PROFESSIONAL ISSUES

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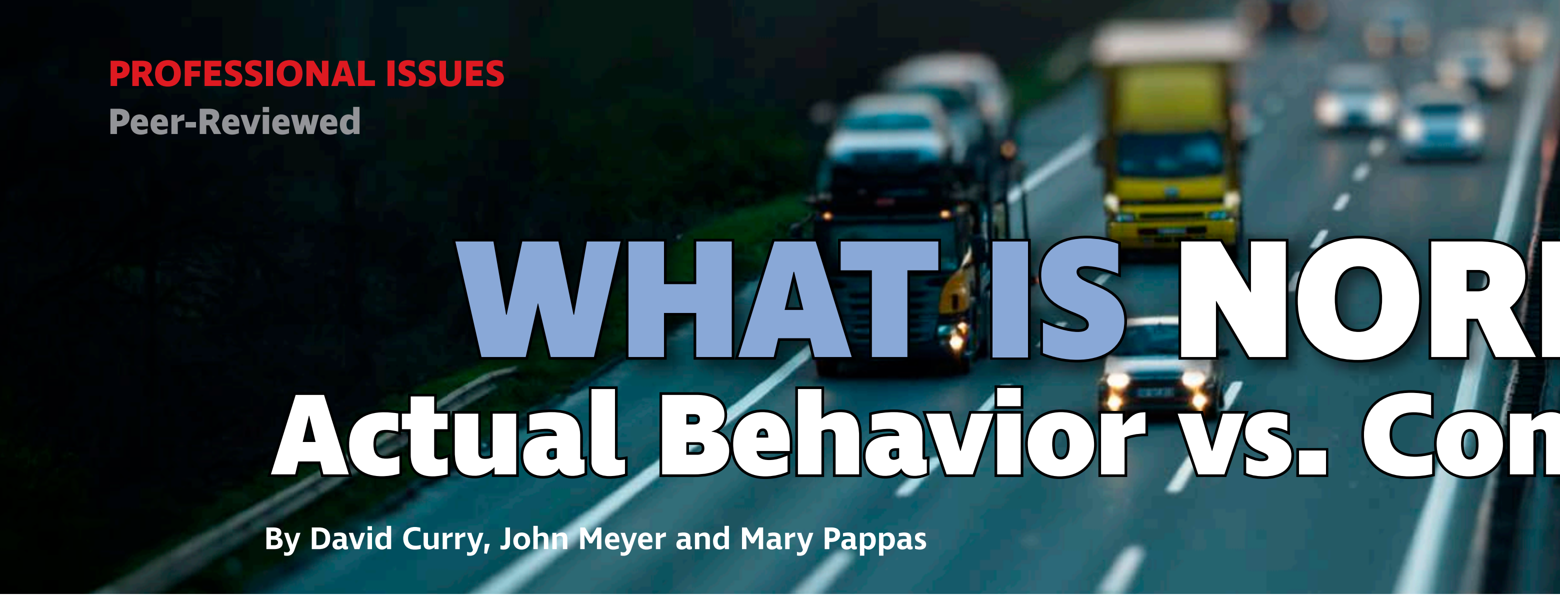


WHAT IS NOR

Actual Behavior vs. Con

By David Curry, John Meyer and Mary Pappas

IN OUR INCREASINGLY LITIGIOUS SOCIETY, it seems to be increasingly the case that, in the event of an incident, the argument is made in a court of law that noncompliance with laws, rules or regulations is *prima facie* evidence that the actions of the individual leading up to the event were inherently unsafe. It is not infrequently argued that such noncompliance rises to the level of negligence and, thus, warrants an increased level of penalty or punishment for such noncompliance.

To understand when such arguments may or may not be valid, it is necessary to first understand the meanings of the terms *safety* and *negligence* as they relate to individual behavior, as well as to have a perspective on whether the rules represent a true consensus on the part of the population about whether those rules are either appropriate or valid.

The National Safety Council's (NSC, 2015) *Accident Prevention Manual* defines the word *safe* to mean "a condition of relative freedom from danger." The same source defines *safety* as "The control of recognized hazards to attain an *acceptable* [emphasis added] level of risk." ANSI B11.0-2020 defines the term *acceptable risk* as "a risk level achieved after risk reduction measures have been applied. It is a risk level that is accepted for a given task (hazardous situation) or hazard" (p. 18).

KEY TAKEAWAYS

- **Safety is a function of the level of risk that the population as a whole is willing to accept for a particular activity, not of the adherence to a particular standard or of the elimination of all risk.**
- **Negligent action or behavior must be evaluated in light of the normal behavior of the subject population.**
- **Driving normally cannot be negligent, but doing so does not absolve a driver of consequences that may result from noncompliance with applicable rules.**

It is clear from both definitions that the degree of risk that is considered safe is based on the acceptability of the risk involved, not that a product, task or activity is risk free. Safety is thus a relative, not an absolute, concept. In short, safety involves a risk level that the affected population generally considers to be acceptable for any given task or situation at the point in time that it occurs. If that population considers an action or behavior acceptably safe before an incident or event, one cannot in light of hindsight categorize that same action as having been unsafe simply because the outcome was not anticipated or desired or because the action did not comply with published guidance.

To use an example, prior to the late 1960s, federal law did not require seat belts in cars; vehicles were considered acceptably safe without them. This does not mean that seat belts would not have reduced the likelihood of injury or death for vehicle occupants involved in crashes had the devices been installed in earlier model-year vehicles, but rather that the bulk of the driving public (and the federal government) at that time did not consider the lack of seat belts to represent an unreasonable risk. Seat belts had been available as an option or aftermarket item for many years prior to them becoming mandatory (they were first patented in the U.S. in 1885), but the driving public did not routinely choose to add seat belts to their vehicles (i.e., the risk of driving without them was acceptable to them). Driving without them was considered safe (although not without risk).

As Curry et al. (2018) note:

> Webster's New World Dictionary defines *negligence* as "failure to use a reasonable amount of care when such failure results in injury or damage to another." Black's Law Dictionary similarly defines it as "failure to exercise the standard of care that a reasonably prudent person would have exercised in a similar situation." The latter source also states that a reasonable person is one who "acts sensibly, does things without serious delay and takes proper but not excessive precautions." Heuston (1977) says:
>
> > The reasonable man connotes a person whose notions and standards of behavior and responsibility correspond with those generally obtained among ordinary people in our society at the present time, who seldom allows his emotions to overbear his reason and whose habits are moderate and whose disposition is equable. He is not necessarily the same as the average man—a term which implies an amalgamation of counter-balancing extremes.
>
> The sum total of these statements is that an assertion of negligence must be based on the normal behavior of the members of the subject population.

If such is the case, then declaring normal behavior to be somehow negligent is inherently unsupportable.

Safety rules or laws, on the other hand, imply that a particular behavior is either inherently safe or unsafe on the basis of compliance with a predetermined value set by the rule-maker. A simple example of this would be a 70-mph speed limit on a particular section of freeway. Noncompliance with the speed limit set by lawmakers potentially subjects the individual to a penalty. Such noncompliance may or may not, however, have anything to do with the inherent safety of the activity involved. While it is true that there is commensurately less kinetic energy in a body moving at 70 mph than one moving at 71 mph, the difference is so slight as to be almost negligible. Is 70 mph on the subject roadway somehow inherently safe, while 71 mph is unsafe? This question is particularly vexing given that prevailing traffic may be moving at a considerably higher speed than either value.

