Time of the day dependence of social practices and energy demand

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Abstract

The starting point of this work is that the time dependence of social practices at specific points of the day shapes the timing of energy demand. This work aims to assess how dependent energy-related social practices in the household are in relation to the time of the day. The analysis of the 2005 Office for National Statistics National Time Use Survey makes use of statistically-derived time dependence calculations for six social practice: preparing food, washing, cleaning, washing clothes, watching TV and using a computer. The focus is on social practices over temporal scales of different days of the week and months of the year, with particular emphasis on February and June. Findings will have implications on the way flexibility is conceptualised and the effectiveness of intervention aimed at practices rather than individuals (e.g. through price and technology).

1. Introduction: Time dependence: social practices and the timing of energy demand

Whilst the volume of energy demand relates to many factors (e.g. weather, type of appliances, types of building), patterns throughout the day are a direct reflection of people's practices. A simple example derives from the substantial difference between residential electricity load curves for weekdays and weekends. During the same season the weather can be equal at the weekend compared with the weekday. Everything else remains the same between a day of the week and the weekend: building, appliances, fuel substitution, price of energy and appliance control, and even the moment of the day in which sunlight is present or absent. What changes between weekday and weekend is people's activities.

Following Becker's (1965) rational economic modelling of household time use, the issue of how energy demand relates to time has been approached from various angles. Rational action theories of consumption and time offer causal explanations of changes in the relationship between consumption and time. They are based on the assumption that work and consumption are practices that consume time. Since volumes of time are determined, extra time spent on either practice will reduce the time available for other practices (Southerton, 2003). Attempts to move away from the causal relations rationale explored the extent to which increases in working hours have brought about a reduction in domestic activities (Hochschild, 1997). Practice theories consider the relation between time and consumption in relation to the fact that human activities are ordered recursively across space and time (Giddens, 1984). The patterning of social life is a consequence of routine, collective and conventional nature of consumption (Reckwitz, 2002). From practice theory, the timing of energy demand can be defined as the result of the socio-temporal organisation of daily practices.

Peak energy demand emerges as a phenomenon which epitomises the relevance of practices as a unit of analysis in this context. Technical factors (including weather, building characteristics, appliance design, appliance control, interdependencies between energy services, etc.) have partly explained variations in volumes of energy demand, but have inevitably failed to describe any intra-day variation in patterns (e.g. residential electricity load profiles). The timing of energy demand is not determined by individuals' desire to consume energy at a given point of the day, but by the way people's practices are ordered and dependent on time.

Specific work in Theme 1 of the DEMAND project has attempted to describe the phenomenon of peak energy demand in terms of synchronicity of practices, sequencing and (lack of) flexibility. Peaks are also triggered by an infrastructure that simultaneously services those multiple 'doings'. Social practices have characteristics which define the way energy demand comes about. They are habitual, synchronised, varied, sequenced and contingent (Walker, 2014).

The issue of time dependence of social practices has been debated for some time at a conceptual level, but seldom been operationalised in empirical research. The starting point of this work is that the time dependence of social practices at specific points of the day shapes energy demand in households. This work aims to assess how dependent energy-related social practices are in relation to the time of the day. It addresses specific questions regarding time dependence of practices; the variation of time-dependence throughout the working days of the week; and the relationship between time dependence and seasonality.

The analysis of the 2005 Office for National Statistics National Time Use Survey makes use of time dependence calculations for six social practice: preparing food, washing, cleaning, washing clothes, watching TV and using a computer. The focus is on social practices over temporal scales of different days of the week and months of the year, with particular emphasis on February and June.

This work introduces the concept of time dependence as a way of synthetizing related issues of synchronicity, sequencing and flexibility. As such, time dependence is defined as high occurrence of the same practice over the same periods of the day. Practices which repeatedly take place at the same time of the day are said to be time dependent. Two simple observations underpin the concept of time dependence of social practices. First, social practices have rhythms (Jalas, 2002). Rhythms introduce the possibility of time dependence in social practice ordering (Pantzar & Shove, 2010). Rhythms and routines co-exist and are interdependent, not rival (Shove et al, 2009). This is not to say that time follows exogenous forces or that practices have independent rhythms (Lefebvre, 2004). Quite the opposite, time can be a quantitative measure of the ordering of practices, notwithstanding the temporal dynamics within and across practices. Second, empirical evidence shows the time dependence of the peak energy demand phenomenon (Wardle et al, 2013): with different intensities, depending on the season, every morning and evening of any weekday there are the same peaks in electricity demand. Peaks are seemingly time-bound and are the signal of societal synchronisation.

Two critical clarifications on the definition of time in this work are that: (i) time is socially constructed, meaning that the distinction, for instance, of weekday and weekend is entirely attributable to the framework of time as designed by the society in which we are living in; and (ii) the resolution of time in this paper is generally intra-day (in tune with the discussion on peak demand, loads profiles and timing of energy demand).

After this introduction, Section 2 describes the dataset on which the analysis is based and the statistical methods for measuring time dependence. Section 3 analyses which practices are more or less time dependent. Section 4 examines how time-dependence vary throughout the working days of the week. Section 5 explores whether time dependence changes depending on seasons. Section 6 discusses the implications of this work and concludes.

2. Data and methodology

The analysis presented in this paper is based on the 2005 Office for National Statistics (ONS) Time Use survey, which is the most recent, nationally representative survey available in the UK. The Time Use Survey contains 10-minute intervals information about respondents' activities based on a list of the 30 pre-coded activities. A day begins at 4am and ends the following day with the last recording taken at 3.50-4am. Respondents are able to specify a primary activity, a secondary activity and their location at that moment in time. The Time Use survey was conducted over four months: February, June, September and November. The four months were selected by the ONS as to avoid the atypical holiday periods (i.e. non-everyday life) throughout the year and to represent the different seasons of the year (Lader et al, 2006). Weekend respondent diary diaries are not included in this study as this report is concerned only by weekday social practices. After excluding weekend diary days, a final sample of 3,554 respondent diary days is available for analysis.

By excluding Saturdays and Sundays from the study, an issue was created, in that the weights that came with the dataset were no longer valid. To overcome this issue, new weights were calculated for the dataset based on the methodology used by Lader et al (2006) in the original survey. The dataset was adjusted so that days of the week and months of the year were equally represented.

