Nicotine & Tobacco Research Volume 6, Number 1 (February 2004) 85–94

Taylor&Francis healthsciences

The "low-tar" strategy and the changing construction of Australian cigarettes

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[Received 29 August 2002; accepted 28 February 2003]

This article documents design changes in Australian cigarettes since the adoption of a "low-tar" harm reduction strategy in 1966. It also determines the relative contributions of specific technologies to machine-tested tar and nicotine yields in 1980 and 1994, using data from tobacco industry documents. Our findings are consistent with a first generation of low-tar cigarettes, which relied primarily on filtration efficiency, being displaced by a second generation, which relied heavily on filter ventilation and were more attractive to consumers. In 1980, both tar and nicotine yields correlated most strongly with filter density ($r = -.66$, $p < .01$, and $r = -.70$, $p < .01$), whereas in 1994 both tar and nicotine yields correlated most strongly with percentage filter ventilation ($r = -.97$, $p < .01$, and $r = -.95$, $p < .01$). We also found that median percentage alkaloid content of tobacco rods rose from 2.16% in 1980 to 2.4% in 1994, despite median nicotine yield declining from 1.0 mg to .58 mg. These changes can be expected to reduce the utility of the FTC/ISO yield testing system.

Introduction

"Low-tar" cigarettes have generally been identified by the standard FTC/ISO test, which provides the tar, nicotine, and carbon monoxide yields of brands when machine smoked. Since the late 1960s, public health authorities in a number of countries, including Australia, have pursued a low-tar harm reduction strategy, encouraging smokers who refuse to quit to switch to lower yield brands (e.g., Anti-Cancer Council of Victoria [ACCV], 1966, 1967). Downward trends in yields over the past three decades have invited belief that both low-tar and regular cigarettes have become less hazardous. This would be the case if, first, yield figures provide useful information about actual deliveries of tar, nicotine, and carbon monoxide to smokers and, second, the composition of tar has not changed markedly over time and does not vary markedly per milligram between low-tar and regular brands (Djordjevic, Stellman, & Zang, 2000). However, current epidemiological evidence is not consistent with a decline in overall disease risks for either all smokers or low-tar smokers as a subgroup (Burns, Major, Shanks, Thun, & Samet, 2001). Further, several studies have found that smokers' nicotine intakes correlate weakly with the machine-tested nicotine yields of their chosen brands (Jarvis, Boreham, Primatesta, Feyerabend, & Bryant, 2001; Ueda et al., 2002; Woodward & Tunstall-Pedoe, 1993). It appears that the anticipated benefits of yield reductions failed to occur largely because nicotine-addicted smokers titrate their nicotine intakes and inevitably smoke lower yield cigarettes more intensively (Benowitz, 2001; Russell, 1989). However, nicotine-addicted smokers may not have provided the only obstacle to success for the low-tar harm reduction strategy. Low-tar cigarettes may have become more conducive to compensation during the past three decades, allowing increasing gaps between nominal yields and actual deliveries.

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First- and second-generation low-tar cigarettes

A number of innovations have contributed to reductions in machine-tested tar and nicotine yields since the 1950s (Hoffman, Djordjevic, & Hoffman, 1997; Kozlowski, O'Connor, & Sweeney, 2001). In order of introduction, these innovations were filter tips, reconstituted tobacco, porous paper, ventilated paper, expanded tobacco, and ventilated filters.

ISSN 1462-2203 print/ISSN 1469-994X online © 2004 Society for Research on Nicotine and Tobacco
DOI: 10.1080/14622200310001656907

We propose that there have been two generations of low-tar cigarettes, distinguished according to whether they employed filter ventilation. The purpose of this distinction is to contrast both feasible yield reductions and the probable ease with which smokers have been able to gain tar and nicotine deliveries in excess of nominal yields.

Early low-tar cigarettes relied primarily on high filtration efficiency and secondarily on high static burn rate to produce lower machine-tested yields than regular cigarettes. Despite significant consumer interest in so-called safer cigarettes, early low-tar brands met with limited acceptance (Adlkofer, n.d.; Oldman, 1982). Possible reasons for this limited acceptance are as follows:

- High draw resistance. High-efficiency filters necessarily have high draw resistance, which can be only partially counterbalanced with expanded tobacco and porous or ventilated paper. Resistance to draw, or RTD, is a measure of the effort required to gain a standard puff of smoke from the cigarette. According to a Philip Morris internal document (Lin, 1990), filter efficiency above around 60% produces unacceptable draw resistance in the absence of filter ventilation.
- Blandness. Prior to the 1980s, smokers frequently reported that low-tar brands had insufficient flavor to satisfy (Adlkofer, n.d.; John & Wakeham, 1980; Oldman, 1982).
- Low nicotine delivery. The dissatisfaction smokers reported as blandness may have reflected nicotine deliveries below reward thresholds.

