Does the Daylight Savings Time Causes People to Change More than their Clock?

Sanjukta Basu

November 14, 2019

Abstract

The Daylight-Saving Time (DST) has a long and controversial history, in regard to both its implementation and main intent. This paper attempts to take advantage of the natural experiment created by DST twice a year to study how individuals are affected by an arbitrary change in clock. I study how individuals' respond to the DST by adjusting their daily schedules when the clock changes. The main findings are - first, individuals are affected by the DST change which is reflected in their time engagement in activities of various intensity. Second, retired individuals are more affected than the working population even though they have more flexible daily routines. Third, disabled population increase light-moderately intensive activities, but their sleep and relaxing schedules are unaffected. Fourth, comparing two states with similar geographical and climatic conditions - Arizona and New Mexico but opposite DST law provides an interesting case study.

1 Introduction

The First World War created a law which forced citizens to change their clocks twice a year. This law was known as the Daylight Savings Time in the USA. Canada first introduced the concept as early as 1908 in some provinces. Germany and Austria were the first to implement DST throughout their countries. Over the years, the main intent of the law, namely, to save energy, was lost.

DST has been in discussion among policymakers in the recent past. After the results of an online poll, the European Union is in consideration to remove DST. Many states in the US, like Florida, California, Oregon and Louisiana, are also taking measures to re-evaluate the need of DST in their constituencies.

My paper is appropriate in the current policy horizon. I study how the change in clocks, bi-annually, changes people's behavior in the first few days. Though the clock changes by one hour only, everyone is forced to re-adjust their internal clock twice a year as a result. I study how daily time schedules change for individuals who are subjected to it. I also study if there is any change in their mood or well-being indicators.

In the US, all states except Arizona and Hawaii change their clocks twice a year to follow the daylight savings time. Indiana did not have daylight savings before 2006. They adopted the policy in 2006 and started changing the clock twice a year. I use the American Time Use Survey (ATUS) for analyzing DST in the USA. My sample of study is limited to those respondents who were interviewed within a week, before and after, the change in time due to DST, both spring and fall.

I find that there is a significant change in individuals' behavior when subjected to the DST change twice a year. Sedentary activities, such as sleeping, relaxing, driving, etc. decline by 30 minutes after the springtime change and 50 minutes after the fall DST. The spring clock change induces individuals to spend more time in light intensity activities. In the fall, these individuals increase vigorously intensive activities but reduce light intensive tasks. I find the opposite effect in the spring. Retirees are more intensely affected than the working population. Lastly, I compare Arizona and New Mexico. Both states are geographically and climatically similar, but Arizona does not have DST while New Mexico always adopted the law. I find New Mexicans reduce sedentary activities during spring but increase during fall. They also claim to be more stressed during spring as compared to Arizonians after the implementation of DST.

I find a difference in pattern of behavior between the control and the treated states when I study all 50 states vis-a-vis comparing only Arizona and New Mexico. This could be due to the lack of sufficient number of control groups as compared to the number of treatment groups in the larger sample of study. To solve this, I will try other methods such as the Conley-Taber method in the future.

2 Background

Daylight saving time (DST), also known as Summer Time in some countries, is the practice of advancing clocks during the summer months so that evening daylight lasts longer. Typically, regions that use daylight saving time adjust clocks forward one hour close to the start of spring and adjust them backward in the autumn to standard time. These regions follow the standard time during the winter months. DST has been used in the USA and in many European countries since the World War I.

The DST plan was formally adopted in the USA in 1918 when standard time zones were established. After the war ended, it was repealed in 1919. During World War II, year-round DST was instituted again from February 1942 to September 1945. After World War II, there was no federal law regarding DST and states and regions were free to choose whether or not to observe DST. This caused confusion, especially in many industries such as broadcasting, transportation and others in those who required to coordinate with other countries. In 1966, the Uniform Time Act established a system of uniform (within each time zone) Daylight Saving Time throughout USA and its possessions, exempting only those states in which the legislatures voted to keep the entire state on standard time [1].

DST is used to match activity peaks of a population with the daylight hours. The major underlying purpose of implementing and extending DST in USA and other European countries is energy conservation. However, recent research in fields of energy, has shown that DST does not reduce energy consumption but can actually increase it. Aries & Newsham (2008) conducted a literature survey on the effect of DST on saving energy around the globe. They found mixed evidence. They conclude that while some studies are able to show no significant reduction in energy use, others concluded a slight but statistically significant reduction in energy consumption. They also show that some studies found a rise in fuel consumption and recreational traffic. Kotchen & Grant (2011) takes advantage of a natural experiment in the state of Indiana to provide the first empirical estimates of DST effects on electricity consumption. They found that DST increased residential electricity demand.

Economists have shied away from the discussion of DST resulting in a lack of sufficient literature. However, other fields of study have been analyzing the role of DST on various aspects of the economy. Kotchen & Grant (2011) shows that the role of DST in energy consumption is inefficient. However, the influence of DST

[1] http://www.webexhibits.org/daylightsaving/e.html

extends much beyond energy consumption to health (Lahti *et al.* (2010)), traffic (Varughese & Allen (2001)), leisure and labor productivity.

Varughese & Allen (2001) shows that there was significant increase in automobile accidents for the Monday immediately following the spring DST. The authors believe sleep deprivation is a major reason behind the increase in road fatalities. Lahti *et al.* (2010) showed that transition into and out of DST cause minor jet lag symptoms such as sleep disruption, cardiac rhythm fragmentation and change in fatigue. They show that though social timing changes instantly, bodily timing changes more slowly. They found that the impact of DST, though mild, is significant for patients suffering from seasonally affecting disorder, bipolar disorder or chronic sleep loss. Other studies in the medical literature show that disruption in sleep pattern detriments well-being (Short *et al.* (2013) and Gallicchio & Kalesan (2009)).

