ± 0.03).

RESULTS

Half (7) of our sample gave evidence of at least some vent blocking. Complete blocking (score 3) was observed in 3 (21%) of the filters. Because of the relatively small number of subjects, those who blocked at all were combined into one group (blockers) to compare with nonblockers.

Blockers had higher smoke exposures than nonblockers, but were heavier smokers in other respects. CO levels were 113% higher and salivary cotinine levels were 77% higher in Blockers than Nonblockers (see Table 1). Blockers also smoked 51% more cigarettes per day (CPD) and reported having their first cigarette of the morning (TTF) much earlier than did nonblockers (see Table 1).

TABLE 1

VENT BLOCKING AND MEAN EXPOSURE (± SEM) TO CIGARETTE SMOKE AS MEASURED BY SALIVARY COTININE, EXPIRED-AIR CARBON MONOXIDE (CO), CIGARETTES/DAY, AND TIME TO THE FIRST CIGARETTE OF THE DAY (TTF)

	Nonblockers (N = 7)	Blockers (N = 7)
Cotinine (ng/ml)	209 ± 56	369 ± 16*
CO (ppm)	15.4 ± 4.4	32.9 ± 2.3†
Cigarettes (No./day)	17.6 ± 2.5	26.6 ± 2.6*
TTF (min)[a]	97.9 ± 45.8	11.4 ± 3.9*

*$p<0.05$, *t*-test, two-tailed ($df = 12$).
†$p<0.01$.
[a]A logarithmic transformation was done before *t*-test.

Blocking was correlated with CPD and TTF (r's = .58, −.69, $ps<0.05$). (CPD and TTF correlated .87.) Hierarchical regression analyses showed in general that TTF is the best single predictor (controlling for the others) of biochemical exposure, followed closely by blocking status and CPD. With this small sample, however, errors in even one score can have a large influence on the size of the correlation coefficients, and hence on the relative importance of the variables in a multiple regression analysis (4). Further, a dichotomous variable (i.e., the score of blocking) has an upper limit of about .80 in the magnitude of correlation that can be found with a normally-distributed variable (24), impairing the ability of blocking to compete for "variance explained" with the more normally-distributed TTF and CPD. More importantly, statistical adjustment procedures (as in analysis of covariance of multiple regression) are sometimes treated mistakenly as if they can remake the world by "holding one variable constant" while assessing the "independent" contribution of another variable. These statistical procedures are most meaningful when they correct for "nuisance" variables, rather than when they try to partition variance among variables that are functionally-interrelated and highly intercorrelated (19).

We found evidence for two distinct smoking types: a heavy smoking syndrome (characterized by blocking, smoking sooner, and smoking more often) and a light smoking syndrome (characterized by not-blocking, smoking later, and smoking less often). By recoding CPD (20 or less = 0, 21 plus = 1) and TTF (greater than 30 min = 0, within 30 min = 1) [cf. Fagerstrom (5)], these variables are equally disadvantaged with the blocking variable by being put in a dichotomous scale. Each of these two-level scales (Blocking, TTF, and CPD) partitions the alveolar CO scores in essentially the same fashion. If one treats each of these independent variables as if they were ratings by separate judges of the heaviness of smoking, the reliability coefficient (i.e., the interclass correlation coefficient) is very high (.89), indicating that these separate "judges" (i.e., TTF, CPD, Blocking) are measuring very much the same thing.

Nonblockers were much more likely than blockers to feel light-headed when smoking (never = 0, always = 4) and "light-headed, nauseous, dizzy or ill" after the first cigarette of the day (same scale) (see Table 2). Blockers and nonblockers do not differ significantly in age or number of years smoking ($ps>0.35$). They also did no differ in the "minimum number of cigarettes that they can comfortably smoke in one day" [blockers = 10.8 ± 2.2, non

TABLE 2

MEAN RATINGS (± SEM) OF CIGARETTE STRENGTH, TASTE, EASE OF DRAW, LIGHTHEADEDNESS AND ILLNESS FROM CIGARETTES BY NONBLOCKERS AND BLOCKERS

	Nonblockers (N = 7)	Blockers (n = 7)
Perception of Cigarette		
Taste (dislike very much = 1 like very much = 5)	3.9 ± 0.4	4.6 ± 0.3
Strength (very weak = 1 very strong = 5)	1.9 ± 0.3	1.9 ± 0.3
Draw (very easy = 1 very difficult = 5)	2.7 ± 0.4	3.0 ± 0.4
Reaction to Cigarette		
Lightheaded (never = 0, always = 4)	1.86 ± 0.1	1.00 ± 0.3*
Lightheaded, dizzy, ill, or nauseous after first cigarette (never = 0, always = 4)	2.29 ± 0.4	0.86 ± 0.3*

*$p<0.01$, t-test, two-tailed ($df=12$).

blockers $= 6.4 \pm 2.5$, $t(12) = 1.31$, $t = 0.22$]. Nonblockers reported a smaller "maximum number of cigarettes that they could comfortably smoke" [nonblockers $= 23.6 \pm 2.1$, blockers $= 39.3 \pm 4.7$, $t(12) = 3.06$, $p<0.01$].

