



## Frequency and longitudinal trends of household care product use

Rebecca E. Moran<sup>a</sup>, Deborah H. Bennett<sup>a,\*</sup>, Daniel J. Tancredi<sup>b</sup>, Xiangmei (May) Wu<sup>a</sup>, Beate Ritz<sup>c</sup>, Irva Hertz-Picciotto<sup>a</sup>

<sup>a</sup> Department of Public Health Sciences, University of California, Davis, CA, United States

<sup>b</sup> Department of Pediatrics, University of California, Davis, CA, United States

<sup>c</sup> Department of Public Health Sciences, University of California, Los Angeles, CA, United States

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### ABSTRACT

The use of household cleaning products and air fresheners exposes people to a variety of chemicals, including some that have been shown to be irritants, potential carcinogens and endocrine disrupting compounds. In addition, some react with ambient ozone infiltrating to the indoor environment to form potentially toxic secondary pollutants. Although realistic estimates of usage patterns are necessary for modeling potential exposures in risk assessments, few studies have documented cleaning habits and product usage to characterize how they vary between households and over time. In addition, understanding within-household temporal variability of use is important to assess the reliability of exposure questionnaires used in epidemiological surveys and improve the cost-efficiency of data collection. In the SUPERB (Study of Use of Products and Exposure-Related Behavior) study, frequencies of use of eight types of household cleaning products and air fresheners and the performance of different types of cleaning tasks are collected in three annual telephone and six quarterly web-based surveys. All-purpose and glass cleaners were the products most frequently used among all products surveyed. Use frequencies differed by demographic and other household characteristics for some products. Product usage was internally consistent, with over 75% of pairwise cross-sectional correlations between product types statistically significantly different from zero. In addition, each product type was correlated with at least one cleaning habit. Frequency of cleaning product use and performing cleaning tasks did not vary by season. An examination of intra-household variability showed moderately to highly consistent usage patterns over time, with lower temporal consistency observed among products used more frequently, such as all-purpose cleaners. Frequency of household care product usage was consistent enough that in epidemiologic studies, participants can be classified, for example, into three categories on the basis of a single assessment, with only minimal misclassification.

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### 1. Introduction

Household care products, such as cleaning products and air fresheners, are frequently used in homes throughout the US. On average, US adults have been reported to spend 20–30 min a day cleaning their homes, although this time does not necessarily involve the use of cleaning products (Wiley et al., 1991). Cleaning provides health benefits by removing allergens and potential contaminants, such as lead, pesticides and other semi-volatile compounds that partition into dust in homes (Bennett and Furtaw, 2004; Hunt et al., 2008; Lioy et al., 1998; Roberts et al., 1999).

Cleaning products and air fresheners have been related to eye irritation, asthma, allergy, and respiratory irritation (Wolkoff et al., 1998) and most recently to breast cancer (Zota et al., 2010). Specific compounds found in cleaning products, such as ethanolamine, laural dimethyl benzyl ammonium chloride and benzalkonium chloride, have been identified as irritants (Nazaroff and Weschler, 2004). In addition, ambient ozone enters homes from the outdoors (Reiss et al., 1995; Weschler, 2000; Weschler et al., 1992) and reacts with unsaturated compounds in cleaning products forming secondary pollutants of concern (Weschler, 2006). There are a number of unsaturated terpenes found in cleaning products and air fresheners, such as  $\alpha$ -pinene, used for its pine scent, and *d*-limonene, used for its lemon scent, as well as other terpene-related compounds, such as  $\alpha$ -terpineol, linalool, and linalyl acetate. These compounds react with ozone to form OH radicals which in turn form aldehydes and ketones (Singer et al., 2006; Weschler and Shields, 1997), hydrogen peroxide

\* Corresponding author. Department of Public Health Sciences, One Shields Avenue, MS1C, University of California, Davis, CA 95616. Tel.: +1 530 754 8282; fax: +1 530 752 3239.

E-mail address: [dhbennett@ucdavis.edu](mailto:dhbennett@ucdavis.edu) (D.H. Bennett).

(Li et al., 2002), and secondary particulate matter (Singer et al., 2006; Wainman et al., 2000; Weschler and Shields, 1999), all of which are known to have adverse health effects. Synthetic musks and phthalates, common ingredients in air fresheners, are of increasing concern due to their potential estrogenic effects.

Little information is available on the frequency and consistency of use of cleaning products over time in the US (Weegels and van Veen, 2001). As a result of the REACH legislation, efforts to gather such data for the European population are underway (HERA, 2005; Van Engelen et al., 2007). Such data is needed for modeling potential exposures to these compounds in risk assessments. In order to accurately quantify exposure, the following information must be known: the compounds present in the product of concern; the average amount of the product used each time; and the frequency of use of the product (Van Engelen et al., 2007). An understanding of the temporal variability of use is important for understanding the validity of questionnaires used in exposure assessment and epidemiological studies.

As a part of the EPA funded Study of Use of Products and Exposure-Related Behavior (SUPERB), we investigated use patterns of cleaning products and air fresheners along with the frequency of performing different types of cleaning tasks among California residents (Hertz-Picciotto et al., 2010). The SUPERB study aims to develop data collection methods for longitudinal assessment of exposure-related behaviors and evaluate the validity and precision of these methods. As one component of the study, we conducted phone interviews using an interviewer-administered questionnaire. The questionnaire is administered three times on an annual basis to capture longitudinal change. A second component collected information quarterly for six quarters via a web-based survey. In this paper, we focus on the distribution and consistency of use frequency over time in two population-based cohorts, as well as the influence of demographic factors on use.