It should be noted that some early switchers to low-tar brands treated blandness positively: They felt reassured that they were receiving lower tar and nicotine exposures (Oldman, 1982). However, the tobacco industry was clearly convinced that many other smokers sought more satisfying low-tar brands, as well as brands with even lower tar yields (John & Wakeham, 1980; Oldman). Filter ventilation was arguably the key innovation enabling both developments.

Two processes combine to lower machine-tested tar and nicotine yields in ventilated filter cigarettes (Hoffman et al., 1997; Kozlowski et al., 2001). First, dilution related to vent flow reduces the size of the effective puff at the burning cone. Second, the axial flow velocity of the mainstream smoke is reduced, allowing more tar to be captured by the filter. At the same time that the addition of filter ventilation reduces yields, it reduces draw resistance, at roughly 1 mm H_2O per 1% increase in ventilation level (British American Tobacco, 1987). Thus, by combining high levels of filter ventilation with high draw resistance filters, it is possible to produce cigarettes with very low yields but comparable draw resistance to regular cigarettes (British American Tobacco, 1980).

Compensatory smoking with first- and second-generation low-tar cigarettes

Ventilated filter cigarettes offer two separate possibilities for compensatory smoking (Kozlowski et al., 2001). Ventilation levels can be greatly reduced under real smoking conditions, because smokers inadvertently or deliberately cover ventilation holes with their fingers or lips. Ventilated filter cigarettes generally also have "elastic" filters; the effective ventilation level decreases as puff size per unit of time increases (Creighton, 1978; Schneider, 1992). Creighton (1978) identified this as a potential feature of low-yield cigarettes that smokers would prefer. Filter elasticity makes brands with moderate levels of ventilation conducive to full compensation through puff size increases without any finger or lip blocking (Kozlowski & O'Connor, 2002). With these two mechanisms available, smokers can compensate in the way that best suits them: Blocking vents to a large degree for a more regular taste and a high, but acceptable, draw resistance, or leaving vents mostly or even wholly unblocked and taking large, dilute puffs with a mild taste.

Ventilated filter cigarettes are now subject to considerable critical attention, although outside specialist circles there is far less awareness of filter elasticity than ventilation blockage. Also receiving less attention than may be warranted is the possibility that early, nonventilated low-tar cigarettes were not conducive to full compensation. We noted above that high draw resistance was a reported source of dissatisfaction with early low-tar cigarettes and low nicotine delivery was a plausible underlying cause of dissatisfaction. A plausible causal link is that increasing draw resistance constrains puff size (Creighton, 1972; Dixon, 1992; Goodman & Meyer, 1975) and, beyond a certain point, leaves only increased puff frequency as a feasible response to reduced nicotine yield.

If first- and second-generation low-tar cigarettes differ as much as we have proposed, we might expect the following:

- A small market share for low-tar cigarettes before filter ventilation is introduced and an increasing share after its introduction.
- A "floor" for yield reduction before the introduction of filter ventilation, determined by the upper limit for acceptable draw resistance.
- The disappearance of first-generation low-tar brands or their reformulation, as a result of competition for viable market share.

We conducted a study of the history of design changes in Australian cigarettes to assess the fit with the two-generation model of low-tar cigarettes and to assess the importance of particular tar and nicotine yield determinants across all brands. This study included a partial replication of the study of filter ventilation and nicotine content in British, Canadian, and U.S. cigarettes by Kozlowski and colleagues (1998) and an extension of that study, with across-time comparisons of yield determinants. Although the performance of selected Australian low-tar cigarettes under conditions of ventilation blockage and increased puff frequency has been reported previously (Australian Consumers Association, 1993), this was the first study of a broader range of yield determinants in Australian cigarettes.

Method

Data sources and search strategy

Tobacco industry document Web sites, Australian retail tobacconist journals, and *Victorian Cancer News* were searched for information on innovations in cigarettes design and information on the yields and construction of Australian cigarettes. Initial Web site searches used Australian brand names and specific technical terms, linked with Australian tobacco company names (or Australia or Aust**). Later searches used further technical terms identified from discovered documents and names of industry personnel.

