An Exploratory Analysis of Children's Daily Time-Use and Activity Patterns Using the Child Development Supplement (CDS) to the US Panel Study of Income Dynamics (PSID)

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ABSTRACT

This research paper examines the weekday and weekend activity participation characteristics of school-going children. Specifically, the research focuses on the overall time-use of children in different types of activities, as well as on several dimensions characterizing the context of activity participations. These include the temporal (time-of-day and participation duration), spatial (location), with-whom (*i.e.*, accompanying individuals), and episode sequencing dimensions. The data for our analysis is drawn from the 2002 Child Development Supplement to the Panel Study of Income Dynamics.

1. INTRODUCTION

1.1 Background and Research Objective of Study

The focus of analysis in existing activity-based research has almost exclusively been on the activity-travel patterns of adults (16-18 years of age and older; for instance, see Bhat and Srinivasan, 2005; Koppelman and Gliebe, 2002; Bhat and Misra, 2002). One reason for this emphasis on adults' activity-travel patterns is ostensibly that most children do not have the choice of driving on their own, and therefore do not "add" cars directly onto the transportation network. However, by the same token, children depend, to a large extent, on household adults or other adults to drive them to activity events. Such serve-passenger activities constrain adults' activity-travel patterns in important ways. For instance, a parent driving a child to school during the morning peak is unlikely to shift away from the morning peak because of a congestion pricing strategy, even if the parent has a flexible work schedule. Similarly, in the case of a parent dropping a child off at soccer practice, it is not the parent's activity but the child's activity, and its location, that determines the temporal and spatial dimensions of the trip (see Kitamura, 1983).[1] Further, the dimension of "who" is responsible for serving the trip for the child's activity determines which adult's activity-travel pattern is impacted (see Goulias and Kim, 2005 for a recent study emphasizing the *with whom* and *for whom* characteristics of activity participation). Of course, in addition to serve-passenger activities, children can also impact adults' activity-travel patterns in the form of joint activity participation in such activities as shopping, going to the park, walking together, and other social-recreational activities.

The intricate interactions and effects of children's activity-travel patterns on adults' activity-travel patterns can be captured in limited ways by the commonly used approach of including "exogenous" variables representing the number, presence, and age distribution of children. However, such a limited approach is not as behaviorally interesting or appropriate as considering the activity-travel patterns of children, and explicitly inter-linking these with those of adults' activity-travel patterns (see Goulias and Kim, 2005). In addition, the consideration of children's activity-travel patterns is important in its own right. Specifically, children's activity-travel patterns contribute directly to travel by non-drive alone modes of transportation. Also,

[1] One could argue that parents are the "true" decision-makers for the activity participations of children and, therefore, there is no need to directly consider the activity-travel needs and characteristics of children. While this argument may hold for very young children (say, less than 7 years), older children start developing their own independent activity desires (see Stefan and Hunt, 2006). In the latter case, it is the child's activity-travel needs and patterns that expressly impact the activity-travel patterns of adults.

understanding the overall time-use patterns of children, and the context of their non-motorized travel and physical activity participations, is important for promoting the health of children. This is an issue that is gaining increasing attention at the interface of the transportation and public health fields, because of the positive correlation between physically active lifestyles and the development of strong, healthy, and intelligent children (CDC, 2006; Transportation Research Board and Institute of Medicine, 2005).

In summary, there are several compelling reasons to examine and analyze children's activity-travel patterns. This motivates the objective of this research, which is to descriptively examine the weekday and weekend activity participation characteristics of school-going children. In doing so, we focus on the overall time-use of children in different types of activities, as well as on several dimensions characterizing the context of activity participations. These include the temporal (time-of-day and participation duration), spatial (location), with-whom (*i.e.*, accompanying individuals), and episode sequencing dimensions.

1.2 Overview of Earlier Research Relevant to the Current Study

The earlier research efforts in the area of children's time-use and activity-travel patterns may be classified into two broad areas: (1) Time-use studies that provide aggregate daily or weekly time-use statistics, with limited to no examination of the context of activity participations, and (2) Studies that model the factors affecting children's participation in specific activity episodes, such as physical activity participation and hours of television viewing. We briefly discuss the literature within each of these categories in turn in the subsequent two paragraphs.

The time-use studies have been primarily undertaken in the sociology, developmental psychology, economics, and education fields. These studies examine children's time-use in one or more countries (Hofferth and Sandberg, 2001a, and Zill *et al*., 1995; see Larson and Verma, 1999 for a review) or study changes in time-use over time (see Hofferth and Sandberg, 2001b). Many of these studies also examine time spent with family and friends, with an emphasis on time spent with parents (Larson and Verma, 1999; Hofferth and Sandberg, 2001a). The latter emphasis is a result of the desire to examine the effects of parental involvement on children's cognitive and social-emotional development, especially in the context of changing family structure and maternal employment patterns (Bryant and Zick, 1996a; Asmussen and Larson, 1991; Sandberg and Hofferth, 2001). Some of the time-use studies also examine the after-school

activities of children, with the intention of assessing the need for, and benefits of, after-school programs (see Shann, 2001; Posner and Vandell, 1999; Posner and Vandell, 1994; and Hofferth and Jankuniene, 2001). Overall, the broad time-use studies have provided a rich basis for understanding the social-psychological aspects of children's development. However, they either do not focus, or focus in only very limited ways, on the temporal, spatial, "with-whom", and episode sequencing contexts of children's activity-travel participation.

A second broad area of children's activity studies has examined the factors affecting participation in such specific activities as physically active pursuits or sedentary activities (for example, watching television). Many of these studies are motivated by the growing child obesity problem in the United States (CDC, 2005), and the well established epidemiological link between physical activity and obesity reduction/other health benefits. Studies focusing on the correlates of physically active and inactive lifestyles in children include Zakarian *et al.* (1994), Aaron *et al*. (2002), Sallis *et al*. (1999, 2000), Janz *et al*. (1999), Copperman and Bhat (2006), and Gordon-Larsen *et al.* (2000). Some related studies have sought to identify relationships between the time spent in physical activity and time spent in sedentary activities (see Feldman *et al*., 2003) or a relationship between the time spent in both activities to unhealthy attributes in children (see Anderson *et al*., 1998; Robinson *et al*., 1993; Durant *et al*., 1994). Another recent study assessed how television viewing affects time spent in other free time activities and with family members (Vandewater *et al*., 2006).

1.3 The Current Study and the Paper Structure

The current study is close to the spirit of the first category of time-use studies of the previous section in that it examines time-use in all of the children's activities, and not just in specific physically active or physically inactive activity categories. However, our underlying objective of contributing toward activity-based travel analysis requires a much more detailed analysis of the context of activity participation than is examined in the traditional time use studies. In this regard, our study is similar to the recent research work of Stefan and Hunt (2006), who examined activity-travel patterns of Canadian children. But we focus on US children, adopt a more disaggregate taxonomy of activity purposes, examine the "with whom" dimension of activity participation, analyze the location of out-of-home activities, and explore episode sequencing characteristics. Also, in contrast to some other studies that have focused on the travel patterns of

US children (see McDonald, 2006; Clifton, 2003), the current study adopts activity episodes as the unit of analysis and considers the comprehensive context of activity episode participation. We envision our exploratory analysis as an important first step toward informing the development of joint activity-based travel models for children and adults.

