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COVID-19 impacts on residential occupancy schedules and activities in U.S. Homes in 2020 using ATUS

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HIGHLIGHTS
• Time spent at home increased 1.2–1.9 h per day during the pandemic.
• 1-member households spent less time at home.
• 2+ member households spent more time at home.
• Office and kitchen space usage increased during the pandemic.
• Changes to occupancy have strong implications on home energy use.

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ABSTRACT
Many aspects of the daily lives of those living in the United States were substantially impacted by the COVID-19 pandemic in the year 2020. A broad diversity of measures was implemented to curb the spread of the virus, many of which included adjustments to where and how people worked, went to school, and otherwise conducted their daily lives compared to pre-pandemic times. This has impacted how residential buildings are used, how much time people spend in their homes, and as a result, how much energy these buildings consume. The main objective of this study is to analyze, at a national scale, the differences in the occupancy schedules and activities conducted in homes in the U.S., as compared to pre-pandemic. 15 years of American Time Use Survey and Current Population Survey data, from 2006 to 2020, was used in this study to analyze the occupancy schedules for both pandemic (2020) and pre-pandemic (2006–2019) times. These impacts were also analyzed with respect to variables including, weekday/weekend, month of the year, age of the occupants, household income, and household size. The impact of the pandemic on occupant schedules were most substantial in the initial months, whereas as the months progressed, these occupancy profiles slowly changed. Across 2020, people spent, on average, 8 % more time (1.9 h) in their home on weekdays, and 3–6 % (1.2 h) on weekend days. The percentage of time spent for different activities and locations within homes were also studied. For 1-member households, their time spent at home decreased whereas for 2-, 3-, and 4- member households, they spent more time at home. Overall, people spent around 45% more time doing office- and work-related activities at home compared to pre-pandemic, which is likely due to increased remote working and schooling. This research helps to improve the understanding of the occupancy presence and absence profiles in U.S. residential buildings due to the pandemic and provides new insights as to modified profiles for researchers, building designers, and policy makers.

1. Introduction
The World Health Organization (WHO) declared COVID-19 to be a global pandemic in March 2020 as the world population faced a new crisis in the form of the spread of the coronavirus [1]. The pandemic has had substantial impacts on peoples’ lives. More than 532 million cases have been reported, with more than 6.3 million deaths worldwide (as of June 2022) [2]. Along with the detrimental effects on human health, the global economy also has faced a 7 % loss due to pandemic, as reported in April 2022 [3,4]. This impact on the world economy is expected to be seen for many years; for lower-wealth areas, GDP (gross domestic types) may never fully recover to pre-pandemic levels [5,6]. A significant
amount of the workforce lost jobs globally in 2020 compared to what would have been expected without the occurrence of the pandemic [7]. The United Nations also reported that the pandemic resulted in significant reductions in development efforts intended to reduce poverty [8]. The service sector, specifically tourism, was also heavily affected by the pandemic [9,10]. In summary, there were multidimensional detrimental impacts of the pandemic on all the components of people’s daily life. To curb the spread of the virus, different countries took various measures at varying times. Common approaches included lockdowns and stay-home orders which impacted the way people lived [11–13]. Most K-12 schools and many colleges and universities were shifted to remote learning methods where students learned at home, remotely via computer [14–16]. In addition, many people also switched to remote work, where they worked from home instead of in an office, representing an estimated 35% of the workforce [6], which was significantly higher than pre-pandemic [17]. A study analyzing phone data in 2020 found that people tended to spend more time in their homes during periods when there were restrictions on travel and gathering, and cancellations of most public events [18].

Although the pandemic forced people to temporarily adapt to a new way of living during these restriction periods, some of the changes in lifestyle have continued well after the measures have been lifted. For example, a global survey of the workforce that worked from home due to COVID [19] found that this shift in working patterns improved workers’ performance in many situations [20]. A survey from October 2020 showed that 54% of employees wanted to continue working from home even after the COVID pandemic whereas pre-pandemic only 20% of the employees surveyed worked remotely [21]. Respondents also preferred to have flexible work schedules, which were more commonly implemented during the work-from-home periods [22–26].

Given these changes, as expected, the use of residential buildings and their corresponding energy consumption behavior has also changed. As occupant behavior is one of the six key parameters which dictates building energy consumption, particularly in residential buildings, it is therefore important to study how COVID has impacted residential occupancy and occupant behaviors [27]. Several studies have discussed the importance and level of uncertainty in energy consumption in residential buildings due to occupant behavior [28–30]. One study found that residential electricity consumption can vary from 0 to 14 kWh/m² for buildings with similar characteristics in Beijing, China [31]. Plug load and appliance consumption was found to vary by a factor of 10 across homes when occupants have the control over this equipment [32]. Another study showed that the overall energy consumption in similar residential buildings can vary by 3 times due to interaction of occupants with the building systems [33]. Energy consumption patterns also vary significantly based on occupant behavior, particularly in residential buildings [34–38].

Specifically, during the pandemic, various studies have reported utility-level consumption impacts. Overall electricity consumption in Italy had decreased by 28% 1.5 months after the lockdown started [39]. As the number of COVID cases in China reached its peak during the month of March 2020, the maximum reduction in electricity demand was seen during this time [40]. In India, the electricity demand decreased in May 2020 as the number of COVID cases was rising [39]. In the United Kingdom, overall electricity demand decreased by 15% within weeks of the lockdown announcement [41]. Similar trends were also seen in the United States where overall electricity demand fell 19% during the first few weeks of the lockdown in April 2020 [42]. The major electric grids in U.S. experienced a reduction in consumption during the first few months of the pandemic, ranging from 3% to 8% for ERCOT (Electric Reliability Council of Texas), PJM (Pennsylvania, New Jersey and Maryland) and MISO (Midcontinent Independent System Operator) [42–44]. The likely reason for reduction in overall consumption is due to the decreased use of commercial and industrial buildings.

Different outcomes are seen when comparing the consumption for residential buildings across different countries. A study of 2,000 households in the United Kingdom showed that the electricity consumption increased by 17% during working hours in the initial stage of lockdown [42]. In Ireland, residential energy consumption increased by 11–20% [45]. In Nigeria, the projected share of electricity demand from residential buildings compared to the overall consumption increased from 43% to 49% during lockdown periods in 2020 [46]. In Melbourne, Australia, weather adjusted electricity consumption increased by 14% for residential buildings [47]. Similar trends were seen in the United States. A study in Austin, Texas showed 32% higher electricity use in residential buildings in March 2020 compared to last week of February [48]. This increased consumption in the residential sector can be explained by people spend more time in their homes, and therefore using more electricity for their various activities.