Quantitative analyses

Four "C.I. Reports," produced by Philip Morris Limited Australia, were discovered (Balint, 1980, March, May, September; Ruff, 1994), providing performance and construction data for 1980 and 1994 for all three Australian manufacturers' brands (Philip Morris Limited, Rothmans, and W. D. & H. O. Wills). Available data included tar, nicotine, and carbon monoxide yields; tar/puff and puff count; cigarette length, circumference, and draw resistance; paper porosity and additives; filter type, weight, length, and draw resistance; ventilation type and percentage; and tobacco specifications, including tobacco rod weight and percentage alkaloids, sugar, oven volatiles (water and a few other volatile substances that are driven out of the tobacco when it is dried for analysis), stem, and expanded tobacco. The data reported by Balint (1980, May) and Ruff (1994) were used to form two datasets for quantitative analyses. The 1980 dataset contains data on 41 filtered brands, accounting for 85% of market share. The 1994 dataset contains data on 102 filtered brands available in 1994, accounting for 96% of market share (and excludes one nonfiltered brand, Camel, reported by Ruff, 1994). Quantitative analyses also included two calculated variables: Filter density and estimated total alkaloid weight (i.e., weight in milligrams of nicotine and other tobacco alkaloids in each tobacco rod). Analyses were conducted using SPSS, and all significance tests reported below are two-sided.

Results

The first low-tar cigarettes in Australia

In 1966, the ACCV began a campaign for low-tar cigarettes (ACCV, 1966). In 1967, it published its first tar table, comparing 10 popular Australian brands with 56 U.S. brands (ACCV, 1967). The lowest yielding Australian brand, Kent, had a 23-mg tar yield and a 1.4-mg nicotine yield, whereas the lowest yielding U.S. brand, Marvel, had an 8.3-mg tar yield and a .32-mg nicotine yield. However, the second ACCV tar table (ACCV, 1968) included two new low-tar brands: Rothmans's Ransom (7.4 mg) and Wills's Hallmark Dual Filter (Myria Filter) (7.1 mg). Hallmark became the sixth highest seller in Victoria in 1972, with 4% market share (Tyrrell, 1999). Also, by 1972 there were 10 low-tar brands, according to the ACCV criterion of a tar yield below 12 mg (ACCV, 1975).

Key data for Hallmark Dual Filter in 1968 are presented in Table 1, along with comparison data for Marlboro. Hallmark used a dual cellulose acetate/crepe paper filter and had a filtration efficiency of 68%, compared with 38% for Marlboro (which had the highest filtration efficiency of any Philip Morris brand tested in 1968) (Clarke, 1968, February 15, March 1, March 5, March 6). Hallmark also had low percentage alkaloid content tobacco compared with any Philip Morris brand tested in 1968 (Clarke, 1968, February 15, March 5, March 6). However, from 1971 or 1972, Hallmark contained an alkaline filter additive to boost "extractable" nicotine deliveries (Wilson, 1973). Wilson (1971) reported that sodium carbonate had been found effective for this purpose and suggested it would be a useful additive for low-tar cigarettes. We were unable to find any documents detailing the construction of Ransom in the 1960s.

The introduction of filter ventilation

We attempted to track the introduction of filter ventilation in Australia, using retail tobacconist journals. We found a 1965 "topicality" piece ("Cigarettes pin-pointed," 1965) on a naturalistic experiment conducted by Edward de Bono, in which he instructed smokers to put pinholes in their cigarettes as a way of adjusting to weaker ones. However, as far as we could determine, when Australian manufacturers began perforating filters commercially, the development went unreported. In contrast, high porosity paper, charcoal filters, dual filters, and twin density filters

Table 1. Yields and selected construction factors for selected Australian brands, 1968 and 1980.

1968	Hallmark DF	Marlboro		
Tar yield (TPM)	8.2 mg	23 mg		
Nicotine yield	0.53 mg	1.24 mg		
Carbon monoxide yield	NA	NA		
RTD	177.8 mmH_2O	119 mmH_2O		
Filter weight	155 mg	97 mg		
Ventilation	0	0		
Alkaloid content (dry weight basis)	1.6%	1.9%		
Tobacco weight[a]	804 mg	836 mg		
Estimated total alkaloid weight	11.26 mg	14.21 mg		
1980	**Hallmark DF Melbourne**	**Hallmark DF Sydney**	**Hallmark Ultra Mild**	**Ransom Select**
Tar yield (CPM)	6.7 mg	5.4 mg	5.1 mg	4.9 mg
Nicotine yield	0.5 mg	0.4 mg	0.6 mg	0.3 mg
Carbon monoxide yield	11.5 mg	9.3 mg	4.2 mg	8.8 mg
RTD	150 mmH_2O	129 mmH_2O	96 mmH_2O	130 mmH_2O
Filter weight	148 mg	148 mg	168 mg	152 mg
Ventilation	0	28%	59%	27%
Alkaloid content (dry weight basis)	1.6%	1.8%	2.5%	1.6%
Tobacco weight[a]	658 mg	656 mg	630 mg	687 mg
Estimated total alkaloid weight	9.16 mg	9.78 mg	13.78 mg	9.56 mg

