Journal of Children's Health: Vol. 2, Nos. 3–4, pp. 271–295 (2004)
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ISSN: 0888-0018 print / 1521-0669 online
DOI: 10.1080/15417060490960215

Young Children's Mouthing Behavior: An Observational Study via Videotaping in a Primarily Outdoor Residential Setting

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ABSTRACT

Detailed information on children's mouthing activities helps researchers assess children's exposure to toxicants via the non-dietary ingestion route (i.e., exposure resulting from contacts between the mouth and non-dietary objects such as fingers, toys, and dirt). For the analyses presented in this article, 38 children (20 female and 18 male) aged 1 to 6 years were videotaped for 2 hours each during natural play primarily in the outdoor residential environment.

The data were analyzed separately by location (i.e., indoor or outdoor). For each location, mouthing frequency, contact duration, and hourly duration data were analyzed along gender and ≤24 months >24 months age groupings. Several significant differences were found for mouthing activities occurring outdoors. Children ≤24 months of age were found to have significantly longer contact durations with the hands than children >24 months of age ($p = 0.04$). Furthermore, for all ages, frequencies of mouthing contacts with the hands and non-dietary objects were significantly higher for girls than boys ($p = 0.01$ and $p = 0.008$, respectively). Girls also had significantly shorter hand-to-mouth contact durations than boys ($p = 0.04$). Although not statistically significant, mouthing frequencies with hands and non-dietary objects were higher indoors than outdoors while contact durations were similar between the two locations.

Key Words: non-dietary ingestion, children, activity pattern, micro-level, mouthing behavior, exposure

INTRODUCTION

During normal development, young children pass through a stage characterized by a profuse mouthing of objects (Bearer 1995; Turgeon-Obrien 1996; Groot *et al.* 1998). Such behavior may dramatically increase young children's exposure to toxicants via the non-dietary ingestion route through ingestion of non-dietary items like dirt and paint chips. Mouthing activities such as sucking fingers and mouthing toys are associated with elevated blood levels of lead in young children (Freeman *et al.* 1997). Previous research has also identified non-dietary ingestion as a leading cause of lead poisoning among children living in environments with high levels of lead dust (Chao and Kikano, 1993). Furthermore, children playing outside on wooden structures treated with chromated copper arsenate (CCA) may be exposed to arsenic through the non-dietary ingestion route via hand-to-mouth activities (Hemond and Solo-Gabriele 2004). Detailed information on children's mouthing behavior would help estimate children's exposure to environmental toxicants (Cohen-Hubal *et al.* 2000). In particular, micro-level activity data would help researchers track and identify events and factors that lead to high exposure through the non-dietary route.

This article presents the results from an analysis of the micro-level data gathered on mouthing contact frequency and duration of children aged 14 to 82 months. The data were collected by videotaping young children during natural play in primarily outdoor residential environments (e.g., backyards and local parks). The videotape recordings were then translated into ASCII computer files with second-by-second detail through the use of a specialized software called VirtualTimingDevice™.

The videotaping method employed in our study allows researchers to capture events of short duration. This method was chosen because the duration of most mouthing contacts is less than 4 seconds (Zartarian *et al.* 1998; Freeman *et al.* 2004) and it is difficult to capture events of such short duration via other direct observational techniques like parental observation or record-keeping (Timmer *et al.* 1985). VirtualTimingDevice™ allows researchers to capture the duration of each mouthing contact. Contact duration may be important in modeling the amount of toxicant that is loaded or removed from a surface with each mouthing contact.

Six previous studies reported findings on mouthing frequencies (Table 1). Zartarian *et al.* (1997, 1998) collected frequency data in the Salinas Valley of California for mouthing contacts with the hands and non-dietary objects by videotaping 4 children in a primarily indoor home environment and then transcribing the videotapes with the VirtualTimingDevice™ software (previously known as VideoTraq). Reed *et al.* (1999) videotaped a total of 30 children aged 2 to 6 years in either a daycare center or a residence in New Brunswick, New Jersey. Mouthing contact frequencies were then collected by manually recording the frequency over 5-minute intervals. For the purpose of scoring, behaviors (i.e., hand-to-mouth, mouth-to-object) were assigned different one- or two-letter codes. Freeman *et al.* (2001) employed the same data collection method as Reed and collected data from 19 children in the residential home environment. Tulve *et al.* (2002) analyzed data from a direct observation study

Table 1. Summary of previous quantitative studies on children's mouthing behavior

Study	Method	Mouthing contact boundary	Non-dietary includes hands	Location	Observation period	Age	n	Mouthing frequency[a] (contacts/hour)		Mouthing contact duration[a] (seconds)		Hourly mouthing duration[a] (minutes/hour)	
								Indoor	Outdoor	Indoor	Outdoor	Indoors	Outdoor
AuYeung *et al.* (current study)	Videotaping, computer software	Lips, inside of the mouth, and tongue	Yes	Primarily outdoors	2 hours	18–24 months	Indoors: n = 1 Outdoors: n = 8	84.8 (73.5)	13.9 (7)	1 (1)	2 (3)	11.1 (10.7)	0.8 (0.4)
						25–82 months	Indoors: n = 8 Outdoors: n = 30	19.5 (13.3)	14.6 (8.6)	1 (1)	1 (1)	0.9 (0.7)	0.6 (0.2)
Black *et al.* (2004)	Videotaping, computer software	Lips and inside of the mouth	No	Primarily indoors	4 hours	7–12 months	13	18.1[b] (14)	—	—	—	1.9 (1.8)[b,e]	—
						13–24 months	12	8.4[b] (13.3)	—	—	—	0.8 (1.3)[b,e]	—
						25–36 months	18	5.5[b] (9.9)	—	—	—	0.5 (0.8)[b,e]	—
						37–53 months	9	8.4[b] (9)	—	—	—	1.1 (0.9)[b,e]	—
Freeman *et al.* (2004)	Videotaping, computer software	Lips, inside of the mouth, and tongue	No	Primarily indoors	4 hours	24–55 months	10	4.8[b] (9.3)	—	2–4[b]	—	—	—
Tulve *et al.* (2002)	Trained observers, manual recording	Mouth and tongue	Yes	Primarily indoors	5 to 60 minutes per day for 1–6 days	11–24 months	69	73 (12)	—	—	—	—	—
						25–60 months	117	31 (9)	—	—	—	—	—
Juberg *et al.* (2001)	Parents, manual recording	Inside of the mouth	Yes	Primarily indoors	1 day	0–18 months	107	—	—	—	—	0 (pacifiers)[f] 0.67 (non-pacifiers)[f]	—
						19–36 months	110	—	—	—	—	0 (pacifiers)[f] 0 (non-pacifiers)[f]	—

(*Continued on next page*)

Table 1. Summary of previous quantitative studies on children's mouthing behavior *(Continued)*

Study	Method	Mouthing contact boundary	Non-dietary includes hands	Location	Observation period	Age	n	Mouthing frequency[a] (contacts/hour)		Mouthing contact duration[a] (seconds)		Hourly mouthing duration[a] (minutes/hour)	
								Indoor	Outdoor	Indoor	Outdoor	Indoors	Outdoor
Freeman *et al.* (2001)	Videotaping, manual recording	Inside of the mouth	No	Primarily indoors	4 hours	3–4 years	3	3[b] (3.5)	—	—	—	—	—
						5–6 years	7	0[b] (2.5)	—	—	—	—	—
						7–8 years	4	0[b] (3)	—	—	—	—	—
						10–12 years	5	0[b] (2)	—	—	—	—	—
Reed *et al.* (1999)	Videotaping, manual recording	Inside of the mouth	No	Primarily indoors	3–7 hours	2–6 years	30	3.6[b] (8.5)	—	—	—	—	—
Groot *et al.* (1998)	Parents, manual recording	Inside of the mouth and tongue	Yes	Primarily indoors	10 fifteen-minute periods per day for 2 days	3–6 months	5	—	—	—	—	5.6[c,f]	—
						6–12 months	14	—	—	—	—	2.1[c,f]	—
						12–18 months	12	—	—	—	—	0.83[c,f]	—
						18–36 months	11	—	—	—	—	0.42[c,f]	—
Zartarian *et al.* (1998, 1997)	Videotaping, computer software	Inside of the mouth	Yes	Primarily indoors	6–10 hours	2–4 years	4	16.5 (12.5)[d]	—	3	—	—	—