This increased use of energy-consuming appliances and devices was also observed. Internet usage increased due to the increased remote working, and escalated use of streaming and social media services [49–51], resulting in increased use. A recent survey showed that during pandemic, people preferred to cook more at home and eat out less, which also would result in more energy consumption [52]. Another study compared heating, ventilation, and air conditioning (HVAC) and non-HVAC consumption in residential building during pandemic and pre-pandemic times showed increased use of weather-normalized HVAC use, as well as increased non-HVAC use [53]. Both of these changes are likely due to changes in occupant behavior, and in occupancy in residential buildings. However, there is limited study of national-level characterization of occupant behavioral changes across U.S. residential buildings as compared to pre-pandemic. Many of the above-mentioned studies include smaller sample sizes and are not representative of the U.S. population as a whole. Studying occupancy patterns in residential buildings and how they differ during the pandemic is therefore needed, to better understand how residential households, overall, have adjusted their occupancy and in-home activities.

Such schedules are also important to building energy modeling applications. In current engineering practices, a majority of the building related energy modeling software use existing and predefined schedules based on the Reference Building and Prototype Building models [54,55], ASHRAE 90.1–1989 and the ASHRAE Advanced Energy Design Guide [56,57], and the Building American Housing Simulation Protocol [60–62]. These schedules were developed pre-pandemic, and some were also based on engineering judgement. However, as it was mentioned in IEA Annex 53, Annex 79 and ISO 18523, occupancy schedules play a significant role in evaluating the energy performance of buildings [27,58,59]. While it is recognized that occupancy schedules that result from data collected in 2020 may not be representative of long-term future occupancy post-pandemic, they provide insight into the relative impacts and variations across different segments of the population, as well as overall, based on the most recent available data. In addition, given that trends are more toward remote work in the foreseeable future, studying COVID-19 impacts on residential occupancy provides a preview of potential occupancy trends moving forward, or in the event of another similar type of event [19–26].

The main objective of this study is to evaluate, for the U.S. overall, the typical occupancy schedules of residential building in the United States during the pandemic and compare these results with pre-pandemic occupancy profiles across different timescales and population segments. The results of this analysis can help building designers and energy modelers to understand the pandemic-related changes in occupant behaviors and schedule patterns in the residential building sector, which might help them to implement modified control and demand-response strategies. This research consists of five sections. Following this introduction, the next section describes the dataset utilized in this research. The third section discusses overall methodology for this study, while the results and discussion are in the fourth section. The final section includes the conclusions and a discussion about limitations of this study and possible future work.
2. Dataset

To study the occupancy profiles of residential buildings in the United States, it is beneficial to use a dataset that is representative of the overall population. The American Time Use Survey (ATUS) and Current Population Survey (CPS) are two datasets collected on an annual basis, that are statistically representative of the U.S. population [60,61]. Both these surveys are administered and managed by the U. S. Bureau of Labor Statistics and the U.S. Census Bureau and published every year. CPS collects information related to employment, economic, and other characteristics of the U.S. population. Selected households from those who were participated for 8 months or more in the CPS, are selected for participation in the ATUS. Each participant’s data is then weighted using a weighting factor, for use in collectively representing the overall U.S. population. The objective of the ATUS is to collect data on how the U.S. population spends their time, in particular what activities they perform and where they perform them. This survey also is linked with additional data on financial, economic, and social characteristics of the participants.

In the ATUS, participants self-report their location and activity information for a single day at 5-minute intervals, over a 24-hour period, from 4:00 am to 3:59 am the following day. The activities reported are classified into 470 types across 3 major tiers. Only primary activities are stored; secondary activities, i.e., the activities occurred concurrently with the primary activities, are not reported. This survey was first published in the year 2003 and has continued to be publish annually. However, since the method used to calculate the weighting factor was changed in 2006, only data from 2006 to 2020 (15 years) has been used in this research. It should be noted that the ATUS data collection was, like many efforts, impacted by the pandemic. No data was collected during the start of the lockdown, from mid-March to mid-May 2020. The unavailability of data for these 2 months makes it difficult to evaluate how occupancy profiles were impacted in the initial stage of the pandemic using this dataset. However, the ATUS data, after mid-May 2020, provides an important source of household activity and occupancy schedules for use in exploring the impact of the pandemic on the daily lives of the U.S. population.

3. Methodology

From each year of ATUS data, occupant activity and location information and their characteristics including age, number of household members, day of the week, and month of the year of the collected data were extracted. Similarly, from the CPS, household income information was extracted. Both the datasets have an occupant identifier for use in linking the surveys. After extracting and combining the data from these two datasets, location and activities were mapped to the presence/absence of the participant in a residential building. After the mapping, the presence and absence of occupants from home (residential spaces) was divided into 5-minute timesteps, and translated to a 0 or 1, where 0 represents absence and 1 implies presence within a residential building. It was assumed that the reported location and activity remained constant throughout the 5-minute time intervals between reports. Both the location and activity information were also converted to a schedule from 12:00 am to 11:59 pm in order to be compatible with a typical day, and with the required format of schedules used in energy modeling tools.

As the objective of the study is to analyze how occupancy schedules were impacted by various variables including month of the year, day of the week, occupant age, household income, and number of household members, the processed and converted mapped occupancy data were subdivided into multiple groups. To do so, first, averaged occupancy profiles were subdivided into weekdays and weekends. These occupancy data were also divided by month across 2018, 2019 and 2020 for comparison. Occupancy information was also divided based on occupant age, including 7 age groups: under 25, 25 to 34, 35 to 44, 45 to 54, 55 to 64, 65 to 74 and over 75, which is consistent with the Residential Energy Consumption Survey (RECS) data [62]. This is driven by findings from other studies that suggest that age groups were likely impacted differently by the pandemic [63-65]. As occupancy profiles also vary with the number of household members, as shown in previous studies [62,64], households were also studied based on the number of members.

Household income was also evaluated, as recent literature has suggested differential impacts from the pandemic on households across different income levels [63,66]. This was evaluated by dividing the data into three income groups, low income (LIH), middle income (MIH) and high-income households (HIH). Since the number of household members is important for this calculation, in addition to household income, this is also reported in Table 1 [63,66]. The thresholds for LIH and HIHs were selected based on recommendations given by U.S. Office of the Assistant Secretary for Planning and Evaluation (ASPE) and previous studies [63,67,68]. MIHs included all households with incomes in between these two thresholds.

After the calculating average profiles for different household types, more detailed analysis was done on the monthly variation in occupant schedules. To identify the specific type of profiles, cluster analysis was performed across all months on weekdays and weekends. To group the time series profiles, a Dynamic Time Wrapping (DTW) cluster algorithm was used, as the advantage of DTW is that it can group the profiles based on patterns even if they are not time synchronized [69,70]. Several studies have used DTW algorithm to predict occupant behavior and their influence on building consumption [71-73]. To implement the algorithm, the `dtwclust` package was used in R where three clusters were used, recognizing that prior studies have identified 3 major occupancy patterns in ATUS data [74]. Patterns were analyzed and are discussed across each of the clusters.

