Journal of Exposure Science and Environmental Epidemiology (2006) 16, 287–298
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www.nature.com/jes

Video methods in the quantification of children's exposures

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In 1994, Stanford University's Exposure Research Group (ERG) conducted its first pilot study to collect micro-level activity time series (MLATS) data for young children. The pilot study involved videotaping four children of farm workers in the Salinas Valley of California and converting their videotaped activities to valuable text files of contact behavior using video-translation techniques. These MLATS are especially useful for describing intermittent dermal (i.e., second-by-second account of surfaces and objects contacted) and non-dietary ingestion (second-by-second account of objects or hands placed in the mouth) contact behavior. Second-by-second records of children contact behavior are amenable to quantitative and statistical analysis and allow for more accurate model estimates of human exposure and dose to environmental contaminants. Activity patterns data for modeling inhalation exposure (i.e., accounts of microenvironments visited) can also be extracted from the MLATS data. Since the pilot study, ERG has collected an immense MLATS data set for 92 children using more developed and refined videotaping and video-translation methodologies. This paper describes all aspects required for the collection of MLATS including: subject recruitment techniques, videotaping and video-translation processes, and potential data analysis. This paper also describes the quality assurance steps employed for these new MLATS projects, including: training, data management, and the application of interobserver and intraobserver agreement during video translation. The discussion of these issues and ERG's experiences in dealing with them can assist other groups in the conduct of research that employs these more quantitative techniques.
Journal of Exposure Science and Environmental Epidemiology (2006) **16,** 287–298. doi:10.1038/sj.jea.7500459; published online 12 October 2005

Keywords: *dermal exposure, video translation, microlevel activity patterns, observational data, interobserver agreement, videotaping.*

Introduction

The Food Quality Protection Act (FQPA) (United States Congress, 1996) emphasized the importance of determining aggregate exposure (i.e., exposure from the dermal, inhalation and ingestion routes) of adults and more importantly of children, to pesticides and other contaminants used in and around the home, in order to assess total health risks. A number of initiatives stemming from the FQPA and the National Research Council's report "Pesticides in the Diets of Infants and Children" (NRC, 1993) have been implemented to protect children, including but not limited to: (1) the Federal Executive Order of 21 April 1997, "Protection of Children from Environmental Risks and Safety Risks," (2) Centers for Children's Environmental Heath and Disease Prevention Research established by the Environmental Protection Agency (EPA), Centers for Disease Control and Prevention (CDC), and the National Institute of Environmental Health Sciences (NIEHS) (O'Fallon et al., 2000), (3) Children's Health Act, (4) Strategy for Research on Environmental Risks to Children, (5) Child-Specific Exposure Factors Handbook, (6) Guidance for Assessing Cancer Susceptibility from Early-Life Exposure (Williams et al., 2003).

Direct methods for determining personal exposure to environmental chemicals involve the placement and analysis of collective devices at the point of exposure (e.g., patches worn on the skin for dermal exposure, personal monitor for inhalation exposure). These devices often prove cumbersome and expensive to wear over any substantial monitoring period, especially for young children. As a result, indirect exposure modeling methods have been developed that rely heavily on the use of various forms of activity patterns. These models also use environmental concentrations and other exposure factors (e.g., residue transfer efficiencies, soil adherence, deposition rates) to estimate human exposure to harmful chemicals. The EPA recognizes models for assessing exposure and dose based on various forms of activity patterns (US EPA, 1999). The different approaches dictate the level of detail, the level of accuracy, the computational structure of

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Received 1 September 2004; accepted 1 September 2005; published online 12 October 2005

the exposure/dose model, the form of the output, and the adequacy of the exposure and dose estimates for risk determinations.

Very early activity pattern studies utilized questionnaires or self-administered diaries to collect time-use data (Chapin, 1974; As, 1975; Robinson, 1977; Szalai, 1972). These questionnaires and diaries produced macrolevel activity patterns describing general human activities (e.g. playing outdoors, reading indoors, or working in an office). In the mesolevel activity approach, exposure and dose are modeled with more specific data on locations and contacts by lumping some characteristic of activity over some arbitrary time frame. An example includes being indoors for 10 min, outdoors for 2 min, and having three contacts with soil sometime within a 15 min period, and being outdoors for 5 min and having 7 contacts with grass some time in the following 15 min. Models which use mesolevel activity data, such as EPA's new Stochastic Human Exposure and Dose Simulations (SHEDS) model (Ozkaynak et al., 1999), attempt to preserve sequences of activities, at least at some level, and characterize the variability of the data.

Dermal exposure, defined as the mass loading of a chemical on the external surface of human skin, depends in part on detailed information regarding the frequency and duration of contacts between the skin and contaminated objects and surfaces in our environment (i.e., dermal activity patterns). For children, these intermittent dermal activity patterns are particularly difficult to describe simply through observation and recall, because children are very active (i.e., high contact frequencies and short contact durations). Dermal contact activity results in temporal and spatial variability in deposition and removal rates of chemicals onto and away from the skin surface, and multiple contact mechanisms through which chemicals can be loaded or removed at the skin surface. Although the exposure dynamics are simpler to describe for non-dietary ingestion exposure, this route also requires the frequency and duration of objects or hands placed in the mouth. Therefore, dermal exposure and non-dietary exposure are both recognized as requiring detailed human activity patterns in order to be modeled more extensively. Focus is now being given to procedures and techniques for quantifying both dermal exposure and non-dietary ingestion exposure, through the collection of more detailed human contact activity. One possibility is in the form of microlevel activity time series (MLATS). MLATS is an improvement over the mesolevel activity approach since detailed (second-by-second) data on sequential contacts are intuitively necessary for appropriately handling removal mechanisms and loadings from multiple media in dermal and non-dietary exposure. Both macro- and mesoactivity patterns can be extracted from microlevel activity patterns with manipulation of the data.