Social practices are the unit of analysis of this work. The activity codes that have been selected from the 2005 UK Time Use Survey are: preparing food and drinks, cooking, washing up; washing, dressing/undressing, etc; cleaning, tidying house; washing, ironing or mending clothes etc; watching TV and videos/DVDs, listening to radio or music, and; using a computer.

How can we measure time of the day dependence? If practices take place in large amounts during the same period and not at all at other times of the day, this implies high time dependence. On the contrary, practices which happen with the same frequency regardless of the time of the day will have low time dependence.

To examine where time dependence exists throughout the day, six selected social practices are analysed over two temporal scales. First, individual weekdays are analysed throughout the day for each social practice. Second, individual months are analysed throughout the day for each social practice. Time dependence is operationalised as the frequency of a single practice in the same time periods. Time dependence can be measured as follows:

$$T_{DEP} = \frac{\mathrm{Max}\,[x_i - \mathrm{m(X)}]}{m(X)}$$

where x_i is the frequency of the practice *x* at the time of the day *i* and *m* is the mean value (amount of minutes). The numerator consists of the maximum deviation from the mean. Like standard deviation, this will be heavily influenced by the volume of minutes associated with specific practices. For example, TV watching is much more dominant in terms of distribution of practices throughout the day than washing clothes. By dividing for the mean average T_{DEP} controls for the volume of practices.

For practices taking place in large amounts during the same period and not at all at other times of the day standard deviation and T_{DEP} will be higher because this is representative of a distribution of the practice which is not equally spread around the day (or time independent).

The centred moving average of an hour is estimated to examine time dependence throughout the working days of the week and across seasons.

In order to capture how time dependence varies across seasons, the standard deviation across seasons and among different days of the week is derived as:

$$\sigma(T_{DEP}) = \sqrt{\frac{\sum_{i=1}^{N}[x_i - m(X)]^2}{N}}$$

where x_i is the frequency of the practice *x* at the time *i* and *m* is the mean value.

In principle the presence of several 0 values (or unrecorded entries) in time use diaries calls for the use of the first difference estimator. However, unrecorded entries are significant for the analysis as in principle a practice with all zero values and a restricted period of the day with high frequency would be highly time dependent. Hence unrecorded entries need to be accounted for by estimating simple deviations of each data point from the mean. Shorter duration and lower frequency practices will be associated with a higher T_{DEP}.

3. Which are the most (and least) time dependent practices?

Figure 1 shows the centred average percentage of each social practice throughout the day. Watching TV/listening to music experiences the greatest time dependence of all social practices, with a peak of 49% of respondents reporting television in the hour surrounding 21:20. Throughout the majority of the day watching TV is the most reported social practice considered in this study.

Time dependences in preparing food occur during three periods of the day: the morning, the afternoon and the evening. The concentration periods vary in magnitude and length: the morning peak lasts from 06:00 to 09:00; the afternoon peak is smaller in both magnitude and size, lasting from 12:00 to 13:30; the evening peak is the greatest, starting at 16:00 and ending at 20:00. The analysis shows that there is a convergence of people undertaking this activity during the evening.

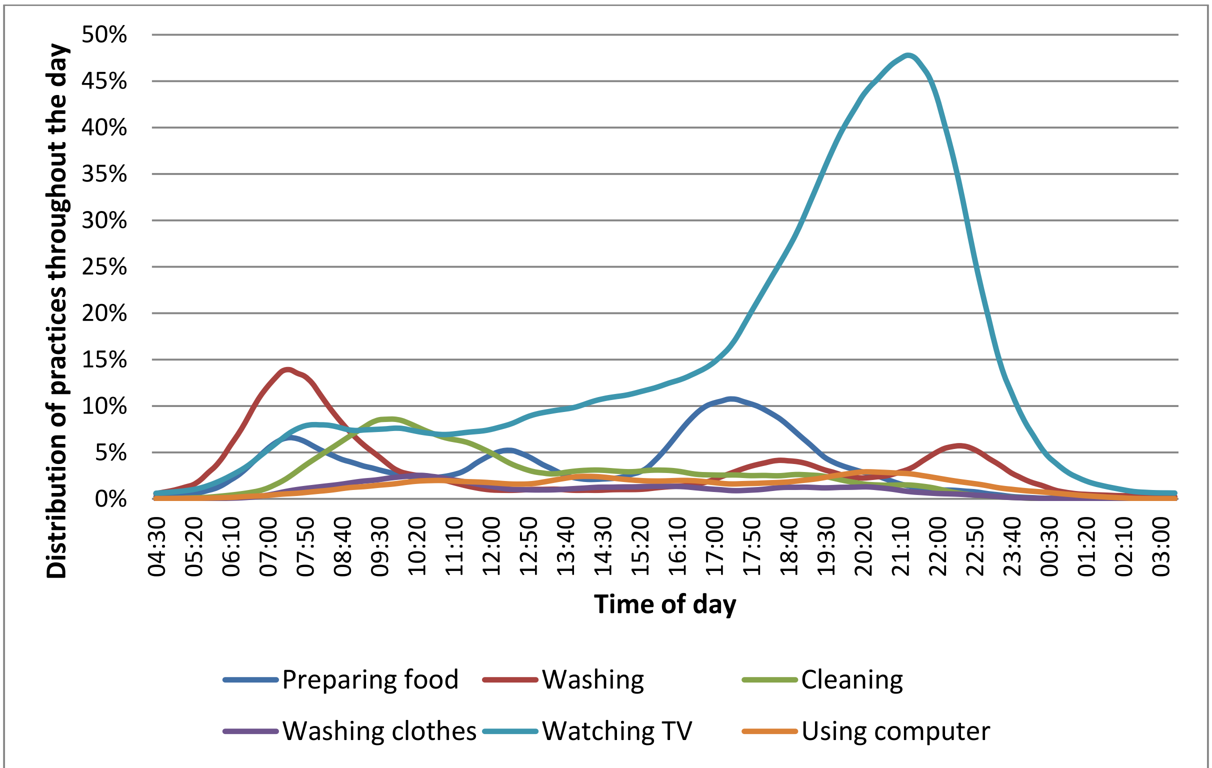

Figure 1. *Distribution of practices throughout the day*

Washing and dressing experience two concentration periods: a large one during the morning and a small one during the late evening. The morning period is of the greatest interest as it appears to show a similar rate of increase until around 07:30, when the number of respondents who report this activity falls. The convergence of washing at this time is a significant one because this practice can lead to the use of an electric shower, which has a very high electricity demand. The final social practice that shows time dependence during the day is cleaning. The time dependence of cleaning occurs throughout the duration of the morning and into the early afternoon.