The location distribution of occupants within their home was also evaluated. To do so, all activities defined as being in a residential building were divided into 7 different groups, specifically those located in the bedroom, bathroom, living room, kitchen/dining room, office room, garage, and other areas (e.g. laundry, storeroom). All activities reported in the ATUS were then mapped to all the 7 indoor locations. As an example, sleeping activities were mapped to bedroom, whereas food preparation and kitchen cleaning activities were mapped to the kitchen or dining room. This mapping is done as ATUS data does not the specific location within their home. The percentage of time distribution was then calculated for occupants based on the time when occupant was present in their home. This analysis represents how people spent their time in residential space prior to and during the pandemic.

4. Results and discussion

4.1. Overall percentage presence in home

Percentage presence time (PPT) in residential spaces for people on both weekdays and weekends for the overall population as well as

| Table 1 | Threshold household incomes for LIH and HIH income households in 2020 [Note: Total gross incomes are considered here]. |
|---------|------------------------------------------------------------------------------------------------------------------|
| Number of members | 1-person | 2-person | 3-person | 4-person |
| Low Income Household (LIH) Threshold | < $15,000 | < $20,000 | < $25,000 | < $30,000 |
| High Income Household (HIH) Threshold | > $75,000 | > $100,000 | > $125,000 | > $150,000 |
different age groups is shown in Fig. 1. These percentage values are compared across the years from 2018 to 2020. The Y-axis represents percentage of the day people spent at home where 100 represents people staying at home for 24 h whereas 0 represents the absence of people from their home throughout this period. As shown in Fig. 1.a, on weekdays, PPT for all the age groups are notably higher in 2020 compared to the two previous years. For those under 25, the average PPT during the pandemic time is 80%, which is 12% higher than in 2018 and 2019. During the pandemic, as most of the school and colleges were switched to remote learning method, students spent most of their time in their home which likely resulted in the higher PPT value. Similarly, as majority of the workplaces switched to work from home, the difference in PPT of people 25 to 54 is around 10%. However, for older people, this value is lower, at 5% and 2% for those 65 to 74 and over 75, respectively. Overall, for all the population, average PPT value increased by around 8% on weekdays (approximately 1.9 h). A similar trend of higher PPT is also seen on weekends as shown in Fig. 1.b. However, unlike weekdays, the difference in the PPT during the pandemic compared to the previous 2 years were almost identical across all age groups, at approximately 3% to 6%. On average, people spent around 1.2 h more in their homes on a weekend day during the pandemic (2020).
4.2. Variation in occupancy on weekdays and weekends

Average profiles for weekdays and weekends prior to and during 2020 are shown in Fig. 2 where the y-axis represents the occupancy fraction, i.e., the fraction of people in a home with respect to total number of people in the studied group. The higher the value of the occupancy fraction (OF), the higher the probability of people being in a residential building. An OF 1.0 implies that all occupants are at home, whereas 0.0 OF represent no one at home. The x-axis represents the time of day, starting at midnight.

As shown in Fig. 2, for pre-pandemic periods, for both weekday and weekends the OF is high in the early morning, decreases slowly until around noon, then increased gradually to its maximum at night. This also indicates that people stay at home more on weekends compared to weekdays, as to be expected. The change in residential occupancy is substantial compared to the consistency of the prior years. From 2006 to 2019, the calculated occupancy profiles from ATUS data have remained almost identical, with a minimum OF of around 0.4 in weekdays. This increased to approximately 0.55 during the pandemic. Overall distribution of the average profiles is also compared and shown in Fig. 3. From Fig. 3, both the mean and variance of the OF remained almost constant for past 14 years, from 2006 to 2019. However, in 2020, mean of average OF increased significantly from 0.7 to 0.8 and the variance also reduced. This signifies that, during weekdays of pandemic, people spent more time at home and the variation throughout the day is smaller. Similar results can also be seen on weekends as the difference between the minimum OF was more than 0.1 (Fig. 2) along with the higher mean and lower variance (Fig. 3). This indicates that more people

Fig. 4. Average daily occupancy profile for months of (a) January, (b) February, (c) March (partial month), (d) May, (e) June, (f) July, (g)August, (h) September, (i) October, (j) November, (k) December, for 2018, 2019 and 2020 based on ATUS data.
stayed at home throughout the week during the pandemic. For both weekdays and weekends, the OF reached its peak at an earlier time in 2020, compared to previous years, which signifies that nearly all people were at home for a longer duration during this period.

4.3. Monthly variation

The variation in the OF across the months of 2020 in comparison to 2019 and 2018 is shown in Fig. 4. Due to the unavailability of data for April 2020 in the ATUS, the OF value for April is not shown in this Figure. As shown, for the first three months, from January to March, average OF values were similar across all three years, which is expected given the pandemic began in mid-March and given that prior analysis of ATUS data indicated high levels of consistency in derived occupancy data [64].

A significant difference is noted in the average OF profile in 2020 as compared to the previous years is noted in Fig. 4.d to 4.k, from May to December. A paired t-test was used across the years for each month during and before pandemic, resulting in p-values is less than 2*e-16. This suggests that the average occupancy profile for each month is significantly different during pandemic compared to pre-pandemic years. As shown, for all months before pandemic, the minimum average OF values was around 0.5. However, in the months after the pandemic began, i.e., in May 2020, the monthly average OF values was close to 0.8. The difference in the minimum OF was more than 0.25 for approximately 5 h. This suggests that people spent significant larger amounts of time at home. In May 2020, the OF value reached its second peak around 8:00 pm which is 2.5 h earlier than the previous years, which peaked at approximately 10:30 pm. This suggests that if people left their home, they came back home earlier compared to pre-pandemic.

A similar trend to May can be seen in June (Fig. 4.e). However, the minimum OF value decreased slightly to 0.7 compared the 0.8 observed in April. This suggests that more people began to go out more as time continued, although they continued to return earlier than pre-pandemic. The minimum OF values then gradually decreased from 0.7 to 0.6 between June and September 2020. In addition, during these months, the time in evening that the peak OF values gradually shifted to later. This implies that people slowly began to go out of their homes for longer periods, staying out later in the day. For the last three months of the year, however, this trend leveled off, with the average OF values remaining similar in terms of the OF value and the time of day when those OF values occurred. The minimum OF was close to 0.7, and the
evening peak occurred around 9:00 pm, as compared to minimum OFs of 0.6–0.7 and evening peaks at 11:00 pm pre-pandemic. In summary, the overall occupancy schedules in 2020 varied substantially from that of other years, however these differences between years varied depending on the month of the year, as the pandemic progressed.

