An Empirical Analysis of Children's After School Out-of-Home Activity-Location Engagement Patterns and Time Allocation

Rajesh Paleti
The University of Texas at Austin
Dept of Civil, Architectural & Environmental Engineering
1 University Station C1761, Austin, TX 78712-0278
Tel: (512) 471-4535; Fax: 512-475-8744
Email: rajeshp@mail.utexas.edu

Rachel B. Copperman
Cambridge Systematics, Inc.
9015 Mountain Ridge Dr, Suite 210
Austin, TX 78759
Tel: (512) 691-8508; Fax: 512-691-3289
Email: rcopperman@camsys.com

and

Chandra R. Bhat*
The University of Texas at Austin
Dept of Civil, Architectural & Environmental Engineering
1 University Station C1761, Austin, TX 78712-0278
Tel: (512) 471-4535; Fax: (512) 475-8744
Email: bhat@mail.utexas.edu

*corresponding author

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ABSTRACT

Children are an often overlooked and understudied population group, whose travel needs are responsible for a significant number of trips made by a household. In addition, children's travel and activity participation during the post-school period have direct implication for adults' activity-travel patterns. A better understanding of children's after school activity-travel patterns and the linkages between parents and children's activity-travel needs is necessary for accurate prediction and forecasting of activity-based travel demand modeling systems. In this paper, data from the 2002 Child Development Supplement (CDS) of the Panel Study of Income Dynamics (PSID) is used to undertake a comprehensive assessment of the post-school out-of-home activity-location engagement patterns of children aged 5 to 17 years. Specifically, this research effort utilizes a multinomial logit model to analyze children's post-school location patterns, and employs a multiple discrete-continuous extreme value (MDCEV) model to study the propensity of children to participate in, and allocate time to, multiple activity episode purpose-location types during the after-school period. The results show that a wide variety of demographic, attitudinal, environmental, and others' activity-travel pattern characteristics impact children's after school activity engagement patterns.

Keywords: children's activity patterns, children's time-use, discrete-continuous model systems, post-school travel, and activity-based travel analysis

1. INTRODUCTION

More daily trips in the United States are undertaken during the 3-4 pm hour of the day than during any other hour, and 43.1% of all daily trips are made between 2-8pm (USDOT, 2003). This peak in trips during the afternoon period can be attributed in part to children's after school activity and travel patterns, suggesting that children's travel needs play a role in the congestion that plagues many of our nation's cities. In fact, a study examining data from the 1995 National Personal Travel Survey found that approximately 30% of children do not go directly home after-school, and instead travel from school to participate in other activities. In addition, approximately 40% of children make an additional trip after returning home from school (Clifton, 2003).

Children's travel and activity participations during the post-school period, in addition to contributing directly to afternoon trips, also have implications for adults' activity-travel patterns. For instance, Reisner (2003) found that parents spend considerable time and resources transporting children to and from after-school activities, while other studies have found that parents, especially mothers, make frequent stops on the commute to work and to, or from, non-work activities due to the need to escort children to activities (Hensher and Reyes, 2000; McGuckin and Murakami, 1999; Wallace *et al*., 2000; McGuckin and Nakamoto, 2004). It is these activities, and their location, that determine the temporal and spatial dimensions of adults' serve-passenger trips and joint activities. Thus, a better understanding of children's after-school activity-travel patterns, and the linkages between parents and children's activity-travel needs, is necessary for accurate prediction and forecasting of activity-based travel demand modeling systems (see Copperman and Bhat, 2007 for an elaboration of this point).

In contrast to the need to examine and model children's activity-travel patterns, existing activity-based research and modeling systems have almost exclusively focused their attention on the activity-travel patterns of adults (see Bradley and Bowman, 2008). This motivates the objective of the current research study, which is to develop and apply an approach to characterize the post-school activity-travel patterns of children. In doing so, one has to consider several dimensions of children's post-school activity-travel patterns, as we discuss next.

1.1 Representation Framework of Children's Post-School Activity-Travel Patterns

At a fundamental level, the complete characterization of a child's post-school activity-travel pattern entails the full spatial, temporal, activity purpose, and travel mode attributes of each activity episode undertaken after school, as well as the sequencing of all activity episodes (in-home as well as out-of-home). The representation analysis framework proposed here has the following salient characteristics: (1) It considers all the relevant activity-travel attributes of a child's post-school activity-travel pattern, (2) It includes both the generation and scheduling of activity episodes, and (3) It considers time as an all-encompassing continuous entity within which children make activity/travel decisions. The framework represents children's post-school pattern as a series of out-of-home activity episodes of different types potentially interspersed with periods of in-home activity stays.

The characterization of the post-school activity-travel pattern is accomplished by identifying a number of different attributes within the pattern. The attributes are classified on the basis of the level of representation with which they are associated; that is, whether they are associated with the entire post-school pattern (pattern-level attributes), a specific period of the post-school pattern that may comprise participation in multiple episodes of potentially multiple activity purposes at one or more out-of-home activity locations (activity instance-level attributes), or a specific episode within an activity instance (episode-level attributes).

Pattern-level attributes are associated with the overall progression of a child's pattern and include three activity-travel dimensions: (1) the broad characterization of the activity instance immediately following the end of classes at school (*i.e.*, whether the child goes home, stays at school, or goes to a non-home location at the end of classes), (2) the broad characterization of the activity instance immediately following any stay-at-school episode (*i.e.*, whether the child goes home or goes to another location after staying at school), and (3) the broad characterization of the post-home arrival period (whether a child stays at home for the entire evening after arriving back home for the first time in the afternoon/evening, or pursues one or more activity instances of non-home activity participation after returning home). Activity instance-level attributes correspond to the purposes, broad locations, and durations of activity episode participations at each activity instance. The episode-level attributes refer to the precise spatial location, time-of-day, travel mode, and sequence of each episode within each activity instance. The sequencing of episodes also includes the determination of whether there are any in-

home episodes interspersed between the out-of-home activity episodes of each activity instance. At the end of this three-level representation, one essentially has characterized the complete post-school activity-travel pattern of a child.[1]

1.2. Analysis Framework of Children's Post-school Activity-travel Patterns

As in the modeling of adults' activity-travel patterns, the joint modeling of all the attributes of the representation scheme for children discussed in the earlier section is infeasible because of the large number of attributes and the large number of possible choice alternatives for each attribute. There is a need to develop an analytic framework to model the representation that is behaviorally plausible, while also being feasible to implement from a practical standpoint.

The analysis approach proposed here considers the pattern-level attributes first, followed by the activity instance-level attributes, and finally the episode-level attributes. The underlying basis for such a framework is that the decisions regarding pattern-level attributes are driven by the basic activity needs of the child (and the household of which the child is a part). Consequently, and consistent with the derived demand philosophy of the activity-based approach, the pattern-level decisions are considered to be at the highest level of the analysis hierarchy (see Bhat and Koppelman, 1999). In contrast, decisions regarding the episode-level attributes tend to be driven primarily by scheduling convenience, short-term temporal constraints, and travel conditions. Therefore, these attributes are relegated to the lowest level of the analysis hierarchy. The activity instance-level attribute are positioned at the intermediate level of the analysis hierarchy since these attributes shape the precise temporal and spatial sequencing of out-of-home episodes and in-home episodes. The above analysis structure is also consistent with the notion that individuals form a skeletal activity pattern (or program) to start their day, and then implement the pattern through shorter term scheduling and sequencing decisions (see Cirillo and Axhausen, 2010). In the context of the proposed analytic structure, the pattern-level corresponds to the skeletal activity program, while the episode-level corresponds to the shorter term scheduling/sequencing decisions. The activity instance-level straddles the two. In this paper, we develop and implement the analysis

[1] If one desires, it is also possible to detail the in-home activity episode attributes as part of the activity instance-level attributes and episode-level attributes. In this paper, we do not consider the in-home episodes of children. Also, the focus here is on the post-school activity-travel pattern at the daily level. While one would expect that there would be weekly or longer period rhythms in the post-school patterns of children, data for such an analysis of the longer period patterns of children are scarce to unavailable. However, an important future research area is to examine such longer-term rhythms in children's activity-travel participations.

framework for the pattern level and the activity instance level, leaving the analysis framework for the episode level for future research.

Figure 1 shows the seven possible patterns based on the three activity-travel dimensions characterizing the pattern-level (as identified in the third paragraph of Section 1.1). The patterns are numbered at the bottom of Figure 1 and correspond to the following:

1. Return directly home from school and stay at home,
2. Return directly home from school and go back out,
3. Stay at school after school, then return home and stay home,
4. Stay at school after school, then return home and go back out,
5. Stay at school after school, then go elsewhere,
6. Go elsewhere after school, then return home and stay home, and
7. Go elsewhere after school, then return home and go back out.

For Patterns 2, 4, and 7, note that the "go back out" activity instances include all episodes until the final return home at the end of the day. Thus, Pattern 2 may represent a child who goes back out to do personal business after returning home directly from school, then returns home from the personal business episode, and then goes back out again to recreate. The personal business episode, the home return, and the recreation episode all are contained in the "go back out" activity instance of Pattern 2. For Pattern 5, one could extend the pattern to a return home followed by a "go elsewhere" activity instance, but such an extended pattern rarely occurs. So, we confine the analysis to a "stay at school" activity instance followed by one or more episodes pursued at one or more non-home locations (within the "go elsewhere" box) and a return home/stay home episode.

