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Residual tobacco smoke pollution in used cars for sale: Air, dust, and surfaces

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Residual tobacco smoke pollution in used cars for sale: Air, dust, and surfaces

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Regular tobacco use in the enclosed environment of a car raises concerns about longer-term contamination of a car's microenvironment with residual secondhand smoke pollutants. This study (a) developed and compared methods to measure residual contamination of cars with secondhand smoke, (b) examined whether cars of smokers and nonsmokers were contaminated by secondhand smoke, and (c) how smoking behavior and restrictions affected contamination levels. Surface wipe, dust, and air samples were collected in used cars sold by nonsmokers (n=20) and smokers (n=87) and analyzed for nicotine. Sellers were interviewed about smoking behavior and restrictions, and car interiors were inspected for signs of tobacco use. Cars of smokers who smoked in their vehicles showed significantly elevated levels of nicotine (p<.001) in dust, on surfaces, and in the air compared with nonsmoker cars with smoking ban. When smokers imposed car smoking bans, air nicotine levels were significantly lower (p<.01), but dust and surface contamination levels remained at similar levels. Smoking more cigarettes in the car and overall higher smoking rate of the seller were significantly associated with higher secondhand smoke contamination of the car (p<.001). Use of a cutpoint for nicotine levels from surface wipe samples correctly identified 82% of smoker cars without smoking bans, 75% of smoker cars with bans, and 100% of nonsmoker cars. Surface nicotine levels provide a relatively inexpensive and accurate method to identify cars and other indoor environments contaminated with residual secondhand smoke. Disclosure requirements and smoke-free certifications could help protect nonsmoking buyers of used cars.

Introduction

Secondhand smoke is a complex and dynamic mixture of more than 4,000 chemicals, many of which are irritants, toxins, mutagens, and carcinogens in humans (California Environmental Protection Agency, 1997; U.S. Surgeon General, 1986). It is well understood that tobacco smoked in the enclosed environments of passengers cars can cause extremely high air concentrations and exposure to secondhand smoke pollutants (Offermann, Colfer, Radzinski, & Robertson, 2002; Ott, Klepeis, & Switzer, 2007; Park et al., 1998; Rees & Connolly, 2006; Zhou, Li, Zhou, & Haug, 2000). Recent research indicates that tobacco smoked in indoor environments may pose additional, longer-term risk of secondhand smoke exposure (Daisey, 1999; Daisey, Hahanama, & Hidgson, 1998; Matt et al., 2004; Singer, Hodgson, Guevara, Hawley, & Nazaroff, 2002). This is because volatile secondhand smoke components (e.g., nicotine, naphthalene) adsorb into surfaces within minutes of emission. Subsequently, this residual secondhand smoke is re-emitted from contaminated surfaces into the air over days and weeks, accumulates in dust, and deposits on surfaces. Similarly, secondhand smoke particulate matter trapped in a car eventually deposits and accumulates on surfaces. Sunlight, extreme temperature, and limited air exchange in a car that is not in use facilitate further chemical reactions and adhesion of secondhand smoke pollutants to dust and surfaces.

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Research from controlled laboratory studies suggest that some materials used in car interiors may be particularly good secondhand smoke reservoirs, including upholstery, carpeting, and ceiling liners (Cieslak & Schmidt, 2004; Van Loy et al., 1997). This raises concerns that cars remain contaminated with tobacco pollutants long after cigarettes have been smoked in them. However, cars might be ventilated through opening windows or air-conditioning systems, facilitating the removal of contaminants. While there is research on the air pollution levels reached in cars during active smoking (Park et al., 1998; Rees & Connolly, 2006; Zhou et al., 2000), there are no studies examining lingering tobacco smoke pollution of cars. Therefore, we examined whether cars of smokers are contaminated with residual secondhand smoke and whether contamination levels are affected by smoking behavior and restrictions.

