Daylight saving time and fatal crashes: The impact of changing light conditions

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ABSTRACT

Introduction: Time changes in the fall and spring result in different light conditions in the morning and afternoon, which may impact U.S. roadway safety. *Methods:* We investigated the number of fatal crashes in the contiguous United States from 2010 to 2019 in the 5-weeks before and after biannual time changes focusing on crashes that occurred at times when light conditions changed. *Results*: Fatal crashes among motor-vehicle occupants decreased in the 5 weeks after the fall time change (−7.1%) and increased in the 5 weeks after the springtime change (+12%). The reverse was true for fatal crashes among pedestrians/bicyclists, increasing after the fall time change (+13%) and decreasing after the springtime change (−24%). Overall, time changes resulted in a net decrease of 26 fatal pedestrian/bicyclist crashes and an increase of 29 motor-vehicle occupant crashes. Pedestrian and bicyclist fatal crash counts were strongly associated with ambient light conditions: the net decrease of all 26 pedestrian/bicyclist crashes could be attributed to the changing light conditions, but only 2 of the additional motor-vehicle occupant crashes were associated with changing light conditions. *Conclusions*: Changing light conditions from biannual time changes have differential effects depending on time of day and road user type. The switch to daylight saving time in the spring results in an increase in motor-vehicle occupant fatal crashes and a reduction in pedestrian/bicyclist fatal crashes, while the opposite occurs following the switch to standard time in the fall. These effects are largely dependent on the ambient light conditions at the time of the crash, especially for pedestrians and bicyclists. *Practical applications*: The sensitivity of pedestrians and bicyclists to changing ambient light conditions supports the need for improved pedestrian and bicyclist infrastructure and continued efforts to develop vehicle technology to help avoid or mitigate crashes with pedestrians and bicyclists.

1. Introduction

The observance of daylight saving time and its impact on roadway safety has been a topic of interest for decades (e.g., Antle, 2023; Crawley, 2012; Sood & Ghosh, 2007; Ferguson et al., 1995). Past research has produced somewhat inconsistent estimates for the effect of daylight saving time on roadway safety due to varying sample sizes, geographical foci, and control variables. The sudden offset of light conditions relative to daily routines represents a threat to safe driving from two main sources: impaired cognitive capacity stemming from sleep disruption (Antle, 2023; Fritz et al., 2020; Harrison, 2013; Coren, 1996) and less visibility due to reduced ambient light in the mornings and afternoons during or adjacent to rush hour (Ferguson et al., 1995; James, 2022; Stevens & Lord, 2006). To determine the effect of time changes and associated changes in light conditions on highway safety, we conducted an analysis of nationwide fatal crash data among motor-vehicle users and pedestrians and bicyclists.

Observance of daylight saving time in the United States involves moving the clock ahead 1 h on the second Sunday in March and back 1 h on the first Sunday of November, marking the return to standard time. The change to daylight saving time in the spring can result in 1 less hour of sleep, while the return to standard time in the winter can result in an extra hour. Although individuals tend to adjust their activities immediately following the time change, sleep behaviors can take a week to adjust fully (Kantermann et al., 2007). Disruptions to sleep quality may result in drowsy driving, which is in turn associated with increased crash risk (Czeisler et al., 2016). However, the specific impact of sleep disruption on traffic safety is inconsistently demonstrated across several studies and overall may be quite small (see Antle, 2023, for a review). For this reason, the current study largely focused on changing light conditions as the mechanism through which time changes affect fatal crash rates.