The MLATS data collected by Stanford describes predominantly dermal contact behavior for the indoor and outdoor environments. The nature of the collected MLATS data also allows us to extract activities related to non-dietary (i.e., hand-to-mouth and object-to-mouth contacts) and even inhalation exposure (i.e., simply the time spent in various microenvironments). Stanford's unique method of capturing children's MLATS lies in the use of a computer-based video-extraction technique to extract children's activities from video footage (Zartarian et al., 1997a). Others have adopted our method for the collection of microlevel activity patterns (e.g., Black et al., 2005). While observing a subject's specified bodypart from videotaped footage (played back on a computer or a television screen) a user highlights a cell in each of three grids on the monitor interface (i.e., the palette) corresponding to microenvironment, activity, and object contacted (Figure 1), thereby activating a computer clock that records continuous time. Results of this video translation for a given subject yield the American Standard Code for Information Interchange (ASCII) files containing records of the following fields: an exposure boundary (e.g., left hand, right hand, mouth), microenvironment (e.g., kitchen, garden, bedroom), micro-activity (e.g., playing, resting, repetitive action, continuous action), object contacted (e.g., hard floor, upholstered furniture, soil, vegetation, clothing), and duration in seconds (see Figure 2). Each recorded line in the file corresponds to a unique time sequence of activity-related events (i.e., amount of time that body part spent touching that object in that microenvironment while performing that activity).

The process of collecting MLATS is labor intensive. It requires the development of step-by-step methodologies suitable for the specific exposure scenarios as defined by the needs of a particular project, and then the implementation of the methodologies to recruit and videotape subjects, train personnel, translate the videotaped activities into usable text files, and interpret the activity patterns. During the videotaping and video-translation process, steps must also be taken to insure that quality MLATS data are collected and the data remains organized, and protected.

Methods

Activity Pattern Studies Conducted by ERG

In 1994, Stanford's Exposure Research Group (ERG) pioneered the first pilot field study on MLATS by videotaping four children of farmworkers in the Salinas Valley of California (Zartarian et al., 1995), and converting their videotaped data to text files of contact behavior using video-translation methodologies. The data set produced was used as impetus to develop the Dermal Exposure Reduction Model (DERM), a set of algorithms to estimate children's exposure to pesticides by combining MLATS, environmental concentrations and exposure factors. DERM's utility was then demonstrated by assessing the dermal exposure of these children (2–4 years old) to the pesticide, alachlor (Zartarian,

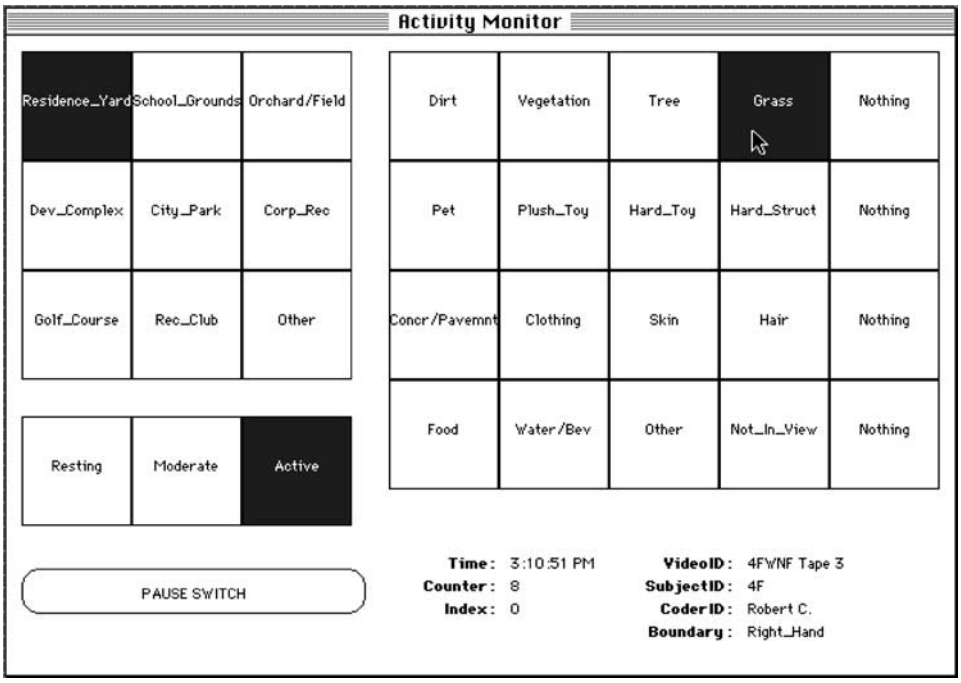

Figure 1. General interface (i.e., palette) used in Video Translation Software. A Virtual Timing Device (VTD) palette typically contains three distinct grids, describing the possible microenvironments visited, object/surface categories contacted, and activity level exerted. When one box in each grid is highlighted corresponding to the videotape activities of the subject's bodypart, a computer clock is activated and duration for the unique combination can be seen at the bottom of the screen, during the translation session.

Bodypart	Location	Object Contacted	Activity-Level	Duration (s)
Right_Hand	Orchard/Field	Tree	Moderate	30
Right_Hand	Orchard/Field	Hard_Struct.	Moderate	10
Right_Hand	Orchard/Field	Hard_Struct.	Active	40
Right_Hand	Residence-Yard	Hard_Toy	Moderate	10
Right_Hand	Residence-Yard	Nothing	Moderate	10

Figure 2. Example results of a Videotape Translation (i.e., Videotraq Output). Results of a video translation for a given subject yield ASCII files containing sequential records of the following fields: an exposure boundary (e.g., left hand, right hand, mouth), microenvironment (e.g., kitchen, garden, bedroom), activity level or contact type (e.g., playing, resting, repetitive action, continuous action), object contacted (e.g., hard floor, upholstered furniture, soil, vegetation, clothing), and duration in seconds.