Hamermesh *et al.* (2008) and Hamermesh *et al.* (2006) show that the effect of DST goes beyond those who are subjected to it directly. Individuals who live in regions that do not have DST are also affected as they alter their timing of work to synchronize activities more closely with those subjected to DST. My study aims to provide a holistic impact of daylight savings on individuals who are subjected to it as well as those who are not using individual data.

DST has been a topic of discussion for policymakers currently. Netherlands gathered a petition for DST abolition in March 2017, joined later by Finland in January 2018. Finland had called for its abolition across the EU in January 2018, after gathering a petition of more than 70,000 people calling on its government to stop the practice earlier in the same year. In March 2017, Netherlands petitioned for the same to the European transport commissioner[2]. The European Parliament

[2] http://www.euronews.com/2018/03/22/no-change-likely-to-eu-clock-change-rules-despite-strong-opposition

voted on February 8, 2018, to ask the European Commission to re-evaluate DST in Europe. An online consultation, ran by the Commission, showed that more than 80 percent of the participants do not want to change clocks anymore[3]. This online poll received the highest number of responses ever in any Commission public consultation. Based on the results, the Commission proposed to eliminate the bi-annual clock changes in the European Union in 2019.

Not far behind the European Union, certain states in the US have joined the discussion on abolition of DST. The Florida senate passed the Sunshine Protection Act in March 2018 to keep the daylight saving time all year-round and abolish the bi-annual clock change [4]. In November 2018, California also voted to allow the state to make the DST year round and remove the bi-annual clock change. Louisiana State Legislature approved a resolution in May 2018 to study whether Daylight Saving Time or standard time is best for the state. Recently, Oregon, Idaho and Washington have introduced bills in their respective legislatures to end the twice a year clock changes [5]. In 2015, a house bill was filed to end DST in the state of Washington, however, it was defeated.

3 Data

Data on time diaries is obtained from the American Time Use Survey (ATUS). The dataset is limited to observations recorded a week before and after the daylight savings time change, both in the fall and the spring. I drop all observations which do not meet the above requirement.

[3] http://europa.eu/rapid/press-release_IP-18-5302_en.htm

[4] https://www.nytimes.com/2018/03/08/us/daylight-saving-time-florida.html

[5] https://www.argusobserver.com/news/daylight-savings-bills-lawmaker-hopeful-for-coordination/article_47d6e102-2cd7-11e9-a172-4fcbdc7cfbf3.html

The American Time Use Survey (ATUS) is administered by the Bureau of Labor Statistics (BLS) from 2003 to 2017. It measures the amount of time people spend in different activities from 4 AM of the previous day to 4 AM of the interview day (Hofferth & Sobek (2018)). It is a nationally representative survey done via telephone interviews to a selected sample of Current Population Survey (CPS) respondents. Since ATUS respondents were interviewed in CPS before, I can identify individuals state of residence, sociodemographic and socioeconomic characteristics.

The main advantage of this dataset is that ATUS contains detailed information regarding the amount of time an individual spends engaging in various activities. Along with the time diaries, the data also provides the metabolic equivalent (MET) value associated with the ATUS primary activity codes. This is an activity-level variable. Tudor-Locke *et al.* (2009) linked MET value with each activity collected in the ATUS data. Based on this information, I can measure the level of activity an individual does, more accurately, in a certain amount of time and categorize by their level of strenuousness. I categorize activities into three main groups: sedentary (MET value is below 1.5) which includes activities such as sleeping, relaxing, watching TV, reading, etc. (Mansoubi *et al.* (2015)); light intensity activities (MET value between 1.5-3) such as slow walking, strolling, shopping, etc.; and moderate to vigorous intensity activities (MET value above 3) includes brisk walking, hiking, jogging, soccer game, etc.

Some states in the USA do not follow DST, namely Arizona and Hawaii. Indiana implemented DST after 2006. I view these states as the control group in the analyses for the US. I use the Difference-in-Differences estimation technique for analyzing the impact of DST on daily time schedules.

To study the impact of DST more intensely, I compare two states which are similar geographically and climatically but differ in terms of the implementation of the DST law - Arizona and New Mexico. Arizona never had DST while New Mexico implemented it in 1966 when the Uniform Time Act was introduced in the country. Both states are very similar in size and situated on the same latitudinal gradient.

The final sample consists of 262,931 for the whole population and 6757 for Arizona and New Mexico combined, who have recorded their responses a week before or after the daylight savings change in the fall or the spring.

4 Empirical Strategy

I will be testing the effect of the daylight savings time on two groups of outcomes: mood and well-being indicators, and the metabolic equivalent (MET) value associated with activities as given in the ATUS. I use a difference-in-differences estimation approach for this analysis.

First, I study the change in time spent in activities grouped by their MET value as a result of the daylight savings time. Daily activities are grouped into three groups based on the MET value - sedentary (MET value < 1.5), light intensity activities (MET value between 1.5 and 3.0) and medium to vigorous intensity activities (MET value > 3.0). I use the following equation

$$duration(metcategory)_{ijst} = constant + \beta Postxtreated_{it} + \rho X_i + \gamma_t + \delta_s + \eta_j + \epsilon_{ist} \tag{1}$$

where, $duration(metcategory)_{ijst}$ gives the total time spent doing activities which has a MET value defined as sedentary (met value below 1.5), light (met value between 1.5 and 3.0) or medium to vigorous activity (above 3.0), for individual i, interviewed on day j, for state s and year t. Other variables include $Postxtreated_{ist}$ is the interaction term and the coefficient of interest depicting the DID estimate; X_i indicates individual characteristics: age, race, sex, education level and employment status; γ_t gives the year fixed effects; δ_s gives the state fixed effects; η_j gives the dummy for the day of the week, j of the interview; and ϵ_{ijst} gives the error term.

