

**WHEN, WHERE, HOW LONG, AND WITH WHOM ARE INDIVIDUALS
PARTICIPATING IN PHYSICALLY ACTIVE RECREATIONAL EPISODES?**

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ABSTRACT

This paper offers a comprehensive analysis of physical recreational activity engagement by simultaneously examining the location, time of day, day of week, and social context of these activities. Data from the 2007 American Time Use Survey is used to estimate a mixed multiple discrete continuous extreme value (MDCEV) model that simultaneously captures the multiple activity categories that people may choose and the time that they allocate to each of the activity categories. It is found that a host of socio-economic, demographic, household, employment-related, and environmental variables affect the choice of physical recreational activity engagement with respect to location, time of day, day of week, and social context.

Keywords: Physical activity, social interaction, time use, multiple discreteness, maximum simulated likelihood

1. INTRODUCTION

1.1. Background

It is well established now that physical activity participation is important for the health and well-being of people. Physical inactivity is strongly correlated with obesity and several diseases including coronary heart disease, colon cancer, nerve disorders, and mental disorders including depression (Struber, 2004, USDHHS, 2008). Regular physical activity enhances muscle and bone strength, decreases body fat, and reduces symptoms of depression and anxiety in humans (USDHHS, 2008, CDC, 2006). Unfortunately, despite campaigns to encourage people to exercise and participate in physically active episodes, almost one-half of adults do not meet recommended levels of physical activity while one-third of adults are categorized as completely inactive (CDC, 2009). The picture is not much better for teenagers and high school students who also show very poor levels of physical activity, with 65.3 percent of high school students not meeting recommended levels of physical activity guidelines (CDC, 2002). More than one-third of adults, or over 72 million people, were obese in 2005-2006 (Ogden *et al.*, 2007). Among children and teenagers aged 2-19 years, 15.6 percent are categorized as overweight and 16.3 percent as being obese (Ogden *et al.*, 2008).

Researchers have established a clear link between physical activity (or, inactivity) and personal health condition (*e.g.*, Haskell *et al.*, 2007, Steinbeck, 2008). In recent years, transportation researchers have been drawn into the study of physical activity engagement patterns of individuals because of the potential association between built environment attributes and levels of physical activity participation. Questions are being asked as to whether the suburban land use configurations marked by sprawl, segregated land use patterns, low density developments, wide streets with poor grid connectivity, and poor non-motorized and transit levels of service are leading to sedentary lifestyles devoid of physical activity, both in the utilitarian (say, bicycling and walking trips undertaken specifically to pursue an activity) and recreational realms (Sallis *et al.*, 2004, TRB, 2005, Killingsworth, 2003).

Numerous studies have been undertaken to examine the influence of built environment variables on physical activity engagement patterns, while controlling for household and personal socio-economic and demographic characteristics (*e.g.*, Huang *et al.*, 2009, Berrigan and Troiano, 2002, Ewing *et al.*, 2003, Handy *et al.*, 2002). In general, these studies have uniformly found that the built environment does influence physical activity engagement, primarily through enhanced bicycling and walking mode use to undertake daily travel and activities. However, in a recent review, Wendel-Vos *et al.* (2007) note that a majority of the tested associations between environmental variables and physical activity (recreational physically active episode engagement) were non-significant. Dunton *et al.* (2008) note that one explanation for this finding is the potentially poor quality of environmental variables used in the studies; it is often difficult to get detailed environmental and contextual variables that characterize the location and timing of individual physical activity episodes. Where studies have found an association between the environment and physically active recreational episode engagement, they have generally been confined to the study of the impacts of providing specific recreational or non-motorized transport facilities in specific locations (*e.g.*, Krizek and Johnson, 2006, Krizek *et al.*, 2007, Dill and Carr, 2003, Merom *et al.*, 2003).

The above discussion points to the high level of interest and research underway in the study of physical activity engagement patterns of individuals among transportation and public health researchers. In addition to correlating physical activity engagement patterns to household and person socio-demographic variables, built environment variables, and specific facility-related

impacts, there is a desire and need to better understand physical activity engagement patterns in a more holistic framework. In fact, Dunton *et al.* (2008) explicitly state that “due to a number of methodological challenges, research to date has been unable to provide a comprehensive description of where and with whom physical activity takes place among US adults”. This has motivated recent research into examining various dimensions of physical activity engagement. Dimensions of interest that describe various facets of physical activity engagement include:

- Nature of the episode, *i.e.*, whether it is a utilitarian active episode or a purely recreational active episode or both
- Location of the episode, *i.e.*, whether the episode is undertaken at home, in an indoor facility outside home, outdoors in open space, or at an outdoor facility
- Timing of the episode, both in terms of time of day and day of week of activity engagement
- Social context of the episode, *i.e.*, whether the episode is undertaken alone or with others and if others are present, whether the accompanying persons are household members or non-household members (or a mix of both)
- Duration of the episode

A few recent studies by the authors have examined these facets of physical activity engagement, and shed light on one or more dimensions of physical activity episodes (see Sener and Bhat, 2007, Sener *et al.*, 2010, and Sener and Bhat, 2011). However, these earlier studies do not explicitly consider or model, within a unified framework, all the spatial, temporal and social contexts of physical activity participation. This paper constitutes an attempt to further advance the recent stream of research to provide a comprehensive and holistic analysis of physical activity engagement by adults.