1996). For these four pilot study children, the videotapes captured 4–8 h of their day, up to 70–95% of which was spent indoors. Two papers have been published on the general dermal contact activities and non-dietary contact activities for these children (Zartarian et al., 1997b, 1998).

Since then, Stanford has collected a unique and extensive database of children's MLATS (Table 1) using more refined and thorough videotaping and video-translation methodologies. This database of activity data results from a number of separate studies, including those sponsored by the Research Triangle Institute (RTI), the Outdoor Residential Exposure Task Force (ORETF), and the EPA. Most of the studies were geared towards collecting activity patterns for quantifying dermal and non-dietary ingestion exposure. However, for the RTI study we gathered activity patterns for non-dietary ingestion exposure associated directly with meal events (Akland et al., 2000; Ferguson et al., 2000, 2005). Study 6 is an unsponsored longitudinal study (LTS), currently with one subject, to investigate how the frequencies and durations of contact with objects and surfaces, among other activity variables, change with age. The videotaping and video-translation methodologies developed from our three main dermal and non-dietary studies (Studies 2, 3, and 5) are discussed in this paper.

Study 2, the ORTEF project, involved videotaping 36 children, aged 1–12 years, for 2 h each, as they performed their normal outdoor activities on turf and other outdoor surfaces. Duration and frequency of contact between 15 body parts (Table 2) and various objects contacted by the bodyparts were collected for this project. The primary emphasis was on contact with grass, bare ground and vegetation (garden plants, trees, etc.). Ultimately, the data from this study was used by ORETF members in conducting exposure and risk assessments, applicable to the use of their pesticides on residential lawns. Study 3, the EPA project, gathered 2 h of data on 20 children, aged 1–6 years, for contact activity of the hands and mouth. Additional dermal and non-dietary contact activity data were also extracted from pilot Study 1.

As part of U.C. Berkeley's Center for the Health Assessment of the Mother and Children of Salinas

Table 1. Database of children's microlevel activity time series.

Study	Number of children	Community	Age (months)	Recorded hours per child	Primary location	Bodypart	Funding source
1	4	Agricultural	24–48	6–8	Indoor, outdoor	Hands, mouth	NA
2	8	Suburban	12–36	1–2	Indoor	Mouth	RTI
3	36	Suburban	12–144	1–2	Outdoor	Hands, legs, mouth, torso, back, arms	ORTEF
4	20	Suburban	12–72	1–2	Outdoor	Hands, mouth, surface area	EPA
5	23	Agricultural	6–24	4–6	Indoor, Outdoor	Hands, mouth	EPA & NIEHS
6	1	Suburban	6–60	60	Indoor & Outdoor	Hands, mouth	NA

Since 1994, Stanford has developed a unique and extensive database of children microlevel activity time series for over 92 children. This database of activity data results from a number of separate studies gathering information for children's dermal, and non-dietary ingestion activities.

Table 2. Bodypart designations.

Code	Body part	Code	Body part
BTR:	Back torso	LUL:	Left upper leg
FTR:	Front torso	RFT:	Right foot
LFT:	Left foot	RHD:	Right hand
LHD:	Left hand	RLA:	Right lower arm
LLA:	Left lower arm	RLL:	Right lower leg
LLL:	Left lower leg	RUA:	Right upper arm
LUA:	Left upper arm	RUL:	Right upper leg
MTH	Mouth		

The Virtual Timing Device (VTD) software and translation methodologies dictate that the activities of only one bodypart can be tracked at a time. The process is labor intensive and, therefore, most projects have only tracked the dermal and non-dietary contact activity of the mouth and hands for each child. For one project, we individually tracked the activities of 15 body parts, as the designations show. This allows a more thorough assessment of total dermal exposure.

(CHAMACOS), sponsored by EPA and NIEHS, ERG conducted a Time Activity Assessment (TAA) to quantify and characterize exposure-prone behavior of 23 children of farmworkers (aged 6 and 24 months) at home in the Salinas Valley (Study 5, Table 1). The collected MLATS data were analyzed in terms of frequency and duration of contact with various objects for the children's hands and mouth. This information can later be integrated into a multipathway, multimedia model to enable quantification of dermal and non-dietary ingestion exposure to pesticides. We have published one study on the mouthing behavior for the children in this study (AuYeung et al., 2004).

Human Subject Protocol and Questionnaire Administration

Human subject protocols for each project were approved by the "Stanford Administrative Panel on Human Subjects" and outlined the following: subject recruitment plans, consent form and questionnaire administration plans, videotaping and video-translation methodologies, subject incentives, and plans for protecting the subject's identities. For the majority of projects, questionnaires were administered to the subjects' families to aid in understanding their environment and their exposure practices. The subjects in the ORTEF and EPA projects, for example, answered a short three page questionnaire with the following seven sections: demographics, socioeconomics, activity patterns, outdoor layout (e.g., percent grass area), lawn care treatment, indoor pesticide use, and personal contact with pesticides (e.g., wearing shoes outside). A longer questionnaire, administered for the TAA portion of the CHAMACOS project, had 233 questions separated into seven main sections: observational house data, dermal exposure, ingestion exposure, inhalation exposure, activity pattern, pesticide application at home, sociodemographics, and pesticide application at work.