At the activity instance-level, the emphasis is on analyzing the attributes of each out-of-home activity episode within the "stay at school", "go back out", and "go elsewhere" activity instances of the child's chosen pattern of Figure 1 (these instances are identified by the dark boxes in Figure 1, and have been numbered within the dark boxes). The attributes of the out-of-home activity episode participations include activity purpose, duration, and location type, where the location type attribute is applicable only for the episodes in the "go back out" and "go elsewhere" activity instances. It should also be noted that, while any activity purpose taxonomy may be used for episodes at this level, the one adopted in the empirical analysis of the current paper includes seven activity purposes – organized activities, personal business, recreation,

social, childcare, meals, and other. These activity purposes were determined based on the classification scheme adopted in the survey that formed the basis for the empirical analysis, as well as on ensuring that a reasonable number of children actually chose each activity purpose in the sample. Similar considerations led to the use of four location types for activity episode participations in the "go back out" and "go elsewhere" activity instances – school, someone else's home, restaurant, and other location type include whether the child goes home directly after school or stays at school or number of stops of each activity type and the sequencing of all episodes (both stops and in-home episodes).

An important characteristic of the current analysis framework is that we assume children are the decision-makers for their post-school activity-travel decisions. One can indeed question this assumption. For instance, a child's activity participation at the grocery store after returning home from school may be driven by the need of an adult to undertake grocery shopping for the household, or a child's activity participation at the park may be driven by a desire on the part of an adult to spend some joint recreation time with the child. Even in the case of a child participating in organized activities such as soccer practice, it may be argued that it is the parent who wants her/his child to partake in soccer practice. If the activity participation of children is primarily driven by the activity participation needs/responsibilities and decisions of adults, one approach, along traditional lines, would be use adults as the decision-makers, and focus on adult activity-travel patterns. The analyst may use the presence, number, and age distribution of children in the household as determinant variables (among other variables) to model adult activity-travel patterns (including the joint activity-travel patterns with children) and impute children's activity-travel patterns. However, this would certainly miss independent episodes undertaken by children, especially older children who are capable of participating in activities by themselves. Besides, studies in the literature have pointed out that children as young as 6-8 years start developing their own identities and individualities, and social needs (see Stefan and Hunt, 2006, CDC, 2005, Eccles, 1999). They then interact with their parents and other adults to facilitate these activity-travel needs. If one were to accept that children decide on their activity-travel participations from a very young age, it would be appropriate to use children as the decision-makers, and use adult and household demographic variables (among other variables) as determinant variables to model the activity-travel patterns of children. In actuality, there is likely to be a combination of adult decisions and child decisions that lead up to children's activity-

travel patterns. But the activity-travel field is in its infancy in its understanding of children-adult activity-travel and decision-making interactions. Thus, we prefer to use an approach that is either purely adult-centric or purely child-centric. In this paper, we adopt the second "child-centric" approach for two main reasons. First, we are interested in children's activity-travel patterns (regardless of who makes the decisions), as opposed to the dominant focus on adult activity-travel patterns in extant activity-based research. In analyzing children's activity-travel patterns, it is easier to work directly with children as the unit of analysis. Second, few data collection efforts have obtained information that allows a comprehensive study of children's activity-travel patterns. The 2002 Child Development Supplement (CDS) to the Panel Study of Income Dynamics (PSID) is an exception. This survey effort obtained detailed information on all aspects of both in-home and out-of-home activity participation of a sample of about 2500 children from sampled households. In using this rich dataset, a child-centric approach needs to be adopted.

1.3 Current Study in the Context of Earlier Studies

As indicated earlier, the focus of the current study is on the first two levels – the *pattern* level and the *activity instance* level – of the three-tiered representation framework for modeling children's activity-travel patterns. In doing so, we build upon several earlier studies that have examined one or more dimensions of children's activity participation within these two levels. We provide a brief overview of these studies below.

In the context of the *pattern* level of our proposed representation framework, Clifton (2003) and McDonald (2005) descriptively examined the percentage of students who returned directly home from school, made stops on the way home from school, and who went back out after returning home. But these studies did not estimate models to study the factors affecting a child's choice of post-school activity pattern. These studies also did not examine the activity location instance (whether at school or elsewhere) of the activities pursued immediately after school, nor did they consider all possible after school patterns.

Several studies have examined children's participation and duration of participation in activities by purpose during the after school period. These studies contribute to the *activity instance* level of our proposed framework, and can be grouped into three areas: (1) Studies that examine a specific type of after school activity such as leisure participation or structured activities (see, for example, Huebner and Mancini, 2003; Sener *et al*., 2008; and Harrell *et al*.,

1997), (2) Descriptive time-use studies which examine children's overall daily participation rate and duration of participation in a variety of activities (see, for example, Hofferth and Sandberg, 2001; Copperman and Bhat, 2007; Stefan and Hunt, 2006; and Larson and Verma, 1999), and (3) Studies that examine the factors affecting after-school daily or weekly activity participation within a select age or population group (see, for example, Zill *et al*., 1995; Posner and Vandell, 1999; and Shann, 2001). The studies identified above, while providing important insights, are focused on overall time-use in activities after school, rather than on activity instances.

An important aspect of the current study is the emphasis on the location dimension of activity instances. In particular, we recognize school as an important location for after-school activities. There are three reasons to explicitly consider school as a possible location for children's post-school activities. First, school is a popular activity location for after school activities. A study by Copperman and Bhat (2007) found that over 20% of children participate in activities at school during the post-school period. In addition, Hofferth and Jankuniene (2001) found that 8% of children, aged 5 to 13, remain at school directly after school. Second, if a child remains at school after classes, he/she may not have the option to take the school bus home since the school bus normally departs immediately at the end of classes. Previous research on school mode choice does not recognize this issue as a factor in mode choice decisions (see Yarlagadda and Srinivasan, 2007 for a review of school mode choice studies). Third, the explicit consideration of the propensity of children to participate in activities at school provides an improved characterization of children's post-school activity-travel pattern.

Notwithstanding the importance of the location dimension for after-school activities in general, and the importance of considering school as a potential location in particular, there has been only one study by Hofferth and Jankuniene (2001) that has explicitly examined children's activity location directly after school. However, this earlier study is descriptive in nature and does not consider the location of activity instances beyond that pursued immediately after school (*i.e.*, it does not consider the location of out-of-home instances pursued after a child returns home from school or from the non-school location activity episode(s) pursued immediately after school).

The rest of this paper is structured as follows. Section 2 describes the analysis framework and model formulation. Section 3 discusses the data source and sample formation,

and presents the *pattern* level and *activity instance* level descriptive statistics. Section 4 presents the empirical analysis results. Finally, Section 5 concludes the paper.

2. MODELING STRUCTURES

In this section, we present the alternatives and the model structures used for each of the pattern and activity instance models.

2.1 Pattern Model

As indicated earlier in Section 1.1, there are seven possible alternatives for a child's post-school activity-travel pattern (see Figure 1). We considered a simple multinomial logit model as well as different two-level nesting structures to analyze the choice among these seven alternatives. However, the nesting structures were not supported by the data, either because the log-sum parameter exceeded one or was not significantly less than one. Thus, the final model structure for location class sequencing in the current paper corresponded to a simple multinomial logit (MNL) model.

2.2 Activity Instance Model

This model examines the activity episode purpose-location type attributes, as well as the activity duration, for each out-of-home episode within the "stay at school", "go back out", and "go elsewhere" instances, conditional on the child's pattern. As indicated in Section 1.2, we identify seven activity purposes. Further, for episodes in the "stay at school" instance (box 2 in Figure 1), there is only one location type, which is "school". Thus, for the episodes in this box, the only available activity episode purpose-location type combinations are the seven activity purposes. For the out-of-home episodes in the "go back out" and "go elsewhere" boxes, there can be four location types – school, someone else's home, restaurant, and other. Technically, then, one could have 28 activity purpose-location type combinations for each of these two box types. However, many of these combinations seldom occur in the sample. For instance, consider "personal business" episodes within the non-stay at school instances (boxes 1, 3, 4, 5 and 6 of Figure 1). Almost all of these episodes occur at a location other than at someone else's home, school, or at a restaurant. Thus, we use a single "personal business" alternative without further partitioning this by location type.

After careful consideration of the number of episodes of each possible activity episode purpose-location type combination in the sample, we identified a total of twelve alternatives for the empirical analysis: (1) Organized activities at school, (2) Organized activities at a location other than school, (3) Personal Business, (4) Recreation at someone else's home, (5) Recreation at school, (6) Recreation at other locations, (7) Social at someone else's home, (8) Social at locations other than someone else's home, (9) Childcare, (10) Meals at restaurant, (11) Meals at a location other than a restaurant (over 70% of such episodes are at someone else's home), and (12) Other. At each activity instance, the child spends only a certain amount of the total time available to him/her in different out-of-home (OH) activities. This non-OH time must also be considered in the total time available for a child at each instance. More specifically, we first computed the "daily" available time from school end time to the time when children could be expected to be back home at the end of the day. To do so, we determined the time in the late night of the weekday by when 95% of children had returned home (the return time had a very long and narrow right tail, with some very young children reporting arrival home past midnight; to circumvent this problem, we decided to use the 95% latest time of arrival back home at the end of the day. This 95th percentile latest time of arrival at home is calculated by age group, since it is generally the case that younger children return home earlier compared to older children. Then, within each instance, the available time for the instance is computed as the difference between the daily available time and the sum of participation durations in all OH activities in all instances prior to the current instance (including the travel time from school to home for the "go back out" instances in patterns 2 and 4). Such an estimation procedure is also consistent with an application procedure that, for each pattern, begins with the activity instance that is chronologically the first instance within the pattern and then works its way to other instances later in the day.