Data from Clarke (1968, March 1, March 6) and Balint (1980, May).
CPM, corrected particulate matter (TPM minus water and nicotine); NA, not available; OV, oven volatiles; RTD, resistance to draw; TPM, total particulate matter, or moist tar.
[a]1968 tobacco weights are "as received", and 1980 weights are "12.5% OV." These two measures are roughly equivalent.

were well publicized (e.g., "Hallmark—First Australian dual filter," 1963; Liggett & Myers, 1964; Philip Morris, 1990; Rothmans, 1974; Wills, 1960).

Industry documents were more revealing but did not enable identification of the first ventilated filter, low-tar cigarette in Australia. A British American Tobacco document on filter ventilation in "sophisticated markets" (Haslam, 1977) shows that at least one ventilated filter cigarette was available in Australia in the first quarter of 1974. Ventilated filter brands had a mere .1% market share in Australia in 1974 (compared with 6% in the United Kingdom and United States) but had gained a 1% share by 1977.

The likely first ventilated filter cigarette in Australia is Ransom Select, which replaced Ransom in 1974 and had lower yields (5 mg tar, .3 mg nicotine), despite an increase to King Size. Also, an article in *Victorian Cancer News* in 1975 (ACCV, 1975) drew attention to its low carbon monoxide yield, again strongly suggesting filter ventilation. However, advertisements claimed only that it was "the world's first multi filter King Size" (Rothmans, 1974).

Low-tar brands in 1980

In the 1980 dataset, 10 brands had tar yields of less than 10 mg and seven of these brands were filter ventilated. The four lowest yielding brands in the 1980 dataset are compared in Table 1. Sydney-manufactured Hallmark Dual Filter became ventilated in 1978 (Nicholls, 1978). Hallmark Ultra Mild, introduced in 1979, constituted a more radical innovation. It had a single cellulose acetate filter, instead of the dual crepe/cellulose acetate filters used by Hallmark Dual Filter and Ransom Select. It also had the highest level of ventilation and second highest percentage alkaloid content of any brand tested by Philip Morris Limited in 1980 (after Escort Extra Mild, which had 43% filter ventilation and 2.6% alkaloids content, dry weight basis) (Balint, 1980, March, May, September).

Three other brands in the 1980 dataset (Wills Super Mild, Benson and Hedges Extra Mild, and Craven Special Mild) used dual crepe/cellulose acetate filters. This type of filter disappeared from major Australian brands between 1980 and 1994. Nonventilated low-tar brands also disappeared between 1980 and 1994. Hallmark Dual Filter was removed from the market in 1990 ("Price list," 1990), but we were unable to determine how long the nonventilated variety persisted.

Low-tar brands in 1994

A marked downward shift in the tar and nicotine yields of Australian brands occurred between 1980 and 1994. Based on the ACCV's original definition of low-tar brands as those with tar yields below 12 mg, only one brand in the 1994 dataset would not qualify as low tar (Marlboro Red, with a 12.4-mg tar yield). The low-tar market in 1994 also was dominated by "light" and "mild" variants of leading brands rather than stand alone low-tar brands like Hallmark and Ransom.

On-pack labeling of tar and nicotine yields began in 1982, using four categories of nominal yields or "tar bands": "4 mg or less," "8 mg or less," "12 mg or less,'' and ''16 mg or less'' (Winstanley, Woodward, & Walker, 1995). A ''2 mg or less'' tar band was added in 1989 and a ''1 mg or less'' tar band in 1990. Ruff (1994) reported the following market shares for each tar band in 1994: 1 mg or less: 4.8%, 2 mg or less: 7.6%, 4 mg or less: 13.2%, 8 mg or less: 28.3%, 12 mg or less: 28.9%, and 16 mg or less: 16.1%. Table 2 presents the mean values and standard deviations for yields and selected construction factors for non-menthol brands in each tar band (Ruff, 1994). Only 11 brands in the 1994 dataset did not use filter ventilation, and all were in the 12 mg or less and 16 mg or less tar bands. Mean percentage alkaloid content was highest in the 1 mg or less and 2 mg or less tar bands, although highest mean estimated alkaloid weight was in the 16 mg or less tar band. The lowest alkaloid content brands on either a percentage or total estimated weight basis were in the 4 mg or less, 8 mg or less, and 12 mg or less tar bands. Figure 1 presents a scatterplot of estimated total alkaloid weights of brands in each tar band. The upper value outliers are the Marlboro brand family and the lower value outliers are Rothmans brands.