ADEMPERCEM/ISTOCK/GETTY IMAGES PLUS

MAL DRIVING?

npliance With the Rules

Many (if not most) human capabilities and behaviors fall into what is referred to as a normal distribution. Such a normal distribution is a curve in which most values cluster in the middle of the range, while the remainder tapers off symmetrically toward either extreme (i.e., commonly referred to as a bell curve; Figure 1). The mean or average is in the center of the curve. The likelihood of a particular behavior or action is expressed by the height of the curve at any particular point. The normal range encompasses approximately the center 70% of the population (i.e., the 15th to 85th percentile), and extends one standard deviation in either direction from the mean. The normal range in Figure 1 is depicted in the dark blue center section; the percentages of the population that fall two and three standard deviations in either direction from the mean are noted on the figure as well. Approximately 95% of a normal population falls within two standard deviations of the mean.

Based on the noted definitions, a reasonable approach would be to define *negligent* behavior as behavior that falls significantly outside the normal range of variability. This approach has the value of being based on what the population as a whole considers reasonable and proper behavior, while simple noncompliance with rules does not. If such a standard is to be useful, it would obviously be necessary to know what the normal range of behavior is for a particular activity.

Most people consider themselves to be safe drivers in that they normally do not expose themselves or others to what they consider to be an unacceptable level of risk. The level of risk that the population as a whole finds to be acceptable (i.e., normal driving), by definition, constitutes safe (not minimum risk) driving. This is inherent in the concept of acceptable risk. Guidance suggesting or requiring more conservative driving may result in lower risk, but this does not in and of itself make such noncompliance guidance necessarily unsafe or negligent.

This does not suggest that driving normally somehow renders a driver nonculpable for incidents caused by their actions; the person is simply not negligent in terms of their behavior. Negligence can only be considered in terms of the degree of deviation from normal driving behavior. To assess whether a particular driver's conduct rises to this level, it is necessary to be aware of exactly what the normal range of behavior is. The remainder of this article focuses on comparing traffic rules and guidance to actual behavior that is normally exhibited by motorists on American roadways.

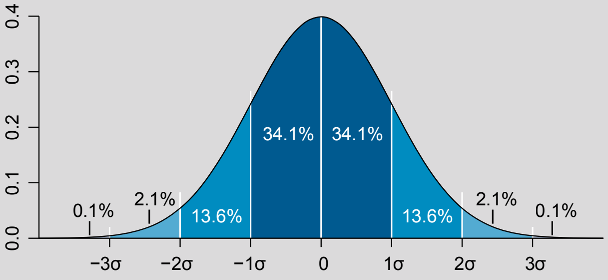
Speed Limits

According to the Federal Highway Administration (FHWA), all states and most local agencies claim to use the 85th percentile speed of free-flowing traffic (i.e., the speed below which 85% of the traffic is traveling under unconstrained conditions) as the primary factor in establishing speed limits. The basic intent of speed zoning is to identify a safe and reasonable limit for a given road section, and the 85th percentile speed reflects a safe speed as determined by the majority of drivers. This value is then to be modified based on other criteria.

FIGURE 1

NORMAL DISTRIBUTION

Sample standard normal curve with associated probability distribution. While the shape of the curve may vary, the associated percentages of the population associated with a particular number of standard deviations from the mean do not.



Note. By M.W. Toews—Own work, based (in concept) on figure by Jeremy Kemp, on 2005-02-09, CC BY 2.5, https://commons.wikimedia.org/w/index.php?curid=1903871

TABLE 1

SPEED LIMIT DETERMINATION FACTORS REPORTEDLY UTILIZED

	Percent of time used	
Factor	**By state agencies**	**By local agencies**
85th percentile speed	100%	86%
Roadside development	85%	77%
Accident experience	79%	81%
10 mph pace	67%	34%
Roadway geometrics	67%	57%
Average test run speed	52%	34%
Pedestrian volumes	40%	50%

Note. Adapted from "Speed Concepts: Informational Guide (Publication No. FHWA-SA-10-001)," by E.T. Donnell, S.C. Hines, K.M. Mahoney, R.J. Porter & H. McGee, 2009, Federal Highway Administration.

TABLE 2
SPEED ADJUSTMENT FACTORS RECOMMENDED BY HIGHWAY CAPACITY MANUAL

Weather type	Range	Speed adjustment factor
Clear	N/A	1.00
Light rain	> 0.00 to 0.10 in./hr	0.98
Medium rain	> 0.10 to 0.25 in./hr	0.94
Heavy rain	> 0.25 in./hr	0.93
Very light snow	> 0.00 to 0.05 in./hr	0.89
Light snow	> 0.05 to 0.10 in./hr	0.88
Medium snow	> 0.10 to 0.50 in./hr	0.86
Heavy snow	> 0.50 in./hr	0.85
Low wind	> 10.00 to 20.00 mph	0.99
High wind	> 20.00 mph	0.98
Cool	34 to 49.9 °F	0.99
Cold	-4 to 33.9 °F	0.98
Very cold	< -4 °F	0.94
Medium visibility	0.50 to 0.99 miles	0.94
Low visibility	0.25 to 0.49 miles	0.93
Very low visibility	< 0.25 miles	0.93

Note. Adapted from "Highway Capacity Manual (Publication No. HCM2010). Volume 4: Applications Guide," by Transportation Research Board, 2010, The National Academies of Sciences, Engineering and Medicine.

Table 1 (p. 21) presents the basic criteria reportedly used to guide speed limit determination. (In practice, speed limits are frequently set for political or other purposes, rather than based on safety per se.)

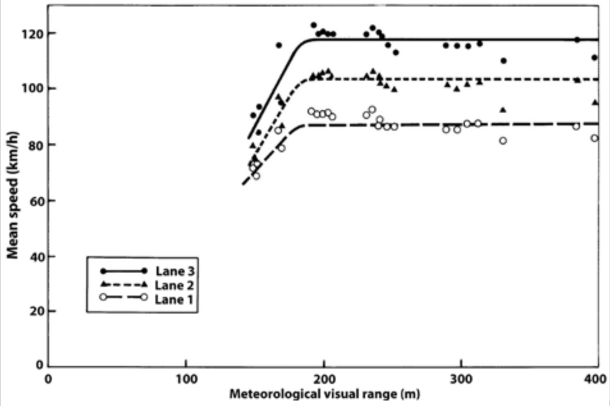
The current edition of the *Manual of Uniform Traffic Control Devices* (MUTCD) requires that:

> Speed zones (other than statutory speed limits) shall only be established on the basis of an engineering study that has been performed in accordance with traffic engineering practices. The engineering study shall include an analysis of the current speed distribution of free-flowing vehicles. (FHWA, 2009, p. 56)

The same source also states that even after adjustments for other considerations, "When a speed limit within a speed zone is posted, it should be within 5 mph of the 85th percentile speed of free-flowing traffic" (p. 58). While there is no mandatory national consensus method of conducting such an engineering study, that specified by the state of Kansas is typical:

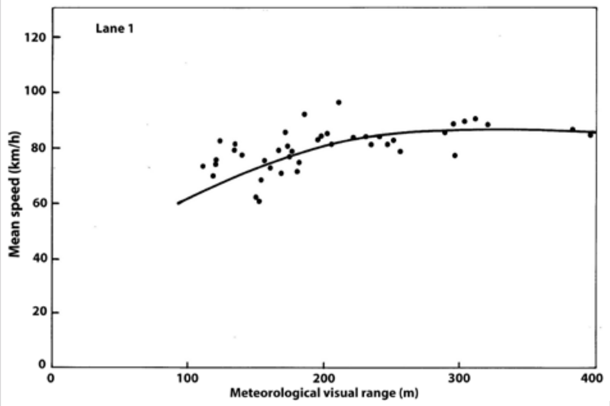
> Radar is used to collect speed data from random vehicles on a given roadway. Off peak hours are normally used in conducting a spot speed study with the speed of approximately 50 free flowing vehicles in each direction obtained. On low volume roads where it would be difficult to obtain a sample of 100 vehicles, the study may be terminated after a study period of one hour. Vehicles are selected at random from the free flow of the traffic stream to avoid bias in the results. (Kansas Department of Transportation, n.d.)

FIGURE 2
DAYTIME TRAVEL SPEED BY VISUAL RANGE



Note. Adapted from "Some Aspects of Motorway Traffic Behavior in Fog (TRRL Laboratory Report No. 958)," by M.E. White & D.J. Jeffery, 1980. Copyright 1980 by the Transport and Road Research Laboratory.

FIGURE 3
NIGHTTIME TRAVEL SPEED BY VISUAL RANGE



Note. Adapted from "Some Aspects of Motorway Traffic Behavior in Fog (TRRL Laboratory Report No. 958)," by M.E. White & D.J. Jeffery, 1980. Copyright 1980 by the Transport and Road Research Laboratory.

Other states such as Missouri and Texas use the same basic process but mandate a higher number of subject vehicles be sampled. The methodology as it is normally employed involves the calculation of the 85th percentile speed based on the sample, then rounding that value up to the nearest 5 mph increment (i.e., if the calculated 85th percentile speed was 68 mph, then the posted limit would be 70 mph). The 85th percentile speed method is based on the assumption that the majority of drivers are attempting to drive in a safe, reasonable fashion. In many jurisdictions, however, speed limits are frequently not set using any type of objective methodology but rather are based on legislative fiat. This latter method is not necessarily based on any type of objective safety criteria.

For roadways that use statutory rather than empirically determined speed limits, studies have repeatedly demonstrated that the posted limit frequently does not represent the maximum or even average speed of travel of vehicles using it. A set of naturalistic studies conducted by FHWA involved testing at more than 150 locations in several states to examine actual driver compliance with statutory speed limits (Tignor & Warren, 1990). The results indicated that more than 70% of motorists exceeded the posted speed limits in urban areas, with some sites having compliance rates as low as 3%. Fewer than 10% of the sites tested had compliance rates of greater than 50%. The report concluded, "Our studies show that most speed zones are posted 8 to 12 mph below the prevailing travel speed and 15 mph or more below the maximum safe speed" (Tignor & Warren, 1990). A more recent study by Johnson and Murray (2010) examined travel speed at 19 locations on rural interstate highways across the U.S. Their data suggested that roughly 48% of all heavy trucks were compliant with the speed limit across sites (many heavy trucks have governors that artificially restrict their maximum speed of travel), while only about 29% of automobiles were compliant. Speed limits can thus be thought of as being set at the 29th percentile level for automobiles. The 85th percentile travel speed across test locations was approximately 4 mph higher than the posted speed limit for trucks and 7 mph for automobiles. Traveling somewhat in excess of the posted speed limit on highways thus represents normal, not extraordinary, behavior on the part of vehicle operators (which is unlikely to surprise experienced motorists).

Note that most motorists do not elect to travel at or near the design speed of a particular highway. Design speed is a selected speed used to determine the various geometric features of the roadway, based on such things as topography, anticipated operating speed, the adjacent land use and the functional classification of the highway. From 1954 until 2001, the American Association of State Highway and Transportation Officials' (AASHTO's) *A Policy of Geometric Design of Rural Highways* defined design speed as "the maximum safe speed that can be maintained over a specified section of highway when conditions are so favorable that the design features of the highway govern." In the 2001 edition, the word *safe* was removed from the definition when AASHTO recognized that operating speeds can be greater than the design speed, and the term was removed to avoid the perception that speeds greater than the design speed were "unsafe" (Donnell et al., 2009).

In short, average travel speeds are not equivalent to posted speed limits, but are typically several miles per hour faster. One standard deviation above or below the average travel speed represents the normal range of speed for the population variability; the posted speed limit may or may not fall within this range.

Weather

One of the more common exhortations given to motorists when driving in inclement weather (e.g., rain, snow, ice, wind) is to reduce their travel speed. The guidance provided in the *California Driver Handbook* is typical:

> Slippery roads: Slow down at the first sign of rain, especially after a dry spell. This is when many roads are the most slippery, because oil and dust have not washed away. A slippery road will not give your tires the grip they need. Drive more slowly than you would on a dry road. Adjust your speed as follows:
> - Wet road—go 5 to 10 mph slower
> - Packed snow—reduce your speed by half
> - Ice—slow to a crawl (State of California DMV, 2020, p. 85)

In reality, typical driver response is somewhat different. Table 2 shows data from Volume 4 of the *Highway Capacity Manual* (TRB, 2010). It provides numeric values for adjustment of the expected free-flow speed on highways due to various conditions. In practice, these values vary slightly based on the design speed of the roadway in question. As can be seen by reference to the table, if one takes the adjustment factor for "light rain" (a drop of 2%) and applies it to a 70-mph roadway, this will result in an expected speed reduction of 1.4 mph, not the 5 to 10 mph recommended by the *California Driver Handbook*. Even the reduction for heavy rain would not reach the reductions recommended in the *California Driver Handbook*. The *Highway Capacity Manual* is designed for planning purposes, but empirical studies examining these issues have shown speed reductions related to rain of 1% to 7% with the speed changes dependent on rain intensity (from "trace" to > 0.25 in./hr) and speed reductions for snowfall in the ranges of 3% to 15%, again dependent on snowfall rate (from "trace" to 0.5 in./hr; Agarwal et al., 2006). These values are consistent with other naturalistic studies. Edwards (1999) found that highway speeds were reduced by slightly less than 3 mph for rain, and just over 2 mph for fog, while Rahman and Lownes (2012) saw a speed decrease of 1.7 mph (3.7%) under rain conditions. The mean time gap between succeeding vehicles increased slightly under rain conditions (0.13 s) in the latter study.

Travel speeds under fog conditions vary primarily as a function of the visibility distance. Under daytime visibility distances of greater than 200 m (about 656 ft), highway speeds do not differ significantly from those without fog present. Below this distance, speed typically decreases in a linear fashion with visibility distance (Figure 2). Nighttime travel speeds under fog show a somewhat less abrupt transition in travel speeds (Figure 3).