[a]Based on median contacts with non-dietary objects and hands (presented in parentheses).
[b]Non-dietary object calculations did not include hand-to-mouth contacts.
[c]Estimated from graph in paper. Values presented are based on extrapolation from 5 hours of observation.
[d]Computed by adding the median frequencies for left-hand to mouth and right-hand to mouth contacts.
[e]Converted by multiplying percent of observed time by 60 minutes/hour.
[f]Computed by dividing minutes per day by 24 hours/day.

in which observations on 90 children aged 10 to 60 months were collected using a zero–one sampling approach in the home environment. The mouthing behavior was sampled at 15-second intervals, during which a score of one was assigned if the mouthing behavior occurs; a score of zero was assigned otherwise. Black *et al.* (2004) videotaped approximately 52 children for about 4 hours each in a primarily indoor home environment in a small colonia south of Laredo, Texas, and transcribed the videotapes using the VirutalTimingDevice™ software (Table 1). Freeman *et al.* (2004) videotaped 10 children for approximately 4 hours each in a primarily indoor home environment and transcribed the videotapes using the VirtualTimingDevice™ software.

Two previous studies collected information on children's mouthing durations (Table 1). Groot *et al.* (1998) asked parents of 42 young children (3–36 months) in the Netherlands to observe their children for ten 15-minute periods each day for two days and note the times during which the child had something in his/her mouth. The durations were summed for the 5 hours of observation and extrapolated to yield a daily mouthing duration. Juberg *et al.* (2001) also employed a similar parental observation method to obtain mouthing durations for 217 children aged 0–36 months living in Western New York. For that study, the parents were asked to observe their children for the entire day and to document each item mouthed and its time in and out of the child's mouth. The durations were summed to give daily mouthing durations.

Among the previous studies on children's mouthing behavior, only two studies (Zartarian *et al.* 1998; Freeman *et al.* 2004) have reported mouthing contact duration data (i.e., the length of each contact). Zartarian *et al.* (1998) reported mouthing contact duration data based on four children, which was transcribed using VirtualTimingDevice™ while Freeman *et al.* (2004) reported mouthing contact duration data based on ten children which was transcribed using VirtualTimingDevice™.

This study expands upon the previous studies in two ways: First, mouthing contact durations are calculated based on a larger dataset of 38 children. Second, while all previous studies on children's mouthing behavior were conducted in a primarily indoor setting (i.e., residential home or daycare), this study focuses on collecting information on children's mouthing behavior in a primarily outdoor residential environment. Studying mouthing behavior in outdoor environments may be important in helping estimate exposure to toxicants unique to outdoor environments (e.g., arsenic from CCA-treated wooden play structures).

METHODS

Recruitment of Subjects

In order to obtain independent and identically distributed samples, the 38 children (Figure 1) in our study were recruited by calling telephone numbers randomly extracted from the telephone directory for a 300–400 square mile portion of the San Francisco peninsula stretching from San Mateo County to Santa Clara County. Through a phone survey, families who lived in a residence with a lawn and whose

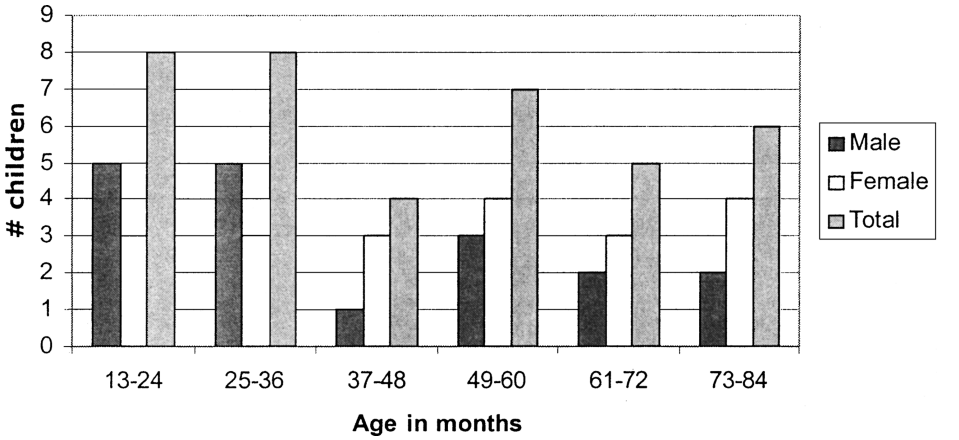

Figure 1. Age and gender distribution.

annual household income was greater than $35,000 were asked to participate in the studies. Due to time constraints, 8 children were recruited through acquaintances with children between 1–6 years and who were willing to participate in the studies. Of the 38 children analyzed in this study, one 3-year-old child was not recruited randomly due to time constraints.

All of the children analyzed in this study lived in suburbia. The median household income was >$100,000 per year. Of the 31 households that provided ethnicity data, 55% were Caucasian, 16% were Mexican American, 6% were African American, and 7% belonged to other ethnicities. No selection/exclusion criteria were used other than age and willingness to participate.

Videotaping

The analyses presented in this article come from data collected from two studies conducted by the Exposure Research Group at Stanford University between 1998 and 1999. For both studies, approximately 2 hours of videotape data were collected for each child in a primarily outdoor residential setting in the Peninsula region of the San Francisco Bay Area. Videotaping took place from August 1998 through May 1999. A large percentage, 38%, of the videotaping was performed in October 1998. The subjects were videotaped only on days with fair weather (i.e., no rain).

A team of two researchers videotaped each child's activities. During videotaping, the team kept as far as possible from the child in order to minimize influence on the child's normal activities. If it was not possible to clearly videotape what the mouth was touching, the cameraperson voice-annotated information about the surface or object the mouth was touching. In addition, field notes were taken by the second researcher to clarify details concerning the objects and surfaces the child contacted. For example, if a child contacts an object that may not be easily identifiable by the viewer (e.g., a small eraser in the mouth), the researcher would make a note identifying the object in a log sheet.

While in many cases the act of observing a phenomenon changes it, there are exceptions to this influence. For example, anecdotal reports indicate that young children adapt well to the presence of strangers (Bentzen 1985). In particular, remaining as inconspicuous as possible during observation helps to lessen impacts on a child's natural behavior. Since the children in this study were mostly filmed outdoors, there were many situations where it was possible for the cameraperson to videotape from a distance by zooming in on the child. Also, after habituating to the presence of a stranger and a videocamera, most children's attention focused mainly on play. This was especially true for children who were engaged in interactions with playmates or parents.

The videotaping method has content validity because the videocamera faithfully captures mouthing events without bias. This is important because other observation methods, such as parental reporting, may yield less accurate and less detailed accounts of children's mouthing behavior (Reed *et al.* 1999; Black *et al.* 2004). Reed *et al.* found that while parental reports provided reasonable qualitative information on children's mouthing activities with the hands, they did not correspond well with direct observations of mouthing frequencies with non-dietary objects. Similarly, Black *et al.* (2004) compared mouthing frequencies collected by researchers via videotaping with mouthing behavior information collected from parental reports and found that children reported as "never" having mouthing contacts with the hands or non-dietary objects nonetheless were found to have median mouthing frequencies of 9.6 and 6.4 contacts per hour, respectively, with these object categories.