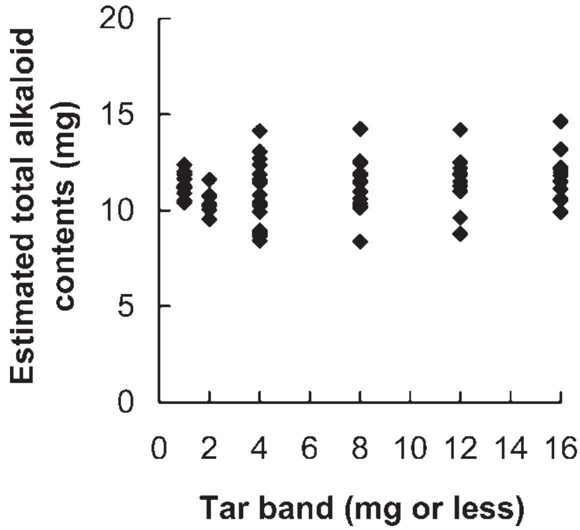

Figure 1. Alkaloid contents by tar band.

Comparisons between 1980 and 1994 datasets

Table 3 presents the median values and ranges for yields and various construction factors to enable broad comparisons between the 1980 and 1994 data sets. No figures are sales weighted, because market share was available only for the 1994 data set. Three sets of figures particularly stand out:

1. Tobacco rod weights were lower in 1994 than 1980, with the median value declining by 18%. The lowest weights in 1994 were in ''50s''—ultra-slim cigarettes in packs of 50, introduced in 1990.
2. Median percentage alkaloid content of tobacco rods increased from 1980 to 1994, whereas the ranges remained very similar. Median estimated total alkaloid weight declined by only 8% from 1980 to 1994.
3. The proportion of tested brands using filter ventilation rose markedly between 1980 and 1994, as did the median level of filter ventilation. The range of ventilation levels was wider in 1994.

Note that the 1980 dataset contains six brands with dual crepe/cellulose acetate filters, whereas all brands in the 1994 dataset had either single ($n=96$) or dual ($n=6$) cellulose acetate filters.

Table 4 presents correlation matrices for (a) the entire 1980 dataset, (b) nonventilated brands in the 1980 dataset, and (c) the entire 1994 dataset. For the entire 1980 dataset, tar yield correlated most strongly with filter weight, filter density, and percentage ventilation, and nicotine yield correlated most strongly with filter density, filter weight, and estimated total alkaloid weight. Exclusion of the six dual filter brands resulted in tar yields correlating most strongly with filter ventilation ($r=-.71$, $p<.01$), but nicotine

Table 2. Mean (*SD*) for yields and selected construction factors for the 1-mg, 2-mg, 4-mg, and 8-mg tar bands in 1994 dataset (not including menthol brands).

	Band					
	1 mg or less ($n=9$)	2 mg or less ($n=9$)	4 mg or less ($n=18$)	8 mg or less ($n=15$)	12 mg or less ($n=12$)	16 mg or less ($n=13$)
Tar yield (CPM), mg	1.29 (0.23)	2.36 (0.65)	3.41 (0.58)	6.4 (1.12)	8.91 (0.98)	10.87 (0.85)
Nicotine yield, mg	0.19 (0.03)	0.30 (0.04)	0.40 (0.08)	0.68 (0.10)	0.91 (0.11)	1.00 (0.13)
Carbon monoxide yield, mg	1.81 (0.27)	2.79 (0.89)	3.6 (0.63)	6.2 (0.90)	8.18 (1.17)	9.88 (0.78)
Filter weight, mg	141 (6.9)	123 (14.3)	119 (18.3)	103 (10.9)	97 (7.2)	92 (6.0)
Ventilation	77% (2.6)	69% (5.0)	62% (3.5)	36% (8.0)	21% (9.8)	4% (6.3)
Alkaloid content (dry weight basis), mg	2.46 (0.09)	2.46 (0.11)	2.27 (0.33)	2.30 (0.13)	2.36 (0.12)	2.36 (0.15)
Tobacco weight (12.5% OV), mg	523 (31)	496 (31.1)	543 (54.4)	549 (50.5)	558 (57.8)	564 (42.7)
Estimated total alkaloid weight, mg	11.34 (0.70)	10.64 (0.73)	10.74 (1.67)	11.06 (1.35)	11.53 (1.40)	11.64 (1.14)

Data from Ruff (1994).
CPM, corrected particulate matter; OV, oven volatiles.

Table 3. Descriptive statistics for 1980 and 1994 datasets (median values and ranges in brackets, unless indicated otherwise).

