DRIVING DURING THE DAY AND NIGHT, DARKNESS AND LIGHT

Researchers have long recognized that nighttime travel is far more dangerous than daytime travel for motor-vehicle drivers and nonmotorists. The reasons for this disparity have neither been widely communicated nor fully grasped except at a very basic level (i.e., it is easier to see in daylight than in darkness). A critical factor in this discussion is the engineering concept of stopping sight distance (SSD). Engineers define SSD as the minimal distance at which a driver at an eye-height of three and one-half feet can see an object in the roadway that is at least two feet high, and brake in time to stop before striking the object. This summary examines traffic safety risks associated with both time of day and light conditions.

Daily light conditions in Washington State vary greatly depending on season. About two-thirds of fatal crashes that occurred in December were in darkness, while two-thirds of fatal crashes in July occurred during daylight conditions (four to five percent in each month happened at dawn or dusk). Daylight in December casts lower ambient light levels than daylight in July. For a full calendar year, fatal crashes in Washington are nearly equivalent between daylight and dark conditions, thereby hiding the seasonal extremes. However, fatal crashes involving impairment, distraction, speeding, and pedestrians were proportionately higher in darkness than in daylight conditions. Fatal crashes totaled by hour show similar patterns. Three-fourths of all vehicle-miles traveled (VMT) on state roads accrued during daytime hours, between 6:00 a.m. and 5:59 p.m. However, the same hourly period accounted for only about half of all fatal crashes. By contrast, the hours between 6:00 p.m. and 5:59 a.m. accounted for only one-fourth of state road VMT, yet generated almost half of all fatal crashes on state roads. Whether "nighttime" is defined by light condition or by specific hourly periods, traffic deaths are over-represented at night.

Darkness poses a complicated challenge for all traffic users, particularly on roads without additional lighting. While the driving-related physics of motion and force are the same at night and during the day, the physics of light leading to driver and nonmotorist perception at night are quite different from those occurring during the day. The difference is a function of luminance: the intensity and saturation of light reflecting off physical surfaces in the environment (in this case, the roadway environment). The lower levels of illumination at night lead to poorer retinal function and reduced driver SSD. At lower luminance levels, the retinal cones (highly sensitive cells typically engaged during focused attention) can no longer facilitate accurate perception of fine detail in the visual field. In darkness, the far less sensitive retinal rods predominate, generating lower quality images tarnished by poor spatial and temporal resolution, decreased contrast sensitivity, and distorted or missing color vision. When retinal rods dominate, visibility becomes even more challenging for all road users; vehicles, bicyclists, pedestrians, and roadway/roadside factors become more difficult to distinguish adequately. Even more problematic is the fact that dependence on retinal rods reduces visual processing speed, which increases motorist reaction times and further increases stopping distances.

During daylight hours, drivers have more sight-distance capability so are able to adjust their vehicle speeds more quickly and appropriately to the changing demands of safe driving. For example, a child suddenly darting out into the roadway several hundred yards distant will be in less danger when an approaching vehicle driver has ample SSD to slow or stop well before endangering the child. Consistent driver reaction times (ranging between 1.5 and 2.5 seconds for most people) means that the vast majority of daylight drivers will have plenty of time to perceive the child, let up on the accelerator to slow the vehicle, and brake to stop it altogether, compared to drivers at night.

In spite of the fact that drivers are less able to perceive risks and respond appropriately during nighttime driving, their driving behavior does not change accordingly. Nighttime travel speeds are consistent with daytime speeds, which means that motorists regularly outdrive the visual capacity afforded by their headlight beams. A number of researchers have advocated lower travel speeds at night in order to improve motoring, bicycling, and walking safety, but such appeals have not led to speed limit changes. Additional nighttime factors compound the visibility issues created by poor illumination, even for the most perceptually robust of drivers. Though driving between 6:00 p.m. and 5:59 a.m. generates only one-fourth of state road VMT, over half of impaired driving and speeding-involved, and more than three-fourths of all pedestrian-involved fatal crashes on state roads happen during those same hours.