Subject Recruitment

For the EPA and ORTEF studies, random digit dialing, believed to be effective in capturing various socioeconomic groups within a defined area, was used. The sample pool was limited to households in a 300–400 square mile area in the southern region of the San Francisco Bay peninsula associated with the Pacific Bell®, 1998 Palo Alto, Redwood City & Menlo Park telephone directory-residential listings. The protocol for random dialing followed a specific sequence of tasks, each aimed at developing an intimate rapport with the family. Telephone numbers were extracted randomly from the telephone directory and if, after initial phone contact, families satisfied the requirements of the studies and were willing to participate, they were sent study literature prior to family meetings and videotaping sessions. We found that families were far more responsive and willing to participate when a female researcher interacted with them over the phone. Other studies have used similar random digit dialing methods (e.g., Adgate et al., 2000).

In contract, recruitment for the Farmworker Pilot study and on the TAA portion of the CHAMACOS study involved personal recruitment through references in farmworker communities. For the TAA study, for example, the goal was to solicit farmworker families with a child aged 6–12 months or 22–26 months (10 children per age group, and

equal gender ratios). Recruitment was conducted at day cares, clinics, farm worker meetings, labor camps, Women, Infant, and Children (WIC) classes, community festivals (e.g., Día de Trabajador Agrícola), and through contacts from CHAMACOS and the California Rural Legal Assistance (CRLA), with the use of posters and pamphlets. Owing to the difficulty in obtaining qualified and willing participants, partly due to the time commitment, there was no random selection of participants in this study. Future projects can consider videotaping over several days and offering greater incentives to reduce intrusiveness. The children in the TAA Farmworker study came from poor families with no college-level education, while because of geographic location the children in the EPA and ORTEF study came from middle to upper income families with some college-level education. Table 3 shows additional demographic data for the four main studies discussed in this paper. The NAs indicate that some data were not collected in that study, or in a similar reportable format.

Videotaping

Videotaping human activity for exposure assessment has become a more common practice over the past decade (Reed et al., 1999; Quackenboss et al., 2000; Freeman et al., 2001; Shalat et al., 2001; Wilson et al., 2004). For each study, we designed a videotaping protocol to ensure the collection of quality activity data through proper equipment handling, and techniques for obtaining quality footage. Consent forms and questionnaires were administered to subject before

Table 3. Demographic data for the four studies.

Demographic data	Study 1: Pilot study	Study 5: CHAMACOS	Study 4: EPA	Study 2: ORTEF
# Children	4	23	20	36
Race				
Caucasian			45%	64%
Other	100% (Mexican)	100% (Mexican)	40%	22%
No reply			15%	14%
Home				
Single family dwelling	75% (some mobile homes)	78% (some mobile homes)	NA	75%
Apartment	25%	22%	NA	14%
Condominium			NA	6%
No reply			NA	5%
Income level				
>$100,000			45%	61%
$60,000–100,000			25%	28%
$20,000–$60,000			25%	12%
<$20000	100%	100%		
No reply			5%	
Time at current residence				
<1 year	NA	NA	10%	17%
1–5 years	NA	NA	55%	64%
>5 years	NA	NA	30%	17%
No reply	NA	NA	5%	2%
Siblings				
No siblings		17%	15%	
1 sibling	25%	30%	50%	42%
2–3 siblings	75%	40%	30%	28%
No reply		13% (4–5 siblings)	5%	31%
Mother's occupation				
Outside the home	75% (mostly field work)	50% (mostly field work)	45%	64%
Inside the home	25%	50%	25%	14%
No reply			35%	22%

The Pilot Study and the CHAMACOS study are very similar in their demographics because the subjects were children of farmworkers. The EPA and ORTEF studies were similar because they were conducted around the more affluent areas of Menlo Park and Palo Alto, California. The NA indicates that the data were not collected or could not be reported in a similar format.

Table 4. Steps of a videotaping protocol.

Initial family meeting
Posting videotaping session
Verification of videotaping session
Pretaping preparation
Conducting the videotaping session
Equipment return and data log-in
Family follow-up

The steps of a videotaping protocol allow us to manage our team of researchers (e.g., "posting videotaping session"), keep track of paperwork and equipment (e.g., "equipment return and data log-in"), record quality videotape data (conducting the videotaping session), and conduct ourselves in an appropriate fashion around the subject and subject's families (family follow-up).

videotaping and, therefore, the videotaping protocol also covered these procedures. Table 4 lists the main components of a typical videotaping protocol for a project.

The "Initial Family Meeting" was our opportunity to explain the project and answer questions from family members, obtain their consent (in English or Spanish) for participation of their child, secure a videotaping date, take height and weight measurements, and allow the their child to become familiar and comfortable with the videotaping crew and equipment. On occasion, we have found it necessary to cease our videotaping and protect the child from imminent danger (e.g., chewing on a power cord, placing a sharp knife in pocket, placing small bead in mouth). For this reason, the initial family meeting is used to stress to parents that the videotaping crew will not act as caregivers. Experience showed us that the families and the children were more comfortable having at least one female researcher present.

"Posting the Videotaping Session and Pre-Taping Preparation" allowed the entire research team to coordinate videotaping sessions and organize the necessary materials (e.g., recharge batteries, pack consent forms and log sheets, pack backup cameras) to ensure a smooth videotaping session with the family. The child was preassigned a partially randomly generated 6-digit alpha-numeric code (e.g., code "970M06" means that child "970" was a 6-month-old boy) to keep their identity confidential, and this code was placed on all paperwork.