A secondary aim of this study was to determine if the odor of residual secondhand smoke is associated with nicotine contamination of used cars. Comprehensive research reviews by the U.S. Surgeon General (U.S. Surgeon General, 1986, 2006), the National Research Council (National Research Council, 1986), and the California Environmental Protection Agency (California Environmental Protection Agency, 1997) as well as research conducted by the tobacco industry (Dravnieks, O'Connell, & Reilich, 1975) indicate that secondhand smoke contains many odorant compounds (e.g., pyridine, pyrrole, pyrazine, benzene) that are experienced as unpleasant, making offensive secondhand smoke odor a common complaint among nonsmokers. The Surgeon General Report (U.S. Surgeon General, 2006) concludes "The evidence is sufficient to infer a causal relationship between secondhand smoke exposure and odor annoyance" (p. 546). If cars of smokers are contaminated with secondhand smoke, potential buyers may be able to detect secondhand smoke odor and other visible signs of tobacco use, which may help buyers purchase uncontaminated cars.

In summary, this study compared different measures of secondhand smoke contamination of cars, examined whether dust, surfaces, and air in cars of smokers were contaminated by secondhand smoke, how smoking behavior and restrictions affected levels of secondhand smoke, and whether signs of tobacco use in a car are associated with secondhand smoke contamination.

Methods

Participants

Forty nonsmokers and 87 smokers were recruited between January 2005 and April 2006 who had advertised a used car for sale in the San Diego (USA) print editions of the *Auto Trader* magazine, a popular weekly publication for used cars. To qualify, sellers had to be 18 years or older and be the owner and primary user of the car for at least the past year. To be eligible for the *nonsmoker group* with smoking ban, a seller may not have smoked cigarettes in the past 12 months, and no cigarettes may have been smoked in the car by other drivers or passengers. To be eligible for the *smoker group*, sellers must have currently smoked on average at least one cigarette per week. We further distinguished between smokers with and without car smoking bans. Qualifying sellers were invited to participate in a study on cigarette smoking in cars and an appointment was made to visit the seller for an interview and to examine the car. Table 1 provides descriptive information about the sellers and their cars. The Institutional Review Board at San Diego State University approved the research protocol.

Measures

Face-to-face interviews. Sellers were interviewed about their personal background, car, tobacco use of drivers and passengers, and smoking restrictions in the car. The following smoking behaviors were computed based on multiple interview questions: (a) The *number of cigarettes smoked by the seller per week* is a weighted average of cigarettes smoked anywhere on workdays and nonworkdays during an average week over the past year. (b) The *number of cigarettes smoked in the car per week* is the number of cigarettes smoked by the seller, other drivers, and passengers in the car during an average week over the past year.

Direct observation. Interviewers rated the following signs of tobacco use in the car using a 3-point rating scale (none, some, a lot): stains, burn marks, use of ashtray, and odors. An overall index of tobacco use signs was created by summing the four ratings. The index has an intraclass correlation of .81, indicating good internal consistency.

Environmental samples. Dust, surface, and air samples were collected in all smoker cars and 50% of nonsmoker cars. To determine *surface nicotine* levels, prescreened cotton wipes were wetted with 1.5 ml of 1% ascorbic acid and then wiped over a 100-cm^2 area on the dashboard. This is a modification of a wipe method developed by us previously (Matt et al., 2004). Wipes were placed in glass vials, transported in coolers, and stored at $-20°C$ for analysis. Prior to extraction, deuterated internal standards were added: nicotine d_3 (CDN Isotopes Inc., Pointe Claire, Quebec, Canada) and cotinine d_4 (Aldrich Chemical Company Inc., Milwaukee, WI). One

Table 1. Characteristics of sellers and their cars.