Translation of Videotapes Using VirtualTimingDevice™

The videotapes were "translated," or converted into ASCII activity data files, using a specialized software package developed at Stanford University (VirtualTimingDevice™). Translation occurs as a researcher watches a videotape playback and simultaneously activates the appropriate object, location, and contact type cells on the VirtualTimingDevice™ palette (Figure 2) to match the activity of the videotaped child. As the child touches a new object surface, changes location, or changes contact type, the translator records the change by clicking on the cell in the appropriate grid to match the new category. For each child, transcriptions were done separately for the left hand, the right hand, and the mouth. If two objects simultaneously touched a body part, the object with the higher surface area in contact with the body part was recorded. The activity patterns are stored as ASCII text files with sequential, second-by-second information on microenvironments visited and objects/surfaces contacted (Figure 3). Integer math was used to record the length of each contact (i.e., fractions are dropped). Contacts lasting less than one second were recorded as zeros.

The location grid in the VirtualTimingDevice palette (Figure 2) used in these studies was primarily designed to capture the different outdoor locations that a child may spend time in. The contact type grid (Figure 2) consists of two cells that capture the kinds of contact types a child may have with an object or surface, that is, either a

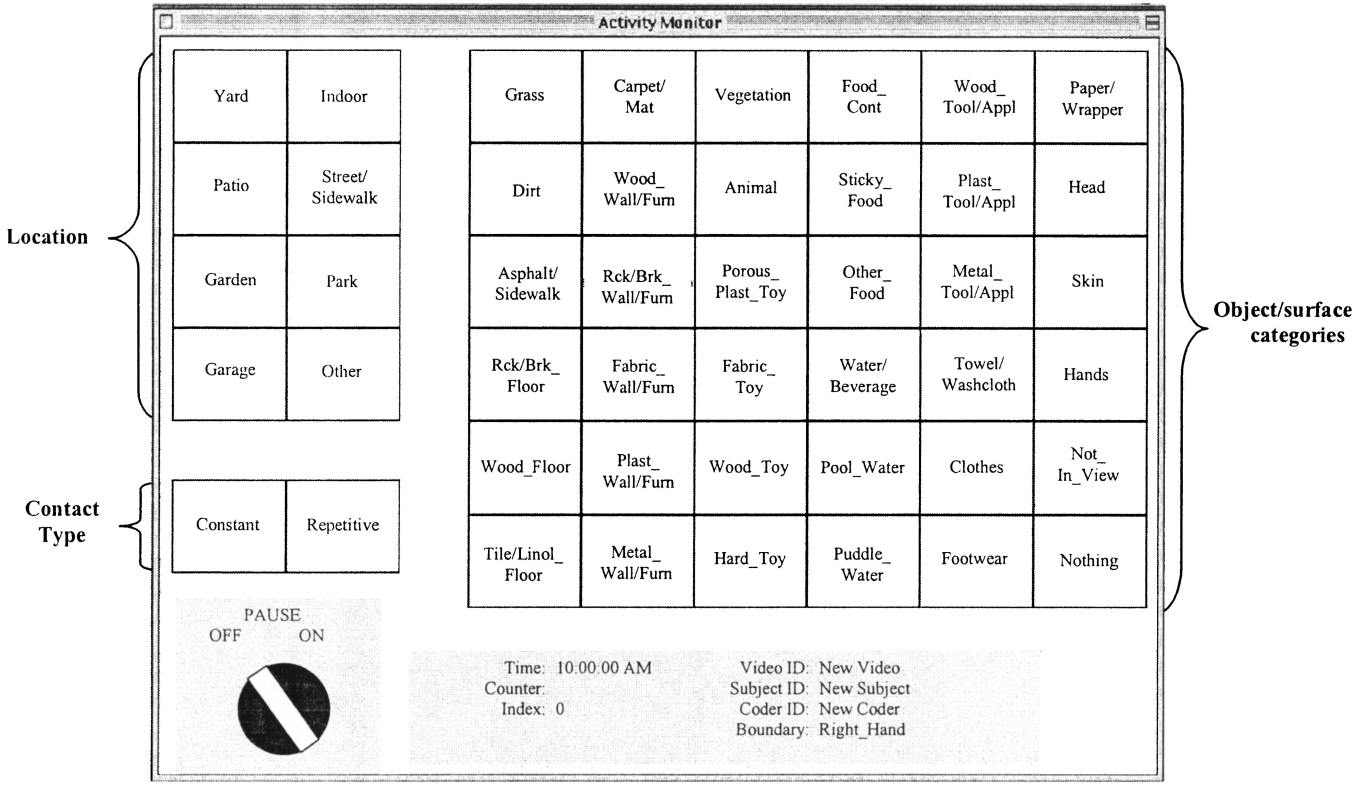

Figure 2. VirtualTimingDevice palette for the mouth.

Bodypart	Location	Activity	Object	Duration
Mouth	Yard	Constant	Skin	1
Mouth	Yard	Constant	Hard_Toy	4
Mouth	Yard	Constant	Hands	2
Mouth	Patio	Constant	Hands	3
Mouth	Yard	Constant	Hands	7
Mouth	Yard	Constant		

Figure 3. Example of translation file output.

constant contact or repetitive contacts such as touching the mouth with the hand in quick succession or bouncing a ball with the hand. Finally, the 36 object categories in the objects/surfaces grid represent objects/surfaces that children most commonly come into contact with. The main difference between the "Wall/Furniture" categories and the "Tool/Appliance" categories is that "Wall/Furniture" objects/surfaces are assumed to be stationary and thus handled less often, while "Tool/Appliance" objects/surfaces are assumed to be mobile and thus handled more often. Therefore, "Tool/Appliance" objects/surfaces are assumed to be covered with less residues or dust than "Wall/Furniture" objects/surfaces. The "Paper/Wrapper" category includes all paper products and food wrappers. "Vegatation" refers to plant parts (including fruits) growing on a plant. For example, a tomato growing in a subject's garden/yard would be labeled as "Vegetation," whereas the same tomato would be labeled "Sticky Food" after it is washed.

Quality Control of Videotape Translation

Rigid training and quality control protocols were applied to guarantee a high quality of data (Ferguson *et al.* submitted 2004). For example, in order to ensure a high quality of the translated files, 5–10% of the translated files were randomly selected to be checked by an experienced translator. To check a file for inter-observer agreement, an experienced translator translated the first 15 minutes of the selected videotape to produce a standard file. The standard file and the first 15 minutes of the selected file were then compared using S-Plus software to obtain total agreement between location, contact type, and object designations. The translator passed the quality control test if total agreement was at least 90%. In general, if the two files had greater than 10% difference, then the translator had to repeat translation for the segment that was checked as well as any other segment where similar errors may have occurred.

Data Processing

The translated files were processed in two ways before the data were analyzed. First, repetitive contacts, that is, consistent, rhythmic contacts with an object (e.g., touching the mouth repeatedly or bouncing a ball with the hand) were assumed to alternate between contacts with the surface/object and air ("Nothing") at the

Bodypart	Location	Activity	Object	Duration
Mouth	Yard	**Repetitive**	Hands	**2**
Mouth	Patio	Constant	Hands	3

Bodypart	Location	Activity	Object	Duration
Mouth	Yard	**Constant**	Hands	**0.5**
Mouth	Yard	**Constant**	Nothing	**0.5**
Mouth	Yard	**Constant**	Hands	**0.5**
Mouth	Yard	**Constant**	Nothing	**0.5**
Mouth	Patio	Constant	Hands	3

Figure 4. Processing repetitive contacts.

