Report

Current Biology

A Chronobiological Evaluation of the Acute Effects of Daylight Saving Time on Traffic Accident Risk

Highlights

- Spring DST transition acutely increases fatal traffic accident risk by 6% in the US
- ~28 fatal accidents could be prevented yearly if the DST transition was abolished
- Spring-DST-transition-associated fatal accident risk is highest in the morning
- Locations further west in a time zone are affected more by the spring transition

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In Brief

Reports about Daylight Saving Time (DST) and traffic accident risk are inconsistent. Fritz et al. show that the spring DST transition acutely increases fatal accidents, especially in the morning and locations further west in a given time zone. Results do not support claims that DST reduces afternoon rush-hour accidents due to better illumination.

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A Chronobiological Evaluation of the Acute Effects of Daylight Saving Time on Traffic Accident Risk

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SUMMARY

There is evidence that the spring Daylight Saving Time (DST) transition acutely increases motor vehicle accident (MVA) risk ("DST effect"), which has been partly attributed to sleep deprivation and circadian misalignment [1–6]. Because spring DST also shifts clock time 1 h later, mornings are darker and evenings brighter, changing illumination conditions for peak traffic density. This daytime-dependent illumination change ("time of day effect") is hypothesized to result in DST-associated afternoon and evening accident risk reductions [2, 5, 7]. Furthermore, sunrise and local photoperiod timing depend on position in time zone. The sun rises at an earlier clock time in the eastern regions of a given time zone than in the western regions, which is thought to induce higher levels of circadian misalignment in the west than in the east ("time zone effect") [8, 9]. This study evaluated the acute consequences of the DST transition on MVAs in a chronobiological context, quantifying DST, time of day, and time zone effects. We used large US registry data, including 732,835 fatal MVAs recorded across all states (1996–2017), and observed that spring DST significantly increased fatal MVA risk by 6%, which was more pronounced in the morning and in locations further west within a time zone. DST-associated MVA risk increased even in the afternoon hours, despite longer daylight hours. The MVA risk increase waned in the week subsequent to DST, and there were no effects of the fall-back transition to Standard Time (ST) on MVA risk, further supporting the hypothesis that DST-transition-associated, preventable circadian misalignment and sleep deprivation might underlie MVA risk increases.

RESULTS AND DISCUSSION

Spring DST Acutely Increases Fatal MVA Risk

To test the hypothesis that spring transition to DST acutely (i.e., for up to one week) increases motor vehicle accident (MVA) risk, we analyzed data of 732,835 fatal MVAs in the contiguous United States (US) from 1996 to 2017. Raw numbers of MVAs followed a markedly seasonal rhythm (Figure 1A). After modeling this seasonal rhythm by using splines and adjusting for relevant co-variates (see Figure 1B), we observed a modestly increased fatal MVA risk during the five workdays (Monday to Friday) after DST transition ("DST week"; incidence rate ratio [IRR] = 1.06; 95% confidence interval [CI] 1.03 to 1.09; $p < 0.001$) compared with any other week of the year. Neither the weeks prior nor subsequent to DST showed increased fatal MVA risks as compared with any other week of the year (excluding spring DST week; $IRR_{prior} = 1.00$; 95% CI 0.98 to 1.03; $p = 0.883$ and $IRR_{subsequent} = 1.02$; 95% CI 0.99 to 1.04; $p = 0.200$) (Figure 2). A direct comparison of the DST week with the adjacent weeks showed a significant increase in MVA risk in the DST week compared with the week before DST (IRR = 1.06; 95% CI 1.02 to 1.10; $p = 0.002$) (Table S1), further supporting the hypothesis that the observed risk increase during spring DST week is due to the DST transition. In absolute numbers, this risk increase translates to an additional 5.7 (95% CI 3.1 to 8.3) fatal MVAs per day from Monday to Friday after DST transition—that is 28.5 (95% CI 15.4 to 41.6) during the workweek after the transition—meaning that 626.9 (95% CI 339.3 to 914.4) out of 8,958 fatal MVAs in the 5 workdays after DST transition from 1996 to 2017 were attributable to DST, and thus were preventable. In secondary analyses, we also analyzed MVA risk in the DST week, and the two control weeks before and after the DST week on a per-day basis (including also Saturdays and Sundays), where we observed similar effect sizes across days of each week (Figure S1). Specifically, we had already observed an MVA risk increase on the DST Sunday (IRR = 1.06; 95% CI 1.02 to 1.11; $p = 0.025$), despite most people being more flexible in their schedules on weekends (and consequently allowing them to make up for the time change by just sleeping longer) than during the work week. The DST effects observed during the five workdays Monday to Friday after DST transition were completely absent again on the following weekend (IRR = 1.00 each for Saturday and Sunday).

In 2007, the Energy Policy Act extended DST in the US to begin on the second Sunday of March and end on the first Sunday of November, replacing the first Sunday of April and last Sunday of October as the respective start and end dates, a schedule followed since 1987 [11]. When we tested whether the DST effect followed this change in timing, and whether and to what extent

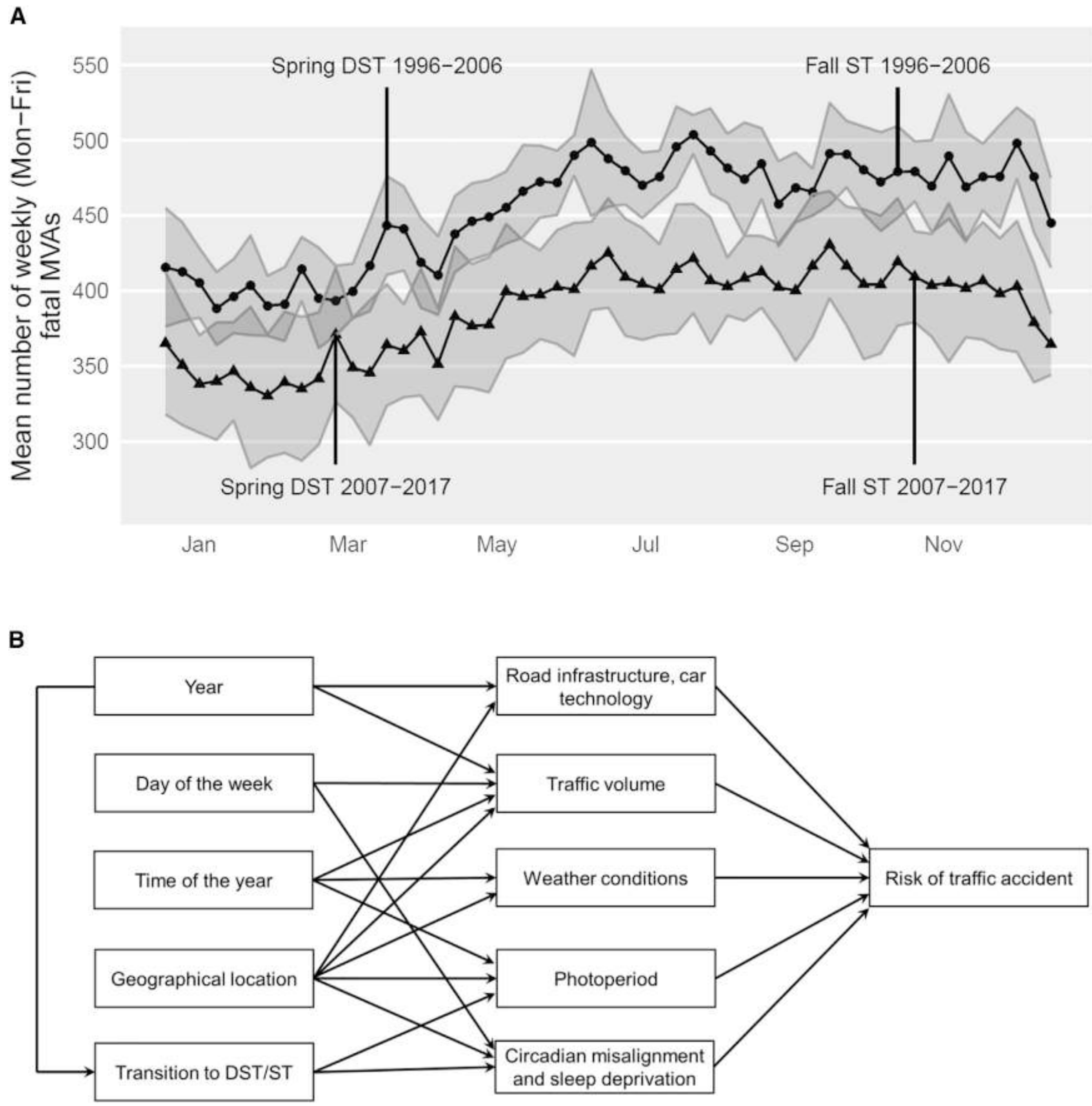

Figure 1. Fatal MVA Numbers Over the Course of a Year and Variables Causally Influencing MVA Risk

(A) Mean number of weekly (Monday to Friday) fatal MVAs over the course of a year, for the time period ≤ 2006 (upper time series) and ≥ 2007 (lower time series). Only MVAs from Monday to Friday were used for the calculation of the means given that our main analysis focused on weekdays only as well. Each dot and/or triangle represents one week of the year. Standard deviations are displayed as gray bands. Abbreviations are as follows: DST, Daylight Saving Time; MVA, motor vehicle accident; ST, Standard Time.

