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Fatal accidents following changes in daylight savings time: the American experience

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Abstract

Objective: This study examines specific hypotheses that both sleep loss and behavioral changes occurring with the time shifts for Daylight Savings Time (DST) significantly effect the number of fatal traffic accidents in the United States of America.

Background: It has been reported that there is a significant increase in the number of automobile accidents in the spring shift to DST due to the loss of 1 h of sleep. But the extra hour gained at night with the shift from DST in the fall has been variably reported to be associated with increases and decreases in the number of automobile accidents which may reflect either behavioral anticipation with an extended late night prior to the change or the benefit of extra sleep after the change.

Methods: Data from 21 years of United States' fatal automobile accidents were gathered. The mean number of accidents on the days at the time of the shifts (Saturday, Sunday and Monday) was compared to the average of the corresponding mean number of accidents on the matching day of the weeks preceding and following the shift. This was repeated for each DST shift. The number of accidents for a particular shift was also correlated with the year of the accidents.

Results: There was a significant increase in accidents for the Monday immediately following the spring shift to DST ($t = 1.92$, $P = 0.034$). There was also a significant increase in number of accidents on the Sunday of the fall shift from DST ($P < 0.002$). No significant changes were observed for the other days. A significant negative correlation with the year was found between the number of accidents on the Saturdays and Sundays but not Mondays.

Conclusions: The sleep deprivation on the Monday following shift to DST in the spring results in a small increase in fatal accidents. The behavioral adaptation anticipating the longer day on Sunday of the shift from DST in the fall leads to an increased number of accidents suggesting an increase in late night (early Sunday morning) driving when traffic related fatalities are high possibly related to alcohol consumption and driving while sleepy. Public health educators should probably consider issuing warnings both about the effects of sleep loss in the spring shift and possible behaviors such as staying out later, particularly when consuming alcohol in the fall shift. Sleep clinicians should be aware that health consequences from forced changes in the circadian patterns resulting from DST come not only from physiological adjustments but also from behavioral responses to forced circadian changes.

Keywords: Traffic accidents; Daylight Savings Time; Sleep loss; Alcohol consumption; Circadian; Behavioral changes

1. Introduction

The 1-h adjustments required for Daylight Savings Time (DST) can be seen as producing two very differ-

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ent effects: (1) physiological adjustment to an obligatory 1-h phase advance or delay of the circadian rhythm of sleep and (2) behavioral adjustments anticipating the changes in time available on Saturday night into early Sunday morning. In relation to the first effect, it has been shown that significant disruption in sleep patterns occurs due to DST and persists up to 5 days after a change to or from DST [1]. The resulting change in sleepiness seems likely to alter the risk of automobile accidents. On one hand, the loss of 1 h with the change to DST in the spring leads to a loss of sleep while the body's circadian system adjusts to the phase advance with a possible increase in risk of accidents. The effects will be more pronounced on Monday after the shift when, unlike Sunday, most people cannot 'sleep-in' late and must rely upon a successful 1-h phase advance to ensure adequate sleep. On the other hand, the gain of 1 h with the change from DST in the fall permits a 1-h gain in sleep time while the body adjusts to the sleep delay, but this should occur mainly for people who are normally sleep deprived by forced awakenings on workday. This might, for these sleep deprived individuals, reduce sleepiness and therefore somewhat reduce the risk of accidents particularly on Monday after the shift from DST. Physiological adjustment is also generally considered easier for phase delay than for phase advance. Thus the physiological effects expected from DST changes would primarily be decreased sleep time and possible increased accidents principally on the Monday after the spring change to DST.

Sleep related behaviors may, however, also be altered on the night of the DST changes. In particular, in the fall the addition of an hour in the early morning may encourage those who normally stay out late into Sunday morning to stay out even later. They would then drive home 1-h later and presumably less alert than usual thereby increasing risks of accidents on the Sunday morning of the change, particularly if alcohol is involved [2]. The loss of an hour in the spring might encourage some to come home earlier than usual thereby reducing the risk of accidents on Saturday night and Sunday morning. Given the problems of adjusting to an earlier sleep time, it, however, seems unlikely that this behavioral strategy would be either successful or particularly attractive for the spring. In contrast, given the ease of adjusting to a longer day the behavioral strategy of staying out later may be a successful adaptation to the change in the fall. This behavioral adaptation may be particularly appealing to those who already prefer to stay out late that night.

