U.S. Department
of Transportation
National Highway
Traffic Safety
Administration

NHTSA

DOT HS 812 858 March 2020

Analysis of SHRP2 Speeding Data

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Suggested APA Format Citation:

Richard, C. M., Joonbum, L., Brown, J. L., & Landgraf, A. (2020, March). *Analysis of SHRP2 speeding data* (Report No. DOT HS 812 858). Washington, DC: National Highway Traffic Safety Administration.

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT HS 812 858		

4. Title and Subtitle	5. Report Date
Analysis of SHRP2 Speeding Data	March 2020
	6. Performing Organization Code
7. Authors	8. Performing Organization Report No.
Christian M. Richard, Joonbum Lee, James L. Brown, and Andrew Landgraf	
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
Battelle Memorial Institute 505 King Avenue 110 Columbus, Ohio 43201-2696	11. Contract or Grant No. DTNH22-11-D-00229/0002
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Office of Behavioral Safety Research National Highway Traffic Safety Administration 1200 New Jersey Avenue SE Washington, DC 20590	Final Report: September 2013 – March 2018 14. Sponsoring Agency Code

15. Supplementary Notes

Dr. Randolph Atkins was the Contracting Officer's Representative on this project.

16. Abstract

Speeding-related crashes continue to be a serious problem in the United States and attempts to address this problem through a variety of approaches have not led to a substantial reduction in speed-related fatalities. A better understanding of speeding behavior is needed to inform the development of new speeding countermeasures. To address this issue, researchers conducted an in-depth investigation of driver speeding behavior using SHRP2 NDS data, which included numerous observations across various situations, environments, and driver characteristics. The research activities encompassed several steps. Sampling and data processing activities were conducted to obtain a set of trips that was suitable for examining multiple aspects of speeding. Key measures were then extracted from the trip data, including: (a) periods in which drivers had an opportunity to speed (which served as an exposure measure), and (b) speeding episodes within those periods. Using these data elements, situational and driver-specific predictors of speeding were examined using descriptive statistics and regression analyses. In addition, speeding episodes were used to identify different types of speeding and to develop a typology of speeders. Five types of speeders were identified, and these groups differed in terms of their aggregate speeding behavior, demographic characteristics, and attitudes about speeding and risk taking.

17. Key Words	18. Distribution Statement
driver, speeding, SHRP2 NDS, naturalistic driving, safety, driver behavior, driver type, speeding episode, risk-taking, driver behavior questionnaire	This document is available to the public from the National Technical Information Service, www.ntis.gov.

19 Security Classif. (of this report)	20. Security Classif. (of this page)	21 No. of Pages	22. Price
Unclassified	Unclassified	127	

Form DOT F 1700.7 (8/72) Reproduction of completed page authorized

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List of Acronyms

CTRE	Center for Transportation Research and Education
FFE	Free-flow Episode
FL	Florida
g	Gravitational acceleration
GIS	Geographic Information System
GPS	Global Positioning System
IN	Indiana
IRB	Institutional Review Board
MfS	Motivation for Speeding
mph	Miles Per Hour
ms	Milisecond
NC	North Calorina
NDS	Naturalistic Driving Data
NHTSA	National Highway Traffic Safety Administration
NSSAB	National Survey of Speeding Attitudes and Behaviors
NY	New York
PSL	Posted Speed Limit
PA	Pensylvenia
RID	Roadway Information Data
SE	Speeding Episode
SHRP2	2nd Strategic Highway Research Program
SUV	Sport Utility Vehicle
TCD	Traffic Control Devices
WA	Washington

Executive Summary

Speeding-related crashes continue to be a serious problem in the United States. In 2017, 26% of all fatal crashes (9,717 fatalities) had speeding as a contributing factor (National Center for Statistics and Analysis, 2019). So far, attempts to address this problem through a variety of approaches have not led to a substantial reduction in speed-related fatalities. The percentage of speeding-related fatalities in 2017 (26%) is only slightly lower than it was in 2000, when it was at 29% (Liu, Chen, Subramanian, & Utter, 2005). A better understanding of speeding behavior is needed to inform development of new speeding countermeasures. To address this issue, researchers conducted an in-depth investigation of driver speeding behavior—with numerous observations across various situations, environments, and driver characteristics. A substantial amount of research has been conducted on causes of speeding and a multitude of factors have been found to be associated with speeding or speed-related crashes. Despite all this research, there is still uncertainty regarding the relative importance of these factors, and how this information can be used to develop countermeasures that effectively target specific types of drivers.

Studying speeding behavior poses many challenges. Much of the existing knowledge on speeding has been developed through small observational studies, traffic records data, and self- report surveys. Technology is now providing new insights on speeding behavior through naturalistic driving studies, which allow researchers to collect data on driving behavior from drivers as they engage in their normal day-to-day driving. The largest naturalistic driving study, to date, is the Strategic Highway Research Program 2 (SHRP2). The SHRP2 NDS was a comprehensive naturalistic study collecting driving data in six regional sites in the United States located in Pennsylvania, New York, North Carolina, Florida, Indiana, and Washington State. Data collection was conducted from late 2010 to late 2013. SHRP 2 collected data from 3,539 passenger vehicle drivers over 12-24 months, which generated approximately 4,200 driver years of data and up to 5.4 million trip files. One aspect of the SHRP2 NDS data that is particularly useful for examining speeding behavior is the collection of real-time vehicle records, such as GPS, speed, acceleration, braking, steering, and forward radar, as well as multiple video views of the driving environment and inside the vehicle.

The SHRP2 project generated a very large and unique data set that provides information on many aspects of traffic safety, including speeding. The current study conducted an initial exploration of the SHRP2 data with regards to speeding. It is important to note that this “first look” examined the high-level aspects of speeding behavior. There were many ways in which analyses could have been focused, such as limiting analyses to certain road types or posted speed limits, to certain locations and situations, or to certain driver populations. However, one of the key strengths of the SHRP2 data is the breadth of information available about drivers and the immediate roadway environment, which provides a unique opportunity to understand the relative contributions of different situational, roadway, and driver-specific factors to speeding. Thus, the current research focuses on understanding speeding behavior at a more global level.

Objectives

This initial exploration of the SHRP2 data addressed the following research questions related to driver speeding behavior:

1. What is the relationship between situational factors and speeding?
2. What driver-specific factors predict how much individual drivers speed across all their trips?
3. Can speeding be categorized into different types based on the characteristics of individual speeding episodes?
4. Is it possible to develop a typology of speeder groups that classifies drivers based on their speeding behavior?

Overview of Approach

The research activities encompassed several steps (see ES-1). To begin, sampling and data processing activities were conducted to obtain a set of trips that was suitable for examining multiple aspects of speeding (see ES-1). Key measures were then extracted from the trip data, including: (a) periods in which drivers had an opportunity to speed, and (b) speeding episodes within those periods. Using these data elements, situational and driver-specific predictors of speeding were examined using descriptive statistics and regression analyses. In addition, speeding episodes were used to identify different types of speeding and to develop a typology of speeders.

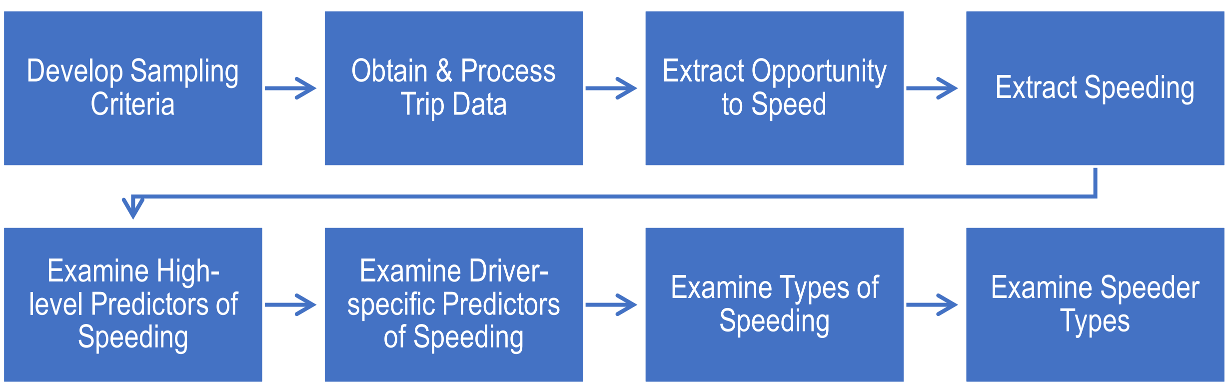

Figure ES-1: Overview of the different steps in the research approach.

The driver sample consisted of all available SHRP2 primary and secondary study participants aged 16 to 65. A decision was made to exclude older drivers because of resource limitations. A total of 2,910 drivers were included in the sample. A total of 203,831 trips were obtained. The mean number of trips per driver ranged between 75 and 89, with all but Pennsylvania averaging over 80 trips per driver. Mean trip durations ranged from 20 to 25 minutes across sites.

Individual trips were divided into different segments based on vehicle speed relative the PSL. The two key segments included:

1) *Free-Flow Episodes (FFEs)*, when the vehicle was traveling fast enough that the speed could plausibly represent the driver's chosen speed for those roadway conditions. Since information about lead vehicles was unavailable, it was possible that drivers were still boxed in by other traffic. Nevertheless, FFE represent the best available estimates of opportunity to speed.
2) *Speeding Episodes (SEs)*, when the vehicle was traveling fast enough relative to the PSL to be classified as speeding. Note that because of data limitations, SEs did not account for driving that was "too fast for conditions" but below the speeding threshold.

The current research used a very specific definition of speeding. Speeding was initially operationalized as discrete events or episodes (SEs) in which the vehicle speed exceeded the PSL limit by at least 10 mph for longer than 6 seconds. These SEs consisted of a continuous period of driving above the speeding threshold. However, as discussed below, the primary data analyses were conducted on a subset of SE that had an additional, more-stringent criterion of exceeding the PSL by at least 15 mph at some point during the SE.

Speeding Episodes

Driving 10 mph above the PSL was relatively common, and 99.8% of drivers had at least one occurrence of this within their trip sample, yielding an average of 2.75 SEs per trip. There was a total of 623,202 SEs in the full dataset. To reduce the number of SEs for analysis and to make the dataset more manageable, SEs were further filtered based on multiple criteria, including removing SEs associated with PSL transitions, and removing SEs with a low maximum speed above the PSL. Vehicle speed during an SE also had to reach at least 15 mph above the PSL to be retained. In effect, the additional criteria removed the SEs that were borderline speeding based on earlier criteria.

The filtered dataset contained 71,113 SEs. The SEs that remained systematically biased the analysis sample towards SEs that occurred on high-speed roadways, in addition to being at the more severe end of the speed exceedance spectrum. The removal of SEs associated with PSL transitions and those that were just above the speeding threshold meant that SEs in the sample were also less likely to reflect incidental or unintentional speeding. Average maximum speeds for most SEs ranged between 12 mph to 20 mph above the PSL. Most also lasted less than 2 minutes and SEs with the highest speeds tended to be shorter.

At the trip level, the type of speeding examined in this study was relatively uncommon. Thirty-seven percent of all drivers averaged less than 1 SE per 10 trips. Only a small percentage of drivers (9%) averaged more than one SE per trip. Drivers in the 16-24 age group tended to average a higher number of SEs per trip than the older age groups.

High-level Predictors of Speeding

The overall amount of speeding was relatively low for most drivers. Only 13% of all drivers spent more than 5% of their FFE time speeding. There was substantial variation in average speeding amount across sites, with 4 times as many drivers speeding 5% of the time in Florida compared to Washington State. The amount of speeding also varied by driver age and a variety of situational factors including month, day of week, and time of day.

Predictors of Speeding Within FFEs

A key question in this research is: When drivers have an opportunity to speed, what factors influence how much they speed, if they do at all? This question was investigated by conducting a linear regression analysis to predict the proportion of time within an FFE that drivers were speeding (i.e., how much speeding they were doing). The FFE was the unit of analysis in the regression modeling. The outcome measure in the regression model was the amount of speeding on an FFE (i.e., the SE duration divided by the FFE duration). Twenty-one predictors were selected as fixed effects covering various sources. These included select situational and demographic variables, and measures related to driver behaviors, attitudes, and capabilities.

Situational factors: Several situational factors were significant predictors of speeding in the final model. FFE duration showed a positive relationship with the SE proportion. This finding suggests that longer opportunities support a higher proportion of speeding. The site variable was significant and may have reflected broader characteristics of the road network. It could also have reflected driver-related aspects such as driving culture, local attitudes about speeding, or even experience with local law-enforcement practices. Start hour was significant. Compared to the nighttime period, other periods (morning, afternoon, and evening) were associated with more speeding, which likely reflected a combination of situational factors including traffic conditions and ambient light conditions. Compared to winter months, spring and fall months were associated with more speeding. This pattern is partially consistent drivers speeding less when safety risk is potentially noticeably elevated because of ice or snow.

Demographic factors: Among the demographic factors, only years of driving was statistically significant. The results indicated that drivers with less experience (i.e., younger drivers) had more speeding.

Driver behavior/attitude/capability factors: Multiple variables in this category were significant in the final model. A common theme in the pattern of results for these variables was that factors related to risk taking were typically associated with more speeding. Drivers that self-reported two or more traffic violations in the last three years tended to show a higher proportion of speeding compared to drivers had no violations. Similarly, reporting one crash was associated with more speeding, compared to no crashes. Higher sensation-seeking scores were associated with more speeding. The dominant pattern among the other psychological constructs was that driver types that most frequently reported engaging in aggressive, risk-taking, anti-social, and poor driving behaviors were also associated with more speeding.

Driver-specific predictors

A regression model was developed to identify driver-specific factors that predicted how much individual drivers speed overall. The unit of analysis was individual drivers. The outcome measure was based on the same outcome measure in the previous regression analysis (the ratio of SE duration to FFE duration); however, the SE ratios for individual FFEs were averaged per trip and then the mean SE ratios per trips were averaged per individual driver to derive a single, global measure of how much drivers sped. Eighteen predictors that were similar to the previous model were selected as fixed effects, and a total of 2,357 drivers' data were used to build/test the regression model.

Situational factors: In the driver-level model, fewer variables were available since trip-level variables such as start hour and month of the trip were excluded during the averaging process.

FFE duration showed a positive relationship with the SE proportion. In the driver-level model, this indicated that drivers that generally drove on roadways that afforded greater opportunities to speed tended to speed more overall. Regarding site, compared to New York, Washington State drivers were associated with less speeding, but Pennsylvania and Florida drivers were associated with more speeding. The speed limit variable indicated that drivers who tended to have more of their FFEs on higher speed roadways sped significantly more.

Demographic factors: Similar to the previous results, years of driving was the only significant demographic factor. The results showed that less experienced (and typically younger) drivers sped more.

Driver behavior/attitude/capability factors: Multiple variables in this category were significant in the final model. Drivers that self-reported two or more traffic violations in the last three years tended to show a higher proportion of speeding compared to drivers had no violations. Similarly, reporting one crash was associated with more speeding, compared to no crashes. Higher sensation-seeking scores were associated with more speeding. The dominant pattern among the other psychological constructs was that driver types that most frequently reported engaging in aggressive, risk-taking, anti-social, and poor driving behaviors were also associated with more speeding. Finally, drivers with a higher Attention Deficit Hyperactivity Disorder (ADHD) confidence index (which represents chances that a significant attention problem exists) were more likely associated with higher amount of speeding.

Types of Speeding

The research also categorized types of speeding based on the characteristics of individual speeding episodes. The underlying premise behind this analysis was that speeding could result from qualitatively different types of driving behaviors. A k-means cluster analysis was conducted on select SE variables that represented four fundamental properties of SEs (magnitude, duration, variability, & form) to divide them into different types of speeding based on shared characteristics. A three-cluster outcome provided the best solution. The three types included:

Momentary Speeding: This type of speeding was typically comprised of a brief increase then decrease in speed. The Momentary speeding label captures the transient nature of these SEs, especially since the short duration is the defining attribute of this type of speeding. This type speeding could be unintentional, or it may occur in the service of a short-term tactical objective, such as making a lane change or passing another vehicle. Momentary speeding could also reflect the influence of local topography, such as being accelerated by gravity on a downhill grade. Another possibility is that it reflects brief inattention to the vehicle's speed, possibly while platooned with other fast-moving traffic. The key behavioral implication is that it seems to reflect neither a deliberate intent to speed in a sustained way, nor cautious attention to diligently keep below 10 mph above the PSL, which typically represents drivers' perceived threshold for speeding (Richard et al., 2012). Momentary SEs all reached at least 15 mph above the PSL, so the SEs were unlikely to have occurred from normal fluctuations around a target speed that was below the 10 mph threshold.

Cruising Speeding: This type of speeding was comprised of longer duration speeding consistent with speed maintenance behavior. Cruising speeding involved longer stretches of speeding that had lower speed variability, low maximum speed, and a generally flat shape. A defining characteristic of Cruising SEs was a high rate of speed reversals per minute. These reversals often represented speed fluctuations around a stationary or drifting set point, which seemed to reflect consistent speed maintenance behavior for much of the SE. Another noteworthy characteristic of Cruising SEs is that they typically lasted for minutes. This means that drivers had ample time to observe the speedometer and become aware that were speeding. It is likely that this type of speeding reflects a conscious decision by drivers to speed.

Riskier Speeding: This type of speeding was characterized by multiple riskier attributes such as long duration, high maximum speed, and higher speed variability. These SEs were consistent with drivers actively controlling their high speeds. These SEs had the highest speeds—especially on low PSL roadways, they had relatively long durations, and speed was consistently varying throughout the SE. In particular, on 35 mph roadways, the average maximum speed in Riskier SEs exceeded the PSL by 65%.

Typology of Speeder Groups

A cluster analysis was conducted to develop a typology of speeders based on the proportion of each SE type within individuals. The analyses also examined whether the resulting speeder groups reflected underlying differences in driver demographics, self-reported behaviors, beliefs, and attitudes. Five speeder groups were identified, including:

Non-speeders. This group was simple to label since they were not observed speeding in the trip sample; however, it was possible that they had SEs on trips that were not included in the dataset. Nevertheless, this group still appeared to be distinct from other groups, with substantially fewer trips and lower exposure to FFEs.

Infrequent Speeders. This group almost never sped, but when they did, it mostly involved Momentary SEs. This group also had the smallest proportion of Riskier SEs. It is possible that this group overlaps with the Non-speeders; however, this group is much more like the other speeder groups when it comes to average number of trips and FFE exposure. Infrequent speeders were the most common speeders, comprising just over half of the driver sample. Thus, they represent modal speeding behavior in the current sample.

Occasional Speeders. Speeding was not a rare occurrence for these drivers; they averaged around one SE every two trips and their proportion of speeding was five times higher than the Infrequent Speeder group. Their average SE duration was over 80 seconds long and their average maximum SE speed was greater than 15 mph above the PSL, so these drivers were clearly not speeders by chance.

Long-duration Speeders. This group of speeders had the highest proportion of Cruising speeding, which reflected more deliberate speed maintenance that was well above the PSL. This group stood out from the other groups by having substantially longer average SE durations and greater total exposure to opportunities to speed. The higher FFE exposure levels suggests that these drivers may have engaged in qualitatively different driving overall, so their travel patterns and/or driving environment could have contributed to this speeding behavior. These speeders also had the second highest amount of speeding, which was almost 10 times greater than the modal Infrequent Speeders. The Long-duration speeders may also have experienced elevated safety risk. This is primarily because the long SE durations—which were compounded by the longest FFE times—resulted in the highest levels of speeding exposure.

High Speeders. These drivers had the highest proportion of speeding, the highest maximum speeds above the PSL, and the highest proportions of the Riskier 3 SEs. Their proportion of speeding time was over 13 times greater than the modal Infrequent Speeders. Even relative to the next-highest Long-duration Speeders, High Speeders had 50% more speeding overall, and twice as high a proportion of Riskier SEs. These drivers were clearly at the high end regarding the riskiness of their speeding behaviors.

These groups were clearly distinct based on the amount of speeding, but also in terms of the underlying characteristics of the SEs associated with each group. Long-duration and High Speeders appeared to engage in speeding that represented some degree of elevated risk, especially the High Speeders. There were clear differences across groups for multiple driver-specific factors. Age appeared to be the most prominent factor. Attitudes and behaviors towards risk also systematically varied across groups; however, it was possible that some of these effects also reflected age differences, since age and attitudes were likely related.

Summary and Conclusions

This study had a broad scope and examined multiple aspects of driver speeding behavior. The SHRP2 database provided a substantial driver sample that covered a wide range of driver traits and travel patterns. With nearly 3000 drivers in the sample it was possible to identify meaningful trends with several psychological constructs. In addition, the huge sample of trips yielded a substantial number of speeding events that would have otherwise been challenging to record in non-naturalistic settings. The new perspectives on speeding that emerged from the analyses were only possible because of the breadth of the SHRP2 NDS dataset.

The research activities conducted in this study included defining and obtaining measures for speeding and suitable exposure measures. Regression analyses were then run using these measures to identify situational, demographic, and psychological predictors of the amount of speeding during individual opportunities to speed, and amount of speeding at the driver level. These analyses were expanded to examine the underlying SEs in more detail, to better understand how SEs differ from each other, and to identify what factors and driver behaviors lead to these differences. The subsequent analysis of the speeder groups suggested that the differences in speeding patterns may have reflected underlying differences in specific groups of drivers. The findings obtained at each stage of this research provided new insights about driver speeding behavior, as well as addressing each of the research Questions.

What is the relationship between situational factors and speeding?

The analyses found clear relationships between situational factors and speeding, but the specific reasons for these links were unclear. Situational factors were examined using variables that reflected aspects of traffic conditions, environmental/weather factors, and roadway characteristics, but these conditions were not directly measured in the data. The indirect evidence suggested that high levels of traffic appeared to act as a constraint on speeding, and factors representing greater traffic congestion (e.g., daytime and weekday driving) were associated with less speeding. Similarly, FFE duration was a strong predictor of the amount of speeding. FFEs duration may reflect roadway characteristics, but it is also likely that FFE duration is influenced by traffic levels. Drivers also sped less at night, which suggests that increased risk associated with low light levels may be associated with less speeding. However, situational factors alone did not determine whether drivers sped. While most drivers had plenty of opportunities to speed, only drivers with certain characteristics took advantage of these chances. Thus, suitable situational conditions may have been necessary for speeding to occur, but they were not sufficient in most instances.

What driver-specific factors predict how much individual drivers speed across all their trips?

Age was the dominant demographic factor affecting speeding. It was a strong predictor of the amount of speeding during FFEs and average amount of speeding across drivers. Age also varied systematically across speeder groups. Older drivers were associated with less speeding overall, which is consistent with expectations. Young adults 20-24 made up the highest proportion of drivers in the Long-duration and High Speeder groups. In contrast, teen drivers 16-19 were much more evenly distributed across all speeder groups, including Non-speeders and Infrequent Speeder groups.

The psychological measures included constructs such as the Driver Behavior Questionnaire (DBQ) and Sensation Seeking Scale that have been used to examine speeding in previous studies. After conducting Factor Analyses to distill the responses to various test batteries, clear patterns emerged regarding the trends in driver responses. Specifically, drivers who sped more or engaged in riskier speeding behavior were more likely to be accepting safety risk, were inclined towards sensation seeking, and to have a higher proclivity for ADHD. The findings from the driver-level regression model were consistent with several previous studies indicating that driver-specific factors are associated with speeding.

Can speeding be categorized into different types based on the characteristics of individual speeding episodes?

The Cluster Analysis identified three basic types of speeding, including: *Momentary* speeding that was typically comprised of a brief increase then decrease in speed, *Cruising* speeding that was comprised of longer duration speeding consistent with speed maintenance behavior, and *Riskier* speeding that was characterized by multiple riskier attributes such as a long duration, high maximum speed, and higher speed variability. In general, the three types seemed to reflect broad difference in underlying speeding behaviors. The SEs showed clear statistical differences that were interpretable as certain speeding behaviors. Moreover, when plotted across PSL, the aggregate characteristics of each SE type systematically varied in ways that were consistent with the explanations. In addition, combining the parameters of the SEs with available information about driving situations made it possible to distinguish these SEs based on relative safety risk. Altogether, this provided a sufficient foundation to use SE type to classify drivers into different speeder groups.

Is it possible to develop a typology of speeder groups that classifies drivers based on their speeding behavior?

The Cluster Analysis conducted based on the proportion of each type of speeding for each driver yielded five interpretable speeder groups that differed along multiple dimensions. These groups were clearly distinct based on the overall amount of speeding, but also in terms of the underlying characteristics of the SEs associated with each group. Long-duration and High Speeders appeared to engage in speeding that represented some degree of elevated risk, especially the High Speeders. In addition, analyses conducted to examine demographic and psychological differences across groups provided converging evidence that the cluster analysis divided drivers into meaningful speeder groups.

The Non-speeders were clearly the most risk-averse of all groups, and they generally reported engaging less often in unsafe behaviors. In contrast, Long-duration and High Speeders were the most accepting of risk-taking and unsafe behaviors. Apart from differences in age and driving patterns, the two riskier groups were mostly indistinguishable in terms of psychological and behavioral aspects. It is possible that they reflect the same type of speeder, and that the differences arose from differences in travel patterns and opportunities to speed (e.g., High speeders might have had similar SEs to Long-duration speeders if they just spent more time driving on open roads). Despite the ambiguities between these groups, the broader differences across speeder groups indicate that the cluster analysis approach was effective in parsing drivers into a meaningful typology of speeders.

The SHRP2 NDS data provided a speeding dataset that was unprecedented in both its detail and breadth of both drivers and trips. The current study took advantage of these elements to examine many aspects of driver speeding behavior. These analyses used behavior data to confirm several findings expected based on previous self-report studies. The analyses also provided new insights about types of speeding, speeder groups, and a potentially more complex relationship between driver age and speeding. Since this research represented an initial look at speeding in the SHRP2 dataset, many of the more specific questions about speeding and driver behaviors remain unanswered. Nevertheless, the research conducted in this study lay the foundation for examining these issues in more detail.

Chapter 1 - Introduction

Speeding-related crashes continue to be a serious problem in the United States. In 2017, 26% of all fatal crashes (9,717 fatalities) had speeding as a contributing factor (NCSA, 2019). In addition, the absolute number of fatalities in speeding-related crashes has remained about the same as in 2015 (9,723 fatalities).

Speeding is a common behavior; most drivers exceed the speed limit at some point. In the National Highway Traffic Safety Administration (NHTSA) *2011 National Survey of Speeding Attitudes and Behaviors* (NSSAB; Schroeder, Kostyniuk, & Mack, 2013), when asked how often they drove 10 or 15 miles per hour over the posted speed limit, over half of the respondents (52%) reported having driven 15 mph over the speed limit on multi-lane divided highways, over one-third (36%) reported having driven 15 mph over the speed limit on two-lane roads, and 36% also reported having driven 10 mph over the limit on neighborhood or residential streets. Nine percent of those surveyed reported having been stopped by the police for speeding in the previous year, and eight percent reported receiving a speeding ticket through the mail for a violation recorded by a speed camera (Schroeder, Kostyniuk, & Mack, 2013). Given the widespread occurrence of speeding and the high toll in injuries and lives lost in speeding-related crashes, as well as the high economic costs of speed-related crashes—estimated at nearly $52 billion in economic costs and over $203 billion in comprehensive costs in 2010 (Blincoe et al., 2015), it is clear that this is a safety issue that demands a great deal of attention.

So far, attempts to address this problem through a variety of approaches have not led to a substantial reduction in speed-related fatalities. The percentage of speeding-related fatalities in 2017 (26%) is only slightly lower than it was in 2000, when it was at 29% (Liu, Chen, Subramanian, & Utter, 2005). In addition, speeding countermeasures have typically been associated with uncertain or limited success. NHTSA's (2017) report, *Countermeasures That Work,* provides a list of speeding countermeasures that have been demonstrated to be effective; however, most of these are one-dimensional in the sense that they focus on enforcement/punishment to reduce speeding. A significant limitation with these types of countermeasures is that they do not seem to be as effective with some driver groups, such as risk-taking young males, because these drivers rarely consider the potential consequences of their behaviors (e.g., McKenna & Horswill, 2006). Similarly, National Cooperative Highway Research Program (NCHRP) Report 500 provides several engineering-based countermeasures to address speeding (NCHRP, 2005). While these countermeasures can be effective in reducing speeding at specific locations, the problem is that they can be expensive and only cover small parts of the transportation network. They are also indiscriminate because other non-speeding drivers are impacted by the countermeasures as well.

A substantial amount of research has been conducted on causes of speeding. Table 1 shows the multitude of factors that have been found to be associated with speeding or speed-related crashes. Despite all this research, there is still uncertainty regarding the relative importance of these factors, and how this information can be used to develop countermeasures that effectively target specific types of drivers.

Table 1. Factors found to be associated with speeding in previous research.

Factor	Example Variables	Example References
Demographic	Age, Gender, Socio-economic & Education Level	Hemenway & Solnick, 1993; Harré et al., 1996; Rienstra & Rietvald, 1996; Stradling et al., 2001; Shinar, Schechtman, & Compton, 2001; DePelsmacker & Janssens, 2006; Charlton et al., 2006; Rhodes & Pivik, 2011; Richard et al, 2013; Richard et al, 2017
Personality	Attitudes, Habits, Personal & Social Norms, Thrill-seeking, Beliefs	Clément & Jonah, 1984; Parker, Manstead, & Stradling, 1995; Arnett et al., 1997; Gabany et al., 1997; Jonah, 1997; Shinar, 1998; Corbett, 2000; Stradling et al., 2001; Jonah et al., 2001; Deffenbacher, Deffenbacher, Lynch, & Richards, 2003; Shinar & Compton, 2004; Dahlen, Martin, Ragan, & Kuhlman, 2005; DePelsmacker & Janssens, 2006; McKenna & Horswill, 2006; Ekos Research Associates, 2007; Harris & Houston, 2010; Fleiter, Lennon, & Watson, 2010; Richard et al, 2013; Richard et al, 2017;
Roadway	Posted Speed	Book & Smigielski, 1999; Haglund & Aberg, 2000; Giles, 2004; Gargoum & Kim, 2016
Environment	Urban/Rural	Martens, Comte, & Kaptein, 1997; Giles, 2004; Rakauskas et al., 2007
Vehicle	Engine Size, Vehicle Age	Wasielewski, 1984; Hirsh, 1986; Stradling et al., 2002; Horswill & Coster, 2002
Risky behaviors	Drinking & Driving, Seatbelt Use, Red-light Running	Hemenway & Solnick, 1993; Rajalin, 1994; Harré et al., 1996; Arnett et al., 1997; Cooper, 1997; Gabany et al., 1997; Retting, Ulmer, & Williams, 1999; Dahlen, Martin, Ragan, & Kuhlman, 2005; Harris & Houston, 2010; Richard et al, 2013; Richard et al, 2017;
Situational	Trip time, Mood, Inattention, Fatigue	Hirsh, 1986; Arnett et al., 1997; Gabany et al., 1997; Shinar, 1998; McKenna & Horswill, 2006; Ekos Research Associates, 2007; Fuller et al., 2009; Harris & Houston, 2010; Peer, 2010; Shinar & Compton, 2004

Types of Speeders

A recent approach for understanding how driver characteristics relate to speeding has been to identify different types of speeders based on their observed or self-reported speeding behavior. NHTSA's *Motivations for Speeding* (MfS) project (Richard et al., 2013) collected actual driving speeds by road type and Posted Speed Limit (PSL) for a sample of volunteer drivers (*n*=164) tracked over several weeks. The participants also completed a number of questionnaires involving driving attitudes and psychological measures. Analyses of speeding on trips indicated that the occurrence of speeding was correlated with multiple driver-specific factors, including: age, gender, permissive attitudes towards dangerous/aggressive driving, and bad driving habits (Richard et al., 2013). The analyses of the driving data also identified four basic speeder types (*incidental* speeders who rarely if ever speed, *casual* speeders who speed often but in small amounts per trip, *occasional* speeders but in large amounts for a few trips, and *habitual* speeders who speed often during most if not all of their trips). The study also found that speeding patterns varied across different roadway types and, in some speed limit ranges, were significantly associated with certain psychological factors.