(B) Directed acyclic graph (DAG) showing variables causally influencing the risk of traffic accidents. According to this DAG, to get an unbiased estimate of the causal effect (i.e., the sum of all unidirectional pathways) of transition to DST and/or ST on traffic accident risk, it is sufficient to adjust for year (by adjusting for year, all non-causal/non-unidirectional pathways from transition to DST and/or ST to risk of traffic accident are blocked, which is, according to the concept of d-separation of causal graph theory, a sufficient criterion for getting unbiased causal effect estimates [10]). However, to increase model fit, we also adjusted our models for day of the week and time of the year (using B-splines). State as a proxy for geographical location was omitted from the models because the many levels of this variable would have led to overadjustment and unstable model estimates. Abbreviations are as follows: DST, Daylight Saving Time; ST, Standard Time.

the magnitude of the DST effect had changed after 2007, we observed an increased MVA risk during the five workdays of the April DST week for the time period 1996–2006 (IRR = 1.05; 95% CI 1.01 to 1.09; $p = 0.006$; this translates to an additional 25.5, 95% CI 6.4 to 42.6, fatal MVAs during these 5 days because of DST). The same was true for the 5 workdays of the March 2007–2017 DST week (IRR = 1.08; 95% CI 1.03 to 1.12; $p < 0.001$; $p_{interaction} = 0.482$; this translates to an additional 33.7, 95% CI 14.4 to 52.9, fatal MVAs per 5 days). As expected, the matching weeks where no change occurred, namely March 1996–2006 and April 2007–2017, did not show an increased MVA risk (Figure 2), suggesting that the observed increases in MVA risk were indeed directly linked to the DST transition.

Previous findings from studies investigating the acute (typically up to two weeks around the transition) effect of DST transition on MVAs have not always been consistent [2], some

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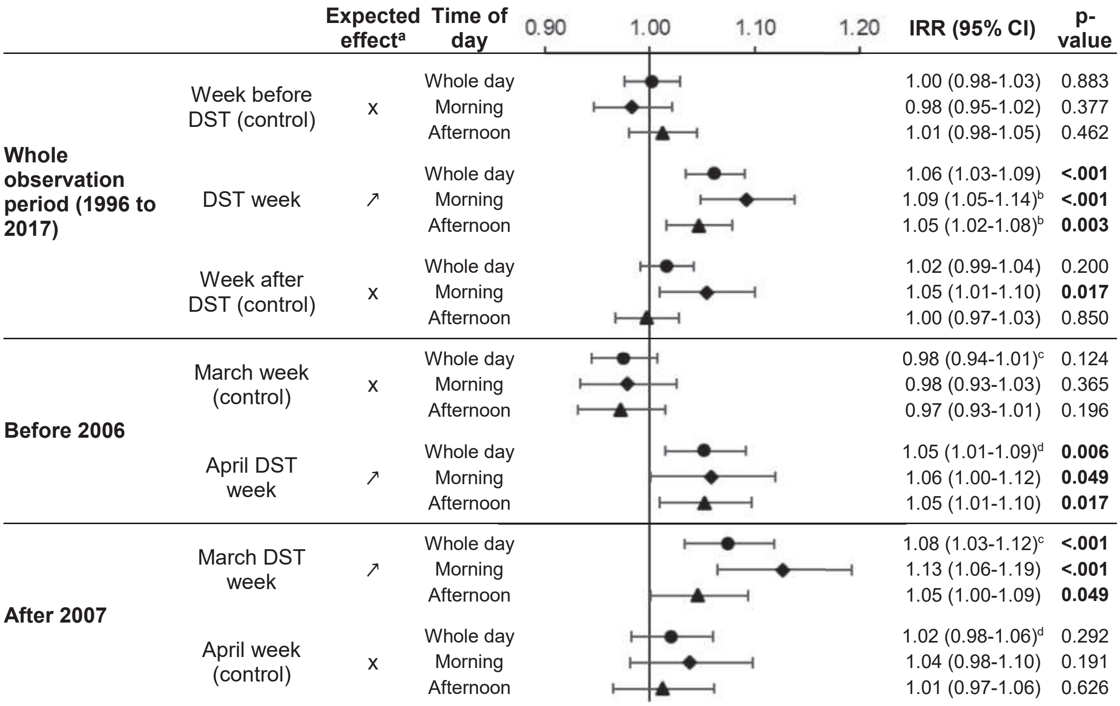

Figure 2. Association of Spring DST Transition with Fatal MVA Risk

All effects are "whole week" (e.g., Monday to Friday) effects, and are given in relation to any other week (i.e., Monday to Friday) of the year. Shown are morning (before 12pm) and afternoon IRR (after 12pm) with their respective 95% confidence intervals (95% CI). DST transition occurred on the first Sunday of April before 2006 and on the second Sunday of March after 2007. Significant p values are marked in bold. Abbreviations are as follows: CI, confidence interval; IRR, incidence rate ratio; MVA, motor vehicle accident. Footnotes are as follows:

[a]↗ increase (particularly before 12pm), x: no effect.

[b]p value for interaction between before 12pm and after 12pm was 0.001.

[c]p value for interaction between March week before 2006 versus after 2007 was < 0.001.

[d]p value for interaction between April week before 2006 versus after 2007 was 0.572.

See also Tables S1 and S2 and Figures S1 and S2.

reporting beneficial effects [12, 13]. Studies observing a risk increase after DST transition generally concluded that circadian misalignment and sleep loss due to DST were responsible for their findings [5, 6, 14–17]. In instances of decreased risk, the beneficial effects were attributed to allowing the afternoon rush hour to take place in better illumination [12, 13], and thus better visibility. However, generalizability of the findings of most studies is limited by data confined to small geographical regions, data originating from different countries across different eras (with associated differences in traffic policies and laws), changes in DST start and end dates and associated weather changes, differential traffic volume and road infrastructure, driver behavior, car technology, and availability of technical assistance systems over time.

DST Effect on Fatal MVA Risk Is Markedly Increased in the Morning Hours, and Slightly Increased in the Afternoon

After establishing that the risk of fatal MVAs is increased in the week after DST transition in data of the US over the last two decades, we aimed to further disentangle how time of day modified the overall risk increase. The mornings are darker during DST than during Standard Time (ST), which might compound a risk increase in the morning [18]. In contrast, inverse effects during later hours have been attributed to better illumination in the afternoon and evening [18]. Separate analyses of the first and the second half of the day showed that fatal MVA risk was increased before 12pm (IRR = 1.09; 95% CI 1.05 to 1.14; $p < 0.001$) in the spring DST week as compared with any other week of the year. After 12pm, we still observed a slightly increased MVA risk, albeit significantly smaller than before 12pm (IRR = 1.05; 95% CI 1.02 to 1.08; $p = 0.003$; $p_{interaction} = 0.001$). The effect before 12pm was still observable in the week after the DST week, although attenuated (IRR = 1.05; 95% CI 1.01 to 1.10; $p = 0.017$). In the control week before the DST week, these effects were absent (Figure 2). Results of MVA risk before and after 12pm were similar when stratified by time period (1996–2006 versus 2007–2017) (Figure 2) and in per-day analyses (Table S2).