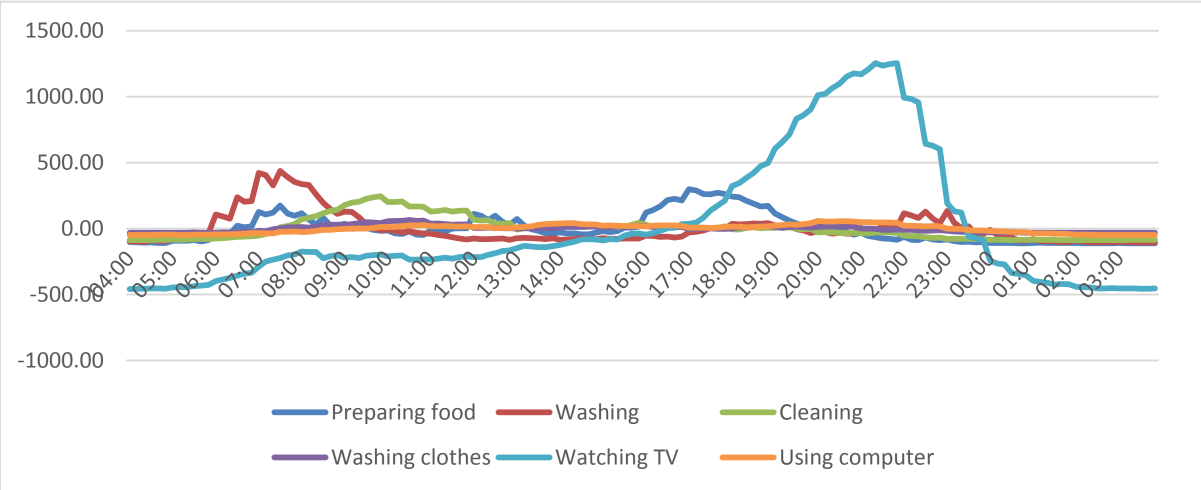

Figure 2. *Statistical deviation of practices*

Figure 2 illustrates that washing and watching TV were the activities to show time dependence throughout the day. Watching TV has high statistical deviation (negative in the morning and positive in the evening). This indicates a higher dependence of TV watching in the evening.

Practice	Standard Deviation	MAX Deviation	T_{DEP}
Preparing food	108.08	299.90	2.69
Washing	120.08	438.90	3.95
Cleaning	86.04	245.99	2.88
Washing clothes	25.63	66.38	2.13
Watching TV	488.12	1256.16	2.64
Using computer	32.08	58.75	1.22

Table 1. *Standard Deviation, MAX Deviation and MAX Deviation/average*

In order to control for the higher volumes of specific practices (e.g. TV watching has the highest frequency at evening peak), Table 1 calculates time dependence making use of standard deviation, MAX Deviation and MAX Deviation/average. Washing has the highest value for the time dependence (T_{DEP}) metric, whereas using computer is the least time-dependent practice. This results in two very different pictures of computer use happening at more or less any time of the day and washing as being extremely bound to time. Preparing food is also highly time dependent, though resulting in a moderate T_{DEP} because of the relatively high frequency of meals in a day.

4. **How does time-dependence vary throughout the working days of the week**?

Figures 3 to 8 show the centred average percentage of activities on the five working days of the week. The y-axis on each of the figures are on varying scales to aid analysis of the data. Preparing food, washing, cleaning and watching TV show similar time dependences throughout the working work to those obtained in Figure 1. In contrast, washing clothes and using the computer display more erratic patterns of time dependences throughout the week. The erratic nature of Figure 5 and Figure 8 is likely to be a result of the smaller scale of the graph, meaning the small changes the patterns of practice appear larger.

The results from Figures 6 to 11 show a shift in practices on Friday evenings. Preparing food and watching TV are associated with lower time dependence, whilst the practice of washing experiences a greater time dependence. On a Friday evening, washing reaches approximately 6%, when it is approximately 2-4% on other days of the week. This finding is likely due to a greater volume of social events, made obvious by the fact washing/dressing in the evening is more diffused than in the rest of the week. The practice of preparing food experiences a sharp increase in time dependence on Mondays, when the average percentage is 14%.

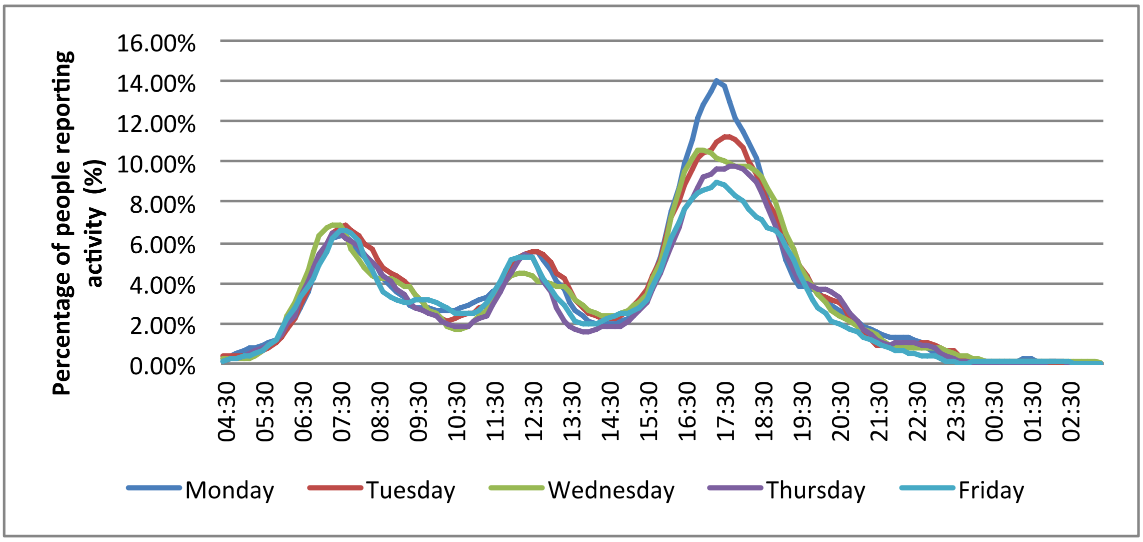

Figure 3. *Centred average percentage of preparing food throughout the day on weekdays*