As children can engage in multiple activity episode purpose-location type combinations within each of the activity instances (boxes labeled 1 through 6) in Figure 1, and allocate time to each of the activity episode purpose-location types, a multiple discrete-continuous extreme value (MDCEV) model formulation is adopted (see Bhat, 2005 and Bhat, 2008) with thirteen alternatives (including the non-OH activity alternative). The MDCEV model is ideally suited for such an analysis because it is a utility-theoretic formulation that accommodates participation in

multiple activity episode purpose-location categories at each activity instance.[2] The MDCEV model uses a non-linear, additive, utility structure that is based on diminishing marginal utility (or satiation effects) with increasing participation duration in any alternative. The model accommodates zero participation in one or more out-of-home episode categories, as well as predicts the time amount of participation in each episode. Note that the MNL model would not be suitable here since it is only appropriate for the choice of a single alternative, while individuals can choose multiple activity purpose-location type combinations during any given activity instance. Besides, the MNL model cannot model the continuous component of duration of participation. In the MDCEV model, we consider the non-OH activity category as the outside good.[3]

While separate MDCEV models can be estimated for each activity instance, we estimate a single universal MDCEV model for efficiency considerations. In doing so, however, we use variables that identify the activity instance, since some activity episode purpose-location type combinations are more likely to occur in certain activity instances than others (for example, "organized activities at school" are more likely to occur in the "stay at school" activity instance than in other activity instances). Also, note that some alternatives may not be available for episodes in some activity instances, which we recognize by considering only the feasible alternatives for each activity instance (for example, "organized activities at location other than school" or "recreation at other locations" are not feasible alternatives for the "stay at school" box in Figure 1). We also estimated several two level nesting structures models using the MDCNEV (multiple discrete continuous nested extreme value) model recently proposed by Pinjari and Bhat (2010). These structures considered location choices as being nested within activity purposes as well as considered activity purposes to be nested within location choices. In particular, for the nesting of location choices within activity purposes, the following nesting possibilities were considered: (1) recreation at someone else's home, recreation at school, and recreation at other location, all nested under a "recreation" nest, (2) social at someone else's home and social at location other than someone else's home nested under a "social" nest, (3) organized activities at

[2] A utility-theoretic formulation, as used here, is one that derives its theoretical basis in microeconomic utility concepts of consumer choice.

[3] The term "outside good" refers to a good that is "outside" the purview of the choice of whether to be consumed or not. That is, the "outside good" is a good that is always consumed by all consumers. In the current empirical context, this is tantamount to the logical condition that the available time at any activity instance be more than the time invested in out-of-home activity episodes.

school and organized activities at location other than school nested under a "organized activity" nest, (4) meals at restaurant and meals at location other than restaurant nested under a "meals" nest, and (5) different combinations of these nests. For the nesting of activity purposes within location choices, the nesting possibilities considered were: (1) Organized activities at school and recreation at school in a "school" nest, (2) Organized activities at some other location, social at some other location, and recreation at some other location in a "some other location nest", (3) social activity at someone else's home and recreational activity at someone else's home in a "someone else's home" nest, and (4) different combinations of these nests. However, none of these different structures turned up nesting parameters significantly different from a value of one. We next briefly describe the basic MDCEV model structure.

Let t_1 be the non-zero amount of time invested in the non-OH activities and t_k be the time invested in alternative k (k = 2, …, K) at each activity instance, where k is an index for all the OH activity episode purpose-location type combinations. Consider the following additive, non-linear, functional form to represent the utility accrued by an individual through time investment in various activity episode purpose-location type combinations at each activity instance (the index for the individual and the activity instance is suppressed in the following presentation)[4]:

$$U(\boldsymbol{t}) = \frac{1}{\alpha_1}\exp(\varepsilon_1)t_1^{\alpha_1} + \sum_{k=2}^{K}\frac{1}{\alpha_k}\exp(\beta' z_k + \varepsilon_k)\left\{\left(t_k+1\right)^{\alpha_k} - 1\right\} \quad (1)$$

z_k is a vector of exogenous determinants (including a constant) specific to alternative k (there is no such vector for the first alternative because only differences in utilities matter, as shown later). The term $\exp(\beta' z_k + \varepsilon_k)$ represents the random marginal utility of one unit of time investment in alternative k at the point of zero time investment for the alternative. This can be observed by computing the partial derivative of the utility function $U(\boldsymbol{t})$ with respect to t_k and computing this marginal utility at $t_k = 0$ (*i.e.*, $\partial U(\boldsymbol{t})/\partial t_k\big|_{t_k=0}$). Thus, $\exp(\beta' z_k + \varepsilon_k)$ controls the discrete choice participation decision in alternative k. We will refer to this term as the baseline preference for alternative k. α_k is a satiation parameter whose role is to reduce the marginal utility with

[4] Several other additive, non-linear, utility forms, as proposed by Bhat (2008), were also considered. However, the one provided below was the best form in the empirical analysis of the current paper.

increasing consumption of alternative *k*. When α_k = 1 for all *k*, this represents the case of absence of satiation effects. Values of α_k closer to zero imply higher satiation (or lower time investment) for a given level of baseline preference.

From the analyst's perspective, individuals are maximizing random utility $U(\boldsymbol{t})$ at each activity instance subject to the time budget constraint that $\sum_k t_k = T$, where *T* is the total time available for children to participate in various activity episode purpose-location types. The optimal time investments t_k^* (*k* = 1, 2, ..., *K*) can be found by forming the Lagrangian function (corresponding to the problem of maximizing random utility $U(\boldsymbol{t})$ under the time budget constraint *T*) and applying the Kuhn-Tucker (KT) conditions. After extensive, but straightforward, algebraic manipulations, the KT conditions collapse to (see Bhat, 2008):

$$\begin{aligned}
&V_k + \varepsilon_k = V_1 + \varepsilon_1 \text{ if } t_k^* > 0 \ (k = 2, 3, \ldots, K) \\
&V_k + \varepsilon_k < V_1 + \varepsilon_1 \text{ if } t_k^* = 0 \ (k = 2, 3, \ldots, K), \text{ where} \\
&V_1 = (\alpha_1 - 1)\ln(t_1^*) \text{ and } V_k = \beta' z_k + (\alpha_k - 1)\ln(t_k^* + 1) \ (k = 2, 3, \ldots, K)
\end{aligned} \tag{2}$$

Assuming that the error terms ε_k (*k* = 1, 2, …, *K*) are independent and identically distributed across alternatives with a type 1 extreme value distribution, the probability that the child allocates time to the first *M* of the *K* alternatives (for duration t_1^* in the first alternative, t_2^* in the second, … t_M^* in the M^{th} alternative) is (see Bhat, 2008):

$$P\left(t_1^*, t_2^*, t_3^*, ..., t_M^*, 0, 0, ..., 0\right) = \left[\prod_{i=1}^{M} c_i\right]\left[\sum_{i=1}^{M} \frac{1}{c_i}\right]\left[\frac{\prod_{i=1}^{M} \varsigma_i e^{V_i}}{\left(\sum_{k=1}^{K} \varsigma_k e^{V_k}\right)^M}\right](M-1)! \tag{3}$$

where $c_1 = \left(\frac{1-\alpha_1}{t_1^*}\right)$ and $c_i = \left(\frac{1-\alpha_i}{t_i^*+1}\right)$ for *i* = 2, 3, …, *K* and ς_k = 1 if alternative *k* is available for the activity instance under consideration.

3. DATA SOURCE AND SAMPLE

3.1 Data Source

The data source for this analysis is the 2002 Child Development Supplement (CDS-II) to the Panel Study of Income Dynamics (PSID). The PSID is a longitudinal study that collected demographic, employment and health information from a national sample of individuals and households. The CDS-II surveyed over 2,500 children through health and achievement test surveys, primary caregiver and child interviews, and a two-day time-use diary - one for a weekday and the other for a weekend day. The time-use diary collected information on the type, number, duration, and location of activities for each 24-hour survey day beginning at midnight. Paper diaries were mailed to children, filled out on or around the activity day, and then retrieved and reviewed by an interviewer either by phone or in person. Older children and adolescents were expected to fill out their own diary, while primary caregivers aided younger children.