In addition, we investigated time of day effects in a greater temporal resolution, using 4 h bins, and findings showed that the increased spring DST risk was manifest throughout the entire 24 h period, except for the 4pm–8pm bin, and was most pronounced in the early morning hours (4am–8am) (Figure S2). We also observed an increased fatal accident risk toward the end of the day, which would not be predicted by changes in e.g., environmental light levels, and might possibly be a consequence of increased evening activities and the associated higher traffic volume due to the brighter evenings. However, this represents

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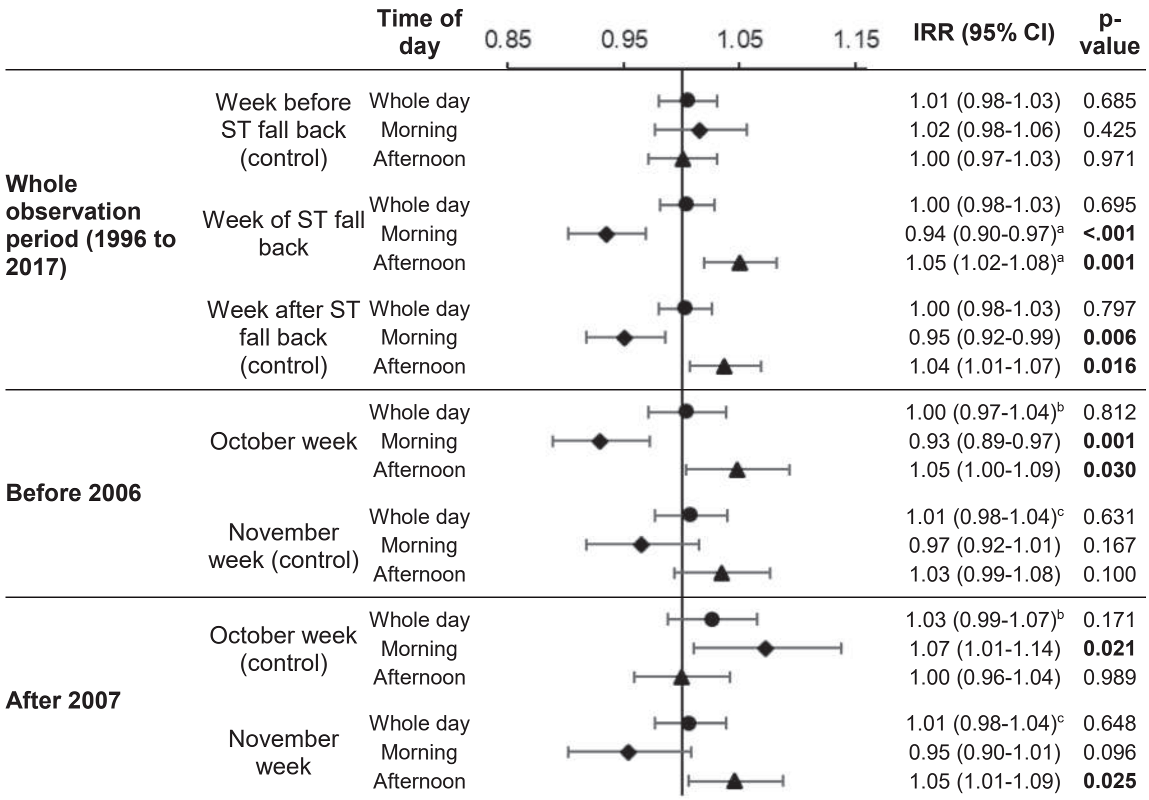

Figure 3. Association of Fall Transition back to Standard Time with Fatal MVA Risk

All effects are "whole week" (e.g., Monday to Friday) effects, and are given in relation to any other week (i.e., Monday to Friday) of the year. Shown are morning (before 12pm) and afternoon IRR (after 12pm) with the respective 95% confidence intervals (95% CI). Transition back to ST occurred on the last Sunday of October before 2006 and on the first Sunday of November after 2007. Significant p values are marked in bold. Abbreviations are as follows: CI, confidence interval; IRR, incidence rate ratio; MVA, motor vehicle accident. Footnotes are as follows:

[a]p value for interaction between before 12pm and after 12pm was < 0.001.

[b]p value for interaction between October week before 2006 versus after 2007 was 0.211.

[c]p value for interaction between November week before 2006 versus after 2007 was 0.770.

See also Tables S1 and S2 and Figures S2 and S3.

a post hoc explanation, and should not be interpreted strongly, as it was not part of our *a priori* hypotheses.

Altogether, our observations suggest that the time-of-day-associated changes in illumination are not the main contributor to the observed DST effect, but that the circadian misalignment and sleep deprivation associated with DST might play a key role in the acutely increased MVA risk in the DST week. In general, accidents are most likely to occur in the morning hours (between 6am and 8am), which has also been attributed to higher levels of driver sleepiness in the first half of the day than in the latter half of the day during any week of the year [19]. This phenomenon appears to be acutely aggravated by DST transition. The absence of a similarly increased MVA risk in the week after DST further indicates that the illumination conditions play a contributing, but minor role. Analyses of the fall transition back to ST further support this interpretation.

Fall Transition to Standard Time Has No Overall Effect on Fatal MVA Risk

The rationale for the analysis of the weeks around the transition back to ST was that this time change is expected to provide more precise insights into the illumination-associated time of day effect, given that the advancement of clock time is expected to have minor effects on circadian misalignment and sleep deprivation [2, 3], if any. Transitioning back to ST did not increase overall MVA risk compared with any other week of the year (IRR = 1.00; CI 0.98 to 1.03; p = 0.695; this translates to a non-significant extra 2.2 (95% CI −8.7 to 13.1) fatal MVAs during the workweek after back transition). Before 12pm, MVA risk decreased in the week of the transition back to ST (IRR = 0.94; 95% CI 0.90 to 0.97; $p < 0.001$), whereas we observed an increase in risk after 12pm (IRR = 1.05; 95% CI 1.02 to 1.08; p = 0.001; $p_{interaction} < 0.001$). Both of these effects were absent in the week prior to the ST transition, but persisted in the subsequent week (Figure 3). A direct comparison of the week of the transition back to ST with the adjacent weeks immediately before and after showed no differences in whole day effects, either. There were, however, significant and opposite effects for a reduced risk before 12pm and an increased risk after 12pm when compared with the week before the transition back to ST, but no time of day effects when compared with the week after the transition week back

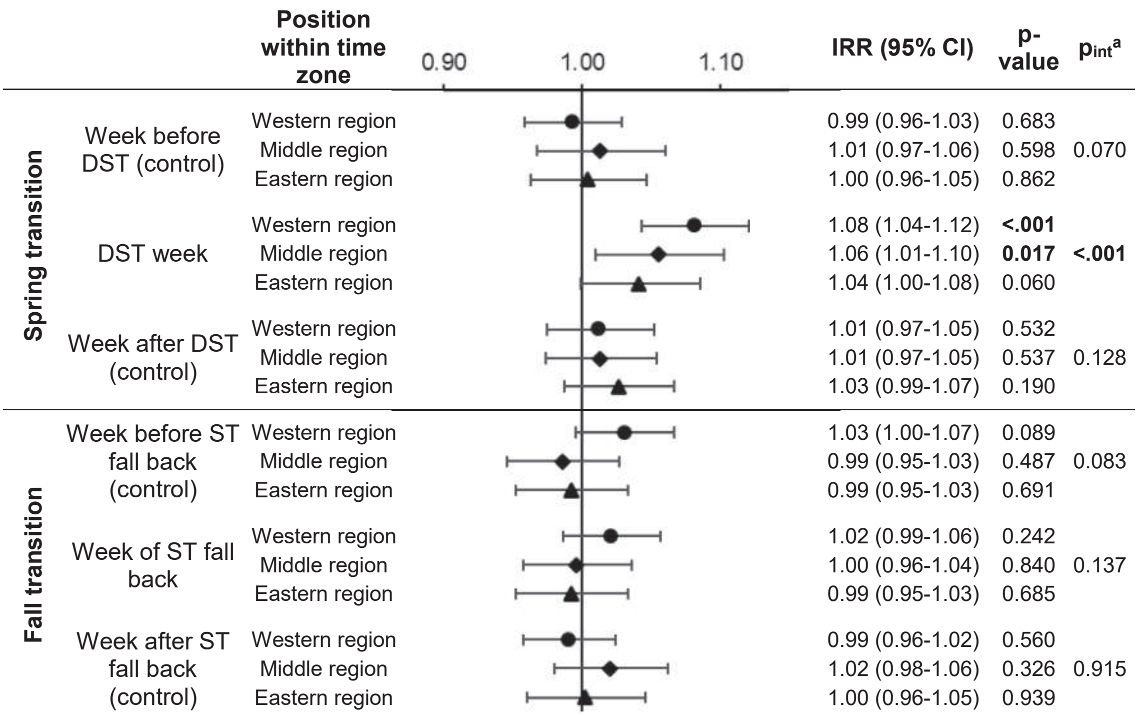

Figure 4. Association of Spring and Fall Time Change with Fatal MVA Risk by Location within Time Zone

Western regions are defined as regions located more than 5 degrees west of the respective time zone meridian; middle regions zero to 5 degrees west from the time zone meridian; eastern regions east of the time zone meridian. All effects are "whole week" (e.g., Monday to Friday) effects, and are given in relation to any other week (i.e., Monday to Friday) of the year with addition of 95% CIs. Significant p values are marked in bold. Abbreviations are as follows: CI, confidence interval; IRR, incidence rate ratio; MVA, motor vehicle accident. Footnote is as follows:

[a]p value for interaction (p_{int}) between week and position within time zone as an ordinal variable, thus testing for a trend. See also Table S3.

to ST (Table S1). A time of day analysis using 4 h bins supported these findings (Figure S2). Our results are consistent with how the time of day effect is expected to operate. Analyses by time period were in line with these findings (Figure 3). As in the case for spring DST transition, the by-day analysis supported the overall picture (Figure S3 for whole day effects; Table S2 for before 12pm and after 12pm effects). Thus, in our data, despite intra-day risk shifts, we did not see an overall negative effect of transition back to ST in fall.