Note that to a large degree, fog causes a mixed response on the part of drivers. Speed perception is at least partially a function of optical flow rate (effectively the amount of detail that the eye is exposed to per second). Under foggy (i.e., reduced contrast) conditions, the amount of detail that can be perceived by the eye is reduced due to decreased contrast. To the extent that drivers rely on the flow rate to control speed, this suggests that speed may be increased to some degree under conditions with reduced amounts of visual detail to them, unless the driver consciously attends to the vehicle speed as indicated on the vehicle's dash instruments. However, glances to in-vehicle instruments *decrease* under conditions of high visual driving demand (such as is encountered when driving in fog). This could result in drivers not decreasing their speed under impaired visual conditions as much as they believe they have. Further, to a large degree, perception of leading vehicle distance is the function of the amount of detail that can be abstracted regarding the leading vehicle. Under reduced contrast conditions such as fog or rain, attempting to judge separation distance based on visually detectable detail levels could easily result in an unintended *decrease* in intervehicle separation distance from that intended by even a cautious motorist. Finally, reduced visibility may present the driver with a dilemma: should the driver *reduce* following distance to be able to readily perceive any unexpected action on the part of the leading vehicle or *increase* following distance to allow themselves greater time to react or respond to such if it should occur? Arguments can be made for or against either behavior in terms of relative safety.

To summarize, available data show that, as a whole, drivers do not normally reduce their travel speed in light of weather conditions as much as is advised. For example, a driver who has only reduced speed by several miles per hour due to light rain rather than the 5 to 10 mph recommended by the *California Driver Handbook* and similar manuals is exhibiting normal, not negligent, driving behavior.

Day vs. Night Operations

As discussed by Curry et al. (2018):

> Nighttime drivers are routinely admonished not to overdrive their headlights. While a laudable goal, such an exhortation ignores the simple fact that the distance at which an object can be detected by a driver is a direct function of the reflectivity of the object.

> It is possible to avoid overdriving headlights only if the nature and reflectivity of the obstacle that will be encountered [are] known in advance to the driver so that [the individual] can adjust speed appropriately.
>
> For the average driver, the detection distance under low-beam headlights ranges from more than 3,300 ft for retroreflective marking tape to as little as 75 ft for a dark-clad pedestrian standing to the left of the vehicle's path of travel (Curry, Nielsen, Kidd et al., 2007; Olson, 2007).

Given that the driver cannot know the nature and reflectivity of an obstacle ahead, to avoid overdriving the headlights, a worst-case scenario would have to be assumed (i.e., a dark-clad pedestrian in the location least illuminated by headlights). For the low end of the normal detection range, this would preclude nighttime driving at speeds in excess of about 17 mph when employing low-beam headlights. In reality, nighttime traffic on virtually any roadway considerably exceeds this speed. Drivers reasonably assume that most obstacles they may encounter after dark (primarily other vehicles) will be detected not by the illumination provided by their own headlights, but rather by the emanations of the lights on any potentially opposing vehicle. Federal, state and local laws typically do not mandate different speed limits based on day or night conditions; the last state with such a requirement (Texas) rescinded that law in 2011.

Also, based on published studies, most drivers do not routinely employ their high-beam headlights and, thus, do not take advantage of the increased illumination they provide. A 2008 on-road study conducted employing 87 drivers operating vehicles not equipped with daytime running lights for an average of 26 days each found that high-beam headlights were activated approximately 9% of the time that headlights were in use (Buonarosa et al., 2008). A more detailed analysis of the data revealed that combined over all drivers and all road types, high beams were used for 3.1% of the distance driven at night (Mefford et al., 2006). Drivers used high beams most frequently on local roads (8.9%), while rarely using them on limited-access roads (0.2%). Overall, high beam use was less than 10% on any road type. High beam use under the most favorable conditions identifiable in this study (rural roads, no opposing traffic and no leading vehicle) was 25.4%. Older drivers employed high beams three times more frequently than did younger drivers.

These results are generally consistent with an earlier study by Hare and Hemion (1968) that was performed at 17 locations in 15 states. The results indicate that only 24% of vehicles used high beams even under clear conditions. Most test locations (14 of 17) were on unlighted, rural, two-lane roadways (i.e., almost ideal conditions for use of high-beam headlighting). Sullivan et al. (2003) obtained high-beam use values of approximately 42% for low volume roadways under clear conditions in Michigan. Iragavarapu and Fitzpatrick (2012) obtained results very similar to the Sullivan data, also determining that drivers employed high beams approximately 42% of the time on rural roadways, with use varying with traffic volume (i.e., unsurprisingly, fewer drivers used high beams when there was more traffic).

Also of interest in this context is the distance at which drivers employing high-beam headlights switch to low beams when encountering other vehicles. Data from the Hare and Hemion (1968) study indicate that drivers switched from high to low beam illumination at an average distance of 1,714 ft from the opposing vehicle. State statutes on the dimming of headlamps vary widely, but they generally require the use of low beams for intervehicle distances less than 600 ft. The dimming action was made in most cases long before significant glare disability occurs, possibly reflecting the onset of driver discomfort or anticipation of discomfort. When two vehicles meet, both on high beams, dimming by the driver of one vehicle usually acts as a reminder for the other driver to dim.

To some degree, newer vehicles have addressed this issue with the incorporation of headlights that can be set to automatically switch between high and low beam settings without the active intervention of the driver based on the amount of incoming light. As such equipment becomes more common, the issue of the use of high and low beam headlights may begin to be of less concern.

Headway

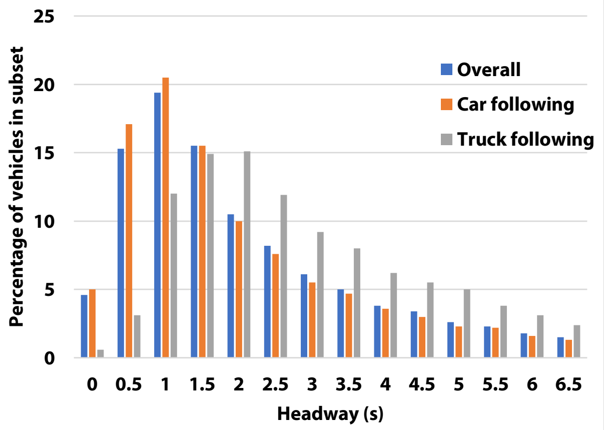
Another common criticism in vehicular crashes involves "following too closely," with individual state driver's manuals routinely advocating a 2-second rule (or even a 3- or 4-second rule). In reality, normal following distances are difficult to quantify in practice without first establishing a boundary condition regarding what constitutes following. If one were simply to examine the average intervehicle separation distance without first establishing this, such an average becomes meaningless (if few vehicles are on a roadway, the gap between succeeding vehicles might be several miles, drastically skewing the average).

A more appropriate measure is the determination of the "minimum comfortable headway" or the "minimum safe headway." The first of these metrics represents a headway that a driver would maintain under normal driving circumstances at a particular speed if the driver had no intent or ability to pass a lead vehicle. The second term represents the closest headway that one can maintain behind a lead vehicle that will still enable one to stop in time if the lead driver were to suddenly brake. Taieb-Maimon and Shinar (2001) examined these variables for a population of 30 drivers ages 21 to 58. Their results indicate that drivers adjusted their following distances to maintain a stable separation from forward vehicles in terms of time, adjusting their distance with the speed of travel (i.e., drivers based their following behavior on time separation, not distance separation, from the forward vehicles). The researchers found that subjects adopted a mean minimum safe headway across all speeds of 0.66 s (95th percentile headway = 1.04 s). More than 93% of the drivers adopted minimum safe headways of less than 1 second. For the same sample, the average comfortable headway was 0.98 s (95th percentile headway = 1.68 s).