3.2 Sample Formation

The process of generating the sample for analysis involved several steps. First, only individuals aged five through seventeen who were enrolled in primary or secondary school and who attended school on the activity day were considered for the analysis. Also, only children who filled out at least a weekday diary and provided complete supplemental information were included. The final sample for analysis includes 2,065 children. Second, activity episode purposes were reclassified from the 365 original types into 8 activity purposes: (1) School, (2) Organized activities (*i.e.* lessons, meetings, and clubs), (3) Personal business (*i.e.* shopping, obtaining services, paying bills, writing e-mails or letters), (4) Recreation (*i.e.* unorganized hobbies and sports, outings, reading, playing, TV viewing, and music), (5) Social (including conversations, being intimate, parties, visiting, and religious services), (6) Childcare (*i.e.* daycare, being babysat) (7) Meals (including snacks), and (8) Other. Third, activity episode locations were collapsed into five location types: (1) Home, (2) School, (3) Someone else's home (including other parents' home), (4) Restaurant, and (5) Other. Fourth, out-of-home activity instances were identified by re-organizing the activity episodes based on location of performance (in-home or out-of-home), followed by the tracing of the sequence of out-of-home and in-home episodes. Fifth, the time investments across all activity episode purpose-location types in an activity instance were aggregated to obtain total activity instance time investments. Thus, for each individual, there is a

complete profile of multiple activity episode purpose-location type participation at each activity instance point. Sixth, the amount of time spent in non-OH activities within each instance is calculated. As indicated in Section 2.2, this is achieved by first determining the 95th percentile latest arrival time back home at the end of the day. As expected, this is found to be 9:30 pm for 5-7 year olds, 9:45 pm for 8-11 year olds, 10:35 pm for 12-15 year olds, and 11 pm for 16-17 year olds. The day-level post-school time available is computed as the difference between the time above and the school end time, and then the time available for each instance is obtained as the difference between the day-level post-school available time and the sum of all out-of-home participation durations until that instance (including the travel time from school to home for the "go back out" activity instances in pattern 2 and pattern 4).[5] Finally, individual and household demographic and socio-economic characteristics, as well as attitude and environment variables, were appended to the activity and time use data set to compile a comprehensive database suitable for modeling children's activity-location engagement patterns as a function of observed characteristics.

The age distribution of children in the final sample is as follows: 5-7 years (24.5%), 8-11 years (34.4%), 12-15 years (30.3%), and 16-17 years (10.8%). The household annual income distribution is as follows: less than $35K (38.4%), 35K-90K (42.8%), and > 90K (18.8%). The average household size is 4.13, the average number of adults in the household is 2.04, and the average vehicle ownership is 1.77. About two-thirds of children in the sample have an internet connection at home. The distribution by region of the country is as follows: North East (13.6%), North Central (24.2%), South (42.7%), and West (19.5%). The detailed distribution of all the independent variables considered in the model specification is not provided here to conserve on space. However, the pattern level and activity instance level attribute statistics of the children are discussed in detail in the next section.

3.3 Pattern and Activity Instance (Episode Purpose-Location Type) Level Statistics

Figure 1 provides statistics on the percentage of children in each pattern. As can be observed, 65.6% of all children go directly home after school (corresponding to Patterns 1 and 2), 13.9%

[5] We should note that the strong institutional structure of school schedules was obvious from the CDS data, with distinct times of school release for elementary, middle school, and high school children. This school end time plays a role in the computation of the day-level post-school available time. However, no information on any regular after-school mandatory activities such as sports, projects, *etc*. was available in the data.

stay at school immediately after school (corresponding to Patterns 3, 4, and 5), and 20.5% go elsewhere immediately after school (corresponding to Patterns 6 and 7). Hofferth and Jankuniene (2001), McDonald (2005), and Clifton (2003) also find similar results. Overall, over 30% of children do not go home directly after school, and a majority of children (57.7%) participate in at least one out-of-home activity after school. These findings reinforce the notion that children's activities are responsible for a significant number of household trips.

Table 1 presents the number and percentage of activity episode purpose-location type participations within each activity instance (the percentages are computed row-wise, so that for each activity episode purpose-location type combination, the percentages sum to 100 across all activity instance columns). By definition, the "Stay at school" activity instance (box 2 in Figure 1) does not include some activity episode purpose-location type combinations (see Columns 5 and 6 of Table 1).

There are several interesting insights that may be drawn from Table 1. First, the majority of organized activities at school take place directly after school (*i.e.*, in activity instance "stay at school"), while the majority of organized activities at locations other than school are undertaken by children who first return directly home from school (*i.e.*, in box 1 of Figure 1). Second, personal business is most likely to be undertaken after returning home directly from school (in box 1 of Figure 1) and directly after school (in box 5 of Figure 1). It is quite possible that these statistics indicate children accompanying an adult on the adult's errands, rather than a child undertaking his/her own personal business needs. Third, among all activity episode purpose-location type alternatives, children participate most in "recreation at someone else's home" (see the second column of Table 1 labeled "Total"; the row labeled "Other" has a higher number than "Recreation at someone else's home", but is a combination of several activity episode purpose-location types). The majority of participations in "recreation at someone else's home" is undertaken immediately after-school (in box 5 of Figure 1). The finding that many children travel to a friend's or relative's home immediately after school, instead of to their own home, emphasizes the importance of considering inter-household interactions in school and post-school mode and activity choice models. Finally, over 96% of "childcare" episodes occur immediately after school, either at school or at another location. This finding is logical, since it is during the afternoon period, when parents are still at work, that a child needs non-parent adult supervision.

Table 2 presents additional descriptive statistics on participation in the activity episode purpose-location types, including (1) the percentage of activity episode purpose-location type cases that are participated alone within an activity instance, (2) the percentage participated in combination with other episode types, (3) the total number of each episode type across all activity instances, and (4) the mean duration of participation in each activity episode purpose-location type alternative, conditional on participation in that alternative. The findings reveal that all the children participate in non-OH activities (which is the outside good) in combination with other episode types (see column 3 of Table 2), and organized activities and childcare are the activities that are most likely to be undertaken in isolation (see column 2 of Table 2). In combination with the findings from Table 1, the implication is that many children stay at school for the sole purpose of participating in organized activities or daycare, or make a single one stop tour immediately after school or from home to undertake these activities. On the other hand, social activities and meals at a location other than a restaurant are most likely to be undertaken in conjunction with other episode types. It is also noteworthy that "meals at restaurant" have a much higher solo participation rate and duration of participation compared to meals at other locations. This finding reinforces the importance of examining episode location in addition to activity type. With regard to duration of participation, not surprisingly, organized activities, recreation, and receiving childcare have the longest duration of participation, while personal business and meals have the shortest duration of participation (see last column of Table 2).

4. EMPIRICAL ANALYSIS

4.1 Variable Specification

Discrete choice and MDCEV model specifications were developed and estimated for this study. Several types of variables were considered as determinants of children's activity-travel patterns. Also, different variable specifications and functional forms (*e.g.*, linear and non-linear income and age effects) were attempted to identify the model specification that provided the most intuitively appealing behavioral interpretation and statistical indications. The final set of exogenous variables in the models may be classified into five groups:

1) Child demographics: grade (grade k-4, grade 5-8, grade 9, and grade 10-12), ethnicity (Caucasian, African American, Hispanic, and other), disabled (whether child is physically or

mentally disabled or not), and overweight status (whether child has BMI above 95% in the child's gender and age group or not).

2) Household demographics: household income (yearly income is less than $25,000, $25,000-$90,000, or above $90,000), number of household vehicles, household size, number of adults in household, single child household (whether child is only child in household or not), internet access (whether household has internet or not), single-family home (whether household resides in single-family house or not), primary caregiver (whether primary caregiver is mother, father, grandmother, or other individual), age of primary caregiver, presence of younger siblings, and presence of older siblings.

3) Child's attitude variables: high educational ambition (whether child's preferred education is to attend professional/graduate school or not), gifted program participation (whether child has ever attended a gifted program or not), special education participation (whether child has ever attended special education or not) and sociability (whether child socializes with friends at least once a week or less than once a week).

4) Environment/contextual variables: private school (whether child attends private school or not), neighborhood quality (whether primary caregiver believes neighborhood is a good place to raise a child or not), neighborhood safety (whether primary caregiver believes neighborhood is safe or not), city size (whether child resides in county containing city size over 1 million or not), metropolitan area county (whether child resides in county within a metropolitan area or not), and Friday (whether activity day is Friday or not).

5) Others' activity-travel patterns: primary caregiver works after school (whether primary caregiver works on activity day later than child finishes school or not), and other caregiver works after school (whether non-primary caregiver works on activity day later than child finishes school or not).

4.2 Empirical Results

Model estimation results for the pattern MNL model are presented in Table 3 and the model estimation results for the activity episode purpose-location type participation and time-use MDCEV model are presented in Table 4. The reader should note that the missing variables in Table 3 and Table 4 constitute the base category. For instance, in Table 3, the base category for introducing the grade-level variables is grades k-4, while in Table 4 the base category is grades

5-12.[6] Also, note that some estimates may be the same across different alternatives for a variable, which implies that the coefficient values are not statistically significantly different and have been combined. Finally, the variable effects in Tables 3 and 4 reflect the impacts on the utility of alternatives. If a variable effect does not appear in the row corresponding to an alternative (as reflected by a "--" entry), it implies that the alternative forms the base about which the variable effect on other alternatives is evaluated. For instance, in Table 3, the effect of the "Grade 5 to 8" variable appears only for sequences 6 and 7, with the effective coefficient for all the other alternatives being zero.

4.2.1 Pattern Model

4.2.1.1 Child Demographics: The pattern model results in Table 3 indicate that children in grades 5-8 are less likely than children in grades k-4 and grades 9-12 to go elsewhere directly after-school (see the negative coefficient of -0.6093 for Sequences 6 and 7 in the column labeled "Grades 5 to 8"). Such children are more likely to either go back home or stay at school immediately after school. This result is similar to other studies that found that middle school children make the least number of post-school trips and are the most likely to go straight home from school compared to other age groups (McDonald, 2005; Clifton, 2003). On the other hand, adolescents in grades 9 to 12 are more likely than other children to stay at school after school. Further, adolescents in grades 10 to 12 are also more likely than other children to go back out after returning home from school and go elsewhere if they stay back at school after school. The overall higher participation of adolescents in grades 10 to 12 in out-of-home activity episodes may be a result of many of these individuals holding a driver's license (the CDS survey did not collect information on driver's license holding). It may also be a reflection of the higher availability of extracurricular activities at high school relative to middle and elementary school, as well as the greater freedom to remain after school at school to socialize or study with friends.