Our results do not support the proposition that DST reduces overall MVA rates because the beneficial effects of the afternoon rush hour taking place in brighter daylight dominate over all other potential DST-related effects [7, 12, 20]. Although a slightly reduced MVA risk (from −0.5% up to about −10%) has been reported for longer time periods after spring DST (from two weeks up to several months) than the time period after the transition back to ST [12, 13], inferring a causal beneficial effect of DST on MVA risk from this observation does not seem justified. Over the course of several weeks to months after the DST spring transition, many other MVA risk factors, such as traffic flow, weather conditions, photoperiod (i.e., day length; see Figure 1B), and associated behavioral characteristics (e.g., being out longer or more motorbiking during the summer time) change drastically and make such a stringent causal conclusion invalid. From our data, and the observed, rather fast waning of the DST effects over time, it appears more likely that the beneficial long-term effects reported in prior studies are attributable to seasonal changes rather than DST per se (Figure 1A).

DST Effect on Fatal MVA Risk Is More Pronounced in Locations Further West within a Given Time Zone

Emerging evidence suggests that circadian misalignment is more prevalent at locations further west than east within a given time zone. It has also been shown that in western edges of time zones average sleep duration is up to 19 min shorter than in eastern edges [21]. Given that DST transition is thought to aggravate misalignment and sleep deprivation [8, 22], we hypothesized that the DST effect on MVA risk, if indeed attributable to circadian misalignment and sleep loss, should be exacerbated toward western edges of time zones ("time zone effect"). Our hypothesis is in line with prior studies demonstrating that individuals living further west in the time zone are at higher risk for some cancers compared with those living further east in the same time zone [23, 24]. To test the time zone hypothesis, we categorized MVAs according to their location within the respective time zone into: MVAs occurring in (1) the western region—defined as regions located more than 5 degrees west of the respective time zone meridian (39.9% of MVAs occurred in this region); (2) the middle region—zero to 5 degrees distance toward the west from the time zone meridian (31.9%); and (3) the eastern region—east of the time zone meridian (28.2%).

Fatal MVA risk during the five workdays after DST transition was increased by 8% (IRR = 1.08; 95% CI 1.04 to 1.12; $p < 0.001$) in the western regions of time zones as compared with any other week of the year. The risk increase was significantly less pronounced ($p_{interaction} < 0.001$) when moving toward the east; in the middle regions, an IRR of 1.06 (95% CI 1.01 to 1.10; p = 0.017) was observed, whereas in the eastern regions the IRR was 1.04 (95% CI 1.00 to 1.08; p = 0.060) (Figure 4). A 5-degree increase in longitude moving east to west within a time zone was associated with a 4% increased risk of fatal MVAs (IRR = 1.04; 95% CI 1.02 to 1.07; p = 0.001). As in the other DST-related analyses, no such effects were observed in the two control weeks before and after DST transition. Effects were stable across time periods 1996–2006 and 2007–2017 (Table S3). Although IRRs were similar across different regions of time zones before 12pm (IRRs between 1.08 and 1.10; $p_{interaction} = 0.234$), IRRs significantly differed after 12pm ($p_{interaction} < 0.001$), and were highest in the western regions (IRR = 1.08; 95% CI; 1.04 to 1.13; p < 0.001) (Table S3). These results support our hypothesis that DST-induced effects on the circadian system are more severe and harder to recover from in western than in eastern regions of a given time zone. For the fall ST transition, no effect modification by location within time zone was observed for any effect of interest (whole day, before 12pm, after 12pm) (Figure 4; Table S3).

LIMITATIONS AND CONCLUSION

Our study has several limitations. Although this is the largest examination of DST and MVA risk to date, we have little information on the accident circumstances or weather conditions. Furthermore, we do not have information on the distribution of the total traffic volume or individual-level data on sleep deprivation, fatigue, recent transmeridian travel, circadian misalignment, as well as other potentially relevant predictors of accident risk, such as driver's age, car type, vehicle speed, and influence of alcohol. State-specific differences, for example in traffic patterns, volumes, laws, and geographical conditions, add additional heterogeneity to our data. Despite these limitations, the geographical and temporal breadth of our database allowed us to perform the most granular and detailed analysis of DST effects on MVA risk to date, and to discuss these effects in a broad, chronobiological context, including time of day and time zone effects, and their interrelationships.

In conclusion, our data of 732,835 MVAs demonstrates that, in the US, spring DST transition increases the risk of fatal MVAs by approximately 6% in the week after DST transition. Effects are exacerbated in the morning and by living in western regions of time zones. Although the observed effects are of moderate size, yearly DST transition affects billions of individuals, and thus small changes in MVA risk might have a substantial public health effect. Our results support the theory that abolishing time changes completely, would improve public health and reduce geographical health disparities, as observed in our time zone analysis.

STAR★METHODS

Detailed methods are provided in the online version of this paper and include the following:

- KEY RESOURCES TABLE
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- EXPERIMENTAL MODEL AND SUBJECT DETAILS
- METHOD DETAILS
- QUANTIFICATION AND STATISTICAL ANALYSIS
- DATA AND CODE AVAILABILITY

SUPPLEMENTAL INFORMATION

Supplemental Information can be found online at https://doi.org/10.1016/j.cub.2019.12.045.

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AUTHOR CONTRIBUTIONS

Conceptualization, K.P.W. and C.V.; Methodology, J.F. and C.V.; Formal Analysis, J.F. and T.V.; Writing – Original Draft, J.F. and C.V.; Writing – Review & Editing, J.F., T.V., K.P.W., and C.V.; Supervision, C.V.

DECLARATION OF INTERESTS

J.F. and T.V. declare no competing interests. K.P.W., during the conduct of the study, was a scientific advisory board member of and received personal fees from Torvec and received personal fees from Circadian Therapeutics, Inc. and from Kellogg Company; K.P.W. received research support from the NIH, the Office of Naval Research, the PAC-12 conference, and Somalogic, Inc. outside the submitted work. C.V., during the conduct of the study, received research support from the NIH, was a scientific advisory board member of Circadian Light Therapy Inc., and served as a paid consultant to the US Department of Energy outside the submitted work.

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REFERENCES

1. Varughese, J., and Allen, R.P. (2001). Fatal accidents following changes in daylight savings time: the American experience. Sleep Med. *2*, 31–36.
2. Carey, R.N., and Sarma, K.M. (2017). Impact of daylight saving time on road traffic collision risk: a systematic review. BMJ Open *7*, e014319.
3. Kantermann, T., Juda, M., Merrow, M., and Roenneberg, T. (2007). The human circadian clock's seasonal adjustment is disrupted by daylight saving time. Curr. Biol. *17*, 1996–2000.
4. Martiniuk, A.L., Senserrick, T., Lo, S., Williamson, A., Du, W., Grunstein, R.R., Woodward, M., Glozier, N., Stevenson, M., Norton, R., and Ivers, R.Q. (2013). Sleep-deprived young drivers and the risk for crash: the DRIVE prospective cohort study. JAMA Pediatr. *167*, 647–655.
5. Smith, A.C. (2016). Spring forward at your own risk: Daylight Saving Time and fatal vehicle crashes. Am. Econ. J. Appl. Econ. *8*, 65–91.
6. Czeisler, C.A., Wickwire, E.M., Barger, L.K., Dement, W.C., Gamble, K., Hartenbaum, N., Ohayon, M.M., Pelayo, R., Phillips, B., Strohl, K., et al. (2016). Sleep-deprived motor vehicle operators are unfit to drive: a multidisciplinary expert consensus statement on drowsy driving. Sleep Health *2*, 94–99.
7. Adams, J., White, M., and Heywood, P. (2005). Year-round daylight saving and serious or fatal road traffic injuries in children in the north-east of England. J. Public Health (Oxf.) *27*, 316–317.
8. Roenneberg, T., Kumar, C.J., and Merrow, M. (2007). The human circadian clock entrains to sun time. Curr. Biol. *17*, R44–R45.