Reasons for Using Low-Yield Cigarettes

Subjects were provided a list of reasons why people switch to low-yield cigarettes and asked to choose as many as applied to them. Blockers did not differ from nonblockers in the proportion of those who reported switching to low-yield cigarettes for reasons of health (9 of 14, 64%), taste (3 of 14, 20%), price (1 of 14, 7%), or convenience (0%). However, those who switched to low-yield cigarettes in an attempt to quit smoking were more likely to be nonblockers than blockers, $\chi^2(1) = 4.67$, $p = 0.03$: Five out of seven nonblockers reported switching to low-yield cigarettes in an attempt to quit smoking, whereas only 1 of 7 blockers reported doing so. Nonblockers were also more likely to report trying to "force yourself to go as long as possible without having another cigarette" [Never = 0, Always = 4; $2.3 \pm .18$ vs. 1.4 ± 0.2, $t(12) = 3.13$, $p = 0.009$].

Knowledge of Blocking and Effects of Blocking

Twelve smokers reported never blocking the holes on their filters (4 of these had no awareness of vents on their filters), and the two who said they blocked vents gave no evidence of doing so. Overall, presence of hole blocking was unrelated to knowledge of hole blocking, $\chi^2(1) = 2.33$, $p = 0.13$. Subjects were also asked a series of questions about the properties of low-yield cigarettes. Five of 7 nonblockers believed that the tobacco in low-yield cigarettes is much weaker than that in high-yield cigarettes; only 2 of 7 blockers thought so, $\chi^2(1) = 2.57$, $p = 0.11$. Only two subjects (one blocker and one nonblocker) thought that blocking the holes on filters affects only the taste of the cigarette. In summary, despite turning to low-yield cigarettes to get lower exposures, many smokers were ignorant of how these cigarettes were designed and how they were smoking them.

Compensation With the Lowest of the Low-Tar Cigarettes

To examine the claim that smokers of 1-mg tar cigarettes cannot compensate for the reduced yields of these cigarettes (2), we looked at the exposure found in our two, male blockers of 1-mg tar cigarettes (the lowest of the ultra-low yield). They smoked 25 and 28 cigarettes per day; they had CO levels of 37 ppm (i.e., identical scores) and cotinine levels of 303 and 385 ng/ml (mean = 344).

DISCUSSION

We have no guarantee that the vent blocking we measured is typical of the subjects' normal smoking patterns, although the salivary cotinine measure in particular should provide a useful indication of chronic levels of nicotine exposure (1). We note, however, the close concordance between our blocking estimates and those from our prevalance data (17).

The Boundary Model

The boundary model directs us to look for an interaction between individual differences in the biological bases of smoking and the nicotine yields of cigarettes (16). Blockers seem to be heavier smokers who would not remain with ultra-low-tar cigarettes if they could not get reasonable nicotine yields from them, to help them stay above the aversive lower boundary of nicotine withdrawal (16). Those nicotine-dependent smokers who try ultra-low-yield brands and who do not block the vents may be unable to compensate adequately for the low-yield in light cigarettes. These individuals are more likely to switch back to high-yield cigarettes, and hence be under-represented in the current sample. Nonblockers seem to be lighter, more biologically sensitive smokers who appreciate the special opportunity to get lower yields from vented-filter cigarettes, to help them stay away from the aversive upper boundary of too much nicotine. For them, the vented filters present a special opportunity for a low-dose smoke. Blockers do not rate their cigarettes as any stronger or more enjoyable than do nonblockers (see Table 2): Both types of smoker are getting what they want from these cigarettes, but each type must smoke very differently to do so. Earlier, we suggested that if a "dieting" smoker did not miss his or her former high-yield smoke, it might not have gone away (11); now we must add that for some smokers, the higher yield may have gone away and not only do they not miss it, they may be relieved.

Nonblockers may be inherently more sensitive to nicotine than are blockers, or their failure to block vents may have altered the sensitivity of the nonblockers [cf. (25)]. Longitudinal research would be needed to decide this issue. We prefer the former interpretation and find tentative support for it, in that 3 of the 7 nonblockers had smoked an equivalent or lower tar cigarette prior to switching to their current brand. Note also that blockers and nonblockers had smoked for the same number of years, so our findings are unlikely to be due to simple cohort effects in the development of tobacco dependence.