	1980	1994
Tar yield (CPM)	12 mg (4.9–16.3)	5.4 mg (1–12.4)
Nicotine yield	1.0 mg (0.30–1.4)	0.58 mg (0.16–1.24)
Carbon monoxide yield	13.5 mg (4.2–24)	5.3 mg (1.4–11.2)
Puff count	7.4 (5.3–10.2)	6.85 (5.6–8.5)
Total draw resistance	123 mmH_2O (81–153)	105 mmH_2O (55–145)
Porosity	48 ml/cm^2/min (27–220)	53 ml/cm^2/min (15–183)
Filter draw resistance	73 mmH_2O (50–108)	101 mmH_2O (58–148)
Filter length	20.0 mm (14.9–25)	20.9 mm (16.9–26)
Filter weight	108 mg (82–168)	109 mg (77–151)
Filter density	128 mg/cm^3 (100–156)	113 mg/cm^3 (81–153)
Filter ventilation		
n with some ventilation (i.e., % > 0)/*N*	10/41	91/102
Median (range) if % > 0	28% (18–59)	59% (6–80)
Median all	0%	48%
Tobacco rod weight (12.5% OV)	656 mg (530–868)	536 mg (435–685)
Alkaloid content (dry weight basis)	2.16% (1.6–2.6)	2.4% (1.6–2.6)
Estimated alkaloid weight	12.25 mg (8.23–14.67)	11.15 mg (8.16–14.63)

Data from Balint (1980, May) and Ruff (1994).
CPM, corrected particulate matter; OV, oven volatiles.

yields remained most strongly correlated with filter density ($r = -.52$, $p < .01$). When ventilated filter cigarettes were excluded from the 1980 dataset, the construction factors most strongly correlated with tar yield were total draw resistance, filter density, and filter draw resistance, and those most highly correlated with nicotine yield were filter density, estimated total alkaloid weight, and total draw resistance. When only ventilated brands were considered, tar yield was most strongly correlated with filter weight ($r = -.74$, $p < .05$) and tobacco weight ($r = .59$, $p = .07$), and nicotine yield was most strongly correlated with filter weight ($r = -.82$, $p < .01$), total alkaloid weight ($r = .76$, $p < .05$), and filter density ($r = -.67$, $p < .05$). Further, the correlations between tar and nicotine yields and ventilation level were nonsignificant ($r = -.43$, $p = .22$, and $r = -.21$, $p = .56$).

For the 1994 dataset, the construction factors most highly correlated with tar yield were percentage filter ventilation, filter draw resistance, and filter weight, and those most strongly correlated with nicotine yield were percentage filter ventilation level, filter draw resistance, and filter weight. The correlation between nicotine yield and estimated total alkaloid weight was highly significant but was low in comparison with the results for 1980. Exclusion of the 11 nonventilated brands from the analysis did not appreciably alter any of these results.

Table 5 presents the results of regression analyses for the 1980 and 1994 datasets, modelling tar and nicotine yields from RTD, paper porosity, filter RTD, filter length, filter weight, filter density, percentage ventilation, tobacco rod length, tobacco weight, percentage alkaloids, and estimated total alkaloid weight. The regression analyses were conducted stepwise, with criteria of F to enter, $p < .05$, and F to remove, $p > .1$. Between three and five sequential models were generated in each case. For the 1980 dataset, filter density accounted for more of the variance in tar and nicotine yields than any other variable, and the best models were able to account for 86% of variance in tar yields and 82% of variance in nicotine yields. For the 1994 dataset, percentage ventilation accounted for most of the variance in both tar yields (94%) and nicotine yields (90%). Adding other variables to the models improved the variance accounted for by 3% for tar yields and 6% for nicotine yields.

Discussion

We found that filter ventilation was the most important determinant of both tar and nicotine yields in Australian brands in 1994 and that nearly 90% of brands used filter ventilation. These findings are consistent with the findings of Kozlowski et al. (1998) concerning filter ventilation as a determinant of the tar and nicotine yields of Canadian, U.K., and U.S. cigarettes. High levels of filter ventilation enabled nominal tar yields to be reduced to as low as 1 mg in the 1990s and also enabled virtually all Australian manufactured brands in 1994 to have tar yields that met the ACCV's initial criterion for being called low tar. By contrast, filter density was the most important determinant of tar and nicotine yields in 1980, and several nonventilated low-tar brands were still available. Further, prior to around 1974, no low-tar brands in Australia had filter ventilation. Filter ventilation thus appears to have been introduced in Australia some time later than in the United Kingdom and the United States and to have penetrated the market more slowly.