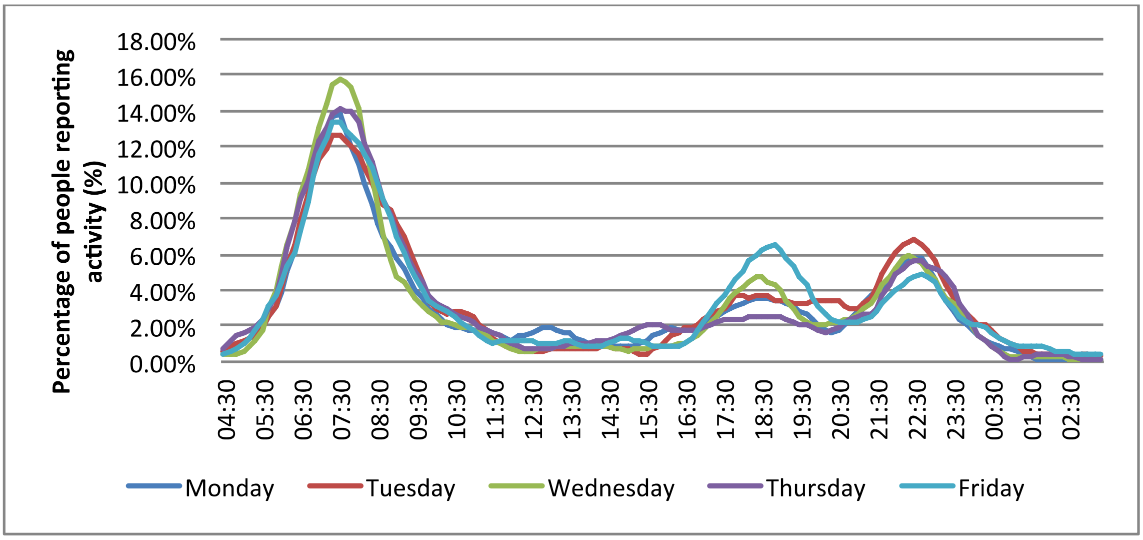

Figure 4. *Centred average percentage of washing throughout the day on weekdays*

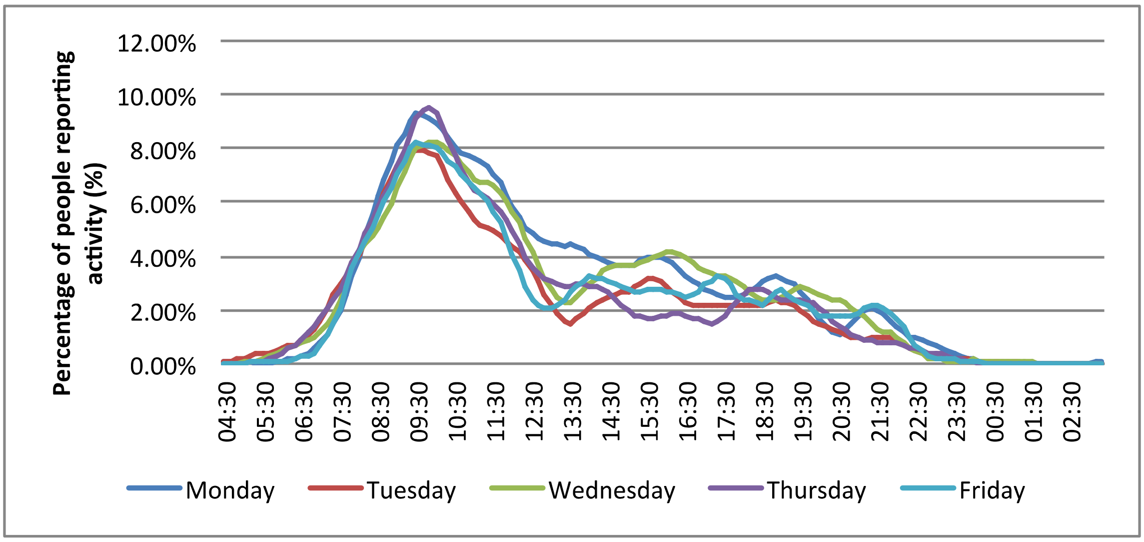

Figure 5. *Centred average percentage of cleaning throughout the day on weekdays*

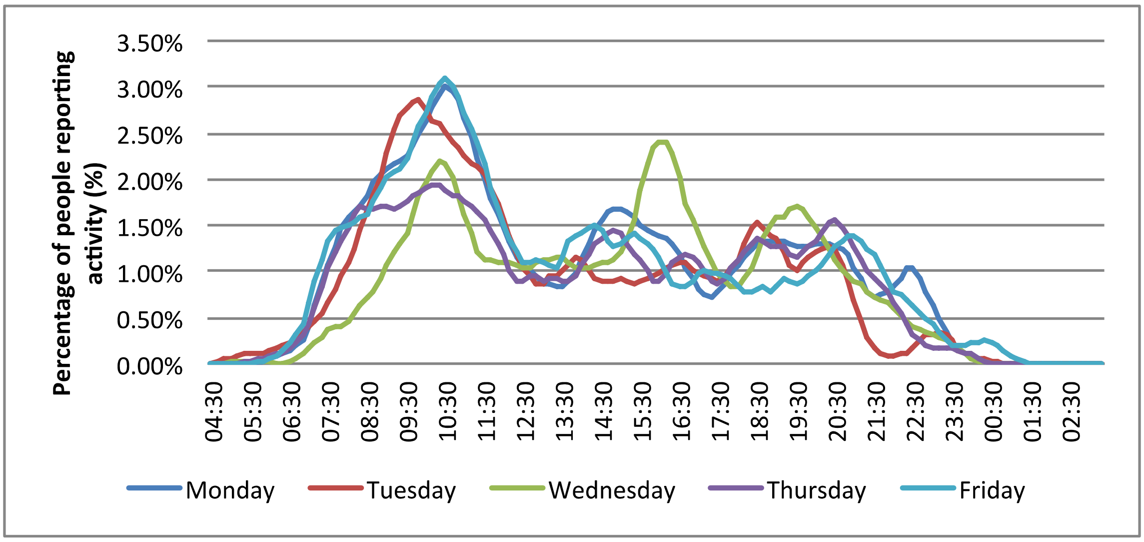

Figure 6. *Centred average percentage of washing clothes throughout the day on weekdays*