Second, to study the change in the self-reported well-being indicators, I use the following difference-in-differences equation. ATUS provides the self-reported mood indicators scaled from 0-6 where 0 is the lowest scale for the particular emotion and 6 is the highest. This data is reported for only three years in the dataset - 2010, 2012 and 2013.

$$w_{ijst} = constant + \beta Postxtreated_{it} + \rho X_i + \gamma_t + \delta_s + \eta_j + \epsilon_{ijst} \tag{2}$$

where w_{ijst} indicates the change in welfare indicator variable - namely happy, sad, stress and tired. All these scales are measured from 0 to 6. With 0 being the lowest and 6 highest. Rest of the terms are same as equation 1.

5 Results

Although daylight savings changes the clock twice a year, the nature of the time change is different in fall and spring. In the fall, the clock is moved back by 1 hour. The length of the day increases as there is an extra hour obtained. While during spring, daylight savings time takes away an hour as the clocks are moved forward by 1 hour. To capture this difference, I study the impact of Daylight Savings Time on individuals subjected to it in the fall and spring, respectively.

Metabolic Equivalent

I divide the total time spent in various activities into three groups based on their MET value - sedentary (MET value below 1.5), light-intensity activities (MET value between 1.5-3.0) and moderate to vigorously intensive activities (MET value above 3.0). Table 1 shows the estimates from equation 1. In the fall, individuals subjected to DST reduce time spent in sedentary activities such as sleeping, relaxing, watching TV, etc. by 50 minutes, and in light intensive activities such as strolling, walking slowly, etc. by 68 minutes. However, individuals increase their moderate to vigorously intensive activities such as jogging, swimming or hiking. The fall DST shifts the clock behind allowing people to now have a longer day suddenly. The sun rises earlier, and it gets darker soon than a few days before. People feel more energized and it is reflected in the extra time they choose to spend on vigorous-intensity activities.

The clock moves forward in the spring and people loses one hour. The day starts earlier, and it gets darker later than before the DST change. My results show that people reduce 30 minutes of sedentary activities and 50 minutes of moderate to vigorously intensive activities after the time change in spring but increases 40 minutes of light intensive activities. As the clock is moved forward, people now wake up earlier than usual even though the clock time is the same as before. People feel more tired which is reflected in the decline in engagement in rigorous activities.

Lastly, I combine the data for the spring and fall DST change. I find that any change in clock reduces time spent in sedentary activities by 50 minutes and light intensive activities by 15 minutes. There is no change on time spent in more intensive activities. All regression estimates are statistically significant at one percent level of significance.

Mood Behavior

Table 2 gives the regression estimates from equation 2. I find that the fall time change makes people happier, more stressed and tired but less sad. In the spring, people also report to be more happy and tired but less sad and stress. However, none of the regression estimates are statistically significant at conventional levels. I am unable to conclude if and how the respondents moods are influenced by the change in clock.

Working vs Retired Population

Working population (those within the age of 15-65 years) are expected to follow a daily routine which is fairly rigid due to a work schedule. I expect these individuals to behave differently than those who are retirees and have more flexible routines. Table 3 gives the estimates from equation 1 for a subset of the population within the working age group. The fall DST change causes a decline in time spent engaging in sedentary activities by 35 minutes and light intensive activities by 77 minutes but increases vigorously intensive activities by 75 minutes. In the spring, time moves 1 hour forward causing individuals to reduce sedentary activities and increase light-intensity activities. Any time change, given by row 3, causes a fall in time spent engaging in sedentary activities by 46 minutes, light to moderate intensity activities by 22 minutes and gain in vigorous exercise time by 48 minutes. These regression estimates are statistically significant at conventional levels.

Table 4 gives the regression estimates for the retired population (those above 65 years of age). I find that these individuals are more susceptible to DST than the working population. In fall, the retirees lose 166 minutes of sedentary activities and gain almost an hour of light-intensive activities. The spring clock change leads to a gain in light intensive activities by 83 minutes and a fall in moderate to vigorously intensive activities by 2 hours. Row 3 shows that any change in clock reduces sedentary activities by a little more than 1 hour and vigorous intensive chores by 1 hour, and gains light-intensive tasks by 77 minutes. All regression estimates are statistically significant at conventional levels.

My results show that although the working population has a more rigid routine, the retirees are affected more due to the clock change. This could be due to them being older and suffering from health complications as a result of age causing them to adjust more slowly to the clock change than the working population who are much younger. It is more difficult for retirees to adjust to the time change and continue with their daily schedule after DST.

Disabled Population

In this section, I look closely at those individuals who have reported to have a disability. I include all individuals who have responded affirmatively to possess any difficulty such as serious vision or hearing impairment, restrictive mobility (such as walking and climbing stairs), cognitive struggle (such as remembering, concentrating or making decision), or any other physical or mental condition which lasted over 6 months and requires the individual to seek assistance for their own personal needs. I find that these individuals increase light intensive activity by 2 hours in the fall. This estimate is statistically significant at conventional levels. The change in sedentary and vigorous chores are statistically insignificant. In the spring, they increase light intensity tasks by 2 hours and moderate to vigorously intensive tasks by almost 3 hours. Row 3 shows that any change in DST, whether spring or fall causes a fall in sedentary activities by 131 minutes, and an increase in light and moderate to vigorous activities by 108 and 134 minutes, respectively. These regression estimates are statistically significant at conventional levels.