"Conducting the Videotaping Session" is the main phase of the videotaping process. Some standard guidelines for "conducting the videotaping session" included using audio-clues to capture information (i.e., activities or surface/object types) that may not have been clear on the videotapes, and being as unobtrusive to the child and family as possible (e.g., carrying lunch, not playing with child). Owing to the diversity of objects and surfaces located in the households, "Field Notes" were also taken during the videotaping sessions to later help clarify the character of objects and surfaces. Researchers had to be cognizant of proper camera lighting, holding the camera steady, and more importantly keeping the child's body parts of interest (e.g., hands, mouth) in focus by staying alert and avoiding the use of a stationary tripod. A stationary tripod was only occasionally used on the 6-month olds in the CHAMACOS study when they remained in the same spot for hours. To deal with videotaping fatigue, personnel shared the videotaping tasks if the session was over 2 h in duration.

For "Equipment Return and Data Log-in" the taping team was responsible for recharging the batteries used, and noting any equipment problems. The taping team was responsible for checking that the Hi-8 tapes used for the videotaping session had been properly labeled and that they could not be erased.

For "Family Follow-Up" once it was confirmed that all the necessary information was received from the family, a thank you letter and a VHS copy of the videotape, when requested, were delivered to the family. By delivering the thank you letter and videotape in person we provided the family with one more opportunity to ask questions.

Virtual Timing Device (VTD) Palette Development

For translation of the children's activities from videotape to text file, the VTD (Ong, 2001) uses a translation palette (Figure 1; also see "Introduction") that was tailored to meet each project's specific needs. The palette can have up to four grids; within grids the number of cells is limited by the size of the screen employed. Palette development requires the balancing of two, sometimes conflicting requirements: maximizing the amount of information collected and maintaining the accuracy and ease of translation.

The VTD palette used on the ORTEF and EPA projects (Table 1, Studies 3 and 4) is found in Figure 3. Micro-environments (Grid 1, upper left) are targeted for the outdoor setting, and were grouped based on potentially different outdoor chemical application practices. For example, outdoor pesticides might be applied more often to the "Garden" than to the "Street/Sidewalk" or to the "Patio". Only one category, "Indoor" was used to represent the child's infrequent trips indoors during videotaping. The object categories (Grid 2, upper right) were designed to capture all possible objects and surfaces and were based on experiences and observations of previous studies (Zartarian et al., 1997b). This object grid contained 36 designations; 34 object/surface categories and "Nothing" and "Not in View". Nine "object classes" were chosen (e.g., ground surfaces, walls/furniture, toys), and "surface types" were matched to the "object classes" (e.g., rock/brick floor, wood wall/furniture, porous plastic toy). In all, 36 cells in the object grid were determined as the maximum number that translators could memorize, navigate and select during translation with acceptable error.

Grid 3 (lower left grid) contained two activity levels, "Constant" and "Repetitive," used for describing the type

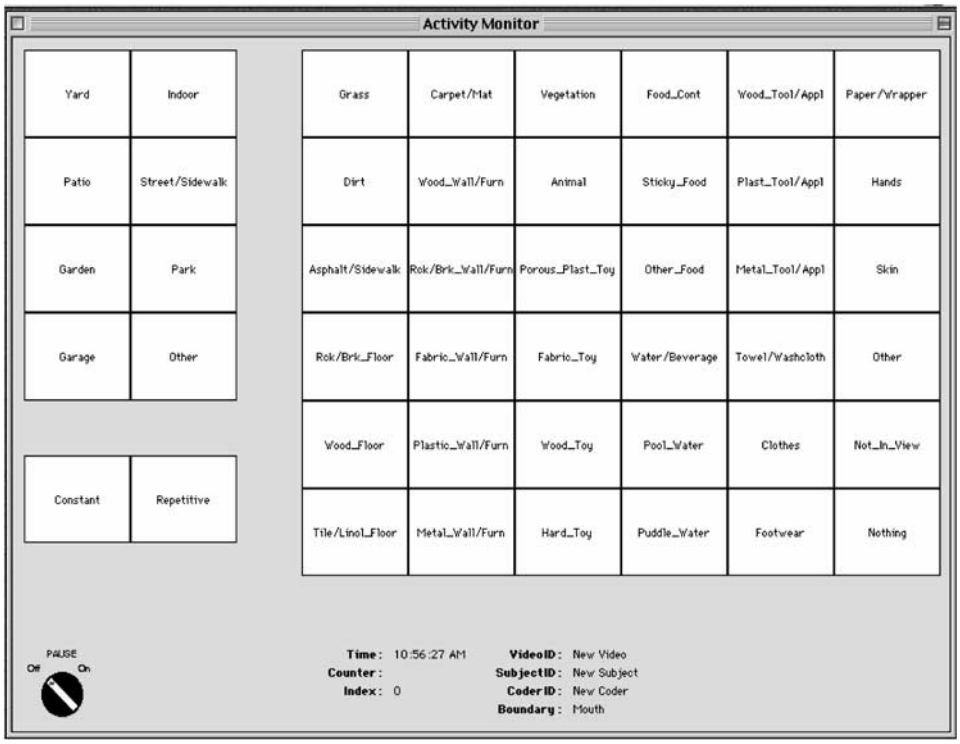

Figure 3. Palette used in the EPA and ORTEF studies. For the two projects that used this palette (i.e., ORTEF and EPA), the microenvironments (Grid 1) were targeted for the outdoor setting, and object categories (Grid 2) were designed to capture all possible object material types contacted in the outdoor environment but also suitable for the indoor environment. The primary emphasis, for the ORTEF project, was on contact with grass, bare ground and vegetation (garden plants, trees, etc.).

of contact between a bodypart and an object or surface, and possibly the level of exertion for a subject. If, for example, a child was running, his feet would repetitively contact the grass at a rate that might be difficult for the translator to toggle between "Grass" and "Nothing". Therefore, the translator simply highlighted "Grass" in the object grid and "Repetitive" in the activity level grid. Later manipulation of the data distributed contact time to the two object categories of "Grass" and "Nothing". For modeling inhalation exposure, repetitive action, especially for the legs, indicates a higher exertion level and, therefore, an increased breathing rate can be applied. Table 5 shows a MLATS data file expanded to address the "Repetitive" allocation; new lines in the data file were created by splitting each 1 s and allocating 0.5 s alternately to "Hard_Toy" and "Nothing". In the first pilot study we used the selections "Resting", "Moderate," and "Active" to describe activity levels and breathing rates. The use of "Constant" and "Repetitive" is an improvement in not only describing breathing rates, but now reducing the error involved in switching rapidly between two objects or an object and nothing. This grid is now better known as "Contact Grid".