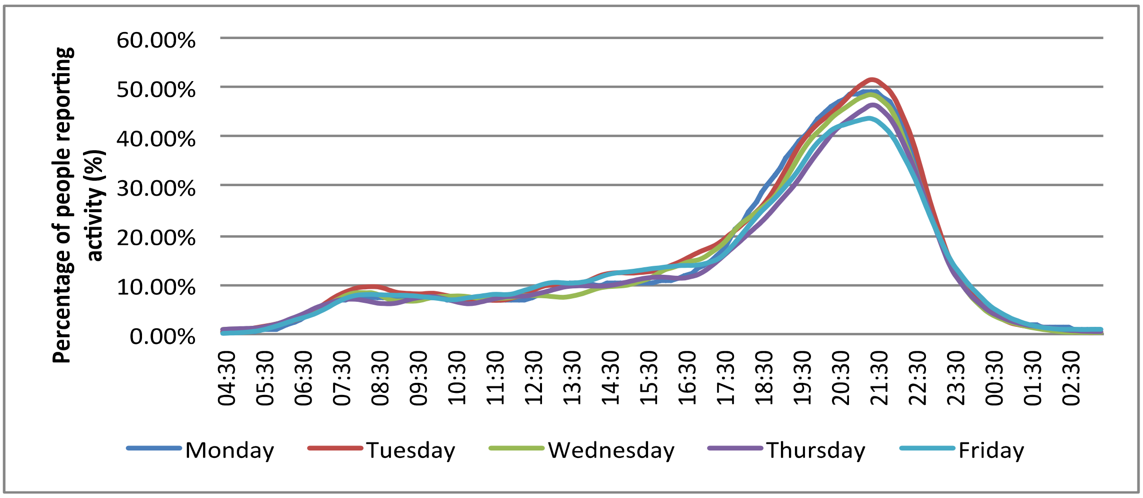

Figure 7. *Centred average percentage of watching TV/listening to radio through the day on weekdays*

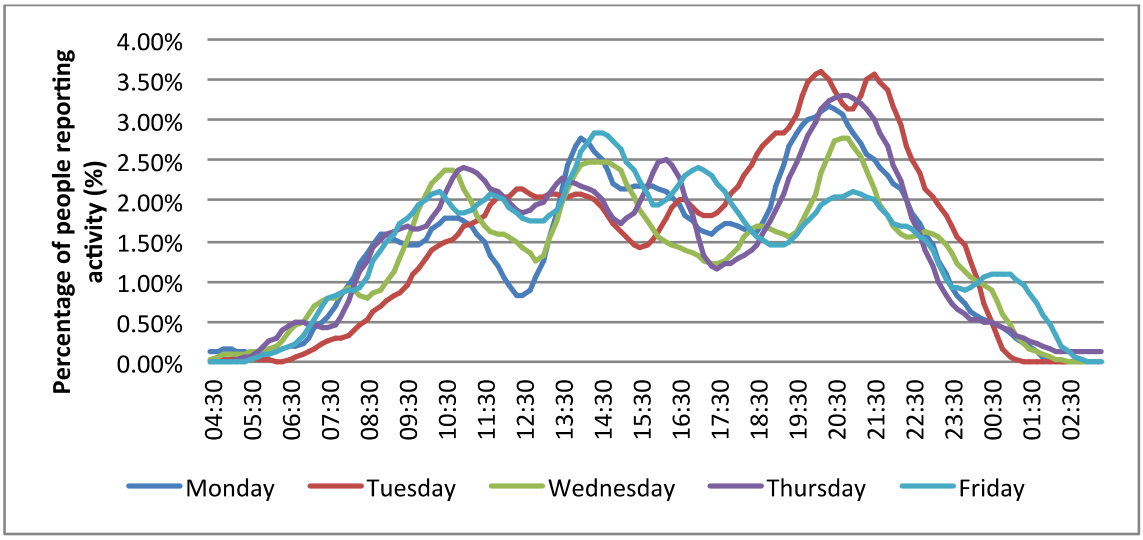

Figure 8. *Centred average percentage of using a computer throughout the day on weekdays*

	Preparing food			Washing			Cleaning			Washing clothes			Watching TV			Computer use			
	σ	MAX	T_{DEP}	σ	MAX	T_{DEP}	σ	MAX	T_{DEP}	σ	MAX	T_{DEP}	σ	MAX	T_{DEP}	σ	MAX	T_{DEP}	σ(T_{DEP})
Monday	25.24	86.67	3.63	22.80	94.89	4.49	19.49	71.84	3.69	5.94	16.33	2.39	104.06	359.11	3.67	6.99	13.95	1.48	108.8
Tuesday	22.84	82.27	3.50	23.48	103.35	4.53	15.79	62.26	4.09	5.90	24.37	4.06	104.57	374.62	3.67	8.24	29.96	2.99	53.8
Wednesday	22.19	81.34	3.58	27.20	129.14	5.94	17.51	60.47	3.33	5.27	22.55	3.93	99.15	352.85	3.71	6.07	21.61	2.42	116.4
Thursday	20.55	72.49	3.46	25.39	119.90	5.37	18.07	72.85	4.47	4.82	16.46	2.80	91.85	342.20	3.80	7.14	24.92	2.51	106.5
Friday	19.25	71.54	3.52	24.05	113.28	4.88	16.84	65.95	4.04	5.90	23.02	3.42	89.77	316.57	3.38	6.11	21.70	2.22	87.4

Table 2. *Standard Deviation, MAX Deviation and MAX Deviation/average for weekdays*

Table 2 shows standard deviation, maximum deviation and time dependence for different weekdays. Different practices present dissimilar standard variations, maximum deviations and time dependences during the week. For example, Watching TV has the highest standard deviation and maximum deviation, whereas washing clothes has low standard deviation and maximum deviation around the whole week.