Bodypart	Location	Activity	Object	Duration
Mouth	Yard	Constant	Hands	1
Mouth	Yard	Constant	Hard_Toy	4
Mouth	**Yard**	Constant	Hands	**2**
Mouth	**Patio**	Constant	Hands	**3**
Mouth	**Yard**	Constant	Hands	**7**

Bodypart	Location	Activity	Object	Duration
Mouth	Yard	Constant	Skin	1
Mouth	Yard	Constant	Hard_Toy	4
Mouth	**Yard**	Constant	Hands	**12**

Figure 5. Processing continuous contact between locations.

rate of two contacts per second. (Figure 4). Second, continuous contacts occurring in different locations were joined to avoid double-counting contact frequencies (Figure 5). Henceforth, the processed data will be referred to as "modified" data and the raw data as "original" data.

Data Analysis

In this study, a mouthing contact was defined as any contact with the lips, inside of the mouth, and/or the tongue. Before the data were analyzed, object and location designations from the VirtualTimingDevice palette were grouped to form 2 location and 16 object/surface super-categories (Tables 2 and 3). The "Other" location

Table 2. Super-category assignment for locations

Super-categories	Virtual TimingDevice palette categories
Indoor	Indoor
Outdoor	Yard, patio, garden, park, garage

category was ignored because the entire dataset contains less than 2 minutes worth of activity with that location designation. Furthermore, the "Nothing," "Not In View," and "Other" object/surface categories were not listed or analyzed because they do not contain data of interest with respect to mouthing behavior patterns. In fact, the total duration of contacts with the "Other" object/surface designation for the entire dataset is less than 3 minutes.

The data were divided by location (i.e., "Indoor" or "Outdoor") for the analysis. To ensure that we analyzed only authentic indoor behavior, we included only indoor data from children who spent 15 or more minutes in view indoors. We assumed that children who spent less than 15 minutes in view indoors would not give a true representation of typical indoor behavior. Fifteen minutes was a natural cutoff point because the children either spent 15 to 40 minutes in view indoors or spent less than 10 minutes in view indoors. This narrowed the dataset for indoor data down to one child $\leq$24 months and 8 children >24 months of age. With the exception of one child who spent only half an hour in view outdoors, all of the children spent at least one hour in view outdoors, with the median time spent in view outdoors being

Table 3. Super-category assignments for objects/surfaces

Super-categories	VirtualTimingDevice palette categories
Animal	Animal
R[o]ck/Br[ick]_Wall/Furn[iture]	R[o]ck/Br[ick]_Wall/Furn[iture]
Clothes/Towels	Clothes, Towel/Washcloth
Fabric	Fabric_Wall/Furn[iture]
Floor	Dirt, Asphalt/Sidewalk, R[o]ck/Br[ic]k_Floor, Wood_Floor, Tile/Linol[eum]_Floor, Carpet/Mat
Food	Sticky_Food, Other_Food, Food_Cont[ainer], Water/Beverage
Footwear	Footwear
Hands	Hands
Metal	Metal_Wall/Furn[iture], Metal_Tool/Appl[iance]
Non-dietary water	Pool_Water, Puddle_Water
Paper/Wrapper	Paper/Wrapper
Plastic	Plastic_Wall/Furn[iture], Plastic_Tool/Appl[iance]
Skin	Skin
Toys	Hard_Toy, Porous_Plast[ic]_Toy, Fabric_Toy, Wood_Toy
Vegetation/Grass	Vegatation, Grass
Wood	Wood_Wall/Furn[iture], Wood_Tool/Appl[iance]

Table 4. Percent time spent outdoors

	n	Median (%)	Mean (%)
≤24 Months	8	97.7	95.8
>24 Months	30	95.3	91.3
All subjects	38	96.0	92.2

1 hour and 40 minutes. The mean and median percent times that children spent outdoors are presented in Table 4.

Contact frequencies were calculated by summing up the number of modified contacts for each of the 16 object/surface super-categories and then dividing by the time in view. Time in view is simply the total of all durations from the original data with the exception of time designated as "Not In View." Contact duration is the duration of each modified contact, and hourly mouthing durations were calculated by summing the modified contact duration (in minutes) for each of the 16 object/surface super-categories and dividing by the time in view (in hours). These calculations were performed separately for the "Indoor" and "Outdoor" location super-categories for each child. Since this study focuses on exposure through the non-dietary ingestion route, dietary contacts (i.e., contacts with the "Food" super-category) were ignored.

Mouthing frequency, contact duration, and hourly duration were analyzed by age and gender, separately (i.e., age alone and gender alone) and in combination. In order to determine the most appropriate way to group the data by age, tree analysis was applied to the modified mouthing data. Applying tree analysis in S-Plus 6 (Tulve *et al.* 2002) to the mouthing contact durations with the hands and non-dietary objects yielded ≤21.5 months and/>21.5 months age groupings, while the same analysis applied on hands and non-dietary object mouthing frequency data yielded age groupings of ≤18.5 months/>18.5 months and ≤63 months/>63 months of age, respectively. These age groupings are very similar to the ≤24 months/>24 month age bins reported by Tulve *et al.* (2002) based on tree analysis performed on the mouthing frequency data in their study. In order to keep our results comparable to results from Tulve *et al.* (2002), and because the age groupings are so similar, we also chose the ≤24 months/>24 months age bins for our data analysis.

To evaluate the joint function of gender and age on mouthing behavior, data belonging to the same age bin were factored by gender. For example, female children ≤24 months were compared with male children ≤24 months, while female children >24 months were compared with male children >24 months.

Since the frequency, contact duration, and total duration data for mouthing contacts with the hands and non-dietary objects are right-skewed, the data are summarized by the median. This is because the median is a more robust statistic than the arithmetic mean; that is, it is less affected by skewness in the distribution of the data (Rice 1995). The Shapiro-Wilk test for normality (Shapiro and Wilk 1965) was applied to each data group to determine whether the data are normally distributed.

At a level of significance of alpha = 0.05, none of the data were found as likely to have come from normal distributions. Therefore, nonparametric tests such as the Wilcoxon rank sum test for two samples and the Wilcoxon signed rank test for two samples (Rice 1995) were used for all of the data analyses.

RESULTS AND DISCUSSION

In this section, we provide statistically significant findings from our data analyses as well as summary statistics of the frequencies, contact durations, and hourly durations of mouthing contacts with the hands and all non-dietary objects. Results from this study are presented along with results from previous studies. However, since it is difficult to compare results across studies due to differences in data collection methods and the subpopulations studied (both in terms of the ages of the children studied and the regions where these studies were conducted), no inferences were drawn regarding differences in results. As all previous studies focused on indoor environments, we only used the data we collected indoors for comparisons. This section ends with a discussion of special observations in our dataset (i.e., children who had the highest mouthing frequencies and longest contact durations and children who had mouthing contacts with unusual objects/surfaces).

Significant Differences

We applied the Wilcoxon tests in S-Plus 6 to perform all statistical analyses. Significant differences in mouthing frequency, contact duration, and hourly duration were tested for gender and age groupings, and between the indoor and outdoor environments. Mouthing behavior data were more robust for outdoor environments and children >24 months than for indoor mouthing behavior or children <24 months of age since more data were available.

We found that for outdoor environments, children ≤24 months of age had significantly longer contact durations with the hands than children >24 months of age ($p = 0.04$). No significant differences in mouthing contact frequencies or hourly mouthing durations with the hands or total non-dietary objects were found between children ≤24 months and children >24 months either indoors or outdoors.

When the Wilcoxon rank sum test for two samples was applied to the data factoring by gender, we found that for outdoor environments, girls had significantly higher mouthing frequencies with the hands ($p = 0.01$) and total non-dietary objects ($p = 0.008$) and shorter contact durations with the hands ($p = 0.04$) than boys. Finally, we found that for outdoor environments, girls had significantly higher hourly mouthing durations with total non-dietary objects than boys ($p = 0.01$).

Applying the Wilcoxon ranksum test for two samples to data grouped jointly by age and gender revealed that for outdoor environments, girls ≤24 months and girls >24 months had significantly higher total non-dietary contact frequencies than boys at comparable ages ($p = 0.04$ for both). For outdoor environments, girls >24 months also had higher mouthing frequencies with the hands than boys of the same age ($p = 0.04$). Finally, for outdoor environments, girls >24 months had significantly

longer hourly durations with total non-dietary objects than boys of the same age ($p = 0.01$).