## 2. Methods

### 2.1. Study population

California residents from homes with young children (97% had a child 5 years or younger) and from homes headed by older adults (generally aged 55 or above) were enrolled in the SUPERB study. Homes with young children born between 2000 and 2005 were identified through birth certificate records for northern California counties (Hertz-Picciotto et al., 2010). Households in which the mother had less than 12 years of education were over-sampled as a means to counter the low rates of participation in research for this socio-demographic group (Korkeila et al., 2001). The older-adult households were a population-based sample selected randomly from housing units in the southern portion of California's Central Valley (hereafter referred to as central California) (Hertz-Picciotto et al., 2010).

### 2.2. Data collection

Data analyzed in this paper were collected using two different platforms – telephone surveys and web-based surveys. Trained interviewers collected data over the telephone using structured questionnaires in three consecutive annual surveys between October 2006 and November 2009. Interviews were conducted in both English and Spanish. A subset of the households that participated in the first telephone survey was invited to participate in a series of self-administered web-based surveys. Participants were asked to complete one web survey that included cleaning products every three months for up to 18 months. The cleaning product section of the telephone interview asked about usage frequency of 8

types of cleaning products (car cleaner, tub and shower cleaners, polish, oven cleaner, floor cleaner, carpet cleaner, glass cleaner and all-purpose cleaner). We only asked about frequency rather than length of cleaning events or amount used as we felt participants would be able to more accurately recall frequency of use. Questions were also asked about 5 types of cleaning habits (dry-mopping floors, wet-mopping floors, sweeping floors, vacuuming hard floors, and vacuuming carpets). In addition, participants were asked about their use of moth repellants and dry-cleaning habits, with questions about air fresheners and scented candles added in the second year. The web-based survey asked about a subset of the more commonly used products and activities (floor cleaner, glass cleaner, all-purpose cleaner, tub/shower cleaner, sweeping hard floors, vacuuming carpets, vacuuming hard floors, and wet-mopping hard floors).

A total of 612 households completed the household care product section of the phone survey in the first year of the study, with 460 households including both a parent and a child and 152 households headed by an older adult. Sixty-nine percent of the households completed the second year and 59% completed these questions for all three years. A subset was recruited for a web-based longitudinal study. A total of 247 households completed the household care section of at least one web-based survey, while 46% completed 3 web-based surveys and 32% completed all 6 web-based surveys.

### 2.3. Data analysis

In the web survey, cleaning product usage and habits were measured as the number of times used in the last month, and in the phone survey, as the number of times typically used per week/month/year (as specified by the participant). Outcomes were transformed to uses per month. For a given cleaning product, a large proportion of the participants reported not typically ever using the product in the phone survey (ranging from 12 to 68% by product) or not having used the given product over the one month period in the web survey. A few participants chose not to answer specific question and these responses were coded as missing values. For questions such as those relating to cleaning hard floors, households that have all carpet were classified as “non-users” or 0 uses for those variables. To account for the large number of zeros, *t*-statistics and *F*-ratios for testing the null hypothesis that mean usage patterns were the same across compared groups were assessed for statistical significance using permutation tests, an alternative to one-way ANOVA and *t*-tests that is better suited for non-normal distributions (Good, 1994). Differences in means were assessed across groups defined by race, gender, education, age group, employment status, and number of children, as well as by whether they hired a professional cleaner or owned furry pets. All statistically significant estimated *p*-values (at a per-comparison alpha level of 0.05) are reported in the results, allowing the reader to focus on single demographic variables. Given the large number of bivariate comparisons (78), there may be some Type I error present. The *p*-values from these bivariate comparisons have been included and may be adjusted for multiple comparisons using standard procedures (e.g. via PROC MULTTEST in SAS/Stat software (SAS Institute Inc., Copyright© 2002–2008)) (Westfall and Young, 1993). We note that there were correlations between race, education, employment, and number of kids, with a significant correlation between unemployment and low education and between being Latino and low education, and a non-significant trend between being Latino and having more children. Therefore, adjusted *p*-values from Type-3 *F*-tests in the SAS/Stat procedure PROC GLM for a multiple linear regression model are also presented in Table 2. We note that the population was not constructed with an even demographic distribution and that permutation testing on the multivariate analysis was not conducted, slightly limiting the precision of *p*-values. Differences were assessed in data collected at the group level

**Table 1**  
Summary statistics for Users in Year 1 of telephone survey, Study of Use of Products and Exposure-Related Behaviors (SUPERB), 2006–2009.