1.2. The Current Paper in Context

Using data from the American Time Use Survey, the current paper specifically examines the location, timing, duration, and social context of physically active recreational episodes. The analysis is thus limited only in the fact that it considers recreational episodes (and excludes utilitarian travel-related physical activity involving walking and bicycling for a specific trip purpose). In particular, the paper makes a significant contribution to understanding the social context of physical activity engagement, an aspect that has been stressed in the literature, both in the fields of transportation and public health. In the transportation literature, analyzing and modeling intra-household interactions in activity engagement has been recognized as an important undertaking. Activity engagement patterns of individuals are influenced by task allocation, joint activity engagement, and activity dependency relationships inherent to any social network (Axhausen, 2005). There are plenty of examples of research studies that document the importance of social networks, social relationships, and intra-household interactions on activity engagement and time use patterns (*e.g.*, Goulias and Henson, 2006, Carrasco and Miller, 2009, Arentze and Timmermans, 2008, Gliebe and Koppelman, 2002, Srinivasan and Bhat, 2008). The social context plays an important role in physical activity engagement due to the inter-personal influences and dependencies that may be at play. If one household member wants to engage in a recreational activity, then that household member may influence other household members to join the activity. Children may be dependent on adults for their ability to access, travel to, and participate in physically active recreational episodes, particularly those located outside home. In fact, Wendel-Vos *et al.* (2007) note that “social

support and having a companion for physical activity were found to be convincingly associated with different types of physical activity including walking, bicycling, vigorous physical activity/sports, leisure time physical activity in general...”.

On a similar note, the spatial and temporal dimensions of physical activity engagement are also important facets that merit further study. Activity-based analysis of travel behavior explicitly recognizes the role of time-space interactions in determining activity-travel choices of individuals (Pendyala *et al.*, 2002). In addition, research has shown that there are systematic tendencies of variability in recreational physical activity engagement between weekdays and weekend days. In general, it has been found that individuals are more likely to engage in physical activity on weekdays than on weekend days (see, for example, Buchowski *et al.*, 2004, Treuth *et al.*, 2007, Behrens and Dinger, 2003), although overweight and obese adults were found to be more active on weekend days than on weekdays (Young *et al.*, 2009). An understanding of the time-space dimensions and day of week preferences of individuals for physically active recreational participation can provide valuable insights into the types of interventions that may enhance people’s opportunities to engage in such healthy pursuits. In addition, such insights can help inform the specification and design of activity-based model systems sensitive to a wide range of public health and physical activity related policy questions.

Motivated by the above discussion, this paper uses data from the 2007 American Time Use Survey (ATUS) to model physically active recreational activity participation of adults in a holistic framework. Specifically, this paper involves the joint modeling of the duration, location, timing, day of week, and social context of physically active recreational activity engagement. The model formulation adopted in this paper corresponds to the mixed multiple discrete continuous extreme value (MDCEV) model developed by Bhat which provides the ability to jointly model the discrete choice dimensions and the continuous time allocation (duration) decision in a simultaneous equations framework (Bhat, 2005, 2008). This MDCEV system accommodates the fact that individuals (particularly, adults in our context) may choose to participate in multiple types of physical recreational activity episodes as defined by day of week, time of day, accompaniment, and location

The next section presents the modeling methodology adopted in this paper. The third section presents a description of the data and the sample used in this study. Model estimation results are presented in the fourth section. Concluding thoughts are offered in the fifth and final section.

2. MODELING METHODOLOGY

2.1. Basic Structure

This section offers an overview of the MDCEV model structure, which is used to examine adults’ physically active recreational activity participation, and time investment, in each “activity day-of-week-location-accompaniment-timing” combination alternative (for ease in presentation, the activity “day of week-location-accompaniment-timing” combination alternatives are simply referred to as activity alternatives in the rest of this paper). The reader is referred to Bhat for the intricate details of the model structure (Bhat, 2005, 2008).

Let t_k be the time invested in activity alternative k ($k = 1, 2, \dots, K$). Consider the following additive, non-linear, functional form to represent the utility accrued by an individual through the

time investment vector $\mathbf{t} = \{t_1, t_2, \dots, t_K\}$ in various activity alternatives (the index for the individual is suppressed in the following presentation):¹

$$U(\mathbf{t}) = \sum_{k=1}^K \frac{1}{\alpha_k} \exp(\beta' z_k + \varepsilon_k) \{(t_k + 1)^{\alpha_k} - 1\} \quad (1)$$

z_k is a vector of exogenous determinants (including a constant) specific to alternative k . 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 $U(\mathbf{t})$ with respect to t_k and computing this marginal utility at $t_k = 0$ (i.e., $\partial U(\mathbf{t}) / \partial t_k |_{t_k=0}$). Thus, $\exp(\beta' z_k + \varepsilon_k)$ controls the discrete choice participation decision in alternative k . This term is referred to as the baseline preference for alternative k . α_k ($\alpha_k \leq 1$) is a satiation parameter whose role is to reduce the marginal utility with increasing consumption of alternative k , thus reflecting the effects of satiation or diminishing marginal utility with increasing level of participation. When $\alpha_k = 1$ for all k , this represents the case of absence of satiation effects. Lower values of α_k imply higher satiation (or lower time investment) for a given level of baseline preference, while higher values of α_k imply lower satiation (or higher time investment) for a given level of baseline preference. The constraint that ($\alpha_k \leq 1$) for $k = 1, 2, \dots, K$ is maintained by reparameterizing α_k as $[1 - \exp(-\lambda_k)]$, where λ_k is a scalar to be estimated.