Not surprisingly, children who are mentally or physically disabled desist from undertaking out-of-home activities after returning directly home from school. Children who are overweight partake less than their non-overweight peers in out-of-home activities after returning

[6] Note that the difference in introducing the base categories is purely for efficiency in presentation. For instance, we could have retained the same base category of grades k-4 in Table 4 (as in Table 3), but this would have entailed three columns related with grade levels in Table 4 – one for grade 5 to 8, another for grade 9, and a third for grades 10 to 12 - with the coefficient in each of these columns being +0.7003 (t-stat of 3.32). By using grades 5 to 12 as the base in Table 4, we are able to use a single "grades k-4" category with the coefficient being -0.7003 (t-stat of -3.32).

home. In the face of increasing levels of obesity in children, this result warrants more attention and research.

4.2.1.2 Household Demographics: Children living in high income households and/or in households with several vehicles are more likely to go elsewhere directly after school and to participate in additional out-of-home activity episodes after returning home. This result reinforces the notion that children in households with higher income and higher number of vehicles make more daily trips (McDonald, 2005). In addition, this finding may shed additional light on why households with higher income and higher number of vehicles are more likely to drive their children from school (Yarlagadda and Srinivasan, 2007; Bradshaw and Atkins, 1996; Mackett *et al*., 2002). However, further research should be undertaken to disentangle the causation effects to understand whether children are being driven from school because they are undertaking out-of-home activities directly after school, or whether they make a stop on the way home from school because they are traveling by car.

With regard to household composition, if the child is an only child, then s/he is more likely than other children to stay at school after school or go elsewhere directly after school. The latter result may be a reflection of having more opportunities to participate in out-of-home activities, since the child does not have to compete with other children for parental escorting. On the other hand, the results also indicate that children in households with several adults are less likely to go elsewhere directly after school.

Interestingly, if a child lives in a household with internet access, the child has a high propensity to go home directly after school and remain at home for the remainder of the day. This may be due to the use of the internet for homework and socializing, as a substitute for studying elsewhere or socializing in person. Another notable finding is that children who live in single-family dwelling units tend to go elsewhere after school and then pursue additional out-of-home activities. While this result should be further examined, this variable may be a proxy for neighborhood characteristics that are not directly examined in this study. The next variable effect in Table 3 indicates that if the father is the primary caregiver, then the child is more likely to go elsewhere after school and then stay home for the rest of the evening. Finally, in the group of household demographics, if a child has older siblings in the household, the child is more inclined to go elsewhere directly after school and go back out after returning home. This result

may be either due to the older siblings taking on the escorting responsibilities for their younger sibling, or the younger sibling accompanying the older sibling on the older sibling's activities.

4.2.1.3 Child's Attitudes: Children who have high educational ambition tend to stay at school after school. Similarly, children who have ever been in a gifted program are more likely to stay at school after school or go elsewhere directly after school. Further research should be undertaken to determine whether these children choose to take part in more after school activities because they have high educational ambitions or whether the involvement in after school activities influence their educational ambitions. If the latter, it would suggest the development of policies and campaigns to encourage more after-school activities. Children who socialize with friends at least once a week outside of school are positively predisposed toward going elsewhere after staying at school or after returning home. By nature, these children may have a strong desire to undertake out-of-home activities, so they can interact more with friends and peers.

4.2.1.4 Environment/Contextual Variables: Children who attend private school are likely to go back out after returning directly home from school or to stay at school after school. Private schools may provide more after-school programs and extracurricular activities at school, compared to public schools. The results also indicate that children who live in high quality neighborhoods tend to return home directly and then go back out. Children who live in safe neighborhoods are more likely to stay at school after school and then go elsewhere. In addition, if a child lives in county containing a city size over 1 million, s/he is less likely to go elsewhere after school and then return home and go back out. The above three results need further exploration. Finally, if it is a Friday, children have an inclination to go back out after returning home or go elsewhere after staying at school. This is to be expected, since children are likely to be allowed to participate in more activities out of home in the evening when not faced with the constraint of going back to school the next day.

4.2.1.5 Others' Activity-Travel Patterns: As expected, children whose primary caregivers are working after the end of school tend to stay at school after school or go elsewhere directly after school. If a child's non-primary caregiver works after school, then a child is more likely to stay at school after school and then return home and go back out.

4.2.2 Activity Episode Purpose-Location Type Model

Table 4 presents the results of the activity episode purpose-location type model, which are discussed by variable group below. The estimates presented in the table refer to the β vector in Equation (1).

4.2.2.1 Child Demographics: Children in kindergarten through fourth grades are less likely to participate in organized activities at school, socialize at someone else's home, and eat meals at a restaurant. The result that young children are less likely to participate in organized activities at school is perhaps because of fewer options available to them in school compared to their older counterparts in middle and high schools. Also, young children are more likely than other children to participate in childcare. This result is consistent with the findings of earlier studies (see, Copperman and Bhat, 2007, Hofferth and Sandberg, 2001; McDonald, 2005; Hofferth and Jankuniene, 2001).

The child demographic effects also reveal that race affects episode type participation. Caucasian-American children are more likely to undertake organized activities at a location other than school and recreation at school, while Hispanic-American children are more likely to pursue recreation at other locations and African-American children are less likely to eat out at restaurants (see Sener and Bhat, 2007 for similar results). Of course, it is important to disentangle whether it is truly race and culture that is contributing to differences in time-use in different kinds of activity episode purpose-location types, or whether it is a proxy reflection of differences in activity opportunities across schools and neighborhoods.

4.2.2.2 Household Demographics: Not surprisingly, children living in high income households have a higher tendency to eat out during the post-school period relative to children in low income households (see, also, McDonald, 2005). The household size and "only child" variable effects indicate that single children with several adults in the household are predisposed toward undertaking personal business activities. Interestingly, children with several adults in the household are less likely to participate in recreation at someone else's home and meals at location other than restaurant, while single children are more likely to participate in social activities at locations other than someone else's home. Also, single children are less likely to

participate in childcare. This is probably because parents with only one child may be more accommodating of the requirements of the child by sharing the responsibility rather than leaving the child at a child care facility. Children in households with internet access tend to undertake organized activities at locations other than school, if they participate in out-of-home activities at all. Perhaps this can be attributed to better awareness of organized activity opportunities through the internet.

Children living in single-family dwelling units are more likely to undertake personal business activities and recreation at non-school locations. Again, the single family dwelling unit variable may be a proxy for neighborhood characteristics that are not directly examined in this study. Also, children whose grandparent is the primary caregiver have a higher propensity to undertake recreation at locations other than school and participate in child care. However, as the age of the primary caregiver increases, the inclination to participate in child care reduces. Children with younger siblings are less likely to participate in social and recreational activities at someone else's home. On the other hand, if a child has an older sibling in the household, the child is more inclined to pursue recreational activities at school and locations other than school. Children might prefer spending time (such as playing sports, watching TV together at home, *etc.*) with their younger siblings rather than go to some other place, given that there is not much age difference. Children who have older siblings are also less likely to participate and spend time in child care and other activities. This is probably because their older siblings take care of them while the parents are not at home.

4.2.2.3 Child's Attitudes: The child's attitude variables reveal that children who have high educational ambitions have a lower propensity to pursue personal business, recreational, and social activities at someone else's home after school. These children may be choosing to spend their time on educational activities, such as studying, instead of on other activities. Also, children who have ever been in a gifted program are more inclined to participate in organized activities and are less likely to attend childcare, while children who are in special education are predisposed toward personal business activities and childcare. This latter result is quite intuitive, since special education children may need extra care, and so are more likely to accompany their parents on errands instead of participating in other activities independently or spending time at a child care facility. Finally, children who socialize with their friends at least once a week are

more likely to socialize at someone else's home, perhaps because they would like to expand opportunities to meet new people.

4.2.2.4 Environment/Contextual Variables: The results show that children attending private school have a higher tendency relative to other children to undertake organized activities at locations other than school. Parents who send their children to private school may also have the desire to provide additional extracurricular activities for their children. Also, children attending private school are less inclined to partake in personal business and social activities at someone else's home. Children who reside in a metropolitan area county are more likely to receive childcare and eat meals out-of-home. Finally, the day of week effect reveals lower levels of participation in organized activities at locations other than school, and higher levels of participation in virtually all other out-of-home activities, on Friday.

4.2.2.5 Others' Activity-Travel Patterns: The effect of others' activity-travel patterns indicate, not surprisingly, that if a child's primary caregiver works during the after school period, the child is less likely to pursue personal business and more likely to socialize at someone else's home and attend daycare. Interestingly, if the non-primary caregiver works after school, then a child is less likely to participate in other activities and eat at restaurant.