To a large degree, the preference for a particular headway is a function of: 1. the self-predicted response time of the individual driver; 2. an estimate of the likelihood of the leading vehicle suddenly braking; and 3. an estimate of the likely braking level that will be utilized. Studies have demonstrated that, even on surface streets, normal braking levels average only about 0.22g (7.1 ft/s^2), with a maximum of level of about 0.40 g (12.9 ft/s^2; McLaughlin & Serafin, 2000). Typical braking levels of highways are substantially lower. Even in collision and near-collision emergency braking, the average braking level is only about 0.44g (14.2 ft/s^2), with a 90th percentile value of about 0.62g (20 ft/s^2; Wood & Zhang, 2017). It has been proposed that differences in intervehicle headways adopted across individuals are a function of individual differences in perceptual-motor skills (Van Winsum, 1998; Van Winsum & Brouwer, 1997). Their studies showed that the efficiency of the visual-motor component of braking was a strong, significant predictor of choice of time headway to the lead vehicle in such a way that less efficient braking on the part of the individual motorist resulted in a preference for a longer time headway. In short, drivers who follow with short headways tend to be those who respond quickly to typical changes in leading vehicle velocities. It is only in the event of either extremely rare events or cases of distraction that this is likely to result in incidents.

FIGURE 4

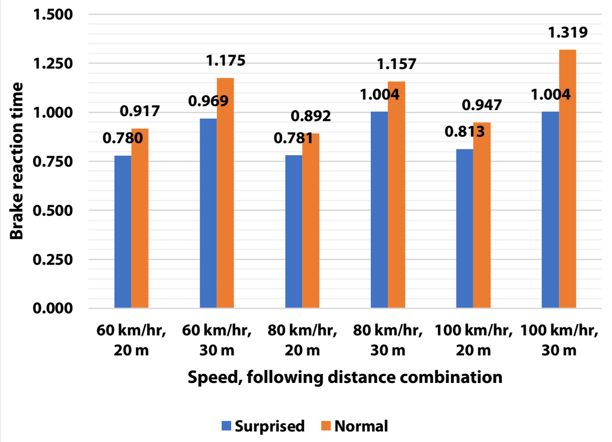
HISTOGRAM OF CAR FOLLOWING DISTANCES



Note. Adapted from "Measurement and Analysis of Heterogenous Vehicle Following Behavior on Urban Freeways: Time Headways and Standstill Distances," by A. Houchin, J. Dong, N. Hawkins & S. Knickerbocker, 2015, *Civil, Construction and Environmental Engineering Conference Presentations and Proceedings, 99*.

FIGURE 5

BRAKE REACTION TIME FOR VARIOUS SPEED/DISTANCE SCENARIOS



Note. Adapted from "Modeling Reaction Time in Car-Following Behavior Based on Human Factors," by A. Mehmood & S.M. Easa, 2009, *International Journal of Engineering and Applied Sciences, 5*(2), 93-101.

There is also evidence that typical headway distances are affected by vehicle type. Trucks, likely due to reduced braking capability tend to follow at greater distances than automobiles. Perhaps surprisingly, the type of vehicle that is being followed also influences following distances. Figure 4 is adapted from a study conducted on Iowa highways (Houchin et al., 2015). Examination of the data shows that most drivers follow at distances considerably lower than those recommended in the various state driver's manuals.

Note that most guidance regarding appropriate following distances in driver's manuals appears to be based on an assumed reaction time for the following driver. This value is often derived from worst-case conditions regarding driver age, gender, level of distraction and other parameters that may affect reaction time (i.e., they are not based on *likely* reaction times). Several studies have demonstrated that reaction times to lead vehicle braking events are not uniformly distributed, but rather are a function of speed, headway and driver arousal levels. In most cases of short following distance, drivers are actively attending to the lead vehicle to a considerably greater degree than would be the case with longer following distances; the need to potentially react in short order limits the attentional excursions that might occur in more benign situations. For example, if following at a distance of 1,000 ft, there is no need for the trailing driver to immediately respond to even heavy braking on the part of the leading vehicle. The trailing driver is far enough back that more than adequate distance exists to avoid contact even if the following driver brakes at a significantly lower level than the leader. Typically, in such a situation, an attentive driver will delay applying the brakes until they have considerably reduced the separation distance between the two vehicles.

Figure 5, based on a study by Mehmood and Easa (2009), demonstrates reaction times for following drivers based on headway, speed and the type of event in question. As Figure 5 shows, the reaction times decrease as a direct function of the time available to the following driver.

Response to Traffic Control Devices

Another area where unsafe operation or negligence is frequently alleged is in conjunction with traffic controls (primarily stoplights or stop signs). One sometimes hears jocular references to "California stops" when dealing with a driver only slowing down rather than coming to a complete stop at stop signs. In reality, most searches for cross traffic at intersections appear to occur during the approach to a stop sign, rather than after bringing the vehicle to a complete stop. Typical pause times at stop signs for vehicles coming to a complete stop are approximately 1 s. Given that glances to vehicle side mirrors (which require a less robust head rotation) average between 1 and 1.5 s (Taoka, 1990), a one-second pause obviously does not allow drivers time to look both left and right while stopped. Table 3 (p. 26) shows data from an FHWA report analyzing the behavior of more than 31,000 vehicles at 142 intersections across four states (Pietrucha et al., 1989). The data make it clear that *not* coming to a complete stop for a stop sign, particularly for automobiles, is more the norm than coming to a complete stop. Across all conditions, only about 35% of the automobiles observed came to a complete stop; slightly over 96% of the observed trucks did. A more recent study involving 2,400 vehicles in Minnesota also indicates that the percentage of vehicles coming to a complete stop at a stop sign was approximately 35% (Woldeamanuel, 2012).