The data for our analysis is drawn from the 2002 Child Development Supplement (CDS) to the Panel Study of Income Dynamics. The CDS provides a rich base to examine the many dimensions of activity participation. Specifically, the survey collects information on all aspects of both in-home and out-of-home activity participation of a sample of children for one weekday and one weekend day. The survey explicitly obtains information on all persons (both household and non-household members) accompanying the respondent for each activity episode. The survey also uses a disaggregate activity classification scheme and employs an extensive location typology to capture the spatial dimension of activity episode participation. The time-use and activity patterns of school-going children aged 5-18 years are considered in the analysis.

The rest of this paper is structured as follows. The next section describes the data source and sample formation procedure. Section 3 presents aggregate characteristics of children's time-use by activity purpose and by activity location. Section 4 examines the location and with whom dimensions of children's participation in activity episodes. Section 5 examines the sequencing of children's activity episodes. Finally, Section 6 summarizes the important findings from the research.

2. DATA SOURCE AND SAMPLE FORMATION

2.1 Data Source

The data source for this analysis is the 2002 Child Development Supplement (CDS) to the Panel Study of Income Dynamics (PSID). The PSID is a longitudinal study that collected demographic, employment and health information from a nationally representative sample of individuals and households. The CDS 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. The diary also collected information on who was present, and participating, and who was present, but not participating, in each activity. 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.

2.2 Sample Formation

The process of generating the sample for analysis involved several steps. First, only individuals aged five through eighteen who were enrolled in primary or secondary school were considered for the analysis. Also, only children who filled out time diaries on both the weekday and weekend day were included. Based on these criteria, a total of 1970 children were selected for analysis. Second, activity types were reclassified from the 365 original purposes into 11 activity types: (1) Work (for pay), (2) Household Chores (including non-paid child care), (3) Meals (including snacks), (4) Organized Activities (*i.e.* lessons, meetings, and clubs), (5) Studying (including non-school classes and homework), (6) Recreation (*i.e.* unorganized hobbies and sports, outings, reading, playing, TV viewing, and music), (7) Social (including conversations, being intimate, parties, visiting, and religious services), (8) Personal Business (*i.e.* shopping, obtaining services, paying bills, writing e-mails or letters), (9) Personal Care, (10) Receiving Child Care (*i.e.* daycare, being babysat), and (11) School.[2] Additionally, because of the rather diverse nature of the organized activities, recreation, and personal business purpose categories, these were further classified into several finer categories for exploration. Third, activity episode locations were collapsed into eleven location types: (1) Home, (2) Parent's work place, (3) Child's work place, (4) Someone else's home (including other parents' home), (5) restaurant, (6) Outdoor recreational area, (7) School, (8) Church, (9) Store/retail business, (10) Non-retail business (including indoor recreational facilities and daycare), (11) Other. Fourth, activity episodes were assigned to specific time periods in the day based on the start-time of the activity, and then episodes of the same type within a time period were aggregated. For school-going children on a weekday, the school activity is used as a "peg", and the day is divided into two time periods - before-school (3 a.m. to school start time) and after-school (school end time to

[2] The focus in the current paper is only on non-sleep episodes. Also, because of the activity-based emphasis of the current paper, we do not expressly focus on travel episodes. Rather, the characteristics of travel episodes are indirectly considered through the context of activity participation.

midnight).[3] For weekend days, the day is divided into five time periods (3 a.m. to 8 a.m., 8 a.m. to noon, noon to 4 p.m., 4 p.m. to 8 p.m., and 8 p.m. to midnight). Activity episodes beginning between midnight and 3 a.m. are excluded from the analysis to avoid inclusion of activities that are a continuation of the previous day's scheduling. Fifth, "with whom" participation categories were created for each activity episode, based on the presence of other individuals who were around and/or participated in each episode. The "with whom" information was grouped into ten mutually exclusive and collectively exhaustive categories: (1) No one else (or alone), (2) Only with Mother, (3) Only with Father, (4) Only with sibling(s), (5) Immediate family combinations (more than one of father, mother, and siblings), (6) Only with extended family, (7) All other family combinations (immediate and extended family combinations), (8) Only with child's friend, (9) Only with other non-relative, (10) Other combinations. Finally, out-of-home activity episodes (or stops) and tours (home-to-home sojourns) 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.

3. AGGREGATE TIME-USE CHARACTERISTICS

This section provides a broad overview of children's time-use by presenting participation rates and duration of time spent in (1) different types of activities across all children and by age groupings (Section 3.1), (2) different activity types by time period of the day, and different location types by time period of the day (Section 3.2), (3) different types of finer activity categories within the broad activity purposes of organized activities, recreation, and personal business (Section 3.3).[4]

3.1 Participation and Time Spent in Activity Purposes by Age

Table 1 presents participation percentages and average duration of participation by activity purpose for the weekday and weekend day, respectively (the weekend numbers are in parenthesis). In these tables, an entry of '–' in any cell implies that the participation rate in the corresponding activity purpose is less than 0.5%. Also, the average duration of participation in

[3] The school activity is used as the basis for defining time periods on weekdays for school-going children because other non-school activities tend to be scheduled around the school activity (see Frusti *et al.*, 2003).

[4] The terms "activity purposes" and "activity types" will be used synonymously in this paper.

each activity purpose is computed as the mean of the total duration of participation across all episodes of that purpose, across children who participate in the activity purpose.

The second column of the table, labeled "Total", presents statistics for the entire sample of children. This column indicates that, as expected, a high fraction of children participate in school activity on weekdays (the average duration is about 6.5 hours), while almost no child participates in school activity on weekends (see the first row corresponding to "school" in Tables 1). Also, almost every child eats, recreates, and pursues personal care activities each day (the reason for the meal percentage being less than 100% may be attributed to meals not being considered as the primary activity)[5]. In addition, except for the three purposes of school, studying, and receiving child care, children participate at least as much (and generally much more) in each of the other activity purposes over the weekend days than the weekdays. The difference is particularly noticeable for the recreation, social, and personal business (including shopping) purposes. For the recreation purpose, the participation rates are not very different between weekdays and weekend days, though the average duration of participation among children who recreate is about 3.5 hours on weekdays and 6.5 hours on weekend days. For the social and personal business purposes, there is a substantial increase in both the participation rates and mean durations over the weekend days (see Larson and Verma, 1999 and Hofferth and Sandberg, 2001a for similar results).

The rest of the columns in Table 1 provide the participation rates and mean durations by age group. The row corresponding to the "work" purpose shows that the work participation rate is substantive only for adolescents (15 to 18 year olds). These adolescents work, on average, for about 4.5 hours on a weekday and 6 hours on a weekend day. Finally, as children get older, the participation rates and mean durations in organized activities, social activities, and personal business increase, while the participation rate and duration of time spent receiving child care decreases. This is consistent with the increased professional, social, and shopping activities among adolescents compared to younger children (see Hofferth and Sandberg, 2001a and Bhat and Lockwood, 2004).

[5] For example, if a child eats breakfast while watching television, television may be recorded as the primary activity while eating is recorded as the secondary activity.

3.2 Participation Rates and Duration by Time-of-Day for Each Activity Purpose and Each Activity Location

The previous section examined overall time-use patterns in different activity purposes, as well as the variation in these patterns by age. In this section, we introduce time-of-day of participation in different activity purposes, as well as consider the joint time-of-day and location contexts of participation.

Table 2a provides the participation rates and mean duration by time-of-day for each non-school activity purpose for weekdays (see footnote under Tables 2a and 2b for a precise explanation of how the mean duration value is computed). This table is confined to the vast fraction of children who go to school on the weekday (all subsequent analyses on weekdays is also based only on school-going children). Table 2a indicates, not surprisingly, that children participate in all activities except personal care at a higher rate and for a longer duration during the after-school period than the before-school period. This is similar to the higher rate of activity participation in the post-work period for adult workers (see Bhat and Singh, 2000), and is a result of more time availability and the absence of a rigidly constrained activity in the post-school period. Most of the participations in the before-school period are for meals and personal care.