	Nonsmoker cars, car smoking ban (*N*=40)	Smoker cars, car smoking ban (*N*=8)	Smoker cars, no ban (*N*=79)
Seller			
Gender (% female)	36	25	23
Age (years)[a]	38	34	33
Current smokers (% past month)			
Not at all	100	0	0
Some days	0	38	41
Everyday	0	62	59
Number of cigarettes smoked (week) [a]			
Seller: anywhere	0	38.0	39.5
All drivers and passengers: in car	0	0	15.6
Car			
Age[a]	7.1	5.3	7.2
Mileage[a]			
Total	58,924	54,876	88,262
Past year	8,135	8,944	10,303
Asking price ($)	8,868	6,131	5,269
Make (%)			
American	50.0	62.5	50.6
European	20.0	0	24.1
Japanese	27.5	25.5	22.8
Other	2.5	12.5	2.5
Smoking signs in car (%)			
Burn marks	0	14.3	31.4
Ash marks	0	14.3	30.0
Odor	0	28.6	51.4
Used ashtray	0	0	38.2

Note. [a]Geometric mean.

molar KOH (aqueous) was added and the sample vortexed. Methylene chloride was then added, the sample vortexed, the wipes pushed to the bottom with a glass rod while the top layer was removed to a clean amber vial. The sample was evaporated, and nicotine mobile phase (80% acetonitrile, 20% ddH_2O, in pH 5 buffer of 40 mM ammonium formate, pH adjusted by formic acid) was added, vials were crimped, and the sample stored in the dark until analysis with HPLC–tandem mass spectrometry. The coefficient of variation (CV) of the method was <5% for duplicates and <10% for replicates in this study. Results are expressed in µg of nicotine per m^2 of surface area. The detection limit was approximately 0.10 µg/m^2. Nicotine levels on blanks were subtracted from those determined on the wipes, and the corrected levels are reported. Wipe field blank values were a median of 6.1 ng nicotine/wipe (25th percentile, 4.1 ng/wipe, 75th percentile, 9.9 ng/wipe). The median CV for replicate measures of surface nicotine was CV=10.2%, indicating that the measurement error was small relative to the amount of nicotine detected in dust samples.

To determine *dust nicotine* level, dust samples were collected with a High-Volume-Small Surface-Sampler (HVS4, CS3 Inc., Bend, OR) from car floors and upholstery. Dust samples were collected into methanol-washed Teflon bottles, transported cooled, weighed, and sieved with a stainless steel, methanol-washed, 150-µm mesh sieve, weighed again, and 50 mg removed to a glass vial with a Teflon-lined cap. An aliquot of 10% acetic acid (aqueous) was added to stabilize the nicotine, and the sample was stored at −20°C until analysis. Samples were processed in a manner similar to wipe samples, except that ethyl ether was used to elute nicotine and the eluent removed to a clean vial and centrifuged before analysis. The results are expressed as µg of nicotine per g of dust. The detection limit was approximately 0.2 µg nicotine/g dust, based on detection of 10 ng in a 50-mg sieved dust sample. The median CV for replicate measures of dust nicotine was CV=2.6%, indicating that the measurement error was very small relative to the amount of nicotine detected in dust samples.

To determine *air nicotine* levels, an air sample was collected in the car's interior with a passive diffusion monitor badge that was placed in the car at the time of the on-site inspection. One week later or when the car was sold (whichever came first), they were removed and mailed back to the research office by the owner following instructions for handling the badges. The number of minutes exposed was recorded. The badges consisted of a modified 37-mm 3M Organic Vapor Monitor (3-M, St. Paul, MN) with a Teflon filter coated with a glycerol / phosphoric acid mixture. (Filter collector was modified from Kuusimaki et al., 1999.) The filters were then processed as for wipe samples, and results are expressed as µg of nicotine per m^3 of air. The sampling rate was empirically determined to be 18.4 ml/min at room temperature and >25 ft/min face velocity, and this sampling rate was used in air calculations. Actual sampling rates would likely vary because of undersampling in still air and over-sampling in high ventilation conditions. As each subject's use of car, window position, speeds driven, etc, would affect air movement and were not controlled in this study, the air values reported here must be considered approximate. The limit of detection was approximately 0.0053 μg/m^3 for a 7-day exposure, based on 11 ng detected on the filter and subtracting a 10-ng blank, and assuming a 18.4-ml/min sampling rate. Nicotine levels found on blanks were subtracted from those determined on the exposed air monitors, and the corrected levels are reported. Air filter blanks were a median of 1.9 ng nicotine/ filter (25th percentile, 0.9 ng/wipe, 75th percentile, 3.4 ng/wipe). The median CV for duplicate measures of air nicotine was CV=2.1%, indicating that the measurement error was very small relative to the amount of nicotine detected in the air samples.