Actual driver behavior in response to changes in signal lights is also typically not well understood by potential jurors. Typically, they assume that the response by safe motorists to a change in signal light color is to immediately apply the brakes and bring the vehicle to a stop. In reality, normal driver response is considerably more complex. What typically occurs is that the oncoming motorist is exposed to a change in signal color, then performs a complex analysis involving distance from the intersection, speed of travel, maximum level of braking that they regard as acceptable and the likely stopping distance required to bring the vehicle to a stop at that braking level. Other factors that the driver must consider are the probable length of the amber phase of the traffic signal and the behavior and proximity of surrounding and trailing vehicles. In practice, the average perception reaction time (PRT) to a signal light change has been shown to have a mean of 1 s and an 85th percentile value of about 1.33 s (McGee et al., 2012). The

TABLE 3
BEHAVIOR OF MOTORISTS AT STOP SIGNS

Driver action	Vehicles by movement					
	Cars			Trucks		
	Turning left	Going straight	Turning right	Turning left	Going straight	Turning right
No queue on arrival						
Came to full stop, proceeded with conflict	0.02%	0.01%	0.03%	0.00%	0.00%	0.01%
Came to full stop, proceeded without conflict	1.18%	2.05%	1.26%	0.03%	0.17%	0.08%
Stopped for cross traffic, proceeded with conflict	0.29%	0.25%	0.12%	0.04%	0.02%	0.02%
Stopped for cross traffic, proceeded without conflict	6.07%	6.24%	4.79%	0.60%	0.35%	0.34%
Did not stop completely, proceeded with conflict	0.24%	0.29%	0.23%	0.07%	0.01%	0.07%
Did not stop completely, proceeded without conflict	9.54%	16.82%	17.56%	0.63%	0.74%	1.07%
Traffic queue on arrival						
Came to full stop, proceeded with conflict	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%
Came to full stop, proceeded without conflict	0.26%	0.58%	0.25%	0.00%	0.04%	0.00%
Stopped for cross traffic, proceeded with conflict	0.11%	0.07%	0.04%	0.00%	0.00%	0.01%
Stopped for cross traffic, proceeded without conflict	2.52%	2.34%	1.84%	0.12%	0.11%	0.11%
Did not stop completely, proceeded with conflict	0.08%	0.13%	0.14%	0.03%	0.00%	0.02%
Did not stop completely, proceeded without conflict	4.41%	7.22%	7.62%	0.23%	0.26%	0.23%

Note. Adapted from "Motorist Compliance With Standard Traffic Control Devices (Report No. FHWA-RD-89-103)," by M.T. Pietrucha, K.S. Opiela, R.L. Knoblauch & K.L. Crigler, 1989, Federal Highway Administration.

TABLE 4
DURATION OF MINIMUM YELLOW CHANGE INTERVAL

Approach speed (mph)	Approach speed (ft/s)	Minimum yellow change interval (s)[a]	Braking distance (ft) required at 10 ft/s^2	Braking time (s) required at 10 ft/s^2	Total stopping distance (ft) [PRT + braking distance]
25	36.7	3.0[b]	67	3.7	104
30	44	3.2	97	4.4	141
35	51.3	3.6	132	5.1	183
40	58.7	3.9	172	5.7	231
45	66	4.3	218	6.6	284
50	73.3	4.7	269	7.3	342
55	80.7	5.0	328	8.1	409
60	88	5.4	387	8.8	475

Note. Adapted from "Signal Timing Manual (2nd ed.; NCHRP Report No. 812)," by T. Urbanik, A. Tanaka, B. Lozner, E. Lindstrom, K. Lee, S. Quayle, S. Beaird, S. Tsoi, P. Ryus, D. Gettman, S. Sunkari, K. Balke & D. Bullock, 2015, Transportation Research Board.
[a]Assumes negligible approach grade. [b]The Manual of Uniform Traffic Control Devices does not recommend yellow intervals of < 3.0 s.

Transportation Research Board's *Guidelines for Timing Yellow and All-Red Intervals at Signalized Intersections* recommends that the approach speed used to set yellow change intervals be the estimated 85th percentile travel speed on the subject roadway (i.e., a value estimates to be 7 mph greater than the posted speed limit, or approximately the upper end of the normal speed range; McGee et al., 2012). The recommended change interval (yellow light time) is calculated using the following equation:

Equation 1

$$Y = t + (\frac{1.47V}{2a + 64.4g})$$

where:
Y = length of yellow light, in seconds
t = PRT (s); set at 1.0 s
a = deceleration rate (ft/s^2); set at 10 ft/s^2
V = 85th percentile approach speed (mph)
g = approach grade (percent divided by 100; negative for downgrade)

The deceleration level used in the equation is based on a braking level higher than the average typically used by motorists (discussed previously) but still below the upper end of that considered comfortable according to AASHTO (i.e., 11.2 ft/s^2). Assuming that a signal light has an appropriately set minimum yellow change interval, the distance in the last column of Table 4 represents the *minimum* distance away at the time of signal change at which a typical driver would be expected to be able to stop prior to entering the intersection employing a comfortable level of braking (the a parameter in Equation 1). At shorter distances or with slower perception reaction times, either uncomfortable braking levels would need to be employed, or there would be an increased likelihood of the motorist electing to proceed forward through the intersection without stopping.

An all-red clearance interval is an optional signal timing parameter that provides a period at the end of the yellow change interval during which the signal is red for all directions of travel prior to the display of green for the following phase. The purpose of this interval is to allow time for vehicles that entered the intersection on yellow to reach an appropriate location prior to the signal turning green for cross traffic. This does not necessarily equate to vehicles being completely out of the intersection, but rather at a position within the intersection such that they are unlikely to collide with vehicles proceeding forward on the following light phase. The use of a red clearance interval is optional, and there is a lack of consensus on its application or duration. Research indicates that the use of a red clear-

TABLE 5

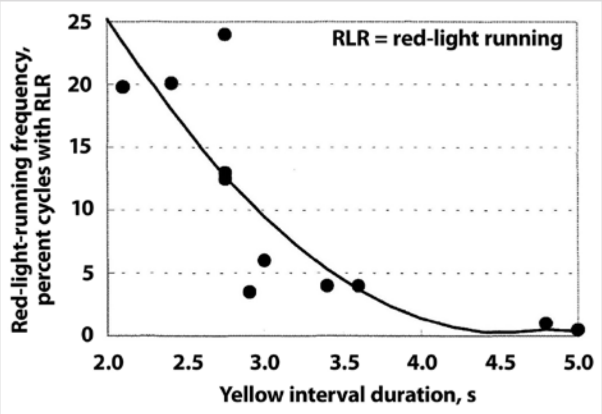
RECOMMENDED RED CLEARANCE INTERVAL LENGTHS

Approach speed (mph)	Recommended red clearance interval (s)				
	Width of intersection (ft)				
	30	***50***	***70***	***90***	***110***
25	0.4	0.9	1.5	2.0	2.5
30	0.1	0.6	1.0	1.5	2.0
35	0.0	0.4	0.8	1.1	1.5
40	0.0	0.2	0.5	0.9	1.2
45	0.0	0.1	0.4	0.7	1.0
50	0.0	0.0	0.2	0.5	0.8
55	0.0	0.0	0.1	0.4	0.6
60	0.0	0.0	0.0	0.2	0.5

Note. Adapted from "Signal Timing Manual (2nd ed.; NCHRP Report No. 812)," by T. Urbanik, A. Tanaka, B. Lozner, E. Lindstrom, K. Lee, S. Quayle, S. Beaird, S. Tsoi, P. Ryus, D. Gettman, S. Sunkari, K. Balke & D. Bullock, 2015, Transportation Research Board.

FIGURE 6

RED-LIGHT-RUNNING FREQUENCY & YELLOW DURATION RELATIONSHIP



Note. Adapted from "Review and Evaluation of Factors That Affect the Frequency of Red-Light Running (Report No. FHWA/TX-02/4027-1)," by J. Bonneson, M. Brewer & K. Zimmerman, 2001, Texas Department of Transportation.

ance interval results in a significant reduction in right-angle crashes when employed (Souleyrette et al., 2004). Recommended red clearance interval length can be calculated using the following equation:

Equation 2

$$R = \left(\frac{W + L}{1.47V}\right) - 1$$

where:
R = red clearance interval, in seconds
V = 85th percentile approach speed (mph)
W = intersection width (ft)
L = length of the vehicle (ft)

The 1 s reduction in this equation is reflective of the fact that lead vehicles in a queue at a signal light have been shown not to enter the intersection for at least one second after their light turns green. Table 5 shows the results of this equation for various combinations of approach speed and intersection width.