A follow-up analysis of the MfS data further developed the typology of speeders based on characteristics of actual speeding episodes (Richard, Divekar, & Brown, 2016). The speeder types were slightly different than the original groups, but a consistent and important finding was evidence for a small group of drivers that was notably distinct from other groups by speeding more often and having speeding episodes that had “riskier” characteristics, such as higher maximum speed over the PSL. Moreover, these speeders also reported engaging in risky driving behaviors more frequently than others (e.g., such as tailgating, taking risks when in a hurry, and cutting off other drivers), and they had the most favorable attitudes towards speeding. The distinctiveness of this speeder type leads to an important practical implication of categorizing drivers as different types of speeders, which is the possibility of specifically directing safety campaigns and countermeasures towards this group. Because their behaviors and attitudes are outside the norm, they can be identified both by their on-road behavior and by using personal inventory items, which may be a practical way to identify drivers from this group. This is also the most critical group to focus on because they engage in the most aggressive type of speeding, likely in conjunction with other risky driving behaviors. Therefore, changing their behavior may have disproportionately large benefits in terms of reducing speeding-related crashes.

The notion of speeder types has also been examined using national data. NHTSA’s 2011 *National Survey of Speeding Attitudes and Behaviors* (NSSAB) survey collected a wide range of speeding-related information, including self-report driving behavior and attitudes on public acceptability of various countermeasures (Schroeder, Kostyniuk, & Mack, 2013). This national survey provided additional insights into patterns of speeding behavior. Cluster analyses of the national survey data indicated that 86% of all respondents in the survey fell into one of three distinct types of driving behavior based on six core questions on their driving tendencies per passing other vehicles and matching the flow of traffic, their average speeds on different types of roads, and how often they had been stopped for speeding. Of those respondents classified in the cluster analyses, 30% of the drivers were classified as non-speeders, 40% as sometimes speeders, and 30% were classified as speeders. For these survey respondents, concerns over the danger of speeding and attitudes towards various countermeasures clearly varied by speeder type.

A recent study compared the NSSAB typology above with one based on the MfS study. The study involved a survey of Idaho drivers with 0, 1, or 2+ speeding-related convictions in the past three years (Richard et al. 2017). The MfS typology was constructed using survey questions about driver attitudes, beliefs, and situational aspects related to speeding, while the NSSAB was based on questions about self-reported speeding behavior. Both typologies significantly predicted speeding convictions, and the group representing the most frequent speeders was more accepting of risky driving behaviors than other groups that sped less.

Table 2 provides a comparison of speeder typologies across the studies described above. The categories are divided into low-, intermediate-, high-levels of speeding across drivers, and the groups from individual studies were assigned to the most appropriate overall category. The table indicates that there was substantial diversity regarding the basis for developing the speeder types across studies (see second column). All of the typologies have a low-speeder group that represents drivers that almost never speed, or only engage in speeding that appears incidental. Each typology also has a high-speeder group. The value in the typology approach is that although they types are defined primarily by various aspects of speeding-related behaviors and attitudes, the groups differ significantly along other attitudes, beliefs, and other psychological factors in the expected ways. And while there are consistent demographic trends between the groups (i.e., younger drivers are higher speeders), all groups contain a mix of genders and ages, yet driver beliefs and behaviors are the key differentiators between groups. Overall, the concept of speeder types appears to have some merit. However, the studies listed in the table do not point to a single consistent typology. In particular, the specific interpretation and labeling of each group varies, which is likely due to differences in the measures used to define the groups. Nevertheless, the notion of speeder types warrants additional examination.

The current research further examined driver typologies using driving data from the SHRP2 Naturalistic Driving Study (NDS). The SHRP2 data available for analysis (see discussion below) provided a rich dataset of driver-specific and vehicle speed data that facilitated a detailed examination of speeding behaviors. The research approach was similar to the MfS Follow-on study, and development of a speeder typology was based on the types of speeding episodes that occurred among drivers.

Table 2. Comparison of speeder typologies across recent NHTSA studies.

Study	Basis for Grouping	Low-Speeder Group	Intermediate-Speeder Group	Highest-Speeder Group
MfS	Occurrence and amount of speeding on a trip	Incidental	- Casual - Occasional	Habitual
MfS Follow-on	Frequency and types of speeding events	Incidental	- Typical - Situational	Deliberate
NSSAB	Self-reported speeding behavior	Non-speeders	Sometimes Speeders	Speeders
Idaho Survey (NSSAB)	Self-reported speeding behavior	Non-speeders	Sometimes Speeders	Speeders
Idaho Survey	Self-reported speeding-related attitudes and beliefs	Infrequent	Casual	- Emotional - Aggressive

SHRP2 Naturalistic Driving Study

Studying speeding behavior poses many challenges. In particular, much of the existing knowledge on speeding has been developed through small observational studies, traffic records data, and self-report surveys. Technology is now providing new insights on speeding behavior through naturalistic driving studies, which allow researchers to collect data on driving behavior from drivers as they engage in their normal day-to-day driving. The largest naturalistic driving study, to date, is the Strategic Highway Research Program 2 (SHRP2). The SHRP2 NDS was a comprehensive naturalistic study collecting driving data in six regional sites in the United States located in Pennsylvania, New York, North Carolina, Florida, Indiana, and Washington State. Data collection was conducted from late 2010 to late 2013. SHRP 2 collected data from 3,539 passenger vehicle drivers over 12-24 months, which generated approximately 4,200 driver years of data and up to 5.4 million trip files. This large sample of drivers covered eight age ranges evenly divided by gender. The SHRP2 study includes four types of data files:

- **Naturalistic Trip (NDS) Data**: NDS data includes real-time vehicle records, such as GPS, speed, acceleration, braking, steering, and forward radar, as well as multiple video views of the driving environment and inside the vehicle. The NDS data was collected in trips with each trip lasting from the time the vehicle ignition is turned on until the ignition is turned off.

- **Driver Assessment Data**: Assessment data was collected for each driver that participated in this project. This data includes data on each driver's vision, visual-cognitive, cognitive, and physical status collected at the beginning of their participation in the study.
- **Roadway Information Data (RID)**: Detailed roadway data were collected, including lane and road width, road geometry, posted speed limit, intersection data, etc.
- **Supplemental Data**: Data from other sources were linked to roadway data, including crash histories, work zones, etc.

The SHRP2 project generated a very large and unique data set that provides information on many aspects of traffic safety, including speeding. The current study conducted an initial exploration of the SHRP2 data with regards to speeding. It is important to note that this "first look" examined the high-level aspects of speeding behavior. There were many ways in which analyses could have been focused, such as limiting analyses to certain road types or posted speed limits, to certain locations and situations, or to certain driver populations. However, one of the key strength of the SHRP2 data is the breadth of information available about drivers and the immediate roadway environment, which provides a unique opportunity to understand the relative contributions of different situational, roadway, and driver-specific factors to speeding. Thus, the current research focuses on understanding speeding behavior at a more global level.

Objectives

The initial research questions had a strong focus on the relationship between various factors and speeding and crashes or near-crashes. The original research questions were as follows:

1. What is the relationship between speeding and crashes (and near crashes)?
2. How do seasonal changes affect speeding and crashes (and near crashes)?
3. How does time of day (daylight / nighttime) affect speeding and crashes (and near crashes)?
4. Do demographic differences affect speeding and crashes (and near crashes)?
5. How do speeding and crashes (and near crashes) vary with regard to speed limit and road type?

The objectives of the current study changed partway through the project. The research was originally proposed before the SHRP2 dataset was made available for research use, and the initial release version lacked PSL information, which was essential for identifying speeding. Subsequent data releases partially addressed this problem by adding PSL information collected by the SHRP2 mobile data collection van. The van recorded detailed roadway information on the most frequently traveled roadways at each site; however, the vast majority of driving by SHRP2 participants occurred on roads that were not covered by the SHRP2 mobile van. Consequently, a substantial proportion of speeding-related crashes and near-crashes occurred on roadways that had to be excluded from the dataset used for the current project.

Given the limitations with the availability of PSL data, it was not possible to reliably examine the link between speeding and crash/near-crash events. Not only were many of the crashes missing from the speeding dataset, but travel on roads that were not covered by the mobile van were also excluded from trip data used in this study. As a result, it was not possible to develop reliable exposure measures for crashes, or to connect most of them with precursor speeding events. Consequently, the research questions that examined relationships between speeding and crashes could not be addressed using the available speeding dataset.

In lieu of these limitations, the research questions were revised to take advantage of the available data and focus on underlying aspects of driver speeding behavior that could be examined using the dataset. With the exception of probing the direct link between speeding and crashes, the revised set still examined the key predictors from the original set of questions. In addition, the revised questions also expanded the investigation to more broadly examine the behaviors and driver-specific aspects associated with speeding.

This initial exploration of the SHRP2 data addressed the following research questions related to driver speeding behavior:

1. What is the relationship between situational factors and speeding?
2. What driver-specific factors predict how much individual drivers speed across all their trips?
3. Can speeding be categorized into different types based on the characteristics of individual speeding episodes?
4. Is it possible to develop a typology of speeder groups that classifies drivers based on their speeding behavior?

The remainder of this report includes chapters that describe the activities undertaken to lay the foundation for this research, prepare the SHRP2 data for analysis, and address the research questions described above.

Chapter 2 - Overview of the Approach

The SHRP2 NDS provides a huge repository of speed data in the form of 1-Hz vehicle speed recordings within individual trips. A relatively small subset of these trips was selected to examine driver speeding behavior. A priority was to leverage the unprecedented number of participants in the SHRP2 dataset to obtain a broad sample of drivers for analysis. Thus, obtaining a large driver sample was prioritized over obtaining a large sample of trips for individual drivers.

The research activities encompassed several steps (see Figure 1). To begin, sampling and data processing activities were conducted to obtain a set of trips that was suitable for examining multiple aspects of speeding (see Figure 1). Key measures were then extracted from the trip data, including: (a) periods in which drivers had an opportunity to speed, and (b) speeding episodes within those. Using these data elements, situational and driver-specific predictors of speeding were examined using descriptive statistics and regression analyses. In addition, speeding episodes were used to identify different types of speeding and to develop a typology of speeders. The steps identified in Figure 1 are summarized in the sections that follow. They are also covered in more detail in separate chapters in this research report.

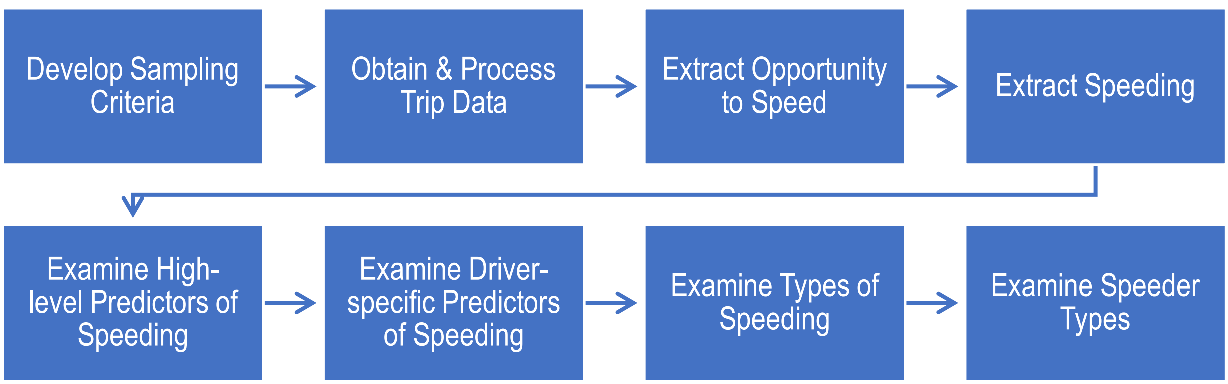

Figure 1. Overview of the different steps in the research approach.

Develop Sampling Criteria: Since data processing of 1-Hz time-series data is resource intensive, only a small proportion of the 5.4 million available SHRP2 trips could be sampled. Steps were taken to balance trip characteristics, such as trip start time and start month, to support the research objectives, and to compensate for data quality limitations in the time-series data. The corresponding report chapter describes the sampling approach and summarizes basic driver and trip characteristics in the obtained sample.

Obtain & Process Trip Data: Data acquisition, processing, and validation was a critical element of the research. Only parts of individual trips met the data quality requirements. Further, usable driving data had to be combined with roadway data to determine posted speed and certain roadway characteristics. The corresponding report chapter provides an overview of key data processing steps and analysis concepts, such as how the opportunity to speed and individual speeding episodes were defined.

Extract Opportunity to Speed: On most trips, drivers were limited regarding when they could speed. Speeding typically requires open-road conditions, and does not occur if a driver is boxed in by slow traffic or stopping for Traffic Control Devices (TCD). Thus, a key unit of information in this research was driver's exposure to driving conditions in which they had an opportunity to speed, and thus may have had a choice to speed or not speed. In this study, opportunity to speed was estimated by identifying periods, called Free Flow Episodes (FFEs), in which the vehicle was traveling at speeds near the PSL or faster. Free Flow driving periods were interspersed with non-FFE driving, which had to be excluded from the driving data. The corresponding report chapter summarizes the characteristics of FFEs including differences across the study sites.

Extract Speeding: Speeding was the primary dependent measure in the study. During some FFEs when drivers had the right opportunity, some chose to exceed the PSL by enough to be considered speeding. Speeding Episodes had to occur within FFEs, and thus had to be extracted from FFE data. The corresponding report chapter summarizes the basic characteristics of SEs, and examines differences across the participants and study sites.

Examine High-level Predictors of Speeding: Dividing the time drivers spent speeding during an FFE by the total FFE duration provides a measure of amount of speeding. The amount of speeding observed varied substantially across drivers and across certain situational factors, such as time of day. The corresponding report chapter describes how the amount of speeding varied across drivers and high-level situational factors. This included regression analyses conducted to examine what factors were associated with the amount of speeding within FFEs.

Examine Driver-specific Predictors of Speeding: Across study drivers, there was wide variation in the frequency and amount of speeding. The SHRP2 dataset contains detailed information about individual participants, which provides an excellent opportunity to examine how driver characteristics influence speeding behavior. The corresponding report chapter describes the regression analyses conducted to identify driver-specific predictors of speeding at the individual level.

Examine Types of Speeding: Individual speeding episodes can differ in multiple ways, including duration, speed variability, and maximum speed exceedance among other characteristics. Previous research has indicated that there may be distinct types of speeding differentiated by the characteristics of the time-series speed data. Moreover, these types of speeding may reflect different underlying speeding behaviors. The corresponding report chapter describes analyses conducted to identify and characterize different types of speeding.

Examine a Typology of Speeder Types: The various types of speeding reflect underlying driver behaviors. Drivers differ in the extent to which they engage in certain types of speeding episodes. These differences form the basis for a typology of speeders based on their speeding behaviors. The corresponding report chapter describes the analyses conducted to develop the typology and it provides a summary of how different speeder groups differ in terms of demographics, self-reported behaviors, and certain psychological constructs.

Chapter 3 – Driver and Trip Characteristics of the Sample

This chapter describes the drivers and trips included in the study sample. The SHRP2 dataset contains over 5.4 million individual trips. Since data processing of 1-Hz time-series data is resource intensive, only a small proportion of the available SHRP2 trips were sampled. The sample was focused on drivers aged 16-65, which are the age groups that are most likely to engage in speeding (Charlton et al., 2006; Schroeder, Kostyniuk, & Mack, 2013). In addition, because PSL data were limited to the major roadways that were most frequently travelled across all participants, the sample was focused on driving conducted on higher-speed roadways.

Driver Sample

The driver sample consisted of all available SHRP2 primary and secondary study participants aged 16 to 65. A decision was made to exclude older drivers because of resource limitations. A total of 2,910 drivers were included in the sample (see Table 3).

The number of drivers varied across sites because the SHRP2 sites differed in the number of drivers enrolled in the study, which ranged from around 150 at the rural sites (PA & IN), 350 at NC, and around 450 at the large urban sites (NY, FL, WA). Note that the actual number of participants included in the driver counts is higher because some study participants had additional household members that also drove the enrolled vehicle and agreed to become secondary participants.

Table 3. Driver counts by site and demographic variables.

	FL	IN	NC	NY	PA	WA	Row Total
Count of Drivers	552	175	383	548	165	535	2910
Count of Female Drivers	295	96	205	316	92	281	1580
Count of Male Drivers	257	79	177	232	73	254	1329
Count of 16-24 Drivers	320	93	159	271	78	267	1508
Count of 25-44 Drivers	133	41	122	146	47	147	769
Count of 45-64 Drivers	99	41	102	131	40	121	633

Figure 2 provides descriptive statistics based on driver ages across sites for female and male participants. The thicker black line within each box indicates the median age, and the dot indicates the average age. Younger and senior drivers were overrepresented in the overall SHRP2 sample, and Figure 2 reflects the skew towards young drivers based on the sampling approach in the current study. At most sites, the median driver age category was 20-25, and the average age was around 30. Note that the participant age distributions differed across data collection sites, which accounts for the variation across sites in Figure 2.

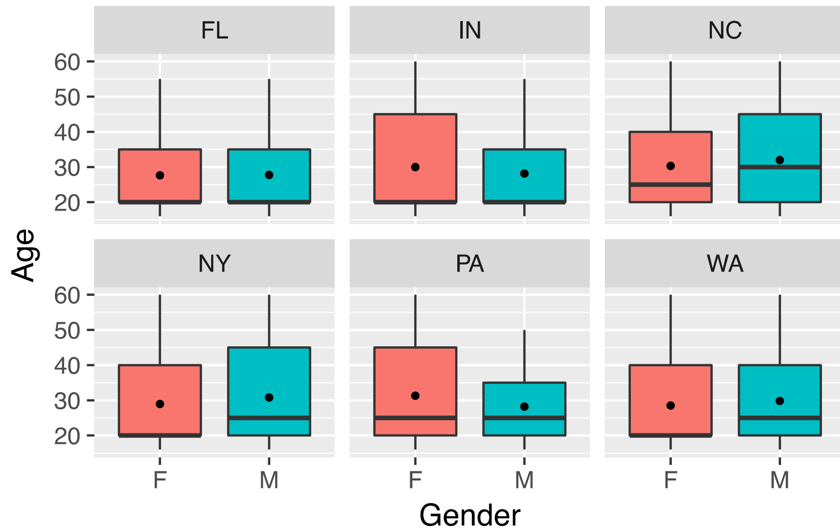

Figure 2. Boxplot showing driver ages across sites for female and male participants included in the sample.

Figure 3 shows driver education levels across the sites for the sampled participants. There were clear differences across age, with younger age groups having a higher prevalence of "some high school" and "some college" because their education was ongoing. Across sites, there were also differences in the level of educational attainment. Drivers from North Carolina had generally higher educational attainment than the other sites, but the differences were relatively minor. Overall, the sample drivers tended to be more educated than the national population of drivers (Antin et al., 2015)

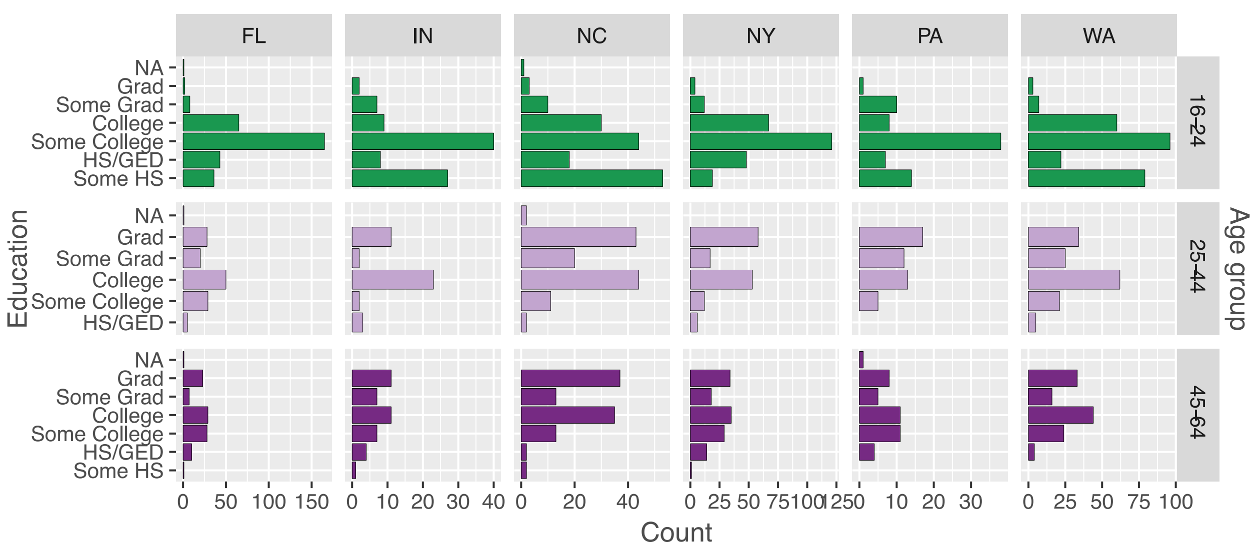

Figure 3. Driver education levels by site and age group.

Figure 4 shows the distribution of vehicle types by gender across sites. A clear majority of participants drove cars. The distribution of vehicles is relatively consistent across sites. In all sites, males were substantially more likely to drive pickup trucks than females. In contrast, females were more slightly likely to drive cars and SUV/Crossovers.

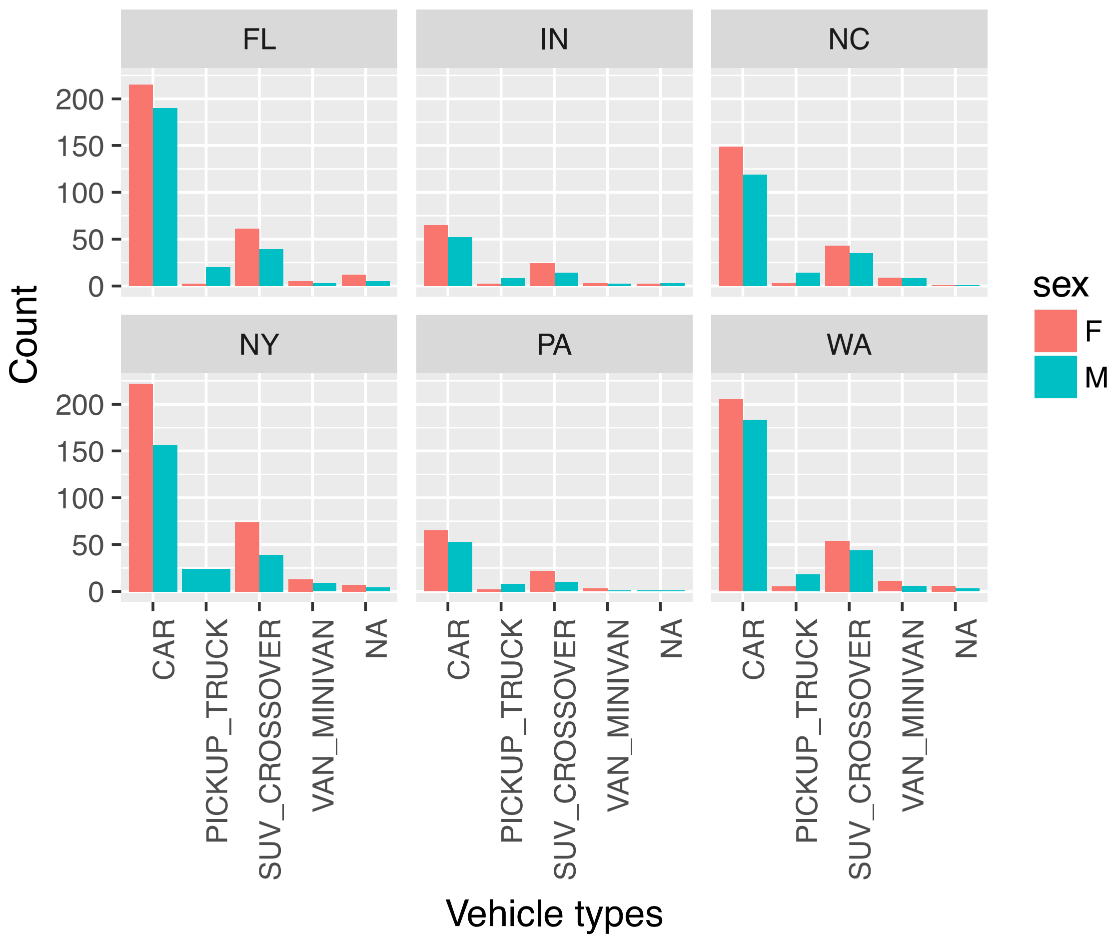

Figure 4. Distribution of vehicle types across sites by driver gender.

Overall, the sample was particularly large in comparison to typical studies examining the speeding behavior of individual drivers. The age distribution of drivers was skewed towards younger drivers, which was expected since the SHRP2 study oversampled drivers in the 16-24 age groups. There were also demographic differences across sites, but these were relatively minor and expected given the general urban/rural site differences. However, these differences were likely offset to some degree by the fact that the smaller sites were located in University towns with highly-educated populations. There were other demographic and attitudinal differences between drivers across sites. Chapters 7-9 cover these aspects in more detail.

Trip Sample

Trip sampling was constrained by a key data limitation in the SHRP2 dataset. Specifically, reliable PSL data were only available for roadways traveled by the SHRP2 mobile data collection van. This information was vital to the analyses because it was required to determine when drivers were speeding. However, the mobile van only traversed a subset of the roadways traveled by SHRP2 participants—specifically, the roadways that participants traveled most frequently. Consequently, it was not feasible to obtain a completely randomized trip sample. Moreover, the available roads were primarily Interstate Freeways, state highways, and major arterials roads, which ultimately limited the generalizability of the findings across the road network. The SHRP2 RID website: http://www.ctre.iastate.edu/shrp2-rid/rid.cfm provides more detailed information about the specific roadways included in the Mobile Van dataset.

The overall goal of this research was to gain a better understanding speeding behavior, and the sampling strategy was correspondingly geared towards obtaining trips that provided drivers with ample opportunity to speed. Since PSL data were limited to higher-speed roadways, supporting criteria were included in the sample query to improve the chances of observing speeding on individual trips.

In order to maximize driving on roadways with known PSLs, the query to generate the sample included a requirement that trips contained at least 50% of the miles traveled on roadways covered by the mobile van data. Trips taken on lower speed and lower capacity roadways such as residential streets were largely excluded from the trip sample. Since these roadways of interest are often commuter roads, additional criteria were added to exclude trips made under congested traffic conditions. Specifically, trips had to have a maximum speed greater than 25 mph, and the vehicle had to be in motion for at least 50% of the trip duration. Finally, a minimum trip duration of 15 minutes was imposed to ensure that drivers had sufficient opportunities to speed. The criteria described above were specifically selected to increase the prevalence of speeding events, but this came at a cost of limiting generalizability to specific road types, and it precluded using the sample to estimate the general prevalence of speeding.

After filtering trips based on the previously described criteria, the final sample was populated by randomly selecting qualifying trips stratified by the different levels of Distance, Time of Day, Day of Week, and Day in Study. The remaining criteria, which are described above, included:

- Trip Duration >= 15 minutes
- % CTRE Van Coverage >= 50%
- Max Speed During Trip >=25 (in conjunction with roads of interest)
- Time Moving >= 50% * Trip Duration

Table 4 provides basic descriptive information about the trips sampled from each study location. A total of 203,831 trips were obtained. The mean number of trips per driver ranged between 75 and 89, with all but Pennsylvania averaging over 80 trips per driver. The other rural site, Indiana, had the second-lowest average number of trips, which suggested that the lower values likely arise from less overlap between mobile van coverage and where drivers actually drove during the study in more rural areas. Mean trip durations ranged from 20 to 25 minutes across sites, which reflects the minimum 15-minute trip-sampling criterion.

Table 4. Descriptive statistics for trips obtained from each site after cleaning.

	FL	IN	NC	NY	PA	WA
Total Trips Obtained	48,874	14,023	33,666	49,200	12,501	45,567
Mean Trips per Driver	88.54	80.13	87.90	89.78	75.76	85.17
Mean Trip Duration (sec)	1406.15	1480.97	1204.70	1140.78	1470.70	1296.14
Mean Availability of PSL Data (%)	70.0	61.8	75.7	68.1	80.6	66.4

Figure 5 shows the number of trips obtained for each participant at each site. The colored regions are comprised of a single bar for each study driver with the height representing the number of trips obtained from that driver (the bars are ordered by number of trips). A maximum of 100 trips was requested from each participant. Many participants had fewer than 100 trips available because they did not take the types of trips that met the trip sampling criteria. This is especially the case for drivers that lived far from roads covered by the SHRP2 mobile van.

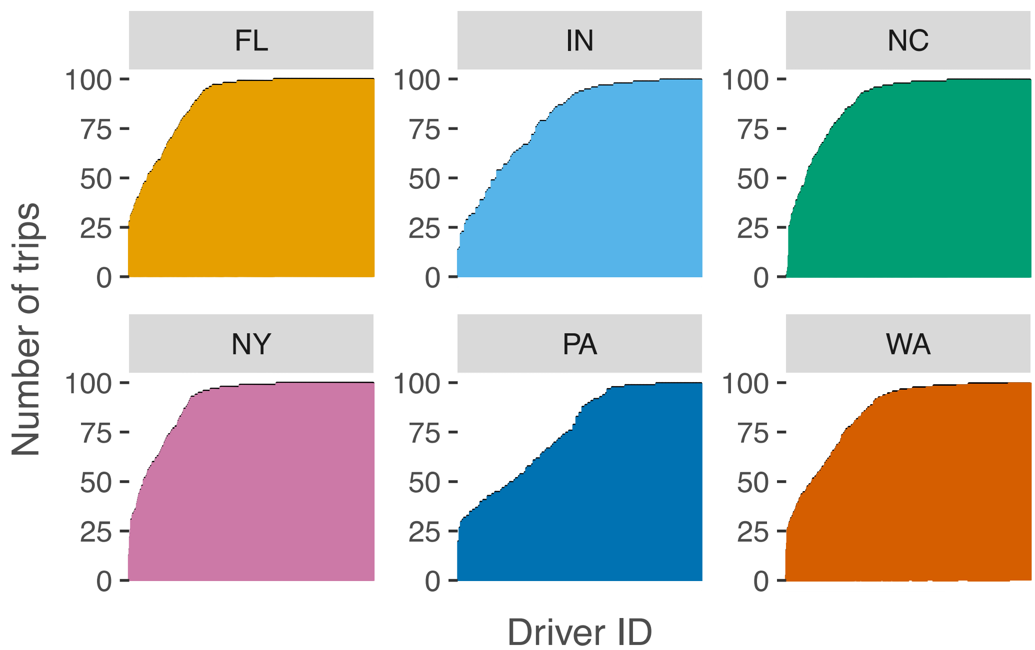

Figure 5. Participants at each site ordered by number of trips.