Washing, cleaning and washing cloths have the highest time dependence and this coincides with Tuesday, Wednesday and Thursday. A simple sum of T_{DEP} for all practices shows that overall Tuesday, Wednesday and Thursday are the weekdays with the highest overall time dependence for all six practices.

Across all practices time dependence varies the most on Thursday, meaning that some practices on this day of the week are extremely time dependent while others are not.

5. Does time dependence change with the season?

Figures 9 to 14 show practices variation across the months of February, June, September and November. The patterns of dependence for preparing food, washing, cleaning and watching TV are similar to those in Figure 1. There is evidence of time dependence for washing clothes and using the computer, which are characterised by patterns that are more erratic across the four months.

Time dependence is lowest in June for all practices apart from washing clothes. In June, the peak in evening time dependence is 4% lower than in February. This reduction in peak increases to 6% between June and both February and November. June has the lowest peak of washing/dressing.

Overall these results point to high seasonality of social practices. Findings are consistent with the known seasonal patterns in energy demand (i.e. highest in winter and lowest in summer). In this analysis on the seasonality of social practices, there is a clear reduction in the peak of energy-related social practices. The evidence suggests that lower volumes and reduced peakiness of social practices may contribute to the reduction in electricity demand in summer periods.

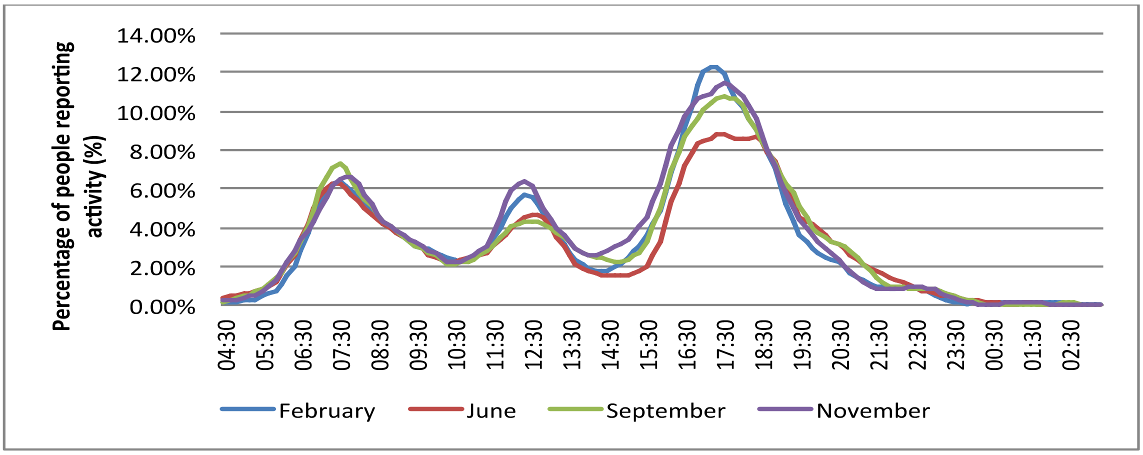

Figure 9. *Centred average percentage of preparing food throughout the day in February, June, September and November*

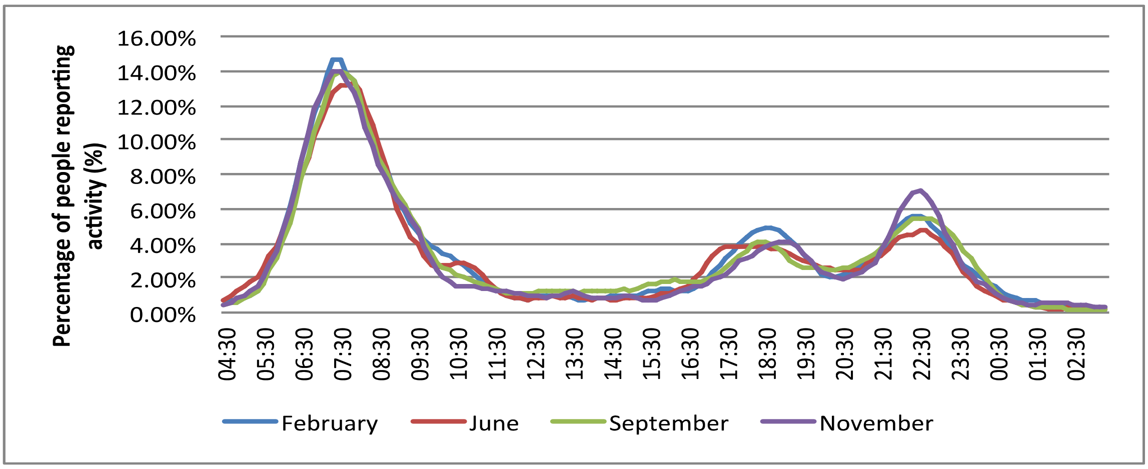

Figure 10. *Centred average percentage of washing throughout the day in February, June, September and November*

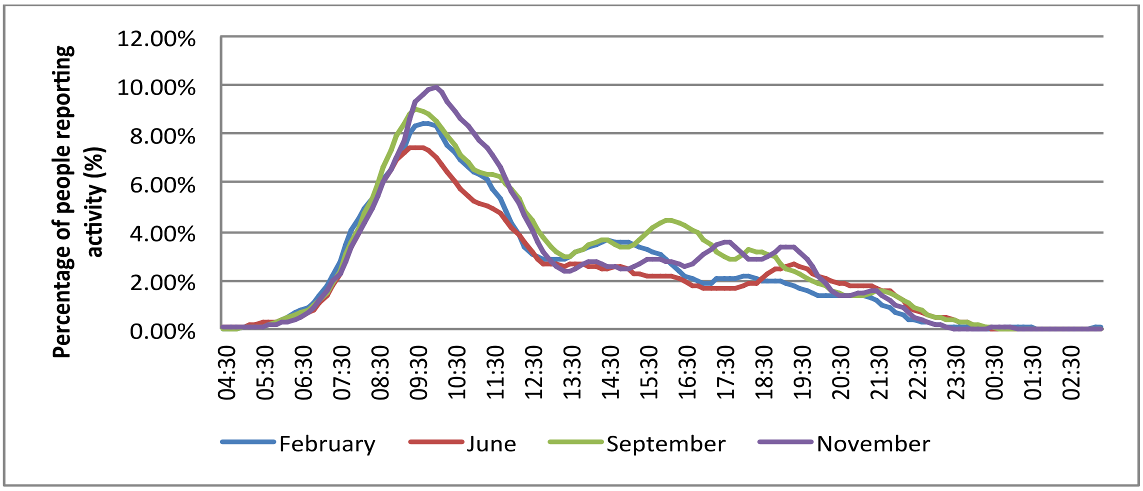

Figure 11. *Centred average percentage of cleaning throughout the day in February, June, September and November*