4.2.2.6 Activity Instance Variables: Activity instance variables were added as independent variables in the activity episode purpose-location type model to accommodate variations in episode type participation based on the activity instance. The results indicate that children staying at school after school (box 2 of Figure 1) are positively predisposed to spend time in organized activities and childcare, and are less inclined to pursue personal business and eat out at locations other than restaurant. Children who stayed at school after school are most likely to pursue personal business, meals at a non-restaurant location, and other activities during any additional out-of-home tours from home (box 3 of Figure 1). On the other hand, children who go elsewhere directly after school (box 5 of Figure 1) are most likely to spend time in recreational activities at someone else's home, receive childcare and eat meals at a location other than a restaurant, and are less likely to undertake organized activities, recreation at school, social at a location other than someone else's home, and meals at a restaurant. The finding that children are

most likely to attend childcare at school or directly after school at another location corroborates the results of the descriptive statistics of Table 2. Finally, children who complete additional tours after coming home from participating in non-school out-of-home activities directly after school (box 6 of Figure 1) tend to pursue organized activities at school, and are less inclined to partake in recreation at location other than school. Overall, these results underscore the different propensities to participate in diverse activity episode purpose-location type combinations at various points in the post-school period.

4.2.2.7 Baseline Preference Constants: The baseline preference constants (see second to last column of Table 4) do not have any substantive interpretations. They capture generic tendencies to participate in each activity episode purpose-location type alternative as well as accommodate the range of the age and household size variables in the model. However, the negative nature if the baseline preference constants (relative to the non-out of home category that forms the base category) is a reflection of the fact that the day-level post-school available time should be more than the time allocated to the many OH episodes at any activity instance (that is, there is always "participation" in the non-OH activity category at any instance).

4.2.2.8 Satiation Parameters: The final column of Table 4 presents the satiation parameter (α_k) estimates for the activity episode purpose-location type MDCEV model. The t-statistics for the α_k parameters have been computed with respect to a value of 1 (*i.e.*, for the null hypothesis that $\alpha_k = 1$ for each *k*). These t-statistics indicate that the satiation parameters are significantly different from 1 for all activity episode purpose-location types except organized activities at school, thereby indicating satiation effects in the duration of episodes. Note that, as indicated earlier, values of α_k farther away from one and closer to zero imply higher satiation (or lower time investment) for a given level of baseline preference.

The satiation effect is very high for non-OH activities (which is the outside good) with the satiation parameter very close to 0. However, this does not mean that time investment in this activity is close to zero. In fact, it can be seen from Table 2 that the average duration of participation in this activity is nearly 290 minutes. Since all the children participate in non-OH activities, it has very high baseline preference but the disparity in duration between the non-OH

activities and all other activities is much smaller compared to the disparity in the participation rates between these activities. The MDCEV model accounts for this by decreasing the utility for the non-OH activities rapidly with time investment in this activity (see Bhat *et al.*, 2006 for a similar discussion).

The satiation effect is close to 1 for child care, indicating that once children attend child care, they will continue to participate in only that activity and spend a substantial duration in the activity. This is consistent with the descriptive statistics in Table 2. At the other end, meals at locations other than a restaurant have the highest satiation effects. Again, this result mirrors the findings in Table 2, which indicate that meals at a location other than a restaurant have a high likelihood of being combined with other episodes and have the lowest average duration levels.

4.3 Likelihood Based Measures of Fit

The log-likelihood value at convergence of the pattern MNL model is -2975.73. The likelihood value for the model with only the constants is -3169.58. The likelihood ratio test for testing the presence of exogenous variable effects is 387.7, which is larger than the critical χ^2 value with 26 degrees of freedom at any reasonable level of significance. The rho-bar squared value, computed with respect to the constants, is 0.053.

The log-likelihood value at convergence of the final activity episode purpose-location type MDCEV model is -17435.6. Further, the likelihood value for the model with only the MDCEV baseline preference constants and the satiation parameters is -18107.24. The likelihood ratio test for testing the presence of exogenous variable effects is 1343.37, which is substantially larger than the critical χ^2 value with 73 degrees of freedom at any reasonable level of significance.

5. CONCLUSIONS

Children are an often overlooked and understudied population group, even though children's travel needs are responsible for a significant number of trips made by a household. In addition, children's travel and activity participation during the post-school period have direct implication for adults' activity-travel patterns. A better understanding of children's after school activity-travel patterns and the linkages between parents and children's activity-travel needs is necessary for accurate prediction and forecasting of activity-based travel demand modeling systems.

In this paper, data from the 2002 Child Development Supplement (CDS) of the Panel Study of Income Dynamics (PSID) is used to undertake a comprehensive assessment of the post-school out-of-home activity-location engagement patterns of children aged 5 to 17. Specifically, this research effort utilizes an MNL model to analyze children's post-school patterns and employs the MDCEV model to study the propensity of children to participate in, and allocate time to, multiple activity episode purpose-location types during the after school period.

There are several important findings from the study. First, over 55% of children pursue at least one out-of-home activity after school. This result confirms the importance of examining children's post-school activity-travel patterns, since in many cases it is the location and timing of children's activities that dictate the activity-travel patterns of other household members. Second, organized activities and childcare are most likely to take place at school directly after school. Third, in addition to demographic characteristics, attitudinal, environmental, and others' activity-travel pattern variables impact children's after school activity engagement patterns. These results confirm the importance of going beyond a simple analysis of age, gender, and household income level when examining travel behavior, and suggest the need to include perceptions and attitude-related variables. Fourth, the findings from our study as well as from some earlier studies suggest rather consistently that children in middle school are the most likely to go straight home after school and remain there throughout. As such, middle school children participate less in out-of-home discretionary, recreation, social, and organized activities compared to their younger and older peers. Further investigation of this finding is warranted, and may suggest the absence of adequate organized activities at school and elsewhere that keep the attention of middle schoolers. This is an important issue, since studies in the sociological field indicate that providing opportunities for, and facilitating participation in, certain forms of discretionary and organized activity pursuits aids the emotional well-being and the mental/physical health of children, reduces the incidence of drug and tobacco use, and helps children develop social skills, teamwork abilities, fairness concepts, and tolerance (see, for example, Hofferth and Sandberg, 2001, United Nations, 2000, Larson and Verma, 1999, CDC, 2006). In this regard, another finding from our analysis is that Caucasian Americans participate more than other races in organized activities outside school and in recreation at school. This raises the issue of whether neighborhoods and schools in non-Caucasian areas have poor facilities and accessibility to recreational and organized activity opportunities. At the least, these

race-related differences need additional scrutiny, especially since they point to race-related differences in participation in mental and physical health-enhancing recreation and organized activity pursuits. Fifth, children in households with internet access are more likely than those in households without internet access to go back home after school and stay at home. The implication is that participation in out-of-home discretionary pursuits may reduce further as more and more households acquire an internet connection at home. A careful examination of children and their use of the internet vis-à-vis their participation in out-of-home pursuits would be a good research topic at the interface of travel demand modeling, public health, and child development. Finally, a host of child demographics (grade level, disability status, and race), household socio-economic and demographic characteristics (income, housing unit type, vehicle ownership, household size and composition), and environmental/contextual variables (public versus private schools, neighborhood quality, metropolitan area characteristics, and week of day) significantly influence children's post-school activity engagement patterns.

From a travel demand modeling standpoint, one of the limitations of current activity-based travel demand model systems is the lack of attention and modeling of the activity patterns of children. Not only does this result in the absence of much needed policy information for promoting active lifestyles among youth, as discussed earlier, it can also result in relatively inaccurate predictions of the activity-travel patterns of adults. After all, many children have to be chauffeured for their participation in school and non-school activity commitments/participations. As a result, other household activities and trips undertaken by adults may need to be organized around the post-school activities undertaken by children. Therefore, for example, a child's activity commitments may make an adult unresponsive to any policy changes that attempt to modify travel mode, time of travel, or destination of travel. Thus, the ability to model children's activity engagement (and the interactions between these engagements and those of adults) within larger activity-based travel model systems would offer a strong basis for forecasting travel in response to shifts in population demographics over time, or land-use and transportation policies. In this context, the model presented in this paper offers a framework for representing and analyzing the activity-travel patterns of children within larger travel demand model systems. Of course, the travel modeling field is only beginning to focus attention on children's activity-travel pattern modeling, and future efforts should aim to integrate the modeling of adults' and children's activity-travel patterns, rather than considering each in isolation.

From a travel survey standpoint, the current study reveals that children have activity-travel characteristics that are unique and different than adults. For instance, they participate in higher levels of structured/organized activities and in unique activity purposes such as daycare. These distinctive dimensions of children's activity-travel patterns should be considered in metropolitan area travel surveys in terms of defining the typology for activity purposes. For instance, if a travel survey combines organized activities with recreational activities, then salient characteristics that differentiate structured activities from other recreational activities would be lost. Another unique aspect of children's activity-travel patterns is the role school plays as a significant location for out-of-home activity participation for both school and non-school activities. On the other hand, most travel surveys do not obtain information on the school location of children in the household. Our analysis recommends collection of such school location information for all school-going children in the household. Finally, a child's activity-travel pattern is impacted by not only household members, but also friends and other non-household members. Our analysis reveals that the level of children's activity participation with non-family members in activities at someone else's home is quite high, highlighting the inter-household interactions generated by children, This suggests that travel surveys consider incorporating questions on with whom individuals travel and participate in activities.

Overall, this study represents the first formulation and application of a comprehensive econometric framework to consider children's post-school location patterns and participation, and levels of participation, in joint activity and location combinations. Future research should explore inter-household and intra-household interactions by incorporating the dimension of "with whom children are performing activities", as well as the joint trip making characteristics of household and non-household members.