From the analyst's perspective, individuals are maximizing random utility $U(\mathbf{t})$ subject to the activity time budget constraint that $\sum_k t_k = T$, where T is the total time available for adults to participate in physical recreation activities.² The optimal time investments t_k^* ($k = 1, 2, \dots, K$) can be found by forming the Lagrangian function (corresponding to the problem of maximizing random utility $U(\mathbf{t})$ 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):

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

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

¹ Several other additive, non-linear, utility forms, as proposed by Bhat (2008), were also considered. However, the one provided in Equation (1) was the best form in the empirical analysis of the current paper.

² The analysis is limited to individuals who undertake some amount of physical recreation activity during the sampled day (i.e., only individuals for whom $T > 0$ are considered).

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

where $c_i = \left(\frac{1-\alpha_i}{t_i^*+1} \right)$ for $i = 1, 2, \dots, M$.

2.2. Mixed MDCEV Structure and Estimation

The structure discussed thus far does not consider correlations among the error terms of the alternatives in the specification of the baseline preference. On the other hand, it is possible that such correlations exist due to factors unobserved by the analyst. For instance, some adults may be more likely to participate in physically active recreation alone or at a certain time of a day such as the morning. Alternatively, some other adults might have a higher propensity to engage in physically active recreational activities at a certain activity location type such as an outdoor park on weekends. To account for such effects, an error component specific to the baseline preferences of all alternatives including the desired activity dimension is introduced. For instance, the predisposition of adults to participate in physical recreational activities alone can be accommodated through an error component specific to the baseline preferences of all physically active recreational activities that include “alone” dimension (that is, an error term common to all activities pursued alone). It should be noted that one can test for several patterns of error components. Such patterns of error components can be accommodated by defining appropriate dummy variables in the z_k vector to capture the desired error correlations, and considering the corresponding β coefficients in the baseline preference of the MDCEV component as draws from a multivariate normal distribution. In general notation, let the vector β be drawn from $\phi(\beta)$. Then the probability of the observed time investment $(t_1^*, t_2^*, \dots, t_M^*, 0, 0, \dots, 0)$ for the adult can be written as:

$$P(t_1^*, t_2^*, \dots, t_M^*, 0, 0, \dots, 0) = \int_{\beta} P(t_1^*, t_2^*, \dots, t_M^*, 0, 0, \dots, 0 | \beta) \phi(\beta) d\beta, \quad (4)$$

where $P(t_1^*, t_2^*, \dots, t_M^*, 0, 0, \dots, 0 | \beta)$ has the same form as in Equation (3).

The parameters to be estimated in Equation (4) include the mean vector and variance matrix of the β vector, and the λ_k scalars ($k = 1, 2, \dots, K$) that determine the satiation parameters α_k . The likelihood function in Equation (4) includes a multivariate integral whose dimensionality is based on the number of error components in β . The parameters are estimated through a maximum simulated likelihood approach using Halton draws (for details, see Bhat, 2003).

3. DATA AND SAMPLE DESCRIPTION

3.1. The Data

The data for the study are derived from the 2007 American Time Use Survey (ATUS), a national survey sponsored by the Bureau of Labor Statistics (BLS) and conducted/processed by the US Census Bureau (BLS, 2010). The household sample for the ATUS is drawn from the set of households that completed the Current Population Survey (CPS). From each sampled CPS household, the ATUS randomly selects one individual of age 15 or over, and collects information

on all in-home and out-of-home activity episodes over the course of a 24-hour period. Episode-level information collected in the ATUS includes activity purpose, start and end time, location of participation (for example, health center, restaurant, library), and ‘with whom’ the individual participated in each activity. Data on a host of household and personal socio-economic and demographic variables are also collected.

3.2. The Sample

3.2.1. Background

The objective of this study is to comprehensively model individuals’ physically active recreational activity participation. Specifically, the intent is to model the time spent in physically active recreational activities in an integrated framework that encompasses several dimensions. As mentioned earlier, this paper does not consider or include utilitarian active travel episodes (such as traveling by walk or bicycle to undertake activities) as the factors affecting utilitarian active travel and physically active recreational episodes can be fundamentally different (McCormack *et al.*, 2007, Hoehner *et al.*, 2005). The categories considered for each discrete dimension are as follows:

- 1) Activity “location” (spatial context)
 - a. In-home or yard (“In-home” for brevity)
 - b. Gymnasiums/health clubs/fitness centers (“Club” for brevity)
 - c. Outdoors away from home – activities pursued in and around residential neighborhood (such as walking/biking/running without any specific destination) or activities pursued at outdoor recreational areas (“Outdoors” for brevity)
 - d. Indoors – out-of-home activities pursued at places not open (such as someone else’s home, work, school, place of worship, other physical activity recreation centers, sports arenas) (“Indoors” for brevity)
- 2) Activity “with whom” (social context)
 - a. Alone
 - b. Only with family members (including children, spouse, unmarried partners, parents, siblings, grandchild, *etc.*)
 - c. Only with friends (including friends, colleagues, neighbors, co-workers, peers, and other acquaintances)
 - d. With both family and friends (a combination of family, extended family, and friends) (“Mixed company” for brevity)
- 3) Activity “time-of-day” (temporal context)
 - a. Morning (4 AM -11:59 AM)
 - b. Afternoon (12:00 PM – 5:59 PM)
 - c. Evening (6:00 PM – 3:59 AM)
- 4) Activity “day-of-week” (temporal context)
 - a. Weekend
 - b. Weekday

Overall, the total physical recreation activity time for each individual is categorized into 96 ($4 \times 4 \times 3 \times 2$) activity “day of week-location-accompaniment-time of day” alternatives. Thus, the value of K in the model structure presented in the previous section is 96.³

3.2.2. Sample Formation

An extensive data preparation process was undertaken for this study. All of the physically active recreational episodes were identified based on the ATUS classification scheme. Activities coded as “participating in sports, exercise and recreation” were chosen for inclusion in this study and only individuals who reported a non-zero time investment for this activity category were included in the analysis. The raw data for these activity episodes were processed to derive time of day, day of week, accompaniment, location, and duration information as described previously. Finally, the time investments across all episodes in the day were aggregated to obtain the total daily time investments in each of the 96 categories. The participation decisions, and the daily time investments, in the 96 categories constitute the dependent variables for the MDCEV model.