Statistical analyses

Statistical analyses were conducted using Stata version 9.2 (StataCorp, 2006). All measures of secondhand smoke contamination and smoking behavior were subjected to logarithmic transformation before analyses were conducted to deal with skewed distributions and to stabilize variances. Associations between measures were examined using Spearman rank order and Pearson product moment correlations, depending on the scale of the measures. Statistical significance was set at $\alpha=0.05$ for two-tailed tests.

To examine how well surface, dust, and air nicotine levels can discriminate between smoker and nonsmoker cars, we determined cut-offs based on their highest combined sensitivity and specificity. Differences in secondhand smoke contamination between groups were tested via Tobit regression models for censored data, and we used robust bootstrap estimates of standard errors to protect against the undue influence of outliers. Associations between ordinal ratings of signs of tobacco use and secondhand smoke contamination were examined using ordered logistic regression models with robust standard errors based on the Huber–White sandwich estimator of variance.

Results

Nicotine contamination of smoker and nonsmoker cars

Table 2 presents means, confidence intervals, and other descriptive information about the contamination of dust, surfaces, and air with secondhand smoke as indicated by nicotine levels. Table 3 shows correlation among measures of secondhand smoke pollution.

Surfaces

Nicotine contamination of surfaces could be detected in 24% of nonsmoker cars, 88% of smoker cars with ban, and 92% of smoker cars without smoking ban. Nicotine levels in smoker cars with ban (M=5.09 μg/m^2; $p<.001$) and without ban (M=8.61 μg/m^2; $p<.001$) were significantly higher than those of nonsmokers with car smoking ban (M=0.06 μg/m^2; overall model fit: $\chi^2(2)=38.30$, $p<0.001$; pseudo $R^2=.14$). That is, regardless of a smoking ban, surfaces in smoker cars were contaminated with residual secondhand smoke. Nicotine levels in smoker cars with smoking bans did not differ from those in smoker cars without smoking ban (M=5.09 vs. 8.61 μg/m^2; $p=.430$). Mean surface nicotine concentrations in smoker cars with and without smoking ban were more than 80 and 140 times higher than levels in nonsmoker cars with ban.

A surface nicotine level cut-off of 0.14 μg/m^2 correctly classified 82% of smoker cars without smoking bans (i.e., sensitivity) and 100% of nonsmoker cars (i.e., specificity). The same cut-off allowed correct classification of 75% of cars of smokers with a car smoking ban.

Dust

Nicotine levels in smoker cars with ban (M=11.61 μg/g; $p=.029$) and without ban (M=19.51 μg/g; $p<.001$) were significantly higher than those of nonsmokers with car smoking ban (M=3.37 μg/g; overall model fit: $\chi^2(2)=24.97$, $p<.001$; pseudo $R^2=.14$). That is, regardless of a smoking ban, dust in cars of smokers was more contaminated with residual secondhand smoke than cars of nonsmokers. Compared with nonsmoker cars, mean dust nicotine concentrations in smoker cars with and without smoking bans were more than three and five times higher, respectively. Nicotine levels in smoker cars with smoking bans did not differ from those in cars with smoking ban (11.61 vs. 19.51 μg/g; $p=.259$).

A dust nicotine level cut-off of 6.18 μg/g yielded the highest combined percentage of sensitivity and specificity for distinguishing between nonsmoker cars and smoker cars without smoking ban. Based on this cut-off, 81% of smoker cars (i.e., sensitivity) and 80% of nonsmoker cars (i.e., specificity) could be correctly classified. The same cut-off allowed correct identification of 75% of cars of smokers with a car smoking ban.

Air

Nicotine contamination could be detected in 53% of nonsmoker cars, 67% of smoker cars with ban and 89% of cars without smoking ban. Nicotine levels in smoker cars with ban (M=.06 μg/m^3; $p=.460$) did not differ significantly from those in nonsmoker cars

Table 2. Residual secondhand smoke contamination of dust, surfaces, and air in used cars for sale by nonsmokers and smoker.