5.1 Comparing Arizona and New Mexico

Arizona and New Mexico are neighboring states with very similar climatic and geographic conditions. They are within the same latitude. The average weather is very hot and dry in the lowlands and cooler in the mountainous regions. Arizona enacted the DST exemption status in 1968 and has not observed DST since then. Historically, New Mexico has always had DST. Comparing these neighboring states to study the effect of DST on its citizen is very useful. I compare these two states where Arizona serves as a control state and New Mexico is the treated state.

Metabolic Equivalent

Table 5 gives the regression estimates for equation 1 focusing only on Arizona (as the control state) and the New Mexico (as the treated state). The fall DST change causes citizens in New Mexico to increase sedentary activities by 70 minutes and moderate to vigorous-intensive tasks by 160 minutes and reduce light activities by 104 minutes as compared to Arizona. These estimates are statistically significant at conventional levels. In spring, the clock change causes a fall in time spent engaging in sedentary activities such as sleeping and relaxing by 78 minutes. This estimate is statistically significant at one percent level of significance. Light and vigorous activities decline by 24 and 21 minutes, respectively. However, these estimates are statistically insignificant at conventional level.

Overall, any change in time, as given in row 3, reduce light intensive activities by 50 minutes. It has no effect on sedentary or vigorous tasks.

Mood Behavior

Table 7 gives the estimates from equation 2 but only for Arizona and New Mexico where New Mexico is subjected to DST twice a year while Arizona is not. Mood indicators are only collected for 3 years in my data explaining the small number of observations. I find that the fall time change makes people happier, less sad and stressed as compared to those interviewed a week before the time change. Individuals report almost 3 points higher on the happiness scale, 3 points lower on stress and sadness scale after the time change. These estimates are statistically significant at 1 percent level of significance. Individuals also report to be less tired, but this estimate is statistically insignificant at conventional levels. The springtime change causes people to lose 1 hour from their day. These individuals report to be less happy, more sad, stressed and tired as compared to those interviewed before the time change. All estimates except the one for the stress scale are statistically insignificant at conventional levels. The spring DST causes individuals to report 2 points higher on the stress scale. My results conclude that the fall DST makes people happier, more relaxed and less stressed while the spring DST reports increased stress due to the sudden fall in the number of hours in a day which takes a while for adjusting.

Working Population

Working population have a more inflexible daily schedule due to office commitments, childcare routines, etc. I use equation 1 to study the impact of DST on the working population of New Mexico as compared to those in Arizona. I find that the fall DST change increases sedentary activities by 90 minutes and moderate to vigorously intensive activities by almost 3 hours. However, there is a fall in chores which are categorized as light-intensive (MET value between 1.5 to 3.0) by little less than 3 hours. These estimates are statistically significant at 1 percent level of significance.

In the spring, the DST causes a fall in sedentary activities by approximately 2 hours and has little to negligible impact on time spent on more intense chores. These estimates are statistically significant at conventional levels. These results support the pre-assumption that individuals subjected to the fall DST feel more relaxed and energized due to the extra hour they perceive to receive in the day. They relax and sleep more while intensifying their exercise routine. I find the opposite effect in the spring. People lose relaxing and sleeping time but does not change time spent on more intensive activities which may be more unchangeable in their daily schedule.

I do not have enough observations to test for the retiree and disabled population.

6 Conclusion

A government policy passed decades ago, forces every citizen in some countries, around the world, to change their clocks twice a year; once in spring and then again in fall. In the spring, the clock moves one hour forward. We lose one hour in the day. In the fall, the clock moves one hour back. We gain one extra hour. This is a practice of advancing clocks during summer months so that evening daylight lasts longer, while sacrificing normal sunrise times. The policy was introduced in the US during the World War I to conserve energy during wartime and give longer daylight. Existing literature (such as Kotchen & Grant (2011) and Aries & Newsham (2008)) shows that contrary to the intent of the policy, DST has not been successful in reducing energy consumption in the modern world.

My research attempts to study how the change in time caused by DST impacts individuals' day-to-day schedules and moods. I use various outcome variables such as sleep pattern, labor productivity, exercise pattern, well-being and mood indicators such as happiness, sadness, tiredness and stress scale. I classify daily activities into groups based on their MET values - sedentary (MET Value < 1.5), light-intensive (MET Value (1.5-3.0)) and moderate to vigorously intensive activities (MET Value > 3.0). I use the ATUS to study the DST change in the USA. I find that respondents reduce sedentary and light intensity activities and increase more intensive tasks after the fall DST implementation and increase light intensity activities while reducing sedentary and vigorous tasks after the spring DST implementation.

Retired individuals have a larger impact than the whole population or working age group from a DST change. They are older than the working age group and hence prone to more age-related health complications. This makes it difficult for individuals in this age group to adjust to the sudden clock change. In the fall, they reduce sedentary and moderate to vigorous activities by 4.5 and 3.6 hours, respectively. Light intensity activity increases. In the spring, these individuals only reduce high intensity activities. Similarly, disabled individuals also increase light intensity activities after DST change in both spring and fall. In the spring, they reduce high intensity activities by 2.2 hours.

For a more appropriate analyses, I compare two states which are geographically similar and belong to the same latitudinal position, but one has been following DST while other never had it - Arizona and New Mexico. Arizona never implemented DST while New Mexico did as early as 1966 when the Uniform Time Act was introduced in the country. I find significant difference in behavior of individuals in New Mexico as compared to Arizona after DST. The fall DST causes individuals in New Mexico to spend more than 1 hour engaging in sedentary activities such as sleeping and relaxing as compared to those in Arizona. In the spring, there is a fall in time spent in relaxing and sleeping by 78 minutes. Fall DST causes individuals to be happier and, less sad and stressed while spring DST increases stress but does not impact happiness or sadness scale. The impact on the working population is more severe than the whole population.