	Parents With Young Children							Older Adults						
	% Users	N	Uses per Month					% Users	N	Uses per Month				
			Mean	SD	Median	90%	Max			Mean	SD	Median	90%	Max
<b>Women</b>														
<i>Product Use</i>		(380)						(100)						
All-purpose cleaner	85%	322*	15.80	19.66	8.67	30.33	121.33	78%	76*	9.18	14.94	4.33	30.33	91.00
Car cleaner	32%	121*	0.92	1.45	0.33	2.01	8.67	20%	20*	0.36	0.48	0.17	1.00	2.01
Carpet cleaner	50%	184*	1.46	3.74	0.33	4.33	30.33	52%	48*	0.68	0.92	0.25	2.01	5.02
Floor cleaner	69%	260*	5.64	8.48	4.33	13.00	60.67	62%	62	6.06	7.72	4.33	13.00	30.33
Glass cleaner	89%	337	9.06	20.80	4.33	30.33	303.33	87%	86*	3.95	5.27	2.01	8.67	30.33
Oven cleaner	35%	130*	0.92	1.88	0.17	3.92	13.00	31%	30*	0.35	0.72	0.17	0.50	4.01
Polish	57%	214*	2.25	3.13	1.00	4.33	30.33	68%	67*	2.66	3.09	1.00	4.33	15.17
Tub/shower cleaner	79%	297*	5.06	6.45	4.33	8.67	30.33	81%	80*	7.48	9.68	4.33	17.33	60.67
<i>Cleaning Habits</i>														
Dry-mop hard floors	31%	113*	7.20	7.58	4.00	20.00	30.00	36%	35*	5.43	5.63	4.00	16.00	20.00
Wet-mop hard floors	91%	341*	6.44	8.35	4.00	20.00	84.00	92%	91*	4.53	5.57	4.00	8.00	30.00
Sweep hard floors	87%	327*	14.19	11.53	12.00	30.00	90.00	77%	76*	8.55	8.04	4.00	20.00	30.00
Vacuum hard floors	58%	220*	7.26	6.88	4.00	20.00	30.00	60%	60	5.15	5.77	4.00	11.00	30.00
Vacuum carpet	90%	336*	9.03	7.95	5.00	20.00	60.00	93%	93	4.73	4.69	4.00	10.00	20.00
<b>Men</b>														
<i>Product Use</i>		(80)						(52)						
All-purpose cleaner	81%	63*	9.94	22.43	4.33	26.00	151.67	61%	31*	6.34	8.75	2.01	13.00	30.33
Car cleaner	47%	36*	0.60	0.77	0.33	1.00	4.33	34%	17*	1.38	1.68	0.50	4.33	4.33
Carpet cleaner	47%	37*	0.91	1.65	0.33	2.01	8.67	52%	27	0.92	1.32	0.33	4.01	4.33
Floor cleaner	63%	50	5.34	7.80	2.01	16.25	30.33	44%	22*	2.82	2.76	2.01	4.33	13.00
Glass cleaner	84%	66*	6.05	14.23	2.01	8.67	91.00	88%	45*	5.62	8.24	2.01	13.00	30.33
Oven cleaner	38%	30*	0.75	1.29	0.19	3.17	4.33	30%	14*	0.23	0.25	0.17	0.50	1.00
Polish	47%	36*	2.02	5.05	0.75	4.33	30.33	58%	29*	2.44	4.19	1.00	4.33	21.67
Tub/shower cleaner	68%	54*	3.62	5.90	2.01	8.67	30.33	68%	34*	7.78	10.97	4.33	30.33	30.33
<i>Cleaning Habits</i>														
Dry-mop hard floors	42%	32*	3.50	3.07	2.00	10.00	10.00	31%	16	4.88	4.18	4.00	15.00	15.00
Wet-mop hard floors	87%	68*	4.62	5.72	2.00	15.00	20.00	79%	41	4.84	4.68	4.00	12.00	20.00
Sweep hard floors	90%	69*	9.88	7.78	8.00	20.00	30.00	73%	38	8.61	7.00	7.00	20.00	20.00
Vacuum hard floors	54%	43*	6.77	6.76	4.00	20.00	20.00	67%	35	4.51	4.04	4.00	10.00	20.00
Vacuum carpet	82%	65*	8.90	8.07	6.00	20.00	31.00	88%	46	6.25	5.32	4.00	15.00	20.00

\*Variable contained missing values, between 1 and 13 values missing.

between the two platforms (phone and web-based surveys) and across seasons (summer – July through October; winter – November through February; spring – March through June). Spearman correlation coefficients were calculated to determine associations in use frequencies relating products to cleaning tasks.

To assess consistency of usage over time for each product, we first described the bivariate distribution of within-subject mean usage and the within-subject range of usage, similar to the comparison described by a commonly used variant of Bland–Altman plots. To improve the robustness of parameter estimates, outliers were trimmed by capping the data at a maximum value of 90 uses per month for all longitudinal analyses of product use.

Intra-household consistency of usage over the course of three annual telephone interviews was quantified by adapting Kendall's intraclass correlation coefficients (Kraemer, 2006) to the setting with a varying number of measurements per timepoint and household. The Kendall intraclass correlation coefficient generalizes the Spearman correlation to more than two timepoints analogously to how the intraclass correlation coefficient for clustered normal data generalizes the Pearson product moment correlation coefficient (Raghavachari, 2005) and is highly recommended for use with ordinal data (Kraemer, 2006). For each product, usage frequencies were transformed to fractional ranks by dividing the within-timepoint ranked-transformed value by 1 + the number of nonmissing usage reports at that timepoint. Kendall's intraclass correlation coefficients were then computed as the ratio of the estimated between-household variance component to the sum of the estimated between- and within-household variance components.

We estimated variance components by restricted maximum likelihood (REML) methods for normally distributed data in mixed-effects models with random household effects (Searle et al., 1992). Although fractional ranks are non-normally distributed, we reason that this approach will produce well-behaved estimates in the setting with unbalanced data based on the observations that intraclass correlation coefficients are averages of pairwise correlation coefficients (Balakrishnan et al., 2005), that the Spearman sample correlation coefficient is computed as the Pearson product moment coefficient on ranked data (Zar, 2010) and theoretical and empirical evidence that the REML approach outperforms alternative (e.g. analysis of variance) approaches to variance component estimation in similar unbalanced data settings (Marcoulides, 1990; McCulloch et al., 2008; Searle et al., 1992).