4.4. Variation by household size

The occupancy schedule variation of households of different sizes (1-to 4-members) is shown in Fig. 5 for both weekdays and weekends, representing more than 90% of households in the U.S. [64]. Subfigures in the left column depicted weekday profiles, whereas weekends are on the right. The red dashed line indicates the average OF in 2020, whereas the solid lines represented the profiles for other years.

To compare the two samples, Wilcoxon Signed Rank Test, which is a non-parametric hypothesis test based on the location of population of data, was conducted for households with different numbers of members for both weekdays and weekends across the pandemic and pre-pandemic years (Table 2). To analyze the result, the smaller sum of positive and negative ranks was evaluated and compared with respect to the sample size. For a sample size of 48 and significance level of 0.005, the critical value (alpha) is 318. This is higher than the test statistics for all type of households (268 for 1-member household and 0 for others), indicating the difference in the profiles is statistically significant for all households.

Table 2

|                  | 1-member | 2-member | 3-member | 4-member |
|------------------|----------|----------|----------|----------|
| Smaller sum of positive and negative ranks (Wilcoxon T) | 268.00   | 0.00     | 0.00     | 0.00     |
| Sample size (number of ranks) | 48       | 48       | 48       | 48       |

Fig. 6. Variation in occupancy schedule for different age group before the pandemic (solid lines) and during the pandemic (dashed lines).
sizes due to the pandemic. This thus justifies the difference in occupancy pattern during 2020 compared to previous years. As shown in the Fig. 5, for both weekdays and weekends, the OF changed notably during the pandemic compared to the previous years. In addition, a higher deviation in minimum OF was seen on weekdays compared to weekends. For households of all sizes, the OF value increased throughout the day for both weekdays and weekends and the amount of increase varied with time of day and type of days. For these types of households, the difference increased from early morning and reached its maximum value during the daytime, between 9:00 am and 3:00 pm, then slowly decreased until midnight. As such, the occupancy profile was impacted most from 9:00 am to 3:00 pm, which would typically, pre-pandemic, be a working period outside of the home. On weekdays, the difference in occupancy profile compared to pre-pandemic was similar for 3- and 4-member households whereas it was slightly smaller for 2-member households. This may be because having a larger household increased the likelihood of the presence of children who require care at home. Specifically for 3- and 4-member households, people also left their home later in morning and returned home earlier in night on both weekdays and weekends.

However, the variation in occupancy profile for 1-member households was different compared to other household sizes. For 1-member households, the OF pattern was similar before and during the pandemic. The main difference was that the profiles were shifted slightly toward the right, suggesting that people left their home later in the morning and returned home later in the evening. On weekends, the first half of the day is very similar, whereas for the second half people stayed out of their home more compared to pre-pandemic. In summary, this analysis suggests that different type of households reacted differently to the pandemic and lockdown measures.

4.5. Variation by occupant age group

The ATUS was then divided into 7 age groups, and for each the average of the OF was evaluated in 2020 compared to prior years (Fig. 6), including both weekdays and weekends. Fig. 6.a shows a comparison of pre-2020 and 2020 average OF for age groups under 45; Fig. 6.b shows age groups 45–64, and Fig. 6.c shows those over 65. For all age groups, the average OF increased notably in 2020 across all days. Schedules for those under 25 were impacted significantly, as shown in Fig. 6.a. For this age group, people were at home more often during pandemic, likely because most schools and colleges were remote. A similar trend is seen for the other age groups. The maximum difference in average OF for people between ages 25 to 64 was around 0.25 for both weekdays and weekends whereas for those younger than 25 and older than 64, it was around 0.3. Also, for all age groups, on average people left their homes later and returned earlier compared to pre-pandemic.

4.6. Variation by household income

The average OF values comparison across years among LIH, MIH and HIHs for both weekday and weekend are shown in Fig. 7. In 2018 and 2019, irrespective of weekdays or weekends, the average OF for LIHs is higher than MIHs and HIHs. On weekends, people from LIHs spent around 21 h at home whereas this value was around 17.5 h on weekdays. However, for HIHs, these values are 19 h and 16 h, respectively, for weekends and weekdays. This suggests that those belonging to HIHs spent the least time at home, whereas those in LIH stayed at home the most compared to other income groups. However, this pattern changed significantly during 2020.

During weekdays of 2020, average OF for MIH and HIHs are similar, and they are higher than the OF of LIH for the majority of the day. People in HIHs, and MIHs spent around 20.8 h and 19 h at home in
residential building is also evaluated. A single family prototype resi
ture and similarly, for cooling, the setback setpoint is 5°C.

For LIH, they still needed to leave their home during the
pandemic. In addition, interestingly, they spent more time outside their
home in 2020 compared to previous years. On weekdays, however, the
average OF of LIH is slightly lower midday, from 6:00 am to 6:00 pm
compared to MIH and HIH. This may be because low-income households
may include those working in service positions on weekdays that
require in-person work without the option for remote work or less likely
to switch to remote working [75,76]. During weekends of 2020, the
average OF for all three income groups are similar without much vari-
ation between them.

The impact of the 2020 occupancy scenarios on the energy use of a
residential building is also evaluated. A single family prototype resi-
dential building is selected as a case study. Weather data for Lansing,
Michigan is used, which is a heating dominated climate and located in
ASHRAE Climate Zone 5A. Occupancy-based setback temperature
method is used for HVAC control, where when occupant(s) are present,
the system runs at the specified setpoint temperature. However, when
no occupants are present, the system runs using a 5°C setback, i.e.,
heating setback setpoint is 5°C less than the heating setpoint tempera-
ture and similarly, for cooling, the setback setpoint is 5°C higher than
the baseline setpoint temperature. From the average occupancy
schedule, when the occupancy fraction is below 50 %, the space
was assumed to be empty and for other scenarios, occupants are present in
the space. EnergyPlus was used to evaluate the building performance
and the impact on the HVAC energy consumption is shown in Fig. 8. As
shown, there is negligible variation in consumption for lower income
households. However, for MIH and HH, energy consumption increased
significantly during the pandemic. For MIH, overall HVAC consumption
increased by around 10 %. For HIH, the cooling energy consumption
increased by more than 50 %. Total HVAC consumption is also increased
by 15 % for HH along with total increase in electricity consumption is
around 10 %.

4.7. Indoor location variation

The indoor location and primary activity variations of people on both
weekdays and weekends were next studied and compared across years as
shown in Fig. 9, as well as Table 3. Indoor locations include bedroom
(BR), bathroom (BT), living room (LR), dining room/kitchen (DR), office/
study room (OR), other (OT), and garage (GR); corresponding
mapping between the primary activities and the indoor location is given
in Appendix A.