DST is an archaic law which does not produce the intended impact on energy consumption. However, it disrupts individuals' daily life twice a year causing them to change their schedules and adjust to the new clock. Individuals are forced to reprogram their internal clock twice a year. Some state governments, such as Florida, California, Oregon, etc., are discussing the removal of DST. While in Europe, the European Commission was asked to re-evaluate the DST in the spring of 2018. An online survey of citizen showed high support to remove DST. These instances show that individuals subjected to this policy wants it removed or repealed. My study makes a case in favor of the repeal of the DST law in the USA.

References

Aries, Myriam BC, & Newsham, Guy R. 2008. Effect of daylight saving time on lighting energy use: A literature review. *Energy policy*, **36**(6), 1858–1866.

Gallicchio, Lisa, & Kalesan, Bindu. 2009. Sleep duration and mortality: a systematic review and meta-analysis. *Journal of sleep research*, **18**(2), 148–158.

Hamermesh, Daniel S, Myers, Caitlin Knowles, & Pocock, Mark L. 2006. *Time zones as cues for coordination: Latitude, longitude, and Letterman*. Tech. rept. National Bureau of Economic Research.

Hamermesh, Daniel S, Myers, Caitlin Knowles, & Pocock, Mark L. 2008. Cues for timing and coordination: Latitude, Letterman, and longitude. *Journal of Labor Economics*, **26**(2), 223–246.

Hofferth, Sandra L., Flood Sarah M., & Sobek, Matthew. 2018. American Time

Use Survey Data Extract Builder: Version 2.6 [dataset]. *College Park, MD: University of Maryland and Minneapolis, MN: University of Minnesota IPUMS 2018*. https://doi.org/10.18128/D062.V1.2, Last accessed on September 19, 2018.

Kotchen, Matthew J, & Grant, Laura E. 2011. Does daylight saving time save energy? Evidence from a natural experiment in Indiana. *Review of Economics and Statistics*, **93**(4), 1172–1185.

Lahti, Tuuli, Nysten, Esa, Haukka, Jari, Sulander, Pekka, & Partonen, Timo. 2010. Daylight saving time transitions and road traffic accidents. *Journal of environmental and public health*, **2010**.

Mansoubi, Maedeh, Pearson, Natalie, Clemes, Stacy A, Biddle, Stuart JH, Bodicoat, Danielle H, Tolfrey, Keith, Edwardson, Charlotte L, & Yates, Thomas. 2015. Energy expenditure during common sitting and standing tasks: examining the 1.5 MET definition of sedentary behaviour. *BMC public health*, **15**(1), 516.

Short, Michelle A, Gradisar, Michael, Lack, Leon C, Wright, Helen R, & Dohnt, Hayley. 2013. The sleep patterns and well-being of Australian adolescents. *Journal of adolescence*, **36**(1), 103–110.

Tudor-Locke, Catrine, Washington, Tracy L, Ainsworth, Barbara E, & Troiano, Richard P. 2009. Linking the American Time Use Survey (ATUS) and the compendium of physical activities: methods and rationale. *Journal of Physical Activity and Health*, **6**(3), 347–353.

Varughese, Jason, & Allen, Richard P. 2001. Fatal accidents following changes in daylight savings time: the American experience. *Sleep medicine*, **2**(1), 31–36.

Table 1: Change in Types of Activities given by the MET value:

	MET Val.<1.5	MET Val. (1.5-3.0)	MET Val.>3.0
post_fall=1 × dst_states=1	-50.27***	-68.84***	65.27***
	(14.10)	(9.619)	(25.17)
Observations	32597	67603	8361
post_spring=1 × dst_states=1	-30.78**	39.84***	-50.97**
	(15.01)	(10.60)	(23.93)
Observations	34217	70087	8561
post_all=1 × dst_states=1	-49.56***	-15.98**	11.73
	(10.04)	(6.965)	(16.93)
Observations	66814	137690	16922

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Source: Bureau of Labor Statistics and American Time Use Survey. Dependent variable: Time spent in minutes on activities when divided into either of the three groups of activities based on the MET value. The three groups are defined as - sedentary activities (MET value < 1.5), light intensive activities (MET value between 1.5-3.0) and moderate to vigorously intensive activity (MET value > 3.0). In the fall, the clock moves back by 1 hour. In the spring, the clock moves forward by 1 hour. For row 3, I combine all individuals who have been subjected to any time change: fall or spring.

Table 2: Respondents' mood change when subjected to DST

	Happy	Sad	Stress	Tired
post_fall=1 × dst_states=1	0.176	-0.486	0.617	0.0755
	(0.397)	(0.342)	(0.435)	(0.481)
Observations	3564	3575	3580	3574
post_spring=1 × dst_states=1	0.434	-0.0217	-0.377	0.421
	(0.427)	(0.365)	(0.464)	(0.508)
Observations	3741	3746	3751	3752
post_all=1 × dst_states=1	0.172	-0.133	0.226	0.221
	(0.277)	(0.237)	(0.301)	(0.331)
Observations	7305	7321	7331	7326

t statistics in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Source: Bureau of Labor Statistics and American Time Use Survey. Dependent variable: Mood scales are given by between 0 - 6. Higher the number on the scale, the respondents feel more strongly about the corresponding emotion. In the fall, the clock moves back by 1 hour. In the spring, the clock moves forward by 1 hour. For row 3, I combine all individuals who have been subjected to any time change: fall or spring.