Applying the paired signed rank test to the mouthing frequency, contact duration, and hourly duration data did not yield significant intra-child differences between indoor and outdoor environments. However, this may be due to the small dataset (9 children) that we included for indoor data analysis.

Mouthing Frequency

Tables 5 and 6 show the frequencies for mouthing contacts with non-dietary objects that occurred in the indoor and outdoor residential environments, respectively. "Footwear" and "Floor" are not listed because there was only one contact in the entire dataset with each of these object/surface super-categories.

The data were analyzed separately for the indoor and outdoor environments because recent studies (Freeman *et al.* 2001; AuYeung *et al.* 2004; Black *et al.* 2004) found a difference in mouthing frequency between the indoor and outdoor environments with the mouthing frequency of hands and non-dietary objects being higher indoors than outdoors. While the differences were not statistically significant, a similar trend was observed from the results of this study for all three age groupings (i.e., ≤24 months, >24 months, all subjects).

Our indoors non-dietary mouthing frequency for children ≤24 months of age are similar to the findings by Tulve *et al.* (2002) for a similar age group. Tulve *et al.* (2002) reported a median non-dietary object mouthing frequency of 73, whereas we calculated a mouthing frequency of 84.8 contacts per hour. In order to compare our data to data reported by Black *et al.* (2004), which did not include hand-to-mouth contacts in the non-dietary object category, we subtracted all hand contacts from total non-dietary contacts with the mouth and found a mouthing frequency with non-dietary objects (excluding hands) of 11.3 contacts per hour (Table 1). This is slightly higher than the findings by Black *et al.* (2004) for similar age groups (8.4 contacts per hour).

Our indoors hand-to-mouth contact frequency findings for children ≤24 months is much higher than findings by Tulve *et al.* (2002) and Black *et al.* (2004) for similar age groups. Tulve *et al.* (2002) and Black *et al.* (2004) reported just 12 and 13.3 contacts per hour, respectively, whereas we found 73.5 contacts per hour. However, since our data analysis for children ≤24 months of age in indoor environments is based on only one child, our data for this age group for indoor environments is not robust.

For children >24 months of age in the indoor residential setting, our findings of 13.3 contacts per hour for median hand-to-mouth contact frequency are similar to findings for similar age groups reported by Zartarian *et al.* (1997) (12.5 contacts per hour), Reed *et al.* (1999) (8.5 contacts per hour), Tulve *et al.* (2002) (9 contacts per hour), Black *et al.* (2004) (9–9.9 contacts per hour), and Freeman *et al.* (2004) (9.3 contacts per hour). However, these findings are higher than the findings reported by Freeman *et al.* (2001) (3.5 contacts per hour).

Table 5. Outdoor mouthing frequency (contacts per hour)*

Age in months	n	Statistic	Object/surface categories													
			Animal	Clothes/ towels	Fabric	Hands	Metal	Non-dietary water	Paper/ wrapper	Plastic	Skin	Toys	Vegetation/ grass	Wood	Total non-dietary	Non-dietary (excluding hands)
≤24	1	Range	0	11.3	0	73.5	0	0	0	0	0	0	0	0	84.8	11.3
		Mean	0	11.3	0	73.5	0	0	0	0	0	0	0	0	84.8	11.3
		5th Percentile	0	11.3	0	73.5	0	0	0	0	0	0	0	0	84.8	11.3
		25th Percentile	0	11.3	0	73.5	0	0	0	0	0	0	0	0	84.8	11.3
		Median	0	11.3	0	73.5	0	0	0	0	0	0	0	0	84.8	11.3
		75th Percentile	0	11.3	0	73.5	0	0	0	0	0	0	0	0	84.8	11.3
		95th Percentile	0	11.3	0	73.5	0	0	0	0	0	0	0	0	84.8	11.3
		99th Percentile	0	11.3	0	73.5	0	0	0	0	0	0	0	0	84.8	11.3
>24	8	Range	0	0–18.8	0	0–35.3	0–2.1	0	0–3.3	0–1.7	0–2.5	0–23	0	0–4.9	0–52.2	0–45.9
		Mean	0	3.2	0	13.9	0.3	0	0.4	0.2	0.8	3.3	0	0.6	22.7	8.8
		5th Percentile	0	0	0	2.2	0	0	0	0	0	0	0	0	2.8	0
		25th Percentile	0	0	0	7.6	0	0	0	0	0	0	0	0	10.8	0
		Median	0	0	0	13.3	0	0	0	0	0	0	0	0	19.5	1.9
		75th Percentile	0	2.7	0	17.2	0	0	0	0	1.8	1.8	0	0	33.5	8.8
		95th Percentile	0	14	0	29.4	1.4	0	2.1	1.1	2.4	15.6	0	3.2	47.6	34.5
		99th Percentile	0	17.8	0	34.1	2	0	3.1	1.6	2.5	21.5	0	4.6	51.3	43.6
All subjects	9	Range	0	0–18.8	0	0–73.5	0–2.1	0	0–3.3	0–1.7	0–2.5	0–23	0	0–4.9	0–84.8	0–45.9
		Mean	0	4.1	0	20.5	0.2	0	0.4	0.2	0.7	3	0	0.5	29.6	9.1
		5th Percentile	0	0	0	2.5	0	0	0	0	0	0	0	0	3.2	0
		25th Percentile	0	0	0	8	0	0	0	0	0	0	0	0	11.7	0
		Median	0	0	0	14.8	0	0	0	0	0	0	0	0	22.1	3.7
		75th Percentile	0	5	0	18.3	0	0	0	0	1.7	1.7	0	0	39	11.3
		95th Percentile	0	15.8	0	58.2	1.3	0	2	1	2.3	14.6	0	2.9	71.8	32.9
		99th Percentile	0	18.2	0	70.4	1.9	0	3	1.6	2.5	21.3	0	4.5	82.2	43.3

*Shows data from children who had more than 15 minutes in view indoors.

Table 6. Outdoor mouthing frequency (contacts per hour)