Many drivers are aware of the increased presence of impaired and heedless drivers in nighttime traffic, as those issues are widely publicized. Alcohol in particular exacerbates some of the visual problems created by nighttime driving. The slower reaction time and other perceptual-motor deficits created by alcohol impairment increase the visual-processing and neuromuscular-response time associated with rod-dominant retinal function at night. Finally, some of the incentives governing whether motorists follow and obey posted speed limits and other essential traffic laws may be weakened by the reduced presence of effective law enforcement at night. For all these reasons, the perils of nighttime travel on our roads remain an issue.

Reference Summaries:

Bullough J.D., Skinner N.P., Pysar R.M., Radetsky L.C., Smith A.M., and Rea M.S. (2008). **Nighttime glare and driving performance: research findings**. Washington, DC: National Highway Traffic Safety Administration (NHTSA), DOT HS 811 043 (September 2008). https://trid.trb.org/view/886701

After NHTSA received numerous complaints in the early 2000s about "headlamp glare", in 2005 Congress authorized NHTSA to conduct a study of the problem. The resulting report summarizes the authors' own experimental results and those of others, and also provides an overview of research information on headlight intensity, mounting, and alignment, and how these factors combine to affect driver performance. One of their most important findings is that "low-beam headlamps provide insufficient visibility to detect and respond to potential roadway hazards at driving speeds above 30 to 40 mph" (V-1). Other researchers recommended that vehicle drivers operate at night with their high-beam lights permanently on in order to enhance overall visibility during nighttime conditions. However, the authors conclude that motorists cannot escape the "inherent conflict between increasing headlamp intensity to improve forward visibility and limiting intensity to prevent glare for other drivers" (V-6). On the one hand, increasing the forward illumination of headlights to enable greater stopping sight distance (SSD) would improve roadway visibility and safety performance for all drivers in the absence of vehicles traveling in the opposite direction. However, that same heightened illumination under two-way traffic conditions would result in untolerable glare and decreased visual performance for the majority of drivers. This inherent conflict between glare and illumination necessitates the use of low-beam headlights, which "provide insufficient visibility to detect and respond to potential roadway hazards at many driving speeds above 30 to 40 mph" (p. V-1). The report also mentions the wide variation in headlight beam direction among motor vehicles, as well as the widespread prevalence of dirty and faulty headlights.

Coate D. and Markovitz S. (2004). **The effects of daylight and daylight saving time on US pedestrian fatalities and motor vehicle occupant fatalities.** *Accident Analysis and Prevention*. 36: 351-357. https://www.sciencedirect.com/science/article/abs/pii/S0001457503000150

The authors of this article utilized multiple regression analysis to estimate the effects of changing from daylight savings time (DST) back to standard time (ST) on pedestrian and vehicle-occupant fatality. They used county-level FARS data for 1998 and 1999 to show that maintaining DST instead of moving back to ST in those years would have resulted in 171 fewer pedestrian fatalities and 195 fewer vehicle-occupant fatalities per year. A large share of this safety improvement stems from the observation that pedestrian travel numbers in particular tend to be larger during late-afternoon periods than during early-morning periods.

Owens D.A. and Tyrrell R.A. (1999). **Effects of luminance, blur, and age on nighttime visual guidance: a test of the selective degradation hypothesis**.
https://www.researchgate.net/profile/D_Owens2/publication/285589271_OwensTyrrell%2799-JEPA-Driving-Test_of_SelectiveDegradatinH/links/5660967008ae418a78666c7a/Owens-Tyrrell99-JEPA-Driving-Test-of-SelectiveDegradatinH.pdf