From Table 3, it can be seen that the usage of OR space in 2020
increased by around 45 % compared to year 2019. Total time spent in
DR space also increased slightly in 2020. However, it is important to
note that this percentage distribution is calculated based on the total
time people spent at home. Thus, as people spent more time at home in
2020 compared to previous years, the change in total time duration in
these spaces are even higher. As shown in Fig. 8, the overall distribution
of time spent varies in 2020 compared to previous years. On weekdays in
2020, the most significant increase can be seen in OR usage. Pre-2020,
on weekdays, OR usage remained consistent, at around 5 – 7 %
throughout the day (8 am to 8 pm). However, this value increased to
around 20 % in 2020 from 8 am to 5 pm and then reduced to around 7 %. As
a significant amount of people worked and went to school remotely,
this led to increase in the usage of at-home office spaces. The usage of
the dining room/kitchen space also increased slightly to 13 % during 12
to 1 pm in 2020, as compared to from 9 to 10 % in prior years. This may
due to people having lunch at home. The use of this space also
increased during dinner time to 26 % in 2020 from 20 % in the previous
years, likely due to similar reason. The impact of increased usage of OR
and DR space also resulted in reduced usage of the BR space on
weekdays.

The use pattern of indoor spaces also changed during weekends in
2020 (Fig. 8.b). In the morning pre-2020, the living room space was used
by around 30 % of people, whereas this reduced to 20 % during 2020.
Usage of the dining room/kitchen space also decreased in 2020. As in
previous years, the usage of this space remained consistently uniform
with two small spikes during the typical lunch and dinner periods.
However, in 2020, the dining room/kitchen space usage decreased in
the morning and again in between lunch and dinner time. At the same
time, it can be seen that for the office space, percentage distribution of
time on weekends is smaller in 2020 compared previous years. As these

|   | 2020 | 2019 | 2018 |
|---|------|------|------|
| Bed (BR) | 58.7 | 60.6 | 60.8 |
| Bath (BT) | 3.0 | 3.7 | 3.5 |
| Living (LR) | 22.7 | 22.9 | 22.8 |
| Dining/kitchen (DR) | 7.4 | 6.9 | 6.9 |
| Office (OR) | 6.2 | 4.3 | 4.2 |
| Other (OT) | 1.7 | 1.5 | 1.6 |
| Garage (GT) | 0.2 | 0.2 | 0.2 |

Fig. 9. Average time spent in different locations within a home on weekdays for all people in (a) weekdays and (b) weekends for year (1) 2020, (2) 2019 and (3) 2018 (Note: percentages are based on those people reported to be at home, and does not include those outside of the home in the calculation.)

Table 3
Percentage time distribution, by room type, that people spent in their home.

| Location   | 2020  | 2019  | 2018  |
|------------|-------|-------|-------|
| BR (Bedroom) | 58.7% | 60.6% | 60.8% |
| BT (Bathroom) | 3.0%  | 3.7%  | 3.5%  |
| LR (Living Room) | 22.7% | 22.9% | 22.8% |
| DR (Dining/Kitchen) | 7.4%  | 6.9%  | 6.9%  |
| OR (Office) | 6.2%  | 4.3%  | 4.2%  |
| OT (Other) | 1.7%  | 1.5%  | 1.6%  |
| GT (Garage) | 0.2%  | 0.2%  | 0.2%  |
Fig. 10. Average time spent in different locations within a home on weekdays in 2020 for people (a) under 25, (b) 25–34, (c) 35–44, (d) 45–54, (e) 55–64, (f) 65–74 and (g) over 75 (Note: percentages are based on those people reported to be at home, and does not include those outside of the home in the calculation).
percentage values are evaluated based on total time people spent at home, and during 2020 people spent more time in home compared to 2018 and 2019, total time duration spent in office space is higher during the pandemic. Detailed analysis of space usage for people of different age group is also evaluated for year 2020 and shown in Fig. 9 and Appendix B1 for weekdays and weekend respectively.

As shown in Fig. 10, starting from midnight to early morning, irrespective of the age group, people spent most of their time in the bedroom, sleeping. In the early morning, the percent of time spent in the bedroom increases, and other locations increase. For people under 25, the percentage of time spent in their home office is greater in the morning; in the afternoon and evening the living room utilization is greatest. This differs from pre-pandemic (Appendix B2 and B3), where the living room usage dominated throughout the day. This difference may be because of the prevalence of remote learning for schools and colleges, perhaps concentrated more in the mornings and early afternoon.

For those age 25 to 64, the time spent in the dining room is comparatively higher in the mornings, likely for breakfast, which then switched to the office space until early evening. The percent time spent in the living room area is low until around 4:00 pm, then increases, likely due to finishing work and transitioning to other activities. Compared to pre-pandemic activity schedules, the usage of living room remains consistent from morning to evening whereas the office space usage is significantly lower for all age groups. Also, unlike 2020, only one spike in dining room usage can be seen during dinner time.

For those 65 and older, the time spent in the living room was comparatively higher throughout the day, with the maximum amount for those over 75. Similarly, people in this age range spent significant more time in the dining room/kitchen area, making and eating food, preparing meals, and related activities, during the lunch and dinner time periods. The amount of time spent for meals in the dining/kitchen area is greater for those in older age groups. Compared to pre-pandemic, the major difference is seen in the increased usage of dining/kitchen area spaces.

Overall, in 2020, less variation in indoor space usage is seen on weekends, with the primary difference being less time spent in office/study spaces. Those in younger age groups spent more time in the office/study rooms, likely due to work and/or school related activities requiring work on weekends. Overall, the percentage of time spent in the living room, dining room, and bathroom were also higher on weekends compared to weekdays.