			Object/surface categories													
Age in months	n	Statistic	Animal	Clothes/ towels	Fabric	Hands	Metal	Non-dietary water	Paper/ wrapper	Plastic	Skin	Toys	Vegetation/ grass	Wood	Total non-dietary	Non-dietary (excluding hands)
≤24	8	Range	0	0–10.2	0–2.2	0.6–49.9	0–1.5	0	0–0.7	0–1.1	0–3.1	0–5.6	0–3.8	0–1.5	4.4–58.3	0.7–18.1
		Mean	0	2.6	0.3	13	0.3	0	0.1	0.2	0.9	1.7	1.1	0.2	20.4	7.4
		5th percentile	0	0	0	1.3	0	0	0	0	0	0	0	0	6.2	1.8
		25th percentile	0	0.8	0	4.1	0	0	0	0	0	0	0	0	11.6	3.8
		Median	0	1.8	0	7	0	0	0	0	0.6	0.7	0	0	13.9	6.3
		75th percentile	0	3.2	0	14.6	0.2	0	0	0.1	1	2.5	2.1	0	22.6	10.2
		95th percentile	0	7.8	1.4	39.1	1.2	0	0.5	0.9	2.8	5.6	3.8	1	48.9	15.3
		99th percentile	0	9.7	2	47.7	1.4	0	0.7	1.1	3	5.6	3.8	1.4	56.4	17.5
>24	30	Range	0–6.4	0–4.6	0–0.6	0–43.6	0–1	0–6.9	0–4.6	0–0.7	0–5	0–15	0–33.2	0	0–53.6	0–33.2
		Mean	0.3	0.8	0	11.3	0	0.2	0.5	0	0.9	2.3	1.3	0	17.7	6.4
		5th percentile	0	0	0	0.2	0	0	0	0	0	0	0	0	0.6	0
		25th percentile	0	0	0	4.7	0	0	0	0	0	0	0	0	7.6	0.8
		Median	0	0.3	0	8.6	0	0	0	0	0	0	0	0	14.6	4.4
		75th percentile	0	1.3	0	14.8	0	0	0	0	1.4	2.1	0	0	22.4	9.5
		95th percentile	0.6	3.5	0	27.7	0	0	3.8	0.3	3.5	10.3	1.9	0	43.8	19
		99th percentile	4.9	4.5	0.4	39.5	0.7	4.9	4.5	0.6	4.6	13.7	24.3	0	53	29.6
All subjects	38	Range	0–6.4	0–10.2	0–2.2	0–49.9	0–1.5	0–6.9	0–4.6	0–1.1	0–5	0–15	0–33.2	0–1.5	0–58.3	0–33.2
		Mean	0.2	1.2	0.1	11.7	0.1	0.2	0.4	0.1	0.9	2.2	1.3	0	18.3	6.6
		5th percentile	0	0	0	0.4	0	0	0	0	0	0	0	0	0.8	0
		25th percentile	0	0	0	4.4	0	0	0	0	0	0	0	0	9.2	0.9
		Median	0	0.6	0	8.4	0	0	0	0	0	0	0	0	14.5	4.6
		75th percentile	0	1.6	0	14.8	0	0	0	0	1.4	2.1	0	0	22.4	9.8
		95th percentile	0.2	4.3	0.1	31.5	0.7	0	3.5	0.5	3.4	10.1	3.7	0	51.7	18.5
		99th percentile	4.4	8.1	1.6	47.6	1.3	4.3	4.4	1	4.5	13.4	22.3	0.9	56.6	28.6

For children >24 months of age in the indoor residential setting, our findings of 19.5 contacts per hour for median mouthing frequencies with total non-dietary objects are similar to findings reported by Zartarian *et al.* (1998) (16.5 contacts per hour). They are lower than the values reported by Tulve *et al.* (2002) (31 contacts per hour). Comparing our findings for median mouthing contact frequencies for non-dietary objects (excluding hands) with those reported by Freeman *et al.* (2001, 2004) and Black *et al.* (2004), our findings of 1.9 contacts per hour is similar to the frequencies reported for similar age groups by Freeman *et al.* (2001) (3 contacts per hour for children 3–4 years of age and 0 contacts per hour for children 5–6 years of age) and lower than the values reported by Freeman *et al.* (2004) (4.8 contacts per hour) and Black *et al.* (2004) (5.5–8.4 contacts per hour).

Interestingly, in outdoor environments, the distribution of mouthing frequencies with the hands and total non-dietary objects is very similar between children ≤24 months of age and children >24 months of age. The median mouthing frequencies with the hands for children ≤24 months and children >24 months are 7 and 8.6 contacts per hour, respectively. For total non-dietary objects, the median frequencies for children ≤24 months and children >24 months are 13.9 and 14.6 contacts per hour, respectively.

Mouthing Contact Duration

Tables 7 and 8 show the median contact durations for mouthing contacts with non-dietary objects indoors and outdoors, respectively. For all age groups (≤24 months, >24 months, all subjects), the median contact duration for total non-dietary objects is 1–2 seconds. The range of median contact durations for all object categories and all age groups for the indoor and outdoor environments is 1–6 seconds. This confirms findings from Zartarian *et al.* (1998) and Freeman *et al.* (2004) that mouthing contacts have extremely short durations (Table 1).

Median contact durations in indoor and outdoor environments are quite similar while the maximum mouthing contact durations tend to be higher for outdoor environments than for indoor environments. This is most likely due to the fact that this was a primarily outdoor study and there were much more data available for outdoor environments than for indoor environments, thus allowing more outliers in the right-tail to be captured for outdoor environments relative to indoor environments. Overall, the long outlier contact durations belong to children ≤24 months who liked to put things into their mouths and keep them there. This is particularly true for the "Hands" and "Clothes/Towels" super-categories.

Hourly Mouthing Duration

Tables 9 and 10 show the hourly contact durations for mouthing contacts with non-dietary objects indoors and outdoors, respectively. Our median hourly mouthing duration of 11.1 minutes per hour with non-dietary objects for children ≤24 months of age is slightly higher than findings by Groot *et al.* (1998) of a median hourly duration of 8.4 minutes per hour for children 12–18 months old and much higher

Table 7. Indoor median duration per mouthing contact (seconds)[a,b,c,d]

			Object/surface categories													
Age in months	n	Statistic	Animal	Clothes/ towels	Fabric	Hands	Metal	Non-dietary water	Paper/ wrapper	Plastic	Skin	Toys	Vegetation/ grass	Wood	Total non-dietary	Non-dietary (excluding hands)
≤24	1	Range	—	—	—	1–34	—	-	—	—	—	—	—	—	1–34	—
		Mean	—	—	—	5	—	—	—	—	—	—	—	—	5	—
		5th Percentile	—	—	—	1	—	—	—	—	—	—	—	-	1	—
		25th Percentile	—	—	—	1	—	-	—	—	—	—	—	—	1	—
		Median	—	—	—	1	—	—	—	—	—	—	—	—	1	—
		75th Percentile	—	—	—	5	—	—	—	—	—	—	—	—	5	—
		95th Percentile	—	—	—	25	—	—	—	—	—	—	—	—	25	—
		99th Percentile	—	—	—	32.6	—	—	—	—	—	—	—	—	32.6	—
>24	8	Range	—	0–18	—	0–12	5	—	1–4	1–3	1–3	1–9	—	1–4	0–18	0–18
		Mean	—	3.3	—	2.7	5	—	2.5	2.3	2.3	5.8	—	2.5	3.2	4
		5th Percentile	—	0	—	0	5	—	1.2	1.2	1.2	2.1	—	1.2	0	0.7
		25th Percentile	—	1	—	1	5	—	1.8	1.8	2	3	—	1.8	1	1
		Median	—	1	—	1	5	—	2.5	2.5	3	6	—	2.5	1	3
		75th Percentile	—	3	—	3	5	—	3.3	3	3	8.3	—	3.3	5	5
		95th Percentile	—	10.8	—	10	5	—	3.9	3	3	9	—	3.9	9.9	9
		99th Percentile	—	16.6	—	11.5	5	—	4	3	3	9	—	4	13.1	15
All subjects	9	Range	—	0–18	—	0–34	5	—	1–4	1–3	1–3	1–9	—	1–4	0–34	0–18
		Mean	—	3.3	—	3.5	5	—	2.5	2.3	2.3	5.8	—	2.5	3.6	4
		5th Percentile	—	0	—	0	5	—	1.2	1.2	1.2	2.1	—	1.2	0	0.7
		25th Percentile	—	1	—	1	5	—	1.8	1.8	2	3	—	1.8	1	1
		Median	—	1	—	1	5	—	2.5	2.5	3	6	—	2.5	1	3
		75th Percentile	—	3	—	3	5	—	3.3	3	3	8.3	—	3.3	5	5
		95th Percentile	—	10.8	—	11.4	5	—	3.9	3	3	9	—	3.9	11	9
		99th Percentile	—	16.6	—	29.6	5	—	4	3	3	9	—	4	27.3	15

[a]Shows data from children who had more than 15 minutes in view indoors.
[b]Zeros represent contacts that lasted less than 1 second.
[c]A dash (—) means there were no contacts with that object/surface category.
[d]Contacts of <1 second duration were treated as contacts with zero seconds of duration for the purpose of calculating the mean.