3.2.3. Sample Characteristics

The final sample extracted for analysis consists of 2147 individuals aged 15 years and over. Table 1 presents the descriptive statistics of each of the relevant exogenous variables. The first entry in the table “1103 (51.4)” for the “Male” variable under the “#(%) or Mean” column indicates that 1103 of the 2147 individuals are male, which corresponds to 51.4% of the individuals. Other entries may be similarly interpreted. In the interest of brevity, a detailed discussion of the socio-economic and demographic characteristics is not provided here. However, it is sufficient to note that an examination of the sample demographic characteristics indicates that the sample offers appropriate and reasonable levels of variability for variables of interest. Therefore, the focus of this subsection is on the physically active recreational activity engagement patterns of individuals.

Table 2 presents a summary of recreational activity engagement of the sample. The mean activity duration is 105 minutes or 1.75 hours. The sample is about equally divided between weekday and weekend activity episode engagement. The mean episode duration is longer on weekend days than on weekdays, consistent with expectations. The rest of the table offers insights into recreational activity engagement by the dimensions of interest. For example, 27 percent of respondents report pursuing a recreational activity episode at home. The mean duration for these episodes is 60 minutes. Among those individuals who participated in in-home physically active recreational episodes, nearly 81 percent reported participating in only this type of activity. About 20 percent, however, engage in at least one other type of activity alternative. Nearly one-half report undertaking an activity episode alone; however, in comparison to group activities, these solo activities are shortest in average duration. Physical activity episodes

³ There is obviously some subjectivity in the way the categories have been defined in this paper. One may certainly adopt even finer categories for the spatial, temporal, and social dimensions. For instance, in the context of the spatial dimension, the “Outdoors” activity location category may be further divided into two sub-categories such as “Walking/biking/running without any specific destination” and “Physical activities pursued at outdoor recreational areas”. Similarly, along the temporal context, the “Morning” activity time-of-day category may be divided into finer time periods such as “Morning-Early-Off-Peak (4 AM – 6:59 AM)”, AM Peak (7:00 AM – 8:59 AM), and Morning-Late-Off-Peak (9 AM – 11:59 AM). However, for this initial research effort, we decided to use relatively broad characterizations of the space, time, and social context to keep the number of total alternatives to a manageable size and also due to data considerations (the finer categorization leaves fewer individuals selecting each combination category).

undertaken in the morning tend to be slightly longer than those undertaken in the evening, although this statistic does not control for day-of-week effect. An examination of the right hand side of the table clearly shows that substantial percentages of individuals are participating in more than one activity alternative, thus calling for the use of the MDCEV model structure that accommodates a multiple discrete choice process in which individuals choose multiple alternatives from a choice set.

A more detailed analysis of physical recreational activity episode engagement was conducted along the dimensions of interest in this paper. The ensuing table has 96 cells with each cell showing the number of individuals who chose the alternative corresponding to that cell. To keep the presentation simple and streamlined, this table is not provided in this paper. However, the table offers key insights into those alternatives that are chosen more than others. For example, 147 of the 1104 individuals who reported their activity time use patterns on a weekday pursued a physical recreational activity episode alone at-home in the morning. Likewise, 80 individuals reported engaging in a physically active recreational episode on a weekday only with friends outside home at an indoor facility in the afternoon period. For purposes of preparing for model estimation, the sample sizes in each cell were examined carefully to identify any alternatives that were rarely or never chosen. It was found that there were a considerable number of alternatives for which sample sizes were extremely thin. For example, only one person reported a physically active recreational episode on a weekday at a club outside home in the evening with only family members in tow. Many other cells, particularly those pertaining to “club” alternatives and “mixed company” alternatives, revealed very small cell values. Therefore, for purposes of model estimation, several alternatives were aggregated along one or more dimensions to yield a final choice set of 39 alternatives. These are: (1) Alone, In-home, Morning, Weekend, (2) Alone, In-home, Afternoon or Evening, Weekend, (3) Alone, In-home, Morning, Weekday, (4) Alone, In-home, Afternoon, Weekday, (5) Alone, In-home, Evening, Weekday, (6) Alone, Outdoors, Morning, Weekend, (7) Alone, Outdoors, Afternoon or Evening, Weekend, (8) Alone, Outdoors, Morning, Weekday, (9) Alone, Outdoors, Afternoon or Evening, Weekday, (10) Alone, Indoors, Morning, Weekend, (11) Alone, Indoors, Afternoon or Evening, Weekend, (12) Alone, Indoors, Morning, Weekday, (13) Alone, Indoors, Afternoon or Evening, Weekday, (14) Alone, Club, All time periods, Weekend, (15) Alone, Club, Morning, Weekday, (16) Alone, Club, Afternoon, Weekday, (17) Alone, Club, Evening, Weekday, (18) Only family, In-home, Morning or Evening, Weekend, (19) Only family, In-home, Afternoon, Weekend, (20) Only family, In-home, All time periods, Weekday, (21) Only family, Outdoors, Morning, Weekend, (22) Only family, Outdoors, Afternoon or Evening, Weekend, (23) Only family, Outdoors, All time periods, Weekday, (24) Only family, Indoors or Club, Morning or Evening, Weekend, (25) Only family, Indoors or Club, Afternoon, Weekend, (26) Only family, Indoors or Club, Morning or Evening, Weekday, (27) Only family, Indoors or Club, Afternoon, Weekday, (28) Only friends, Outdoors, Morning, Weekend, (29) Only friends, Outdoors, Afternoon or Evening, Weekend, (30) Only friends, Outdoors, All time periods, Weekday, (31) Only friends, Indoors, Morning or Evening, Weekend, (32) Only friends, Indoors, Afternoon, Weekend, (33) Only friends, Indoors, Morning, Weekday, (34) Only friends, Indoors, Afternoon, Weekday, (35) Only friends, Indoors, Evening, Weekday, (36) Only friends, Club, All time periods, All days of the week, (37) Only friends or Mixed company, In-home, All time periods, All days of the week, (38) Mixed company, Out-of-home, Morning or Evening, All days of the week, and (39) Mixed company, Out-of-home, Afternoon, All days of the week.