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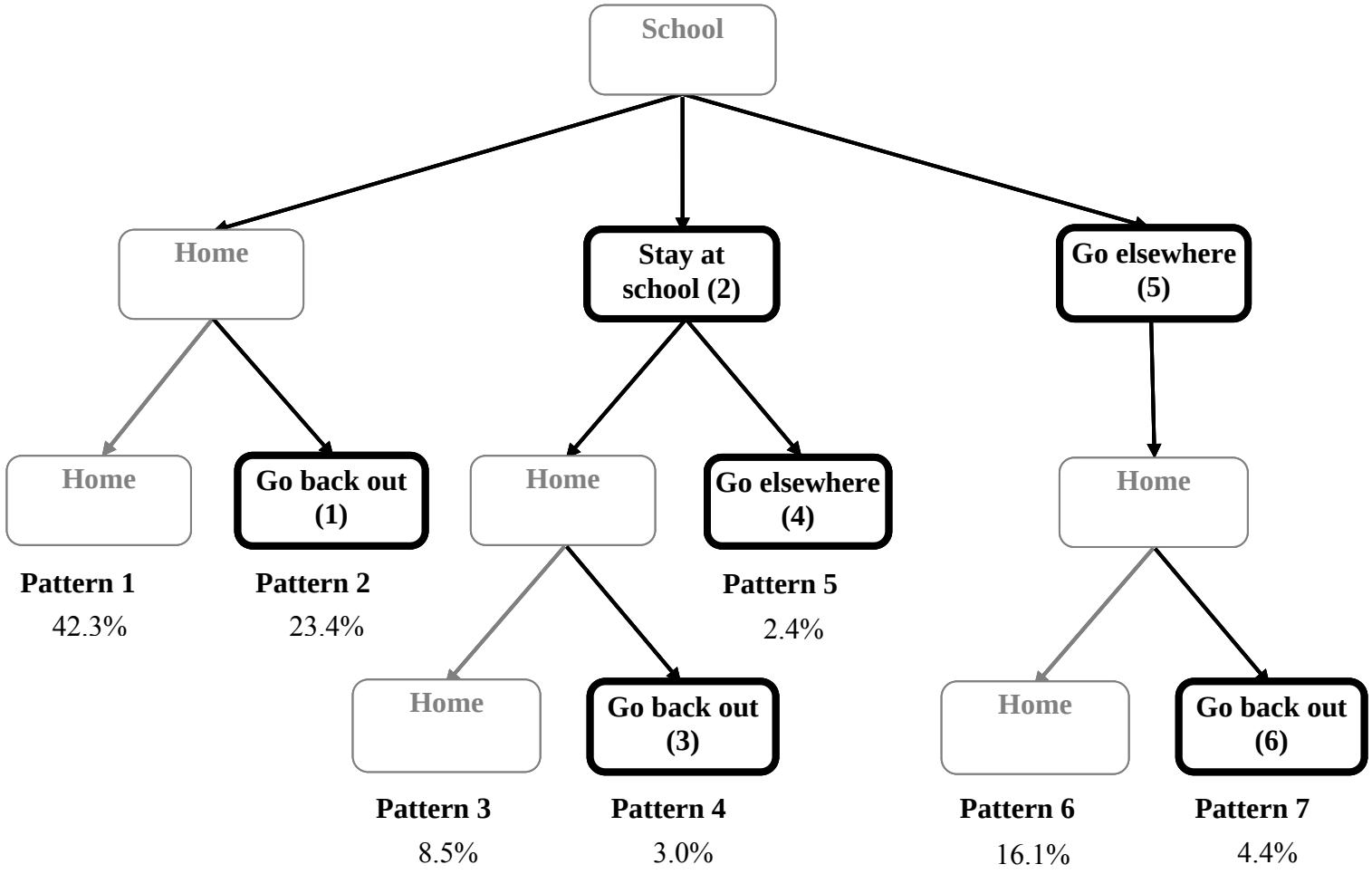

Figure 1. Children's Post-School Patterns and Percentage of Children Choosing Each Pattern

Table 1. Number and Percentage of Activity Episode Purpose-Location Type at Each Activity Instance

Activity episode purpose-location type	Total	Go back out (1)		Stay at school (2)		Go back out (3)		Go elsewhere (4)		Go elsewhere (5)		Go back out (6)	
		Num.	% of type	Num.	% of type	Num.	% of type	Num.	% of type	Num.	% of type	Num.	% of type
Non-OH activities	1375	480	100.0	281	100.0	61	100.0	49	100.0	415	100.0	89	100.0
Org. activities at school	225	38	16.4	151	67.1	6	2.7	4	1.8	15	6.7	11	4.9
Org. activities at location other than school	167	94	56.3	--	--	15	9.0	8	4.8	30	18.0	20	12.0
Personal business	235	100	42.6	1	0.4	10	4.3	16	6.8	87	37.0	21	8.9
Rec. at someone else's home	244	91	37.3	--	--	3	1.2	8	3.3	130	53.3	12	4.9
Rec. at school	87	32	36.8	35	40.2	6	6.9	1	1.1	4	4.6	9	10.3
Rec. at other location	175	86	49.1	--	--	9	5.1	5	2.9	66	37.7	9	5.1
Social at someone else's home	115	56	48.7	--	--	6	5.2	6	5.2	35	30.4	12	10.4
Social at location other than someone else’s home	109	43	39.4	28	25.7	5	4.6	7	6.4	17	15.6	9	8.3
Childcare	122	4	3.3	52	42.6	0	0.0	1	0.8	65	53.3	0	0.0
Meals at restaurant	99	52	52.5	--	--	8	8.1	6	6.1	24	24.2	9	9.1
Meals at location other than restaurant	138	29	21.0	8	5.8	1	0.7	10	7.2	87	63.0	3	2.2
Other	309	84	27.2	65	21.0	9	2.9	14	4.5	131	42.4	6	1.9
Total	3400	1189	35.0	621	18.3	139	4.1	135	4.0	1106	32.5	210	6.2

Table 2. Descriptive Statistics of Activity Episode Purpose-Location Type Participation

Activity episode purpose-location type	Only activity episode purpose-location type in activity instance (%)	Act. episode purpose-location type + other act. episode purpose-location types in act. instance (%)	Total num.	Mean duration in activity instance (min.)
Non-OH activities	---	100.0	1375	289.2
Organized activities at school	71.7	28.3	225	110.9
Organized activities at location other than school	60.9	39.1	167	98.9
Personal business	50.6	49.4	235	45.1
Recreation at someone else's home	37.1	62.9	244	106.1
Recreation at school	48.3	51.7	87	102.1
Recreation at other location	35.8	64.2	175	95.7
Social at someone else's home	1.7	98.3	115	82.3
Social at location other than someone else’s home	4.5	95.5	109	68.6
Childcare	79.5	20.5	122	127.4
Meals at restaurant	35.0	65.0	99	61.2
Meals at location other than restaurant	10.1	89.9	138	31.9
Other	33.2	66.8	309	111.7

Table 3. Pattern MNL Model

	Constants	Child Demographics				
		Grade 5 to 8	Grade 9	Grade 10 to 12	Disabled	Overweight
Go home then:						
Stay at home (Pattern 1)	--	--	--	--	--	--
Go back out (Pattern 2)	-1.7200 (-11.71)	--	--	0.5130 (3.76)	-0.8322 (-2.29)	-0.2448 (-2.08)
Stay at school then:						
Return home and stay home (Pattern 3)	-2.7805 (-19.82)	--	0.9430 (4.17)	1.0316 (6.16)	--	--
Return home and go back out (Pattern 4)	-5.1121 (-19.00)	--	0.9430 (4.17)	1.0316 (6.16)	--	-0.2448 (-2.08)
Go elsewhere (Pattern 5)	-4.9256 (-19.88)	--	--	0.7106 (2.20)	--	-0.2448 (-2.08)
Go elsewhere then:						
Return home and stay home (Pattern 6)	-1.2859 (-6.50)	-0.6093 (-4.71)	--		--	--
Return home and go back out (Pattern 7)	-3.6013 (-9.73)	-0.6093 (-4.71)	--		--	-0.2448 (-2.08)

Table 3 (cont.) Pattern MNL Model

	Household Demographics				
	Income is $90,000+	**Num. of hh vehicles**	**Only one child lives in hh**	**Num. of adults in hh**	**Household has internet**
Go home then:					
Stay at home (Pattern 1)	--	-0.2256 (4.66)	-0.2850 (2.18)	--	0.3190 (-3.12)
Go back out (Pattern 2)	0.3101 (2.52)	--	-0.2850 (2.18)	--	--
Stay at school then:					
Return home and stay home (Pattern 3)	--	-0.2256 (4.66)	--	--	--
Return home and go back out (Pattern 4)	0.3101 (2.52)	--	--	--	--
Go elsewhere (Pattern 5)	0.3101 (2.52)	--	--	--	--
Go elsewhere then:					
Return home and stay home (Pattern 6)	--	--	--	-0.2838 (-3.40)	--
Return home and go back out (Pattern 7)	0.3101 (2.52)	--	--	-0.2838 (-3.40)	--

Table 3 (cont.) Pattern MNL Model

	Household Demographics		Other's Dem.	Child's Attitudes		
	Single-family dwelling unit	**Father is prim. caregiver**	**Has older sibling**	**High educ. ambition**	**Gifted program**	**Sociable**
Go home then:						
Stay at home (Pattern 1)	--	--	--	--	-0.3201 (2.88)	--
Go back out (Pattern 2)	--	--	--	--	-0.3201 (2.88)	0.5647 (5.11)
Stay at school then:						
Return home and stay home (Pattern 3)	--	--	--	0.4361 (3.19)	--	--
Return home and go back out (Pattern 4)	--	--	--	0.4361 (3.19)	--	0.5647 (5.11)
Go elsewhere (Pattern 5)	--	--	--	0.4361 (3.19)	--	0.5647 (5.11)
Go elsewhere then:						
Return home and stay home (Pattern 6)	--	0.6698 (2.94)	--	--	--	--
Return home and go back out (Pattern 7)	0.8878 (2.79)	--	0.4375 (1.98)	--	--	0.5647 (5.11)