The VTD palette used for CHAMACOS only had a few minor changes from the ORTEF/EPA palette. For example, the microenvironments were changed to suit both indoor and outdoor activities in a farming community. The living room, dining room, and hall were all grouped together under living room, kitchen was separate, and orchard was combined with garden. In addition, the ambiguous category "Other" was

Table 5. Data file before and after processing of repetitive action.

Bodypart	Location	Activity	Object	Duration
Before processing				
Right hand	Park	Constant	Wood_floor	30
Right hand	Park	Repetitive	Hard_toy	2
Right hand	Park	Constant	Wood_floor	100
After processing				
Right hand	Park	Constant	Wood_floor	30
Right hand	Park	Constant	Hard_toy	0.5
Right hand	Park	Constant	Nothing	0.5
Right hand	Park	Constant	Hard_toy	0.5
Right hand	Park	Constant	Nothing	0.5
Right hand	Park	Constant	Wood_floor	100

Some project palettes contain a grid indicating if an activity is repetitive or constant. Repetitive action refers to any consistent rhythmic action with an object, such as bouncing a ball or tapping a surface. In processing MLATS any duration allocated under repetitive action for an object can be allocated between the object and "nothing". This is achieved in this table by creating new lines in the data file by splitting each 1 s into a half and allocating each of the 0.5 s alternately to the object and "nothing".

removed and the "Head" category was separated into "Head" and "Mouth" to make the quantification of ingestion exposures more precise.

Video Translation

For each study, a video-translation protocol was prepared with the following main sections designed to guide translators and maintain the quality of the data: "Quality Assurance," "Preparing Translation Assignments," "Translation and Decision Criteria," and "Storing Files". "Quality Assurance" is discussed separately under the "Results" section.

In "Preparing Translation Assignments", 30-min translation segments were used to balance the desire to have a continuous record with the need to avoid errors due to fatigue. "Tape Processing Log Sheets" and the "Field Notes" with the object designations are then assigned to the translators with the associated translation segments.

For "Translation" the translators were not allowed to translate more than four 30-min segments at one time and no more than 4 total hours in a day, avoiding translation fatigue and errors. "Translation" protocols also included the following rules for the translators: review the tapes before starting the translation in order to become familiar with the child's activities, translate the easier body parts (e.g., mouth contained less fast moving activities than the hands), and each translator should stick to a child for consistency of category designation.

"Decision Criteria" describes the rules for assigning a child's action to a particular object, location and activity. For example, the protocol tells the translator to change the object first (this tends to change more frequently than the contact type or location), activity and then location, if all three changes occur simultaneously. When the video was unclear about what the child was contacting, the protocol also advised the translators when to utilize voice annotations, "Field Notes" or the "Not-In View" choice on the palette. If a child contacted more than one surface or object, translators were advised to select the object that had the largest contact area with the bodypart. The protocols also contained clear descriptions of objects, activity, and location categories and category examples. For example, the category of "Hard Toy" would include: plastic jewelry, bike, cup in sand box, pacifier, magnet, hair clips, comb, crayon, and sunglasses, just to mention a few.

Results and discussion

Quality Assurance

In general, by writing and adhering to protocols for each step (e.g., recruiting, videotaping, video translation, recruiting) we created guidelines for maintaining the quality of the collected MLATS data. The most labor intensive, subjective, and possibly error-prone aspect of gathering MLATS lies in the translation of the activity patterns from videotape to text files. Therefore, interobserver, and more recently, intraobserver agreement protocols were developed as an integral part of our methodologies for maintaining quality assurance and consistency on our MLATS data. In addition, all personnel on the projects were required to take a videotaping and/or video-translation training program. With the immense data collected on the studies, it was imperative for us to also design a data management program. Below is a discussion of these quality assurance steps.

Interobserver and Intraobserver Agreement (i.e., Spot Checks) Interobserver agreement refers to the measurable agreement between two persons or groups of people on something they observe (Repp et al., 1976; Boykin and Nelson, 1981). The observed event here is a videotaped activity. Intraobserver agreement refers to the measurable agreement for the same person on the same activity he/she observes at two different times. Interobserver agreement was determined through randomly designated checks conducted by experienced researchers (spot checkers) on approximately 10% of each translator's translated files, to check for a 90% agreement in object, location, and activity designations between the translator and spot checker. Not only did spot checks maintain the quality of translation (knowledge of possible file checking kept translators alert), but they also helped translators to gauge their translation skills and identify areas for improvement.

Intraobserver agreement (i.e., intraobserver spot checks) has recently been added to our quality assurance process, and was determined by requiring each translator to retranslate a selected 4–5% of their segments for a bodypart. The selected segments for retranslation were based on when they were originally translated, preferably segments translated within a 2-month time period. During this period we assumed that the translator had maintained a certain level of skill and was still familiar with the object and location categories encountered in the segment, but not overly familiar with the exact sequence of events or individual objects. On occasions where the disagreement was highly subjective (e.g., poor video quality), a discussion was held to resolve the conflict. Black et al. (2005) recently used our videotaping and video-translation methodologies to capture the mouthing and food-handling behavior for 52 children on the US/Mexico border. Authors mention having two individuals both transcribing 30 min of five randomly selected tapes to determine reliability measurements (we call this interobserver agreement) of frequency and durations of contact.