One of the most consistent findings regarding the effect of time changes on crash risk is that hours of darkness around a time change produce more crashes than hours of daylight (e.g., James, 2022; Laliotis et al., 2019). Only 25% of travel occurs during nighttime, but 49% of motor-vehicle occupant fatalities and 77% of pedestrian fatalities occur during hours of darkness (NHTSA, 2023a; Varghese & Shankar, 2007), with twilight conditions and the first hour of evening darkness showing the highest frequency of pedestrian crashes (Griswold et al., 2011). These findings suggest that pedestrians may be disproportionately impacted by the abrupt shift in ambient light conditions. Fatal crashes involving pedestrians have been shown to occur more frequently following the switch to standard time in the fall (Ferguson et al., 1995) and less frequently following the switch to daylight saving time in the spring (Sood & Ghosh, 2007). Overall, daylight saving time specifically and more daylight hours in general both seem to reduce pedestrian crash fatalities (Coate & Markowitz, 2004).

What remains unclear is whether the shift between standard and daylight saving time produces a net change in crashes. Previous research has suggested that permanent daylight saving time could save lives, finding increases in fatal crashes when light levels changed from light to twilight and decreases when light levels changed from twilight to light (Ferguson et al., 1995). In contrast, other research has found that crash numbers merely shift from morning to afternoon, or vice versa, with the total number of crashes remaining constant (James, 2022; Smith, 2016; Stevens & Lord, 2006).

The current study was conducted to provide an updated assessment of the impact of daylight saving time on fatal crashes for motor-vehicle occupants and pedestrians and bicyclists. Our analyses were based on the 10 most recent years of fatal crash data from the Fatality Analysis Reporting System (FARS) from all daylight saving time-observing states in the contiguous United States, with a focus on crashes that occurred at times where ambient light conditions differed as a result of a time change.

2. Data collection and methods

Data on fatal crashes in the United States were obtained from the NHTSA Fatality Analysis Reporting System (FARS) from 2010 to 2019 (NHTSA, 2020), aggregated for the 5 weeks before and after each biannual time change: from early February to mid-April in the spring and from early October to mid-December in the fall. We selected the 5-week interval to allow for an examination of how durable the effects of the changing clock were, beyond the acute effects of loss of sleep. The longer timeframe allowed for analysis of crash rates after people had time to adjust their behavior to the altered light conditions. This time frame was a middle ground between studies that have examined much shorter time frames (5 days; Fritz et al., 2020) and those that looked much farther out (9–13 weeks; Ferguson et al., 1995). Crashes were restricted to those occurring in the morning (4 a.m.–10 a.m.) and afternoon (3p.m.–9p.m.). These "morning" and "afternoon" periods encompass morning and evening rush hour travel as well as the shifting occurrence of sunrise and sunset and associated shifts in ambient light. Fatal crashes were defined as those where at least one individual was killed. Data were limited to the contiguous United States; crashes that occurred in Arizona were excluded from the analysis because the state does not participate in daylight saving time.

Ambient light conditions were calculated using sunrise and sunset times obtained from the longitude and latitude of each crash. For the purposes of our analysis, light condition was discretized into three levels: dark, twilight, or light. Twilight was defined as the period when the geometric center of the sun is between 6 and 12 degrees below the horizon, and it is neither fully dark nor fully light (i.e., nautical twilight).

All models of weekly fatal crash counts were done using Poisson regression, with fatal crash counts predicted by a binary variable representing the time change (before, after), season (fall, spring), and an interaction between the two. We also included a variable representing

the number of weeks into a given period (1, 2, 3, 4, 5) to help account for seasonal effects not related to the time change. These relationships were modeled using mixed effects models with weekly observations nested within the year. Season was also included as a nesting term when it improved model fit. Only random intercept terms were used; slopes were specified to be fixed in all cases.

We separated crashes involving pedestrians and bicyclists from those involving motor-vehicle occupants because the impact of changing light conditions was expected to differ by road user. Pedestrians and bicyclists were grouped together because although there are several key differences between them (e.g., bicyclists often travel faster than pedestrians, may be equipped with a light, etc.) research suggests that the nature of the threat posed to them by motor vehicles is comparable (Monfort and Mueller, 2023; Monfort et al., 2024). Furthermore, the number of bicyclist crashes was relatively small, and concerns related to sample size discouraged their separation.