Table 8. Outdoor median duration per mouthing contact (seconds)[a,b,c]

Age in months	n	Statistic	Object/surface categories													
			Animal	Clothes/ towels	Fabric	Hands	Metal	Non-dietary water	Paper/ wrapper	Plastic	Skin	Toys	Vegetation/ grass	Wood	Total non-dietary	Non-dietary (excluding hands)
≤24	8	Range	—	1–69	1–2	0–136	1–6	—	4	2–4	0–2	0–6	0–6	1–2	0–136	0–69
		Mean	—	6.5	1.5	9	2.2	—	4	3.3	1	1.7	1.3	1.7	6.7	3.2
		5th Percentile	—	1	1	1	1	—	4	2.2	0	0	0.9	1.1	0	0
		25th Percentile	—	1	1	1	1	—	4	3	1	0.8	1	1.5	1	1
		Median	—	2	1.5	3	1	—	4	4	1	1.5	1	2	2	1
		75th Percentile	—	6	2	8.3	2	—	4	4	1	2.3	1	2	6	2
		95th Percentile	—	23.2	2	40.5	5.2	—	4	4	2	3.2	3.5	2	30	8.8
		99th Percentile	—	59.1	2	77.2	5.8	—	4	4	2	5.4	5.5	2	71.4	39
>24	30	Range	1–2	0–6	2	0–40	1	1–13	1–37	1–2	0–4.5	0–41	0–52	—	0–52	0–52
		Mean	1.4	1.5	2	2	1	3.5	8.2	1.3	1.4	3.9	3.5	—	2.4	3.3
		5th Percentile	1	0	2	0	1	1	1	1	0	0.5	1	—	0	0
		25th Percentile	1	1	2	1	1	1	2	1	1	1	1	—	1	1
		Median	1	1	2	1	1	2	4	1	1	3	2	—	1	2
		75th Percentile	2	2	2	2	1	4	7	1.5	2	4	3	—	2	3
		95th Percentile	2	4	2	5	1	10	33	1.9	4	10.5	9.2	—	7	9.3
		99th Percentile	2	5.2	2	17.4	1	12.4	36.2	2	4.3	27.3	30.2	—	24.6	33.2
All subjects	38	Range	1–2	0–69	1–2	0–136	1–6	1–13	1–37	1–4	0–4.5	0–41	0–52	1–2	0–136	0–69
		Mean	1.4	3.7	1.6	3.5	1.9	3.5	8	2.3	1.3	3.6	3	1.7	3.4	3.2
		5th Percentile	1	0	1	0	1	1	1.1	1	0	0	0.9	1.1	0	0
		25th Percentile	1	1	1	1	1	1	2	1.3	1	1	1	1.5	1	1
		Median	1	1	2	1	1	2	4	2	1	2	2	2	1	2
		75th Percentile	2	3	2	2	1.5	4	6.8	3.5	2	4	2.8	2	3	3
		95th Percentile	2	11.2	2	12	4.8	10	32.3	4	3.3	9.4	8.1	2	11	9
		99th Percentile	2	47	2	41.6	5.8	12.4	36.2	4	4.2	26.1	23.5	2	40	37

[a]Zeros represent contacts that lasted less than 1 second.
[b]A dash (—) means there were no contacts with that object/surface category.
[c]Contacts of <1 second duration were treated as contacts with zero seconds of duration for the purpose of calculating the mean.

Table 9. Indoor hourly mouthing contact duration (minutes per hour)*

			Object/surface categories													
Age in months	*n*	Statistic	Animal	Clothes/ towels	Fabric	Hands	Metal	Non-dietary water	Paper/ wrapper	Plastic	Skin	Toys	Vegetation/ grass	Wood	Total non-dietary	Non-dietary (excluding hands)
≤24	1	Range	0	0.4	0	10.7	0	0	0	0	0	0	0	0	11.1	0.4
		Mean	0	0.4	0	10.7	0	0	0	0	0	0	0	0	11.1	0.4
		5th Percentile	0	0.4	0	10.7	0	0	0	0	0	0	0	0	11.1	0.4
		25th Percentile	0	0.4	0	10.7	0	0	0	0	0	0	0	0	11.1	0.4
		Median	0	0.4	0	10.7	0	0	0	0	0	0	0	0	11.1	0.4
		75th Percentile	0	0.4	0	10.7	0	0	0	0	0	0	0	0	11.1	0.4
		95th Percentile	0	0.4	0	10.7	0	0	0	0	0	0	0	0	11.1	0.4
		99th Percentile	0	0.4	0	10.7	0	0	0	0	0	0	0	0	11.1	0.4
>24	8	Range	0	0–1.3	0	0–1.9	0–0.2	0	0–0.1	0–0.1	0–0.1	0–2.1	0	0–0.2	0–3.7	0–3.7
		Mean	0	0.2	0	0.7	0	0	0	0	0	0.3	0	0	1.2	0.6
		5th Percentile	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0
		25th Percentile	0	0	0	0.2	0	0	0	0	0	0	0	0	0.6	0
		Median	0	0	0	0.7	0	0	0	0	0	0	0	0	0.9	0.1
		75th Percentile	0	0	0	0.8	0	0	0	0	0	0.1	0	0	1.3	0.4
		95th Percentile	0	0.9	0	1.6	0.1	0	0.1	0.1	0.1	1.4	0	0.1	3.3	2.6
		99th Percentile	0	1.2	0	1.8	0.2	0	0.1	0.1	0.1	2	0	0.2	3.6	3.5
All subjects	9	Range	0	0–1.3	0	0–10.7	0–0.2	0	0–0.1	0–0.1	0–0.1	0–2.1	0	0–0.2	0–11.1	0–3.7
		Mean	0	0.2	0	1.8	0	0	0	0	0	0.3	0	0	2.3	0.6
		5th Percentile	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0
		25th Percentile	0	0	0	0.3	0	0	0	0	0	0	0	0	0.7	0
		Median	0	0	0	0.7	0	0	0	0	0	0	0	0	0.9	0.1
		75th Percentile	0	0.1	0	0.9	0	0	0	0	0	0	0	0	2.5	0.4
		95th Percentile	0	0.9	0	7.2	0.1	0	0.1	0.1	0.1	1.3	0	0.1	8.1	2.5
		99th Percentile	0	1.2	0	10	0.2	0	0.1	0.1	0.1	1.9	0	0.2	10.5	3.5

*Shows data from children who had more than 15 minutes in view indoors.

Table 10. Outdoor hourly mouthing contact duration (minutes per hour)

Age in months	n	Statistic	Object/surface categories													
			Animal	Clothes/ towels	Fabric	Hands	Metal	Non-dietary water	Paper/ wrapper	Plastic	Skin	Toys	Vegetation/ grass	Wood	Total non-dietary	Non-dietary (excluding hands)
≤24	8	Range	0	0–2.1	0–0.1	0–15.5	0–0.1	0	0	0–0.1	0–0.1	0–0.2	0–0.1	0	0.2–15.8	0–2.1
		Mean	0	0.3	0	2.7	0	0	0	0	0	0.1	0	0	3.1	0.5
		5th Percentile	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0
		25th Percentile	0	0	0	0.2	0	0	0	0	0	0	0	0	0.2	0.1
		Median	0	0.1	0	0.4	0	0	0	0	0	0	0	0	0.8	0.2
		75th Percentile	0	0.1	0	1.5	0	0	0	0	0	0.1	0	0	3.1	0.4
		95th Percentile	0	1.4	0.1	11.5	0.1	0	0	0.1	0.1	0.2	0.1	0	11.7	1.5
		99th Percentile	0	2	0.1	14.7	0.1	0	0	0.1	0.1	0.2	0.1	0	15	2
>24	30	Range	0–0.2	0–0.2	0	0–2.4	0	0–0.4	0–0.7	0	0–0.2	0–1.4	0–1.3	0	0–2.6	0–2.1
		Mean	0	0	0	0.4	0	0	0.1	0	0	0.1	0.1	0	0.7	0.3
		5th Percentile	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		25th Percentile	0	0	0	0.1	0	0	0	0	0	0	0	0	0.2	0
		Median	0	0	0	0.2	0	0	0	0	0	0	0	0	0.6	0.1
		75th Percentile	0	0	0	0.4	0	0	0	0	0	0.1	0	0	1	0.5
		95th Percentile	0	0.1	0	1.2	0	0	0.5	0	0.1	0.7	0.4	0	2.1	1.3
		99th Percentile	0.1	0.2	0	2.2	0	0.3	0.6	0	0.2	1.2	1.1	0	2.5	1.9
All subjects	38	Range	0–0.2	0–2.1	0–0.1	0–15.5	0–0.1	0–0.4	0–0.7	0–0.1	0–0.2	0–1.4	0–1.3	0	0–15.8	0–2.1
		Mean	0	0.1	0	0.9	0	0	0.1	0	0	0.1	0.1	0	1.2	0.4
		5th Percentile	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		25th Percentile	0	0	0	0.1	0	0	0	0	0	0	0	0	0.2	0
		Median	0	0	0	0.2	0	0	0	0	0	0	0	0	0.6	0.1
		75th Percentile	0	0	0	0.6	0	0	0	0	0	0.1	0	0	1.2	0.5
		95th Percentile	0	0.1	0	2.6	0	0	0.4	0	0.1	0.6	0.2	0	2.9	1.4
		99th Percentile	0.1	1.4	0.1	11.2	0.1	0.3	0.6	0.1	0.2	1.2	1.1	0	11.5	2.1