Figure 6 summarizes trip counts by driver age group and gender for each site. Although the median values were generally the same across age groups at most sites, the older age groups tended to have a wider range in terms of number of trips (i.e., more drivers with fewer trips). This was especially the case in the more urban sites, and pattern trended in the opposite direction for the rural sites, especially in PA. The spread of counts across gender appeared to be similar at most sites, although there were several exceptions.

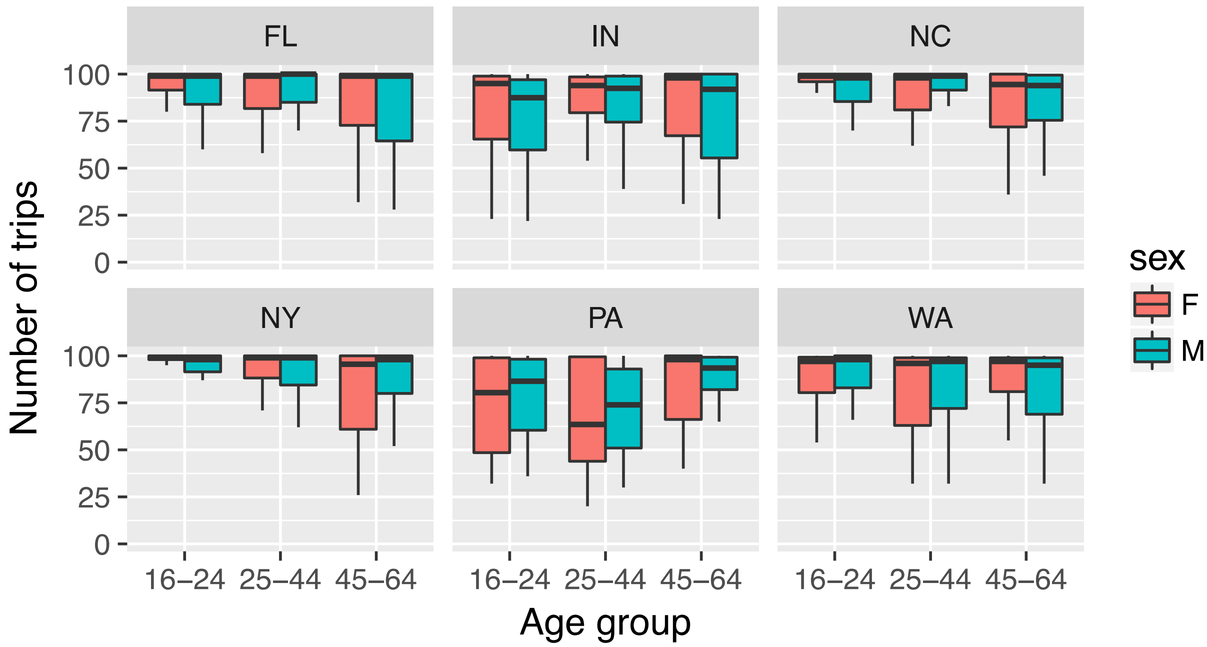

Figure 6. Boxplot showing number of trips obtained by age group and gender.

Figure 7 provides a comparison between trips in the sample and the population of trips in the broader SHRP2 dataset. The SHRP2 population curve is based on a subset of 150,696 randomly sampled trips that were matched by participant and duration (out of 5.4 million available SHRP2 trips). As the figure indicates, there is a reasonably good match between the analysis sample and the SHRP2 trips across Time of Day and Day of Week. However, a consistent pattern is that the analysis sample underrepresents trips taken during periods of higher traffic congestion (i.e., the morning and afternoon rush-hour periods) and over-represents periods with less congestion (i.e., evenings and weekends). Certain trip sampling criteria, such as the speed and time moving requirements, likely account for these differences.

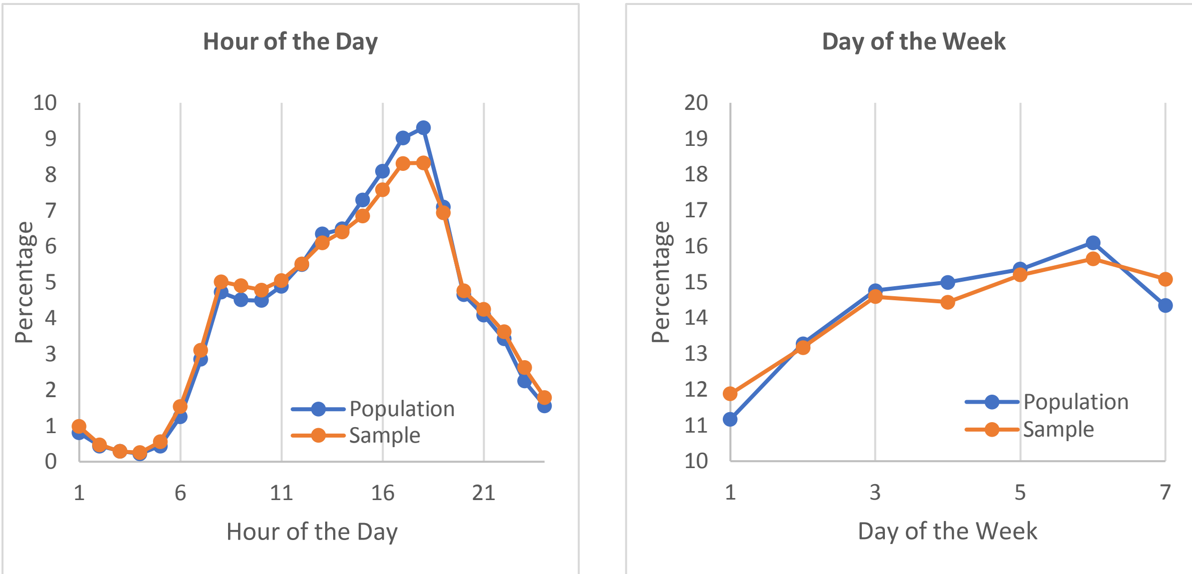

Figure 7. Comparison of the trips distributions across Hour of the Day and Day of Week (1=Sunday) in the study sample and the SHRP2 Population.

In summary, drivers in the sample were younger and better educated than the national driving population. In urban areas, younger drivers had a more complete trip sample than older age groups, while the opposite held in the two rural sites. Overall, the trips represented a slice of normal driving. Specifically, the trip sample was biased towards longer, higher-speed trips that occurred on higher-capacity roadways like those traversed by the SHRP2 mobile van. The sample trips likely also overrepresented driving under lighter traffic conditions, which reflected the need to obtain driving under free-flowing conditions in which drivers had a better opportunity to speed. These sampling considerations have important implications regarding generalizing the findings; however, the sample certainly contains both drivers and driving conditions that are of interest when it comes to examining speeding behavior.

As a subset of the SHRP2 study, the sample is not representative of the US driving population, which constrains the generalizability of the findings. However, as exploratory research, this study will provide important information about driver speeding behaviors on high-speed, high-capacity roadways.

Chapter 4 - Data Processing

Data acquisition, processing, and validation were critical elements of the research approach, since only certain segments of individual trips met the data quality requirements. Further, usable driving data had to be combined with roadway data to determine posted speed and certain roadway characteristics. This section provides an overview of key data processing steps and analysis concepts, such as how the opportunity to speed and individual speeding episodes were defined. A companion report provides a detailed description of the specific methodological approach used in this research (Brown & Richard, 2018).

Individual trips were divided into different segments based on vehicle speed relative the PSL. This resulted in four types of trip segment, which included (see also Figure 1):

1) *Unusable Driving*: These segments were missing PSL information and were excluded from the any data processing and analysis. They are not discussed further in this report.
2) *No Opportunity to Speed*: PSL was available, but vehicle speed during these segments was so slow that it was unlikely to represent driving conditions in which speeding was possible (i.e., the vehicle was stopped, decelerating to or accelerating from stopped, or the vehicle speed was constrained by other traffic or road users).
3) *Free-Flow Episodes (FFEs)*: PSL was available, and the vehicle was traveling fast enough that the speed could plausibly represent the driver's chosen speed for those roadway conditions. Since information about lead vehicles was unavailable, it was possible that drivers were still boxed in by other traffic. Nevertheless, FFE represent the best available estimates of opportunity to speed.
4) *Speeding Episodes (SEs)*: PSL was available, and the vehicle was traveling fast enough relative to the PSL to be classified as speeding (see definition in following section). Note that because of data limitations, SEs did not account for driving that was "too fast for conditions" but below the 10-mph threshold (e.g., poor roadway conditions).

Figure 8 illustrates the different segments of a trip for driving where PSL was available using a hypothetical vehicle speed profile (i.e., unusable segments are not shown).

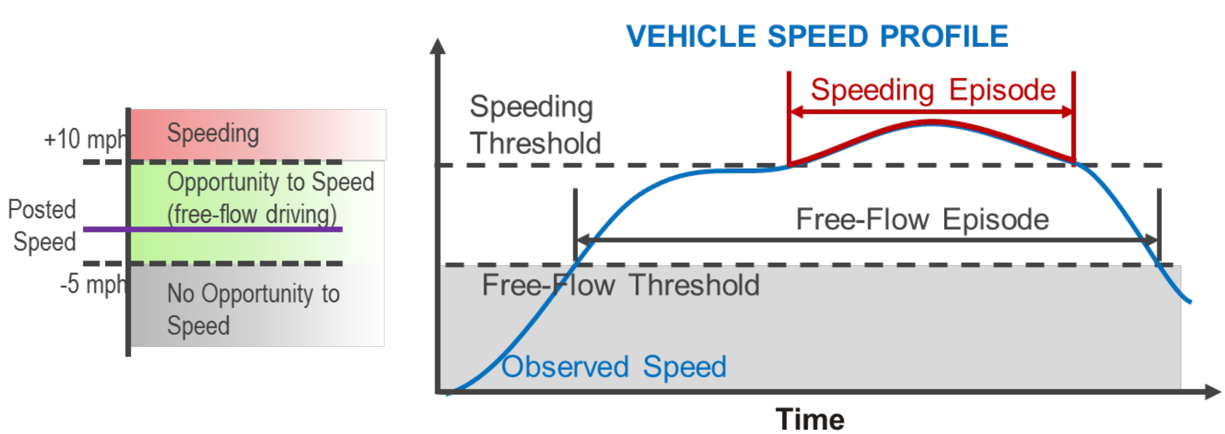

Figure 8. Characterization of Free Flow Episodes and Speeding Episodes.

Definition of Speeding

The current research used a very specific definition of speeding. Speeding was operationalized as discrete events or episodes in which the vehicle speed exceeded the PSL limit by at least 10 mph for longer than 6 seconds. These SEs consisted of a continuous period of driving above the speeding threshold. The SE ended when the speed dropped below the speeding threshold for at least 6 seconds, and the end of the SE was the point at which vehicle speed initially dropped below the threshold.

A challenge in this study is that there is no accepted threshold for defining speeding, and the safety risk of traveling at a specific vehicle speed is highly dependent on the driving conditions. The speeding threshold of 10 mph above the PSL in the current research is consistent with earlier investigations of naturalistic speeding studies (Richard et al., 2013). While driving 10 mph above the PSL is unlikely to represent an acute safety risk under most fair-weather driving conditions, it does correspond with a speed range that many drivers believe they are at risk of getting a speeding ticket. Moreover, for many drivers, the risk of a speeding ticket is more tangible than the possibility of a speeding-related crash (Richard et al., 2013), so it may be a more immediate influence on their behavior. Another consideration is that there is no practical way to assess the actual riskiness of the immediate roadway conditions across all of the driving included in the sample. Thus, the 10-mph threshold serves an important methodological distinction for making data processing and analysis tractable.

The definition of speeding used in this study could reflect a variety of underlying behaviors. Some could reflect intentional efforts to speed, such as a thrill-seeking driver might do on an open road, or a driver that is speeding to make up time on a trip for being late. This speeding could also reflect a variety of unintentional speeding behaviors. For example, a driver may intend to keep near the PSL without exceeding it, but normal variations in speed may briefly cause the driver to exceed the PSL. Similarly, if a driver becomes less vigilant in actively monitoring the speedometer, it is possible that the vehicle could exceed the PSL when roadway conditions afford faster driving, or if the driver is following other speeding vehicles. Finally, the underlying behavior could reflect a mix of the two. One example would be a driver that does not wish to speed, but who is surrounded by vehicles that are all speeding. In this case, the driver may want to avoid slowing other traffic, especially knowing that they are less likely to be stopped for speeding because they are following a vehicle platoon. Without better information on traffic and roadway conditions, it is difficult to directly identify the underlying behavioral antecedents.

As discussed more in Chapter 6 below, the simple threshold of 10 mph above the PSL resulted in over 623,202 separate SEs. To facilitate analysis of the SEs, additional criteria were included with the objective reducing the overall number of SEs that were examined in detail. One of the criteria was that vehicle speed had to exceed 15 mph above the PSL at some point during the SE. This requirement likely changed the types of speeding represented in the analysis sample. Specifically, unintentional SEs--in which drivers were trying to remain below the PSL—were more likely to be excluded. In addition, the overall riskiness of the SEs in the sample was likely higher because of greater kinematic energy of the faster moving vehicles.

Processing of Time-series data

To support this definition of speeding, time series of GPS driving data were parsed into Free-flow Episodes (FFEs) and Speeding Episodes (SEs), which represented short yet continuous segments or “snippets” of driving time extracted from a trip. Free-flow Episodes were used as a proxy for a driver’s opportunity to speed within a trip. FFEs excluded parts of a trip where a vehicle was stopped, trapped in traffic congestion, slowing to a stop for a traffic control device, etc.—situations in which it would be unlikely that a driver had a chance to speed. Speeding Episodes were used as the primary data element in the analysis of speeding, and they represented an interval of driving in which a vehicle was speeding. In the current study, speeding conceptually represented a risk of getting a speeding ticket more than a clear risk of getting into a speed-related crash. The MfS findings report (Richard et al., 2013) provides a detailed discussion of the justification for the definitions and thresholds used for FFEs and SEs. The operational definitions of these data elements were as follows:

- A *Free-Flow Episode*, which represented the opportunity to speed, occurred when the driver was traveling at or above a threshold set at 5 mph below the posted speed limit. This speed criterion had to be maintained for at least 30 seconds to be included.
- A *Speeding Episode* was defined as continuous driving at or above a threshold set at 10 mph above the posted speed limit. This speed criterion had to be maintained for at least 6 seconds to be included. The additional criterion that speed had to exceed 15 mph above the PSL was applied after the data were processed and SEs were obtained.

Figure 9 below shows the data processing steps. Up to 100 trips were selected from individual drivers. For each trip, available PSL (blue line) was combined with the vehicle speed time-series (green line) to calculate the relative speed. From here, continuous segments of driving meeting the FFE criteria were extracted from each trip. Basic information and statistics for each FFE were calculated, which resulted in the FFE Data Fields. Within each FFE, continuous segments meeting the SE criteria were extracted, and the SE Data Fields were calculated.

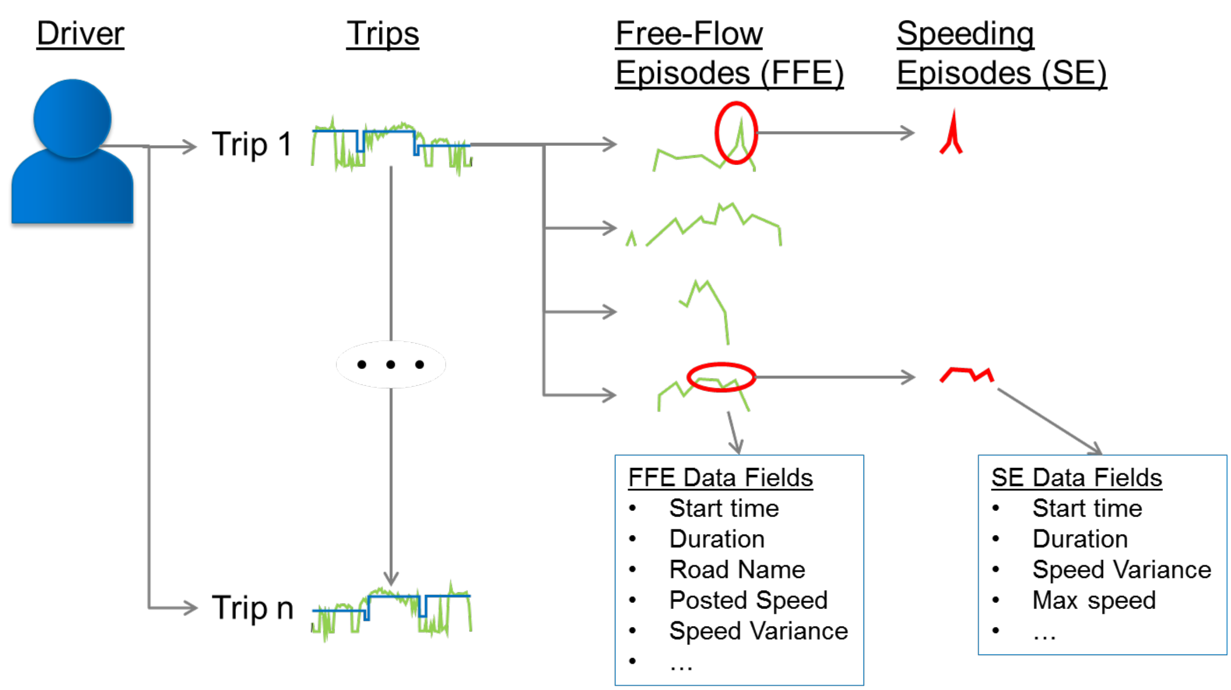

Figure 9. Overview of data process steps used to extract FFEs and SE from individual driver trips.

Note that only a subset of driving within each trip was available for analysis. In particular, PSL data was only available for roads traversed by the SHRP2 mobile data collection van. These typically included the most frequently traveled roadways at each site; however, the mobile data excluded most lower-speed roadways. Consequently, individual trips typically consisted of segments of usable data among segments of unusable data.

Small dips below the FFE or SE threshold were ignored when parsing the episodes to more accurately represent driving behavior by minimizing spurious FFEs and SEs from occurring. This essentially prevented what is practically the same FFE or SE from being parsed into different episodes.

Custom software tools were developed to reduce the time-series data into a set of aggregate variables that identified the characteristics of each trip, FFE, and SE using a common data structure. Examples of variables included in this reduction are descriptive statistics for speed and acceleration, episode duration and timing, speed profile variables, percent time in speed bands above posted speed, and percent time on road feature.

Chapter 5 - Free Flow Episodes

Although a clear definition of "speeding" is essential for examining speeding behavior, it is insufficient on its own. In particular, it lacks a way to reflect exposure and begs the question, "*amount of speeding relative to what?"* Without a way to estimate overall exposure, directly comparing the amount of speeding across drivers, roadway types, geographic locations, etc., becomes problematic. To address this issue, a data construct—*Free-flow Episode*—was extracted from the time-series data. The duration of FFEs could serve as the denominator to measures related to the amount/duration of speeding numerator. Free-flow Episodes were carefully defined and constructed, with the objective of making sure that the measure reflected a proxy for the driver's *opportunity* to speed. For example, time spent warming up a vehicle was not included, nor was time spent idling at a stoplight. A less obvious consideration is that drivers' decisions about speed selection include many instances in which the vehicle's speeds are constrained by traffic control devices or traffic congestion—instances in which drivers clearly have no opportunity to speed. If not accounted for, travel time that represents stopped time or slower driving could end up being overrepresented in terms of chronological time relative to episodes in which drivers are able to select their desired speed, since drivers take longer to travel the same distance in the former case. Consequently, comparing the time that drivers spent speeding to the total amount of time they drove at the trip level likely underestimates their speeding exposure by a substantial amount. This is because their trip data is "diluted" by a large amount of inconsequential time when they were stopped or had no chance to speed.

Free Flow Episodes only represent a best estimate of opportunity to speed based on the available vehicle-speed time-series data. The intention is for FFEs to represent a reasonable measure of a driver's exposure to driving conditions in which they could have a choice to speed. Ideally, this would reflect driving under open road conditions without traffic control devices. However, since only vehicle-speed data were used to calculate FFEs, they do not reliably distinguish between open-road driving and driving in other free flowing traffic at high speeds. Drivers may be traveling at free-flow speeds but still constrained by lead traffic, in which case they would not actually have an opportunity to speed. While the SHRP2 dataset contains radar data and forward video data that could potentially provide information about ambient traffic conditions, it was not feasible to code, validate, and integrate this information with the time-series data used in the current analyses. Preliminary analyses determined that there were multiple data streams that could provide better estimates of the presence of open-road conditions; however, developing a data processing approach to accomplish this was outside the scope of the current project.

To generate the free-flow driving time variable, all driving that was 5 mph or more *below* the posted speed was removed (e.g., on a roadway with a posted speed of 45 mph, only driving time in which the vehicle was traveling at 40 mph or greater was retained). Relative to the complete data set, driving time was also filtered to remove driving that occurred on unvalidated (i.e., uncertain posted speed) roads, and due to other data-integrity issues, such as missing GPS data points. Multiple FFEs could occur during a single trip. Typically, they ended when drivers changed course in a way that required substantial deceleration, such making a turn. To simplify data analysis, FFEs were limited to a single PSL. If the PSL changed midway through an FFE, it was divided into separate FFEs associated with each PSL segment.

Table 5 provides descriptive statistics for FFEs by site. The mean number of FFEs per driver varied substantially across sites, and there was no clear pattern regarding site characteristics and the number or duration of FFEs.

Table 5. Descriptive statistics for Free-flow Episodes by site.

	FL	IN	NC	NY	PA	WA
Total Number of FFEs	180890	50954	103555	195350	45823	117212
Mean Number FFEs per driver	327.69	291.16	270.37	356.47	277.71	219.08
Mean Number FFEs per trip	3.77	3.87	3.13	4.01	3.76	2.69
Mean FFE duration	219.25	283.65	266.60	182.30	316.29	311.66

Figure 10 shows the distribution of FFEs based on duration across all sites. The mean FFE duration was 243 seconds. The distribution was substantially skewed, and the median duration was 97 seconds, with a mode of 32 seconds. Overall, FFE durations tended to be relatively short, with over 57% of them lasting less than two minutes long.

Differences in FFEs across sites could reflect systematically different driving conditions and opportunities to speed. Some locations may be less amenable to free-flow driving overall. For example, for the Washington site, which primarily covers the Seattle Metro area, there are fewer FFEs per driver, but they tend to have longer durations. It is possible that opportunities to speed in Washington are infrequent because of congested traffic conditions and limited to longer segments of higher-capacity roadways. Thus, when these drivers have the rare chance to travel at free-flow speeds, they may be able to do so for longer periods. New York shows the opposite pattern. Drivers have more FFEs per trip, but these tend to be relatively short. It is unclear what is the actual source of these differences. It could be that long, continuous stretches of high-capacity road segments are less common in the road network covered in the study, and that longer FFEs are "broken up" into shorter segments because roadway elements prompt speed reductions shorter intervals. However, this is speculation at this point, but it could be examined using the RID data.

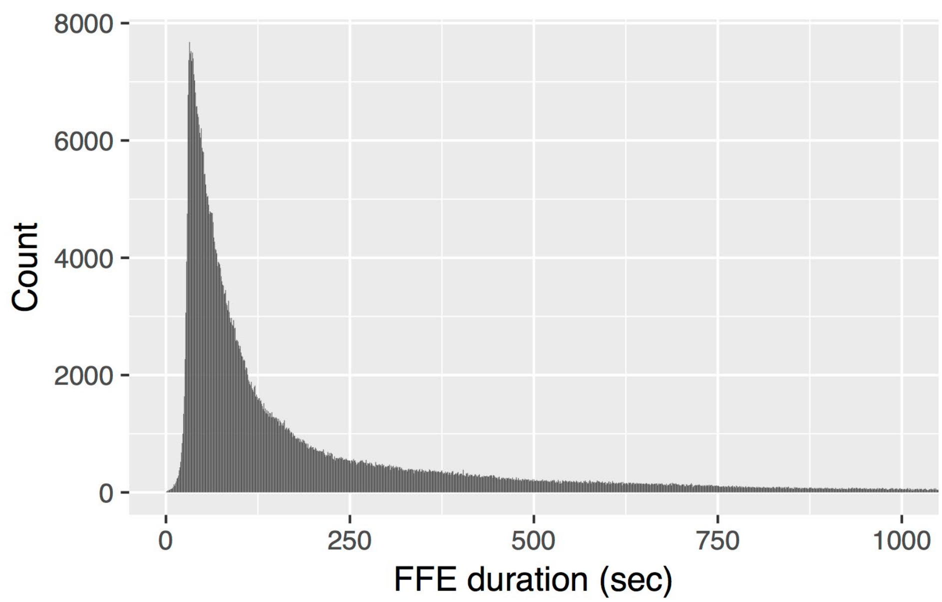

Figure 10. Counts of FFEs by durations across all sites.

One pattern that will be examined in more detail in later chapters is that drivers spend far more time driving at free-flow speeds than they do speeding (Speeding accounts for approximately 2.5% of all FFE time). Thus, a fundamental question about speeding behavior is why does driving in some free-flow situations develop into speeding but not in other free-flow situations? And, how does this proclivity vary across individual drivers, or groups of drivers that share certain characteristics?

Figure 11 shows how average FFE duration varied across month for each site. Two patterns were noteworthy. The first was that across all sites, there was little variation in average durations across months. A few individual months stand out as being higher than most, but there are no clear seasonal differences in average FFE duration. The absence of a seasonal difference could be due to the selection criteria that favored higher-speed longer trips. In this case, FFEs during inclement months may over-represent roadways with superior winter driving conditions, such as freeways and highways.

Another noteworthy pattern was that average FFE durations varied substantially across sites. Two of the urban locations (FL & NY) had the shortest FFE durations, while the two rural sites (IN and PA) were among those with the longest durations. Surprisingly, the Washington site had the second longest average FFE durations. For the urban areas, these patterns could reflect characteristics of the local roadway networks traversed by the SHRP2 mobile van, as described above. In rural areas, participants may have driven more often on long stretches of roadway with minimal traffic.

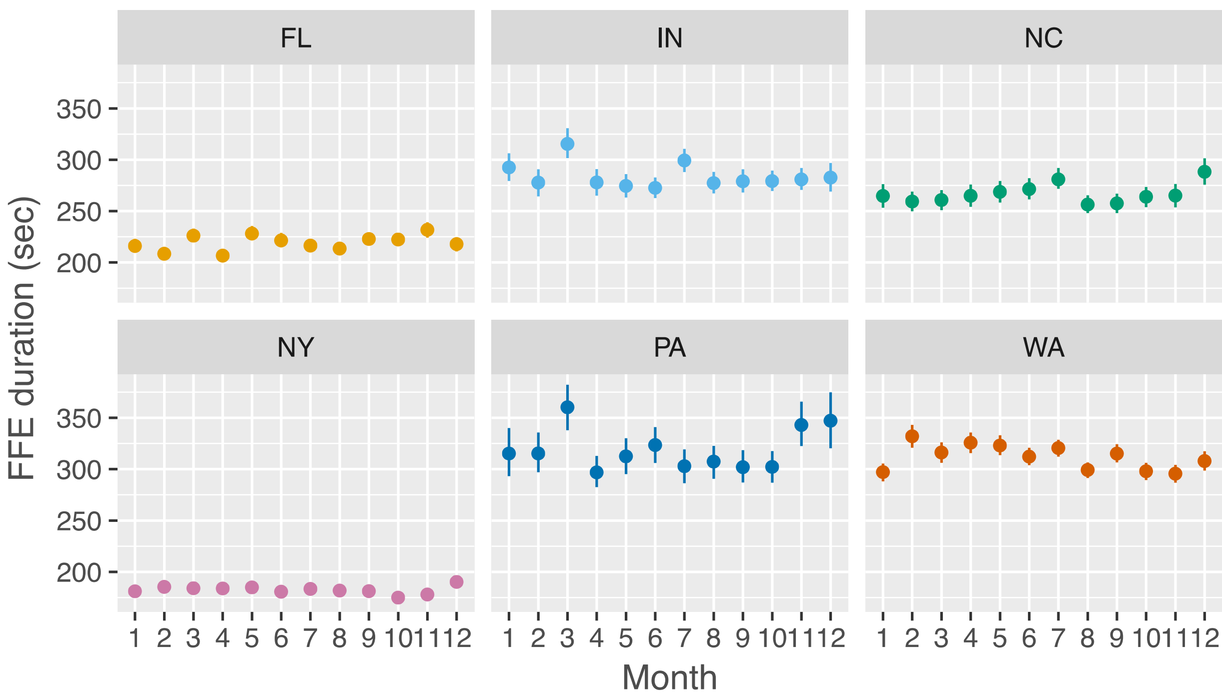

Figure 11. Average FFE Duration across month and site (January = 1).

Figure 12 shows average FFE durations across day of week and site. There is a consist pattern evident at all sites. Specifically, FFE durations are longer on weekends than on weekdays. This is consistent with the notion that lighter traffic levels on weekends facilitate longer FFE durations. Another possibility is that participants regularly make different types of trips on weekends that afford longer FFEs.

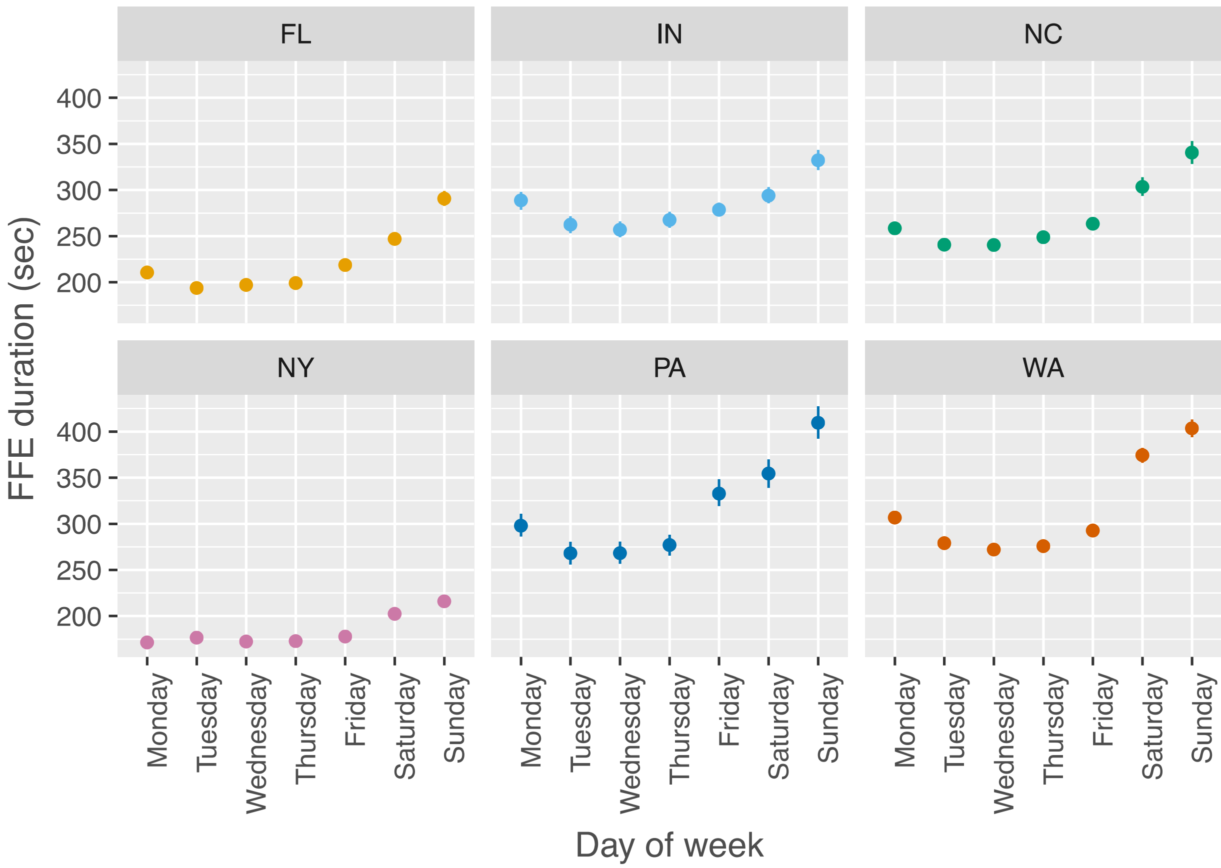

Figure 12. Average FFE duration across day of week and site.