3. Results

3.1. Impact of daylight saving time on fatal crashes

Light condition and type of road user were key determinants of the impact of time changes on fatal crashes. Overall, the time change was associated with a 3.3% increase in weekly fatal crashes in the spring, 95% confidence interval (CI) [0.8%, 5.8%], and a 2.4% decrease in fatal crashes in the fall, 95% CI [0.3%, 4.5%]. However, the spring and fall time changes were associated with differential effects by road user.

Disaggregating motor-vehicle occupants from pedestrians and bicyclists yielded different effects of the time change by road user for each season. Overall, the fall was worse for pedestrians and bicyclists and the spring was worse for motor-vehicle occupants. Specifically, although the springtime change resulted in a 12% increase in fatal motor-vehicle occupant crashes, 95% CI [9.1%, 15%], it was also associated with a 24% decrease in fatal pedestrian/bicyclist crashes, 95% CI [20%, 28%]. The inverse was true for the fall time change: a 7.1% reduction in fatal motor-vehicle occupant crashes, 95% CI [4.8%, 9.4%], and a 13% increase in fatal crashes involving pedestrians and bicyclists, 95% CI [8.0%, 18%]. The net result of these effects over 5 weeks were 50 additional fatal crashes with pedestrians and bicyclists in the fall and 76 fewer in the spring, and 119 more fatal crashes with motor vehicles in the spring and 90 fewer in the fall. The overall result was a decrease of 26 pedestrian and bicyclist fatal crashes and an increase of 29 motor-vehicle occupant fatal crashes. These effects are shown in Table 1, summarized in Fig. 1, and represented in time series in Fig. 2.

3.2. Impact of changing light conditions on fatal crashes

The effects of a changing clock should be most evident in the morning and afternoon hours, where light conditions suddenly differ from those before the time change. Many crashes in our sample occurred

Table 1

Regression results for motor vehicle occupants for crashes between 4–10 AM and 3–9 PM.

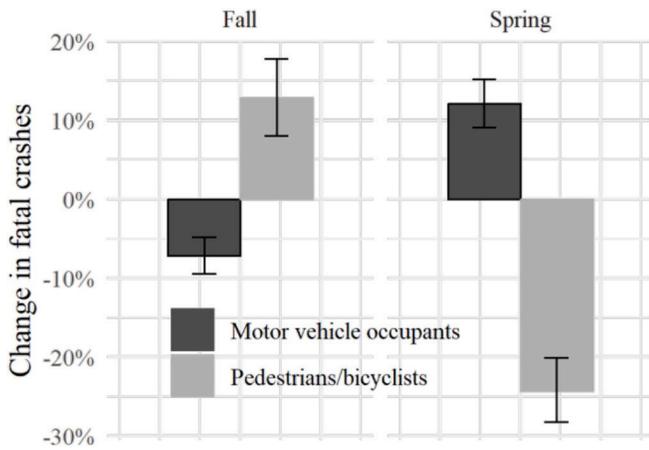| OVERALL						
	Rate ratio		95% confidence interval		*p*	
	MVO	VRU	MVO	VRU	MVO	VRU
Week	1.00	0.99	[0.99, 1.00]	[0.97, 1.00]	0.523	0.019
Before vs. after	1.08	0.89	[1.05, 1.10]	[0.85, 0.93]	0<.001	0<.001
Spring vs. fall	0.94	0.54	[0.91, 0.97]	[0.51, 0.57]	0<.001	0<.001
Season × before vs. after	0.83	1.49	[0.80, 0.86]	[1.39, 1.59]	0<.001	0<.001

Fig. 1. Changes in weekly fatal crash counts for fall and spring by road user (error bars represent 95% CI).

in light conditions that would have remained the same had the clock shifted an hour. It is unlikely that these crashes were directly affected by the altered light conditions from the time change. Focusing on the subset of crashes whose light conditions would have been different in the other period provides an estimate for the number of fatal crashes that were a direct result of changing light. Using sunrise and sunset times, we flagged crashes from our sample that would have had different ambient light conditions had the clock shifted an hour; a visualization of this process is depicted in Fig. 3.