Table 2b provides the time-use patterns by time-of-day for each activity purpose for weekend days. Similar to the before-school period on weekdays, very few children participate in activities during the early morning hours (see the column labeled “3 a.m. to 8 a.m.” in Table 2b). The overall levels and intensity of activity participation are also on the low side during the late evening period (8 p.m. to midnight), like in the early morning period. The dominant activities during this late evening period are leisure type activities (meals, recreation, social, and personal care activities). The daytime weekend time periods (8 a.m. to noon, noon to 4 p.m., and 4 p.m. to 8 p.m.) constitute the most intense activity periods, and have very similar participation percentages in most activity purposes. The most common activity type of participation during these periods is recreational activity, with 67%-80% of children participating in recreation for about 2-2 ½ hours.

Tables 3a and 3b are similar to Tables 2a and 2b, respectively, except that the classification is by activity location rather than activity purpose. Home is, by far, the most common location for activity participation on both weekdays and weekend days, especially on

weekdays.[6] The other common location for both before-school and after-school activities on weekdays is school, presumably reflecting the prevalence of day-care arrangements available at most schools and after-school clubs/ meetings. Interestingly, another very common location for activity participation during the after-school period on weekdays, and on weekend days, is someone else's home, highlighting the importance of friends and extended family in determining children's daily activities and activity locations. However, during the mid-morning period (8 a.m.-noon) on weekend days, church is the most frequented location outside of home, with a mean activity duration of 2 ½ hours. Similarly, "store/retail business" is a relatively frequent activity location in the early afternoon period (noon-4 p.m.) of weekend days, indicating the prevalence of out-of-home personal business (including shopping) activity during this period. Non-retail businesses, outdoor recreational areas, and restaurants are also popular activity locations during this early afternoon period on weekend days.

3.2 Participation Rates and Durations in Disaggregate Activity Purposes

The organized activity, recreation, and personal business purposes comprise a rather diverse set of activity types, with potentially quite different contextual dimensions. In this section, we examine participation rates, and durations of participation, in each of the disaggregate activity types that make up the broader activity purposes identified above. Figure 1 presents the results. For each of the three broad activity purposes, the figure provides the percentage of individuals participating in the broad activity purpose who participate in each of the finer activity types. For example, the weekday bar for "sports practice or games" for organized activities shows that about 60% of children who participated in organized activities took part in "sports practice or games". In addition, the number just above the bar indicates that, among the children who participated in "sports practice or games", the mean duration of participation is 118 minutes.

As can be observed from the figure, the most common organized activity type participated in during the weekday is "sports practice or games", while the corresponding type during weekend days is "clubs and other meetings". As one would expect, for both "sports practice or games" and "clubs and other meetings", the mean duration among those who participate in these activities is longer over the weekends than the weekdays.

[6] In Table 3b for weekend days, the low participation rate in the home location in the early morning period (28.5%) reflects the low number of children reporting non-sleep activities during this period.

The recreation activity comprises many different kinds of sub-activities (see bottom panel of figure 1). Not surprisingly, TV or movie watching is the dominant type of recreation activity on both weekdays and weekend days, with almost 85-90% of recreators undertaking this activity. The mean durations in this activity is also quite substantial (about 2 hours on weekdays and more than 3 hours on weekend days). Free play, and video or computer games, also have a relatively high percentage of participation and mean durations compared to other recreational activities. Passive and active recreational travel are two of the most infrequently participated recreational activities. Overall, children participate much more in physically passive recreational activities, and spend substantial amounts of time in such activities, than in physically active recreational activities.

In the category of personal business activities (top right figure), shopping represents the largest percentage of personal business activities on both the weekday and weekend days, though its share on weekend days is much higher. For all other personal business activity categories, the participation rate on weekdays is higher. The mean durations, however, is always higher on weekend days for all personal business activities.

In the rest of this paper, we do not maintain the disaggregate classification of this section, to limit the scope of the study and maintain focus. However, the diverse nature of the broad activity types should be recognized in the ensuing discussions.

4. EPISODE-LEVEL ANALYSIS

The previous section provided a descriptive analysis of children's overall time-use patterns during the day. In this section, we examine the detailed context of children's activity episodes. Specifically, the location of performance, and the type of companionship arrangement, of episodes are analyzed. The contexts of "where" and "with whom" dimensions of episode participation are important determinants of travel patterns and the inter-relationships between activity-travel patterns of different individuals.

4.1 Location of Activity Episode Participations

Table 4 provides the percentage of episodes in each non-school activity purpose that is pursued in-home and out-of-home (the percentages add up to 100% for each row). The results show that work and organized activity episodes are most likely to be pursued out-of-home on both

weekdays and weekend days, with over 90% of these episodes pursued out-of-home. In contrast, episodes corresponding to meals, household chores, studying, recreation, and personal care are primarily pursued in-home, particularly on weekdays. On weekend days, the absence of school-related activity provides more flexibility to port these activities out-of-home. The predominantly in-home nature of recreation activities is also consistent with "television or movie viewing" and "playing video or computer games" being the primary kinds of recreational activities (see Section 3.3).

There is a more even split between the in-home and out-of-home locations for social, personal business, and "receive childcare" episodes, though there are also much more differences in these splits between weekdays and weekend days compared to other episode types. For social and personal business episodes, the location is skewed toward the out-of-home category on weekend days. The substantially high percentage of out-of-home personal business episodes over the weekends may be attributed to shopping being the dominant personal business activity on weekends (see Figure 1). For the "receive childcare" episodes (last row of table), the percentage is much higher for the out-of-home category on weekdays (when adults are likely to be at work) and much higher for the in-home category on weekend days (when adults seek child care at home to maximize the time gained from the child care arrangement to pursue out-of-home activities).

Table 4 provides important information on the propensity to pursue out-of-home episodes of each activity type, but does not examine the type of location where out-of-home episodes are pursued. Figure 2 provides this information for all the non-school activity purposes, except for work, household chores, and personal care (children work primarily at their work place, while household chores and personal care are almost exclusively pursued in-home; see Table 4). The results in Figure 2 show that someone else's home is a very common location for participation in all types of out-of-home episodes, except for organized activities and personal business episodes. This is particularly the case for recreation and social episodes on both weekdays and weekend days, and for "receiving child care" episodes on weekend days. Another very frequent location for participation in all types of out-of-home episodes (except personal business episodes) on weekdays is school. On the other hand, on weekends, a rather large fraction of organized activity and social out-of-home episodes are pursued at church. Studying-related out-of-home episodes

are pursued primarily at someone else's home or school, on both weekdays as well as weekend days. Finally, and as expected, most personal business episodes are pursued at store locations.

4.2 Companionship Arrangement of Activity Episodes

As indicated in the introductory section of the paper, the joint activities of children with other individuals introduce linkages in the activity-travel patterns of all the individuals involved. Thus, it is of interest to understand the individuals who accompany children in their activity episode participations. For in-home episodes, the only activity type whose episodes have a rather high chance of being pursued alone is personal business (about 27% of in-home personal business episodes are pursued alone). Among episodes pursued jointly or with other persons around, a vast majority of in-home episodes of all types involve only the immediate family (mother, father, sibling or combinations), or immediate family and other non-family members. In the rest of this section, we do not present the companionship arrangement for in-home activity episodes because of the dominance of immediate family members as accompanying individuals.