Figure 13 shows the average FFE duration by average number of FFEs in each hour of the day (0=12am). The hours are color-coded to reflect the general traffic conditions during a period of the day. Blue hours represent evening and nighttime driving (7pm-5am), green hours represent daytime driving (9am-2pm), and red hours represent two blocks of commute times (6am-8am & 3pm-6pm).

At most of the sites, changes in traffic conditions throughout the day affect both the number and average duration of FFEs. During commute hours, FFEs are consistently shorter and more frequent than at night. This pattern could reflect more frequent interaction with slower moving traffic during rush hours. In this case, potentially longer FFEs would be broken up into a greater number of smaller FFEs when drivers encounter slower moving traffic that causes them to slow below the FFE threshold speed. Another possibility is that drivers make systematically different trips during the day, and that the differences in FFEs reflect the effect of the roadway network on opportunity to speed.

There are also differences in the distribution of points across sites. The most prominent difference is apparent in New York, where the data points are concentrated in a small region, and the differences across time periods is smaller than at other sites. This suggests that traffic conditions may play a secondary role to road network characteristics in influencing the count and duration of FFEs at this site. Similarly, Pennsylvania also shows a less pronounced effect of time period on FFEs, although there is variability across time of day. This may be due to lighter traffic conditions.

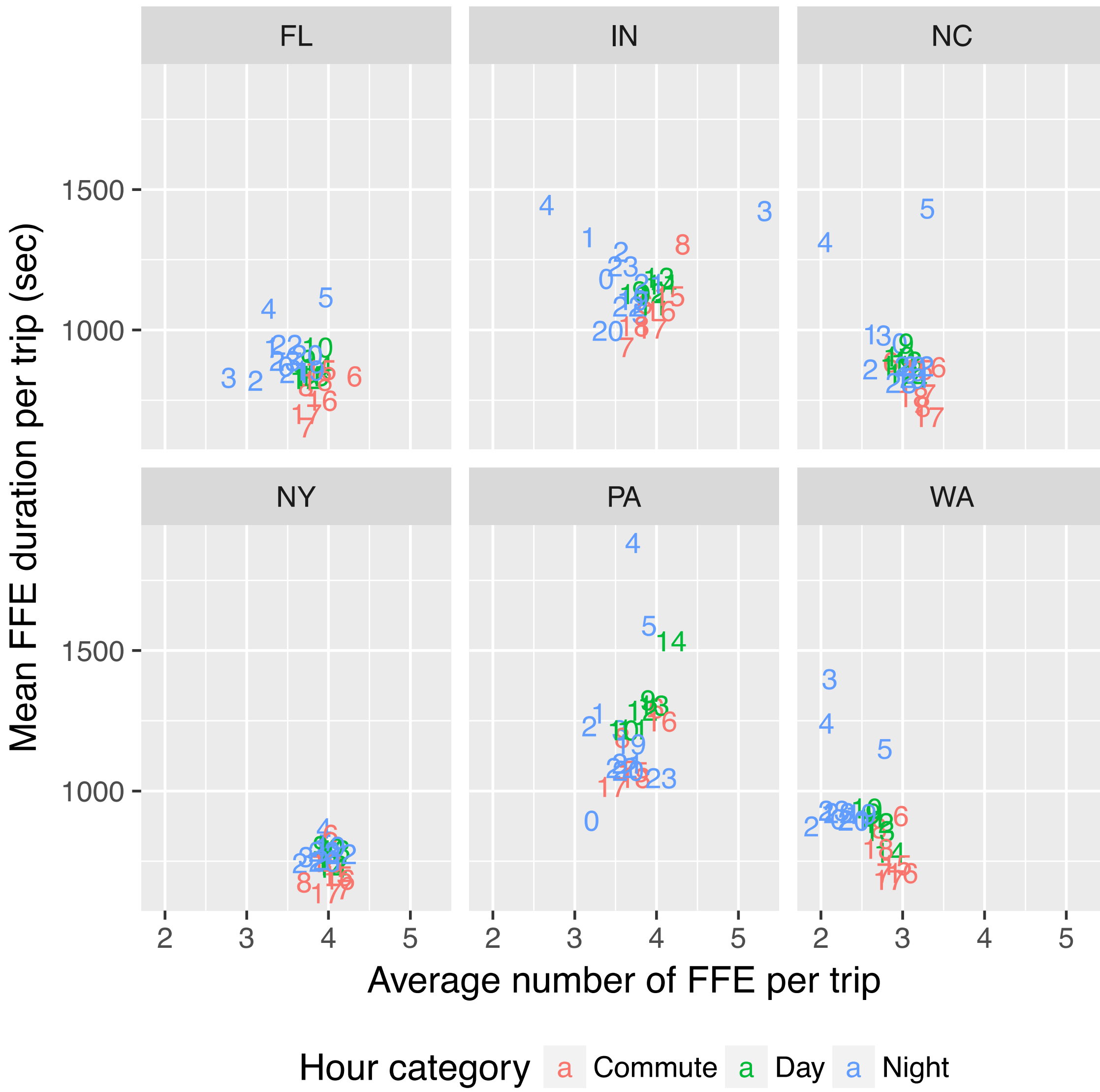

Figure 13. Average FFE duration by average number of FFE in each hour of the day (0=12am).

Figure 14 shows the average FFE duration across PSL categories by site. The pattern is consistent across all sites and indicates that FFE durations are longer on higher speed roads. At the low end, this likely reflects driving on roadways with more traffic control devices and greater traffic volumes that limit FFE duration. On the higher end, it likely represents longer stretches of limited-access roadways with fewer TCDs, multiple lanes for maneuvering around slower traffic, and generally more open traffic conditions.

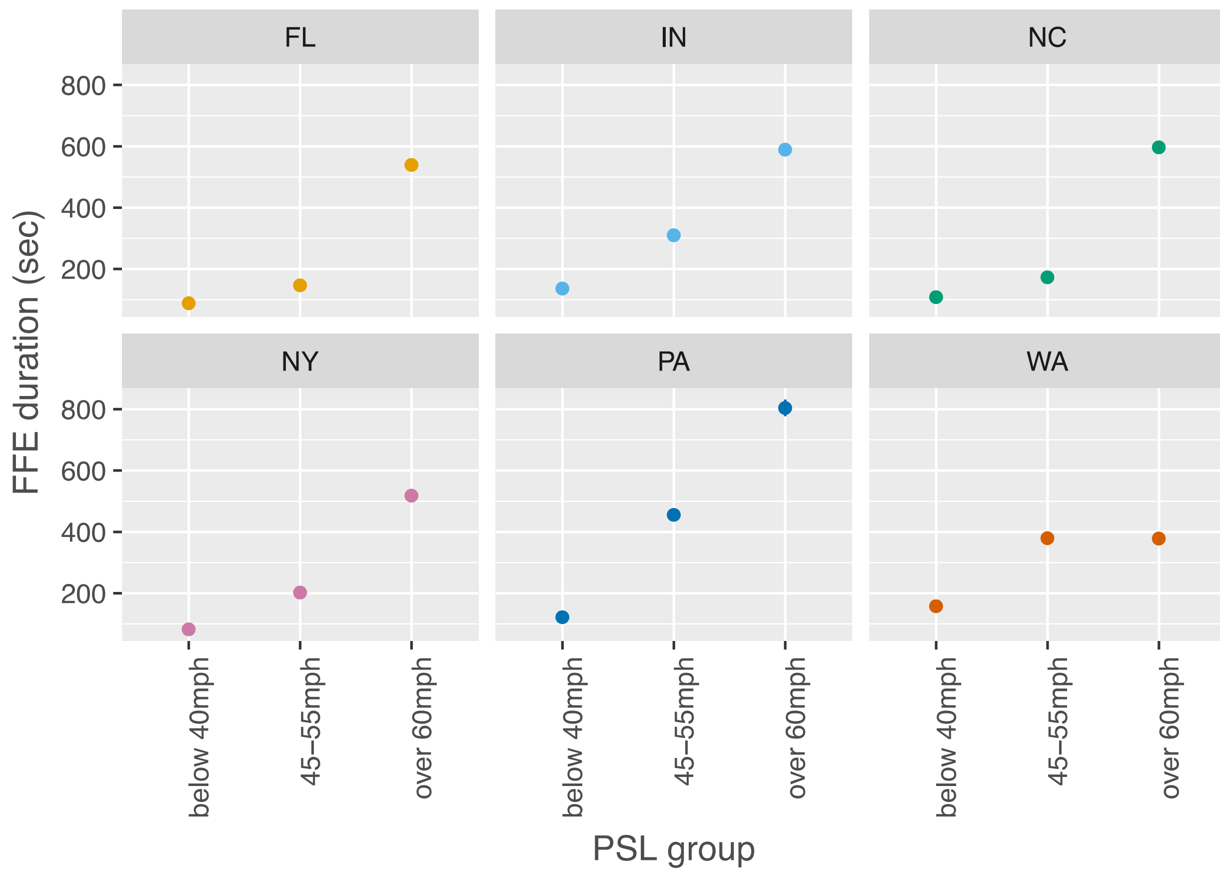

Figure 14. Average FFE duration across Posted Speed Limit categories by site.

In summary, FFE frequency and duration varied substantially across sites. There appears to be a clear influence of traffic conditions on these measures. The roadway network may also influence FFE characteristics; however, the specific effects are more difficult to interpret.

Chapter 6 - Speeding Episodes

Speeding was the primary dependent measure in the study. During some FFEs when drivers had the right opportunity, some chose to exceed the PSL by enough to be considered speeding. Speeding was operationalized as distinct, continuous episodes in which the vehicle exceeded the PSL by at least 10 mph, among other criteria. Speeding Episodes had to occur within FFEs, and thus had to be extracted from FFE data. The corresponding report chapter summarizes the basic characteristics of SEs and examines differences across the participants and study sites.

Driving 10 mph above the PSL was relatively common, and 99.8% of drivers had at least one occurrence of this within their trip sample, yielding an average of 2.75 SEs per trip. There was a total of 623,202 SEs in the full dataset. To reduce the number of SEs for analysis and to make the dataset more manageable, SEs were further filtered based on multiple criteria:

1) SEs on trips that had less reliable roadway data and trip measures (short trips & low PSL) were removed
2) SEs associated with PSL transitions during trips were removed. This included PSL changes that occurred within the SE, 10 seconds before the SE, or 10 seconds after the SE
3) SEs with a low maximum speed above the PSL—the maximum difference between travel speed and the PSL— were removed. Vehicle speed during an SE had to reach at least 15 mph above the PSL to be retained.

The filtered dataset contained 71,113 SEs. The SEs that remained systematically biased the analysis sample towards SEs that occurred on high-speed roadways, in addition to being at the more severe end of the speed exceedance spectrum. The removal of SEs associated with PSL transitions and those that were just above the speeding threshold meant that SEs in the sample were also less likely to reflect incidental or unintentional speeding. Figure 15 shows the distribution SEs that were filter out relative to those that were retain in terms of maximum speed above the PSL. After filtering, the "clean data" that remained had a distribution that clearly shifted towards higher maximum speeds above the PSL than the initial set of SEs.

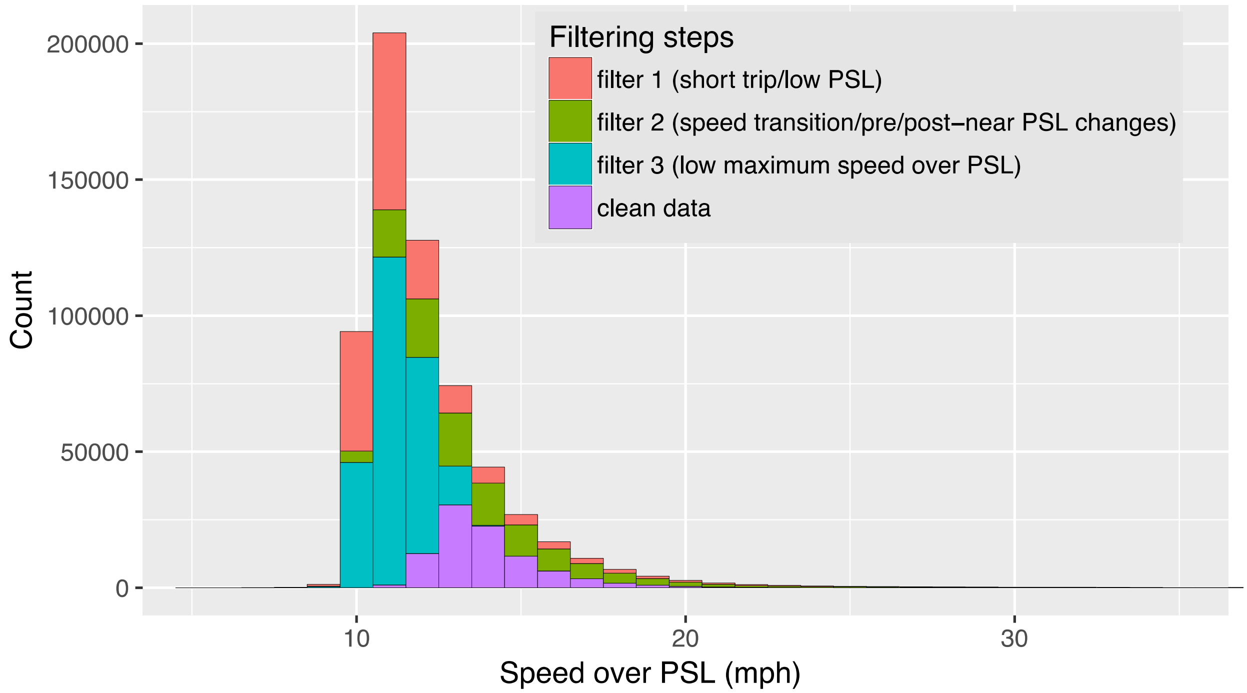

Figure 15. SEs lost through filtering different types of for the analysis dataset.

Table 6 provides the basic descriptive statistics for SEs at each site. There were more SEs per trip at the rural sites and these tended to have longer mean durations. The statics related to vehicle speed were otherwise very similar across sites.

Table 6. Descriptive statistics for SEs at each site.

	FL	IN	NC	NY	PA	WA
Total Number of SEs of all types	176,314	54,687	105,901	136,630	70,663	79,007
Total Number of SEs After Filtering	24500	5513	10026	12933	8271	9870
Number of Participants	552	175	383	548	165	535
Mean Number of SEs per driver	44.38	31.50	26.18	23.60	50.13	18.45
Mean Number of SEs per trip	0.50	0.40	0.28	0.25	0.68	0.21
Mean SE Duration	65.01	69.36	64.55	64.52	75.81	56.57
Mean SE Speed	70.84	67.60	71.36	67.21	66.54	70.25
Mean SE Speed over PSL	14.04	13.91	13.65	13.81	14.07	13.78
Mean of Maximum Speed over PSL	17.84	17.67	17.26	17.43	18.03	17.59
Mean SE Speed Std. Dev.	2.15	2.10	2.00	2.03	2.18	2.12
Mean SE Max Deceleration	-0.08	-0.08	-0.07	-0.07	-0.08	-0.08
Mean SE Max Acceleration	0.07	0.07	0.07	0.07	0.07	0.08

Figure 16 shows the duration and the average of the maximum speed above the PSL speed of each SE in the dataset. Although the x-axis on the graph only goes to 1000 seconds, there were only nine SEs that were longer than 1,000 seconds. The density contours on the figure indicate that the majority of data points were concentrated near the bottom left of the plot. The points are color coded by the maximum speed above the PSL reached during the SE. Average maximum speeds for most SEs ranged between 12 mph to 20 mph above the PSL. Most also lasted less than 2 minutes and SEs with the highest speeds tended to be shorter.

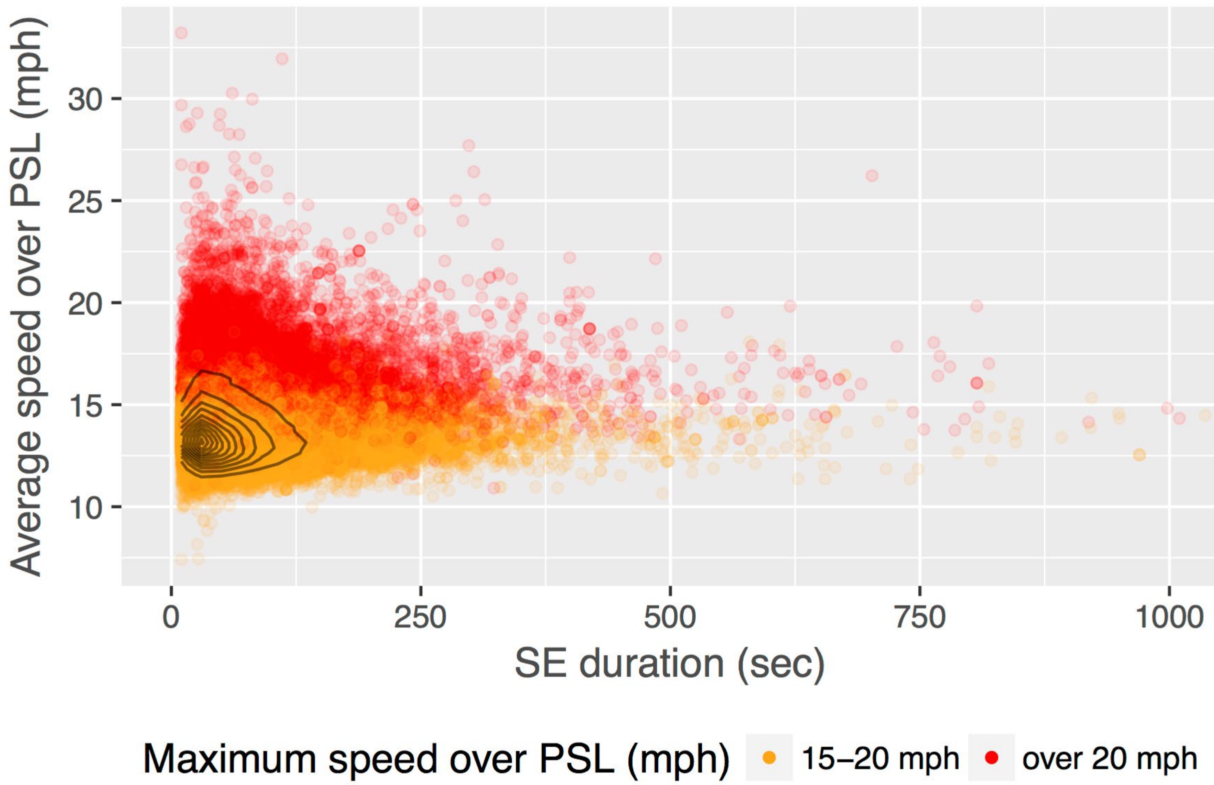

Figure 16. Duration and average speed above the PSL speed of each SE in the dataset.

Figure 17 shows how the distribution of SEs speeds and duration varied across sites. In general, the pattern was relatively consistent across sites. Although the differences are subtle, FL appears to have more SEs with higher maximum speeds above the PSL.

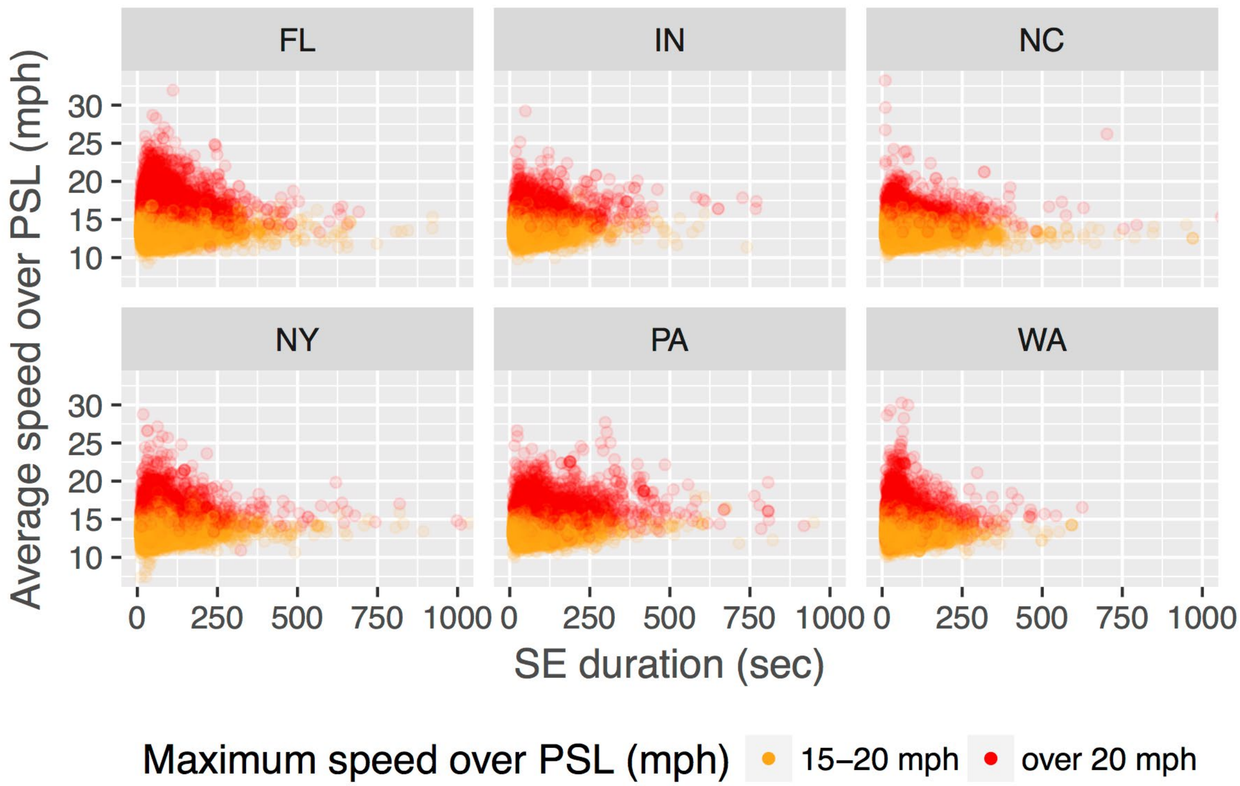

Figure 17. Duration and average maximum speed above the PSL of each SE in the dataset across site.

Figure 18 shows that the average of maximum speeds above the PSL were highest at the lowest PSLs examined, dropping slightly on higher-speed roads. However, the difference across the full PSL range was only one mph. This is a somewhat counterintuitive pattern, given that higher speed exceedances on lower PSL roads means that drivers are speeding by a proportionately higher amount, and that overall safety risk may be correspondingly greater. This higher speed exceedance on lower PSL roads has been observed in other naturalistic speeding data (Richard et al., 2013). It could reflect some combination of factors, including:

- Longer SE durations observed on higher PSL roadways may diminish the influence of brief peaks in speed on mean speed. In this case, the trend towards lower speeds over PSL is primarily a mathematical artifact of SE duration
- Higher absolute speeds may feel more dangerous to drivers, even on roadways designed for high speeds
- On lower speed roads, PSL may be set disproportionately lower than design speeds accommodate, giving drivers the impression that it is safe to go faster

Figure 18 also shows mean duration for SEs across PSL. Mean SE duration increased steadily with higher PSLs. This likely reflects the fact that higher PSL roadways tend to be highways and freeways that may have limited access points and TCDs, and multiple lanes that provide greater opportunities to maintain higher speeds.

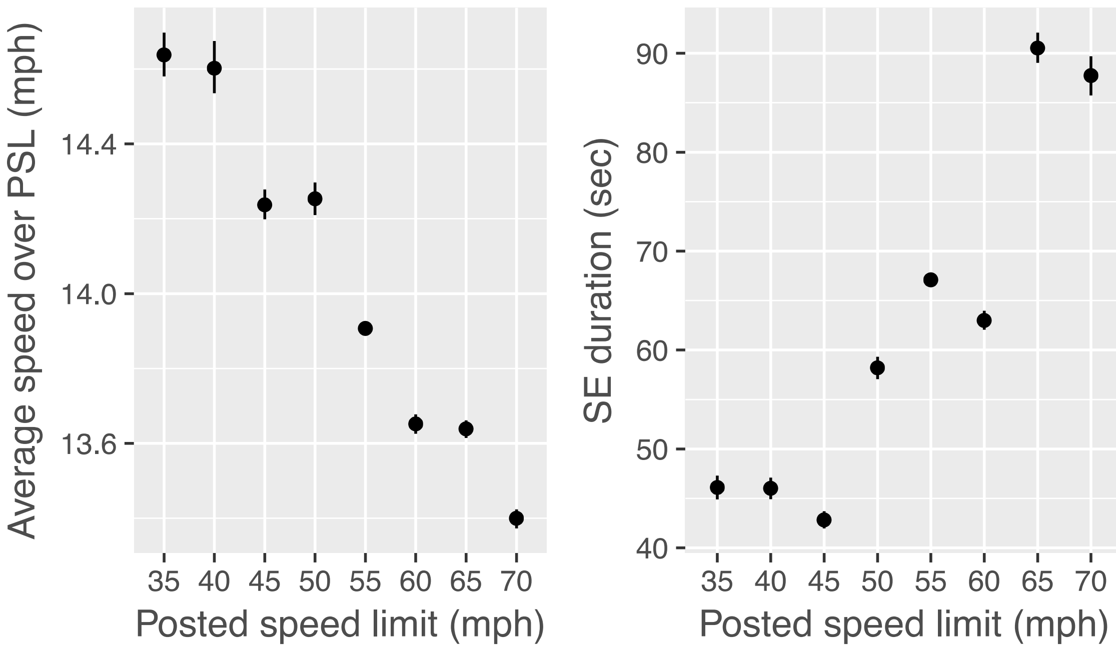

Figure 18. Average speed above the PSL (left), and mean SE duration (right) for speeding on roadways with different PSL ranges.

Figure 19 shows the distribution of SE speeds and duration across PSL. The basic form of the distributions was similar across PSL, but there were some trends across PSL. Specifically, as PSL increased, there was a general trend towards a greater proportion of the SEs having longer durations. The higher PSL categories, particularly 70 mph roadways had relatively fewer SEs that exceeded 20 mph above the PSL.

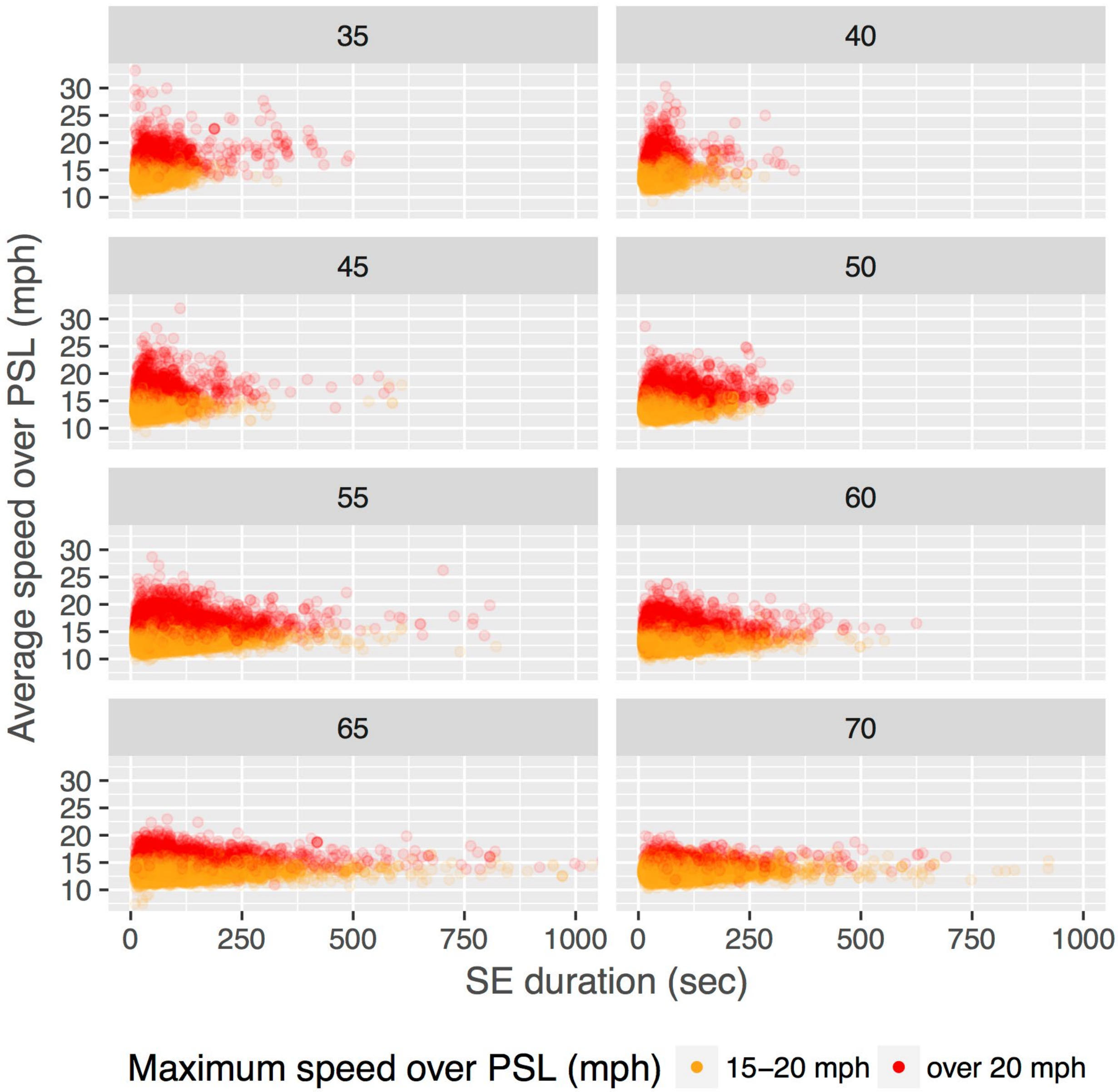

Figure 19. Distribution of SE average speed over PSL speed and duration across PSL value.

The next set of charts provides information about SEs across drivers. The histogram in Figure 20 shows how frequently SEs occurred for individual drivers, accounting for the number of trips taken (i.e., only considering trips with FFEs). Specifically, the figure shows counts of the ratio of SEs to trips across drivers. The histogram is positively skewed, with around 10% of all drivers averaging zero SEs per trip taken, and 37% of all drivers averaging less than 1 SE per 10 trips. Only a small percentage of drivers (9%) averaged more than one SE per trip. At the trip level, the type of speeding examined in this study was relatively uncommon. However, there were some outliers in the distribution. Two percent of drivers averaged more than 2 SEs per trip, and a smaller number (0.5%) had more than 3 SEs per trip (not shown in the figure).