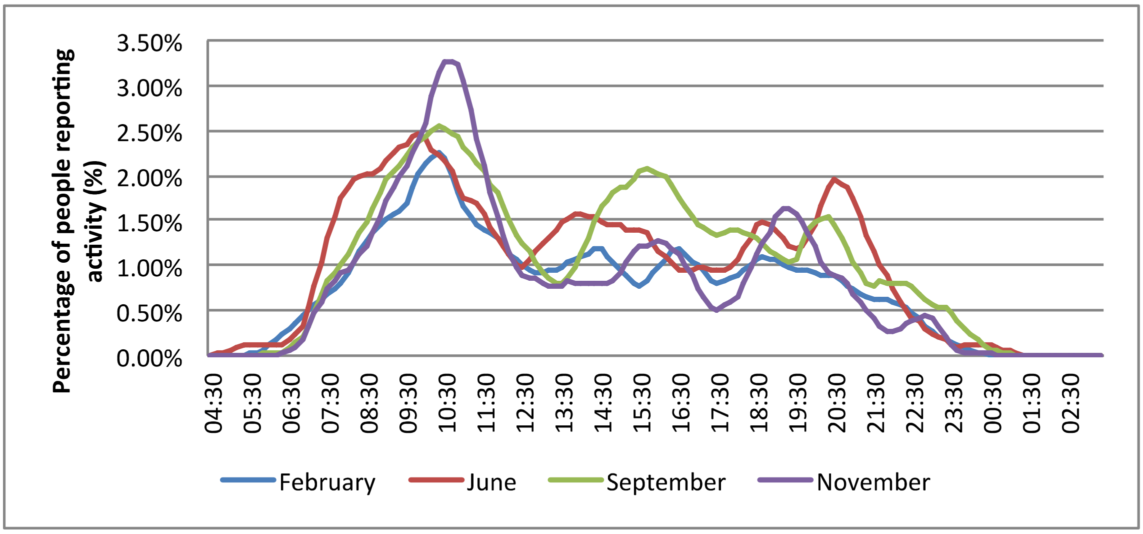

Figure 12. *Centred average percentage of washing clothes throughout the day in February, June, September and November*

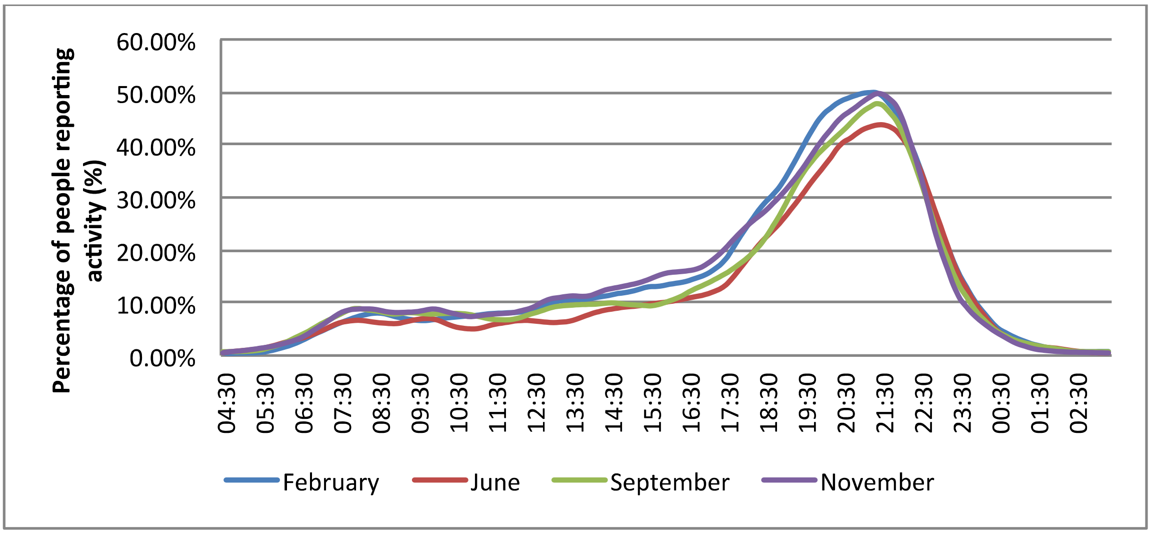

Figure 13. *Centred average percentage of watching TV/ listening to radio throughout the day in February, June, September and November*

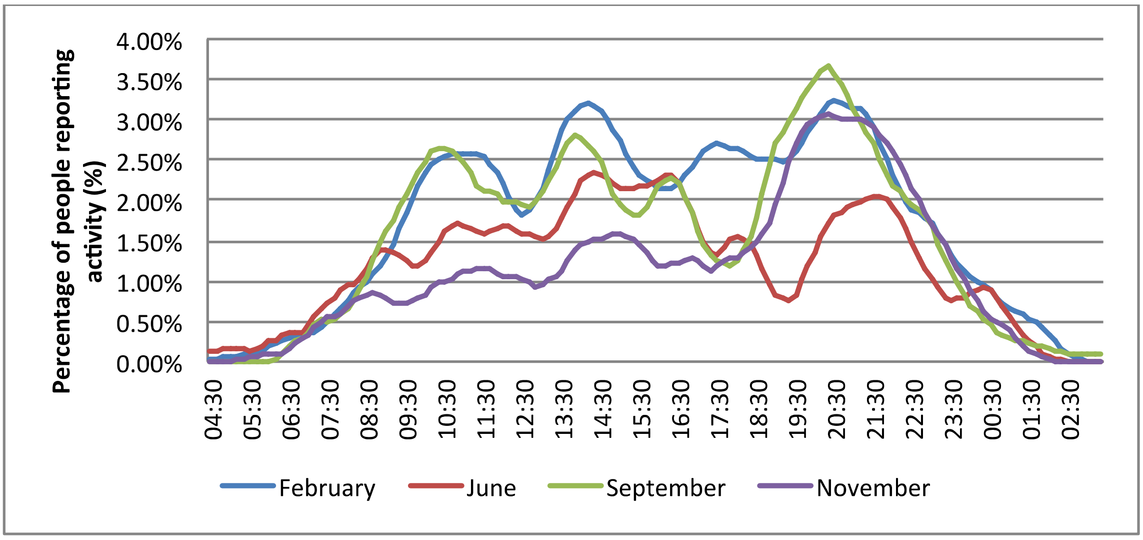

Figure 14. *Centred average percentage of using a computer throughout the day in February, June, September and November*