Table 3: Change in Types of Activities given by the MET value for the working population

	MET Val.<1.5	MET Val. (1.5-3.0)	MET Val.>3.0
post_fall=1 × dst_states=1	-35.81**	-77.17***	74.58**
	(15.08)	(10.28)	(29.39)
Observations	25907	57559	5659
post_spring=1 × dst_states=1	-38.38**	33.95***	2.106
	(16.28)	(11.44)	(30.00)
Observations	27775	60420	6060
post_all=1 × dst_states=1	-46.26***	-22.96***	48.68**
	(10.79)	(7.463)	(20.61)
Observations	53682	117979	11719

t statistics in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Source: Bureau of Labor Statistics and American Time Use Survey. Dependent variable: Time spent in minutes on activities when divided into either of the three groups of activities based on the MET value. The three groups are defined as - sedentary activities (MET value < 1.5), light intensive activities (MET value between 1.5-3.0) and moderate to vigorously intensive activity (MET value > 3.0). In the fall, the clock moves back by 1 hour. In the spring, the clock moves forward by 1 hour. For row 3, I combine all individuals who have been subjected to any time change: fall or spring.

Table 4: Change in Types of Activities given by the MET value for the retired population

	MET Val.<1.5	MET Val. (1.5-3.0)	MET Val.>3.0
post_fall=1 × dst_states=1	-166.2***	56.05**	115.6
	(41.71)	(27.88)	(81.06)
Observations	7163	10746	1448
post_spring=1 × dst_states=1	-29.49	83.04***	-120.5***
	(35.73)	(25.58)	(41.39)
Observations	7021	10580	1296
post_all=1 × dst_states=1	-64.32**	77.53***	-59.18*
	(26.24)	(18.62)	(33.98)
Observations	14184	21326	2744

t statistics in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Source: Bureau of Labor Statistics and American Time Use Survey. Dependent variable: Time spent in minutes on activities when divided into either of the three groups of activities based on the MET value. The three groups are defined as - sedentary activities (MET value < 1.5), light intensive activities (MET value between 1.5-3.0) and moderate to vigorously intensive activity (MET value > 3.0). In the fall, the clock moves back by 1 hour. In the spring, the clock moves forward by 1 hour. For row 3, I combine all individuals who have been subjected to any time change: fall or spring.

Table 5: Change in Types of Activities given by the MET value for the disabled population

	MET Val.<1.5	MET Val. (1.5-3.0)	MET Val.>3.0
post_fall=1 × dst_states=1	-93.16	120.4***	7.585
	(58.26)	(41.89)	(96.30)
Observations	2859	3480	409
post_spring=1 × dst_states=1	9.875	120.4***	176.3**
	(54.69)	(45.06)	(83.89)
Observations	2689	3316	407
post_all=1 × dst_states=1	-131.9***	108.5***	134.9**
	(36.40)	(31.67)	(54.67)
Observations	5548	6796	816

t statistics in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Source: Bureau of Labor Statistics and American Time Use Survey. Dependent variable: Time spent in minutes on activities when divided into either of the three groups of activities based on the MET value. The three groups are defined as - sedentary activities (MET value < 1.5), light intensive activities (MET value between 1.5-3.0) and moderate to vigorously intensive activity (MET value > 3.0). In the fall, the clock moves back by 1 hour. In the spring, the clock moves forward by 1 hour. For row 3, I combine all individuals who have been subjected to any time change: fall or spring.

Table 6: Change in Types of Activities given by the MET value: Comparing Arizona and New Mexico

	MET Val.<1.5	MET Val. (1.5-3.0)	MET >3.0
post_fall=1 × dst_states=1	70.58**	-104.1***	161.5***
	(32.28)	(20.63)	(58.24)
Observations	873	1818	224
post_spring=1 × dst_states=1	-78.97**	24.28	21.00
	(34.41)	(22.06)	(58.24)
Observations	852	1725	210
post_all=1 × dst_states=1	-5.493	-49.54***	43.33
	(23.18)	(15.08)	(36.49)
Observations	1725	3543	434

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Source: Bureau of Labor Statistics and American Time Use Survey. Dependent variable: Time spent in minutes on activities when divided into either of the three groups of activities based on the MET value. The three groups are defined as - sedentary activities (MET value < 1.5), light intensive activities (MET value between 1.5-3.0) and moderate to vigorously intensive activity (MET value > 3.0). Arizona does not follow daylight savings time while New Mexico does. In the fall, the clock moves back by 1 hour. In the spring, the clock moves forward by 1 hour. For row 3, I combine all individuals who have been subjected to any time change: fall or spring.

Table 7: Respondents' Mood Change when Subjected to DST: Comparing Arizona and New Mexico

	Happy	Sad	Stress	Tired
post_fall=1 × dst_states=1	2.868***	-2.846***	-2.926***	-1.724
	(0.925)	(0.769)	(1.044)	(1.090)
Observations	107	107	106	107
post_spring=1 × dst_states=1	-1.084	0.320	2.067**	0.190
	(1.043)	(0.721)	(0.937)	(1.027)
Observations	85	85	85	85
post_all=1 × dst_states=1	0.623	-0.718	-0.533	-0.0889
	(0.566)	(0.517)	(0.632)	(0.625)
Observations	192	192	191	192

t statistics in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Source: Bureau of Labor Statistics and American Time Use Survey. Dependent variable: Mood scales are given by between 0 - 6. Higher the number on the scale, the respondents feel more strongly about the corresponding emotion. Arizona does not follow daylight savings time while New Mexico does. In the fall, the clock moves back by 1 hour. In the spring, the clock moves forward by 1 hour. For row 3, I combine all individuals who have been subjected to any time change: fall or spring.