Videotaping Reliability A concern with capturing human activity on videotape is the degree to which the presence of a camera alters behavior. Our experience and the experience of others (e.g., Bentzen, 1985) indicate that young children, in a short space of time, adapt well to the presence of strangers

quickly resuming their attention on play, especially in the outdoor environment, and especially if they are engaged in active play. Naturally the techniques and training of the videotaping crew can affect the success of capturing natural behavior. In particular, remaining as inconspicuous as possible during observation helps to lessen impacts on a child's natural behavior. For our studies, the camerapersons were instructed not to interact with the children or interfere in their play and to utilize the camera's zoom where possible.

Nevertheless, there are subjects that required the videotaping crew to use judgment in proceeding with their videotaping session. For example, during a videotaping session, researchers calmed down an apprehensive child by turning off the camera and replaying footage for the child. This made the child more comfortable and videotaping resumed. It was also desired of the videotaping crew to recognize when a child was play-acting (i.e., camera-induced behavior) and turn the camera off. We found this to occur more often with older female children, especially in the presence of their friends. Parents were also familiar with their children's moods and would often indicate to the videotaping crew or the child that they are behaving differently.

Training For videotaping, it is crucial that those collecting observational data be well trained (Buckley et al., 2000). After reading the videotaping protocols thoroughly, our trainees practiced videotaping a child for 2 or more hours to avoid the following errors: not keeping the camera steady (making better use of the zoom lens helps to avoid this), not keeping the child's entire body in focus, and unnecessarily interacting with the child.

During video-translation training, trainees underwent a three-step translation-training program: (1) reading a manual that contained information about the VideoTraq software (e.g., launching the program, entering output file header information, and selecting a contact boundary), (2) hands-on practice with the VideoTraq software and familiarization with the palette to be used on a particular study (i.e., memorization of grid box location and names), and (3) translation of four 15-min, increasingly difficult, training tapes of children. The training tapes were also translated by three experienced researchers to produce "standard" VTD output files. Trainees were required to have less than 10% total error compared to the "standard files" to complete the video-translation training program and insure interobserver agreement, otherwise, mistakes were discussed with the experienced translator and the trainee repeated the tape until they passed.

Paperwork Organization Studies of this type typically generate large volumes of data and involve many people, including subjects, researchers and staff. Privacy and other concerns related to the use of human subjects add to the complexity and importance of record keeping. Records for a single subject may include consent and interview forms, multiple videotapes (with backups), and large numbers of translation files (60 or more for some of the ORETF children). It is crucial that the filing and coding systems employed properly categorize documents and facilitate their retrieval, correlation and use. On our studies, document and videotape copies with the children's alpha-numeric codes were used in processing and analysis. All originals were secured in a locked filing cabinet in the ERG offices and organized by projects (e.g., pilot study, ORTEF, EPA) and by category (i.e., log sheets, questionnaires, consent forms). Folders and tapes were color coded to differentiate between studies. All generated video-translation text files were also labeled with the child's alpha-numeric code, and translators immediately saved copies of the file they translated on both the hard disk of their translation computer and onto a floppy disk. The copy on the floppy disk was later stored on the manager's project computer for possible spot checks and permanent storage in a database.

Data Analysis

Utilization of the large volume of data generated via translation (ORETF study translations generated from ~4000 to 20,000 contacts per child) is greatly assisted by development of a database (e.g., Microsoft Access™) and use of statistical software packages(e.g., S-PLUS™). There are a number of methods to analyze and utilize MLATS data. Researchers may want to purely understand human behavior and, therefore, analyze the MLATS data for activity trends, by age group or by gender. Researchers may also want to use these activity patterns in their sequential form, in models to estimate human exposure and dose (e.g., the DERM; Zaratarian, 1996), and others may require the extraction of statistics of relevant activity data. Here is a brief list of information that can easily be extracted from MLATS data for use in modeling exposure and in understanding human behavior: (1) duration and frequency of contact between objects (i.e., toys) or surfaces and bodyparts (i.e., mouth, hands, legs), (2) distribution of durations (e.g., do short contact durations occur more than long contact duration?), (3) duration in each microenvironment as a percentage of total time videotaped, (4) contact frequency and duration data for specific object categories while children are in a certain microenvironment (e.g., yard, bedroom), and while engaged in macroactivities (e.g., playing outside, sitting indoors, swimming), and (5) estimates of the body part surface area involved in a subject's contacts.

For surface area estimation in (5), we incorporated results from an experiment we conducted to assess how much surface area is involved in various types of hand contacts. There are 35 possible types of hand contacts ("Pinch Grip," "Open Hand Grip," "Partial Front Fingers," "Side Hand," etc.).

Translators then used the children's text files of contacts for the hands, located where on the videotapes every contact occurred, observed the contacts, and categorized *every* contact. Collecting surface area data is time consuming and has only been completed for the left and right hands of 20 children on the EPA Study 4.

Method Utility

Others in the field of dermal exposure assessment have used hand recording or timers for activities while observing children. With these methods you cannot verify the accurate collection of the data or later obtain additional information for the same time period. A more recent study utilized hand recording from collected videotapes for infants (Kranz et al., 2004). With hand-recording, however, it is difficult to collect both duration and frequency for an activity, and also record the sequential order of activities when the subject is very active (i.e., for older active children). As a result videotaping with video translation using the VTD offers wider applications and more accuracy and details in the collection of children sequential activities.