The companionship arrangement (*i.e.*, who participated with the child) for out-of-home non-school episodes is presented in the form of pie-charts in Figure 3, with each row corresponding to the companion-type distribution for episodes of each activity purpose (the work activity purpose does not appear in the figure, because, by definition, work activities are pursued alone). There are two columns of pie-charts in Figure 3, one for weekdays and another for weekend days. Several insights may be drawn from the figure. First, and as one would expect, episodes for studying are the most likely to be pursued alone (see the large fraction of the "No one else (alone)" category in the third row of the pie-charts). Among the non-study episodes, recreation episodes are more likely to be pursued alone relative to episodes of other types. Second, the results show that children are more likely to be accompanied by only their mother than only their father on weekdays for all episodes except social episodes. This is consistent with the notion that the mother bears more of the responsibility for child-care and related child activities (Bryant and Zick, 1996b; Sayer *et al.*, 2004). It may also be the result of men being more likely to be employed in a household and working longer hours (Korenman *et al.*, 2005), which constrains their time with children. The latter explanation is compatible with the finding that the participation levels of children with only their fathers increase between weekdays and weekend days for all episode types, except social activity episodes (see Yeung *et al.*, 2001 for

similar results). Third, the participation levels of children with only their mothers and with only their fathers is substantially different for personal business (mostly shopping) episodes (see the last row of pie-charts on the second page of Figure 3). This result reinforces the stereotype that men are much less likely to pursue shopping-related activities compared to women (Niemeier and Morita, 1996). Fourth, children are most likely to pursue episodes with only their siblings for recreational episodes compared to other episode types. Fifth, children participate much more with their immediate family (combinations of parents and siblings) in all activity episodes over the weekends. This is particularly the case for out-of-home meals, social, and personal business episodes. Overall, the higher participations with the immediate family over the weekend are a clear result of more time availability to be together as a family over the weekends. Sixth, children participate with only their friends rather substantially, particularly in social and recreational episodes. Children also participate with only other non-relatives very substantially (upwards of 50%) in organized activity episodes. In addition, children participate at rather high intensity levels with combinations of family and non-family members.

Overall, it is indeed remarkable that children mostly participate with other individuals in their activities rather than alone. Further, children participate with their immediate family members (and no one else) at less than 50% for all episode types. The rather high fraction of joint out-of-home episodes undertaken with non-household members (with or without family members) emphasizes the importance of recognizing inter-household interactions in the context of a household's social network, in addition to intra-household interactions.

5. EPISODE SEQUENCING

The analysis thus far has focused on overall time-use during the day (Section 3) and the location/with whom dimensions of individual episode participations (Section 4). In this section, we examine how children organize their weekday and weekend days; *i.e.*, we develop simple measures associated with the organization of various out-of-home episodes into an overall daily activity-travel pattern.

5.1 Activity Episode Chaining

This section of the paper examines the sequencing of out-of-home activity episodes (*i.e.*, stops) in terms of the organization of the episodes into tours (home-to-home sojourns). Specifically, we

examine the propensity of children to undertake multiple types of out-of-home activity episodes, as a part of the same sojourn or home-based tour. The activity episode chaining for each activity purpose *T* is described in terms of a *chaining propensity index*, which is defined as the ratio of the number of multiple-stop tours containing an episode of *T* to the total number of tours containing an episode of activity purpose *T*. For example, if out of 1000 home-based tours, each comprising at least one shopping activity episode, 700 tours comprise only one or more shopping episodes and the remaining 300 comprise one or more other (non-shopping) stops in addition to shopping, then the chaining propensity for shopping is 300/1000 = 0.3. Thus, for activity purpose *T*, a chaining propensity of 1 would indicate that all episodes of purpose T are chained with out-of-home activity episodes of other purposes, while a chaining propensity of 0 would imply that episodes of purpose *T* are never chained with out-of-home activity episodes of other purposes.

The chaining propensities by activity purpose are presented in Table 5a for both weekdays and weekends. In the overall, 41% of all out-of-home tours involving children's episodes are chained (*i.e.* involve activity episodes of different purposes), while 43% of all tours on weekend days are chained (see first row of Table 5a). The marginally higher chaining on weekend days is presumably a reflection of more relaxed time constraints, and more impulsive participations in other activity purposes when participating in a specific activity purpose. A further examination of the chaining propensity by activity purpose reveals several interesting results. Among all purposes, school episodes are the only ones that are more likely to be undertaken in isolation than being chained with episodes of other activity purposes (this is particularly the case during weekend days). For weekday work episodes, the propensity to chain with episodes of other activity purposes is about the same as the propensity to not chain, while weekend work episodes are more likely to be undertaken in isolation. Perhaps the relatively strict spatial and temporal constraints within which the school/work activity is undertaken, and the long durations invested in episodes of these purposes, make it undesirable for children to chain these activity episodes with other out-of-home activity episodes. Among non-school and non-work purposes, episodes for meals and personal care are the most likely to be chained. This is quite intuitive, since out-of-home meals and personal care episodes are likely to be pursued in combination with other episode types such as shopping. Finally, a comparison of the differences in chaining propensities across weekdays and weekend days reveals that out-of-home episodes

for studying, social, and “receiving child care” are particularly likely to be chained with episodes of other purposes over the weekdays relative to weekend days.

Table 5a provides a good indication of the motivation behind the sequence of episode participations, but does not provide information about the spatial location component of chaining. For example, a shopping episode at a shopping mall may be followed by a meal episode at the mall, in which case both of these episodes would appear as being chained. However, there is no spatial dislocation (*i.e.*, no travel) between the two episodes. To examine the extent of chaining in terms of travel, Table 5b provides the information on chaining of out-of-home episodes by activity location. The first row clearly indicates that, while the chaining propensities by purpose are about the same on weekdays and weekends, there is much more spatial diversity (scattering) in the location of participation of the episodes over the weekend days. Specifically, only 26% of weekday tours involve episode participations at multiple locations, compared to 66% of weekend tours. This is indeed interesting, suggesting that individuals appear to be more willing to invest time in travel, perhaps to their desired locations for participation in each type of activity, over the weekends. On the other hand, there is a tendency to pursue activities at a single location in tours on weekdays. Among the different activity location categories, episodes undertaken at the parents’ work place are most likely to be chained with other locations, while those undertaken at school and church are the least likely to be chained (especially on weekdays).

5.2 Activity Purpose of the First and Last Out-of-Home Episodes of the Day

This section examines the sequencing of out-of-home activity episodes in the context of the entire day by examining the likelihood that out-of-home episodes of each activity purpose are undertaken as the first and last out-of-home episode for the day, conditional on participation in that activity purpose (Table 6). This analysis is restricted to only persons undertaking two or more out-of-home activity episodes during the day.