than the median of 0.67 minutes per hour reported by Juberg *et al.* (2001). Likewise, our median hourly mouthing duration of 0.9 minutes per hour with total non-dietary objects for children >24 months of age is higher than findings by Groot *et al.* (1998) of a median hourly mouthing duration of 0.42 minutes per hour for children 18–36 months old. For children ≤24 months and children >24 months, our median indoor hourly mouthing durations for non-dietary objects (excluding hands) are 0.4 and 0.1 minutes per hour, respectively. These values are much lower than the values reported by Black *et al.* (2004) for similar age groups (Table 1).

For hourly mouthing durations with the hands, our calculated indoor value of 10.7 minutes per hour for children ≤24 months is much higher than the value of 1.3 minutes per hour reported by Black *et al.* (2004) for children 13–24 months of age. For children >24 months, our calculated indoor values of 0.7 minutes/hour is similar to the values of 0.8 and 0.9 minutes/hour reported by Black *et al.* (2004) for children aged 25–36 and 37–53 months, respectively.

Special Observations

Two children had exceptionally high mouthing frequencies with hands outdoors. One child (18 months old) had a hand-to-mouth frequency of 49.9 contacts per hour, while the other child (59 months old) had a hand-to-mouth frequency of 43.6 contacts per hour. These values are approximately twice the magnitude of the next highest mouthing frequency with hands. In both cases, the children liked to insert their fingers into their mouths. This same 18-month-old child had the highest indoor hand-to-mouth frequency and the longest contact durations with the mouth both indoors (34 seconds per contact) and outdoors (136 seconds per contact). These contact durations were at least two to three times longer than the highest hand-to-mouth contact durations belonging to other children.

Other special observations include one child (53 months old) who had a tenfold or greater higher outdoor mouthing frequency with "Vegetation/Grass" (33.2 contacts per hour) than all other children because she picked a lemon from the yard and sucked on the skin repeatedly. Another child (45 months old) had a three-fold higher mouthing contact duration with "Vegetation/Grass" in outdoor environments (52 seconds per contact) than other children because she picked a tomato from the yard and started eating it. This same child also had the 3 highest outdoor contact durations with "Toys" (41, 28, and 22 seconds per contact) because she blew on a bubble-making toy that was designed to be placed in the mouth. The longest contact durations with "Paper/Wrapper" (37 seconds per contact) occurred as a result of a 77-month-old child who sucked on the plastic wrapper of a popsicle. One child (57 months old) had a tenfold higher indoor mouthing frequency with "Toys," at 23 contacts per hour, than other chidren because he was pretending to fly a model space shuttle. He placed the toy near his face and the toy repeatedly brushed against his lips.

Only one child (56 months old) had mouthing contacts with "Non-dietary water," which was a result of swimming in an outdoor swimming pool. Two children (56 and

73 months of age) had any contacts with "Animals." In both cases, the contacts resulted from either hugging a dog or having a dog brush up against their face/mouth as they were sitting on the ground.

These observations suggest that for most non-dietary objects, specific kinds of activities led to outlier mouthing frequencies and contact durations. However, unusually high hand-to-mouth frequencies seemed to be more closely associated with children's hand-/finger-sucking habits than with particular situations or activities.

CONCLUSIONS

This study found that both gender and age were associated with differences in mouthing behavior. It also confirms results from previous studies (Zartarian *et al.* 1998; Freeman *et al.* 2001) that children's mouthing contact durations tend to be short, with a median duration of less than 5 seconds, and that children's mouthing frequencies tend to be higher indoors than outdoors, whether for the hands or for total non-dietary objects. (Freeman *et al.* 2004, AuYeung *et al.* 2004; Black *et al.* 2001). In addition, we found that indoor and outdoor median contact durations were similar, whether for mouthing contacts with the hands or with total non-dietary objects. We also found that even within the same age group, mouthing frequency varied widely between individual children, suggesting that children are not at equal risk for exposure through non-dietary ingestion. It appears that children's individual inclinations to mouth hands or suck on fingers may lead to exceptionally high mouthing frequencies and long mouthing contact durations with the hands.

In terms of data, this study is unique in providing distributions of outdoor mouthing frequencies and mouthing contact durations with various objects/surfaces. Outdoor mouthing frequencies may be helpful for researchers interested in modeling children's non-dietary ingestion exposures to toxicants like arsenic for which children may become exposed through contact with CCA-treated wood (Hemond and Solo-Gabriele 2004). Mouthing contact duration data may be useful in estimating children's exposures as the amount of exposure per contact event may depend on the contact duration. Although most mouthing contacts lasted only 1–2 seconds, some contacts lasted as long as 52–136 seconds (Table 8).

Currently, the Child Exposure Factor Handbook (USEPA 2002) recommends a value of 9 contacts per hour as a reasonable estimate of hand-to-mouth frequency for children 24–72 months and a weighted average of 49 contacts per hour with total non-dietary objects for children 10–72 months. While our indoor median hand-to-mouth frequency for children >24 months (13.3 contacts per hour) is similar to the recommended value of 9 contacts per hour, our indoor median hand-to-mouth frequency for children ≤24 months (73.3 contacts per hour) is over eight times higher than the recommended value. At the same time, our outdoor median mouthing frequencies with total non-dietary objects is about 3 times lower than the recommended value (USEPA 2002) of 49 contacts per hour. Finally, girls and boys in our study were found to have different mouthing frequencies and contact durations.

These findings suggest that, in the future, it may be useful to summarize mouthing data for young children separately by gender, ≤24 months/>24 months age bins, and indoor/outdoor locations.

It must be noted that mouthing contact frequency and duration alone provide only a rough indication of behavior that leads to non-dietary ingestion exposure and dose. In order to more precisely characterize non-dietary ingestion exposure events, it would be helpful to quantify the fractional surface area that is involved with each contact event. Thus, quantifying fractional surface area for contact events is an important topic for future research.

ACKNOWLEDGMENTS

Special thanks to Kelly Naylor, Nolan Cabrera, Sandy Robertson, Kevin Lee, Amy Munninghoff, Veronica Vieira, Jessica Ramirez, and Angela Lin for their invaluable help in collecting the data presented in this article. This project was supported by EPA STAR grant #R82936201, ORETF Study #ORF018, USEPA Contract #QT-RT-99-001182, and UPS Foundation grant #2DDA103. This research has not been subject to federal peer and policy review and therefore does not necessarily reflect the views of the funding agencies. No official endorsement should be inferred.

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