Table 4. Correlation coefficients for key variables: all brands, 1980 ($n=41$); nonventilated brands, 1980 ($n=31$); all brands, 1994 ($n=102$).

	Tar yield	Nicotine yield	Carbon monoxide yield
All brands, 1980			
Nicotine yield	0.93**		
Carbon monoxide yield	0.82**	0.67**	
Puff count	0.16	0.30	−0.08
RTD	−0.15	−0.24	0.31*
Paper porosity	−0.06	−0.08	−0.10
Filter RTD	−0.55**	−0.53**	−0.16
Filter length	−0.27	−0.11	−0.32*
Filter weight	−0.66**	−0.61**	−0.45**
Filter density	−0.66**	−0.72**	−0.30*
Ventilation %	−0.63**	−0.46**	−0.88**
Tobacco rod length	0.25	0.30	0.23
Tobacco weight	0.21	0.22	0.09
Alkaloid %	0.24	0.44**	0.09
Estimated alkaloid weight	0.39*	0.59**	0.17
Nonventilated brands, 1980			
Nicotine yield	−0.91**		
Carbon monoxide yield	−0.75**	0.70**	
Puff count	0.51**	0.54**	0.57**
RTD	−0.81**	−0.64**	−0.52**
Paper porosity	−0.11	0.03	−0.09
Filter RTD	−0.73**	−0.54**	−0.37*
Filter length	0.12	0.30	−0.36*
Filter weight	−0.41*	−0.29	0.01
Filter density	−0.80**	−0.74**	−0.59*
Ventilation %	NA	NA	NA
Tobacco rod length	0.34	0.38*	0.56**
Tobacco weight	0.42*	0.37*	0.49**
Alkaloid %	0.22	0.46**	0.29
Estimated alkaloid weight	0.50**	0.65**	0.62**
All brands, 1994			
Nicotine yield	0.98**		
Carbon monoxide yield	0.98**	0.96**	
Puff count	−0.19	−0.12	−0.23*
RTD	0.52**	0.50**	0.55**
Paper porosity	0.10	0.19	0.07
Filter RTD	−0.89**	−0.90**	−0.85**
Filter length	−0.64**	−0.66**	−0.61**
Filter weight	−0.76**	−0.76**	−0.72**
Filter density	−0.71**	−0.69**	−0.68**
Ventilation %	−0.97**	−0.95**	−0.96**
Tobacco rod length	0.55**	0.60**	0.53**
Tobacco weight	0.32**	0.37**	0.30**
Alkaloid %	0.01	0.04	−0.03%
Estimated alkaloid weight	0.27**	0.33**	0.23*

Data from Balint (1980b) and Ruff (1994).
NA, not applicable; RTD, resistance to draw.
*$p<.05$, **$p<.01$.

As far as we could determine, the Australian tobacco industry did not publicize the introduction of filter ventilation, although it actively promoted most other yield-reduction innovations between the 1960s and the 1990s. We found no industry documents that explicitly addressed this anomaly. However, we did find Australian and overseas industry documents claiming that smokers' attention should not be drawn to filter ventilation, that invisibility is a desirable feature of particular types of ventilation, and that filter ventilation enables smoke doses to be tailored to individual smokers' needs (Brooks, Gingell, & Stephenson, 1980, pp. 2–5; Foster, 1975, p. 6; Hauni Technik, 1978, p. 9; Hausermann, 1980, p. 2). These internal communications provide an important context for interpreting tobacco industry silence about filter ventilation in Australia in the 1970s and 1980s. They also provide cause for concern. Given the evidence that filter ventilation is easily defeated by smokers' behaviors, it is probably the yield-reduction technology about which consumers and public health authorities could least afford to remain ignorant.

The transition from a market with a handful of low-tar brands, all nonventilated, to one in which low-tar brands held a substantial proportion of market share and all used filter ventilation, was more drawn out than we expected. It is possible that in the absence of publicity of the real innovations, the industry had difficulty convincing smokers that new low-tar brands were more satisfying than those they had tried in the past. It is also possible that it took the tobacco industry time to refine the technology and make

Table 5. Stepwise regression analyses predicting tar and nicotine yields for 1980 and 1994 datasets.