The authors of this article review much of the existing literature on nighttime driving and report that "even for young healthy eyes, the visibility afforded by low-beam headlights is not adequate for travel at speeds above approximately 20 mph." In spite of this finding, though, vehicle speeds are "generally as high at night as in daylight hours" (p. 115). The result, the authors conclude, is that drivers generally overdrive their headlights during nighttime driving. The notable exception to this generalization is older drivers, who typically drive far more cautiously at night than younger drivers. They are also more likely to restrict their nighttime driving or else to avoid it altogether. The authors theorize that older drivers are more aware of the degraded state of their nighttime vision than younger drivers are, and their research results confirm this. Their results also show that older drivers exhibit driving difficulty even at the slightly reduced luminance levels typical of early dusk and late dawn. Moreover, the degradation of visual performance is not uniform but appears to act selectively. For example, the effect of slightly reduced luminance levels on older drivers resulted in significantly more steering errors than at higher luminance levels. However, these slight luminance reductions apparently had no effect on the steering performance of younger drivers. The authors also found that visual performance deficits related to lower luminance appears to be related more to a decrement in pupillary response among older people than to degraded retinal performance.

Johansson G. and Rumar K. (1968). **Visible distances and safe approach speeds for night driving**. Ergonomics. 11: 275-282.
https://www.tandfonline.com/doi/abs/10.1080/00140136808930971

This is one of the most comprehensive early studies on the problems associated with nighttime driving. The authors build on a series of earlier simulator studies they conducted to examine human performance related to nighttime sight distances (in variable conditions), vehicle speeds, prepared and surprised braking reaction-times, stopping distances, and other variables. In this case, 413 different Swedish drivers volunteered to use their own vehicles in a test-track study to determine which vehicle speed levels would result in safe stopping to avoid striking a dark-colored cloth dummy. The results revealed that human performance varies widely across all variables. Drivers reported perceiving the test dummy at varying points during a given test-run, and they demonstrated varied approach speeds, braking reaction times (BRT), stopping distances, and other results. The authors conclude, based on these and other experimental results that normal driver

reaction times vary between 1.6 seconds and 2.5 seconds but placing an unexpected object (e.g., the dummy) in the driver's path will increase BRT by about an additional second. For expectant drivers whose normal reaction time is 2 seconds and whose vehicles are initially traveling at 55 MPH; those vehicles will travel over 350 feet before stopping altogether. For surprised drivers, in that one additional second of BRT their vehicles will travel an additional 80 feet before stopping.

Layton R. and Dixon K. (2012). **Stopping sight distance**. Corvallis: Kiewit Center for Infrastructure and Transportation, Oregon State University. 1-21. https://cce.oregonstate.edu/sites/cce.oregonstate.edu/files/12-2-stopping-sight-distance.pdf

This report reviews and further develops the critical engineering concept known as "stopping sight distance" (SSD), including its other forms, e.g., decision sight distance, passing sight distance, intersection sight distance and railroad crossing sight distance. The authors point out that roadway engineering standards in the U.S. require incorporating appropriate sight distance values for every point on every road into all roadway design projects. They then proceed to describe and quantify the required engineering specifications and important features of each component of sight distance. They also make design recommendations to account for the presence of specific traffic-user populations, such as older drivers, pedestrians, and bicyclists.

Plainis S., Murray I.J., and Pallikaris I.G. (2006). **Road traffic casualties: understand the night-time death toll**. Injury Prevention. 12: 125-128. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2564438/pdf/125.pdf

These authors review evidence related to driver visual performance and explain why it diminishes in lower-luminance light conditions. The reason is that two types of photoreceptors populate the human retina – cones and rods. Cones are able to process visual information far more rapidly than rods, and they also serve to generate precise and detailed visual images, contrast sensitivity, and color vision. The cones function optimally under daytime illumination but function poorly in lower-luminance conditions. At that point, the rods assume a primary visual-processing role, and they function much more poorly than cones for all of the capabilities detailed above. Finally, rods are much less able to process the motion-based information essential to speed and distance judgments, and they process all information more slowly than cones. The result of this overall decrease in visual information processing efficiency is a significant increase in stopping distance during nighttime driving.