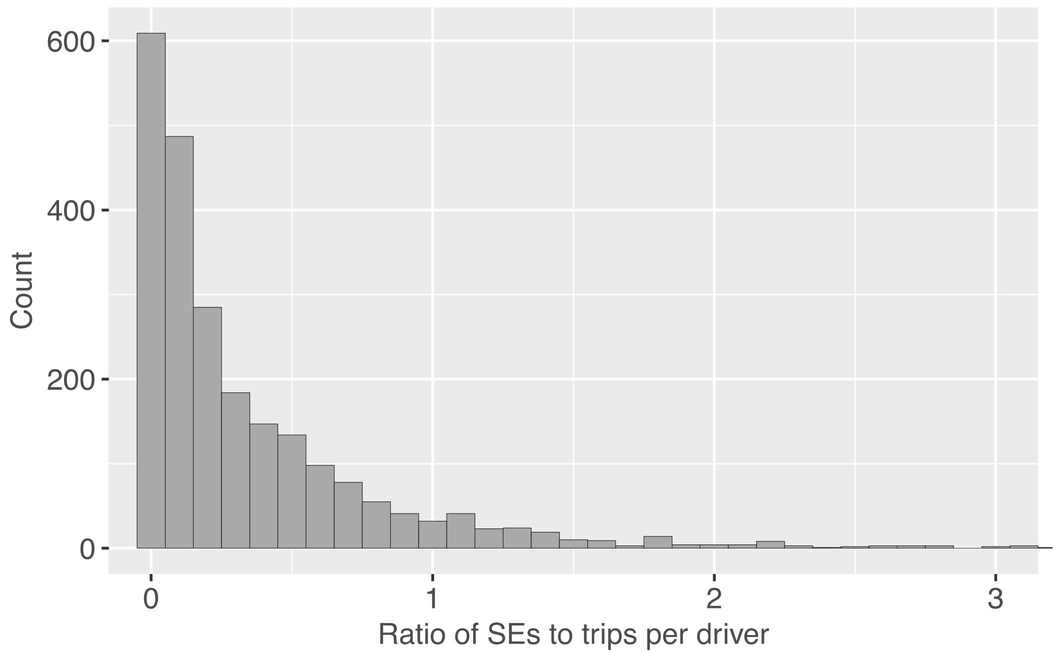

Figure 20. Counts of how often drivers were typically speeding within trips based on the ratio of the number of SEs per trip enumerated across drivers.

Figure 21 shows the same ratios as Figure 20, but broken out into different age groups. Overall, the 16-24 group showed the highest mean ratio (0.45) compared to other groups (25-44 group: 0.31, and 45-64 group: 0.20). For the older groups, the ratio of SEs to trips drops off quickly. Less than 10% of older drivers averaged more than one SE every two trips. For the middle age group, only a slightly greater percentage of drivers exceeded this amount. However, for the youngest group, almost 37% of drivers averaged more than 1 SE every two trips.

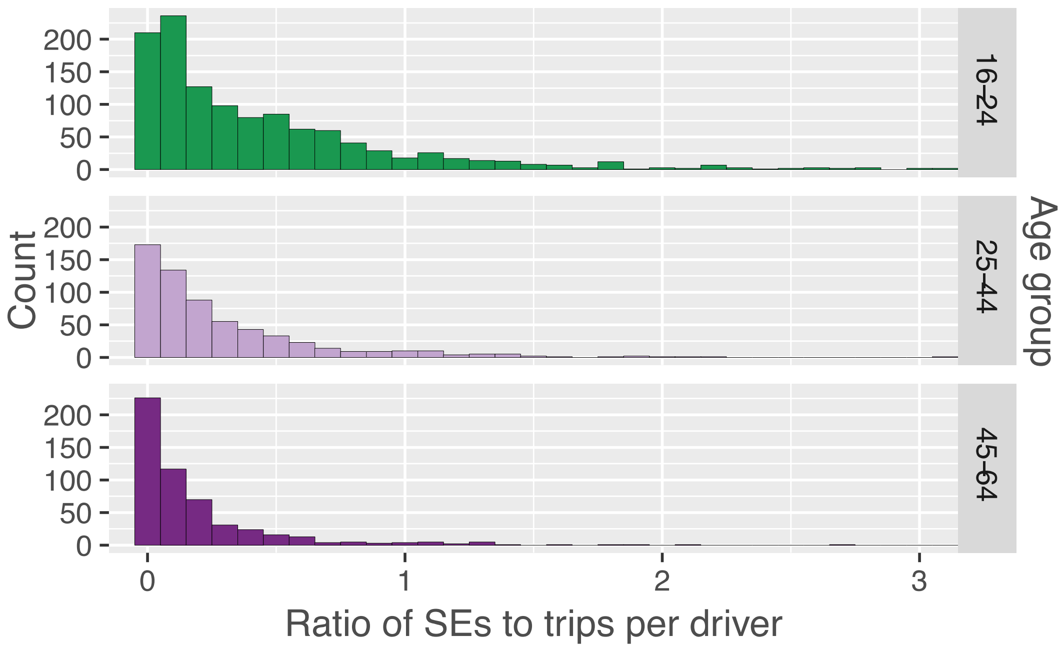

Figure 21. Counts of how often drivers were typically speeding within trips by age group.

After data processing and additional filtering, the study sample yielded over 71 thousand SEs. However, given the large driver and trip sample, this number actually translated into to a relatively small proportion SEs per trip, with almost all drivers averaging less than one SE every two trips. As the earlier scatterplots showing average speed over the PSL by duration indicated, the SEs included in the analyses dataset were on the higher end of speeding severity. Across all sites and all but the highest PSL roadways, a substantial portion of SEs involved tops speeds that exceeded the PSL by over 20 mph. In addition, many SEs lasted for several minutes.

Some of the SEs in the analysis dataset likely reflected unsafe driving behaviors, which drivers may have been aware of at the time. Even if the driving situations were not immediately hazardous, the risk of being stopped for speeding should have been apparent in many of the SEs. Thus, the analysis dataset shows promise for examining factors that may influence drivers to make risky speed choices.

Chapter 7 - High-level Predictors of the Speeding

This chapter addresses the research objective of examining the relationship between high-level situational and driver-specific factors and speeding. Specifically, this chapter investigates driver speeding behavior relative to the driver's opportunity to speed, and how this behavior is influenced by a variety of situational factors such as time of day. Dividing the time drivers spent speeding on an FFE by the FFE duration provides a measure of the *amount of speeding*. This measure can be used to examine questions about how likely were drivers to engage in speeding when they had the opportunity to do so, and what factors were associated with speeding on a particular FFE?

Figure 22 below provides a high-level view of the total amount of FFE time (combined across all FFEs) recorded for each participant by site. Individual participants are shown along the x-axis, and total FFE is shown along the y-axis, which is truncated at 4,000 minutes to better show values across the sample. Total SE duration for each driver SEs is shown as red bars. Note that total FFE time includes total SE time. The distribution is highly skewed and only a few drivers at some sites recorded more than 4,000 minutes of FFEs. The median FFE time across all participants was 1,066 minutes. Drivers in Indiana and Pennsylvania had the highest total FFE time overall, and drivers in New York and Washington had the least. There are several factors that may contribute to this, including participant enrollment patterns, traffic conditions, and which roadways were included in the sample.

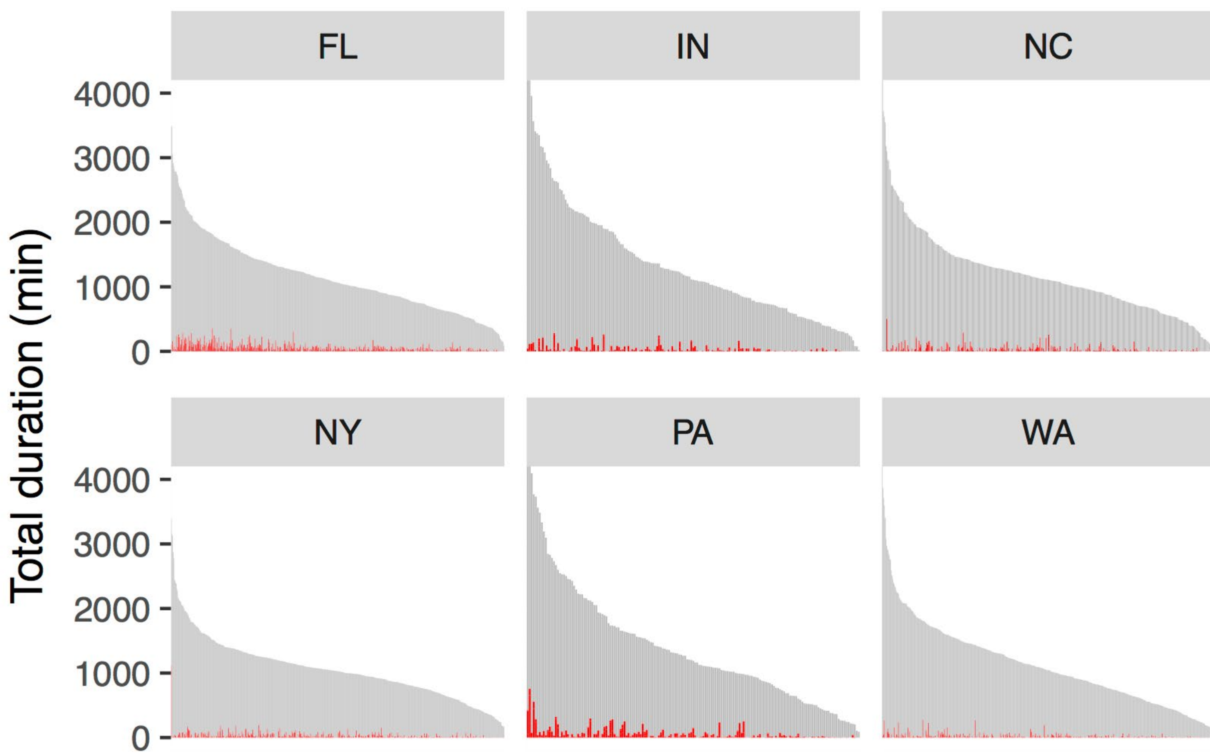

Figure 22. Total amount of SE time (red bars) and total amount of FFE time (gray bars) combined across all trips for each participant at each site. Individual participants are shown along the x-axis.

A clear finding regarding the amount of speeding is that it represents a fraction of the FFE time, and at some locations, such as Washington and New York, the speeding time is barely visible. In addition, there appears to be substantial variation in amount of speeding across drivers.

Figure 23 below provides a different view of the same measures. Total speeding time as a *percentage* of total FFE time is shown along the y-axis. Most drivers spent less than 5% of the FFE time speeding, and only a small number of drivers at each site spent more than 10% of the time speeding. There were clear site differences, with Pennsylvania and Florida having the most drivers spending at least 5% of the time speeding, and Washington and New York having the least. The percentages of drivers at each site who had more than 5% SE time varied substantially across sites: Florida= 28%, Pennsylvania = 26%, Indiana = 18%, North Carolina = 14%, New York= 13%, and Washington = 7%. The 5% cutoff was arbitrary, but it highlights the differences among drivers that sped the most at each site.

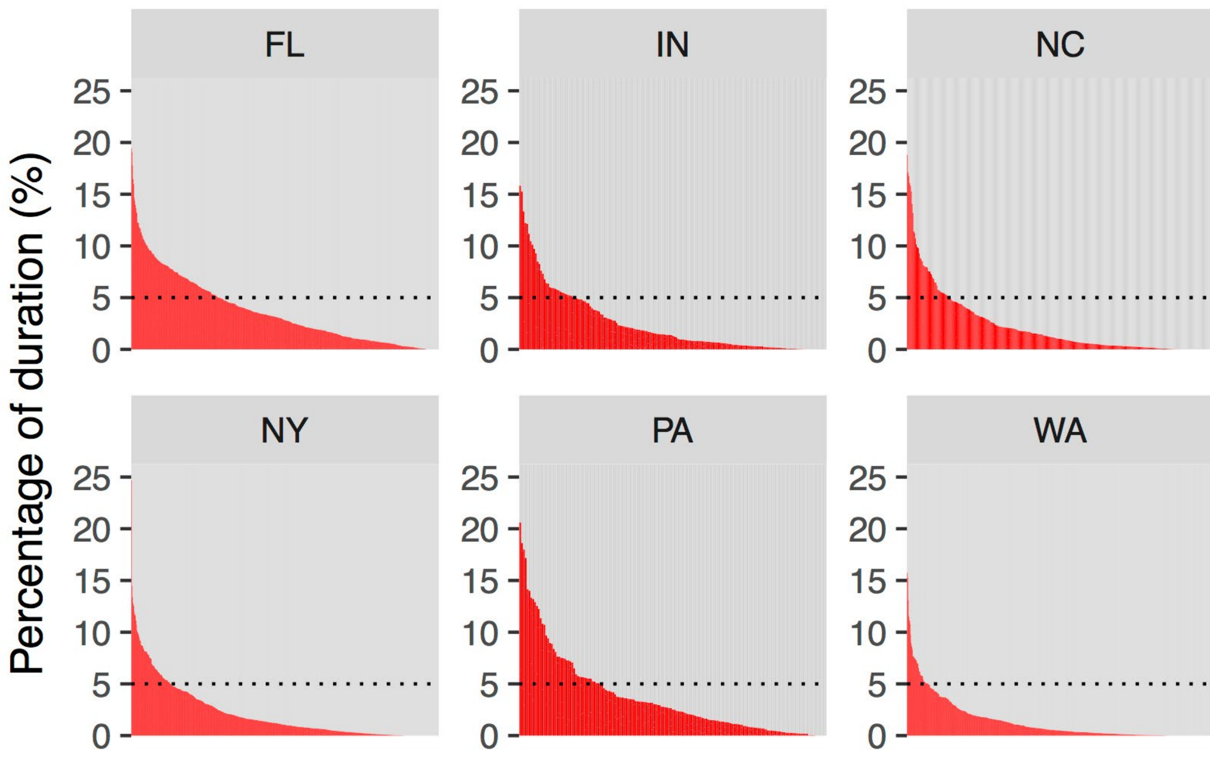

Figure 23. Total SE time (red bars) as a percentage of total FFE time for each participant (shown along the x-axis) at each site.

Figure 24 shows the amount of speeding per driver for different age groups. There is a clear trend towards younger groups have higher overall percentages of SE time relative to FFE time. In particular, the percentage of drivers who had more than 5% SE time in each age group was: 22% for the 16-24 group, 14% for the 25-44 group, and 7% for 45-64 group.

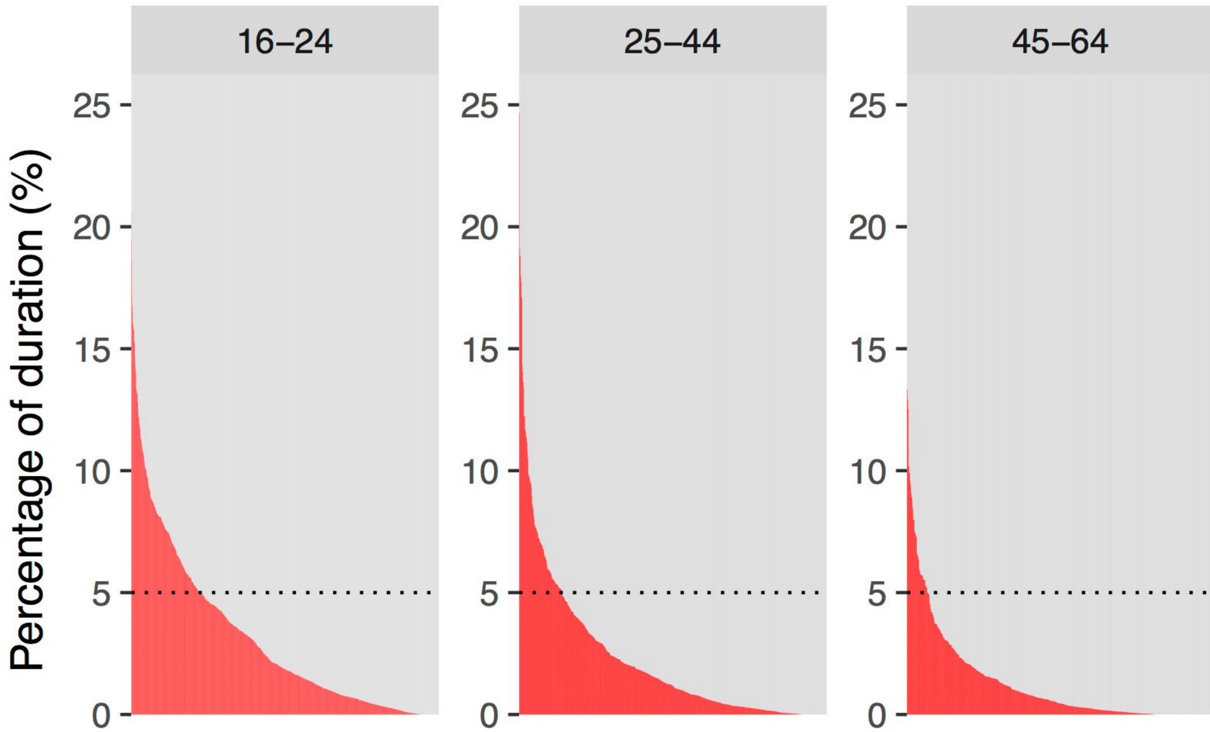

Figure 24. Total SE time (red bars) as a percentage of total FFE time for each participant (shown along the x-axis) by age group.

The amount of speeding also differed substantially across individual trips. These variations can reveal factors that influence how much speeding drivers engage in under different driving conditions. The following sections in this chapter examine the influence of seasonal, daily, and hourly factors in the amount of speeding.

Monthly Variations in Speeding

Figure 25 below shows the percentage of FFE time in which drivers were speeding across months of the year. Although some of the sites show similar patterns, there are marked differences in the proportion of speeding. A likely reason for some of this variation is that sites experience different weather conditions throughout the year. Regarding the amount of speeding, some sites show decreases during the winter months, but the winter trend does not appear to be associated with a substantial reduction in speeding overall. The trip selection criteria in the sampling plan could have diminished seasonal differences because selected winter trips would have been biased towards those that had the fastest driving. It is possible that these higher-speed trips could have involved well-maintained roads.

Figure 25. Percentage of FFE time in which drivers were speeding across months of the year for each site.

Aggregating data across sites showed an elevated level of speeding during the spring (see Figure 26). Surprisingly, August had the lowest proportion of speeding overall. This finding could be due to chance, or it could reflect drivers making different types of trips during this month (e.g., vacation travel with family on board). Speeding was also lower in December and January compared to the fall months, but any winter decrease was small relative to the seasonal change corresponding to the spring increase and summer decrease.

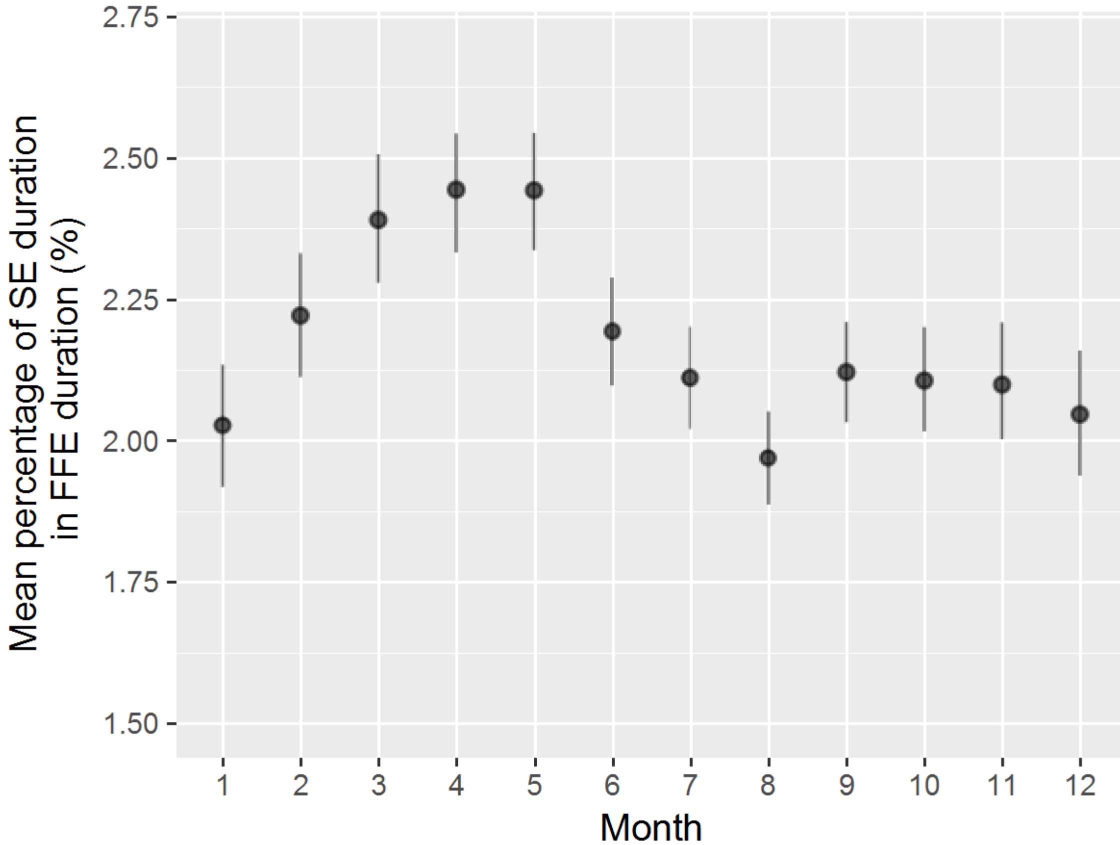

Figure 26. Percentage of FFE time in which drivers were speeding across months of the year averaged across sites.

Daily Variations in Speeding

Figure 27 shows how the amount of speeding varied across day of week. The different sites show some degree of consistency, with most having an elevated proportion of speeding on weekends. NY was an exception in that speeding was only greater on Saturdays, and only by a small amount.

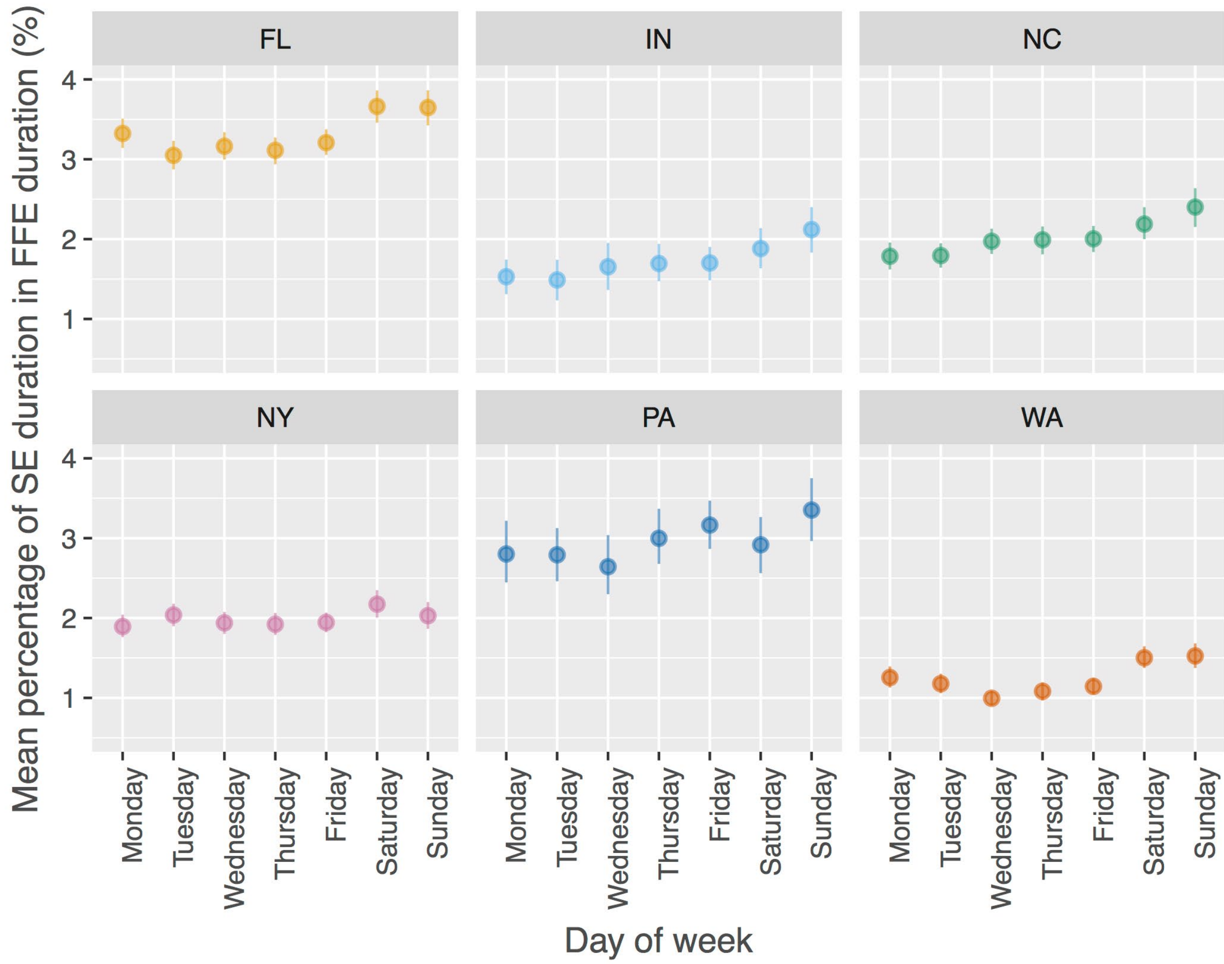

Figure 27. Percentage of FFE time in which drivers were speeding across day of the week averaged for each site.

Combining data across sites clarifies the trend towards a higher proportion of speeding on weekends (see Figure 28). Speeding was lowest between Monday and Thursday, gradually increasing on Friday and peaking on Sunday. This pattern was similar to average FFE duration across weekday. It could reflect lighter traffic conditions on weekends, and/or a potentially different mix of trip types.

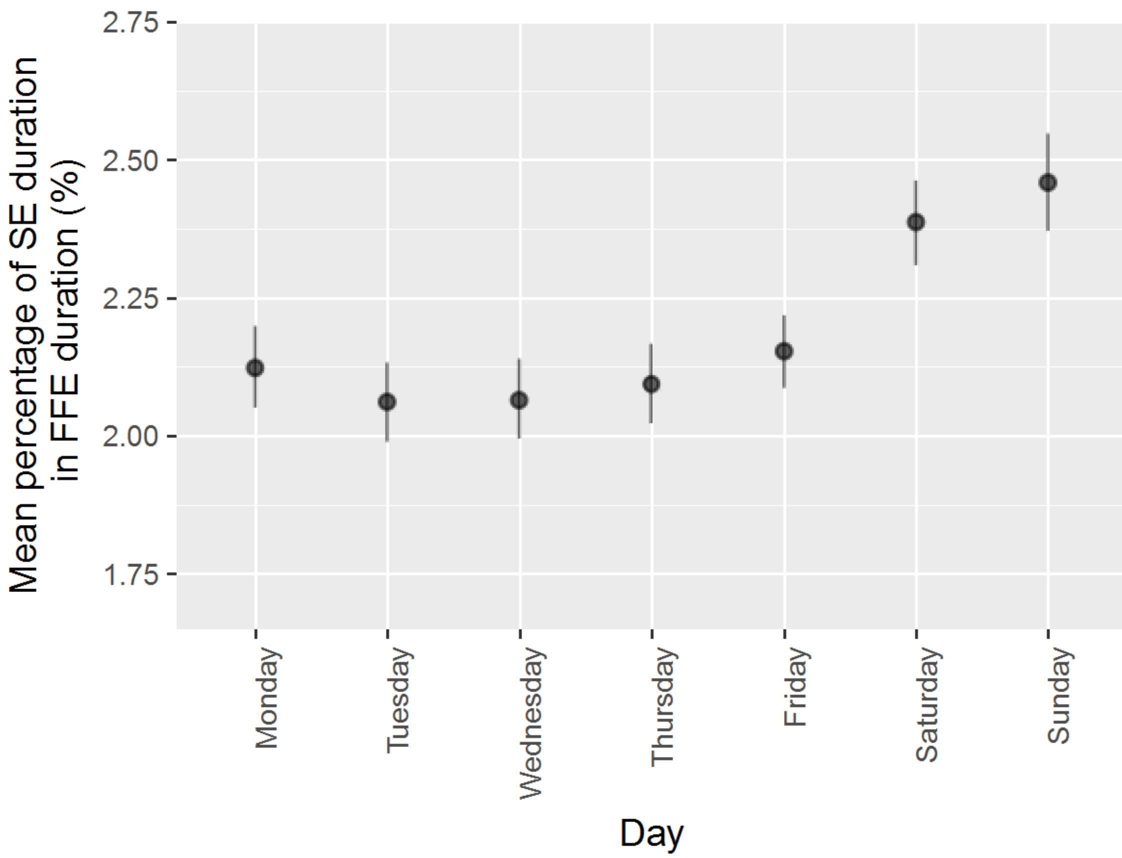

Figure 28. Percentage of FFE time in which drivers were speeding across day of the week averaged across sites.

Hourly Variations in Speeding

There were consistent patterns across sites in the amount of speeding throughout the day (see Figure 29). Speeding levels tended to be higher during the daytime hours at most locations except WA. This suggests that most drivers may have been less willing to speed as much outside of daytime lighting conditions, even though lighter traffic at night may have provided more opportunities to speed. There was greater variability in the data between 1am and 5am, which likely reflects the fact that fewer trips were taken during those hours. Some of the average values were high during this period, which suggests that some individuals may have sped frequently during at night.

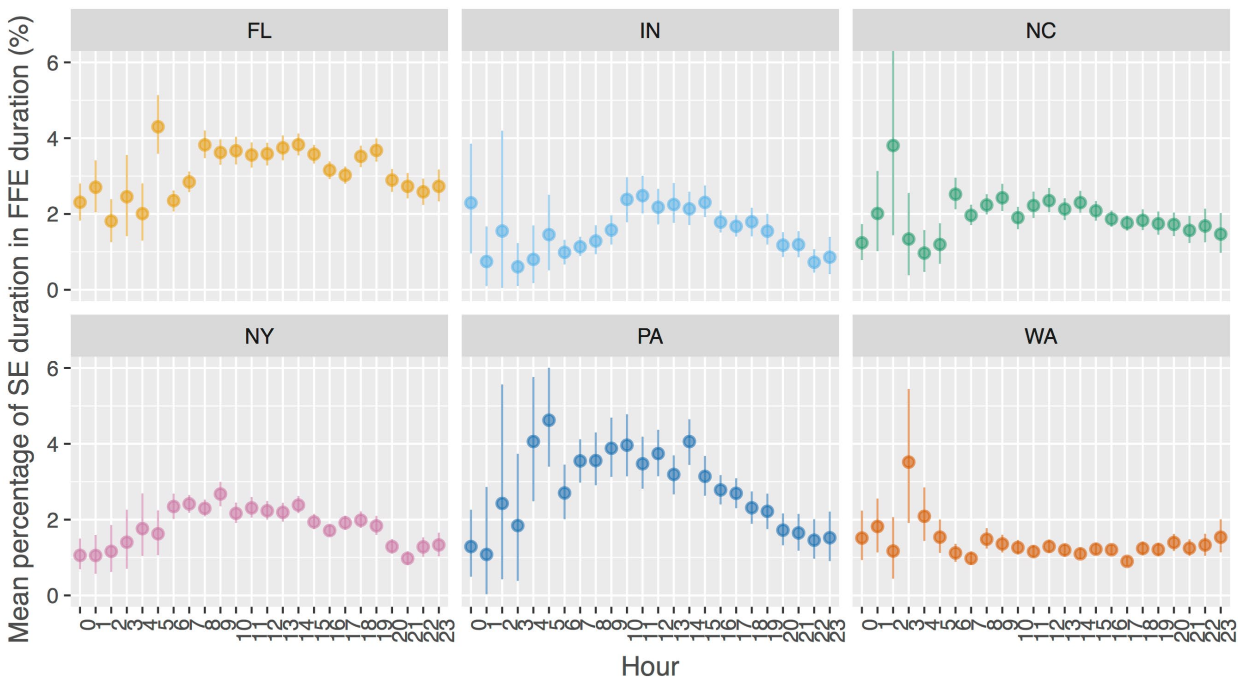

Figure 29. Percentage of FFE time in which drivers were speeding across hour of the day averaged across sites.