5. Conclusions

As the COVID-19 pandemic began in the middle of March 2020, it impacted peoples’ lives substantially. This included how people use their homes, the amount of time spent in their homes, and what activities occurred, where, when, and for how long. Previous research has shown that this, as a result, has impacts how buildings use energy and their energy use patterns. This study works towards quantifying what this impact on occupancy and activities occurring in homes has been using a combination of ATUS and CPS data for 2020, compared to the pre-pandemic years of 2006 to 2019. The impact of different time, occupant-related, and household characteristics on occupancy during the pandemic was evaluated in this study and compared pre-pandemic times. For time variables, the variation in weekday and weekend profiles and across months were evaluated. The impact by age group was also analyzed. For household characteristics, the differential impact across different household incomes and household sizes were assessed. Finally, the activities and indoor locations used throughout a typical day were compared on weekdays and weekends, to pre-pandemic times. The major findings of this study are as follows:

- During the pandemic in 2020, people spent more time at home. Across this period, the average occupancy fraction on weekends and weekdays was 0.15 higher, and 0.1 higher, respectively, throughout the majority of the day. Overall, people spent around 1.9 and 1.2 h more time at home on weekdays and weekends, respectively, which also varies with people’s age. On average, people also came back home earlier on both weekdays and weekends during pandemic period.
- Considering variations across the different months of 2020, in the beginning of the pandemic (May) a maximum occupancy fraction difference of 0.3 was observed compared to pre-pandemic. This decreased slowly throughout the remainder of the year, to 0.15 in September, then remained approximately 0.2 for the last three months of 2020.
- For 2-, 3- and 4- member households, the pandemic resulted in an increase from 17.8 (pre-pandemic) to 19.9 h of time spent at home on weekdays and 20 (pre-pandemic) to 21.1 h spent at homes on weekends. 3- and 4-member households were more impacted. However, 1-person households were comparatively less impacted, where time spent on weekends were similar, and on weekdays they spent on average 32 min less in their home. On weekdays, the time at which people most commonly left their home was also delayed slightly. On weekends, people spent more time outside their home in the evening.
- Across age groups, although different age groups follow different typical occupancy profiles, the overall impact was similar. On average, the occupancy dropped by 0.07–0.08 across a typical 24-hour day, with a maximum difference in occupancy fraction of 0.25 and 0.3 on weekdays and weekends respectively, typically occurring mid-day.
- Across different household incomes, the average occupancy profiles on weekends were similar in 2020. However, on weekdays, people in low-income households spent less time at home during the day compared to the other two income groups. Pre-pandemic, people in the higher income group spent the least time at home (~16 h) and people from low-income households spent the most (~20 h). This pattern reversed during the pandemic where people from low-income households spent around 18.6 h at home which is 0.5 h less than people from the high income group.
- Regarding activities and locations that people spent time in their homes, during the pandemic on weekdays, most time in the morning before noon was spent in office areas, primarily doing remote working and schooling; in the afternoon people continued to work and then transitioned more towards leisure activities, mostly corresponding to the living room area. On weekends, the living room and dining room/kitchen were the two most used spaces across all age groups, whereas younger age groups also used the office/study spaces during this time. Compared to pre-pandemic, the office and kitchen/dining space usage increased significantly whereas the living room and bedroom usage decreased.
There are several limitations associated with this study. The ATUS is based on self-reported data and has followed a consistent methodology for data collection since 2006. The ATUS data is not collected specifically to understand COVID-related impacts on occupant behavior. Therefore, direct correlation between COVID and people’s behavior cannot be confirmed. Further research is needed to confirm the specific reasons for changes in people’s behavior in 2020, including but not limited to the impacts of COVID. Also, as the ATUS is self-reported data, it can be subjected to human error. In addition, the survey contains activity data for individual household members for individual, representative days. The availability activity data for multiple days and for multiple household members is not currently available using existing nation-wide survey mechanisms, however this would be helpful for future work to better understand variation in occupancy schedules within households. In addition, some activities reported in the ATUS also include location information while others are assumed based on the nature of the activity.

In general, this study provides a detailed analysis of occupancy profiles and how people’s activities and occupancy have been impacted by the pandemic in 2020. The impact of different variables due to the pandemic provides detailed insights that can help in understanding how the pandemic may impact the use of residential buildings long-term, and how these profiles vary across different population segments. For future work, as the availability of ATUS data for 2021 becomes available, it would be highly insightful to conduct further analysis to link what has been found in the 2020 data to understand longer term trends in residential occupancy and how they have varied in the various stages of the pandemic.

CRediT authorship contribution statement

Debrudra Mitra: Conceptualization, Methodology, Data curation, Writing – original draft, Writing – review & editing.
Yiyi Chu: Conceptualization. Kristen Cetin: Conceptualization, Methodology, Writing – review & editing, Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. . Mapping between indoor locations and primary activities from ATUS.

| TRCODE | Activity Description                  | TRCODE | Activity Description                  |
|--------|--------------------------------------|--------|--------------------------------------|
| BED    | LIVING                               | 10,501 | Personal emergencies                 |
| 10,101 | Sleeping                             | 10,599 | Personal emergencies                 |
| 10,102 | Sleeplessness                        | 20,101 | Home cleaning                        |
| 10,199 | Sleeping *                           | 20,103 | Interior cleaning                    |
| 10,401 | Personal/Private activities          | 20,103 | Sewing, repairing, & maintaining textiles |
| 10,499 | Personal activities, n.e.c.*         | 20,199 | Housework, n.e.c.*                   |
| 30,101 | Physical care for hh children        | 20,301 | Interior arrangement, decoration, & repairs |
| 30,102 | Reading to/with hh children          | 20,302 | Building and repairing furniture      |
| 30,103 | Playing with hh children, not sports | 20,303 | Heating and cooling                   |
| 30,104 | Arts and crafts with hh children     | 20,399 | Interior maintenance, repair, & decoration, n.e.c.* |
| 30,106 | Talking with/listening to hh children| 20,601 | Care for animals and pets (not veterinary care) |
| 30,199 | Caring for & helping hh children, n.e.c.* | 20,602 | Walking / exercising / playing with animals |
| 30,301 | Providing medical care to hh children| 20,699 | Home security                        |
| 30,302 | Activities related to hh child’s health, n.e.c.* | 20,905 | Household management, n.e.c.*         |
| 30,401 | Physical care for hh adults          | 20,999 | Household activities, n.e.c.*         |
| 30,402 | Looking after hh adult (as a primary activity) | 29,999 | Playing sports with hh children       |
| 30,403 | Providing medical care to hh adult    | 30,105 | Looking after hh children (as a primary activity) |
| 30,499 | Caring for household adults, n.e.c.* | 30,109 | Waiting for/with hh children          |
| 30,599 | Helping household adults, n.e.c.*     | 30,111 | Home schooling of hh children         |
| 40,101 | Physical care for nonhh children     | 30,203 | Waiting associated with hh children’s education |
| 40,102 | Reading to/with nonhh children       | 30,204 | Waiting associated with hh children’s health |
| 40,103 | Playing with nonhh children, not sports | 30,303 | Waiting associated with caring for household adults |
| 40,104 | Arts and crafts with nonhh children  | 30,405 | Waiting associated with helping hh adults |
| 40,105 | Talking with/listening to nonhh children | 30,504 | Waiting associated with helping nonhh adults |
| 40,109 | Caring for and helping nonhh children, n.e.c.* | 40,109 | Looking after nonhh children (as primary activity) |
| 40,301 | Providing medical care to nonhh children | 40,111 | Waiting for/with nonhh children       |
| 40,399 | Activities related to nonhh child’s health, n.e.c.* | 40,203 | Home schooling of nonhh children      |
| 40,401 | Physical care for nonhh adults       | 40,405 | Waiting associated with caring for nonhh adults |
| 40,402 | Looking after nonhh adult (as a primary activity) | 40,503 | Waiting associated with helping nonhh adults |
| 40,403 | Providing medical care to nonhh adult | 40,508 | Waiting associated with working       |
| 40,499 | Caring for nonhh adults, n.e.c.*     | 50,104 | Socializing, relaxing, and leisure as part of job |
| 40,508 | Helping nonhh adults, n.e.c.*        | 50,201 | Income-generating hobbies, crafts, and food |
| 49,999 | Caring for & helping nonhh members, n.e.c.* | 50,301 | Waiting associated with other income-generating activities |
| 80,402 | Using in-home health and care services | 50,305 | Waiting associated with medical services |
| 80,499 | Using medical services, n.e.c.*      | 80,403 | Waiting associated w/personal care services |
| 90,103 | Using clothing repair and cleaning services | 80,502 | Using interior cleaning services     |
| 120,301 | Relaxing, thinking                   | 90,101 |                                   |