The numbers in Table 6 are interpreted as follows. For the school purpose, 78.2% (66.7%) of the episodes occur as the first episode of the weekday (weekend day) and 9.7% (33.3%) of the episodes occur as the last episode of the weekday (weekend day). Thus, the results indicate that school activity episodes have a very high likelihood of participation as the first stop in the day for both weekdays and weekend days, though school episodes are unlikely to be the last episode of weekdays. On the other hand, work episodes are unlikely to be the first

episode, and very likely to be the last episode, on weekdays. However, on weekend days, the likelihood of work being the first episode is about the same as that of being the last episode, and this likelihood is about 45%. Meal episodes on weekdays have about a one-fourth probability of being the first episode and a one-fifth probability of being the last episode. However, meal episodes are less likely to be the first episode on weekend days. For all the remaining purposes, (see the rows corresponding to "household chores" through "receive child care"), episodes of these types are much more likely to be the first episode, and much less likely to be the last episode, on weekend days relative to weekdays. This is particularly the case for organized activity and social episodes. Across both weekdays and weekend days, and among the non-school episodes, personal care episodes are most likely to be the first episode relative to other non-school episodes, and episodes for work, recreation, social, and personal businesses are most likely to be the last episodes. Overall, most activities involving structure and time constraints (school on weekdays and organized activities on weekend days) are participated earlier in the day, and other activities are pursued later.

6. CONCLUSION

The activity-based approach to travel analysis has received substantial attention in the transportation field. In recent years, the importance of recognizing and accommodating inter-household and intra-household linkages in activity-travel patterns has been emphasized (see Koppelman and Gliebe, 2002; Srinivasan and Bhat, 2006; and Goulias and Kim, 2005). However, almost all earlier activity-based analyses have focused solely on the activity-travel patterns of adults. In these studies, children are considered only to the extent that their demographic characteristics (presence, number, and age distribution) impact the adults' activity-travel patterns. On the other hand, explicitly considering children's activity patterns is important for accommodating the linkages between children's and adult's activity-travel patterns, and for the accurate forecasting of activity-travel patterns in general. In this research, we descriptively examine the weekday and weekend activity participation characteristics of school-going children. In doing so, we focus on the overall time-use of children in different types of activities, as well as on several dimensions characterizing the context of activity participations.

There are several important findings from the study. First, the types of activities children pursue are quite different based on age. This is particularly the case for organized activities,

social, and personal business (including shopping) activities, with older children participating more often in these activities, and for longer durations, than younger children. As expected, adolescents (15-18 years) are also much more likely to participate in work activities compared to younger children. Second, there are substantial variations in time-use between weekdays and weekend days, particularly for the recreation, social, and personal business purposes. It is particularly interesting to note the time investment patterns in recreation. Almost all children recreate over the weekday and weekend day, and the time investment in recreation is, on average, 3.5 hours on a weekday and 6.5 hours on weekend days. Within the category of recreation, the dominant type of recreation among children is "TV or movie viewing" and "playing video/computer" games. This reinforces the notion that children participate much more in physically passive recreational activities, and spend substantial amounts of time in such activities, than in physically active recreational activities (see Vandewater *et al.*, 2006). Third, there are significant variations in the intensity and type of non-school activities pursued at different times of the day. Fourth, a rather substantial fraction of out-of-home episodes are pursued at someone else's home on both weekdays and weekends, and at school on weekdays. Fifth, children mostly participate with other individuals (rather than alone) in out-of-home activity episodes, and a significant proportion of these joint participations are with individuals who are not family members. The rather high fraction of joint out-of-home episodes undertaken with non-household members (with or without family members) emphasizes the importance of recognizing inter-household interactions in the context of a household's social network, in addition to intra-household interactions. Sixth, the relatively strict spatial and temporal constraints within which the school/work activity is undertaken, and the long durations invested in episodes of these purposes, appear to make it undesirable for children to chain these activity episodes with other out-of-home activity episodes. Seventh, there is substantial spatial scattering in the location of participation of the episodes in tours over the weekend days, and a tendency to pursue activities at a single location in tours on weekdays. These results perhaps reflect lesser time constraints and more impulsive episode chaining on weekend days relative to weekdays. Finally, most activities involving structure and time constraints (school on weekdays and organized activities on weekend days) are participated earlier in the days, while episodes for other activities are pursued later.

Overall, our findings provide insights into children's time use and activity participation characteristics, including the context of activity participations. In light of our findings, we recommend that future travel surveys and models be suitably enhanced to (1) recognize intra-household and inter-household interactions, (2) include multi-day data collection programs, and (3) explicitly consider children's activity-travel behavior characteristics.

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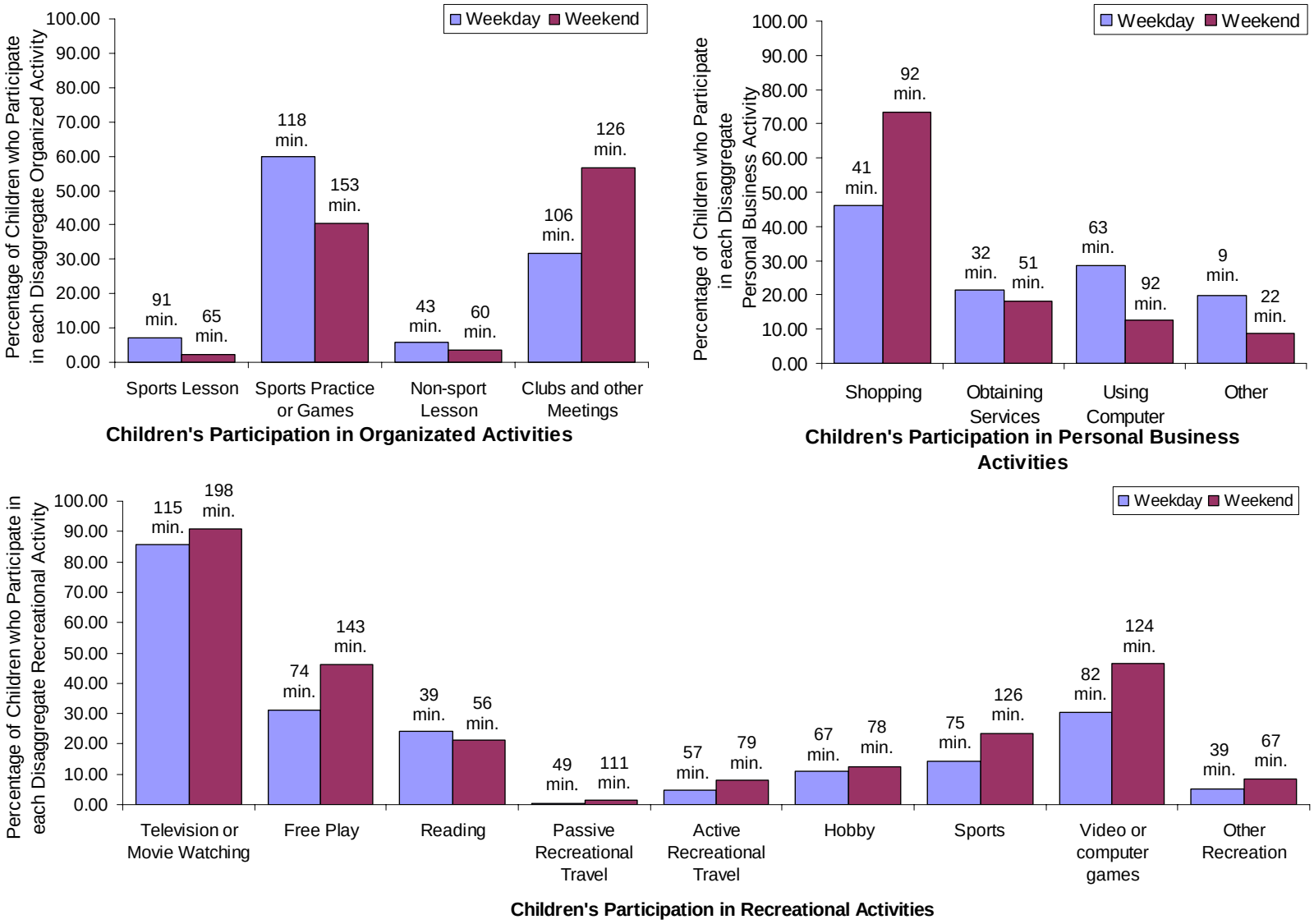

FIGURE 1 Children's participation in disaggregate organized activities, personal business, and recreational activity purposes.