9. Borisenkov, M.F. (2011). Latitude of residence and position in time zone are predictors of cancer incidence, cancer mortality, and life expectancy at birth. Chronobiol. Int. *28*, 155–162.

10. Pearl, J. (2009). Causality: Models, reasoning and inference, Second Edition (Cambridge: Cambridge University Press).

11. Crawley, J. (2012). Testing for robustness in the relationship between fatal automobile crashes and Daylight Saving Time. https://econ.berkeley.edu/sites/default/files/Crawley.pdf.

12. Sood, N., and Ghosh, A. (2007). The short and long run effects of Daylight Saving Time on fatal automobile crashes. B E J Econom Anal Policy *7*, 1–22.

13. Huang, A., and Levinson, D. (2010). The effects of daylight saving time on vehicle crashes in Minnesota. J. Safety Res. *41*, 513–520.

14. Lahti, T.A., Leppämäki, S., Lönnqvist, J., and Partonen, T. (2008). Transitions into and out of daylight saving time compromise sleep and the rest-activity cycles. BMC Physiol. *8*, 3.

15. Harrison, Y. (2013). The impact of Daylight Saving Time on sleep and related behaviours. Sleep Med. Rev. *17*, 285–292.

16. Coren, S. (1996). Daylight savings time and traffic accidents. N. Engl. J. Med. *334*, 924–925.

17. Conte, M.N., and Steigerwald, D.G. (2009). Do Daylight-Saving Time adjustments impact human performance. http://econ.ucsb.edu/∼doug/245a/Papers/AdjustBehavior.pdf.

18. Plainis, S., Murray, I.J., and Pallikaris, I.G. (2006). Road traffic casualties: understanding the night-time death toll. Inj. Prev. *12*, 125–128.

19. Pack, A.I., Pack, A.M., Rodgman, E., Cucchiara, A., Dinges, D.F., and Schwab, C.W. (1995). Characteristics of crashes attributed to the driver having fallen asleep. Accid. Anal. Prev. *27*, 769–775.

20. Ferguson, S.A., Preusser, D.F., Lund, A.K., Zador, P.L., and Ulmer, R.G. (1995). Daylight saving time and motor vehicle crashes: the reduction in pedestrian and vehicle occupant fatalities. Am. J. Public Health *85*, 92–95.

21. Giuntella, O., and Mazzonna, F. (2019). Sunset time and the economic effects of social jetlag: evidence from US time zone borders. J. Health Econ. *65*, 210–226.

22. Roenneberg, T., Wirz-Justice, A., Skene, D.J., Ancoli-Israel, S., Wright, K.P., Dijk, D.J., Zee, P., Gorman, M.R., Winnebeck, E.C., and Klerman, E.B. (2019). Why should we abolish Daylight Saving Time? J. Biol. Rhythms *34*, 227–230.

23. Gu, F., Xu, S., Devesa, S.S., Zhang, F., Klerman, E.B., Graubard, B.I., and Caporaso, N.E. (2017). Longitude position in a time zone and cancer risk in the United States. Cancer Epidemiol. Biomarkers Prev. *26*, 1306–1311.

24. VoPham, T., Weaver, M.D., Vetter, C., Hart, J.E., Tamimi, R.M., Laden, F., and Bertrand, K.A. (2018). Circadian misalignment and hepatocellular carcinoma incidence in the United States. Cancer Epidemiol. Biomarkers Prev. *27*, 719–727.

25. Fatality Analysis Reporting System (FARS). (2018). Analytical User's Manual, pp. 1975–2017. https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812602.

26. Cameron, A.C., and Trivedi, P.K. (2009). Microeconometrics Using Stata (College Station, TX: Stata Press).

27. Heinze, G., Wallisch, C., and Dunkler, D. (2018). Variable selection - A review and recommendations for the practicing statistician. Biom. J. *60*, 431–449.

28. le Cessie, S., Luijken, K., and Goetghebeur, E. (2019). Regarding "Variable selection - A review and recommendations for the practicing statistician" by G. Heinze, C. Wallisch, and D. Dunkler. Biom. J. *61*, 1595–1597.

29. Benjamini, Y., and Hochberg, Y. (1995). Controlling the false discovery rate: a practical and powerful approach to multiple testing. J. R. Stat. Soc. B *57*, 289–300.

STAR★METHODS

KEY RESOURCES TABLE

REAGENT or RESOURCE	SOURCE	IDENTIFIER
Deposited Data		
Fatality Analysis Reporting System (FARS) data	National Highway Traffic Safety Administration (NHTSA)	https://www.nhtsa.gov/research-data/fatality-analysis-reporting-system-fars
County's Center of Population	2000 U.S. Census Bureau	https://www.census.gov/geographies/reference-files/2000/geo/2000-centers-population.html
County's time zone	US Geological Survey time zone boundaries	https://nationalmap.gov/small_scale/mld/timeznp.html
Software and Algorithms		
SAS version 9.4	SAS Analytics Software & Solutions	https://www.sas.com/

LEAD CONTACT AND MATERIALS AVAILABILITY

Further information and requests for resources should be directed to and will be fulfilled by the Lead Contact, Céline Vetter (celine.vetter@colorado.edu). This study did not generate new unique reagents.

EXPERIMENTAL MODEL AND SUBJECT DETAILS

The Fatality Analysis Reporting System (FARS) database, maintained by the National Highway Traffic Safety Administration (NHTSA), is a complete nationwide collection of all qualifying fatal MVAs that occurred since 1975 within the 50 states, District of Columbia, Puerto Rico, and, since 2004, the Virgin Islands. Accidents qualify for the FARS database if they involve a motor vehicle on public routes and a death within 30 days of the accident [25]. For our analyses, we used data from 1996 until 2017, resulting in eleven years of follow-up for both the time period before and after 2007. We excluded Alaska, Hawaii, Puerto Rico, and the Virgin Islands from the analysis, as they are not part of the contiguous United States, as well as Arizona and Indiana where DST was, in at least parts, not observed for the majority of the time period. A small fraction (< 0.1%) of the documented accidents had missing date information and was therefore excluded, leaving 732,835 MVAs for our analysis. The data are publicly available via https://www.nhtsa.gov/research-data/fatality-analysis-reporting-system-fars. This was a secondary data analysis of de-identified information, which is considered exempt by institutional review boards.

METHOD DETAILS

Not applicable.

QUANTIFICATION AND STATISTICAL ANALYSIS

We estimated incidence rate ratios (IRRs) for MVA risk in the weeks around spring DST transition and fall transition back to ST using Poisson regression models. Following the recommendation of Cameron and Trivedi to control for mild violation of the distribution assumption that the variance equals the mean [26], we calculated robust standard errors and 95% confidence intervals (CIs) for all parameter estimates.

Important variables influencing the exposure and outcome and their inter-relationships were depicted in a directed acyclic graph (DAG), guiding us in the selection of relevant covariates for our models (Figure 1B) [27, 28]. Based on this DAG, we regressed the log of the number of daily MVAs on our predictor of interest "type of week" (with levels Monday to Friday before DST, DST week, week after DST, week before fall-back-transition to ST, week of fall back-transition, week after fall-back-transition, and any other Monday to Friday of the year) and the following predictors: year, time within the year (by using B-splines with knots at days 1, 92.25, 183.5, 274.75, and 366), weekday and indicator variables for Sunday of transition to DST (yes versus no) and Sunday of fall back-transition to ST (yes versus no). Although state is a predictor of traffic accident risk (due to different, state-specific traffic patterns, volumes, laws, and particular geographical situations), we did not include this variable in our models because the many levels of the variable state would have led to overadjustment and unstable model estimates. If our hypothesis that DST transition increased MVA risk in the five days after DST transition were true, we would expect to see an IRR > 1 for the level "Monday to Friday of DST week" compared to the reference level "any other Monday to Friday of the year" for the variable "type of week". The absolute number of MVAs attributable to DST and/or ST in the week after DST and/or ST transition was calculated as rate differences using the SAS macro %NLMeans (http://support.sas.com/kb/62/362.html). In by-day analyses, we used the predictor "type of day" (i.e., Monday before DST week, Monday of DST week, Monday after DST week, Monday before week of fall back transition to ST, Monday of fall back-transition week, Monday after fall back transition week, any other Monday of the year, and the same for Tuesday, Wednesday, Thursday, and Friday) instead of "type of week". To address concerns of multiple comparisons, the five p values for Monday to Friday were corrected according to the Benjamini-Hochberg procedure to control the false discovery rate (FDR) at the 0.05 level [29]. Furthermore, we analyzed risk for MVAs occurring before 12pm and occurring after 12pm, both in an overall model formally testing for interaction, and in separate models using only MVAs before 12pm and only MVAs after 12pm, respectively. We did a similar analysis dividing the day into six 4 h bins.