	Seller: nonsmoker	Seller: smoker	
Nicotine concentration	With car smoking ban	With car smoking ban	Without car smoking ban
Dust [μg/g]			
Mean[d]	3.37[a,b]	11.61[a]	19.51[b]
95% *CI*	2.06–6.20	3.38–36.28	14.51–26.12
Quartiles: 25–50–75	1.5–3.1–6.0	4.4–14.6–25.8	7.7–18.5–47.9
Range	0.2–20.3	1.1–76.9	0–609.6
% >LOD[e]	100	100	99
% Correct classifications[f]			
Cut-off=6.18	80	75	81
n	20	8	78
Surface [μg/m^2]			
Mean[d]	0.06[a,b]	5.09 [a]	8.61[b]
95% *CI*	0.00–0.12	0.66–22.39	5.32–13.63
Quartiles: 25–50–75	0.0–0.0–0.07	0.6–3.4–9.4	0.8–5.9–31.5
Range	0–0.3	0–131.8	0–792.2
% >LOD[e]	24	88	92
% Correct classifications[f]			
Cut-off=0.14	100	75	82
n	17	8	78
Air [μg/m^3]			
Mean[d]	0.02[b]	0.06[c]	0.74[b,c]
95% *CI*	0.00–0.05	0.01–0.11	0.47–1.07
Quartiles: 25–50–75	0.00–0.01–0.01	0.02–0.07–0.08	0.05–0.29–1.50
Range	0.0–0.2	0.0–0.1	0.0–18.2
% >LOD[e]	53	67	89
% Correct classifications[f]			
Cut-off=0.02	88	67	74
n	17	6	70

Note. Reported means, confidence intervals, quartiles and ranges for surfaces and air are corrected for nicotine levels found on blanks. [a]$p<.05$; difference between nonsmoker cars and smoker cars with smoking ban. [b]$p<.001$; difference between nonsmoker cars with smoking ban and smoker cars without ban. [c]$p<.01$; difference between smoker cars with smoking ban and smoker cars without ban. [d]Geometric mean. [e]Limit of detection; dust: 0.2 μg of nicotine per gram of dust; surface: 0.1 μg nicotine per square meter; 0.0053 μg of nicotine per cubic meter. [f]Specificity: % correct classifications for nonsmoker cars; sensitivity: % correct classification of smoker cars.

with bans (M=0.02 μg/m^3; overall model fit: $\chi^2(2)=16.74$, $p<.001$; pseudo $R^2=.21$). However, air nicotine concentrations in smoker cars without ban (M=0.74 μg/m^3) were significantly higher than those in nonsmoker cars ($p<.001$) and those in smoker cars with a smoking ban ($p<.001$). That is, smoking bans appear to reduce air contamination levels in cars of smokers. Compared with nonsmoker and smoker cars with smoking bans, mean air nicotine concentrations in smoker cars without bans were 37 and 12 times higher, respectively.

An air nicotine level cut-off of 0.02 μg/g correctly identified 74% of smoker cars without smoking bans (i.e., sensitivity) and 88% of nonsmoker cars (i.e., specificity). The same cut-off allowed correct classification of 67% of cars of smokers with a car smoking ban.

Smoking behavior and nicotine contamination

The number of cigarettes smoked in the car and the total number of cigarettes smoked by the seller were

Table 3. Correlations between environmental samples of nicotine (dust, surfaces, and air) and observable signs of tobacco use in used cars.