	February			June			September			November			
Practice	**Standard Deviation**	**MAX Deviation**	**T_{DEP}**	**Standard Deviation**	**MAX Deviation**	**T_{DEP}**	**Standard Deviation**	**MAX Deviation**	**T_{DEP}**	**Standard Deviation**	**MAX Deviation**	**T_{DEP}**	**$\sigma(T_{DEP})$**
Preparing food	24.08	92.54	3.56	27.37	101.81	3.56	29.22	108.03	3.61	108.05	411.32	3.67	4.9
Washing	29.32	135.64	5.02	29.78	138.94	4.97	31.02	141.57	5.16	120.08	550.14	4.95	9.3
Cleaning	21.30	82.41	4.07	18.54	70.04	3.73	23.03	82.34	3.48	24.51	103.09	4.54	45.9
Washing clothes	5.39	22.91	3.51	6.99	25.51	2.96	7.28	25.56	2.88	7.57	34.98	4.88	92.7
Watching TV	132.19	324.46	2.55	113.63	299.62	2.81	118.33	317.28	2.75	125.89	325.54	2.58	12.7
Using computer	9.91	15.53	1.05	6.75	13.76	1.34	9.91	21.66	1.63	8.06	19.42	2.00	40.3

Table 3. *Standard Deviation, MAX Deviation, MAX Deviation/average for months of February, June, September and November*

Table 3 formalises statistically time dependence of practices across seasons by showing the Standard Deviation, Maximum Deviation and time dependence for the months of February, June, September and November. The highest standard deviation is for watching TV in November, indicating that this practice is particularly spread out in November. Watching TV has consistently high Standard Deviation throughout the different seasons. The lowest standard deviation by seasons is for washing clothes in February. This means that at that time of the year washing clothes is more concentrated around the mean. Computer use has consistently low standard deviation and also the lowest time dependence around February. Computer use has in general the lowest time dependence for every season. This indicates that computer use is not dependent on the hour of the day for most season. TV watching has the second lowest Time Dependence, despite the fact that it is associated with the highest Maximum Deviation in November, partly due to the high volumes of minutes. This means that there is a significant high time dependence of TV watching in the afternoon/evening times, low variation across seasons and yet low overall time dependence over the 24 hours of the day because of the amount of hours associated with TV watching.

Washing clothes has significantly the highest dispersion of Time Dependence across seasons. This means that time dependence varies the most across seasons. Cleaning and computer use also have high levels of seasonality variation. This can be explained by the fact that, for instance, cleaning has a low time dependence in June compared with November. Although preparing food has a relatively high time dependence in terms of the time of the day, it has the lowest seasonal variation.

6. Conclusion

This work studies the relationship between a set of social practices and the time of the day with a view to understand how time-dependent social practices are and how time dependence varies according to days of the week and seasons. By putting emphasis on time dependence and practices, findings highlight times of the day which are linked to practices. The latter are the real independent variable of this analysis. For this reason, this analysis avoids any breakdown into socio-demographic groups, but treats practice carriers equally.

Because the choice of social practices is restricted to their relationship with energy demand in the home environment, the scope of this work has obvious limitations. Practices are not performed in isolation and by treating them individually some of the dynamics of everyday life might be missed. For instance, in real life non-household related practices (e.g. associated with mobility) carry a weight which is at least as significant for understanding both practice complexities and volumes of energy demand as the household practices which were analysed in this work. The choice of the dataset also poses limitations as the analysis is (statistically) significant for the UK in 2005. Time dependence, as measured in this work, is a concept as changeable as time is (Breedveld, 1998). Not only practices change over time, but so does their temporal attribution. Hence, representations of practice performance as captured in the time use studies are linked to methodological biases in coding, interpretation and reporting. Changes in rhythms could be internally produced or externally sourced from technological and social agents.

One of the highest conceptual challenges embedded in the analysis presented in this paper is that it implies dependence, which could be interpreted as some level of causality between time and social practices. Social practices vary not only from one location to the next, but also in time. The presence of space dependence (i.e. the fact that practices vary depending on locations, countries, etc.) allows for scope conditions, including time dependence. The existence of scope conditions does not imply that all social processes typically have standard causal configurations from which deviations can be gauged. Methodological positivism takes for granted the space and time independence of social mechanisms, assuming that causal mechanisms are invariant across time and space (Steinmetz et al, 2002). On the contrary, this work acknowledges the role of time in ordering practices when measuring rhythms and the potential for creating dependence according to the measurements of time, which may not be defined in nature, but are processed by the space and time in which practices are performed.

Examples of the changing temporal and spatial rhythms of social practices (i.e. 'timespace') abound in the literature: the move from lower frequency and higher duration bathing to higher frequency lower duration showering, the change in patterns of consumption in Turkey associated with the import of teabags, and the diverse eating timings and durations in different countries. However, the work on the measurement of rhythms in terms of time dependence is not very developed.

Both conceptual and methodological challenges explain why time dependence of social practices has seldom been operationalised in empirical research. An exception consists of the qualitative analysis presented by Southerton (2006), in which the temporal rhythm of the day is characterised by practices which hold a fixed position in time. This work focused solely on time dependence (controlling for space dependence by including within the scope of the analysis only household-related practices). The ambition is to aid the definition of what is flexible in energy demand by stressing the importance of searching in the realm of collective practices rather than individual behaviour. Correspondingly, interventions through social and technological agents aimed at increasing the flexibility of energy demand may be more effective if they engage with the time dependence of practices and not only price intervention for individual households.

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