Furthermore, we regressed the log of the number of daily MVAs on time period (1996–2006 versus 2007–2017), year, time within the year (by using B-splines), weekday, second Sunday of March (yes versus no), Monday to Friday after the second Sunday of March (yes versus no), first Sunday of April (yes versus no), Monday to Friday after the first Sunday of April (yes versus no), last Sunday of October (yes versus no), Monday to Friday after the last Sunday of October (yes versus no), first Sunday of November (yes versus no), and Monday to Friday after the first Sunday of November (yes versus no). After the full models with interactions regarding time-period, we build models without interaction terms for the two time-periods 1996–2006 and 2007–2017 separately.

To test the time zone hypothesis, we categorized MVAs according to their location within the respective time zone into: MVAs occurring in (i) the western region—defined as regions located more than 5 degrees west of the respective time zone meridian; (ii) the middle region—zero to 5 degrees distance toward the west from the time zone meridian; and (iii) the eastern region—east of the time zone meridian. Information on the exact geographical coordinates was available in 74.4% of all fatal MVAs. For the remaining 26.6%, we imputed the geographical coordinates by the 2000 U.S. Census Bureau county Center of Population. The county Center of Population is the latitude and longitude of the point location in the county at which the population would balance if equally weighting the location of each person in the decennial census (https://www2.census.gov/geo/pdfs/reference/cenpop2010/COP2010_documentation.pdf). Similar to the before 12pm and after 12pm analysis, we fit overall models formally testing for effect modification by location within time zone, as well as separate models restricted to single regions within time zone.

All tests of statistical significance were two-sided, and p values less than 0.05 were considered statistically significant. All analyses were performed using SAS statistical software (version 9.4).

DATA AND CODE AVAILABILITY

Raw data of the Fatality Analysis Reporting System (FARS) is publicly accessible via https://www.nhtsa.gov/research-data/fatality-analysis-reporting-system-fars. Center of Population and time zone data are publicly available via https://www.census.gov/geographies/reference-files/2000/geo/2000-centers-population.html and https://nationalmap.gov/small_scale/mld/timeznp.html, respectively. Code can be obtained from the Lead Contact upon request.

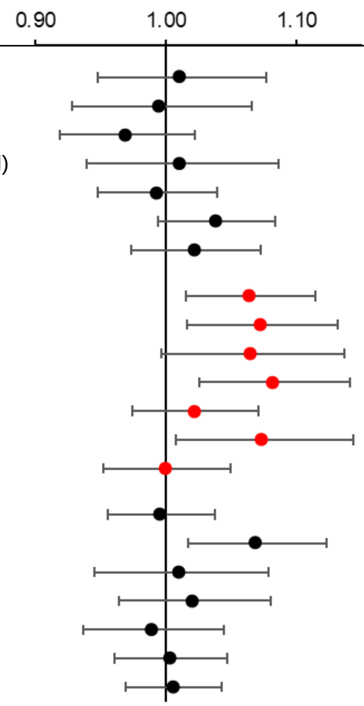
Current Biology, Volume *30*

Supplemental Information

A Chronobiological Evaluation of the Acute Effects of Daylight Saving Time on Traffic Accident Risk

Josef Fritz, Trang VoPham, Kenneth P. Wright Jr., and Céline Vetter

Whole day

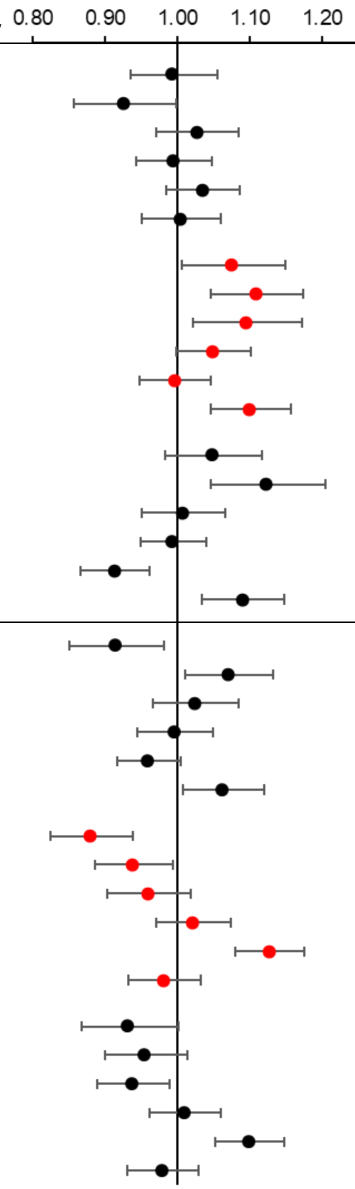


	IRR (95% CI)	p-value
Sunday before DST (control)	1.01 (0.95-1.08)	0.866
Monday before DST (control)	0.99 (0.93-1.07)	0.866
Tuesday before DST (control)	0.97 (0.92-1.02)	0.850
Wednesday before DST (control)	1.01 (0.94-1.09)	0.866
Thursday before DST (control)	0.99 (0.95-1.04)	0.866
Friday before DST (control)	1.04 (0.99-1.08)	0.664
Saturday before DST (control)	1.02 (0.97-1.07)	0.866
DST Sunday[a]	1.06 (1.02-1.11)	**0.025**
DST Monday	1.07 (1.02-1.13)	**0.025**
DST Tuesday	1.06 (1.00-1.14)	0.088
DST Wednesday	1.08 (1.03-1.14)	**0.025**
DST Thursday	1.02 (0.97-1.07)	0.445
DST Friday	1.07 (1.01-1.14)	0.051
DST Saturday	1.00 (0.95-1.05)	0.983
Sunday after DST (control)	1.00 (0.95-1.04)	0.896
Monday after DST (control)	1.07 (1.02-1.12)	0.059
Tuesday after DST (control)	1.01 (0.94-1.08)	0.896
Wednesday after DST (control)	1.02 (0.96-1.08)	0.896
Thursday after DST (control)	0.99 (0.94-1.04)	0.896
Friday after DST (control)	1.00 (0.96-1.05)	0.896
Saturday after DST (control)	1.01 (0.97-1.04)	0.896

Figure S1. Association of spring DST transition with fatal MVA risk. Weekday effects for the whole day. Related to Figure 2.

All effects are given relative to any other Monday/Tuesday/etc. of the year. P-values for Monday to Friday were corrected according to the Benjamini-Hochberg procedure to control the false discovery rate (FDR) at the 0.05 level (that some of the corrected p-values are often identical within a group of correction, is a characteristic of this procedure). Significant p-values are marked in bold. CI – confidence interval, IRR – incidence rate ratio, MVA – motor vehicle accident.

[a]: The shorter day length of the DST Sunday (only 23h) was corrected for by adding the logarithm of the daylength as an offset in the Poisson regression models.



Transition	Week	Time of day	IRR (95% CI)	p-value
Spring transition	Week before DST (control)	12am to 4am	0.99 (0.94-1.06)	0.886
		4am to 8am	0.93 (0.86-1.00)	0.279
		8am to 12pm	1.03 (0.97-1.09)	0.711
		12pm to 4pm	0.99 (0.94-1.05)	0.886
		4pm to 8pm	1.03 (0.99-1.09)	0.506
		8pm to 12am	1.00 (0.95-1.06)	0.886
	DST week	12am to 4am	1.08 (1.01-1.15)	**0.048**
		4am to 8am	1.11 (1.05-1.17)	**0.001**
		8am to 12pm	1.09 (1.02-1.17)	**0.021**
		12pm to 4pm	1.05 (1.00-1.10)	0.071
		4pm to 8pm	1.00 (0.95-1.05)	0.884
		8pm to 12am	1.10 (1.05-1.16)	**0.001**
	Week after DST (control)	12am to 4am	1.05 (0.98-1.12)	0.217
		4am to 8am	1.12 (1.05-1.21)	**0.002**
		8am to 12pm	1.01 (0.95-1.07)	0.806
		12pm to 4pm	0.99 (0.95-1.04)	0.806
		4pm to 8pm	0.91 (0.87-0.96)	**0.002**
		8pm to 12am	1.09 (1.03-1.15)	**0.002**
Fall transition	Week before ST fall back (control)	12am to 4am	0.91 (0.85-0.98)	0.050
		4am to 8am	1.07 (1.01-1.13)	0.050
		8am to 12pm	1.02 (0.97-1.08)	0.508
		12pm to 4pm	1.00 (0.95-1.05)	0.886
		4pm to 8pm	0.96 (0.92-1.00)	0.117
		8pm to 12am	1.06 (1.01-1.12)	0.050
	Week of ST fall back	12am to 4am	0.88 (0.83-0.94)	**<.001**
		4am to 8am	0.94 (0.89-0.99)	0.058
		8am to 12pm	0.96 (0.90-1.02)	0.268
		12pm to 4pm	1.02 (0.97-1.07)	0.467
		4pm to 8pm	1.13 (1.08-1.18)	**<.001**
		8pm to 12am	0.98 (0.93-1.03)	0.467
	Week after ST fall back (control)	12am to 4am	0.93 (0.87-1.00)	0.114
		4am to 8am	0.96 (0.90-1.01)	0.192
		8am to 12pm	0.94 (0.89-0.99)	0.060
		12pm to 4pm	1.01 (0.96-1.06)	0.690
		4pm to 8pm	1.10 (1.05-1.15)	**<.001**
		8pm to 12am	0.98 (0.93-1.03)	0.486