Thus these two hypothesized effects lead to somewhat opposite predicted effects on accident rates but mostly on different days. For the spring change to DST, physiological effects could lead to an increased risk of accidents principally on Monday and less so on Sunday, while, in contrast, behavioral adaptation may lead to some minor decreased risk only on Sunday with no effect on Monday. For the fall change from DST, physiological effects might produce some small decreased accident risk mainly on the Monday after the change and less so on Sunday, while, in contrast, behavioral adaptation may significantly increase risk of accidents only on Sunday with no effect on Monday. No changes in accident risk should occur for the Saturday before either DST change.

In fact, Coren has reported for Canadian traffic accidents over a two year period, that the Monday after the changes showed both a significant increase following the spring change to DST, and a significant decrease following the fall change from DST [3]. Monk similarly reported an increase in traffic accidents after the spring change to DST when changes in level of lighting were controlled by excluding accidents occurring at dawn or dusk [4]. But the fall accident rates for the Monday after the fall change from DST show in various studies both increases, no change and decreases. These prior studies covered only a few years, with one exception did not use data from the United States, and failed to examine all 3 days around the change: Saturday, Sunday and Monday. Thus they could not test for the hypothesized sleep-related behavioral changes on Saturday night and Sunday morning also leading to changes in accidents. An update on this issue using a larger database and more complete analyses of the relevant days to tests for effects of both physiological and behavioral changes is needed.

2. Methods

2.1. Database

The United States National Highway Transporta-

tion Safety Administration maintains records of all fatal automobile accidents for each day of the year, dating back to 1975. Data for a 21-year period from 1975 to 1995 were obtained for the Sunday corresponding to the change, the preceding Saturday, and the following Monday. Since accidents vary considerably for each day of the week, comparison data were obtained from the corresponding Saturdays, Sundays and Mondays in the week before and also the week after the DST changes.

2.2. Statistical analysis

We hypothesized, based on the consistent findings from prior studies, that accidents would increase on Monday in the spring following the change to DST. No change was expected for Sunday or Saturday in the spring. Given the inconsistent results for effects from the fall change from DST and the somewhat conflicting predictions from the physiological and behavioral effects we hypothesized only that the change from DST in the fall would affect accident rates on Sunday and Monday but not the Saturday of the DST change.

To correct for any possible seasonal trends the data for each year from the weeks preceding and following change to DST were averaged for Saturdays, Sundays and Monday, respectively. This average was compared for each year to the data from the respective day of the week that the change to or from DST was made. For the Monday after the spring DST change our hypothesis was directional and analysis used a one-tailed paired *t*-test based on the consistent findings in previous studies [3,4]. All other hypotheses were for changes in either direction and the analyses used a two-tailed paired *t*-test.

Since for this long time period there may have been substantial changes in driving characteristics, the accident rates for both the Sunday and Monday of the changes and for the averages of the preceding and following matching days were correlated with the year of the study.

3. Results

For the spring change to DST, the number of fatal accidents on Monday showed a significant increase from an average of 78.2 from the weeks before and after to an average of 83.5 on the day of the shift ($t = 1.92$, $P = 0.034$) (See Fig. 1), but there was no significant change for fatal accidents on Sunday (means: weeks before and after = 113.4, week of change = 118.1, $t = 1.49$, $P = 0.14$) or Saturday (means: weeks before and after = 145.3, week of change = 141.9, $t = 0.813$, $P = 0.21$).

For the fall change from DST, the number of fatal accidents showed a significant increase for Sunday from an average of 126.4 from the weeks before and after to an average of 139.5 on the day of the shift ($t = 4.03$, $P < 0.001$). The accidents on Monday showed a non-significant decrease from an average of 89.5 from the weeks before and after to an average of 86.1 on the day of the shift ($t = -1.02$, $P = 0.32$) (see Fig. 2). The number of accidents on Saturdays was about the same for the week of the change as it was for the weeks before and after the change (means: 168 and 167, respectively, $t = 0.207$, $P = 0.84$).