4. MODEL ESTIMATION RESULTS

The mixed MDCEV model system estimated for this study included a range of socio-economic, demographic, and contextual variables (not built environment attributes, but environmental conditions, survey day, and housing unit characteristics). The final model specification was obtained after an exhaustive iterative process in which model coefficients were examined with respect to their intuitive behavioral interpretation, magnitude and signs, and statistical significance. In addition to alternative variable specifications, different error component specifications were also considered to generate covariance patterns in the baseline preference of the MDCEV alternatives. The final model estimation results are presented in Table 3 and the following sections offer a detailed discussion of the key findings.

In particular, Table 3a presents parameter estimates corresponding to the baseline preference utility (the β parameter vector in Equation 1), while Table 3b presents the implied satiation parameters (obtained by estimating λ_k and then obtaining the corresponding α_k parameter and its standard error). A ‘-’ entry in Table 3a under a particular activity alternative for a particular variable implies that this variable is omitted from the utility specification for that alternative (that is, the alternative constitutes a base alternative about which the impact of the variable on other alternatives should be interpreted). Note also that any variable that appears in Table 1, but not in Table 3a also serves as a base alternative.

The effects of variables are first identified separately along the day of week, location, with whom, and time-of-day dimensions. Then, any interaction effects of the variables on the physical recreational activity baseline utility for each day of week-location-with whom-time of day combination alternative, over and above the one-dimensional day of week-location-with whom-time of day effects, are presented towards the bottom of the table.

4.1. Baseline Parameter Estimates

Males are less likely to engage in physically active recreational episodes at home, but more likely to engage in such activities outdoors and on weekend days. They also tend to engage in these activities alone or with friends, although it appears that they are less likely to go to the club or recreation center with friends (in comparison to females) (see also Dunton *et al.*, 2008, Carrasco and Miller, 2009, and Srinivasan and Bhat, 2008, for similar results on gender differences). Younger individuals, who are likely to be single or in households without children, have a greater proclivity to engage in physically active recreational episodes with friends or in mixed company in the afternoon. Older individuals have a greater tendency to undertake these activities alone (possibly due to a shrinking of social networks), and at locations other than a club or recreation center. Interestingly, those 30-45 years and above show a lower tendency to engage in these activities solely with family members, possibly because they have a wider social network that includes co-workers, friends, and neighbors. African-Americans and Asians are less likely to pursue activities outdoors in comparison to Hispanics and Whites; Hispanics show a greater tendency to pursue activities outside home, but in indoor facilities. These results are consistent with those reported by Bennett *et al.* (2007) and Gordon-Larsen *et al.* (2000).

Those with a disability are more likely to engage in physically active episodes at home and with family, as one would expect (also reported by Pinjari and Bhat, 2010). Family members can provide them the assistance they need in the home environment. Full time students, who are time constrained, are less likely to engage in physical activities in the morning on weekdays. College students on the other hand are likely to engage in physical activities outside home at a “club”, possibly due to greater access to gym facilities at colleges. They are also more

likely to engage in these activities outdoors in the evening, which is consistent with expectations, but less likely to do so with mixed company. It is plausible that college students who live with family continue to engage in activities only with family members and those who do not reside with the immediate family engage in activities solely with friends and room-mates. Those with higher levels of education are more likely to engage in physical activities alone at organized facilities, perhaps reflecting the availability of income to pay for the use of such facilities and the potential presence of time constraints. They are less likely to engage in these activities at home, outside home at indoor facilities, and solely with family, reflecting that those individuals with higher education levels may have broader social networks that include friends and colleagues. Finally, as expected those who are married are more likely to engage in physical activities solely with family or in mixed company, and less likely during the evening hours, possibly due to household constraints and obligations.

Employed individuals are more likely to engage in physical activities on weekdays during the evening (possibly after work), on weekdays at organized recreational facilities, and outside home with mixed company, reflecting a broader social network comprising co-workers and friends. Those who are employed full time are less likely to engage in physical activities on weekdays in the morning, presumably due to work constraints, and more likely to undertake activities on weekend days outside home with family members. If a spouse is employed, individuals are less likely to engage in physical recreational activities solely with friends, perhaps to enhance the time available to spend with family members. However, this effect is tempered by the interaction effect wherein individuals with an employed spouse are more likely to engage in such activities with friends on weekday evenings outside home.