Overall our results compliment those of Nil *et al.* (22,23), who have examined individual differences in smokers based upon CO absorption. Our results suggest that their low CO absorbers are also probably more sensitive to some of the effects of nicotine (e.g., light-headed from first cigarette) and that, in boundary terms, the upper boundary is important in controlling their smoking rates. Further, they find that larger puff volumes per puff are correlated with being a high absorber of CO and smoking more cigarettes per day (22). This is similar to our finding of greater likelihood of blocking in the otherwise heavier smokers and indicates a syndrome of heavier smoking rather than compensatory smoking procedures being independent factors. Although compensatory smoking techniques are conceptually distinct and can be manipulated in some experimental settings, some of the compensatory techniques appear to be naturally intercorrelated in self selected smokers: One does not necessarily have to find higher puff volumes (per puff) in those who are smoking more cigarettes per day, but one does (22).

Are 1-mg Tar Cigarettes Special?

Benowitz *et al.* (2) have argued that smokers are not able to compensate fully for the reduced yields of *ultra*-low-tar cigarettes, although they can compensate for *low*-tar (e.g., 5 mg tar) cigarettes. Their experimental study did not use regular smokers of ultra-low-tar cigarettes; their correlational study was on smokers who were presenting for smoking treatment; and neither study evaluated for hole blocking. Gori and Lynch (6,7) presented evidence interpreted as showing that 0.1 mg nicotine cigarettes were not subject to nearly the same level of compensatory smoking as even 0.2 mg nicotine cigarettes. Unfortunately, their supposed 0.2 mg nicotine cigarettes were judged by the U.S. Federal Trade Commission (FTC) to be improperly assessed by the standard FTC procedures for testing tar and nicotine yields and to be, in fact, much higher-yield cigarettes than assumed by Gori and Lynch. {The FTC ruled on April 13, 1983 that the 0.2 mg nicotine cigarette was incorrectly rated by their method (48 FED REG 15953). This was upheld by the U.S. District Court for D.C. and the U.S. Court of Appeals for D.C. [FTC vs. Brown & Williamson Tobacco Corporation, 580F.SUPP 981 (D.D.C., 1983), 778F.2d 35 (D.C. CIR., 1985)].} Once this misleading cigarette rating is discounted, the results of Gori and Lynch (7) show a weak linear trend relating the full scale of nicotine yields with plasma cotinine levels and do not offer support for considering 0.1 mg nicotine, 1 mg tar cigarettes as being especially immune to compensatory smoking.

Our results on just two smokers of 1-mg tar cigarettes clearly demonstrate that smokers of ultra-low-yield cigarettes *can* achieve the same exposures from their cigarettes as do smokers of higher-yield cigarettes. Moreover, in a population-based survey, Maron and Fortmann also found that ultra-low-yield smokers were able to attain the smoke exposures found in smokers of higher-yield cigarettes (21). Vent blocking of low-yield cigarettes is associated with higher levels of CO and salivary cotinine. Most respondents denied hole blocking and many were unaware that their filters were ventilated. It appears to be crucial (a) to advise smokers who are trying to reduce the risks of their smoking to be wary of vent blocking and (b) that complete cessation is by far the least risky course (11,13).

Although the current sample size may seem small and unrepresentative, it should be noted that the conclusions of Benowitz *et al.* (2) derived from only 11 paid smokers of higher-tar cigarettes who were able to reside in a research hospital for several days, as well as from 18 ultra-low-tar smokers who were attending a smoking cessation clinic. Ultra-low-yield cigarettes are relatively unpopular [cf. (11, 17, 21)]: nearly half of the cigarettes sold in the U.S. in 1986 delivered 16 or more mg tar, and only 2.6% sold delivered less than 4 mg tar (12). Despite encouragements to smoke ultra-low-yield cigarettes, consumers have resisted their adoption, in part, we think, because an unblocked ultra-low yield cigarette is generally unsatisfying (12). The study of the use of ultra-low-yield cigarettes is, in fact, the study of a rare event; and the adequacy of this sample size should be judged in light of this.

Experimental Vs. Correlational Research

Randomized experimental manipulations are often undertaken to avoid self-selection issues and other biases. This method, however, has the potential risk of missing key factors which give rise to the phenomenon of interest. In the case of hole blocking, laboratory studies have shown us what *can* happen, rather than what *does* happen outside the laboratory. Vent blocking is determined by the interaction between psychosocial and biological pressures on brand selection and smoking behavior. Because cigarettes vary so widely in standard yields, and smokers vary so widely in biological needs and sensitivities, researchers should consider these interacting issues when exploring smoking behavior and its determinants.

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