	Nicotine			Observable signs			
	Dust	Surface	Air	Burn	Ash	Odor	Ash tray
Dust	1.00						
Surface	0.65	1.00					
Air	0.60	0.61	1.00				
Burn marks	0.07[a]	0.26	0.25	1.00			
Ash stains	0.32	0.39	0.33	0.51	1.00		
Odor	0.36	0.55	0.43	0.41	0.46	1.00	
Ash tray use	0.18[a]	0.34	0.40	0.31	0.59	0.41	1.00

Note. [a]Not statistically significant ($p>.05$); all others are significant ($p<.05$).

associated with nicotine concentrations of dust ($\chi^2[2]=45.46$, $p<.001$; pseudo $R^2=.25$), surfaces ($\chi^2[2]=54.39$, $p<.001$; pseudo $R^2=0.20$), and air ($\chi^2[2]=30.04$, $p<.001$; pseudo $R^2=0.38$). In each model, the total number of cigarettes smoked by the seller was associated with nicotine levels independent of the number of cigarettes smoked in the car (changes in pseudo R^2 for dust: 0.07; wipe: 0.08; air: 0.10). This suggests that tobacco use outside the car may contribute to the secondhand smoke contamination of a car's interior in addition to tobacco use in the car. It may also suggest that heavy smokers may smoke more often in the car than reported.

Signs of tobacco use and nicotine contamination

Secondhand smoke odor and ash marks were significantly ($p<.05$) associated with nicotine contamination of dust ($r=0.36$ and 0.32, respectively), surfaces (0.55, 0.39) and air (0.43, 0.33). For burn marks and used ash trays, only correlations with surface wipes (.26; .34) and air nicotine levels (.25; .40) were significant. Table 3 presents all intercorrelations among signs of tobacco use and nicotine contamination.

Figure 1 illustrates the relationships between secondhand smoke odor and nicotine contamination of dust, surfaces, and air. In this graph, nicotine concentrations were standardized such that the mean level is 1.0 for cars without noticeable odor. Therefore, the plotted values show the factors by which nicotine concentrations in cars with "some" and "strong" secondhand smoke odor differ from those with "none". Consistent with the reported correlations, the graph illustrates that cars with stronger secondhand smoke odor showed higher nicotine contamination levels. This was most pronounced for surface contamination. Used cars rated to have strong secondhand smoke odor had surface nicotine levels that were more than 30 times higher than those in cars with "no" secondhand smoke odor ($M=2.58\,\mu g/m^2$) and about 10 times higher than those in car with "some" odor. Dust nicotine concentrations in cars with "strong" odor were approximately five times higher than those in cars with "no" odor ($M=9.75\,\mu g/g$). Similarly, air nicotine levels in cars with strong secondhand smoke odor were eight times higher than those in cars with "no" secondhand smoke odor ($M=0.29\,\mu g/m^3$).

Discussion

This is the first study to examine whether used cars are polluted with residual secondhand smoke at the time they are offered for sale and whether cars of active smokers can be distinguished from those of nonsmokers based on nicotine levels in the dust, air, and on surfaces of a car.

Residual tobacco smoke pollution of used cars

This study shows that smokers leave behind in their cars dust, surfaces, and air that are contaminated