(continued on next page)
| TRCODE | Activity Description                          | TRCODE | Activity Description                                                                 |
|--------|---------------------------------------------|--------|-------------------------------------------------------------------------------------|
| 120,302| Tobacco and drug use                        | 90,104 | Waiting associated with using household services                                     |
| 120,312| Reading for personal interest               | 90,199 | Using household services, n.e.c.*                                                   |
| 120,313| Writing for personal interest               | 90,201 | Using home maint/repair/dec/or/constr svcs                                         |
| 130,109| Dancing                                     | 90,202 | Waiting associated w/ home main/repair/dec/or constr                                  |
| 150,103| Reading                                     | 90,299 | Using home maint/repair/dec/or constr services, n.e.c.*                              |
| 150,105| Writing                                     | 90,301 | Using pet services                                                                   |
| 150,203| Providing care                              | 90,302 | Waiting ass w pet services, n.e.c.*                                                  |
| 10,201 | Washing, dressing and grooming oneself      | 90,402 | Waiting associated with using lawn & garden services                                 |
| 10,299 | Grooming, n.e.c.*                           | 90,502 | Waiting associated with vehicle main. or repair svcs                                 |
| 10,301 | Health-related self care                    | 99,999 | Using household services, n.e.c.*                                                   |
| 10,399 | Self care, n.e.c.*                          | 100,101| Using police and fire services                                                       |
| 80,501 | Using personal care services                | 100,102| Using social services                                                                |
| 80,599 | Using personal care services, n.e.c.*       | 100,304| Waiting associated with using government services                                    |
| 100,299| Waiting associated with eating              | 100,299| Listening to the radio                                                               |
| 90,102 | Using meal preparation services             | 120,306| Listening to/music (not radio)                                                       |
| 110,101| Eating and drinking                         | 120,307| Playing games                                                                        |
| 110,199| Eating and drinking                         | 120,311| Hobbies, except arts & crafts and collecting                                         |
| 110,299| Waiting associated w/eating & drinking      | 120,399| Relaxing and leisure, n.e.c.*                                                        |
| 119,999| Eating and drinking                         | 120,501| Waiting assoc. w/socializing & communicating                                          |
| 150,201| Food preparation, presentation, & clean-up  | 120,502| Waiting assoc. w/attending/hosting social events                                      |
| 40,501 | Housework, cooking, & shopping assistance  | 120,503| Waiting associated with relaxing/leisure                                              |
| 50,202 | Eating and drinking as part of job          | 120,305| Listening to the radio                                                               |
| 90,203 | Waiting associated w/eating & drinking      | 120,307| Playing games                                                                        |
| 20,904 | HH & personal e-mail and messages           | 120,311| Hobbies, except arts & crafts and collecting                                         |
| 30,201 | Organization & planning for hh children     | 120,321| Watching equestrian sports                                                           |
| 30,202 | Homework (hh children)                      | 120,322| Watching equestrian sports                                                           |
| 30,299 | Activities related to hh child’s education | 130,205| Watching baseball                                                                    |
| 30,302 | Obtaining medical care for hh children      | 130,206| Watching baseball                                                                    |
| 30,604 | Obtaining medical and care services for hh adult | 130,207| Watching bowling                                                                     |
| 30,501 | Helping hh adults                           | 130,208| Watching baseball                                                                    |
| 30,502 | Organization & planning for hh adults       | 130,209| Watching dancing                                                                     |
| 40,108 | Organization & planning for nonh children   | 130,210| Watching equestrian sports                                                           |
| 40,201 | Homework (nonhh children)                   | 130,211| Watching equestrian sports                                                           |
| 40,204 | Waiting related to nonhh child’s educ., n.e.c.* | 130,212| Watching equestrian sports                                                           |
| 40,299 | Activities related to nonhh child’s educ., n.e.c.* | 130,213| Watching football                                                                    |
| 40,302 | obtain medical care for nonhh children      | 130,214| Watching golfing                                                                     |
| 40,303 | Waiting related to nonhh child’s health      | 130,215| Watching gymnastics                                                                  |
| 40,404 | Obtaining medical and care services for nonh adult | 130,216| Watching hockey                                                                      |
| 40,505 | Financial management assistance for nonh adults | 130,217| Watching martial arts                                                                |
| 40,506 | Household management & paperwork assistance | 130,218| Watching rodeo competitions                                                          |
| 50,101 | Work, main job                              | 130,219| Watching running                                                                     |
| 50,102 | Work, other job(s)                          | 130,220| Watching running                                                                     |
| 50,199 | Working, n.e.c.*                            | 130,221| Watching running                                                                     |
| 50,299 | Work-related activities, n.e.c.*             | 130,222| Watching running                                                                     |
| 50,302 | Income-generating services                  | 130,223| Watching skiing, ice skating, snowboarding                                           |
| 50,303 | Income-generating services                  | 130,224| Watching soccer                                                                      |
| 50,304 | Income-generating rental property activities | 130,225| Watching softball                                                                     |
| 50,399 | Other income-generating activities, n.e.c.* | 130,227| Watching volleyball                                                                   |
| 50,401 | Job search activities                       | 130,228| Watching running                                                                     |
| 50,403 | Job interviewing                            | 130,229| Watching water sports                                                                |
| 50,404 | Waiting associated with job search or interview | 130,230| Watching wrestling                                                                   |
| 50,405 | Security procedures rel. to job search/photo/ interview | 130,231| Watching wrestling                                                                   |
| 59,999 | Work and work-related activities, n.e.c.*   | 130,232| Watching wrestling                                                                   |
| 60,101 | Taking class for degree, certification, or licensure | 140,103| Watching associated w/religious & spiritual activities                               |
| 60,102 | Taking class for personal interest          | 140,105| Religious education activities                                                       |
| 60,103 | Waiting associated with taking classes       | 150,102| Organizing and preparing                                                              |
| 60,199 | Taking class, n.e.c.*                       | 150,104| Telephone calls (except hotline counseling)                                          |
| 60,201 | Extracurricular club activities             | 150,202| Collecting & delivering clothing & other goods                                       |
| 60,204 | Waiting associated with extracurricular activities | 150,204| Teaching, leading, counseling, mentoring                                              |