The presence of children reduces the likelihood of engaging in physical recreational activities on weekdays in the morning, presumably due to school and household constraints, but increases the likelihood of engaging in these activities with family members in the afternoon (possibly due to child after-school and other family recreational activities). As the number of children increases, activities tend to be done with family or in mixed company, and less so alone on weekends. Lower household incomes are associated with greater engagement alone and outdoors (not in organized facilities of any kind) while higher incomes are associated with a greater tendency to use organized recreational facilities (club) alone and a lower tendency to pursue activities solely with family. It is possible that higher income individuals have a larger social network. Those who have recreational facilities and amenities in the home are less likely to use facilities outside the home and more likely to engage solely with family members, which is intuitive given that home-bound activities are likely to be more family-centric.

During the winter months, individuals are less likely to engage in physical recreational activities outside home, while the trend is reversed in the summer when individuals show a lower propensity to undertake activities in-home. However, family-centric activity engagement tends to show an increase in summer. There is also a regional effect with individuals residing in the south less likely to engage in activities in-home and outdoors. In other words, in the south, the weather may be good enough to motivate individuals to get out of the house, but too hot to remain outdoors in the open. Instead, individuals seek to engage in activities in organized recreational facilities or other indoor facilities (note that an aggregate descriptive statistics of the final sample also showed that individuals from the south spent much more time in physically active recreational activities indoors during August compared to June and July). On a holiday, individuals are more likely to engage in recreational activities with family.

4.2. Baseline Preferences, Satiation Effects, Error Components and Data Fit

The previous discussion presented an interpretation of the impacts of various exogenous variables on physical activity episode engagement choices. This subsection will now focus on additional model parameters that shed considerable light on physical activity participation preferences of individuals and speak to the merits of adopting a mixed MDCEV approach for modeling individual physical activity engagement patterns.

4.2.1. Baseline Preferences

An examination of the baseline preference constants (not presented in the interest of brevity) show that the general tendencies in the sample are consistent with the trends seen in the descriptive statistics presented in Table 2. All of the baseline preference constants are negative compared to the weekday, in-home, alone, morning activity category indicating a higher participation level along these dimensions. Indeed, the descriptive statistics show that there is a higher participation rate and average duration for physically active recreational episodes in this category relative to others.

4.2.2. Satiation Effects

Estimates of the satiation parameters are furnished in Table 3b. These correspond to the estimated values of α_k in Equation 1. The t-statistics of the α_k parameters are computed for the null hypothesis that $\alpha_k=1$, which corresponds to a situation where there are no satiation effects (α_k values close to 1 indicate low satiation effects or high participation durations, while α_k values farther away from 1 indicate high satiation effects or low participation durations). In general, the results reject the null hypothesis of the absence of satiation effects in physical recreational activity participation. The lowest participation durations tend to be associated with outdoor physical recreation activities engaged with friends in the afternoon and evening periods of the weekend. On the other hand, the highest duration level is associated with outdoor physical recreation activities undertaken with friends in the morning time periods of the weekend. It is possible that people enjoy participating in physical recreation activities with friends on weekends, and participating in such activities in the morning provides the ability to spend longer periods of time engaging in the joint activity. In the afternoon and evening, on the other hand, individuals are likely to be time-constrained as they need to return home and take care of household obligations (resulting in the high satiation level for afternoon/evening activities).

High participation durations are also found to be associated with activities undertaken at indoor recreational centers (club) alone, with friends, or with mixed company. On the other hand, lower duration levels are observed for club activities undertaken only with family at all periods of the day on both weekdays and weekend days. This latter effect can be interpreted in two ways. First, the presence of household constraints and obligations may make it burdensome (add disutility) to engage for long periods of time in an activity, thus introducing higher satiation effects. On the other hand, however, it is also possible that household members have other activities that they would like to undertake as a family, thus decreasing the utility associated with participating in any one single “club” activity for a long period of time. Family members may wish to return home, watch television and have a meal together, play outdoors in the park, and so on. Indeed, it is found that activities undertaken only with family members outdoors have little to no satiation effects (value of effect not significantly different from unity). In general, it is found that individuals show higher participation durations when participating in activities (outdoors or at “club”) only with friends (at all times of the day) on weekdays. These individuals

may not have household and family obligations/constraints and would rather engage in activities with friends than be alone at home, thus contributing to this trend. Overall, it is found that satiation levels vary by activity category, with a majority of the categories showing significant satiation effects. This finding clearly supports the use of the MDCEV model structure that incorporates satiation effects in modeling time allocation to multiple activity categories.

4.2.3. Error Components

The final model specification included five error components specific to the out-of-home activity locations and accompaniment dimensions. The five error components and their respective standard deviations and t-statistics are as follows:

- Outdoors: Standard deviation = 1.37 (t-stat = 5.09)
- Club: Standard deviation = 1.68 (t-stat = 5.42)
- Indoors: Standard deviation = 1.75 (t-stat = 6.57)
- With family members only: Standard deviation = 1.76 (t-stat = 6.07)
- With friends only: Standard deviation = 2.12 (t-stat = 6.29)

These results indicate that there are common unobserved factors that predispose individuals to participate in physical recreation activities at specific out-of-home locations. An individual predisposed to undertake physical recreation activities outdoors has a higher propensity to participate in such activities regardless of the day of week, time of day, and social context. This individual, due to unobserved latent factors, is the “outdoor” type of person and will have a tendency to pursue activities “outdoors” regardless of the other dimensions of the activity category. Similar predisposition (or unobserved factors) appears to exist for out-of-home club and indoor facility activities.