Figure S2: Association of spring DST transition and fall transition back to Standard Time (ST) with fatal MVA risk, stratified by time of day in 4h bins. Related to Figure 2 and Figure 3.

All effects are 'whole week' (e.g. Monday to Friday) effects, given relative to any other week (i.e. Monday to Friday) of the year. P-values for the six time slots were corrected according to the Benjamini-Hochberg procedure to control the false discovery rate (FDR) at the 0.05 level (that some of the corrected p-values are often identical within a group of correction, is a characteristic of this procedure). Significant p-values are marked in bold. CI – confidence interval, IRR – incidence rate ratio, MVA – motor vehicle accident.

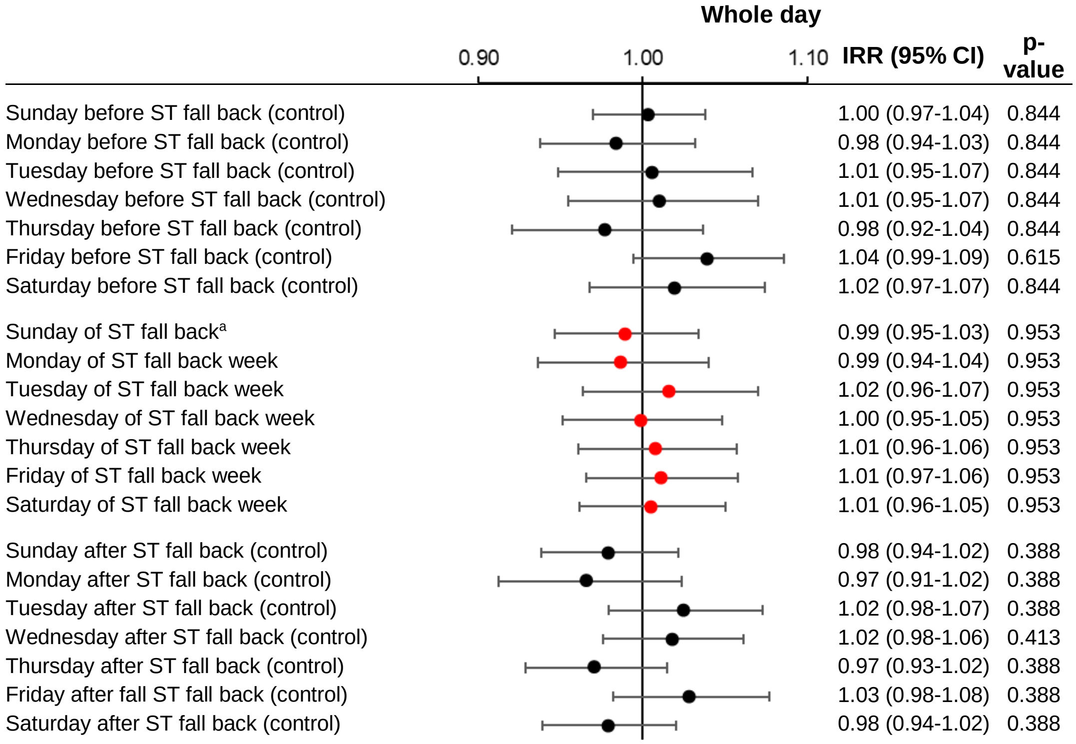


Figure S3: Association of fall transition back to Standard Time (ST) with fatal MVA risk. Weekday effects for the whole day. Related to Figure 3.

All effects are given relative to any other Monday/Tuesday/etc. of the year. P-values for Monday to Friday were corrected according to the Benjamini-Hochberg procedure to control the false discovery rate (FDR) at the 0.05 level (that some of the corrected p-values are often identical within a group of correction, is a characteristic of this procedure). Significant p-values are marked in bold. CI – confidence interval IRR, – incidence rate ratio, MVA – motor vehicle accident.

[a]: The longer day length of the Sunday of back change to ST (25h) was corrected for by adding the logarithm of the daylength as an offset in the Poisson regression models.

		DST week vs. week before DST		DST week vs. week after DST	
		IRR (95% CI)	p-value	IRR (95% CI)	p-value
Spring transition	Whole day	1.06 (1.02-1.10)	**0.002**	1.04 (1.01-1.08)	**0.015**
	Before 12pm	1.11 (1.05-1.17)	**<.001**	1.04 (0.98-1.10)	0.223
	After 12pm	1.03 (0.99-1.08)	0.124	1.05 (1.01-1.09)	**0.021**
	Western region	1.09 (1.04-1.14)	**<.001**	1.07 (1.02-1.12)	**0.010**
	Middle region	1.04 (0.98-1.11)	0.187	1.04 (0.98-1.10)	0.154
	Eastern region	1.04 (0.98-1.10)	0.206	1.01 (0.96-1.07)	0.601
		ST week vs. week before ST		**ST week vs. week after ST**	
		IRR (95% CI)	**p-value**	**IRR (95% CI)**	**p-value**
Fall transition	Whole day	1.00 (0.97-1.03)	0.975	1.00 (0.97-1.03)	0.916
	Before 12pm	0.92 (0.88-0.97)	**0.001**	0.98 (0.94-1.03)	0.491
	After 12pm	1.05 (1.01-1.09)	**0.017**	1.01 (0.97-1.05)	0.530
	Western region	0.99 (0.95-1.04)	0.680	1.03 (0.99-1.08)	0.180
	Middle region	1.01 (0.96-1.07)	0.703	0.98 (0.93-1.03)	0.368
	Eastern region	1.00 (0.95-1.06)	0.994	0.99 (0.94-1.05)	0.721

Table S1. Association of spring DST transition and fall transition back to Standard Time (ST) with fatal MVA risk. Related to Figure 2 and Figure 3.

All effects are ‘whole week’ (e.g. Monday to Friday) effects. Effects of DST/ST week are contrasted against the week before DST/ST, and the week after DST/ST. Significant p-values are marked in bold. CI – confidence interval, IRR – incidence rate ratio, MVA – motor vehicle accident.