Sometimes in environmental epidemiology studies, participants are classified into tertile or quintile exposure groups, such as high, medium, and low users of a specified product. While it may be desired to know use rates of the product over a long time period, it is often not practical to repeatedly ask participants about product usage. In addition, it may be difficult for participants to estimate typical usage over a long time period. As a result, use rates may only be known for a portion of the desired exposure window. Therefore, the goal was to determine whether a single survey can be representative of the average use under the example scenario of classification into tertiles (Adibi et al., 2008; Hauser et al., 2004; Meeker et al., 2005; Peck et al., 2003). We defined the average frequency across all available surveys to be the “true” usage in a household and assigned each household to a tertile for this “true” use. The tertile boundaries were the same for both “average” and “observed”

**Table 2**  
Summary statistics for Demographic and Household differences in Year 1 of telephone survey, Study of Use of Products and Exposure-Related Behaviors (SUPERB), 2006–2009.

Product Use/ Cleaning Habits	Uses per Month				<i>p</i> -values	
	Mean	Median	Mean	Median	Unadjusted	Adjusted
<b>Gender</b>						
	Female		Male			
All-purpose cleaner	12.15	4.33	6.38	1.00	0.0215	0.002
Car cleaner	0.25	0.00	0.35	0.00	0.9662	0.06
Glass cleaner	7.08	4.33	5.02	1.00	0.9637	0.001
Polish	1.39	0.25	1.13	0.08	0.9992	0.009
Tub/shower cleaner	4.43	2.01	3.56	1.00	0.9636	<0.001
Sweep hard floors	11.03	8.00	7.67	4.00	0.0259	0.06
<b>Age</b>						
	Parents		Older Adults			
All-purpose cleaner	12.50	4.33	6.04	2.01	0.0030	0.53
Car cleaner	0.29	0.00	0.21	0.00	0.9916	0.03
Polish	1.23	0.17	1.67	0.50	0.7621	<0.001
Tub/shower cleaner	3.74	2.01	5.79	4.33	0.0287	0.01
Sweep hard floors	11.60	8.00	6.41	4.00	<0.0001	0.75
Vacuum carpet	7.87	4.00	4.79	4.00	0.0005	0.72
<b>Ethnicity</b>						
	Latino		Non-Latino			
Car cleaner	0.50	0.00	0.21	0.00	0.0095	0.16
Floor cleaner	7.49	4.33	2.55	1.00	<0.0001	0.23
Glass cleaner	7.67	4.33	6.37	2.01	0.9997	<0.001
Oven cleaner	0.45	0.00	0.22	0.00	0.3001	0.002
Polish	1.65	0.33	1.25	0.17	0.9229	0.01
Tub/shower cleaner	5.93	4.33	3.81	2.01	0.0457	0.02
Wet-mop hard floors	9.86	5.00	3.85	2.00	<0.0001	<0.001
Sweep hard floors	14.82	20.00	9.12	5.00	<0.0001	<0.001
Vacuum carpet	10.67	8.00	6.17	4.00	<0.0001	<0.001
<b>Employment Status</b>						
	Employed		Unemployed			
Car cleaner	0.34	0.00	0.21	0.00	0.5725	0.02
Floor cleaner	2.67	1.00	4.39	1.25	0.0245	0.49
Wet-mop hard floors	3.69	2.00	6.38	3.00	<0.0001	0.02
Vacuum carpet	6.11	4.00	8.01	4.00	0.0154	0.06
<b>Education</b>						
	<12 Years		13+ Years			
Car Cleaner	0.45	0.00	0.23	0.00	0.1377	0.03
Floor cleaner	7.66	3.01	2.60	1.00	<0.0001	0.003
Oven cleaner	0.57	0.00	0.19	0.00	0.0072	0.03
Tub/shower cleaner	5.53	4.33	3.95	2.01	0.3388	0.005
Wet-mop hard floors	8.67	4.00	4.25	2.00	<0.0001	0.29
Sweep hard floors	14.77	20.00	9.25	5.50	<0.0001	0.02
Vacuum hard floors	3.18	0.00	4.03	2.00	0.9192	0.006
Vacuum carpet	9.85	6.50	6.46	4.00	0.0005	0.90
<b>No. of Children in the Household</b>						
	1–2		3+			
Floor cleaner	3.08	1.00	5.22	2.01	0.0354	0.19
Wet-mop hard floors	4.68	2.00	7.05	4.00	0.0251	0.007
Sweep hard floors	9.90	6.00	15.04	15.00	<0.0001	<0.001
Vacuum carpet	6.74	4.00	10.17	6.00	0.0002	0.01

Comparisons were based on all responses, not just users. Unadjusted *p*-values were estimated via Monte Carlo permutation procedures for independent groups *t*-tests in the SAS/Stat procedure PROC MULTTEST. Adjusted *p*-values are from Type-3 *F*-tests in the SAS/Stat procedure PROC GLM for a multiple linear regression model.

classifications. Individuals were classified into “observed” tertiles based on their reported use rate from only their first survey, as would be the case if only one survey had been completed. The agreement between the “true” and “observed” tertiles provided an estimate for how well a single survey predicts average use level (Peck et al., 2003). Households that completed only one survey were excluded from this analysis. All statistical analyses were performed using Version 9.2 (SAS Institute, Inc., Cary, N.C.) of SAS.