Variables entered	Variables removed	Adjusted r^2 of estimate	*SE*	*F* change	*df*1/*df*2
Predicting tar yields, 1980					
Filter density	–	0.42	2.23	30.15**	1/39
Ventilation %	–	0.75	1.47	51.25**	1/38
Estimated alkaloid weight	–	0.81	1.27	13.62**	1/37
Paper porosity	–	0.84	1.18	7.46*	1/36
Tobacco weight	–	0.86	1.09	7.02*	1/35
Predicting nicotine yields, 1980					
Filter density	–	0.50	0.18	40.72**	1/39
Ventilation %	–	0.64	0.15	16.62**	1/38
Estimated alkaloid weight	–	0.82	0.11	36.52**	1/37
Predicting tar yields, 1994					
Ventilation %	–	0.94	0.79	1610.35**	1/99
Alkaloid weight	–	0.96	0.63	62.39**	1/98
Filter RTD	–	0.97	0.57	19.70**	1/97
Porosity	–	0.97	0.54	11.84**	1/96
Predicting nicotine yields, 1994					
Ventilation %	–	0.90	0.09	879.90**	1/99
Alkaloid weight	–	0.94	0.07	78.75**	1/98
Filter RTD	–	0.95	0.06	21.29**	1/97
Porosity	–	0.96	0.06	8.12**	1/96

Data from Balint (1980b) and Ruff (1994).
RTD, resistance to draw.
*$p<.05$, **$p<.01$.

ventilated filter low-tar cigarettes more attractive to consumers than older style low-tar cigarettes or regular cigarettes. One more recent refinement of ventilated filter low-tar cigarettes that may have made them attractive to a broader range of smokers was an increase in alkaloid contents, especially in the lowest yielding brands. The estimated total alkaloid weights of all 18 brands in the 1-mg and 2-mg tar bands in the 1994 dataset exceeded the estimated total alkaloid weight of Hallmark Dual Filter in 1980. Further, a report by the Australian Consumers Association (1993) showed that when five brands in the 1-mg and 2-mg tar bands were yield tested with filter ventilation fully blocked, all had higher tar and nicotine yields than Hallmark Dual Filter in 1980. This result, taken together with our comparative data on filter weights and densities, is not consistent with the lowest yielding brands in 1994 having higher filtration efficiencies than the lowest yielding non-ventilated brands in earlier years. We do not know how the nicotine deliveries gained from 1-mg and 2-mg brands in the 1990s compared with deliveries gained from the lowest yielding brands in earlier years. However, these results are consistent with yield decreases after 1980 generally being accompanied by changes in construction that made compensation easier.

Kozlowski and O'Connor (2002) have argued that filter ventilation should be banned. Our findings show that such a ban would have a substantial impact on the existing market in Australia. However, the public health benefits would be substantial. First, such a ban would remove what appears to be a highly effective device for titrating nicotine intakes, potentially reducing addictiveness. Second, it would keep smokers from believing they were consuming less dangerous products, because of the increased mildness and reduction in irritation that comes from taking a more dilute puff. Third, it could increase the relative utility of the FTC/ISO yield figures, because remaining low-tar brands would potentially be less conducive to compensation. Finally, it would limit the amount of downswitching that smokers could engage in before having to seriously contemplate quitting, because the yield ranges would be considerably reduced.

Even more benefits can be expected if a ban on filter ventilation is supplemented with other measures. Although a ban on filter ventilation could be expected to increase the relative utility of the FTC/ISO yield test, it would remain inadequate for public health purposes. FTC/ISO tar yields are clearly inadequate to index potential exposures to some important carcinogens (most notably the tobacco-specific nitrosamines), even without taking compensation into account (Hoffman et al., 1997; Gray et al., 2000). However, regulation of potential exposures to specific carcinogens and other toxic smoke constituents is required if smokers' disease risks are to be better managed (Bates, McNeill, Jarvis, & Gray, 1999; Gray, 2000). Further, ongoing use of FTC/ISO yields can be expected to result in many smokers continuing to gain misleading impressions about their relative disease risks, even if available brands become less conducive to compensation than at present. Accordingly, the most prudent approach during development of a new emission measurement system would be to assume that no relative health benefits can be gained from brand switching and to prevent communications inviting belief that certain products are safer. This would mean an end to printing FTC/ISO yields on packs and incorporating "light" and "mild" descriptors in brand names.

Acknowledgments

This study was supported by the U.S. National Institutes of Health (grant 1 R01 CA87110-01A1) and the Victorian Health Promotion Foundation. For technical advice and assistance with information gathering and data analysis, the authors thank James Balmford, Fiona Byrne, Stacy Carter, Claudine Chapeau, Simon Chapman, Helen Dixon, Carolyn Ford, Michael Fotheringham, Nigel Gray, David Hill, Peter Joza, Renata Lacevic, Anita Lal, Murray Laugesen, Jane Martin, Timoli Nixon, Bill Rickert, Michelle Scollo, Cathy Segan, and Mohammad Siahpush. Thanks to Simon Chapman and Nigel Gray for reading earlier drafts and to the reviewers of the first-submitted version for their helpful suggestions.

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