Figure 30 shows the amount of speeding combined across all sites. It highlights the rise in the proportion of speeding during the daylight hours between 7am and 7pm. There may be a dip in speeding during the afternoon commute hours (4-5pm), but there is no corresponding dip during the morning commute.

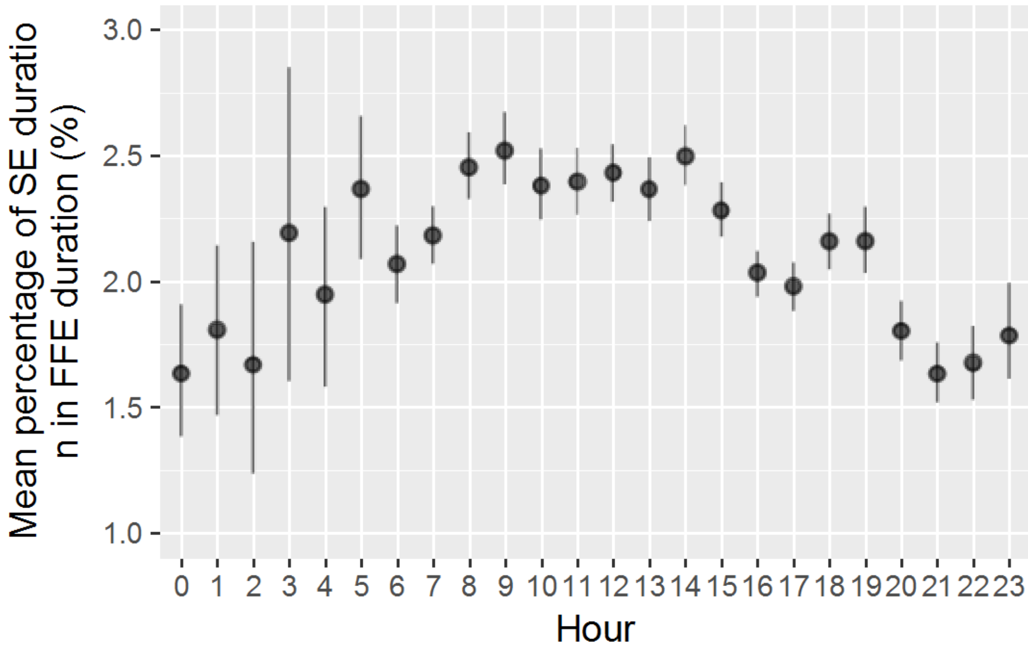

Figure 30. Percentage of FFE time in which drivers were speeding across hour of the day averaged across sites.

Speeding by average FFE and duration

Figure 31 examines the relationship between amount of speeding and approximate measures of overall safety risk. Specifically, it plots the log of the total FFE duration along the x-axis. This measure captures a driver's overall exposure to opportunities to speed. Average FFE speed across all of a driver's FFEs is plotted along the y-axis, which reflect aspects of safety risk related to kinetic energy. The three panels divide the drivers based on the proportion of speeding across all of a driver's trips. There were 2052 drivers that sped less than 5% of the time, 256 that sped between 5-10% of the time, and 50 drivers that sped more than 10% of the time.

In general, there was a slight positive relationship between exposure and higher average FFE speeds. That is, drivers with greater exposure generally tended to drive slightly faster during those opportunities (possibly because higher-speed roadways accommodate more free-flow driving). The more interesting pattern involves how the distribution of points changes with higher amounts of speeding. Specifically, the points become more concentrated in the top right of scatterplot. This suggests that drivers who speed the most have more opportunities on higher speed roads. It is unclear to what extent this pattern simply reflects the roads traveled (higher speed roads with many opportunities) versus driver-specific elements (e.g., some driver that have lot of opportunities may habituate to driving fast).

In some ways, this pattern represents a worst case for speeding-related risk. The drivers that sped most often, had the greatest exposure and they traveled at the highest speeds.

Figure 31. Average speed during FFEs and total FFE duration per driver by percentage of SE duration to FFE duration.

In summary, the overall amount of speeding was relatively low for most drivers. Only 13% of all drivers spent more than 5% of their FFE time speeding. There was substantial variation in average speeding amount across sites, with 4 times as many drivers speeding 5% of the time in Florida compared to Washington State. The amount of speeding also varied by driver age and a variety of situational factors such as month and day of week. Some of these aspects are related, or they may be mediated by common underlying factors. The regression analysis described in the next chapter provides a clearer understanding of the relationships between situational and driver-specific factors and the amount of speeding in individual FFEs.

Chapter 8 - Predictors of Speeding Within FFEs

This chapter examines the research question related to identifying factors that predict the amount speeding that occurs during driving FFEs.

Previous analyses indicated that speeding varied across certain situational conditions (e.g., month of year, day of week, and time of the day). In addition, the amount of speeding as a proportion of total FFE time also varied substantially across individual drivers. A key question in this research is: When drivers have an opportunity to speed, what factors influence how much they speed, if they do at all? This question was investigated by conducting a linear regression analysis to predict the proportion of time within an FFE that drivers were speeding (i.e., how much speeding they were doing).

The FFE was the unit of analysis in the regression modeling. This approach provided some degree of uniformity within each unit, because most infrastructure elements (e.g., PSL, road type, number of lanes, etc.) were typically the same within individual FFEs. The alternative was to use entire trips as the unit of analysis. A trip-level regression analysis is informative for investigating factors associated with the amount of speeding because it may be the best way to explain certain patterns in speeding behaviors, such an unusually high concentration of speeding on a particular trip arising from the driver being late. However, the primary drawback of using trip as a unit of analysis is that driving conditions can vary substantially within the trip, which may mask the effects of certain factors (e.g., a single trip can cover different roadways with varying PSLs). An alternative approach for incorporating trip-wide effects, which was used in the current analysis, was to include trip in the model as a random factor.

The outcome measure in the regression model was the amount of speeding on an FFE (i.e., the SE duration divided by the FFE duration). Single FFEs could include multiple SEs, so the combined duration of all SEs within an FFE was divided by the FFE duration to calculate the total proportion. Twenty-one predictors were selected as fixed effects covering various sources. These included select situational and demographic variables, and measures related to driver behaviors, attitudes, and capabilities. Table 7 provides brief descriptions of each predictor variable. Given that individual drivers could have multiple FFEs (just as individual trips can have multiple FFEs), driver-related and trip-related variables were extracted and matched to the corresponding FFEs. This meant that all of the FFEs from the same driver had the same values for the driver variables. The same was true for trip-specific data such as start hour and day. Trip ID and driver ID were set as random effects in the model. Several of the driver-specific values had a small proportion of missing values, especially the self-reported data (e.g., incomplete questionnaire data). Rather than excluding FFEs with missing driver data, a multiple imputation approach was used to estimate missing values. Averaged values across the multiple imputations were used in regression analyses.

Note also that the variable “Years of Driving” was used instead of Driver Age. Both variables were highly correlated, and separate version of the model run with each variable were essentially the same. The “Years of Driving” variable was chosen because it simplified the model, since it was a continuous variable whereas driver age was categorical.

Table 7. Variables included in the linear regression model.

Situational variables	Variable type	Description/Question
Day of week	Categorical	The day of week when the trip was started based on local time
Start hour	Categorical	The hour of the day at the beginning of the trip based on local time
Month	Categorical	The local date month at the start of the trip
Site	Categorical	The state where data were collected
Speed limit	Continuous	Posted speed limit
FFE duration	Continuous	Duration of the individual FFE
Demographic variables		
Gender	Categorical	Participant's gender
Education	Categorical	Highest level of education
Marital status	Categorical	Participant's marital status
Work status	Categorical	Participant's current work status
Income	Categorical	Family's annual household income
Years of driving	Continuous	Years participant has been driving. This was a proxy for driver age.
Behavior/attitude/capability variables		
Annual miles	Categorical	Average self-reported annual mileage over the past five years
Number of violations	Categorical	Number of self-reported traffic violations in the past three years
Number of crashes	Categorical	Number of self-reported crashes in the past three years
Driving Knowledge	Continuous	The number of questions answered correctly on the driving knowledge questionnaire
raw VSB2	Continuous	Visual Search Test B raw score
ADHD confidence index	Categorical	ADHD confidence index
Total SSS score	Categorical	Total score of Sensation Seeking Scale
Risk Perception Factor	Categorical	Participants' factor loadings on Risk Perception question factors
DBQ cluster	Categorical	Driver type category based on participants' factor loadings on Error/Violation/Lapses/Aggressive Violation DBQ factors

FFE duration was a particularly important variable in the regression model. This is because there is an inherent relationship between FFE duration and speeding. At minimum, FFEs must be long enough to accommodate the SE duration (which had a median of 57 sec and mean of 100 sec), in addition to the time required for the vehicle to accelerate to speeds above the PSL. There may also be other factors involved, such as time needed for drivers to assess the safety of driving at higher speeds, habituation to higher speeds, and/or experiencing a drop of vigilance leading to less frequent speedometer checking. Consequently, there is a minimum FFE duration, below which SEs are impossible or highly improbable. Longer FFEs may also be required to capture the full range of driver behaviors that precede speeding. Thus, for these reasons, FFEs at the short end of the distribution were excluded from the regression analysis.

The key practical question for the current analysis was what minimum FFE duration should be used for the regression. Figure 32 below shows the proportion of FFEs with and without SEs for different time bands. There is a clear trend indicating that FFEs are more likely to contain SEs as they get longer. Over half of all FFEs were less than 120 seconds long; however, only 1.9% of them contained SEs. This raises some interesting explanations regarding FFE duration and these types of speeding. For example, it may be that roadway characteristics and driving conditions that make longer FFEs unlikely also discourage speeding. Another explanation involving driver-specific factors is that drivers may have to "work up" to speeding. It is possible that in most situations, drivers may be unlikely to immediately begin speeding as soon as they get the chance, but as they acclimate to driving at a particular free-flow speed, they become more likely to either intentionally or unintentionally engage in speeding[1].

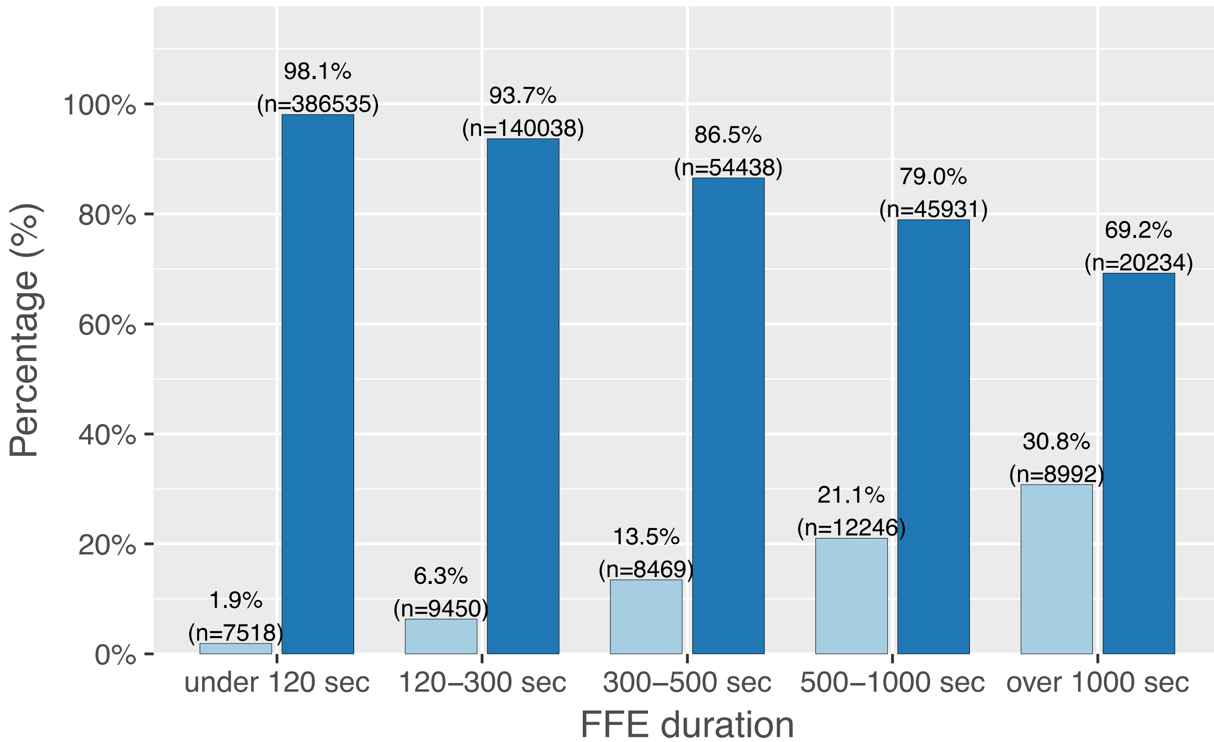

Figure 32. The proportion of FFEs with (light blue) and without (dark blue) SEs for different time bands.

Because of the "structural" constraints on the occurrence of SEs at short FFEs, and the low prevalence of SEs during FFEs that are shorter than 120 seconds, the minimum FFE duration was set to 120 seconds. FFEs longer than 120 seconds (n = 300,005) were extracted from the full dataset and tested using the linear regression model. A backward elimination of non-significant effects was performed by a stepwise variable selection function, and Table 8 presents the final model after the stepwise variable selection.

The final model included 11 predictors. The overall variance explained by the model was relatively low (conditional $R^2 = 0.16$), especially for the fixed effects (marginal $R^2 = .03$). This is unsurprising given the diversity of participants and driving situations covered by the model. For interpreting the output, significant predictors in the final model were grouped into three categories—(a) situational, (b) demographic variables, and (c) measures related to driver

[1] Note that certain types of speeding, such as speeding related to PSL transitions and "unintentional" speeding were excluded from the analysis in earlier steps. If these had been included, it's likely that there would be a higher proportion of SEs at lower FFE durations. The implication is that it is the higher-speed, longer duration speeding included in the analysis that may require longer episodes of free-flow driving to occur.

behaviors, attitudes, and capabilities. To simplify the output table, the coefficients for Trip Month are not shown because they had a large number of categories.

Table 8. Coefficients and p-values for variables in final linear regression model.

Predictors	Coefficient	p-value
(Intercept)	-0.033	0.000***
FFE duration (log)	0.008	0.000***
Years of driving	-0.005	0.000***
Number of violations (1 vs. 0)	0.002	0.196
Number of violations (2 or more vs. 0)	0.009	0.000***
Number of crashes (1 vs. 0)	0.004	0.004**
Number of crashes (2 or more vs. 0)	0.001	0.665
DBQ Cluster (Inattentive vs. Careful)	0.001	0.633
DBQ Cluster (Casual vs. Careful)	0.003	0.029*
DBQ Cluster (Most Aggressive vs. Careful)	0.005	0.004**
Total SSS score	0.000	0.000***
Lawless (Risk-Taking Cluster)	0.002	0.009**
Risk-Seeking (Risk-Taking Cluster)	0.003	0.000***
Site (WA vs. NY)	-0.012	0.000***
Site (NC vs. NY)	0.001	0.899
Site (IN vs. NY)	0.003	0.153
Site (PA vs. NY)	0.013	0.000***
Site (FL vs. NY)	0.013	0.000***
Start hour (Morning vs. Nighttime)	0.012	0.000***
Start hour (Afternoon vs. Nighttime)	0.011	0.000***
Start hour (Evening vs. Nighttime)	0.003	0.003**
Month (vs. January)	◊	-

* $p < .05$, ** $p < .01$, *** $p < .001$

◊ Significant results are described in the text

Situational factors: Several situational factors were significant predictors of speeding in the final model. These variables likely represented a mix of underlying factors somewhat connected to opportunity to speed, either because the immediate conditions accommodated speeding in some way (FFE duration, Site), or the driving conditions were not associated with elevated risk (Start hour, Month).

- *FFE duration*: FFE duration showed a positive relationship with the SE proportion. This finding captures the strong pattern apparent in Table 8 above and suggests that longer opportunities support a higher proportion of speeding.
- *Site*: The site variable could reflect broader characteristics of the road network, but potentially also aspects related to drivers such as driving culture, local attitudes about speeding, or even experience with local law-enforcement practices. Compared to New York, Washington was likely associated with less speeding, whereas Pennsylvania and Florida were likely associated with more speeding.

- *Start hour*: Start hour likely reflected a combination of situational factors including traffic conditions and ambient light conditions. Compared to the nighttime period, other periods (morning, afternoon, and evening) were associated with more speeding. While traffic conditions are likely have been much lighter at night, these increased opportunities did not lead to more speeding. This suggests that safety-relevant factors (e.g., reduced visibility, potential for black ice, driver fatigue) may have discouraged drivers from speeding at night.
- *Month of the trip*: Compared to winter months, spring and fall months were associated with more speeding. This pattern was not uniform across months, but this trend was apparent. This pattern is partially consistent drivers speeding less when safety risk is potentially noticeably elevated because of ice or snow, but it doesn't explain why there is not as much speeding in the summer months.

Demographic factors: Among the demographic factors, only years of driving was statistically significant. Note that this variable was considered to be a proxy for driver age in the analysis. Because of the high number of younger drivers in the SHRP2 sample, driver age was closely related to other demographic variables, such as income, education, and marital status.

- *Years of driving*: The results indicated that drivers with less experience (i.e., younger drivers) had more speeding.

Driver behavior/attitude/capability factors: Multiple variables in this category were significant in the final model. A common theme in the pattern of results for these variables was that factors related to risk taking were typically associated with more speeding.

- *Number of crashes and violations*: Drivers that self-reported two or more traffic violations in the last three years tended to show a higher proportion of speeding compared to drivers had no violations (note that no statistical difference was observed between "no violations" and "one violation conditions"). Similarly, reporting one crash was associated with more speeding, compared to no crashes.
- *Sensation Seeking Score* (Total Score): Higher sensation-seeking scores were associated with more speeding.
- *Driver Behavior Questionnaire* (DBQ): Two DBQ driver types were associated with more speeding, compared to "Careful" driver types. This included "Casual Violators" who sometimes reported disregarding some traffic rules but were otherwise responsible drivers. In addition, "Aggressive" driver types that most frequently reported engaging in aggressive, anti-social, and poor driving were also associated with more speeding.
- *Self-reported risk taking*: The factor scores for two types risk taking components derived from the Risk-taking questionnaire were also significant. Compared to "Careless" risk-taking (i.e., distraction), drivers that scored higher on "Lawlessness" (i.e., not consistently complying with traffic laws), and on "Risk-seeking" (i.e., racing, speeding and risk taking for thrills) sped more.

Discussion of the Regression Analysis

The regression analysis examined what situational, demographic, and driver factors influenced the amount of speeding that drivers engaged in when they had the opportunity to do so. Multiple situational and driver-specific factors were associated with greater amounts of speeding. Overall, most of the trends in the significant findings were interpretable and consistent with expectations.

One trend involving situational factors was that drivers appeared to speed less in riskier driving situations, such as at night or during winter months. Site was also a significant predictor, but it was more difficult to fully interpret. One possibility was that this factor reflected the design of the road network included in the analysis. Specifically, sites with more speeding may have roadways that have longer stretches where sharp curves, steep grades, and vehicle access are less common. The site differences may also reflect regional differences in attitudes and behaviors regarding speeding and/or local enforcement practices.

Several predictors related to driver-specific factors were also significantly associated with the amount of speeding during FFEs. A common theme across these factors was that aspects associated with riskier or unlawful beliefs, attitudes, or behaviors were associated with more speeding. Years of driving experience, which was used as a proxy for driver age was also highly significant, with drivers speeding more if they had less experience driving (i.e., were younger). Years of driving was closely related to several other driver-specific factors. In particular, post-hoc correlation tests showed that years of driving was negatively correlated with total Sensation Seeking score of ($r = -0.30$, $p < .001$), and the "Risk-seeking" factor score for the Risk-taking Cluster ($r = -0.25$, $p < .001$). Also, years of driving and number of violations showed a negative relationship, suggesting that younger drivers were more likely to report having more violations (see Figure 33). The findings clearly supported the notion that less experienced drivers (i.e., young drivers) speed more even after controlling for certain risky attitudes and beliefs that tend to be associated with younger drivers.

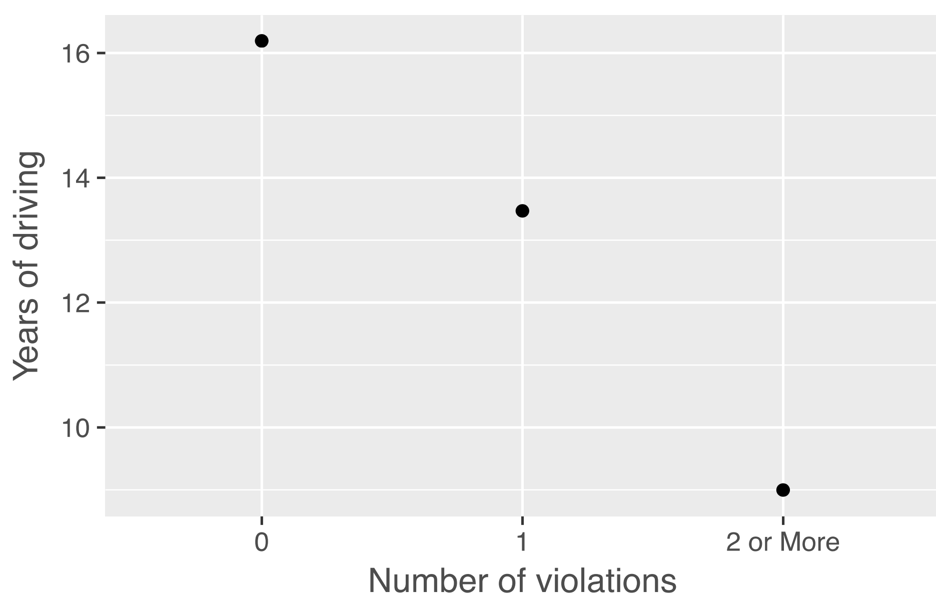

Figure 33. Mean years of driving experience across number of self-reported violations. Error bars are not shown because they are shorter than the radius of the data points.

Another expected finding in the regression analysis was the strong relationship between FFE duration and the proportion of speeding on an FFE. As seen in Figure 32, above, the percentage of FFEs with speeding increases substantially with longer FFE durations. For example, only 2% of FFEs between 30-120 seconds had speeding, whereas 30% of FFEs over 1000 seconds had speeding. This may indicate that drivers need a minimum amount of time to initiate speeding due to behavioral factors (e.g., habituation) or vehicle dynamics. The main analysis excluded short FFEs (under 120 sec) for this reason. However, further analyses might be needed to understand what factors cause speeding within the short FFEs.

As a quick post-hoc examination of short FFEs, the regression analysis was replicated using only FFEs between 30 and 120 seconds in duration. The trends for the significant variables were all in the same direction as the model for longer FFEs. Overall, more situational variables were significant (i.e., PSL and Day of Week were new), and fewer driver-specific factors were significant. The significant driver-specific predictors of speeding included Risk-seeking and Careless Risk-taking Cluster factors, Sensation Seeking, and Number of Violations, but not Years of driving experience. The R^2 of the final model was smaller than the longer-FFE model (conditional $R^2 = 0.09$; marginal $R^2 = 0.007$), which suggests that the situational and drivers-specific factors were poor predictors at short FFEs.

It should also be noted that FFE duration may have also introduced a confound into the interpretation of the results. Specifically, excluding FFEs below 120 seconds may have distorted the driver sample in the analysis. Drivers in areas with lighter traffic and/or long, relatively straight roadways may have been overrepresented in the sample (i.e., rural drivers). However, the short and long FFE datasets only differed by two participants, and the inclusion of Site in the model controlled for some of these differences. Nevertheless, the relationship between FFE durations and SEs merits further investigation.

Chapter 9 - Predictors of Speeding Within Drivers

The regression analysis in the previous chapter indicated that with FFEs longer than 2 minutes, the amount of speeding was positively associated with relatively few situational factors (primarily daylight and springtime). However, multiple driver-specific predictors were significant, and these were generally connected to age and more aggressive/risky behaviors and attitudes. Thus, whether a driver took advantage of an opportunity to speed seemed to depend on certain driver traits. If this is the case, then the same factors should also predict the overall amount speeding across all of a driver's trips. The current chapter addresses the research objective related to identifying driver-specific factors that predict how much individual drivers speed overall.

A second regression model was developed using driver-level variables. Furthermore, FFE variables that were unique to individual FFEs (e.g., duration, PSL, etc.) were aggregated within drivers to calculate a single value for each FFE variable per driver. For example, Average FFE duration represented how long a driver's opportunities to speed were, on average. Both FFE speed limit and FFE duration were averaged per trip first, and then the final average was calculated by averaging across trips. This approach was taken to avoid having longer trips (which potentially have more FFEs) from biasing the average values.

Note that a set of trip-level variables—such as month, day of week, and hour—that could not be reasonably aggregated at the driver-level and were excluded from the driver-level model. Accordingly, the previous random effects (driver ID and trip ID) were also removed. A total of 18 predictors were selected as fixed effects and a total of 2,357 drivers' data were used to build/test the regression model (See Table 9).

Table 9. Variables included in the driver-level regression model.

Situational variables	Demographic variables	Behavior/attitude/capability variables	
Site	Gender	Annual miles	ADHD confidence index
Average Speed limit	Education	Number of violations	Total SSS score
Average FFE duration	Marital status	Number of crashes	Risk Perception Factor
	Work status	Driving Knowledge	DBQ cluster
	Income	raw VSB2	

The outcome measure was based on the same outcome measure in the previous regression analysis (the ratio of SE duration to FFE duration); however, the SE ratios for individual FFEs were averaged per trip and then the mean SE ratios per trips were averaged per individual driver to derive a single, global measure of how much drivers sped. Using the same approach as the previous regression modeling, the backward stepwise variable selection was performed, and multiple imputations were applied for the missing values. Also, as discussed in the previous chapter, 120 seconds was set as minimum FFE duration, and FFEs that were shorter than 120 seconds were excluded before averaging.

After variable selection, the final model included 12 predictors (see Table 10). The proportion of variance explained by the driver-level analysis was relatively low ($R^2 = 0.22$), but slightly higher than the FFE-level model performance (conditional $R^2 = 0.16$). The significant predictors included: the average duration of FFE, number of violations, site, total score of SSS, variables related to aggressive/risk driving, and years of driving (all $p < .001$ level). All highly significant variables in the driver-level model were also strong predictors in the previous FFE model, and the directions of the coefficients were consistent. Two new predictors were observed in the driver-level model; (a) ADHD confidence index, and (b) average speed limit.

Table 10. Coefficients and p-values for variables in the final driver-level regression model.

Predictors	Coefficient	p-value
(Intercept)	-0.007	0.286
FFE duration (average)	0.001	0.000***
Site (WA vs. NY)	-0.013	0.000***
Site (NC vs. NY)	-0.003	0.089
Site (IN vs. NY)	0.001	0.989
Site (PA vs. NY)	0.010	0.000***
Site (FL vs. NY)	0.010	0.000***
Speed limit (average)	0.001	0.027*
Years of driving	-0.001	0.000***
Gender (Male vs. Female)	-0.002	0.059
Number of violations (1 vs. 0)	0.002	0.215
Number of violations (2 or more vs. 0)	0.008	0.000***
Number of crashes (1 vs. 0)	0.004	0.005**
Number of crashes (2 or more vs. 0)	0.001	0.857
DBQ Cluster (Inattentive vs. Careful)	0.001	0.796
DBQ Cluster (Casual vs. Careful)	0.003	0.023*
DBQ Cluster (Most Aggressive vs. Careful)	0.006	0.001**
ADHD Confidence Index	0.001	0.041*
Total SSS score	0.001	0.000***
Lawless (Risk-Taking Cluster)	0.002	0.003**
Risk-Seeking (Risk-Taking Cluster)	0.003	0.000***

* $p < .05$, ** $p < .01$, *** $p < .001$

Situational factors: In the driver-level model, fewer variables were available since trip-level variables such as start hour and month of the trip were excluded during the averaging process. Out of the included variables, Average FFE duration and Site that were significant from the FFE-level analysis were still significant predictors of speeding in the driver-level model. Average speed limit became a significant predictor of the speeding.

FFE duration: As observed from the previous chapter, FFE duration showed a positive relationship with the SE proportion. In the driver-level model, this indicated that drivers that generally drove on roadways that afforded greater opportunities to speed tended to speed more overall.

Site: Compared to New York, Washington State drivers were associated with less speeding, but Pennsylvania and Florida drivers were associated with more speeding (there was no significant difference between NY and IN, NC).

Average Speed limit: Drivers who tended to have more of their FFEs on higher speed roadways sped more.

Demographic factors: Similar to the previous results, years of driving was the only significant demographic factor.

Years of driving: The results showed that less experienced (and typically younger) drivers sped more.

Driver behavior/attitude/capability factors: Driver behavior/attitude/capability variables also showed similar patterns compared to the FFE-level model. In addition, ADHD confidence index variable became a significant predictor.

Number of crashes and violations: Drivers with two or more traffic violations showed a higher amount of speeding compared to drivers had no violations; drivers with one crash were associated with more speeding compared to no crashes.

Sensation Seeking Score (Total Score): Drivers with higher sensation-seeking scores were associated with more speeding.

Driver Behavior Questionnaire (DBQ): As observed from the previous chapter, “Casual Violators” and “Aggressive” driver types were associated with more speeding compared to “Careful” driver types.

Self-reported risk taking: Similar to the previous finding, drivers scoring higher on the “Lawlessness” and “Risk-seeking” risk factors sped more compared to drivers scoring higher on the “Careless” risk-taking factor.

ADHD confidence index: Drivers with a higher ADHD confidence index (which represents chances that a significant attention problem exists) were more likely associated with higher amount of speeding.

Discussion of the Regression Analysis

The results of the driver-level regression analysis were very similar to those from the FFE-level analysis. Most of the significant variables were the same across the two regression models and coefficients of the variables were similar as well. Model performance between two models were comparable, but the driver-level regression model explained slightly more variance ($R^2 = 0.22$) than the FFE-level model ($R^2 = 0.16$). One point to keep in mind is that even though the two regression models involved different units of analysis (FFE-level vs. driver-level), the sources of variance shared substantial similarities. Specifically, all driver-specific variables in the FFE-level regression model were driver-level variables. This means that the FFEs from each driver had identical values on the driver-specific variables across all of a driver’s FFEs, which likely accounts for some of the similarities in the model results.