The aforementioned subset of crashes was used to repeat the prediction of weekly fatal crash counts, this time separately for morning and afternoon and by motor-vehicle occupants and pedestrians and bicyclists (Figs. 4 and 5). We found darker spring mornings produced a 20% increase in fatal pedestrian/bicyclist crashes, 95% CI [5.3%, 36%], and an 11% increase in fatal motor-vehicle occupant crashes, 95% CI [3.0%, 20%]. Conversely, lighter spring afternoons reduced fatal pedestrian and bicyclist crashes by 27%, 95% CI [19%, 35%], and had no effect (< 1% change) on fatal motor-vehicle crashes. The inverse was again true for the fall: lighter fall mornings were associated with a 40% reduction in fatal crashes for pedestrians and bicyclists, 95% CI [33%, 46%], and a 12% decrease in those for motor-vehicle occupants, 95% CI [5.9%, 18%]. Likewise, darker fall afternoons were associated with a 21% increase in fatal crashes for pedestrians and bicyclists, 95% CI [11%, 32%], and a 4% increase in those for motor-vehicle occupants, 95% CI [−1.5%, 6.0%]. The net result of these effects over 5 weeks were

12 fewer fatal crashes with pedestrians and bicyclists in the fall and 14 fewer in the spring, and 14 more fatal crashes with motor vehicles in the spring and 12 fewer in the fall. Time changes resulted in 26 fewer fatal crashes with pedestrians and bicyclists and 2 additional fatal crashes for motor-vehicle occupants. These effects are shown in Tables 2 and 3, summarized in Fig. 4, and represented in time series in Fig. 5.

4. Discussion

Roadway fatal crash trends changed following both the spring and fall time changes, but the effects differed by season, road user, and time of day. Overall, fatal crashes rose following the springtime change and fell after the fall time change with the net effect being a very slight increase in crashes following the springtime change. The changes in fatal crash counts following the springtime change impacted motor-vehicle occupants more than it did pedestrians and bicyclists, while the reverse was true for the fall. After each time change, the time of day that gained an additional light hour (spring afternoons and fall mornings) showed fewer fatal crashes, while the time of day that gained extra darkness (spring mornings and fall afternoons) saw increased fatal crashes. Although the time changes impacted all road users to some degree, pedestrians and bicyclists saw a greater percent reduction in fatal crashes in increased light and the largest increase in fatal crashes in increased darkness. These results indicate a strong relationship between increased darkness and increased fatal crashes, particularly among pedestrians and bicyclists.

The current findings are consistent with trends shown in previous work, specifically with those studies showing a shift in crash distribution following ambient light conditions (Ferguson et al., 1995; Huang & Levinson, 2010; James, 2022; Smith, 2016). Our findings are also consistent with work that observed a decrease in afternoon pedestrian fatal crashes after the springtime change and the reverse effect in the fall (Ferguson et al., 1995).