Table 8: Change in Types of Activities given by the MET value for the working population: Comparing Arizona and New Mexico

	MET Val.<1.5	MET Val. (1.5-3.0)	MET Val.> 3.0
post_fall=1 × dst_states=1	89.98***	-170.6***	174.6**
	(33.98)	(22.69)	(76.44)
Observations	733	1566	172
post_spring=1 × dst_states=1	-102.9***	26.47	-1.115
	(35.40)	(22.75)	(71.56)
Observations	728	1493	144
post_all=1 × dst_states=1	15.36	-83.02***	66.64
	(24.86)	(16.22)	(45.93)
Observations	1461	3059	316

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Source: Bureau of Labor Statistics and American Time Use Survey. Dependent variable: Time spent in minutes on activities when divided into either of the three groups of activities based on the MET value. The three groups are defined as - sedentary activities (MET value < 1.5), light intensive activities (MET value between 1.5-3.0) and moderate to vigorously intensive activity (MET value > 3.0). Arizona does not follow daylight savings time while New Mexico does. In the fall, the clock moves back by 1 hour. In the spring, the clock moves forward by 1 hour. For row 3, I combine all individuals who have been subjected to any time change: fall or spring.

Appendices

A Case Study: Indiana

Indiana along with Arizona and Hawaii chose not to adopt Daylight Savings time when the Uniform Time Act was passed in 1966 in the United States. Indiana's history with time has been long and complicated. After World War II, the federal government lifted the mandate of DST but some states chose to follow. Indiana was officially in the Central time zone, but in the late 40s, some communities chose to follow the daylight-savings time all year-round, thus aligning themselves with the Eastern time zone.

In 1949, the Indiana Senate, after much mayhem, passed a bill which would keep the state on Central time zone and outlaw daylight-savings time. However, the law had no enforcement powers and was ignored by the communities which followed the daylight-savings time all year. A non-binding statewide referendum was conducted in 1956. It asked voters their preference on Eastern versus Central time and the use of daylight-savings time [6]. Those in favor of Central time won with a slight majority but it was clear that not many were in favor of changing the clock twice a year.

A law was passed in 1957 to make Central time the official time of the state but permit any community to switch to DST during the summer. This law was very unpopular and repealed in 1961.

The Uniform DST was passed by the federal government in 1966 allowing any state to exempt themselves as long as the whole state is exempted. During this

[6] https://www.indystar.com/story/news/politics/2018/11/27/indianapolis-indiana-time-zone-history-central-eastern-daylight-savings-time/2126300002/

time, Congress also shifted federal authority over time zones to the Department of Transportation. Between 1968-72, the Indiana General Assembly passed a legislation which would permit Indiana to exempt some counties from following DST if others want to pursue it. This amendment was finally approved and signed by President Richard Nixon in 1972 [7].

This system remained unchanged till the political climate of Indiana changed in 2005. Governor Mitch Daniels argued that the state was losing economic and business opportunities because neighboring states could not keep track of the Indiana time. After multiple defeats, the DST bill of Indiana was finally passed in April 2005. Beginning on April 2 2006, Indiana became the 48th state to observe daylight saving time statewide. The state sets their clocks back an hour in the fall to Eastern Standard Time and ahead one hour in the spring to Eastern Daylight Time [8].

I compare Indiana with other states which always had DST (namely all states besides Hawaii and Arizona) to study if the implementation of the DST law in 2006 influenced the daily schedules of its residents. For this analyses, I use a triple difference model to study how the implementation of the Indiana DST law in 2006 leads to a difference in daily scheduling of respondents living in Indiana as compared to those living in states which always had DST.

$$duration(metcategory)_{ijst} = constant + \beta PostxtreatedxDSTyr_{st} + \rho X_i + \gamma_t + \delta_s + \eta_j + \epsilon_{ist} \quad (3)$$

[7] https://www.indystar.com/story/news/politics/2018/11/27/indianapolis-indiana-time-zone-history-central-eastern-daylight-savings-time/2126300002/

[8] https://www.indystar.com/story/news/2019/03/08/why-indiana-observes-daylight-saving-time-statewide/3092875002/

where, $duration(metcategory)_{ijst}$ gives the total time spent doing activities which has a MET value defined as sedentary (met value below 1.5), light (met value between 1.5 and 3.0) or medium to vigorous activity (above 3.0), for individual i, interviewed on day j, for state s and year t. Other variables include $PostxtreatedxDSTyr_{st}$ is the interaction term and the coefficient of interest depicting the DDD estimate; X_i indicates individual characteristics: age, race, sex, education level and employment status; γ_t gives the year fixed effects; δ_s gives the state fixed effects; η_j gives the dummy for the day of the week, j of the interview; and ϵ_{ijst} gives the error term.

The coefficient of interest is β which measures the DDD estimate. The triple difference arises due to comparing the outcome variables before and after the implementation of the DST law in Indiana. The comparison to before and after the clock change in the fall/spring provides the double difference and the further comparison to other states which always had DST since 1966 provides the triple difference.

Table A1 gives the estimates for equation 3. I find that after the DST change, there a decline in time spent in sedentary activities such as sleeping and relaxing by 111 minutes. Time spent in engaging in light intensity activities also decline by a little less than 2 hours. These estimates are statistically significant at conventional levels. Responders in Indiana significantly changed their routine after the DST implementation in 2006. There is no significant change in time spent engaging in moderate to vigorous intensive activities after the fall DST change. In the spring, time spent engaging in sedentary activities increase after DST implementation in 2006 in Indiana by 149 minutes. These estimates are statistically significant at conventional levels.