### 3. Results

#### 3.1. Cleaning products usage patterns

The distributions of product usage and cleaning task frequencies are summarized by age group (older adults over 55 years of age vs. parents with young children) and gender. Table 1 shows the percent of households that reported use of each cleaning product in the first year of the telephone survey, as well as descriptive statistics for products usage computed for each product in the subset of users. There were no significant differences at the group level in reported use of cleaning products or tasks performed among the three annually repeated telephone surveys conducted in this study, thus results are only presented for the first year of the survey which included the most participants ( $n = 612$ ). Among households that reported using a particular product, glass cleaner and all-purpose cleaner were used most frequently, each used by over 80% of households. Women with young children reported the highest average usage of these two products, using them 9 and 16 times per month, respectively. Car cleaner and oven cleaner were used least frequently.

Significant differences by demographic and other household factors are reported in Table 2, with a few differences highlighted here. Overall, women reported using all-purpose cleaner significantly more frequently than men in both the bivariate and multivariate models. Older adults reported using tub cleaner significantly more often than parents with young children, while parents with young children reported using all-purpose cleaner significantly more times per month, although this was not significant in the multivariate model, as age differences were potentially driven by the higher percent of women in the younger population. Participants who reported Latino as their ethnicity, used a number of products more frequently than those that reported a non-Latino ethnicity. Those with less than 12 years of education also tended to have more frequent cleaning product use than those with 13 or more years of education. There were fewer differences in product use by employment status and by number of children in the home (2 or less children vs. 3 or more children) as reported in Table 2. No significant differences in product use frequencies were observed between those who reported owning furry pets (variables included any furry pet, dogs only, cats only, or both cats and dogs) and those that reported having no furry pets in their home, although mean values were higher for pet owners than non-pet owners for some cleaning products used, such as all-purpose cleaner (18% higher). In addition, no significant differences were seen in use of any products by season.

#### 3.2. Cleaning habit patterns

Table 1 also includes summary statistics for cleaning habits, including vacuuming, sweeping and mopping with significant differences by demographic factors presented in Table 2. We note that a value of 4.0 was a common median value for many of the cleaning habits presented in Table 1, corresponding to a frequency of once per week, a common answer. We found that women swept hard floors more than men. In addition, parents with one or two children reported significantly less frequent wet-mopping of hard floors, sweeping of floors and vacuuming of carpets as compared with parents having three or more children. Latino participants reported sweeping floors, wet-mopping floors and vacuuming carpets significantly more frequently than non-Latino participants. Unemployed participants reported vacuuming carpets and wet-mopping floors more often than employed participants. As with cleaning product use, no significant differences were observed between seasons. The mean values for some cleaning tasks were higher for pet owners than non-pet owners including vacuuming

hard floors (34% higher) and vacuuming carpets (7.5% higher), although none of the differences reached statistical significance.

Women conducted cleaning tasks more frequently than men in the study, but differences were generally not statistically significant (Table 1). However, the woman in the household (either the participating adult or the spouse of a male participant) more frequently was the one who usually cleaned the home (Table 3). A higher percentage of households with older adults, compared to parents with young children, hired professional cleaners to perform the majority of cleaning in the home (Table 3). Overall, the households without a professional cleaner wet-mopped floors and vacuumed carpets significantly more often than the households using professional house cleaners.

### 3.3. Air freshener, candle, and mothball usage patterns

Questions on air freshener, candle, and mothball use were added in the second year of the phone survey and asked in all of the web-based surveys (Table 4). Air freshening sprays were used most frequently, with a median of 8.6 uses per month, and were used by 46% of parents and by 58% of the older adults. Overall, 73% of parents and 61% of older adults burn plain or scented candles. Most people using candles (72% of parents 68% of older adult) burn one or two candles at a time, however there were some users who reported typically burning large numbers of candles, with one individual reporting 15 and 3 people reporting 12 candles burning simultaneously. The only significant difference in any air freshener use based on demographic or household characteristics was increased candle frequency in households with a furry pet ( $p = 0.01$ ).

### 3.4. Data collection platform

At the group level, the type of platform for data collection had no effect on reported cleaning product use or tasks performed, comparing the first telephone survey and the mean use reported in the web-based survey. However, significantly higher use of all-purpose cleaner was reported in the telephone survey than the web-based survey ( $p = 0.0004$ ).

### 3.5. Correlation between product use and habit patterns

Understanding what cleaning products are used in combination is important for evaluating aggregate exposures, particularly if compounds are ingredients of multiple products. All eight types of

**Table 3**  
Frequency results from Year 1 of telephone survey, Study of Use of Products and Exposure-Related Behaviors (SUPERB), 2006–2009.

	Women		Men	
	Parents With Young Children	Older Adults	Parents With Young Children	Older Adults
	<i>n</i> = 380	<i>n</i> = 100	<i>n</i> = 80	<i>n</i> = 52
<i>Who does most cleaning at your house?</i>				
Self	69.47%	63.00%	18.75%	32.69%
Self and spouse/family member	10.53%	7.00%	22.50%	15.38%
Spouse or family member	4.47%	4.00%	46.25%	40.38%
Professional House cleaner	15.26%	26.00%	12.50%	11.54%
D/K	0.26%	0%	0%	0%
<i>Do you get any clothes dry cleaned?</i>				
Yes	39.21%	56.00%	37.50%	48.08%
<i>Do you have an air purifier or plug-in air cleaner?</i>				
Yes	12.89%	13.00%	18.75%	19.23%

**Table 4**

Air Freshener and Candle use per month among the users of the products, Study of Use of Products and Exposure-Related Behaviors (SUPERB), 2006–2009.