Analyses of the effects of years since start of the study showed significant negative correlation between number of fatal accidents and years since start of the study period for most of the Sunday periods (Sunday of and average of preceding and following Sundays: spring, $r = -0.45$, $P = 0.04$, $r = -0.30$, $P = 0.19$, respectively; fall, $r = -0.53$, $P = 0.01$, $r = -0.45$, $P = 0.04$, respectively). The Saturdays showed similar significant negative correlations between number of accidents and years (see Table 1). This is not the

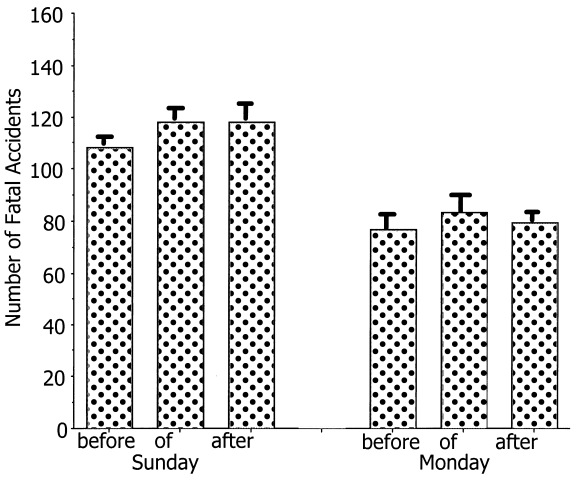

Fig. 1. Average number of accidents per year in the spring shift to DST for the Sunday and Monday of the shift and for the Sundays and Monday before and after the shift. Bars give the standard error of the mean.

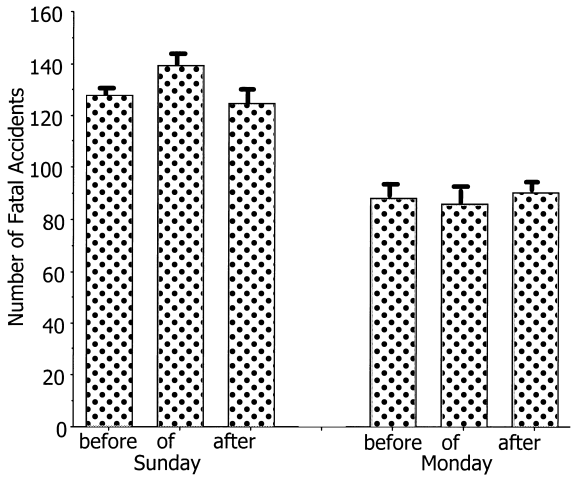

Fig. 2. Average number of accidents per year in the fall shift from DST for the Sunday and Monday of the shift and for the Sundays and Monday before and after the shift. Bars indicate standard error of the mean.

case for any of the corresponding Monday periods (spring, $r = 0.07$, $P = 0.76$, $r = 0.12$, $P = 0.60$, respectively; fall, $r = 0.12$, $P = 0.60$, $r = 0.07$, $P = 0.78$, respectively).

The significant effect of years on the accident rates for Saturdays and Sundays did not have any effect on the magnitude of the increases seen in the fatal accidents. Fig. 3 shows the decreasing number of fatal accidents on Sunday, in the fall both for the weekends with the time shift and for the average of those before and after the time shift. The weekend with the time shift showed consistently greater number of fatal accidents for all but years 2, 4, 13, 20 and 21. None of the differences between the week of time-change and the mean of the preceding and following weeks showed significant change over the years in this study. In particular, for the significant effects, the amount of increases in accidents seen in the spring on Monday of the change and in the fall on the Sunday of the change did not correlate significantly with years since the start of the study period ($r = 0.18$, $P = 0.06$; $r = 0.17$, $P = 0.61$, respectively).

4. Discussion

This is the largest data set ever used to address the issue of the effects of DST changes on accidents and the only data set to look at the Sunday data when sleep-wake behavioral changes may also effect alertness and accidents and to use Saturday as a comparison control. Like the preceding studies, a small significant effect was found for increased accidents in the spring, when the change to DST in the spring tends to shorten sleep times. As expected for this physiological change, the effect was significant for the first working day (Monday) after the change but not for the day of the change (Sunday) when sleeping in late may occur. It should be noted that the effect was small and only significant with a directional hypothesis. Nonetheless, there are now three separate studies all with essentially the same results indicating a small increase in accidents immediately after the spring change to DST. Coren showed this for all accidents in a 2-year sample in Canada [3]. Monk showed this for a similar sample from the United Kingdom