Situational Variables

Regarding the situational variables, the regression results were consistent with Figure 31 from Chapter 7, which showed the relationship between driver's overall amount of speeding and their average FFE speed and duration. Figure 34 below shows a different version of the previous Figure 31. The primary difference is that the y-axis shows average PSL across FFEs rather than average vehicles speed across FFEs (to be more consistent with the regression model). Another difference is that the points, which represent individual drivers, are color according to the site variable.

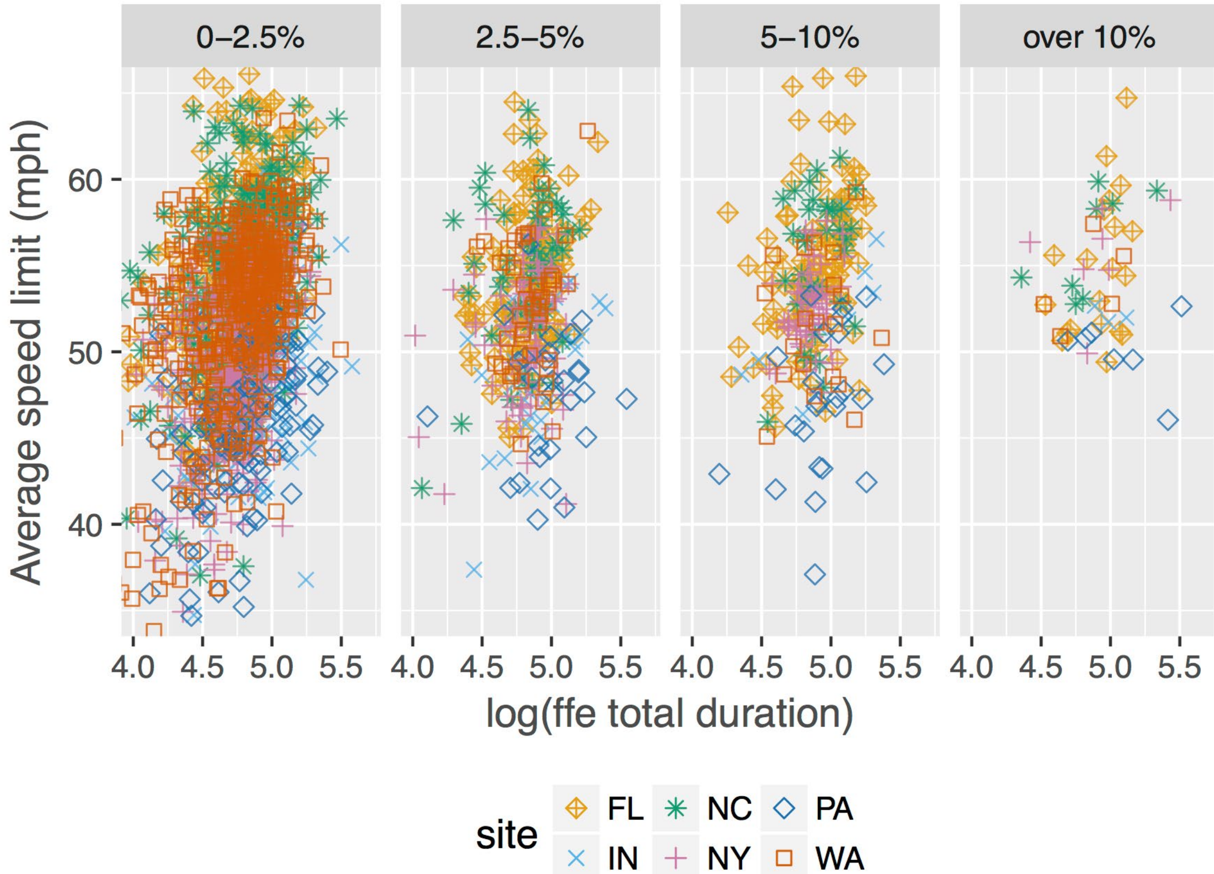

Figure 34. Average Posted Speed Limit across FFEs and log FFE duration for each participant at each site, grouped by the overall amount of speeding associated with each driver.

The figure clearly shows the trends towards longer average FFEs and higher average FFE PSLs being associated with more speeding at the driver level. In particular, the average FFE speed limit increased at higher proportions of speeding and the same trend held for average FFE Duration (see Table 11). However, the explanation for these trends is counterintuitive. This pattern did not arise because the cloud of points shifted to uniquely higher values. Rather, across groups with higher average proportions of speeding, points with lower average PSL and durations drop out of the distributions. The lowest-speeder group contains drivers that overlap with the "Over 10%" group, but they also contain a much wider range of values, especially towards the lower left end, which is less apparent in higher speeding proportion groups. This suggests that longer opportunities to speed—which may be concentrated on roads with higher PSL—may be necessary for individual drivers to reach high proportions of speeding overall.

Table 11. Average Posted Speed Limit and Average Duration across drivers based on their overall amount of speeding.

Percentage of Speeding:	0-2.5%	2.5-5%	5-10%	Over 10%
Average FFE PSL:	51.6	52.5	53.4	54.3
Average FFE Duration:	1120	1283	1431	1628

Another observation is that Florida and Pennsylvania drivers were more common than the other sites in the plots showing more than 5% speeding. Interestingly, average FFE speeds for Pennsylvania were generally lower than for Florida, which may have reflected characteristics of the local road networks. Although these two sites had a greater number of high speeders, one observation that is clearly apparent is that the group that sped over 10% of the time included drivers from all sites. This is again consistent with the notion that driver-specific traits promote frequent speeding outside of situational and regional factors.

Driver-specific Variables

The findings from the driver-level regression model were consistent with several previous studies indicating that driver-specific factors are associated with speeding, such as prior traffic violations (Cleveland, 1959), age/experience (Rienstra, & Rietvald, 1996), and attitudes towards risk (Corbett, 2000). Also, a review of forty studies found a positive relationship (with correlations in the range of 0.30 to 0.40) between sensation seeking and risky driving behavior (Jonah, 1997). In one study, high sensation-seeking scores were associated with speeding, aggressive driving, not wearing seat belts, and drinking and driving (Jonah, Thiessen, and Au-Yeung, 2001). ADHD confidence index, which was not a significant predictor in the FFE-level model, became significant in the current model. Previous research showed that young drivers with ADHD were more likely to be associated with traffic violations such as speeding (Barkley et al., 1993).

The consistency of the SHRP2 findings with previous research is important on multiple levels. At the most basic level, the current findings provide additional evidence for the relationship between driver characteristics and speeding. At the broader level, the findings establish an empirical link between the SHRP2 data and the existing body of knowledge on driver behaviors. The findings confirm that the naturalistic behavioral observations from SHRP2 are consistent with previous findings obtained primarily through indirect measures of behavior, such as self-reports and laboratory studies. This adds to the confidence that the rich behavioral information available in the SHRP2 dataset applies to the broader driving population.

The regression analyses in Chapters 8 and 9 indicated that certain situational and driver-specific variables were associated with the amount of speeding. The next two chapters continue to examine factors that affect speeding, but with a greater emphasis on the underlying speeding behavior. Chapter 10 classifies SEs into different types of speeding based on common characteristics across SEs. Chapter 11 extends this approach by characterizing types of drivers based on the types of speeding in which they engage.

Chapter 10 – Types of Speeding

This chapter addresses the research objective of categorizing types of speeding based on the characteristics of individual speeding episodes. Specifically, it describes how individual SEs were analyzed across all drivers to identify fundamental types of speeding based on their intrinsic properties.

The underlying premise behind the analyses in this chapter is that speeding results from qualitatively different types of driving behaviors. For example, speeding can occur unintentionally because of lack of vigilance, or it can occur because drivers are deliberately exceeding the PSL, such as "thrill seeking" driving or to reduce travel time when late. If speeding results from these different motivations, it is likely that SEs may take different forms depending on the underlying motivations or associated behaviors. Thus, a key objective of this project was to identify different types of speeding within the SHRP2 driving sample.

The basic approach described in this chapter mirrored the previous examination of SEs conducted in the MfS Follow-on analysis project (Richard, Divekar, & Brown, 2016). Specifically, a cluster analysis was run using select SE summary variables to identify groups of SEs that had similar characteristics. Six separate types of speeding were identified in that study, which included the following types:

Speeding Up: The characteristics of these SEs were consistent with speeding up that can occur immediately prior to an increase in the posted speed.

Speed Drop: The characteristics of these SEs were consistent with drivers slowing down after transitioning to a lower posted-speed zone.

Incidental Speeding: This was the most common type of speeding, and it likely represented unintentional or incidental speeding on the part of a driver, since they were brief, exceeding the speeding threshold by only 2-3 mph.

Casual Speeding: This type of speeding was similar to Incidental speeding, but differed primarily in degree, with all variables having higher values. It seemed to represent a more accepting or casual attitude towards speeding in the situations in which they occurred.

Cruising Speeding: The defining aspect of this type of speeding was the long duration relative to the other types, akin to drivers "cruising" along a roadway at elevated speeds for a moderate duration.

Aggressive Speeding: This type of speeding represented more aggressive and/or riskier driving than other types.

The current research used a similar approach to identify types of speeding in the SHRP2 SEs. Note that SEs that corresponded to the first three speeding types (those related to PSL transitions, and those with lower max speeds) were filtered from the dataset in previous steps, so the current dataset should yield fewer types of speeding. This was the first step in a series of analyses to examine aggregate speeding behaviors in the naturalistic SHRP2 data. The objective was to address three questions:

- Is it possible to characterize *types of speeding* based on characteristics of Speeding Episodes?

- Is it possible to classify subtypes of speeders (*speeder groups*) using patterns in their types of speeding?
- To what extent do speeder groups reflect underlying differences in demographics and/or attitudes and beliefs about speeding?

The basic process used to address these questions involved three steps. The first step was to conduct a cluster analysis on select SE variables to divide SEs into types of speeding based on shared characteristics. The second step involved identifying how often each driver engaged in each type of speeding, thus creating a "speeding profile" for each driver (see Figure 35). These speeding profiles were then used as the basis for a second cluster analysis to identify different speeder groups based on similarities in their speeding profiles. The current chapter addresses the first step (characterizing types of speeding), while the next chapter addresses the questions about speeder groups.

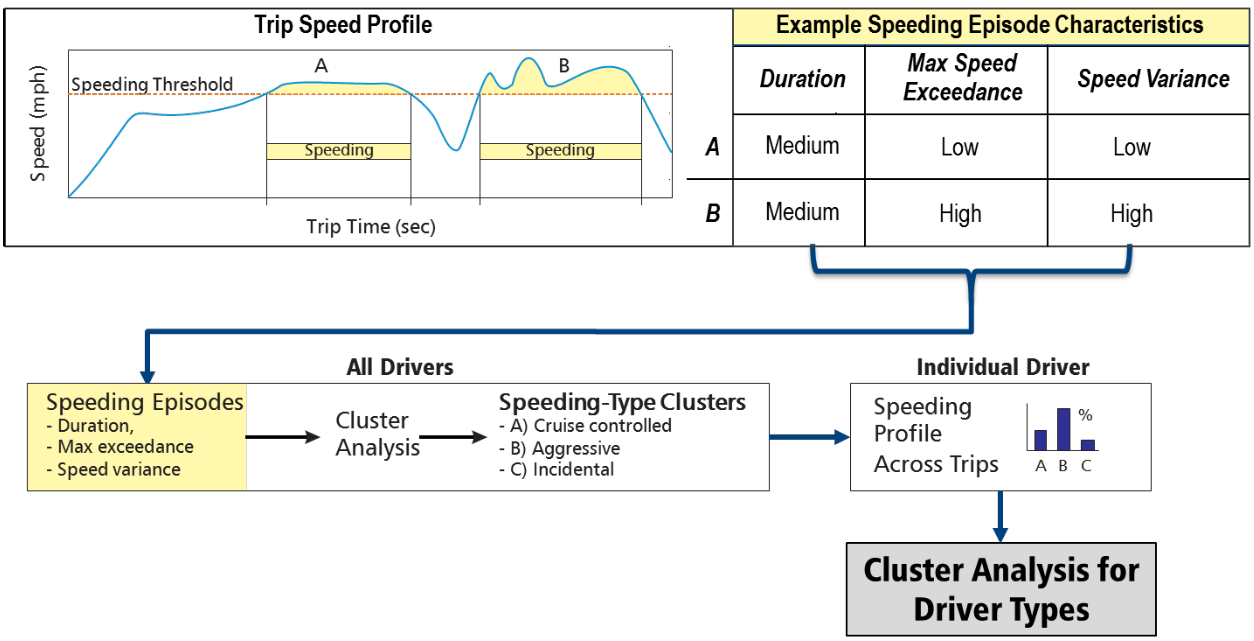

Figure 35. Overview of analytical process used to characterize types of SEs and types of speeders.

Selection of Variables for Speeding Type Analysis

A key objective for the selection of variables for the cluster analysis was to include variables that represented different intrinsic characteristics of SEs. Figure 36 illustrates four of these characteristics: magnitude, duration, variability, and form. Four variables, which can represent those characteristics were calculated and used in the cluster analysis (see Table 12).

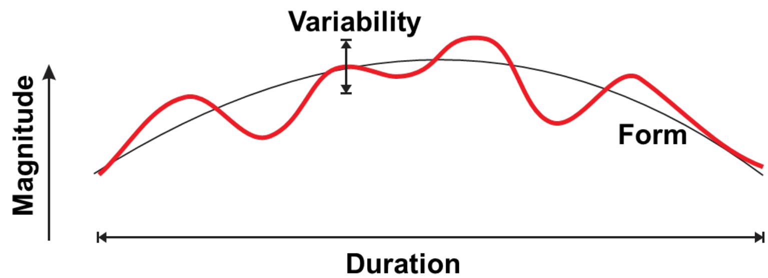

Figure 36. Four intrinsic characteristics of SEs.

Table 12. Description of variables used to represent key characteristics of SEs in the cluster analysis.

Dimension	Variable	Note
Magnitude	Max speed over PSL	Maximum speed above the PSL anytime within the SE
Duration	SE duration (log)	Common logarithm transformation of SE duration
Variability	Inter quartile speed over PSL	Inter quartile = Upper quartile (Q3) – lower quartile (Q1)
Form	Speed reversal rate per minute	Frequency of change in direction of slope in 3 second window moving average

The current approach used different variables than in Richard, Divekar, and Brown, 2016. In the previous study, SE form/shape was represented using a simplistic approach that compared speed levels across quartiles. This approach was unsuitable for the current data because the SHRP2 SEs were substantially longer and more varied in form than in the MfS study. Multiple approaches for categorizing the overall form of the SE were examined. The rate of speed reversals per minute was sufficiently discriminating without being too computationally intensive, so it was selected. This variable was effective for differentiating between SEs that were flat, had a generally peaked shape, or more undulating speed patterns. Details on the interpretation of different reversal-rate patterns are provided in later sections in this chapter.

The four variables in Table 12 were used to cluster the SEs with the k-means clustering algorithm. The analysis was repeated with 1 to 15 cluster centers. A subset of three to six cluster solutions that best fit the data were examined to determine the solution that was (a) most interpretable, and (b) comprised of the most distinct clusters. A three-cluster solution best matched these objectives.

Table 13 shows various descriptive statistics for the three clusters. The first type of speeding was labeled “Momentary” speeding and it was comprised of SEs with the lowest maximum speeds over PSL and shortest durations. These SEs were also the most common. The second type was labeled “Cruising” speeding. This type was comprised of SEs with values for maximum speed over PSL that were comparable to Momentary speeding, but with substantially longer durations. These SEs were almost as common the Momentary SEs. The third type of speeding was comprised of SEs that had the highest maximum speeds over PSL and durations that were comparable to Cruising SEs. These SEs were label “Riskier” speeding. The SEs within each type differed in multiple ways, which are discussed in more detail in later chapter sections. These additional analyses provide the justification for the labels assigned to the SE types.

Table 13. Descriptive statistics for the three speeding-type clusters.

Cluster/ Type	N	Median of max speed over PSL (mph)	Median speed over PSL (mph)	Median duratio n (sec)	Median speed reversal (per min)	Median IQ (mph)	Median speed SD	Median max accel. (g)	Median max decel. (g)
Momentar y	34,270	16.3	13.4	28	6. 7	2.9	1.8	0.06	0.06
Cruising	30,806	16.5	13.1	75	14.3	2.5	1.7	0.06	0.06
Riskier	12,784	21.5	15.8	66	8.4	5.1	3.2	0.08	0.08

SE Speed and Duration: Figure 37 shows the distribution of the three types of speeding in terms of the maximum speed over PSL and duration of each SE. Momentary SEs are nearest to the origin of the plot, which represents a combination of the shortest durations and lowest maximum speeds over the PSL. The two other types of speeding are concentrated in regions that represent either longer durations (Cruising SEs) or both higher speeds and longer durations (Riskier SEs). The three types of speeding vary primarily in terms of degree. There are no clear boundaries between the different types. A broader question is whether the clusters shown below have explanatory value. The analyses that follow, particularly those in later chapter, examine this question.

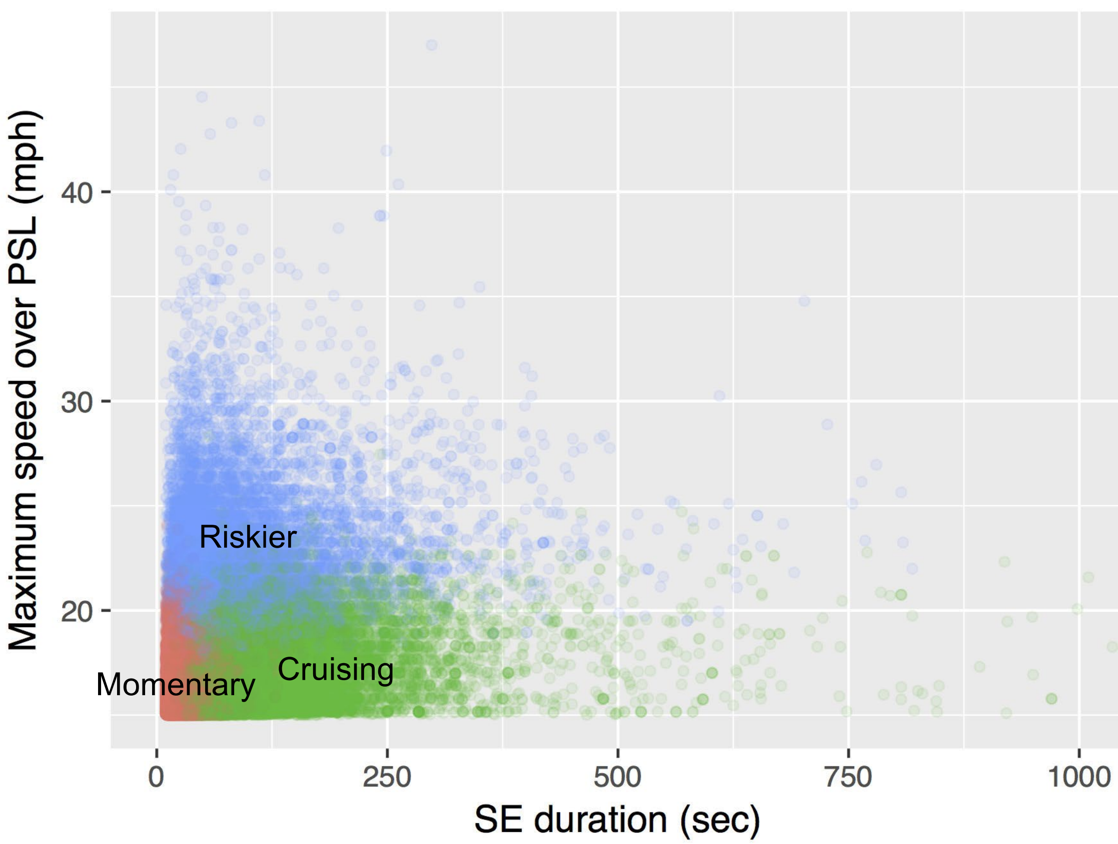

Figure 37. Distribution of three types of speeding in terms of the maximum speed over PSL and duration of each SE.

Figure 38 provides a deconstructed view of Figure 37, above. It includes contour lines that reflect the density of points within each SE cluster. The points for all three types of SEs were skewed towards the shorter, slower end of each distribution. The centroids of Momentary and Cruising speeding were relatively close, with the primary difference being the substantially greater variability in duration among Cruising SEs. The distribution of Riskier SEs was the most distinct. The centroid occurred at a higher maximum speed over PSL, with a high degree of variability in both maximum speed over PSL and SE duration. For these two variables, the three types of SEs differ primarily in terms of degree.

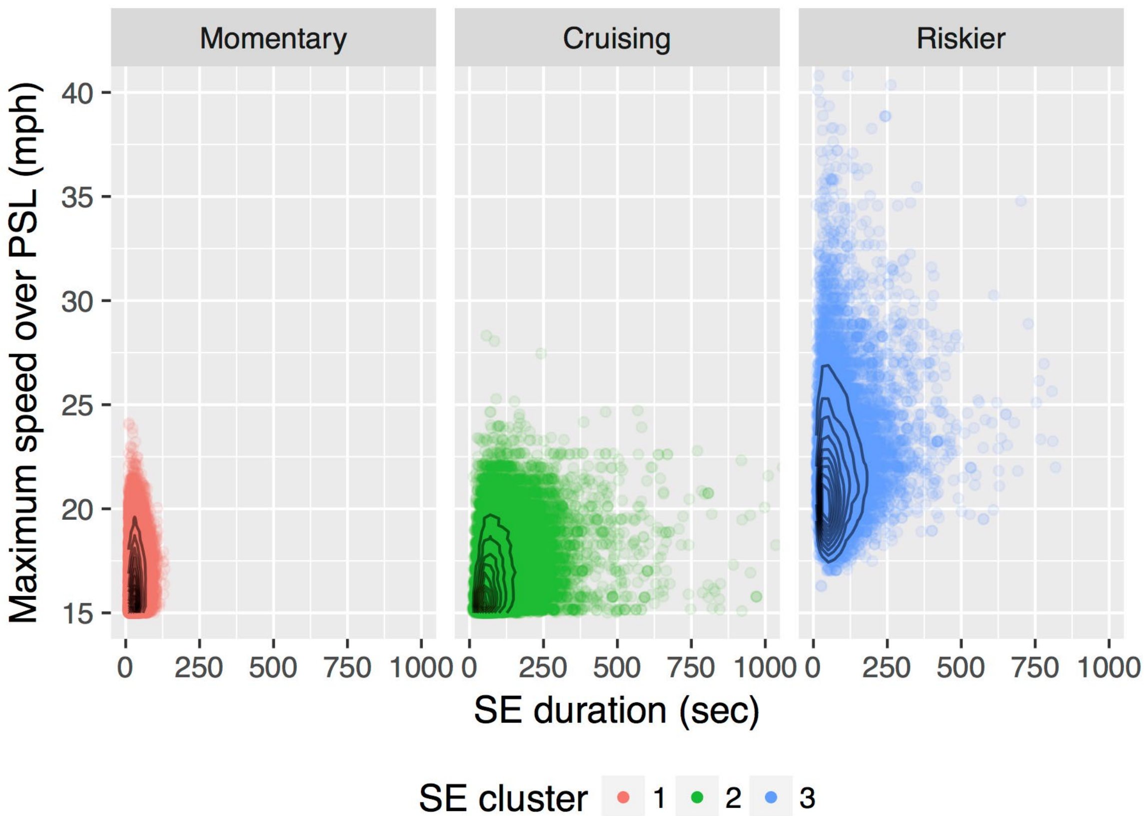

Figure 38. Maximum speed over PSL and duration of SEs isolated by type. The contour lines within the distributions reflect point density.

SE Form: Figure 39 shows the relationship between speed reversal rate and duration for each type, which provides some information about the overall shape of the SEs. Specifically, this measure represents the "switchbacks" in the speed data after limited smoothing. A single peak shape would yield a single reversal (low rate), whereas continuous speed fluctuations around a set point (i.e., cruise control) would be characterized by a high reversal rate.

Reversal rate likely reflects different driver actions. Low rates generally correspond to gradual speed changes, and a single reversal would correspond to a peaked shape, representing a driver steadily speeding up before deciding to slow down. High reversal rates likely correspond to speed maintenance behavior. As drivers try to keep to a target speed, their speed would fluctuate around a set point. An extreme example of this is the use of cruise control with continuous speed oscillations around the cruise speed. Intermediate reversal rates could correspond to more active speed control by the driver, defined by repeated periods of acceleration and deceleration. This could represent repeated traffic interactions, such as speeding to catch up to lead vehicles, slowing to match their speed, then speeding up again once drivers passed the slower vehicles. Intermediate reversal rates could also correspond to driving on grades or to driving fast on winding roadways in which the centripetal force was high enough to noticeably slow the vehicle. Hilly terrain could also yield a similar pattern.

Figure 39 shows the speed reversal rate per minute by duration separately for each type of speeding. Momentary SEs generally had the lowest values (median = 6.7 per minute), with longer-duration Momentary SEs having lower reversal rates. These values corresponded to around three reversals per SE. Cruising SEs had the highest reversal rates, with a median value of 14.3 per minute. This value corresponded to a reversal every 4 seconds. The pattern associated with Cruising SEs was consistent with driver spending a substantial part of the SEs making small speed adjustments. Riskier SEs had a reversal rate that was slightly higher than Momentary SEs (median = 8.4 per minute); however, the trends were different across duration. For Riskier SEs, reversal rate generally increased at longer durations.

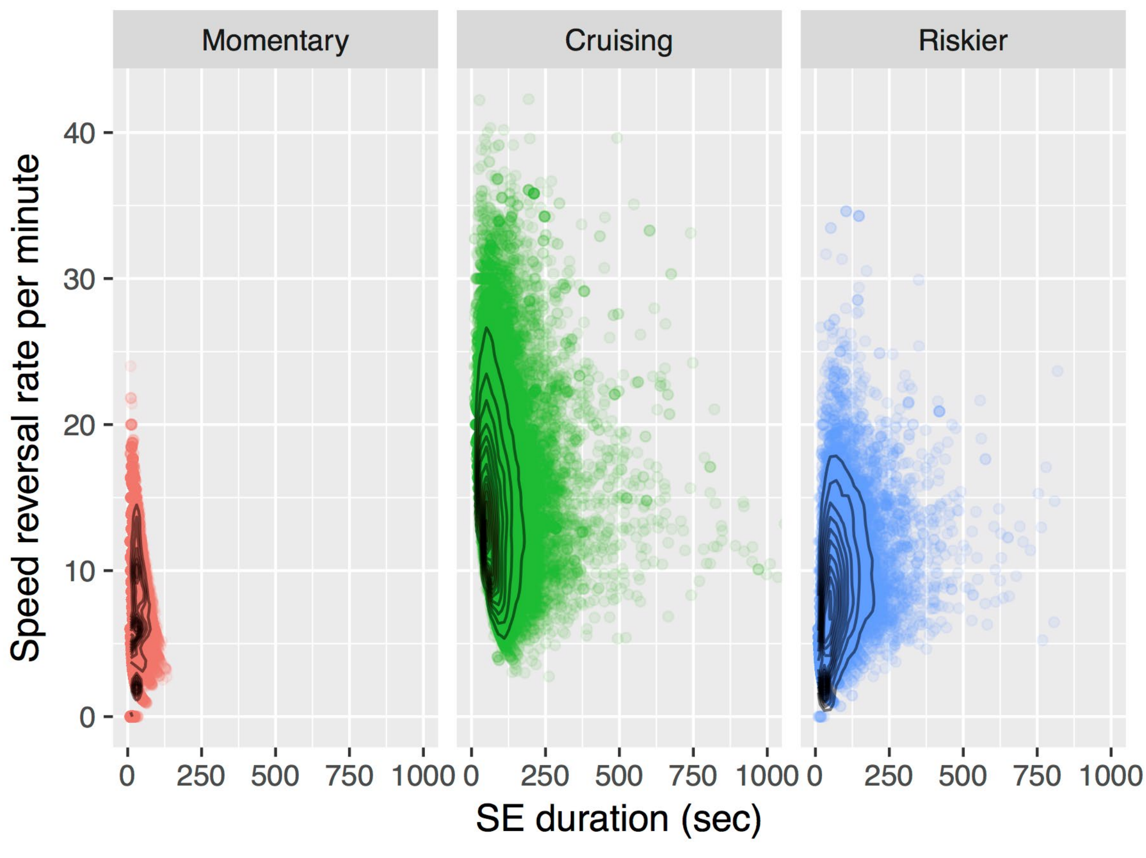

Figure 39. Speed reversal rate (per minute) and duration of SEs isolated by type. The contour lines within the distributions reflect point density.

SE Variability: The primary measure of SE variability was the Interquartile Range (IQ) of speed over PSL, which generally corresponded to the speed band in which drivers spent most of their time. This measure was similar for Momentary and Cruising speeding. There was no systematic relationship with duration for these two SE types (see Figure 40). Despite their similarity, the values likely reflected different characteristics of the SEs. Because Momentary SEs were short and had low mean speeds over PSL, the low IQ range likely reflected the fact that drivers did not have time to reach high speeds, so most of their travel was within a narrow speed band. In this case, the IQ range was directly tied to maximum speed over PSL because most of the SE duration involved the vehicle accelerating to max speed then decelerating.

A different pattern was implied in Cruising SEs. Specifically, the durations of Cruising SEs tended to be longer, which provided drivers with sufficient time to reach faster speeds. In this case, the lower IQ range indicates that speeds were confined to a small range, which is common in speed maintenance behavior. Cruising SEs had the lowest IQ range overall.

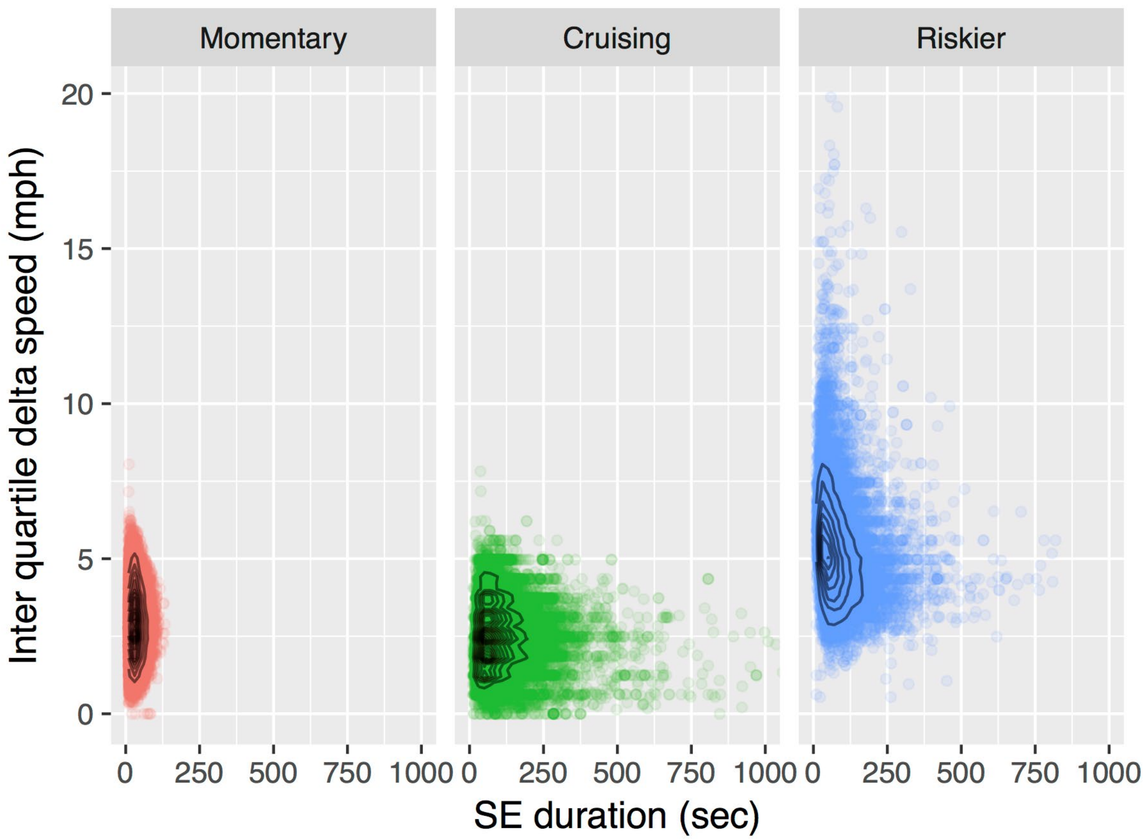

Figure 40. Interquartile range of speed and duration of SEs isolated by type. The contour lines within the distributions reflect point density.