A dilemma zone occurs for drivers when approaching a signalized crossing where the yellow and red intervals are of insufficient length. This results in a situation in which the oncoming vehicle can neither stop in time for the red light using comfortable braking levels nor safely clear the intersection prior to the light changing to red without considerable acceleration. This problem is exacerbated in situations where there is either reduced braking capability (e.g., wet or icy roadways), decreased visibility of the signal lights (e.g., when following behind tall leading vehicles), extended perception-reaction times (e.g., older or distracted drivers) or platooned vehicles. Note that the described equations used for signal timing are predicated on vehicle lengths and deceleration levels for *automobiles*; trucks and buses are longer and have significantly lower comfortable deceleration levels. This results in an increased likelihood of such vehicles being unable to either stop or clear an intersection prior to the traffic signals allowing cross traffic to proceed. Given this, operators of such vehicles frequently have little choice but to either violate the lights at signalized crossings or accelerate through intersections. Recommendations exist for increasing the length of both the yellow and all-red intervals based on truck and bus volumes on a given roadway, but such recommendations are frequently not complied with. Also remember that motorists are not provided with information regarding signal timing or the inclusion of all-red intervals (or whether the signals for a given roadway are appropriately timed). Published research has indicated that red-light-running frequency increases as a function of both total vehicle and heavy vehicle volumes for a particular roadway, as well as decreased yellow interval duration (Bonneson et al., 2001). Figure 6 shows the relationship between red-light running and yellow interval duration.

Right-angle crashes increase exponentially with increases in the frequency of red-light running; however, this trades off with the frequency of rear-end collisions resulting from unexpected heavy braking by leading vehicles approaching an intersection. Data collected on intersections that employ red light cameras provides perspective on this issue. An FHWA study examining the effect of red-light cameras on red-light running found that employing red-light cameras resulted in approximately a 25% reduction in the number of right-angle crashes at the intersections examined, but only at the expense of a 15% increase in the number of rear-end crashes at those same intersections (Council et al., 2005). Note that the total number of crashes (i.e., not the percentages) were virtually identical with and without red-light cameras; the only difference was in the type of crash (rear-end vs. right-angle). The results obtained in this study are among the most favorable involving red-light cameras. A meta-analysis of 21 studies investigating the use of red-light cameras found that in general they reduced right-angle crashes by an average of 10%, while increasing the frequency of rear-end crashes by 40% (i.e., a net increase in the likelihood of crashes; Erke, 2009). Increasing the perceived "risk" involved in running a red light (i.e., increasing the likelihood of being ticketed for not stopping) resulted in an increased likelihood of stopping before entering the intersection on the part of motorists, but did not result in a reduction in the number of crashes occurring at the intersections. In short, there are cases where increasing speed to clear an intersection expeditiously is a more safety-conscious behavior than attempting to stop, particularly in situations where a following driver is in close proximity.

In short, a driver entering an intersection on a red light cannot be automatically assumed to be acting in a negligent or unsafe manner per se. The driver's actions in stopping or not stopping can only be interpreted as a function of light timing, roadway and intersection parameters.

Having Both Hands on the Wheel

Another common exhortation found in driving manuals is to always keep both hands on the steering wheel, typically at the 10 and 2 o'clock positions. Research suggests that most drivers believe that this position affords them the greatest degree of control over the vehicle (Thomas & Walton, 2007). Research also indicates, however, that the hand position actually adopted by motorists in modern vehicles is typically a function of task demand and perceived risk. Jonsson (2011) examined data from more than 1,900 drivers in a naturalistic on-road study and found that, under low-risk driving conditions, male drivers had at least one hand in the upper portion of the steering wheel only about 72% of the time compared to 61% for female drivers. The most common hand position for male and female drivers was with both hands below the midline of the wheel. In short, under benign driving conditions, drivers not infrequently are operating vehicles with only one hand on the wheel. Note that for many in-vehicle tasks (e.g., changing radio stations, adjusting climate controls, shifting gears in manual transmission vehicles), both hands cannot simultaneously be on the wheel while operating the secondary control. Some vehicles have steering-wheel-mounted controls, but even for those vehicles, the hand operating the control typically cannot simultaneously grip and provide steering input while doing so.

Use of Turn Signals

Driver's manuals throughout the U.S. mandate the use of turn signals prior to either lane changes or left or right turns. The purpose of such signaling is to apprise other potentially affected vehicles that the driver will be maneuvering shortly prior to the actual commencement of the actual event. Given the universal requirement for such signaling, it is often contended that drivers who do not so signal are acting in an unusual manner. It has been estimated that a 10% noncompliance rate regarding turn signal use annually would result in approximately 300 billion nonsignaled events annually in the U.S. alone (Ponziani, 2010). If it were assumed that 1 in 150,000 such events resulted in an incident, then the anticipated number of incidents from such signal nonuse would be approximately 2 million. A study examining the frequency of turn signal use under naturalistic conditions found that the noted numbers radically underestimated the likelihood of signal nonuse (Ponziani, 2012). The study amassed data on 10,000 turning vehicles and found that actual signal usage was 74.57%. For lane change maneuvers, 2,000 instances were examined and a signal usage rate of 51.65% was derived. In short, for actual turns, only about three in four drivers used signals, while only slightly more than half of drivers employed signals during lane changes. Nonuse of signals during turns or lane changes is therefore not unusual in any respect, and it would be difficult in the extreme to contend that nonuse would somehow be so far outside the normal behavioral range as to constitute negligence on the part of an individual driver.

Cell Phones

No discussion of driver behavior would be complete in the current age without some discussion of the operation of cell phones while driving. The popular press has been vitriolic regarding the use of cell phones behind the wheel for more than 20 years, largely citing allegorical or anecdotal evidence but being relatively light on research data. Further, the popular accounts typically lump all cell-phone-related activities together as though composing a multipage email and holding a simple conversation were somehow equally demanding of driver visual, manual and attentional resources. Often, popular press accounts cite the fact that a particular research study demonstrated a "significant" effect on the metrics examined in a particular scenario. Often lost in such accounts is the difference between statistical and practical significance. *APA Dictionary of Psychology* defines *statistical significance* as "the degree to which a research outcome cannot reasonably be attributed to the operation of chance or random factors" (VandenBos, 2015). In short, the definition refers to the reliability in that any effect noted will likely be repeatable if the study is performed multiple times. However, the word "significant" in the common vernacular typically means "important; of consequence." These two definitions are not equivalent. A 1-in. difference in lane position variability may be statistically significant (i.e., reliable), but is unlikely to be practically significant (i.e., meaningful) given that lane widths are typically 10 to 12 ft wide while most passenger vehicles are only about 6 ft wide. The data may be accurate, but the presentation of the results can often be misleading to the casual reader (whether intentionally so or not). Data from research studies must be looked at in context to place it into proper perspective.