		Before 12pm		After 12pm	
		IRR (95% CI)	p-value	IRR (95% CI)	p-value
Spring transition	Sun before DST (control)	1.03 (0.96-1.11)	0.881	0.99 (0.91-1.07)	0.867
	Mon before DST (control)	0.98 (0.90-1.08)	0.881	1.00 (0.93-1.09)	0.912
	Tue before DST (control)	0.96 (0.88-1.05)	0.881	0.97 (0.91-1.03)	0.867
	Wed before DST (control)	0.97 (0.88-1.07)	0.881	1.03 (0.95-1.13)	0.867
	Thu before DST (control)	0.99 (0.92-1.07)	0.881	0.99 (0.94-1.04)	0.867
	Fri before DST (control)	1.00 (0.94-1.07)	0.881	1.05 (0.99-1.12)	0.696
	Sat before DST (control)	1.03 (0.98-1.09)	0.881	1.01 (0.95-1.09)	0.867
	DST Sunday[a]	1.07 (1.00-1.14)	0.097	1.06 (0.99-1.12)	0.216
	DST Monday	1.11 (1.03-1.21)	**0.037**	1.05 (0.99-1.12)	0.216
	DST Tuesday	1.09 (0.99-1.20)	0.097	1.05 (0.97-1.14)	0.288
	DST Wednesday	1.12 (1.05-1.19)	**0.002**	1.06 (0.98-1.14)	0.216
	DST Thursday	1.02 (0.95-1.10)	0.549	1.02 (0.96-1.09)	0.521
	DST Friday	1.12 (1.00-1.25)	0.097	1.05 (0.99-1.11)	0.216
	DST Saturday	0.96 (0.91-1.02)	0.253	1.02 (0.95-1.09)	0.648
	Sun after DST (control)	1.00 (0.95-1.06)	0.905	0.99 (0.92-1.06)	0.948
	Mon after DST (control)	1.12 (1.02-1.24)	0.072	1.04 (0.98-1.10)	0.948
	Tue after DST (control)	1.04 (0.94-1.17)	0.609	0.99 (0.91-1.07)	0.948
	Wed after DST (control)	1.06 (0.97-1.16)	0.472	1.00 (0.93-1.08)	0.948
	Thu after DST (control)	0.98 (0.87-1.10)	0.811	0.99 (0.94-1.06)	0.948
	Fri after DST (control)	1.07 (1.02-1.12)	**0.022**	0.97 (0.91-1.03)	0.948
	Sat after DST (control)	1.04 (0.97-1.11)	0.472	0.98 (0.93-1.03)	0.948
Fall transition	Sun before ST (control)	1.06 (0.98-1.15)	0.391	0.94 (0.88-1.01)	0.165
	Mon before ST (control)	1.05 (0.98-1.13)	0.391	0.94 (0.89-1.00)	0.165
	Tue before ST (control)	1.06 (0.97-1.16)	0.391	0.97 (0.92-1.03)	0.572
	Wed before ST (control)	0.99 (0.91-1.09)	1.000	1.02 (0.95-1.10)	0.631
	Thu before ST (control)	0.99 (0.92-1.06)	1.000	0.97 (0.90-1.04)	0.572
	Fri before ST (control)	1.00 (0.91-1.10)	1.000	1.06 (1.02-1.11)	**0.030**
	Sat before ST (control)	1.05 (0.97-1.14)	0.391	0.99 (0.94-1.04)	0.660
	ST Sunday[b]	1.04 (0.99-1.10)	0.148	0.94 (0.88-1.00)	0.116
	ST Monday	0.94 (0.87-1.01)	0.148	1.02 (0.95-1.08)	0.646
	ST Tuesday	0.95 (0.86-1.04)	0.316	1.06 (1.00-1.12)	0.116
	ST Wednesday	0.92 (0.84-1.00)	0.148	1.05 (1.00-1.11)	0.116
	ST Thursday	0.95 (0.90-1.01)	0.148	1.05 (0.97-1.13)	0.249
	ST Friday	0.93 (0.88-0.99)	0.148	1.06 (0.99-1.13)	0.144
	ST Saturday	0.97 (0.90-1.04)	0.389	1.03 (0.98-1.08)	0.249
	Sun after ST (control)	0.99 (0.94-1.04)	0.710	0.96 (0.91-1.02)	0.337
	Mon after ST (control)	0.92 (0.86-0.98)	**0.042**	1.00 (0.92-1.08)	0.984
	Tue after ST (control)	0.97 (0.90-1.05)	0.710	1.06 (1.00-1.12)	0.198
	Wed after ST (control)	0.98 (0.91-1.06)	0.710	1.04 (0.97-1.11)	0.337
	Thu after ST (control)	0.93 (0.87-1.00)	0.160	1.00 (0.96-1.05)	0.984
	Fri after ST (control)	0.96 (0.88-1.05)	0.710	1.07 (1.01-1.13)	0.167
	Sat after ST (control)	1.00 (0.94-1.06)	0.999	0.96 (0.91-1.01)	0.251

Table S2. Association of spring and fall time change with fatal MVA risk. Weekday effects stratified by before 12pm and after 12pm. Related to Figure 2 and Figure 3.

All effects are given relative to any other Monday/Tuesday/etc. of the year. P-values for Monday to Friday were corrected according to the Benjamini-Hochberg procedure to control the false discovery rate (FDR) at the 0.05 level (that some of the corrected p-values are often identical within a group of correction, is a characteristic of this procedure). Significant p-values are marked in bold. CI – confidence interval, IRR – incidence rate ratio, MVA – motor vehicle accident.

[a]: The shorter length of the DST Sunday morning (before 12pm; only 11h) was corrected for by adding the logarithm of the daylength as an offset in the Poisson regression models.

[b]: The longer length of the Sunday of back change to ST morning (before 12pm; 13h) was corrected for by adding the logarithm of the daylength as an offset in the Poisson regression models.

		Dependent Variable	Western part		Middle part		Eastern part		p_{int}
			IRR (95% CI)	p-value	IRR (95% CI)	p-value	IRR (95% CI)	p-value	
Spring transition	Before 12pm	Week before DST (control)	0.97 (0.92-1.02)	0.199	1.00 (0.93-1.07)	0.958	0.99 (0.92-1.06)	0.732	0.314
		DST week	1.08 (1.03-1.14)	**0.002**	1.10 (1.03-1.18)	**0.007**	1.10 (1.03-1.18)	**0.007**	0.234
		Week after DST (control)	1.04 (0.98-1.10)	0.174	1.07 (1.00-1.14)	**0.042**	1.05 (0.98-1.13)	0.146	0.276
	After 12pm	Week before DST (control)	1.00 (0.96-1.05)	0.841	1.02 (0.97-1.08)	0.438	1.01 (0.96-1.07)	0.662	0.147
		DST week	1.08 (1.04-1.13)	**<.001**	1.03 (0.98-1.08)	0.273	1.01 (0.96-1.06)	0.596	**<.001**
		Week after DST (control)	1.00 (0.95-1.04)	0.843	0.98 (0.93-1.04)	0.512	1.01 (0.96-1.07)	0.582	0.329
	Before 2006	March week (control)	0.95 (0.91-1.00)	**0.035**	1.01 (0.96-1.06)	0.687	0.97 (0.90-1.04)	0.380	0.229
		April DST week	1.06 (1.01-1.12)	**0.014**	1.07 (1.01-1.14)	**0.021**	1.01 (0.96-1.07)	0.663	**0.006**
	After 2007	March DST week	1.10 (1.05-1.16)	**<.001**	1.04 (0.97-1.12)	0.230	1.07 (1.01-1.14)	**0.024**	**0.022**
		April week (control)	1.02 (0.97-1.08)	0.391	1.01 (0.94-1.08)	0.833	1.03 (0.96-1.10)	0.407	0.292
Fall transition	Before 12pm	Week before ST back change (control)	1.06 (1.01-1.12)	**0.022**	0.98 (0.91-1.04)	0.464	1.00 (0.93-1.06)	0.895	0.092
		Week of ST back change	0.92 (0.87-0.98)	**0.004**	1.00 (0.94-1.06)	1.000	0.88 (0.82-0.94)	**<.001**	0.392
		Week after ST back change (control)	0.94 (0.89-0.99)	**0.023**	0.98 (0.92-1.05)	0.606	0.93 (0.87-0.99)	**0.031**	0.783
	After 12pm	Week before ST back change (control)	1.02 (0.97-1.06)	0.482	1.00 (0.95-1.05)	0.881	0.99 (0.94-1.04)	0.566	0.222
		Week of ST back change	1.08 (1.04-1.13)	**<.001**	0.99 (0.95-1.04)	0.788	1.07 (1.01-1.12)	**0.015**	0.193
		Week after ST back change (control)	1.02 (0.98-1.07)	0.358	1.04 (0.99-1.10)	0.097	1.05 (1.00-1.11)	0.060	0.757
	Before 2006	October week	1.02 (0.97-1.07)	0.387	1.00 (0.95-1.06)	0.982	0.99 (0.93-1.04)	0.592	0.135
		November week (control)	0.99 (0.95-1.03)	0.492	1.02 (0.96-1.08)	0.523	1.03 (0.97-1.08)	0.366	0.516
	After 2007	October week (control)	1.06 (1.01-1.12)	**0.031**	1.00 (0.95-1.06)	0.897	1.00 (0.95-1.07)	0.876	0.183
		November week	1.02 (0.97-1.07)	0.376	0.99 (0.94-1.05)	0.724	1.00 (0.94-1.07)	0.877	0.599

Table S3. Association of spring and fall time change with fatal MVA risk, by location within time zone, stratified by time of day (before 12pm vs. after 12pm) and time period (before 2006 vs. after 2007). Related to Figure 4.

All effects are given relative to any other week (i.e. Monday to Friday) of the year. Significant p-values are marked in bold. CI – confidence interval, IRR – incidence rate ratio, MVA – motor vehicle accident.