Product Use	% Users	<i>N</i>	Mean	SD	Median	90%	Max
<i>Parents With Children</i>							
Sprays	46%	142	32.83	127.34	8.64	60.80	1459.20
Oils or Air Freshening	14%	44	12.24	24.62	2.00	30.40	152.00
<i>Candles</i>							
Plug-ins <sup>a</sup>	25%	75	0.67	0.81	0.50	1.00	4.32
Solids or Gels <sup>a</sup>	5%	15	0.37	0.36	0.17	1.00	1.00
Moth Repellents <sup>a</sup>	6%	15	0.10	0.25	0.00	0.17	1.00
Plain or Scented Candles	73%	227	4.04	7.79	1.00	12.96	60.80
<i>Older Adults</i>							
Sprays	58%	67	24.70	34.28	8.64	91.20	152.00
Oils or Air Freshening	16%	20	14.79	16.87	8.64	38.00	60.80
<i>Candles</i>							
Plug-ins <sup>a</sup>	19%	21	0.87	1.82	0.50	1.00	8.64
Solids or Gels <sup>a</sup>	7%	8	0.47	0.49	0.29	1.50	1.50
Moth Repellents <sup>a</sup>	20%	22	0.09	0.10	0.08	0.17	0.33
Plain or Scented Candles	61%	75	4.80	8.70	1.00	12.96	45.60

<sup>a</sup> Plug-ins, Solid or Gels, and Moth repellents refer to how often these items are replaced per month.

products were correlated with at least six other cleaning products and were correlated with at least one cleaning habit (Table 5, including participants who did not use products). Only a few cleaning habits were correlated with each other, sweeping hard floors was moderately correlated with wet-mopping hard floors, but negatively correlated with vacuuming hard floors, indicating that people either sweep/mop or vacuum hard floors, but not both.

### 3.6. Longitudinal analyses and reliability

We were interested in looking at intra-household variability. Participants reported the number of times per month they used the product and then for each household, the average use was calculated and the range was calculated as the maximum minus the minimum use rate (Fig. 1). We found that for products used more frequently, there was often a wider range of values reported by an individual. Most frequently households had both an average use of between 1 and 3 times per month and a range of between 1 and 3 uses per month. Stability of usage over time was quantified via Kendall intraclass correlation coefficients, an estimate of how correlated usage rankings at any two timepoints would be. Among products that were used by more than 30% of the participants, we found a relatively higher between-time point stability in usage ranking, as defined by the ratio of between person to total variance, for glass cleaner (0.71) and all-purpose cleaner (0.56), and less stability in usage rankings for carpet cleaner (0.34), floor cleaner (0.44), and tub cleaner (0.48).

Reported frequencies were categorized into tertiles, as is often done in epidemiology studies, in order to determine if use of these types of cleaning products was consistent over time and if a single inquiry could be used as a sufficient approximation of the relative use frequency, as compared to other participants. There was moderate agreement ( $<0.33$ ) between the tertile based on average use across monthly surveys (referred to as “true” usage) and the tertile based on the reported usage in a single survey (referred to as “observed” usage), with better agreement among participants whose true value were either low or high (0.77–0.99) (Table 6). Of the households in the ‘true’ high usage tertile, the percent of visits that had all ‘observed’ visits counted in the highest tertile ranged from 77% to 88% across product categories and from 84% to 89% across habit categories. Likewise, for the households in the ‘true’ lowest tertile, the percent of visits with all ‘observed’ visits in the lowest tertile ranged from 78% to 91% across product categories and

**Table 5**  
Correlation between use frequencies of different products and between frequencies of different cleaning habits for all subjects during Year 1 of telephone survey, Study of Use of Products and Exposure-Related Behaviors (SUPERB), 2006–2009.

	Products								Habits			
	Car cleaner	Tub/shower cleaner	Polish	Oven	Floor	Carpet	Glass	Purpose	Dry-mop hard floors	Sweep hard floors	Vacuum carpet	Vacuum hard floors
<i>Products</i>												
Car cleaner	–											
Tub/shower cleaner	0.09	–										
Polish	0.12	0.25	–									
Oven	0.10	0.15	0.13	–								
Floor	.	0.33	0.30	0.18	–							
Carpet	0.15	0.12	0.17	0.13	.	–						
Glass	0.16	0.35	0.36	0.13	0.34	0.16	–					
Purpose	0.13	0.29	0.23	0.11	0.37	0.21	0.36	–				
<i>Habits</i>												
Dry-mop hard floors	.	.	.	.	0.09	.	0.08	.	–			
Sweep hard floors	0.09	0.20	0.12	0.11	0.18	.	0.15	0.19	.	–		
Vacuum carpet	.	0.14	0.09	0.13	0.10	0.20	0.29	0.22	.	0.25	–	
Vacuum hard floors	.	.	.	.	.	.	0.14	0.09	.	–0.18	0.18	–
Wet-mop hard floors	.	0.20	0.11	0.13	0.28	0.04	0.21	0.13	.	0.34	0.27	.