(continued on next page)
| TCODE | Activity Description                                      | TCODE | Activity Description                                      |
|-------|----------------------------------------------------------|-------|----------------------------------------------------------|
| 60,299| Education-related extracurricular activities, n.e.c.*    | 150,302| Indoor & outdoor maintenance, repair, & clean-up        |
| 60,301| Research/homework for class for degree, certification, or license | 150,399| Indoor & outdoor maintenance, building & clean-up activities, n.e.c.* |
| 60,302| Research/homework for pers. interest                     | 150,401| Performing                                                |
| 60,399| Research/homework n.e.c.*                                | 150,499| Participating in performance & cultural activities, n.e.c.* |
| 60,401| Administrative activities: class for degree, certification, or license | 150,701| Waiting associated with volunteer activities             |
| 60,402| Administrative activities: class for personal             | 150,799| Waiting associated with volunteer activities, n.e.c.*    |
| 60,403| Waiting associates w admin activities                     | 150,801| Waiting associated with volunteer activities             |
| 60,499| Administrative for education, n.e.c.*                     | 159,999| Volunteer activities, n.e.c.*                             |
| 69,999| Education, n.e.c.*                                      | 160,101| Telephone calls to/from family members                  |
| 70,104| Shopping, except groceries, food and gas                  | 160,102| Telephone calls to/from friends, neighbors, or acquaintances |
| 70,105| Waiting associated with shopping                          | 160,103| Telephone calls to/from education services providers    |
| 70,199| Shopping, except groceries, food and gas                  | 160,104| Telephone calls to/from salespeople                     |
| 70,201| Comparison shopping                                      | 160,105| Telephone calls to/from professional or personal care svcs providers |
| 70,299| Comparison shopping                                      | 160,106| Waiting associated with volunteer activities             |
| 70,301| Security procedure related to purchase                    | 160,107| Waiting associated with volunteer activities             |
| 70,399| Security procedure related to purchase                    | 160,108| Telephone calls to/from paid child or adult care providers |
| 80,101| Using paid childcare services                            | 160,109| Telephone calls to/from government officials           |
| 80,102| Paid childcare                                           | 160,119| Telephone calls to (or from), n.e.c.*                   |
| 80,199| use paid childcare service                               | 160,201| Waiting associated with telephone calls                  |
| 80,201| Banking                                                  | 160,202| Telephone calls, n.e.c.*                                 |
| 80,202| Using other financial services                           | OTHER | Laundry                                                  |
| 80,203| Waiting associated w/banking/financial services          | 20,102 | Appliance, tool, and toy set-up, repair, & maintenance (by self) |
| 80,299| Using other financial services                           | 20,801 | Appliances and tools, n.e.c.*                             |
| 80,301| Using legal services                                     | 20,899 | Sports and exercise as part of job                      |
| 80,302| Waiting associated with legal services                   | 50,203 | Security procedure as part of job                       |
| 80,399| Using legal services                                     | 50,204 | Security procedure as part of job                       |
| 80,601| Activities rel. to purchasing/selling real estate        | 60,104 | Extracurricular music & performance activities          |
| 80,602| Waiting associated w/purchasing/selling real estate      | 60,202 | Extracurricular student govt activities                  |
| 80,699| Activities rel. to purchasing/selling real estate        | 60,203 | Waiting associated with telephone calls                  |
| 80,701| Using veterinary services                                | 120,309| Telephone calls, n.e.c.*                                 |
| 80,702| Waiting associated with veterinary services               | 120,310| Arts and crafts as a hobby                              |
| 80,799| Using veterinary services                                | 130,101| Collecting as a hobby                                  |
| 80,801| Security procedure related to service                    | 130,104| Doing aerobics                                         |
| 80,899| Security procedure related to service                    | 130,124| Running                                                 |
| 89,999| Professional and personal services, n.e.c.*              | 130,128| Using cardiovascular equipment                          |
| 100,103| Obtaining licenses & paying fines, fees, taxes           | 130,131| Walking                                                 |
| 100,109| Using government services, n.e.c.*                        | 130,132| Weightlifting/strength training                         |
| 100,401| Security procedure related to civic obligation           | 130,134| Working out, unspecified                                |
| 100,499| Security procedure related to civic obligation           | 130,136| Doing yoga                                              |
| 109,999| Government services, n.e.c.*                             | 130,199| Playing sports, n.e.c.*                                  |
| 120,308| Computer use for leisure (exc. Games)                    | 140,102| Participation in religious practices                     |
| 120,405| Security related to art                                  | 149,999| Religious and spiritual activities, n.e.c.*              |
| 140,104| Security related to religious activities                 | 149,999| Waiting associated with religious activities, n.e.c.*    |
| 150,101| Computer use                                            | 20,701 | Vehicle repair and maintenance (by self)                |
| 150,106| Fundraising                                             | 20,799 | Vehicles, n.e.c.*                                       |
| 150,199| Administrative & support activities, n.e.c.*             | 40,504 | Vehicle & appliance maintenance/repair assistance for nonrhh adults |
| 150,299| Social service & care activities, n.e.c.*                | 90,501 | Using vehicle maintenance or repair services            |
| 150,501| Attending meetings, conferences, & training             | 90,599 | Using vehicle maint. & repair svcs, n.e.c.*             |
| 150,599| Attending meetings, conferences, & training, n.e.c.*    | 90,599 |                                                         |

**Appendix B1**

(see Fig. B1).
Fig. B1. Average time spent in different locations within a home on weekends in 2020 for people (a) under 25, (b) 25–34, (c) 35–44, (d) 45–54, (e) 55–64, (f) 65–74 and (g) over 75 (Note: percentages are based on those people reported to be at home, and does not include those outside of the home in the calculation).
Appendix B2

(see Fig. B2).

Fig. B2. Average time spent in different locations within a home on weekdays in 2019 for people of different age group.
Appendix B3

(see Fig. B3).

Fig. B3. Average time spent in different locations within a home on weekends in 2019 for people of different age group.
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