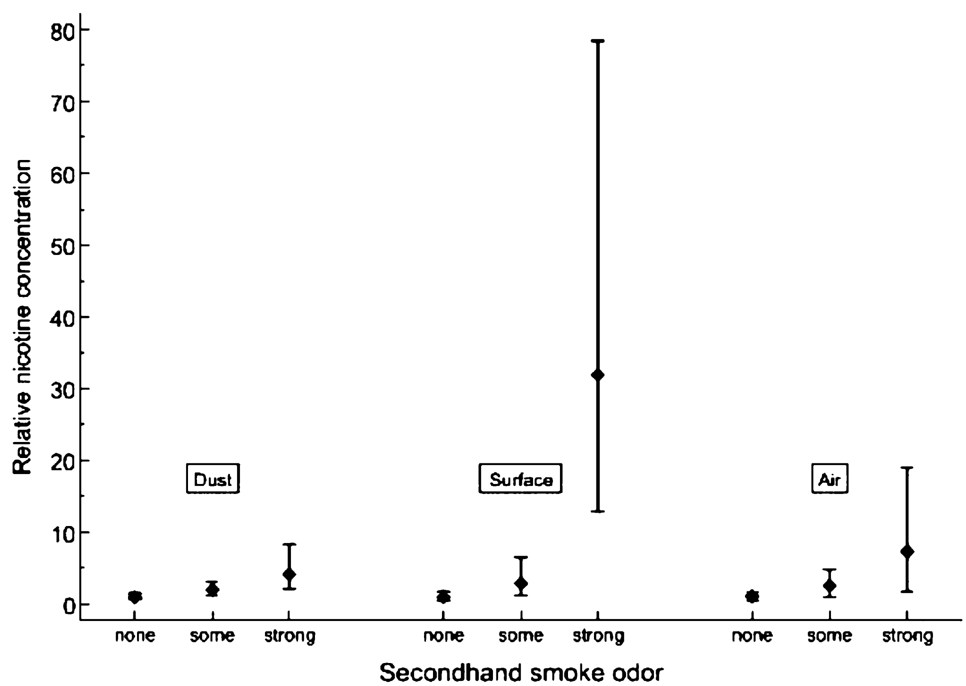

Figure 1. Relative nicotine concentrations (geometric means and their 95% confidence intervals) in dust, surface, and air for used cars with no, some, and strong secondhand smoke odor. Nicotine concentration is standardized to be 1.0 in cars without secondhand smoke odor; i.e., 1 is equivalent to $9.75\,\mu g/g$ of dust, $2.58\,\mu g/m^2$ of surfaces, $0.29\,\mu g/m^3$ of air.

with residual secondhand smoke. At the time they are offered for sale, the used cars of smokers showed significantly elevated levels of residual secondhand smoke of dust, surfaces, and the air compared with low level contamination found in nonsmoker cars with smoking bans.

Surfaces and dust in a car are likely to be the primary reservoirs storing tobacco smoke pollutants when a used car changes ownership. Dust and surface wipe samples were collected in the absence of active smoking, and nicotine found on these media had to be deposited at an earlier time point during active smoking. In contrast, air samples were collected over the course of several days and represent an average air nicotine level, combining nicotine emitted during active smoking and nicotine emitted through desorption from contaminated media (e.g., dust, and surfaces). Air nicotine levels may be quickly lowered through increasing air exchanges (e.g., ventilation systems, driving with an open window, and through the high air exchanges common at highway speeds), replacing contaminated air with fresh uncontaminated air. Lowering dust and surface contamination is more difficult, because contaminants stick to and are trapped on surfaces and as microscopic dust deep in carpets and upholstery throughout the entire vehicle.

Distinguishing nonsmoker and smoker cars

Nicotine levels detected on surfaces, in dust, and in the air discriminate very well between cars sold by smokers and nonsmokers. Overall, nicotine measures based on surface wipes not only were equivalent or superior to measures based on dust or air samples, they were also less costly to collect and to analyze. Compared with dust samples, we estimate that wipe samples cost approximately $30 less per sample because of lower labor costs associated with field collection, sample preparation, and laboratory analyses. All three methods are applicable to other indoor settings and have been successfully tested in homes and apartments (Matt et al., 2004).

Smoking bans and secondhand smoke contamination

Our findings show that a car smoking ban significantly reduced air nicotine levels in a car. In fact, air nicotine levels in smoker cars with bans were not significantly different from those found in nonsmoker cars. However, car smoking bans did not significantly reduce residual contamination of dashboard surfaces and dust trapped in carpeting and upholstery. To understand this differential effect, it should be recalled that car smoking ban was defined as cigarette smoking was not allowed and no cigarettes had been smoked in the car during the previous year. That is, cigarettes may have been smoked in the car before the introduction of the smoking ban. If this was the case, the nicotine contamination of surfaces and dust of smoker cars after abstaining from smoking in the car suggest that residual secondhand smoke contamination is a long-term problem, likely to persist after the used car of a smoker has been sold.