Pedestrians and bicyclists were particularly vulnerable to the time changes in the fall and spring. The pronounced impact of dark conditions on pedestrians and bicyclists mirrors the marked increase in their involvement in fatal crashes observed across the United States over the past 15 years (Hu & Cicchino, 2018; Schneider, 2020). The reasons for this increase are multifaceted, including but not limited to faster crash speeds (e.g., Tucker & Marsh, 2021), pedestrian-unfriendly trends in land use (e.g., Abou-Senna et al., 2022), and more aggressive vehicle designs (e.g., Monfort & Mueller, 2023). These impacts may vary regionally based on the auto-oriented development patterns and the availability of public transit. Recent improvements in vehicle occupant protection have also not benefitted pedestrians and bicyclists; the
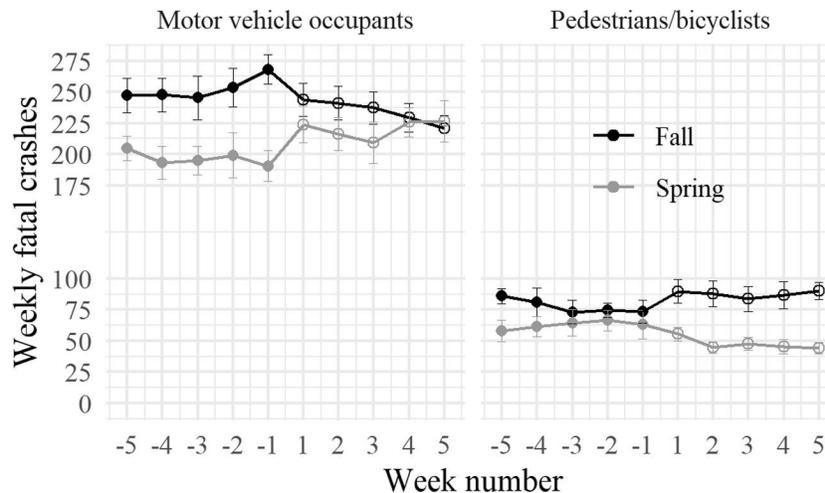

Fig. 2. Average weekly fatal crashes per year for fall and spring by road user (error bars represent 95% CI).
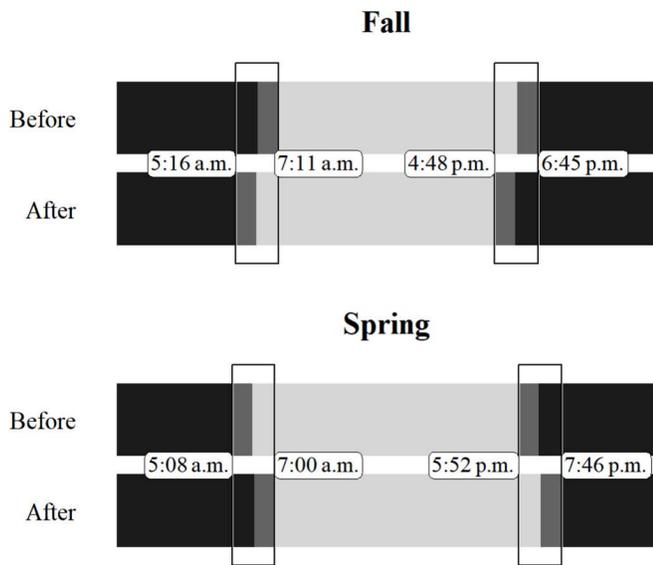
Fig. 3. Representation of the time interval included in the changing light conditions analysis Note. Shading represents light condition: light gray is daylight, dark gray is twilight, and black is darkness. The box represents the timeframe analyzed.
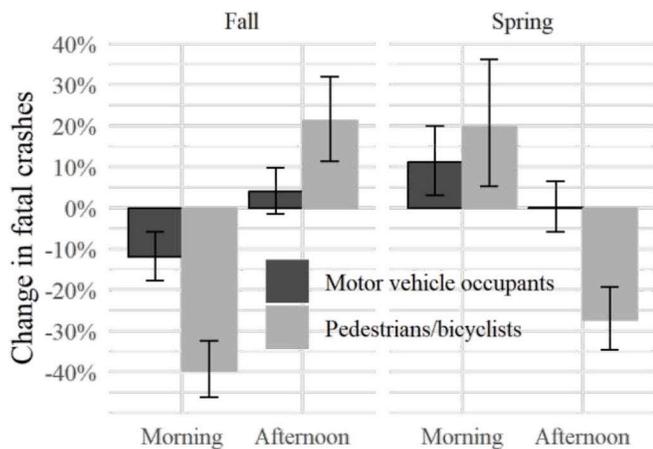

Fig. 4. Changes in weekly fatal crashes per year occurring during hours where daylight conditions would have differed in the other period for fall and spring by road user and time of day (error bars represent 95% CI).