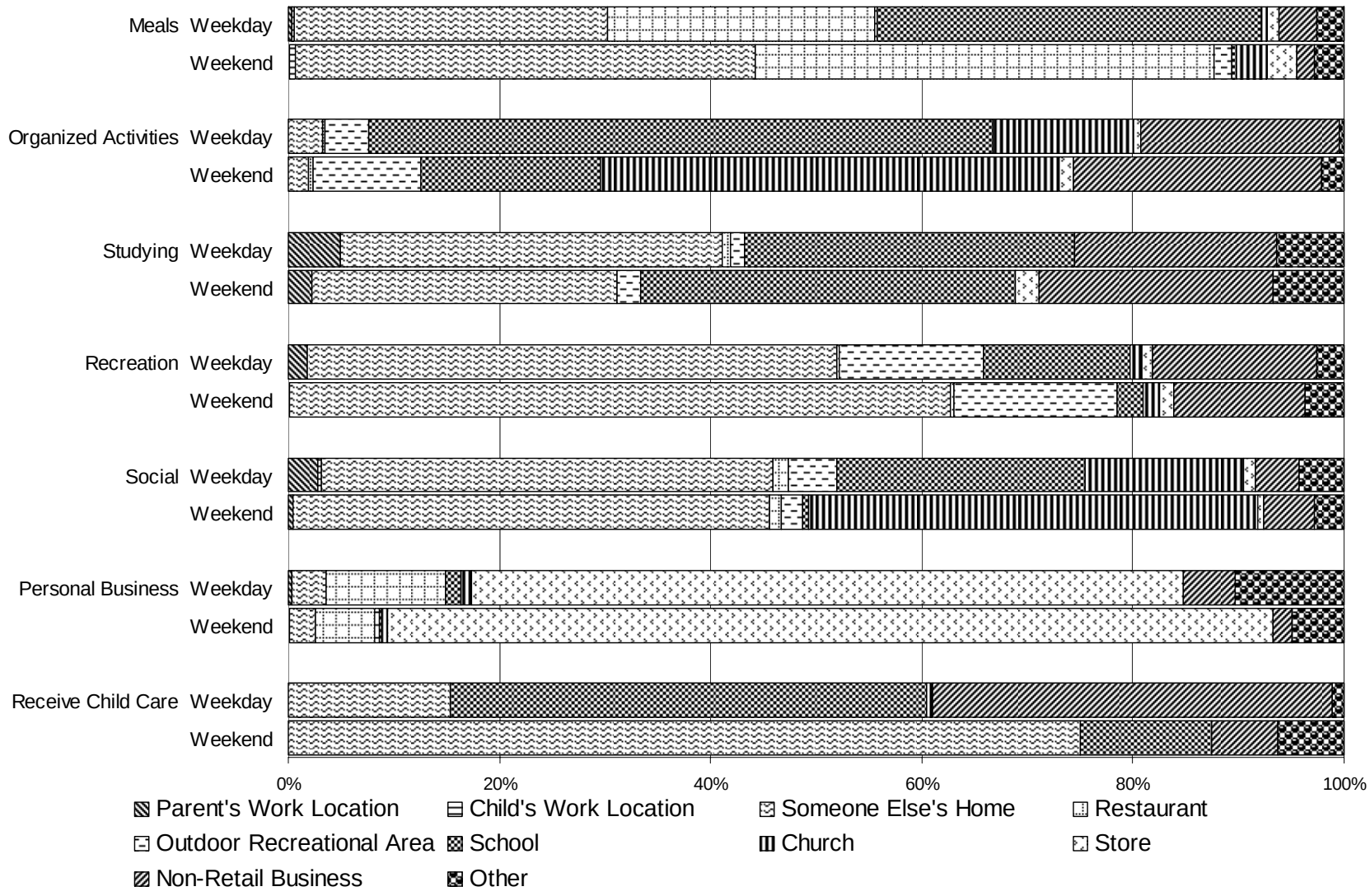

FIGURE 2 Percentage of in-home activity episodes at each location.

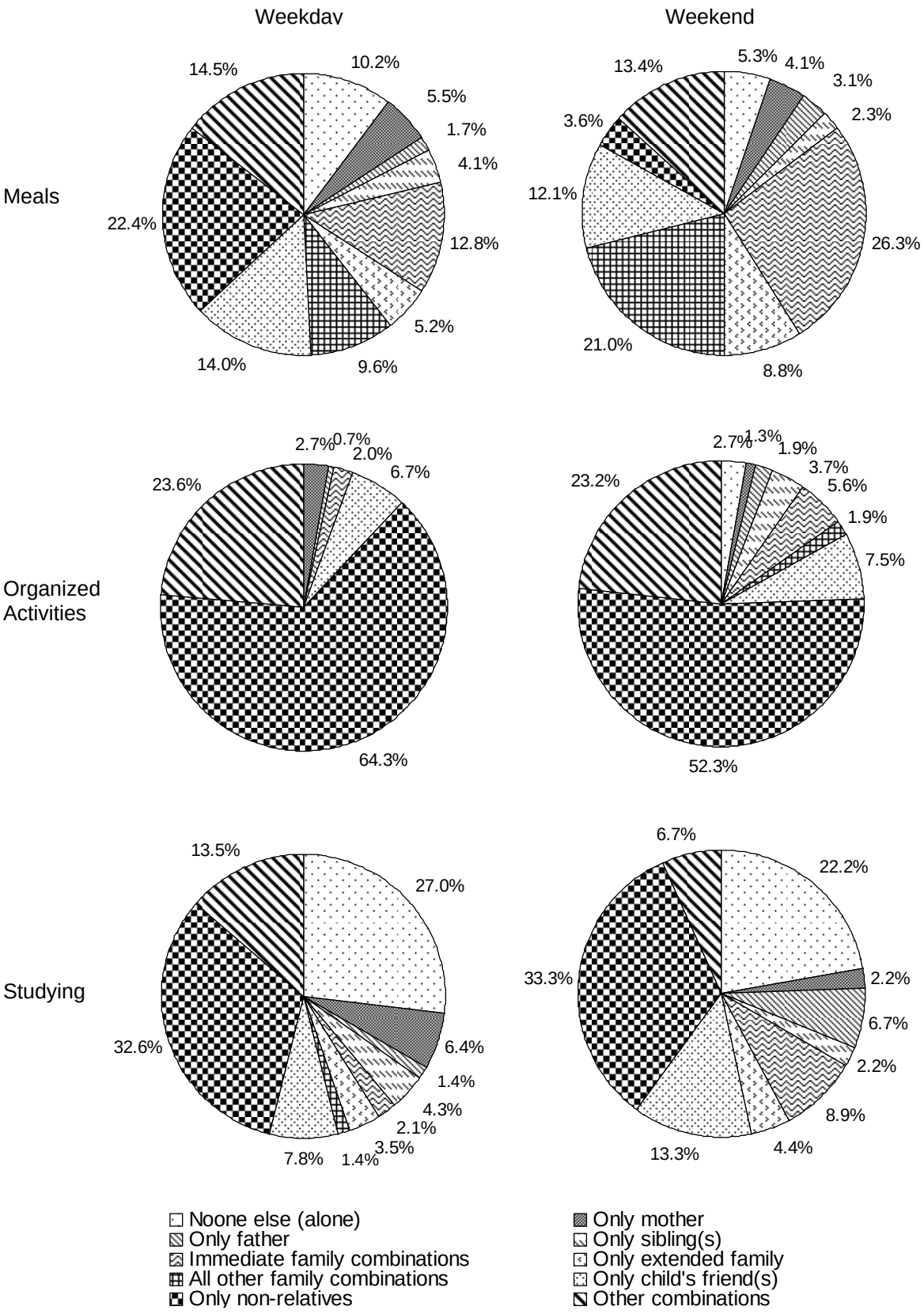

FIGURE 3 Companion type arrangement for out-of-home activity episodes.