The nicotine contamination of cars sold by smokers with a car smoking ban may have other sources. Secondhand smoke can drift into the car from outside. It may be exhaled by smokers in the car after cigarettes were smoked outside, and it can be carried on clothes, hair, and the skin from where it may be released in a car. The hypothesis that secondhand smoke pollutants are transported into the car is supported by our finding that the total number of cigarettes smoked by the primary driver accounted for a significant proportion of variance in secondhand smoke contamination independent of the number of cigarettes smoked specifically in the car. Finally, a car smoking ban is a voluntary personal policy, and smokers may find it especially difficult to abstain from smoking in the privacy of their own car when the circumstances make smoking outside uncomfortable or unsafe.

Observable signs of tobacco use and secondhand smoke contamination

Our findings show that secondhand smoke odor, ash and burn marks, and used ashtrays are not just nuisances and signs that tobacco has been smoked in a car, but that the microenvironment of the car is currently contaminated with persistent residual secondhand smoke. The strongest relationship was observed between secondhand smoke odor and nicotine surface contamination, suggesting that surfaces are an important source for odorant secondhand smoke pollutants. The literature indicates that pyridine and its derivatives make up the strongest odorant components of secondhand smoke (Dravnieks et al., 1975; U.S. Surgeon General, 2006). This is, surfaces may not only be a reservoir for nicotine but also for other compounds that contribute to lingering secondhand smoke odor.

The 2006 Surgeon General's report (U.S. Surgeon General, 2006) concluded that there is a causal relationship between secondhand smoke exposure and odor. Our findings expand on this conclusion by demonstrating that strength of odor is associated with the level of secondhand smoke contamination. In combination, these findings suggest that lingering secondhand smoke odor may serve as a proxy of secondhand smoke contamination and exposure.

This study focused on residual secondhand smoke contamination that remains trapped in a car when it is sold. Research on the chemical composition and physical behavior of tobacco smoke indicates that residual secondhand smoke consists of a subset of compounds of recently emitted secondhand smoke that has lower volatility and higher sorbing properties (e.g., nicotine, phenol, cresols, naphthalene, methylnaphthalenes, 3-ethylpyridine) (Singer et al., 2002). Our findings on secondhand smoke odor suggest that this may also include pyridine, pyrrole, pyrroline, pyrazine, and related derivates.

Although there is currently little known about the specific health effects of exposure to lingering secondhand smoke, also known as thirdhand smoke (Szabo, White, & Hayman, 2006), there are several reasons why residual secondhand smoke pollution of cars should not be ignored. First, residents of industrialized countries spend significant amounts of time in automobiles. For instance, the average vehicle in the U.S. is driven approximately 12,000 miles per year, and adults spend on average 250–300 hours per year in a car (U.S. Census Bureau, 2005). Second, the overall toxicity of lingering tobacco smoke pollutants is a function of many semi-volatile secondhand smoke constituents (only some of which are odorous) that are correlated with residual nicotine levels (Singer, Hodgson, & Nazaroff, 2003). Some of the most toxic secondhand smoke constituents (e.g., PAHs, tobacco-specific nitrosamines) are present a lower levels and are more difficult to detect by regular analytical methods than is nicotine. Yet, these toxic constituents pose a higher risk in terms of secondhand smoke toxicity than nicotine. That is, nicotine serves as a surrogate tracer of several other secondhand smoke constituents. Third, lingering tobacco smoke pollutants are the basis for the possible formation of secondary pollutants generated in reactions of sorbed nicotine (and other pollutants) with ozone and other atmospheric oxidants. These reactions can become a long-term source of volatile irritant pollutants such as formaldehyde and other aldehydes (Destaillats, Singer, Lee, & Gundel, 2006).

This study suggests that surface wipe samples provide a convenient method to identify cars polluted with tobacco smoke with good sensitivity and specificity. Such a method could help in developing tobacco control policies to assist consumers in making informed decisions about purchasing, selling, or riding in cars that are contaminated with lingering tobacco smoke pollutants. One possible policy direction involves educating consumers and used car dealers about the pollution of used cars with secondhand smoke when previous owners were smokers or allowed smoking in the car. For such education efforts to work, a certification process would have to be available that provides buyer and sellers with a valid independent assessment of the secondhand smoke pollution of a car. Until such a certification process is widely available, buyers should trust their nose and ask sellers about tobacco use.

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