Fig. 5. Average weekly fatal crashes per year for fall and spring by road user occurring during hours where daylight conditions would have differed in the other period (error bars represent 95% CI).

Table 2
Regression results for motor-vehicle occupants for morning and evening crashes where the light conditions would differ.

OTHER LIGHT CONDITION, MVO						
	Rate ratio		95% confidence interval		*p*	
	AM	PM	AM	PM	AM	PM
Week	0.99	1.00	[0.98, 1.01]	[0.98, 1.01]	0.538	0.555
Before vs. after	1.14	0.96	[1.06, 1.21]	[0.91, 1.02]	0<.001	0.155
Spring vs. fall	0.87	0.77	[0.81, 0.94]	[0.71, 0.83]	0<.001	0<.001
Season × before vs. after	0.79	1.04	[0.72, 0.88]	[0.96, 1.13]	0<.001	0.359

Table 3
Regression results for bicyclists and pedestrians for morning and evening crashes where the light conditions would differ.

OTHER LIGHT CONDITION, VRU						
	Rate ratio		95% confidence interval		*p*	
	AM	PM	AM	PM	AM	PM
Week	0.98	1.00	[0.95, 1.01]	[0.97, 1.02]	0.201	0.722
Before vs. after	1.66	0.83	[1.48, 1.86]	[0.76, 0.90]	0<.001	0<.001
Spring vs. fall	1.06	0.51	[0.93, 1.20]	[0.46, 0.56]	0.391	0<.001
Season × before vs. after	0.50	1.67	[0.42, 0.60]	[1.46, 1.91]	0<.001	0<.001

combined impact of these effects is that bicyclists and pedestrians are becoming a larger proportion of the fatality count (NHTSA, 2021). As a result, the effect of time changes on fatalities in the years to come may be increasingly relevant for pedestrians and bicyclists. Recent research suggests that rising pedestrian fatalities in darkness have occurred most rapidly in the presence of crossings at unmarked non-intersections along medium- and high- speed urban roadways (Ferenchak & Abadi, 2021; Sanders et al., 2022). Infrastructure improvements may be a powerful means to protect cyclists and pedestrians from crashes that occur as a result of poor lighting conditions. Adding highly visible pedestrian lighting and signals like rapid rectangular flashing beacons and pedestrian hybrid beacons has been shown to increase pedestrian visibility to drivers (Fitzpatrick et al., 2016) and could help reduce fatal crashes, especially between intersections. Improved headlights can make pedestrians more visible to drivers and reduce pedestrian crashes (Brumbelow, 2022) and more robust pedestrian AEB, specifically that works better in dark conditions, could also mitigate or prevent nighttime pedestrian crashes (Cicchino, 2022). Roadway redesigns that reduce
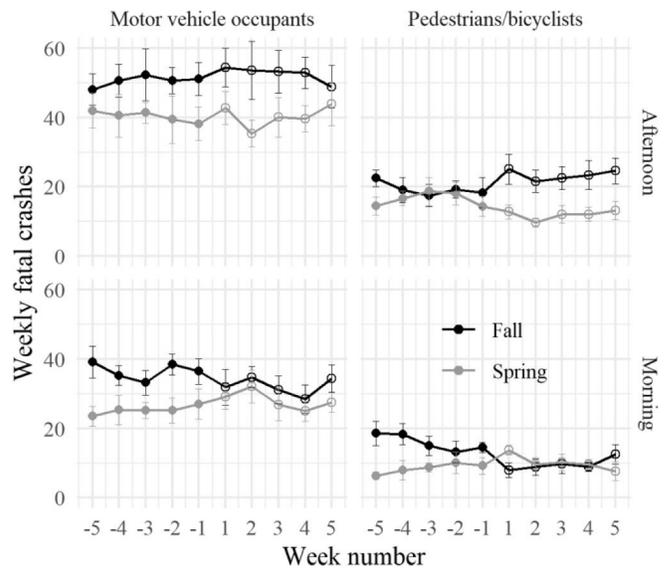
automobile traffic may also increase bicycle traffic and have an overall positive effect on pedestrian and cyclist safety (Gudz et al., 2016). Forthcoming work is expected to establish the root causes of pedestrian crashes at night and propose strategies to mitigate these crashes (Transportation Research Board, n.d.).