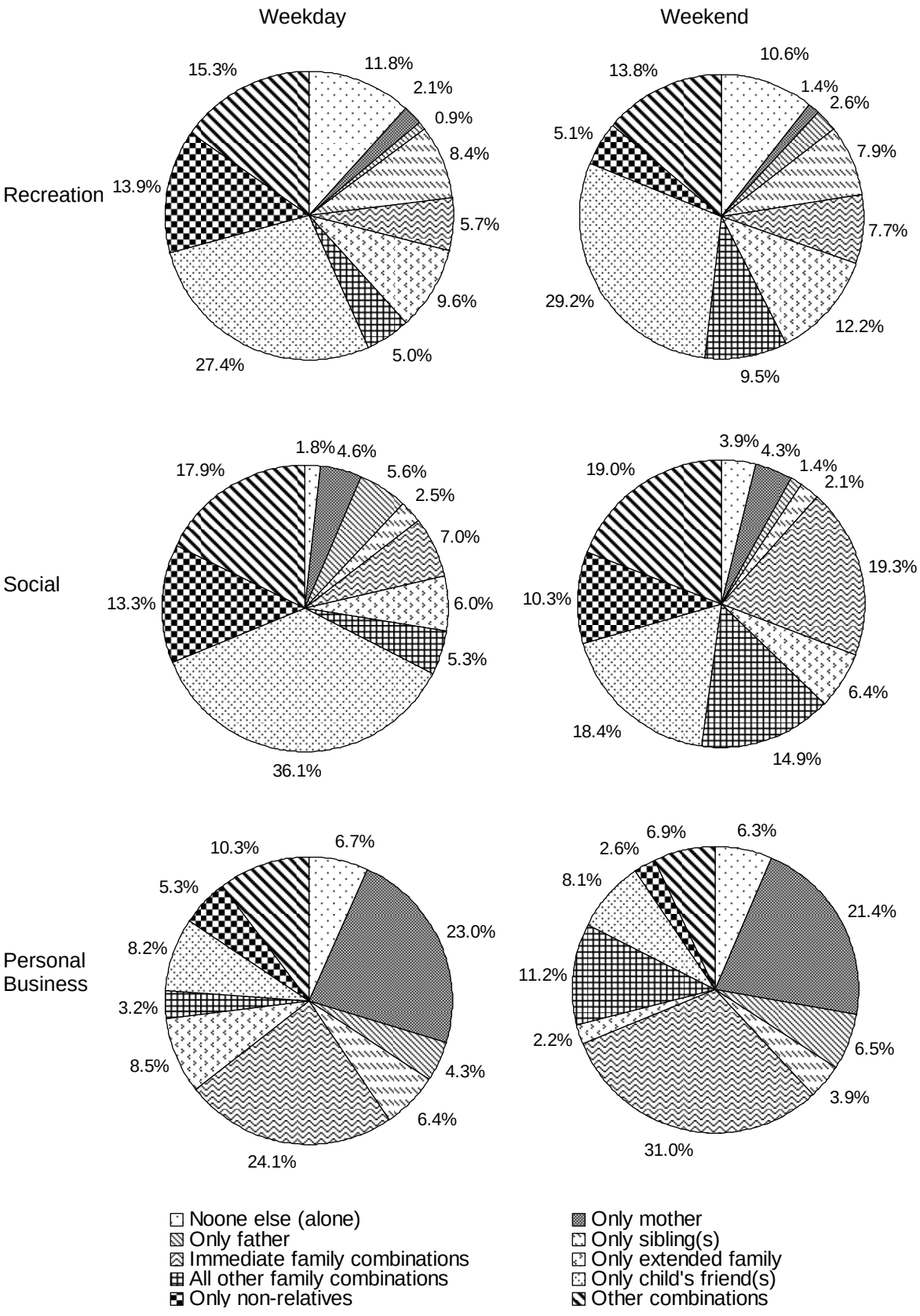

FIGURE 3 (cont.) Companion type arrangement for out-of-home activity episodes.

TABLE 1 Weekday (Weekend) Activity Purpose Participation Percentages and Average Minutes of Total Daily Activity

	Total (N = 1970)		5 to 10 years (N = 874)		11 to 14 years (N = 617)		15 to 18 years (N = 479)	
	%	Minutes	%	Minutes*	%	Minutes	%	Minutes
School	86.8	407.0	89.8	399.3	86.1	420.7	82.3	403.7
	--	--	--	--	--	--	(0.6)	(311.7)
Work	3.2	256.7	--	--	--	--	12.5	265.9
	(3.3)	(352.3)	--	--	--	--	(12.3)	(363.8)
Meals	94.3	57.0	97.8	60.3	94.7	56.9	87.5	50.3
	(95.1)	(78.4)	(98.9)	(85.9)	(95.1)	(74.0)	(88.1)	(68.5)
Household Chores	40.2	46.8	38.7	40.2	44.4	51.8	37.6	51.5
	(51.6)	(76.6)	(52.2)	(65.5)	(55.4)	(82.7)	(45.5)	(91.5)
Organized Activities	15.3	107.5	11.2	85.4	16.0	105.8	21.9	129.9
	(14.3)	(136.9)	(13.3)	(118.1)	(13.9)	(140.5)	(16.5)	(163.1)
Studying	60.3	70.8	65.8	54.6	60.3	76.1	50.3	101.5
	(16.4)	(94.1)	(12.1)	(66.0)	(18.2)	(100.5)	(22.1)	(116.7)
Recreation	94.5	217.1	97.9	204.3	95.6	228.2	86.8	227.7
	(97.9)	(384.9)	(99.5)	(104.4)	(98.9)	(395.7)	(93.7)	(331.9)
Social	37.5	72.6	28.4	51.7	37.6	67.1	53.9	97.6
	(60.1)	(139.9)	(53.7)	(133.8)	(59.5)	(135.9)	(72.4)	(152.7)
Personal Business	23.2	50.8	20.6	37.8	22.9	54.2	28.6	64.5
	(41.2)	(90.2)	(38.7)	(80.2)	(41.8)	(100.8)	(44.9)	(94.3)
Personal Care	98.9	64.4	99.3	65.5	98.7	61.3	98.5	66.4
	(96.1)	(65.4)	(98.1)	(64.8)	(92.9)	(62.5)	(96.7)	(68.6)
Receive Child Care	7.0	117.5	12.9	123.2	3.6	96.0	--	--
	(2.2)	(66.1)	(3.7)	(56.7)	(1.1)	(68.6)	--	--

TABLE 2a Weekday Before and After School Participation Percentages and Mean Activity Duration*