\*Both users and non-users were included. Spearman correlation coefficients. Only significant correlations are shown ( $p < 0.05$ ), with non-significant relationships indicated by “.”.

from 78% to 97% across habit categories. Participants whose average use was in the “medium” tertile had lower agreement as their observed values included a range of values that averaged to a value in the “medium” category.

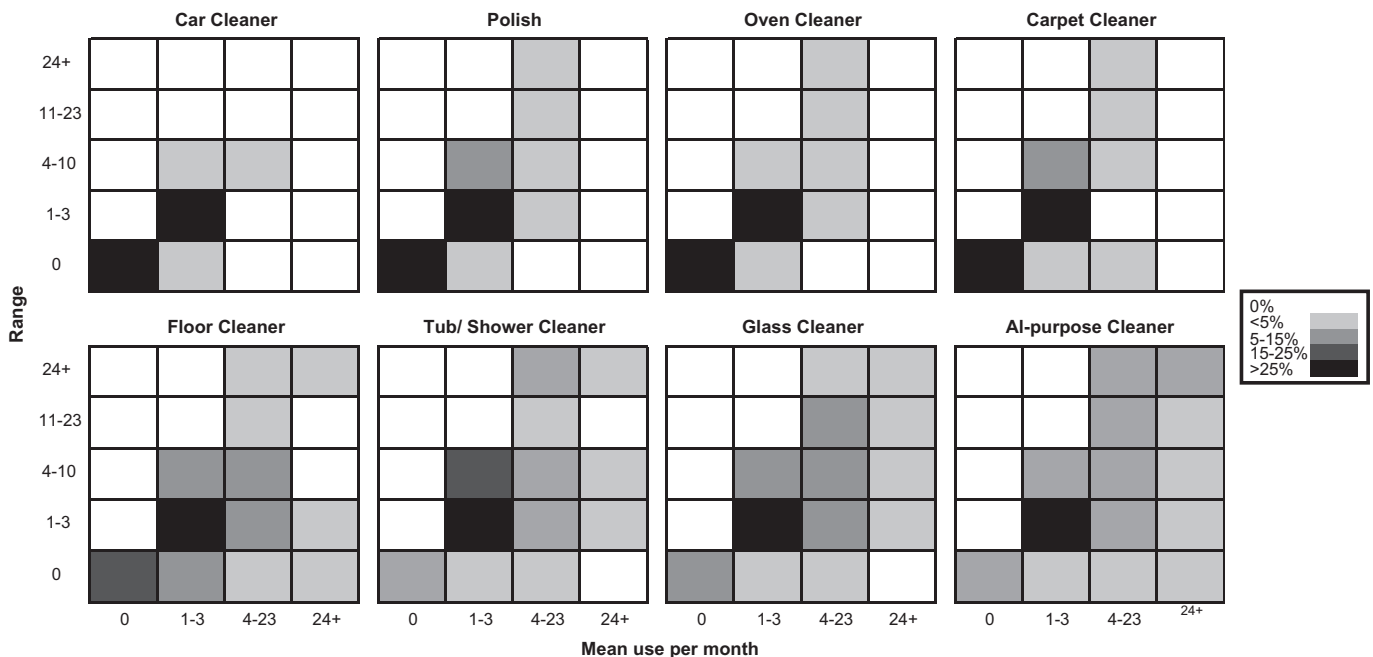
**4. Discussion**

This study provides information on usage patterns of common cleaning products and air fresheners, as well as information on patterns of cleaning tasks among older adults and parents of young children, and the temporal variability associated with use. Use frequency is an important component needed to accurately determine exposure to chemicals of concern in consumer products in risk assessment and because understanding the temporal variability of use is important for understanding the validity of

exposure questionnaires for use in epidemiology studies. Data of this sort are lacking in the published literature.

We found that cleaning product usage varied by socio-demographic factors for 6 out of the 8 types of cleaning products considered and for the 3 most common cleaning habits and thus, one may want to consider groups separately when conducting risk assessments. However, as noted, there were some correlations found between race, education, employment and number of kids in the household, and we were not able to determine the relative contribution of each of these factors to the differences seen. In addition, co-use of cleaning products is common and should be considered when examining exposure to chemicals used as ingredients in many types of products.

One time questionnaires are one of the most economical and noninvasive, and thus widely used, methods for estimating exposure in epidemiology studies. One concern when asking



**Fig. 1.** Mean use per month vs. range of use per month across the three annual telephone surveys, Study of Use of Products and Exposure-Related Behaviors (SUPERB), 2006–2009. Shading of the plots indicates the percentage of the households that fall into each category, with darker squares representing a larger percentage of the study population.

**Table 6**

Tertile analysis for households that completed more than one web-based survey, Study of Use of Products and Exposure-Related Behaviors (SUPERB), 2006–2009.