With respect to accompaniment, it appears that there are significant unobserved factors that predispose individuals to pursue activities solely with family members or solely with friends regardless of the day of week, time of day, and location. It is possible that individuals who enjoy “family time” and family-oriented activities have a proclivity to engage in such activities regardless of the other dimensions. Similarly, those who enjoy socializing with their friends (and conversely, do not enjoy doing activities alone) are likely to engage in such activities regardless of the other dimensions of the activity category. The presence of unobserved factors describing the predisposition (or personality and preferences) of the individual towards these activity locations and accompaniment arrangements should not be ignored given the high level of statistical significance associated with these error components. These findings strongly support the incorporation of mixing in the MDCEV model specification that accommodates error correlation structures.

4.2.4. Likelihood-based Measures of Fit

The log-likelihood value at convergence for the final mixed MDCEV model is -11230.7. The corresponding value for the model with only baseline preference constants and satiation parameters is -11769.3. The likelihood ratio test comparing these two model specifications is 1077, which is substantially larger than the critical chi-square value with 61 degrees of freedom at any level of significance. This finding clearly indicates that the exogenous variables and the error components included in the final model specification significantly contribute to explaining participation in and time allocation to physical recreation activities by day of week, location, accompaniment, and time of day.

5. CONCLUSIONS

Using data from the 2007 American Time Use Survey (ATUS), this study involved the estimation of a mixed multiple discrete continuous extreme value (mixed MDCEV) model system to accommodate the fact that adults may choose to participate in physical recreational activity episodes in a variety of alternative categories defined by day of week, time of day, accompaniment, and location. The mixed MDCEV methodology allows the possibility that individuals may choose multiple activity categories and allocates time to the pursuit of the various activity categories chosen. In addition, the mixed MDCEV incorporates error components that accommodate error correlations across alternatives, thus accounting for unobserved factors that may predispose individuals towards pursuing physical recreational activities along certain dimensions more than others. The mixed MDCEV also incorporates satiation effects, *i.e.*, diminishing marginal utility as one spends longer durations of time at the same activity.

Model estimation results indicated that there are a host of socio-economic, demographic, household, employment, and environmental variables that affect the choice of physical recreational activity engagement. In addition, however, there are significant unobserved effects that predispose individuals to pursue activities outdoors (the “outdoor” type of person) and with either household members only (the “family” type of person) or friends only (the “social” individual). In addition, activity categories varied substantially in their satiation effects, supporting the use of the mixed MDCEV model to incorporate such effects. Activity-based models that purport to simulate the activity-travel patterns of individuals should adopt model specifications that incorporate these types of effects and explicitly recognize the social context of activity engagement (*e.g.*, questions of “with whom” and “for whom” the activity is undertaken).

The paper offers several key insights into the ways in which physical recreational activity engagement can be enhanced. The finding that there are racial disparities, perhaps due to the quality of residential neighborhoods where minorities live, suggests that civic bodies and public agencies should endeavor to provide appropriate neighborhood facilities (both indoor and outdoor) that are safe and accessible to the residents. Such interventions can enhance the physical recreational activity engagement of individuals in those communities. Workplaces that provide amenities for their employees may find that it is well worth the cost of providing such facilities as time-constrained employees take advantage of such resources to engage in physical recreational activities, enhancing the state of their physical and mental health.

The findings in the paper also confirm the notion that the social context of activity engagement is a key aspect that has often been overlooked in studies of physical activity participation. Model estimation results in this paper showed that there are unobserved effects that predispose individuals towards pursuing physical recreation activities with family or friends. In other words, people are “social beings” and have an inherent preference to pursue physical recreation activities in the company of their social circle (whether that be family or friends). The absence of such a social network may have a detrimental effect on physical activity engagement. It is important for civic groups and bodies to assist individuals who are alone (such as the elderly, divorced, widowed) in developing social networks that can motivate the pursuit of physical recreational activities that enhance the state of their physical and mental well-being. Future research efforts that extend this work to include a full slate of environmental variables including built environment and transportation network attributes would go a long way in further identifying policy interventions that can enhance physical recreational activity engagement

among individuals. In a similar vein, this research may be extended to include the psychological aspects of travel behavior, such as perceptions, beliefs, subjective norms, and attitudes associated with physical activity participation and active travel. Such factors can play an important role in physical activity involvement, as has been discussed at length in Ajzen (2005) and Burbidge and Goulias (2009). Unfortunately, data limitations prevented the inclusion of such explanatory variables in this particular study. Finally, as stated before, the focus of our study was on understanding the dimensions of adults' physical activity participation behavior. A similar study of children's (aged less than 15 years old) physical activity patterns is left for further research, and would provide interesting insights into children's physical activity patterns.