	Before School (N = 1708)		After School (N = 1708)	
	%	Minutes	%	Minutes
Work	--	--	3.0	249.3
Meals	66.9	17.5	87.6	41.5
Household Chores	11.4	12.1	33.4	41.8
Organized Activities	1.3	51.6	18.7	10.0
Studying	1.9	29.2	67.2	68.4
Recreation	26.0	28.4	93.3	175.2
Social	5.4	16.6	34.7	61.5
Personal Business	1.2	23.3	16.7	52.6
Personal Care	99.4	34.4	82.5	35.6
Receive Child Care	2.0	33.9	6.6	122.8

TABLE 2b Weekend Time of Day Participation Percentages and Mean Activity Duration by Activity Purpose*

	3 a.m. to 8 a.m. (N = 1970)		8 a.m. to Noon (N = 1970)		Noon to 4 p.m. (N = 1970)		4 p.m. to 8 p.m. (N = 1970)		8 p.m. to Midnight (N = 1970)	
	%	Minutes	%	Minutes	%	Minutes	%	Minutes	%	Minutes
School	--	--	--	--	--	--	--	--	--	--
Work	--	--	1.2	336.8	1.2	281.8	1.2	272.8	0.1	165.0
Meals	11.2	23.1	67.0	30.2	55.2	37.3	64.9	41.4	13.7	31.2
Household Chores	3.2	39.1	21.6	53.0	21.3	62.2	24.4	43.6	6.3	33.8
Organized Activities	0.7	134.8	8.6	120.3	4.1	122.4	2.9	114.4	0.2	61.3
Studying	0.3	126.0	3.0	93.8	5.9	83.9	7.4	77.6	2.9	51.7
Recreation	13.6	80.7	67.1	118.2	76.2	156.7	80.4	142.0	56.2	84.0
Social	2.2	68.2	25.8	113.6	23.9	95.5	26.2	81.5	15.0	52.3
Personal Business	0.4	127.1	10.5	79.9	21.3	83.4	12.3	65.7	3.2	49.0
Personal Care	22.5	25.8	73.2	33.1	28.7	28.2	34.5	31.3	53.0	24.9
Receive Child Care	--	--	0.7	41.9	--	--	0.8	82.9	--	--

* For each child, the activity duration in each purpose and for each time period is computed as the total duration across all episodes of that purpose undertaken during the time period. The mean activity duration for each purpose-time of day condition is then computed as the average across all children who had one or more participations in the purpose-time of day condition.

TABLE 3a Weekday Before and After School Activity Percentages and Mean Duration at each Location

	Before School (N = 1708)		After School (N = 1708)	
	%	Minutes	%	Minutes
Home	99.0	54.6	98.9	417.3
Parent's work location	0.2	22.7	1.2	75.5
Child's work location	0.1	95.0	2.8	253.9
Someone else's home	2.6	54.8	19.2	136.3
Restaurant	0.2	25.0	6.7	52.7
Outdoor recreational area	0.9	11.9	6.9	78.3
School	11.8	30.3	21.9	111.9
Church	0.2	53.0	4.7	95.5
Store/Retail business	0.4	17.7	9.7	44.5
Non-retail business	0.4	53.2	1.8	70.9
Daycare	0.5	42.5	2.3	131.5
Other Location	0.1	52.5	1.5	107.4

TABLE 3b Weekend by Time of Day Percentage and Mean Duration at each Location

	3 a.m. to 8 a.m. (N = 1970)		8 a.m. to Noon (N = 1970)		Noon to 4 p.m. (N = 1970)		4 p.m. to 8 p.m. (N = 1970)		8 p.m. to Midnight (N = 1970)	
	%	Minutes	%	Minutes	%	Minutes	%	Minutes	%	Minutes
Home	28.5	88.2	84.3	140.8	75.5	168.9	81.3	182.1	88.1	195.5
Parent's work location	0.0	--	0.3	96.8	0.3	176.0	0.2	35.0	0.0	0.0
Child's work location	0.4	267.0	1.2	336.8	1.1	285.3	1.0	272.5	0.2	55.0
Someone else's home	3.0	126.8	12.6	121.1	26.6	150.7	23.7	144.6	8.5	142.8
Restaurant	0.2	31.8	4.6	53.0	10.4	52.4	8.6	62.0	1.7	54.2
Outdoor recreational area	0.4	184.4	5.0	110.9	9.6	117.4	3.9	82.3	0.5	81.7
School	0.6	235.5	2.3	173.8	2.4	126.5	1.3	143.5	0.2	100.0
Church	1.3	15.0	18.4	153.5	4.5	104.4	4.7	120.7	0.4	64.4
Store/Retail business	0.2	160.0	8.3	84.1	18.6	93.2	9.4	70.0	1.4	30.6
Non-retail business	0.4	140.7	5.2	137.0	7.5	133.6	4.6	145.0	1.6	104.2
Daycare	0.1	110.0	0.0	--	0.0	--	0.0	--	0.0	--
Other Location	0.4	92.1	1.4	128.2	1.4	83.3	1.2	102.5	0.6	173.9

TABLE 4 Percentage of In-Home and Out-of-Home Activity Purpose Episodes

Activity Purpose	Day of Week	Percentage In-Home	Percentage Out-of-Home
Work	Weekday	1.8	98.2
	Weekend	8.9	91.1
Meals	Weekday	89.6	10.4
	Weekend	76.9	23.1
Household Chores	Weekday	95.6	4.4
	Weekend	88.8	11.2
Organized Activities	Weekday	0.0	100.0
	Weekend	1.8	98.2
Studying	Weekday	90.4	9.6
	Weekend	89.7	10.3
Recreation	Weekday	88.5	11.5
	Weekend	79.4	20.6
Social	Weekday	71.2	28.8
	Weekend	48.0	52.0
Personal Business	Weekday	31.7	68.3
	Weekend	13.2	86.8
Personal Care	Weekday	97.8	2.2
	Weekend	92.4	7.6
Receive Child Care	Weekday	10.8	89.2
	Weekend	66.7	33.3

TABLE 5a Chaining of Activity Episodes by Purpose

	Weekday	Weekend
Overall	0.41	0.43
School	0.48	0.38
Work	0.52	0.40
Meals	0.93	0.91
Household Chores	0.77	0.80
Organized Activities	0.65	0.58
Studying	0.88	0.60
Recreation	0.62	0.62
Social	0.70	0.58
Personal Business	0.67	0.56
Personal Care	1.00	0.99
Receive Child Care	0.96	0.79

TABLE 5b Chaining of Activity Episodes by Location

	Weekday	Weekend
Overall	0.26	0.66
Parent's work location	0.86	0.78
Child's work location	0.57	0.27
Someone else's home	0.65	0.48
Restaurant	0.70	0.82
Outdoor recreational area	0.55	0.52
School	0.25	0.34
Church	0.29	0.39
Store/Retail business	0.68	0.55
Non-retail business	0.62	0.51
Other	0.75	0.67

TABLE 6 The First and Last Out-of-Home Activity Purpose Episodes of the Day

	Weekday		Weekend	
	% of the First Episode	% of the Last Episode	% of the First Episode	% of the Last Episode
School	78.2	9.7	66.7	33.3
Work	8.6	72.4	43.4	45.3
Meals	27.3	20.5	13.1	25.5
Household Chores	17.5	26.3	22.1	20.0
Organized Activities	8.5	67.9	52.4	19.8
Studying	3.8	26.0	36.1	22.2
Recreation	11.4	62.1	30.0	50.4
Social	17.0	51.4	48.9	33.6
Personal Business	15.7	53.3	36.3	36.3
Personal Care	27.2	37.6	50.0	25.4
Receive Child Care	18.6	63.7	30.8	15.4