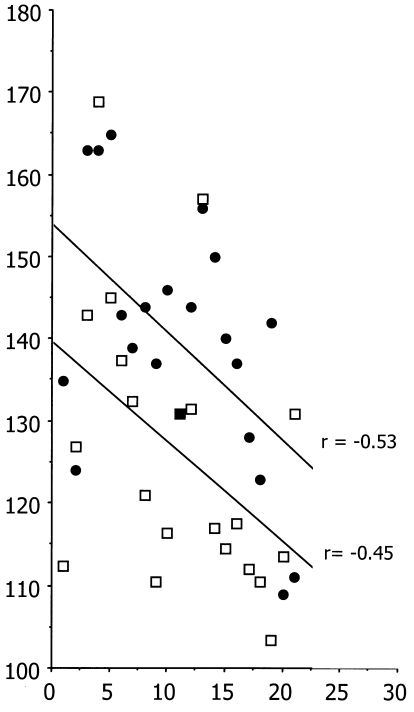

Fig. 3. Number of fatal accidents by year in the fall for the Sunday of the time change (●) and for the averages of the Sundays before and after the time change (□). The top regression line is for the Sunday of the time change and the bottom for the averages of the Sundays on the weekends before and after the change. Note the consistent effect despite the overall decrease in fatal accidents with years.

[4]. Coren also reported it for all accidental deaths reported to the National Center for Health Statistics from 1986 to 1988 [5]. The small magnitude (about 6%) increase is the same for all of these studies contributing to differences in the degree of statistical significance of the findings. The hypothesized behavioral effects decreasing the risks of accidents by driving earlier on Saturday night were not found in any of the Saturday or Sunday data in the spring. These behavioral effects in the spring were, however, expected to be very small if present at all.

The data from the fall were expected to reflect behavioral adaptation more than physiological effects from the obligatory sleep phase delay. Indeed, we found significant increases in Sunday of the shift but no significant changes in Saturday or Monday. Coren demonstrated for Mondays a decrease after the fall shift from DST in his initial study of Canadian traffic accidents [3], but in a subsequent study reported a significant increase in accidents in the fall after shifting from DST [6].

Our study also allowed us to examine effects of changes occurring over the full 21-year time span. There was an interesting consistent decrease in the number of accidents as the years progressed for most Saturdays and Sundays, but not for Mondays. This clearly reflects some social changes in driving habits which may be related to late night (early Saturday and Sunday morning) driving and drinking habits with decreased alcohol related fatalities at these times. It has, indeed, been shown that during years covered in this study there has been a decrease in alcohol related fatalities from accidents [7].

The increase in Sunday accidents after the change from DST supports our hypothesis of a behavioral adaptation anticipating the change giving drivers an extra hour of sleep the next day. In particular, this may translate into staying out and driving later with increasing sleepiness and possibly more alcohol consumption leading to more fatal accidents on early Sunday morning. This is particularly significant since a small amount of alcohol significantly increases sleepiness experienced with sleep deprivation and the combination has particularly disastrous affects for driving skills [2]. The decrease in number of accidents over the years for Saturdays and Sundays also provides further support for possible alcohol involvement in these data. While there may be several reasons for the decrease in fatal accidents on these particular days of the week, the results match those showing a similar decrease in alcohol-related accident fatalities [7]. This provides further support for the view that the increase with the fall change to DST may relate to the combined use of alcohol with increased fatigue from staying out late at night. It deserves note that the magnitude of the increase for Sunday in the fall is greater (10.3%) than that observed in the spring for either Sunday or Monday (6.4%).

From a public health standpoint, the effects of sleep loss associated with DST in the spring appear to be fairly minimal with only about a 6% rate of increase, which is approximately the same as that reported by Coren [3]. But even this small increase is not insignificant and probably justifies public health education to help people adjust schedules to ensure they have adequate sleep during the time of the change in the spring. The public may be unaware that even this small change of 1 h may cause some minor adjustment problems obtaining adequate sleep. The change in the fall may, however, deserve even more attention, at least for the United States. Public health education about the behavioral adjustment to the extra hour during the fall should probably include warnings about alcohol consumption and driving under drowsy conditions later in the morning. The pubic may, again, not be aware that even a small increase in sleepiness when combined with alcohol consumption can have significant adverse effects on driving skills. While it is unclear that the observed effect is related to alcohol consumption and later driving on early Sunday morning, nonetheless we feel that this is a likely hypothesis for the findings that should be examined in future studies. It is often not recognized that changes in sleep wake patterns not only effect sleep times, but also social behaviors. Either of these, physiological or behavioral adaptation to forced changes in the circadian cycle of life, can adversely effect health and increase the risk of accidents.

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