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TABLE 1 Descriptive Statistics of the Final Sample Data

	Variable	Variable Categories	#(%) or Mean
Individual Demographics	Gender	Male	1103 (51.4)
		Female	1044 (48.6)
	Age	15-21 years	317 (14.8)
		22-29 years	213 (9.9)
		30-45 years	628 (29.3)
		More than 45 years	989 (46.0)
	Race	Caucasian	1600 (74.5)
		Hispanic	249 (11.6)
		African American	187 (8.7)
		Asian	77 (3.6)
	Disability	Other races	34 (1.6)
		Disabled	48 (2.2)
		Not disabled	2099 (97.8)
		Studentship status	Non-student
	Part-time student		54 (2.5)
	Full-time student		244 (11.4)
	High school student		183 (8.5)
	Education level	College or university student	115 (5.4)
		High school or less	831 (38.7)
Some college, associate, or technical degree		476 (22.2)	
Marital status	Bachelor's degree or higher	840 (39.1)	
	Married	1116 (52.0)	
	Non-married	1031 (48.0)	
Employment-related characteristics	Respondent Employment	Non-employed	861 (40.1)
		Employed	1286 (59.9)
		Part-time employed (<35 hrs/wk)	258 (12.0)
		Full time employed (>=35 hrs/wk)	1028 (47.9)
	Spousal Employment	Non-employed	1356 (63.2)
		Employed	791 (36.8)
Household Demographics	Children status	Non-children	1049 (48.9)
		Presence of children	1098 (51.1)
		Number of children	0.94 – 1.84*
	Household income	Less than 35K	506 (23.6)
		Between 35K and 100K	907 (42.2)
		More than 100K	734 (34.2)
Physical Environment Factors	Presence of amenities in the house (lawn, garden, pool, etc.)	Amenities are present in the house	257 (12.0)
		Non-amenities in the house	1890 (88.0)
	Seasonal effects and regional characteristics	Winter	439 (20.5)
		Spring	532 (24.8)
		Summer	645 (30.0)
		Fall	531 (24.7)
		Summer-south	216 (10.1)
	Activity day	If the day was holiday	25 (1.2)
		If the day was not holiday	2122 (98.8)

* The mean value for the variable “number of children” is 0.94 for the full sample set (that is, 2147 individuals). The corresponding value is 1.84 for the sample set excluding adults residing in households with no children (that is, 1049 individuals).

TABLE 2 Descriptive Statistics of Physical Recreational Activity Participation

Type of Recreational Activity (2147 individuals in total)	Total number (and %) of individuals participating		Mean duration of participation among those who participate in the activity (mins)	Number of individuals, and % of total number, who participate....			
	#	%		Only in activity category		In the activity category and other activity categories	
				#	%	#	%
Physical Recreational Activity	2147	100	105				
Day-of-week							
Weekday	1104	51.4	85	1104	100	-	-
Weekend	1043	48.6	125	1043	100	-	-
Location							
In-home	578	26.9	60	466	80.6	112	19.4
Out-of-home							
Club	270	12.6	81	234	86.7	36	13.3
Outdoors	664	30.9	112	555	83.6	109	16.4
Indoors	812	37.8	115	717	88.3	95	11.7
With whom							
Alone	1081	50.3	69	970	89.7	111	10.3
Only family	595	27.7	105	515	86.6	80	13.4
Only friends	509	23.7	139	439	86.2	70	13.8
Mixed company	108	5.0	148	82	75.9	26	24.1
Time-of-day							
Morning	1008	46.9	101	795	78.9	213	21.1
Afternoon	962	44.8	92	732	76.1	230	23.9
Evening	475	22.1	73	340	71.6	135	28.4

TABLE 3b The Mixed MDCEV Model Results: Satiation Parameters - α_k Estimates*

		Alone				Only family				Only friends				Mixed company			
		Weekday		Weekend		Weekday		Weekend		Weekday		Weekend		Weekday		Weekend	
		Est.	t-stat	Est.	t-stat	Est.	t-stat	Est.	t-stat	Est.	t-stat	Est.	t-stat	Est.	t-stat	Est.	t-stat
In-home	Morning	0.934	2.72	0.941	4.46	0.950	2.82	0.940	2.68	0.945	2.33	0.945	2.33	0.945	2.33	0.945	2.33
	Afternoon	0.942	3.63	0.955	2.66	0.950	2.82	0.972	1.54	0.945	2.33	0.945	2.33	0.945	2.33	0.945	2.33
	Evening	0.939	3.46	0.955	2.66	0.950	2.82	0.940	2.68	0.945	2.33	0.945	2.33	0.945	2.33	0.945	2.33
Club	Morning	0.974	1.78	0.990	0.83	0.967	2.16	0.961	2.96	0.975	1.55	0.975	1.55	0.986	1.04	0.986	1.04
	Afternoon	0.979	1.15	0.990	0.83	0.961	1.81	0.964	2.46	0.975	1.55	0.975	1.55	0.960	2.15	0.960	2.15
	Evening	0.974	1.10	0.990	0.83	0.967	2.16	0.961	2.96	0.975	1.55	0.975	1.55	0.986	1.04	0.986	1.04
Outdoors	Morning	0.938	3.63	0.978	1.78	0.989	0.70	0.946	2.76	0.982	1.36	0.999	0.11	0.986	1.04	0.986	1.04
	Afternoon	0.971	1.69	0.945	3.53	0.989	0.70	0.968	2.36	0.982	1.36	0.915	4.17	0.960	2.15	0.960	2.15
	Evening	0.971	1.69	0.945	3.53	0.989	0.70	0.968	2.36	0.982	1.36	0.915	4.17	0.986	1.04	0.986	1.04
Indoors	Morning	0.970	1.98	0.935	2.79	0.967	2.16	0.961	2.96	0.952	2.59	0.969	2.01	0.986	1.04	0.986	1.04
	Afternoon	0.984	1.40	0.951	2.12	0.961	1.81	0.964	2.46	0.953	3.06	0.954	2.74	0.960	2.15	0.960	2.15
	Evening	0.984	1.40	0.951	2.12	0.967	2.16	0.961	2.96	0.989	0.89	0.969	2.01	0.986	1.04	0.986	1.04

* The t-statistic is computed for the null hypothesis $\alpha_k = 1$.