The working group in Indiana, between the ages of 15-65 years, react in the similar manner to the DST implementation in 2006 as seen for the whole population. Table A2 shows that in the fall, Indiana's working population spends less time in sedentary and light intensive activities by approximately 2 hours each, and increase time spent at vigorous intensive activities at almost 3 hours. These estimates are statistically significant at conventional levels. The implementation of the DST law in Indiana causes people to lose time spent in sleeping and relaxing when compared to other states which always had DST. In the spring, there is an increase in time spent in sedentary activities by more than 3 hours in Indiana as compared to other DST states. This estimate is statistically significant at one percent level of significance. Time spent at vigorous tasks also increases by 2 hours which is statistically significant at 10 percent level of significance.

Focusing on the retired population, table A3 shows that the implementation of DST in 2006 causes the retirees to increase their sedentary activities by 165 minutes after the clock change in the fall. There is a decline in light intensive activities by 2 hours. Due to a lack of enough observations in the treated group, I am unable to estimate the coefficient for column 3, that is, the time spent engaging in moderate to vigorously intensive activities. In the spring, DST implementation in 2006 causes Indiana retirees to increase engagement in light intensive activities by 4.5 hours and decrease more rigorous tasks by a little less then 4.5 hours. There is no impact on sedentary activities.

Compared to other states which had DST since 1966, the implementation of the law in Indiana in 2006 is large in magnitude and statistically significant. Indiana is an interesting case study. It is the only state to implement DST in the recent times when other states are involved in serious discussion of repealing it.

Table A1: Change in Types of Activities given by the MET value: Case Study of Indiana

	MET Val.<1.5	MET Val. (1.5-3.0)	MET >3.0
post_fall=1 × treated=1 × yr_2006=1	-111.5***	-117.1***	116.8
	(34.29)	(23.94)	(73.41)
Observations	31878	66079	8170
post_spring=1 × treated=1 × yr_2006=1	149.1***	36.23	90.31
	(36.36)	(29.53)	(58.29)
Observations	33582	68718	8394
post_all=1 × treated=1 × yr_2006=1	8.637	-72.52***	88.60**
	(24.75)	(17.97)	(44.91)
Observations	65460	134797	16564

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Source: Bureau of Labor Statistics and American Time Use Survey. Dependent variable: Time spent in minutes on activities when divided into either of the three groups of activities based on the MET value. The three groups are defined as - sedentary activities (MET value $<$ 1.5), light intensive activities (MET value between 1.5-3.0) and moderate to vigorously intensive activity (MET value $>$ 3.0). Indiana did not adopt DST till 2006. I use a triple difference to study if there has been any change in the respondents of Indiana due to the adoption of the policy as compared to all other states who always had DST as control groups. In the fall, the clock moves back by 1 hour. In the spring, the clock moves forward by 1 hour. For row 3, I combine all individuals who have been subjected to any time change: fall or spring.

Table A2: Change in Types of Activities given by the MET value for the working population: Case Study of Indiana

	MET Val.$<$1.5	MET Val. (1.5-3.0)	MET Val.$>$ 3.0
post_fall=1 $\times$ treated=1 $\times$ yr_2006=1	-133.6***	-110.3***	176.0**
	(37.79)	(26.26)	(85.88)
Observations	25272	56177	5508
post_spring=1 $\times$ treated=1 $\times$ yr_2006=1	198.0***	-17.39	134.0*
	(40.60)	(32.25)	(73.32)
Observations	27243	59225	5952
post_all=1 $\times$ treated=1 $\times$ yr_2006=1	15.40	-89.00***	163.1***
	(27.12)	(19.57)	(55.53)
Observations	52515	115402	11460

t statistics in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Source: Bureau of Labor Statistics and American Time Use Survey. Dependent variable: Time spent in minutes on activities when divided into either of the three groups of activities based on the MET value. The three groups are defined as - sedentary activities (MET value < 1.5), light intensive activities (MET value between 1.5-3.0) and moderate to vigorously intensive activity (MET value > 3.0). Indiana did not adopt DST till 2006. I use a triple difference to study if there has been any change in the respondents of Indiana due to the adoption of the policy as compared to all other states who always had DST as control groups. In the fall, the clock moves back by 1 hour. In the spring, the clock moves forward by 1 hour. For row 3, I combine all individuals who have been subjected to any time change: fall or spring.

Table A3: Change in Types of Activities given by the MET value for the retired population: Case Study of Indiana

	MET Val.<1.5	MET Val. (1.5-3.0)	MET Val.> 3.0
post_fall=1 × treated=1 × yr_2006=1	165.0*	-126.1**	0
	(91.73)	(50.37)	(.)
Observations	7073	10592	1425
post_spring=1 × treated=1 × yr_2006=1	24.49	276.6***	-255.7**
	(80.92)	(68.32)	(107.4)
Observations	6904	10387	1256
post_all=1 × treated=1 × yr_2006=1	91.63	-11.02	-320.7***
	(59.06)	(39.31)	(88.58)
Observations	13977	20979	2681

t statistics in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Source: Bureau of Labor Statistics and American Time Use Survey. Dependent variable: Time spent in minutes on activities when divided into either of the three groups of activities based on the MET value. The three groups are defined as - sedentary activities (MET value < 1.5), light intensive activities (MET value between 1.5-3.0) and moderate to vigorously intensive activity (MET value > 3.0). Indiana did not adopt DST till 2006. I use a triple difference to study if there has been any change in the respondents of Indiana due to the adoption of the policy as compared to all other states who always had DST as control groups. In the fall, the clock moves back by 1 hour. In the spring, the clock moves forward by 1 hour. For row 3, I combine all individuals who have been subjected to any time change: fall or spring.