	True (Average)	Observed			Total	Agreement
		Low	Medium	High		
<i>Product Use</i>		(= 0)	(>0–<2)	(2+)		
Floor cleaner	Low	<b>166</b>	1	0	167	0.99
	Medium	166	<b>117</b>	68	351	0.33
	High	46	11	<b>242</b>	299	0.81
		(0–<2)	(2–<4)	(4+)		
Glass cleaner	Low	<b>242</b>	58	5	305	0.79
	Medium	14	<b>143</b>	40	197	0.73
	High	16	22	<b>280</b>	318	0.88
		(0–<2)	(2–<5)	(5+)		
All-purpose cleaner	Low	<b>174</b>	45	3	222	0.78
	Medium	34	<b>172</b>	36	242	0.71
	High	26	40	<b>267</b>	333	0.80
		(0–<1)	(1–<4)	(4+)		
Tub/shower cleaner	Low	<b>172</b>	14	2	188	0.91
	Medium	74	<b>247</b>	74	395	0.63
	High	34	28	<b>202</b>	264	0.77
		(0–<3)	(3–<10)	(10+)		
<i>Habits</i>						
Sweep hard floors	Low	<b>227</b>	34	3	264	0.86
	Medium	42	<b>211</b>	52	305	0.69
	High	19	26	<b>228</b>	273	0.84
		(0–<4)	(4–<6)	(6+)		
Vacuum carpet	Low	<b>254</b>	67	3	324	0.78
	Medium	21	<b>150</b>	43	214	0.70
	High	11	27	<b>267</b>	305	0.86
		(= 0)	(>0–<4)	(4+)		
Vacuum hard floors	Low	<b>101</b>	3	0	104	0.97
	Medium	147	<b>251</b>	84	482	0.52
	High	12	16	<b>230</b>	258	0.89
		(0–<2)	(2–<4)	(4+)		
Wet-mop hard floors	Low	<b>184</b>	40	4	228	0.81
	Medium	53	<b>209</b>	84	346	0.60
	High	20	20	<b>231</b>	271	0.85

Note: Bold values indicate the number of participants that remained in the same category in both the true and observed groupings.

participants to recall past behavior is that if the time interval since exposure is too long or the degree of detail requested about the exposure is too great it is more difficult to accurately estimate exposures such as use rates (Paganinihill and Ross, 1982; Rohan and Potter, 1984). In addition when recall is poor, the likelihood of differential misclassification due to recall bias in case-control studies may be greater (Coughlin, 1990). One purpose of this study was to collect longitudinal data to assess the ability to use recent exposure to access exposures over a longer period, eliminating the need to recall past behavior. As responses are often classified into categories, we analyzed the example of using high, medium and low exposure categories and found moderate agreement over time. Tertiles may be a good way to categorize cleaning product use frequency, especially when asking people to recall past behavior. The usage frequency of cleaning products, in our study, appears to be relatively consistent over time. Thus, a single questionnaire may be sufficient to assess use of cleaning products.

Our study design allowed us to test for seasonal differences, which were hypothesized by (Westat, 1987) to account for differences in the frequency of performing cleaning tasks between initial and follow-up questionnaires conducted in different seasons. By enrolling participants across the span of a year, we were able to test for seasonal differences controlling for an 'order' effect. We found season not to have an effect on the frequency of use or tasks in our study (results not presented). However, our study was conducted in California, where seasonal changes tend to be more subtle than in other parts of the country, thus season may need to be considered for different regions of the US. Also, while season was not associated with use frequency for household cleaning products, it might influence exposure concentrations as ventilation rates may vary

seasonally, for example depending on whether and how many windows and doors are open.

An additional goal of this study was to evaluate the use of web surveys for collecting exposure-related behavior. Our study indicates that web-based data collection yields results similar to phone surveys. While web-based surveys are generally subject to low response rates and attrition (Chang and Krosnick, 2009; Couper, 2000; Fricker et al., 2005), interviewer-administered phone surveys require more staff members and time. Our study found that younger adults seem to be more adept at efficiently using web surveys than older adults and they were more likely to favor web surveys and needed less time to complete each survey (Wu et al., 2011).

Information is available on the purchasing habits for many household care products in the US (Mintel-International, 2010), but these are data not directly comparable to ours. In particular, the EPA Exposure Factors Handbook (EFH) (EPA., 1997) provides information on the frequency of use of a limited number of cleaning products which did not correspond to the products in our study. The EFH also includes time spent doing particular cleaning tasks that involve use of many of the same cleaning products studied in this paper, but it is difficult to directly compare frequency of conducting a cleaning task with frequency of using a cleaning product. In a paper by Zota et al. (2010) examining the relationship between cleaning product use, including air fresheners, and the risk of breast cancer, use frequency by women from Cape Cod, Massachusetts between 1988 and 1995 was reported. Air freshener sprays, oven cleaner, and surface cleaner (all-purpose cleaner) were the only products asked of both the Massachusetts and California women. Approximately 77% of the women in the Zota et al. study reported having used air freshener sprays and 92% oven cleaner, as compared with 49% and 35% of women in the SUPERB study. The percentage of women reporting use of surface cleaner/all-purpose cleaner was similar in both studies; 87% of the women in Massachusetts vs. 85% of younger and 78% of older women in the California based study. The usage frequency among users was also similar in both studies. In SUPERB, median use of air freshener sprays among young women was 8 uses per month, or roughly 2 uses per week, compared to the Zota et al. study where the majority (35%) of women used the spray weekly. Median use of oven cleaner among women in our study was 0.17 uses per month, or approximately 2 uses per year, while Zota et al. indicated that the majority (53%) of their participants reported using oven cleaner between 2 and 6 times per year. Median use of surface cleaner/all-purpose cleaner was 8 uses per month, roughly 2 uses per week, among women in our study and 50% reported using surface cleaner "weekly" in Zota et al.

The main advantage of the SUPERB study is the large population-based cohort that was sampled. One potential limitation was that participants were asked to recall past behavior both over a 1 year period and a 1 month period. However, we found that what participants reported as their "usual" use in the annual survey was not significantly different from the usage they reported when asked about their usage in the last month, which is both a more specific question and a more recent time period, indicating that recall error may not have been a significant limitation.

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