Another often-quoted statistic is that approximately 4% of drivers on the road are actively using cell phones while driving at any given point (Pickrell et al., 2016). Note that this estimate is likely low in that the data supporting it is typically gleaned from counting drivers who either visibly have their phones to their heads, are talking while wearing visible headsets or are visibly physically manipulating the devices (Pickrell & Ye, 2010). With the increased prevalence of Bluetooth headsets and in-vehicle speakerphones, such a methodology would likely have the effect of seriously underestimating the actual usage prevalence (the authors have seen anecdotal estimates as high as 10% to 12%).

Another frequent assertion is that the number of incidents involving drivers actively talking on cell phones is rising. This is likely true, but is of questionable import, since a simple increase in usage would result in an increased number of incidents while on the phone even if the likelihood of an incident was identical between users and nonusers. One could equally correctly cite the fact that most automobile incidents involved drivers wearing blue jeans. While correct due to the prevalence of the wearing of this form of apparel, there is no causal link between the type of pants one is wearing and the likelihood of a traffic incident (i.e., correlation does not imply causality).

A final frequently repeated mantra is that drivers speaking on cell phones respond to critical stimuli "significantly" slower than drivers who are not so occupied. This appears to have some truth based on numerous simulator studies; however, the assertion must be examined in light of the actual data. Most studies find a nominal increase in reaction time for drivers engaged in cell phone conversations (0.10 to 0.25 s), but also find that the drivers typically increase their following distance behind other vehicles to maintain a greater separation between them (i.e., their actual safety margin remains more or less constant; Young, 2015).

A case-crossover analysis of actual incident statistics was published by the AAA Foundation for Traffic Safety in 2018 (Owens et al., 2018). This study investigated the relationship between cell phone use and crash risk using data from the Second Strategic Highway Research Program Naturalistic Driving Study, which included data from a sample of 3,593 drivers whose driving was monitored using in-vehicle video and other data collection equipment for a period of several months. The relationship between

TABLE 6

ODDS RATIOS OF SAFETY-CRITICAL EVENTS WHEN PERFORMING TASKS & DRIVING VS. DRIVING ALONE

Task	Odds ratio
Any cell phone usage	1.14
Dialing a cell phone	3.51
Talking/listening on hands-free cell phone	0.65
Talking/listening on handheld cell phone	0.89
Reaching for headset/earpiece	3.38
Reaching for cell phone	3.74
Texting/emailing/accessing the internet	163.59
Consuming food/drink	1.11

Note. Adapted from "An Assessment of Commercial Motor Vehicle Driver Distraction Using Naturalistic Driving Data," by J.S. Hickman & R.J. Hanowski, 2012, *Traffic Injury Prevention, 13*(6), 612-619.

driver cell phone use and crash involvement was quantified using a case-crossover study design in which a driver's cell phone use in the 6 seconds immediately prior to the crash was compared with the same driver's cell phone use in up to four 6-second segments of ordinary driving under similar conditions (time of day, weather, locality, lighting, speed) within the 3 months prior to the crash. Visual-manual tasks overall and texting in particular were associated with significantly elevated incidence of crash involvement relative to driving without performing any observable secondary tasks [odds ratio (OR) for any visual-manual task: 1.83; OR for texting: 2.22]. The increase in the incidence of crash involvement associated with visual-manual tasks was greater for crashes in free-flow traffic conditions (OR 2.46) and in types of crashes in which the subject driver generally played a clear role (run-off-road crashes: OR 3.15; rear-end crashes: OR 7.77) than for all crash types taken together. The incidence of crash involvement was elevated slightly during handheld cell phone conversation; however, the estimate was not statistically significant (OR 1.16). The odds ratio for hands-free cell phone conversations was not calculated due to the lack of incidents during this condition.

A similar analysis of naturalistic data for 13,306 commercial trucks resulted in the data shown in Table 6 (Hickman & Hanowski, 2012). The measure in question was not incidents per se, but rather safety-critical events of any type (e.g., a crash, a hard braking event, a lane departure/exceedance). All odds ratios in the table are significant except for talking on a handheld phone and consuming food/drink. From the data it can readily be seen that simply talking on a cell phone, whether handheld or hands-free, did not have a negative effect on the likelihood of safety-critical events, but rather *reduced* their likelihood. This does not suggest that cell phone conversations somehow engender a preventive effect regarding incidents, but rather that they typically raise driver workload/arousal to more optimal levels when compared to driving only.

Conclusion

As noted, the concept of acceptable risk means that safety is a function of the level risk associated with a particular activity being acceptable to the population as a whole, not to either an arbitrary standard or to the concept of zero risk. To employ a prosaic example, according to the NSC (2016), in 2014 alone, there were more than 700,000 emergency room visits for incidents involving beds (predominantly falls from them). One could theoretically argue that beds were therefore unsafe and should be eliminated, mandating that people sleep on the floor instead. Such a requirement would undoubtedly eliminate such falls, but the overwhelming bulk of the population would likely disagree that the risk associated with beds was unacceptable and would continue to sleep in them.

Perhaps paradoxically, the overwhelming majority of the population consider themselves to be above average drivers, and as such they typically avoid what they consider to be an unreasonable level of risk on the road. The level of risk that the population as a whole finds to be reasonable (i.e., normal driving) defines what that same population considers to be safe driving in that it embodies an acceptable level of risk. Guidance and rules suggesting or mandating more conservative behavior may result in a lower level of risk, but this does not in and of itself make noncompliance necessarily abnormal, unsafe or negligent. To assess whether a particular driver's conduct rises to such a level, it is necessary to first compare the person's behavior to normal driving to determine whether the difference reaches an unreasonable degree.

This does not, however, suggest that driving normally somehow renders a driver nonculpable for incidents that result from their noncompliance. Culpability generally implies that an act that is performed is wrong or unlawful, but that it does not involve any malicious intent or negligent behavior by the driver. The connotation of the term is associated with fault, rather than malice.

This article attempts to provide the reader with insight into the fact that, while noncompliance with driving statutes may be unlawful, it often represents the norm, rather than the exception. Assertions that normal driver behavior is that which is in strict conformance with the rules is often not representative of the actual state of affairs. **PSJ**

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David Curry, Ph.D. CSP, CHFP, is chief scientist for Solution Engineering Group, where he leads the human factors and safety consulting practice. He is the author of more than 60 technical papers dealing with human factors, safety and incident investigation. He holds graduate degrees in experimental/human factors and cognitive/perceptual psychology, industrial/operations engineering, and business. His experience includes nearly 40 years of work in incident investigation, product design and development, operational testing and analysis, and laboratory and field research in the control/display, aviation and surface vehicle arenas.

John Meyer, Ph.D., P.E., is founder and principal engineer of Edison Engineering. He regularly consults on matters involving complex incident investigation and reconstruction; mechanical engineering issues involving machine design, risk assessment and mechanical failure analysis; and intellectual property disputes. Meyer earned Ph.D. and S.M. degrees in Mechanical Engineering from the Massachusetts Institute of Technology, as well as a B.S. in Physics from Bethel College.

Mary Pappas is a technical/research assistant for both the Solution Engineering Group and Edison Engineering. Her expertise is focused in the automotive/mechanical engineering and human factors/behavioral science arenas.