Table 3 (cont.) Pattern MNL Model

	Environment/Contextual				
	Attends private school	**High quality neighborhood**	**Safe neighborhood**	**City size over 1 million**	**Activity day is Friday**
Go home then:					
Stay at home (Pattern 1)	--	--	--	--	--
Go back out (Pattern 2)	0.6137 (3.04)	-0.4108 (-2.44)	--	--	0.3322 (2.75)
Stay at school then:					
Return home and stay home (Pattern 3)	0.8633 (3.80)	--	--	--	--
Return home and go back out (Pattern 4)	0.8633 (3.80)	--	--	--	0.3322 (2.75)
Go elsewhere (Pattern 5)	0.8633 (3.80)	--	0.7613 (2.27)	--	0.3322 (2.75)
Go elsewhere then:					
Return home and stay home (Pattern 6)	--	--	--	--	--
Return home and go back out (Pattern 7)	--	--	--	-0.8938 (-3.60)	0.3322 (2.75)

Table 3 (cont.) Pattern MNL Model

	Other's Activity-Travel Patterns	
	Prim. caregiver works after sch.	**Other caregiver works after sch.**
Go home then:		
Stay at home (Pattern 1)	-0.6895 (7.13)	--
Go back out (Pattern 2)	-0.6895 (7.13)	--
Stay at school then:		
Return home and stay home (Pattern 3)	--	--
Return home and go back out (Pattern 4)	--	0.6449 (2.36)
Go elsewhere (Pattern 5)	--	--
Go elsewhere then:		
Return home and stay home (Pattern 6)	--	--
Return home and go back out (Pattern 7)	--	--

Table 4. Activity Episode Purpose-Location Type MDCEV Model

	Child Demographics				Household Demographics	
	Grade k to 4	**Caucasian**	**Hispanic**	**African-American**	**Income is $90,000+**	**Household size**
Non-OH activities	--	--	--	--	--	--
Organized activities at school	-0.7003 (-3.32)	--	--	--	--	--
Organized activities at location other than school	--	0.3894 (2.08)	--	--	--	--
Personal business	--	--	--	--	--	0.1124 (1.76)
Recreation at someone else's home	--	--	--	--	--	-0.2078 (-3.33)
Recreation at school	--	0.4312 (1.80)	--	--	--	--
Recreation at other location	--	--	0.6383 (2.25)	--	--	--
Social at someone else's home	-0.5332 (-2.41)	--	--	--	--	--
Social at location other than someone else’s home	--	--	--	--	--	--
Childcare	1.5359 (5.66)	--	--	--	--	--
Meals at restaurant	-0.4015 (-1.66)	--	--	-1.3301 (-3.80)	0.5706 (2.40)	--
Meals at location other than restaurant	--	--	--	--	--	-0.3265 (-3.89)
Other	-0.3187 (-2.12)	--	--	--	--	--

Table 4 (cont.) Activity Episode Purpose-Location Type MDCEV Model

	Household Demographics				Others' Demographics	
	Only child	**Household has internet**	**Single-family dwelling unit**	**Grandparent is prim. Caregiver**	**Age of prim. Caregiver**	**Has younger sibling**
Non-OH activities	--	--	--	--	--	--
Organized activities at school	--	--	--	--	--	--
Organized activities at location other than school	--	0.7668 (2.91)	--	--	--	--
Personal business	0.5714 (2.80)	--	0.3304 (1.92)	--	--	--
Recreation at someone else's home	--	--	--	--	-0.0477 (-4.50)	-0.2201 (-1.90)
Recreation at school	--	--	--	--	--	--
Recreation at other location	--	--	0.6495 (2.82)	1.0194 (2.57)	--	--
Social at someone else's home	--	--	--	--	--	-0.2201 (-1.90
Social at location other than someone else's home	0.4899 (1.95)	--	--	--	--	--
Childcare	-0.5136 (-1.79)	--	--	1.8392 (3.06)	-0.0697 (-3.74)	--
Meals at restaurant	--	--	--	--	--	--
Meals at location other than restaurant	--	--	--	--	-0.0440 (-3.39)	--
Other	--	--	--	--	--	--

Table 4 (cont.) Activity Episode Purpose-Location Type MDCEV Model

	Others' Dem.	Child's Attitudes			
	Has older sibling	High educ. ambition	Gifted program	Special education	Sociable
Non-OH activities	--	--	--	--	--
Organized activities at school	--	--	0.3155 (2.44)	--	--
Organized activities at location other than school	--	--	0.3155 (2.44)	--	--
Personal business	--	-0.2632 (-1.70)	--	0.5986 (2.48)	--
Recreation at someone else's home	--	-0.4871 (-3.79)	--	--	--
Recreation at school	0.2968 (2.10)	--	--	--	--
Recreation at other location	0.2968 (2.10)	--	--	--	--
Social at someone else's home	--	-0.4871 (-3.79)	--	--	0.5696 (2.15)
Social at location other than someone else's home	--	--	--	--	--
Childcare	-0.5335 (-2.07)	--	-0.9223 (-3.17)	0.8376 (2.79)	--
Meals at restaurant	--	--	--	--	--
Meals at location other than restaurant	--	--	--	--	--
Other	-0.4303 (-2.99)	--	--	--	-0.3326 (-2.49)

Table 4 (cont.) Activity Episode Purpose-Location Type MDCEV Model

	Environment/Contextual			Others' Activity-Travel Patterns	
	Child attends private School	**Metropolitan area county**	**Activity day is Friday**	**Prim. caregiver works after sch.**	**Other caregiver works after sch.**
Non-OH activities	--	--	--	--	--
Organized activities at school	--	--	--	--	--
Organized activities at location other than school	0.5725 (2.24)	--	-0.7647 (-2.54)	--	--
Personal business	-0.7704 (-2.35)	--	0.4389 (2.45)	-0.6693 (-4.48)	--
Recreation at someone else's home	--	--	0.8557 (6.06)	--	--
Recreation at school	--	--	--	--	--
Recreation at other location	--	--	0.8557 (6.06)	--	--
Social at someone else's home	-1.1949 (-1.93)	--	1.0427 (4.83)	0.3609 (1.77)	--
Social at location other than someone else's home	--	--	0.7698 (3.23)	--	--
Childcare	--	1.0714 (3.31)	--	1.2695 (4.74)	--
Meals at restaurant	--	0.792 (2.47)	0.7702 (4.47)	--	-0.5469 (-2.29)
Meals at location other than restaurant	--	0.5943 (2.62)	0.7702 (4.47)	--	--
Other	--	--	0.3232 (2.07)	--	-0.3074 (-2.36)

Table 4 (cont.) Activity Episode Purpose-Location Type MDCEV Model

	Activity Instance			
	Stay at school (2)	**Go back out (3)**	**Go elsewhere (5)**	**Go back out (6)**
Non-OH activities	--	--	--	--
Organized activities at school	1.7539 (8.63)	--	-0.6457 (-2.04)	0.6022 (1.71)
Organized activities at location other than school	--	--	-0.9977 (-4.46)	--
Personal business	-4.4746 (-4.21)	0.9760 (3.48)	--	--
Recreation at someone else's home	--	--	0.6783 (4.33)	--
Recreation at school	--	--	-2.0544 (-3.53)	--
Recreation at other location	--	--	--	-0.7001 (-1.94)
Social at someone else's home	--	--	--	--
Social at location other than someone else's home	--	--	-0.7166 (-2.42)	--
Childcare	3.2012 (6.23)	--	2.8108 (5.47)	--
Meals at restaurant	--	--	-0.4507 (-1.70)	--
Meals at location other than restaurant	-0.8538 (-1.98)	1.6672 (4.36)	1.5187 (6.61)	--
Other	--	0.7929 (2.39)	0.8199 (5.71)	-0.8181 (-1.82)

Table 4 (cont.) Activity Episode Purpose-Location Type MDCEV Model

	Baseline Preference Constants	Satiation Parameters
Non-OH activities	--	$3.26*10^{-7}$ (41.32)
Organized activities at school	-7.8566 (-39.03)	0.9093 (3.00)
Organized activities at location other than school	-7.9300 (28.98)	0.9127 (2.86)
Personal business	-7.4112 (-22.35)	0.7388 (5.78)
Recreation at someone else's home	-4.4096 (-9.05)	0.8670 (4.80)
Recreation at school	-8.3256 (-36.24)	0.9103 (2.29)
Recreation at other location	-8.0492 (-32.05)	0.8744 (4.16)
Social at someone else's home	-8.0151 (-27.25)	0.8193 (4.03)
Social at location other than someone else's home	-8.0853 (-46.37)	0.8331 (3.61)
Childcare	-9.8444 (-11.29)	0.9317 (2.59)
Meals at restaurant	-7.9255 (-22.36)	0.8070 (2.67)
Meals at location other than restaurant	-5.9701 (-9.87)	0.6939 (2.77)
Other	-6.5580 (-34.46)	0.8347 (7.34)