The combined videotaping and video-translation method also produces highly usable data. "In View" time refers to the time a translator could actually see the body part being translated and could infer from the tape what was being touched. "Not in View" time occurred when the whole child or a particular body part was out of sight (e.g., cameraman not facing the child, improper lighting, or object obstruction) and a clear determination could not be made. In videotaping active children, proper training was crucial in allowing us to collect quality data and facilitating video translation. On the EPA project, for example, for the mouth across the 20 children, the average usable footage (In View) was over 96% (high 100% and low 89%). On the same project, for the left hand the average usable footage was over 91% (high 98%, low 82%), while the right hand had an average usable footage of over 93% (high 98%, low 87%), demonstrating the high utility of this method.

Much effort within the human risk assessment field is on the development of computer models for the calculation of exposure and dose for the dermal route, as well as the non-dietary ingestion route for both single and multiple exposure events. As a result the collection and analysis of MLATS data is a significant and crucial component of the risk-assessment effort, since this type of data offers the potential for more refined estimates of exposure and intake dose and more insights into the process of chemical loading on the skin surface. These MLATS data have been used in models to estimate children's dermal exposure to Alachlor (Zartarian, 1996), children dermal exposure and dose to Chlorpyrifos (Ferguson, 2003) and children's dermal, non-dietary ingestion and inhalation exposure to lead (Canales, 2004). There are a number of lessons that have been learned with these modeling efforts. The first is that MLATS-based models require more computing time, but this is less of an issue with today's faster computers. Another lesson learnt is the utility of MLATS models in telling us which objects, microenvironments, combination of object and location, or sequence of activities can cause peak exposures, for example. However, the modeling efforts have also demonstrated that MLATS exposure and dose models are parameter intensive and oftentimes, for a particular exposure scenario (e.g., children at play in the home), the literature is not rich with equivalent information on environmental residue concentrations on various objects and surfaces and exposure factors needed for the dermal exposure or dose estimate. Typically, concentrations of environmental contaminants are sampled only from carpets and bare floors (e.g., Simcox et al., 1995; Mukerjee et al., 1997; Lioy et al., 2000; Pang et al., 2002). There have been a limited number of studies that collect residues of contaminants from other surfaces such as children toys (e.g., Wilson et al., 2001). Data on exposure factors, such as residue transfers and soil adherence, under varying contact dynamics and for varying contaminants, are also limited, however, a number of studies have very useful data for modeling (Kissel et al., 1996; Cohen Hubal et al., 2005). Assumptions oftentimes have to be made in MLATS models until suitable data becomes available.

Modeling exposure and dose using MLATS is the indirect way of calculating exposure and requires validation with suitable direct measures to increase model utility and application. For example, a cumulative profile of chemical loading on the skin surface of the hands from an exposure model using MLATS can be compared with results from studies that have collected dermal wipe samples and hand rinses from children (e.g., Fortmann et al., 1991; Fenske et al., 2002). However, a synoptic study, in which hand wipes or hand rinses are collected for the same children videotaped would be the most ideal and accurate validation opportunity. Environmental residue concentrations used in the models should also be collected for the same children. In a similar manner the MLATS exposure and dose models can be validated by comparing the final dose estimates with biological measurements of chemical concentration in urine samples or blood samples for the same children videotaped (Macintosh et al., 1999). Chemical concentration in urine and blood, however, represent chemical mass, which has entered the body through the inhalation, ingestion and dermal routes of exposure.

Conclusion

The videotaping and video-translation methodologies developed by ERG are novel, and result from the experience and refinement of techniques over a number of years and a number of projects. These methodologies can be tailored to gather MLATS for a variety of exposure and risks

assessment scenarios (e.g., occupational exposures such as workers within a chemical plant, or a dry cleaning establishment). Collecting activity patterns using videotaping and video-translation methodologies can be highly reliable if there are strict quality control measures. For our projects we made the effort to implement defined methods and quality assurance steps through the use of videotaping, video translating, spot check, and data management protocols.

What we have collected on the projects mentioned in this paper are short-term activity patterns. Care must be taken in the application of short-term activity patterns (i.e., videotaped data for 1 day) for the assessment of longitudinal exposure (e.g., exposure over various seasons) (Echols et al., 2001). We are making the effort through a longitudinal (Study 6, Table 1) to access how children activity pattern vary as they age and, therefore, possibly how to use these short-term activity pattern to access longitudinal exposure for children (e.g., developing probabilistically relevant activity scenarios per age group). In a similar manner, potential also exist to combine microactivity patterns with macroactivity patterns such as those found in the Consolidated Human Activity Database (CHAD; McCurdy et al., 2000) for use in assessing longitudinal and population exposure.

The activity pattern data gathered by ERG are rich in content and have revealed much about children's contact activity. A significant amount of data have already been processed for government and industry on the frequency and duration of children activity patterns, where the children have been categorized by age and gender. Later work will further analyze the activity patterns from the Farmworker Pilot, EPA, ORTEF, CHAMACOS, and LTS studies to extend our knowledge of children's behavior at different ages and their resulting exposure in and around the home to selected chemicals.

Acknowledgements

We thank many members of ERG over the last 10 years who have helped to develop the videotaping and video-translation methodologies and contributed to the collection of MLATS data for children. This research was in part supported through the U.C. Berkeley's Center for the Health Assessment of the Mother and Children of Salinas (CHAMACOS) program (EPA Grant #R826709 and NIEHS Grant # SP01ES09605). We appreciate the contributions of A. Bradman and B. Eskenazi for their work with us on the Time Activity Analysis (TAA) portion of the CHAMACOS project. Our thanks also to the funding sources and individuals we collaborated with us on other projects, in particular the Outdoor Residential Exposure Task Force (ORETF), and the Environmental Protection Agency (EPA). We also appreciate the time and commitment of the participating families and children on all projects.

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