Our analysis of fatal crash data from the United States allowed for a detailed examination of light conditions using latitude and longitude at the site of the crash. Although this approach allowed us to very accurately pinpoint the times of sunrise, sunset, dawn, and dusk at each crash

location, the ambient light at the time of the crash could have been affected by cloud cover or other environmental factors. Nonetheless, we believe determining light condition from latitude and longitude ensured a consistent definition of light condition across all states that introduced less variability than the police reported light condition found in FARS, which could vary based on the time of arrival at the scene and the subjective assessment of dawn and dusk. Due to the size of the sample and the diversity of geography and microclimates across the United States, weather-related environmental variables were not included in our analysis along with other environmental and social variables sometimes considered in analyses of more limited geographic areas (Huang & Levinson, 2010; Laliotis et al., 2019; Molina et al., 2023).

Traffic volume data was also absent from our analyses. Although some work indicates no marked change in motor-vehicle traffic volume in dark conditions generally (Fotios & Robbins, 2022), other work has shown an increase in afternoon traffic volume following the fall time change, ultimately increasing crash rates (Huang & Levinson, 2010). However, changes in ambient light conditions from time changes strongly predict cycling and walking traffic (Uttley & Fotios, 2017), particularly among recreational travelers (Fotios et al., 2019; Fotios & Robbins, 2022; Uttley et al., 2023; Wessel, 2022). Changing traffic levels are an important determinant of net fatality risk. That is, we observed a 21% increase in pedestrian/bicyclist fatal crashes on darker fall afternoons, a net effect that may have been mitigated by a decrease in pedestrian and bicyclist activity with cooling temperatures and less light. In contrast, the spring brings more afternoon light and warmth, which likely increases pedestrian and cyclist activity; the 27% reduction in pedestrian/bicyclist fatal crashes during this period occurred in spite of a potentially higher traffic volume, while the 20% increase on spring mornings potentially reflects increased activity during unfavorable light conditions. Additional work is needed to better understand the impact of time changes on crash risk independent of traffic type and volume. The current study grouped pedestrians and bicyclists together. Future work could consider the impact of time changes and light condition on pedestrians and bicyclists independently.

5. Conclusions

Light condition and type of road user are key determinants of the impact of time changes on fatal crashes. The shift in daylight conditions after the spring and fall time changes was associated with changes in the distribution of roadway fatal crashes for motor-vehicle occupants and pedestrians and bicyclists. Specifically, fatal crashes increased for pedestrians and bicyclists on spring mornings (+20%) and for motor vehicle occupants on fall afternoons (+4%) but decreased for pedestrians and bicyclists on fall mornings (−40%) and spring afternoons (−27%). The overall result was 26 fewer fatal crashes with pedestrians and bicyclists and 2 additional fatal crashes with motor vehicle occupants. Taken together, we found that time changes and the associated changes in light conditions primarily affected pedestrians and bicyclists but had a small effect on motor vehicle occupants as well.

CRediT authorship contribution statement

Amber N. Woods: Conceptualization, Writing – review & editing, Methodology, Data curation, Formal analysis. **Rebecca A. Weast:** Writing – review & editing, Conceptualization. **Samuel S. Monfort:** Writing – review & editing, Visualization, Methodology, Formal analysis, Data curation.

Declaration of competing interest

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

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