The interquartile range was greatest for Riskier speeding, and there was a general trend towards shorter Riskier SEs having wider ranges. It is unlikely that the wider IQ range was simply a function of these vehicles achieving higher maximum speeds over PSL—similar to what mediates the IQ range in the short Momentary SEs. Even at the low mean acceleration levels observed for this type of SE, it would only take 2-3 seconds for vehicle speed to increase by 5 mph (the difference between Momentary and Riskier maximum speed over PSL). The average duration of Riskier SEs was 66 seconds, so the wider range was not explained solely by the vehicle accelerating to max speed then decelerating. Instead, these drivers were speeding for extended periods with speeds fluctuating within a wider band. There are multiple behaviors that could produce this pattern including:

- Interactions with other traffic, such as speeding to catch up to a platoon ahead, slowing to match its speed, then accelerating again once there is an opportunity to get around lead traffic.
- Traversing a hilly or winding roadway at speeds that are fast enough that maneuvering decelerate the vehicle. This would potentially put a vehicle at risk of traction loss under certain conditions.

Without more reliable radar and GPS data from the vehicles, it is difficult to accurately identify the driver behaviors that underlie differences in speed variability across the SEs. Nevertheless, given the constellation of differences in SE characteristics across the SE types, the data still suggest that these differences may have reflected differences in behaviors and driving situations.

Figure 41 shows example time-series plots for the individual SEs that most closely matched the overall median values on the four key variables for each SE type. These graphs better illustrate the how the variables described above translate into differences in vehicle speed patterns. The black lines show the 3-second moving average of vehicle speed over PSL, and the calculated speed reversal points are shown in red. The interpretations of the time-series for each type of speeding are discussed after the figure.

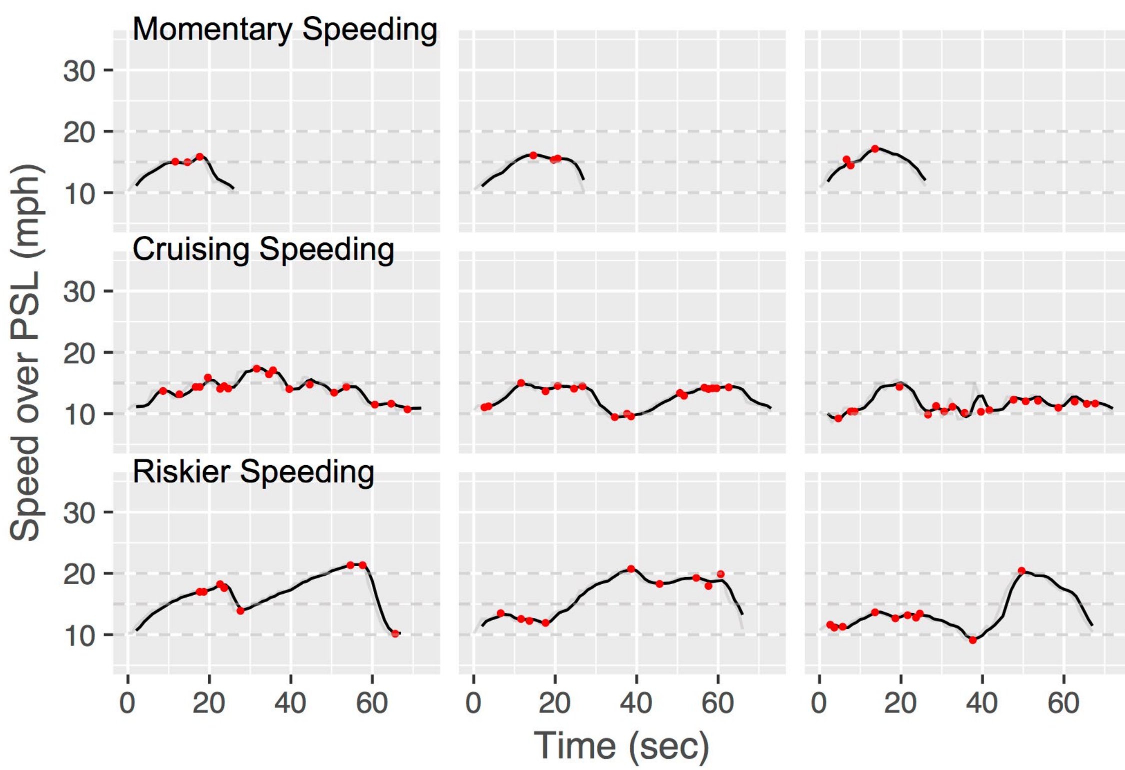

Figure 41. Example time-series plots for the individual SEs that most closely matched the median values for each SE type.

Momentary Speeding: In the examples, above, a substantial portion of the Momentary SE duration involves accelerating to maximum speed, then decelerating. Less time is spent in fluctuations around a set speed. Because these speed changes occur over a relatively brief interval, the statistical characteristics of Momentary SEs are substantially governed by this pattern of acceleration followed shortly thereafter by deceleration. Behaviorally, Momentary speeding could reflect actions such as passing or lane changes, or they could arise from drivers unintentionally driving fast due to road conditions, noticing their elevated speed, and then coasting back to their intended lower speed. Given the transient nature of these time-series, it suggests that drivers were not intending to speed for an extended duration in these instances.

Cruising Speeding: The most prominent characteristics of the Cruising speeding examples above are (a) a pattern of repeated fluctuations around a speed centroid (for certain segments) and (b) the overall flatness of the speed profiles. These SEs have the highest rate of speed reversals per minute, which is generally consistent with speed maintenance behavior. At the extreme end of this speed maintenance behavior is drivers that set their cruise control level within the speeding range. Figure 42 shows time-series that more clearly illustrate the speed-maintenance nature of these SEs. The graph on the left shows highly uniform speed maintenance that indicates activation of cruise control on flat terrain.

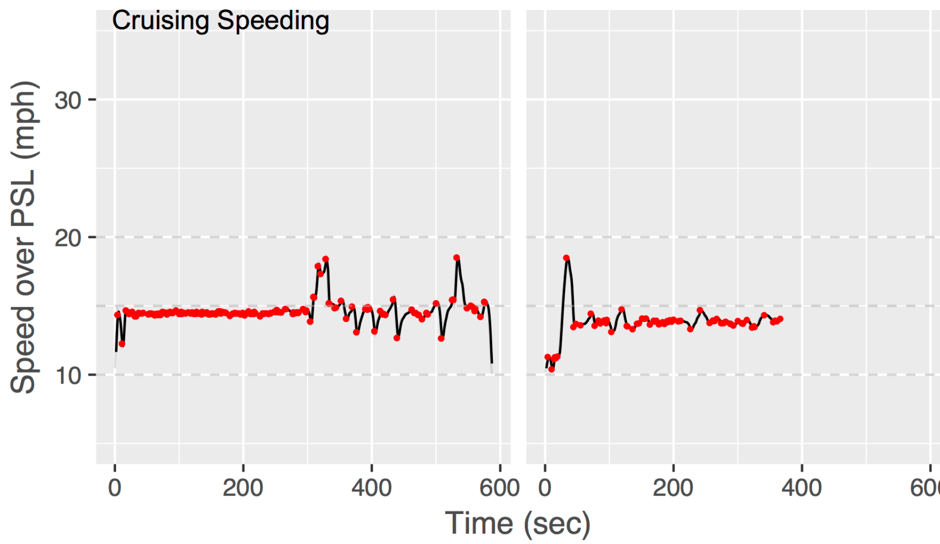

Figure 42. Select Cruising Speeding SE time-series that illustrate the speed-maintenance nature of these SEs.

Riskier Speeding: This type of SE shows a greater variety in the form of the speed profile. Although some degree of speed maintenance is visible, large changes in speed are also evident by fluctuations with larger amplitudes. In some cases, this may reflect more active control of speed than simple speed maintenance. The specific behaviors underlying Riskier speeding are unclear at this time because clear information about the presence of other traffic is lacking in the dataset.

The example Riskier SEs in Figure 41 show gradual changes in speed. A more common pattern within Riskier SEs is an intermediate level of fluctuation in speed (see Figure 43). These time-series suggest a greater degree of interaction between the driver and situational factors—possibly other drivers or changing roadway geometry. Regardless of the underlying cause, these time-series suggest a more active involvement in speed control by the driver.

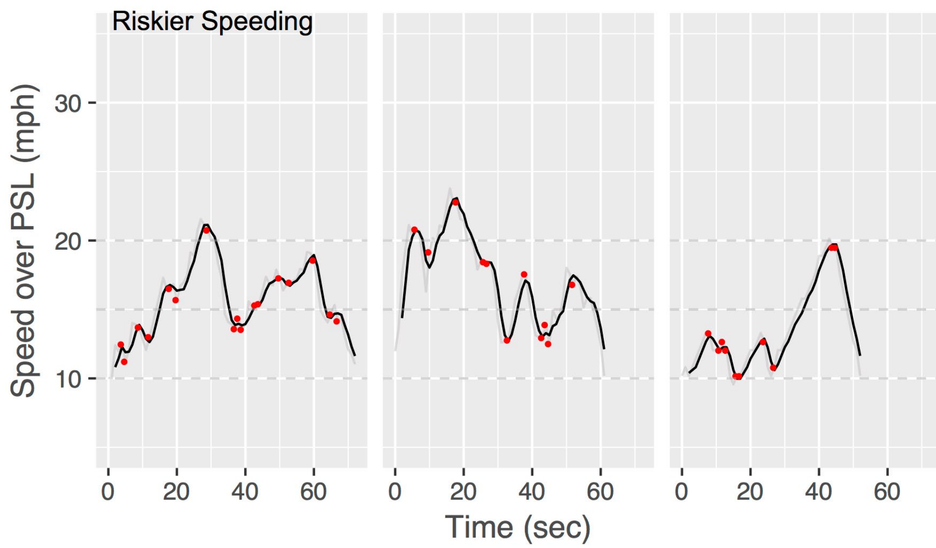

Figure 43. Select Riskier Speeding SE time-series that illustrate active speed control in these SEs.

Figure 44 shows the distribution of SE types across sites. The relative position of the regions of points encompassed by each type of speeding are similar across sites.

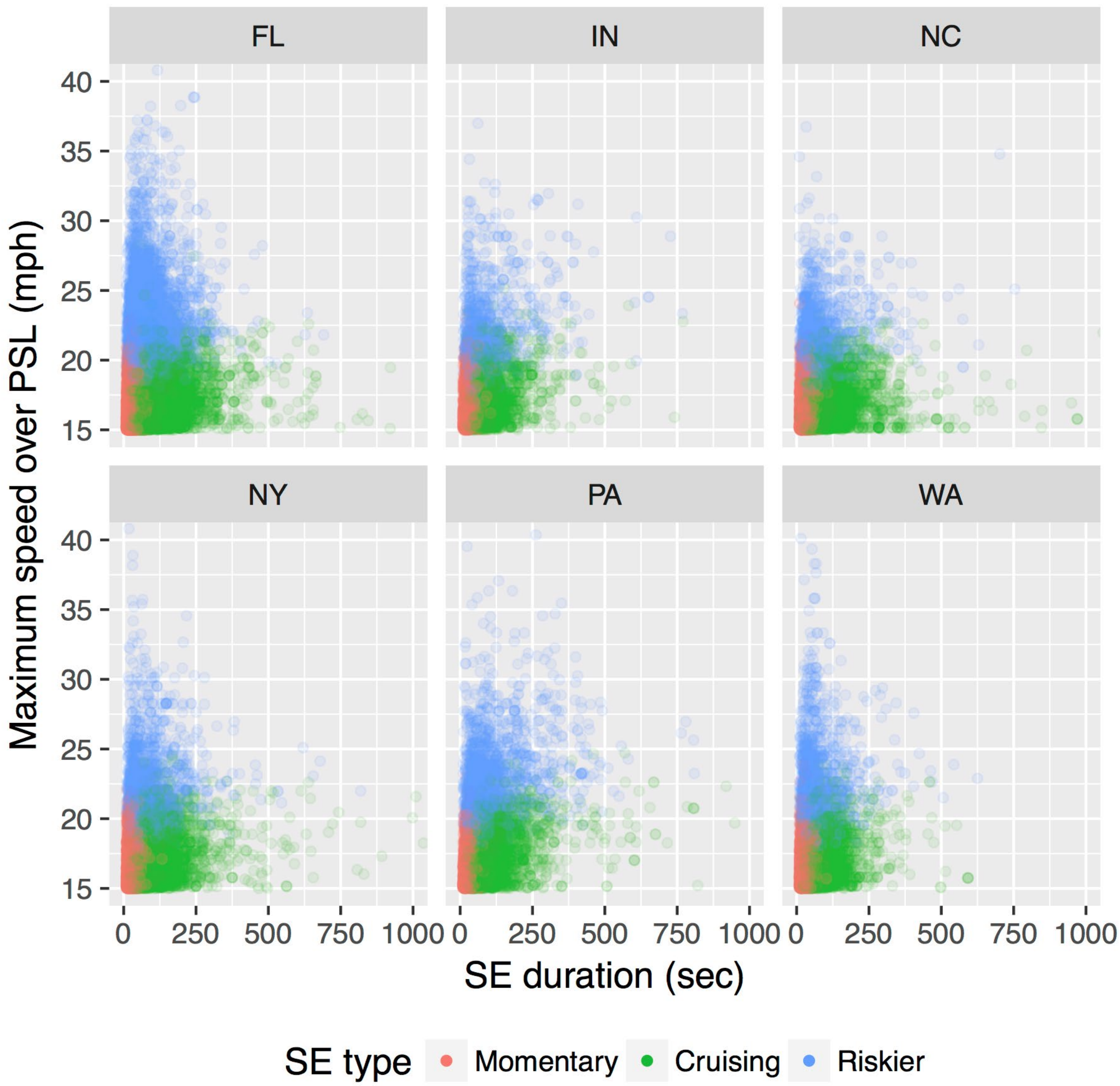

Figure 44. Distribution of speeding types for maximum speed over PSL and SE duration across sites.

Individual sites differed in terms of the relative proportion of each type of speeding. Figure 45 shows the proportion of each type of SE based on the average proportion for drivers at each site. Around half of drivers' SEs at all site were Momentary SEs; however, Indiana, Florida and Pennsylvania had slightly lower proportions of these. For Cruising SEs, the proportion ranged between 35% and 40% for all sites except Washington, which was slightly lower. For Riskier SEs, which had the highest speed, New York and North Carolina drivers had the smallest proportion. Washington, Indiana, and Florida had a slightly higher proportion of Riskier speeding, and

Pennsylvania had the highest proportion. Overall, the sites were quite similar regarding the relative proportions of the different types of speeding.

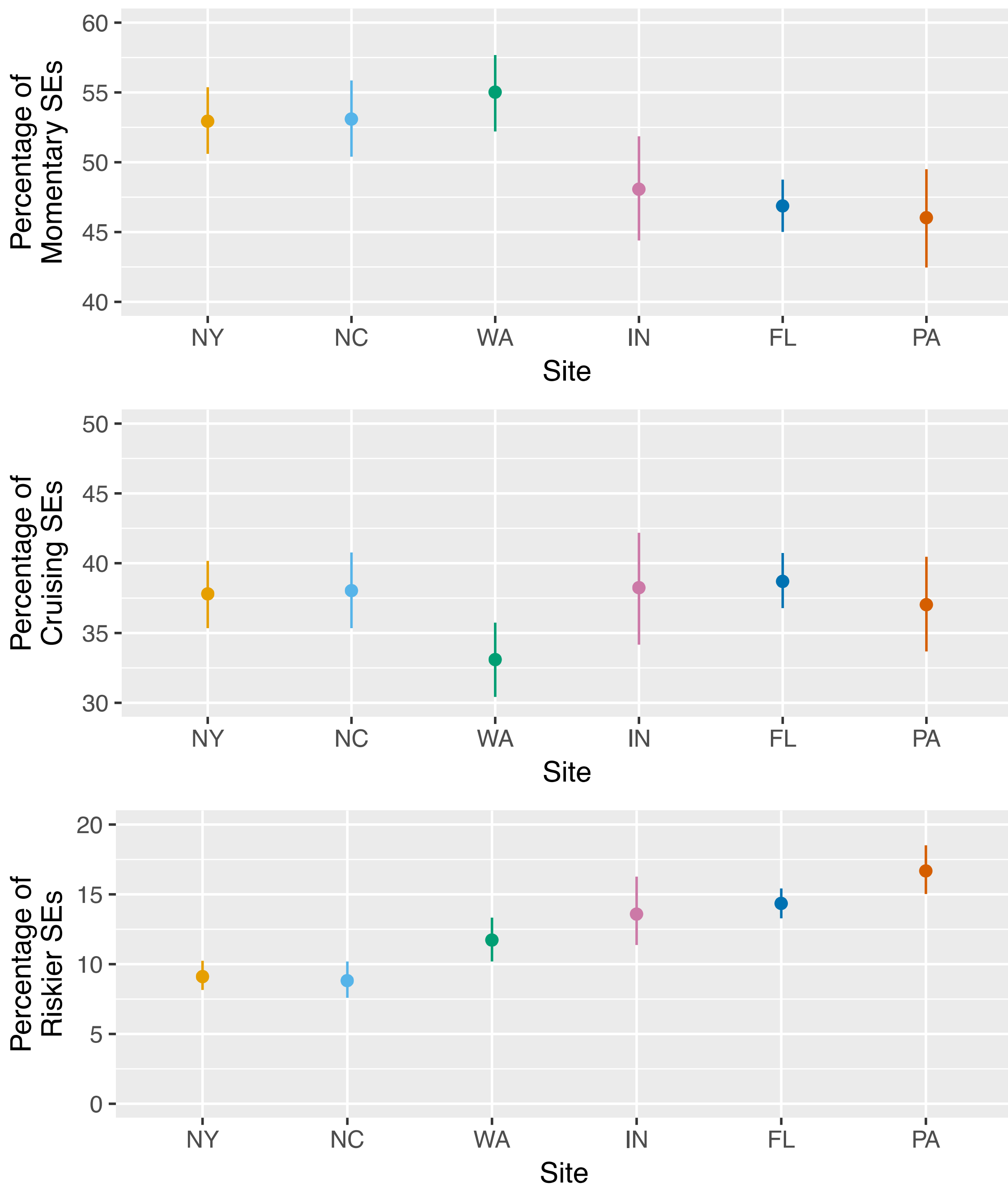

Figure 45. Proportion of each type of SE across sites based on the average proportion for each driver.

Differences in SE Characteristics across Posted Speed Limit

The following set of graphs show differences between the three SE types as a function of PSL. Posted speed limit serves as a proxy for type of roadway, since functional class information is not reliably available in the SHRP2 data used in this study. The highways and freeways typically represented by the higher PSL roadways have features that facilitate longer FFEs and SEs, and general design characteristics, such as more lanes, shallower curves, and longer stretches of straight roads that may facilitate sustained speeding. In contrast, speeding on lower PSL roadways may represent riskier driving given the higher prevalence of other road users, TCDs, and access points.

Maximum speed over PSL: For Momentary SEs, maximum speed over PSL was relatively constant across PSL, but with a slight downward trend (see Figure 46). Speeds were slightly faster for Cruising SEs, with the same trend across PSL. For Riskier SEs, speeds were noticeably faster and there was a pronounced decrease in maximum speeds at higher PSLs. The PSLs that corresponded to major arterial roadways (35-45) had the highest maximum speeds over PSL for Riskier SEs. In these SEs, drivers were traveling 40-60% faster than the PSL on roadways that likely had a greater density of potential hazards than other higher PSL roads (i.e., highways and freeways). Although maximum speeds within an SE were typically maintained only for short periods, Riskier SEs still had a mean speed over PSL of 15.8 mph. On lower PSL roadways, the higher kinetic energy and lower available response time afforded by the higher max speeds suggests that Riskier SEs were potentially the most unsafe of the SE types.

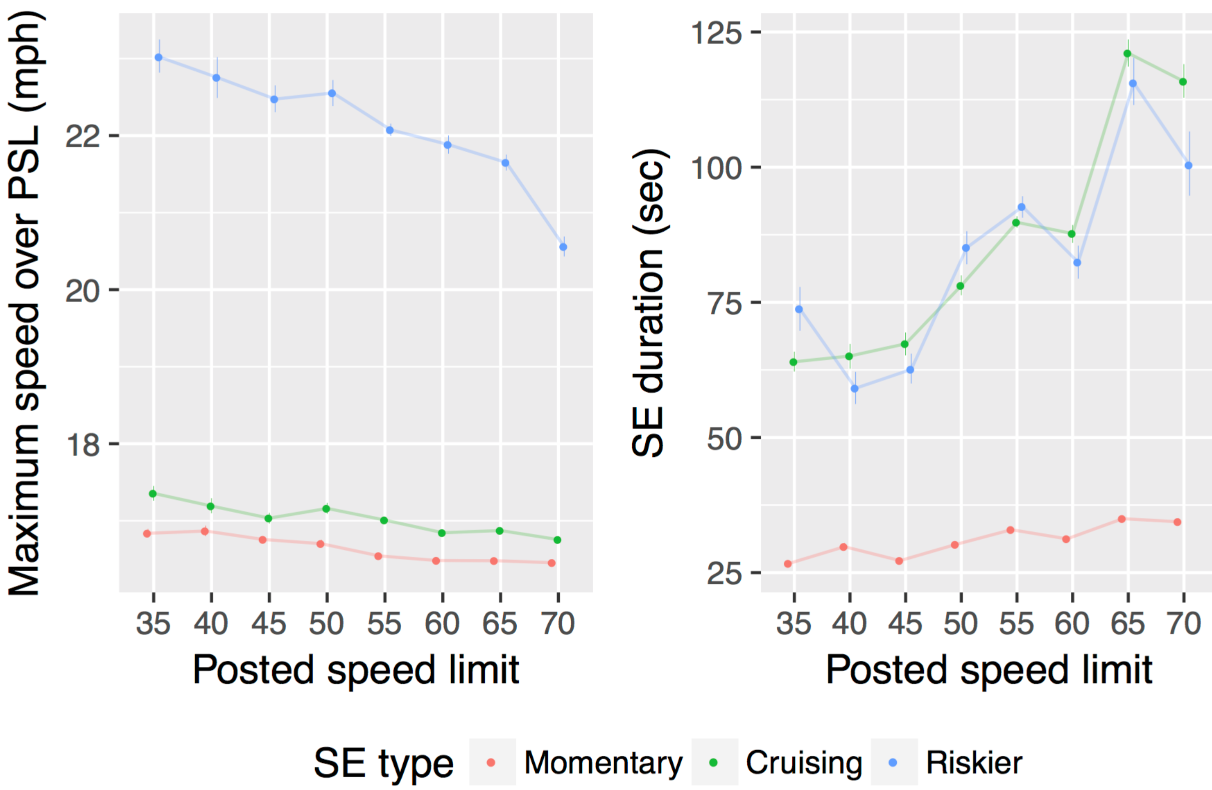

Figure 46. Maximum speed over PSL and SE duration across Posted Speed Limit for each type of speeding.

SE Duration: Duration increased with PSL for all SE types. Although the trend is less apparent with Momentary SEs, all types increased by approximately 40-60% over the PSL range. Mean SE durations were very similar for Cruising and Riskier SEs, with durations being slightly longer for Cruising SEs on higher PSL roadways.

The maximum speed over PSL and duration variables were essential for differentiating the three types of speeding. Each type has a unique combination of high and low values on each dimension:

Momentary SEs have lower speeds and shorter durations, Cruising SEs have lower speeds and longer durations, and Riskier SEs have higher speeds and longer durations. This suggests that the overall typology predominately captures differences in SEs at a high-level and that finer distinctions could be made by adding variables or by selecting Cluster Analysis outputs based on a greater number of clusters. Since the current research is exploratory and focused on high-level aspects of speeding behavior, the simplified typology described in this chapter adequately serves this purpose.

Maximum Longitudinal Acceleration: This measure represents the maximum value for calculated acceleration based on speed changes within SEs. It is an indirect measure of maximum acceleration imputed based on consecutive 1-Hz vehicle speed data points. This calculation accurately reflects acceleration over a timescale of multiple seconds, but because measurement frequency is relatively low, it misses rapid spikes in acceleration and generally underestimates the actual maximum values.

As shown in Figure 47, maximum longitudinal acceleration decreases with increasing PSL for all SE Types. The values are the lowest for Momentary speeding, which is consistent with these SEs having lower maximum speeds and the shortest durations. The values for Cruising speeding are slightly higher than for Momentary speeding. This could reflect the higher max speeds attained in these SEs, but it could also be that the longer SE durations provide more opportunity for a higher max acceleration to occur by chance.

The maximum acceleration values for the Riskier SEs are noticeably higher than other types at all PSLs except for 70 mph roadways. Some part of the higher acceleration level may arise from higher maximum speeds in Riskier SEs. The highest acceleration levels occur on the lowest speed roads where SEs tend to be shorter. Although shorter durations could require greater acceleration levels to reach the higher speeds, it only takes around two to three seconds to increase speed by 5 mph at these acceleration levels.

Maximum Longitudinal Deceleration: This measure represents maximum slowing activity during an SE. It was calculated the same way as maximum longitudinal acceleration, so the same underestimation of high values applies. The trend over PSL is relatively flat for Momentary and Cruising SEs, suggesting that driver slowing behaviors may have been relatively uniform in the different situations represented across PSLs.

Riskier SEs show a pronounced downward trend, which is similar to the max acceleration pattern. In general, the elevated acceleration and deceleration values for Riskier SEs are consistent with the notion that drivers are more active with their speed control, but there is no clear evidence of more aggressive braking behavior. Even accounting for the underestimation of max acceleration from how it is computed, the acceleration ranges are well within the “comfortable” deceleration range.

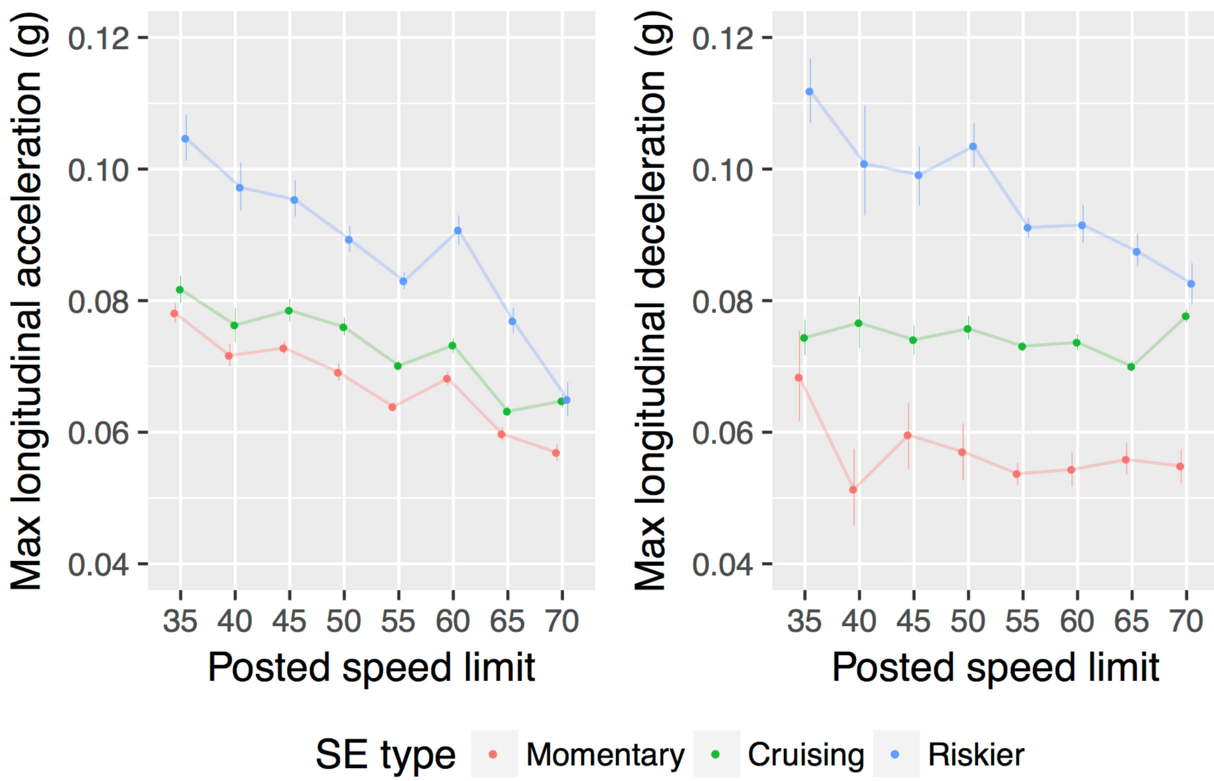

Figure 47. Maximum Longitudinal Acceleration and Deceleration across Posted Speed Limit for each type of speeding.

Standard deviation of longitudinal acceleration: This measure represents the variability in the vehicle's speed changes. The graph in the left panel of Figure 48 shows a general downward trend in standard deviation as PSL increases.

Cruising speeding has the lowest values, which is consistent with speed maintenance. The values for Momentary SEs are only slightly higher, which is likely tied to low overall speed changes with these SEs. The highest values occur in Riskier SEs. This is consistent with more active speed control behavior, in which drivers were repeatedly speeding up and slowing down in response to the driving conditions.

Standard deviation of gas pedal position: This measure reflects how active drivers were with their use of the gas pedal. There was a slight upward trend towards higher PSLs, especially for Momentary and Cruising SEs. This is interesting because, coupled with the trend towards lower standard deviation of acceleration, it suggests that to maintain steadier speeds at higher PSLs, drivers were more active with the gas pedal. Riskier SEs had the highest values overall, which was consistent with drivers actively controlling their speed over an extended period. Cruising SEs consistently had the lowest values, which was consistent with speed maintenance. Momentary SEs had intermediate values, and the strongest positive trend across PSL—increasing to the level of Riskier SEs on 70 mph roads. Since these SEs were short and most had a peaked shape, it is likely that drivers were adjusting the gas pedal position for most of the SE, which is consistent with making lane change or passing maneuver.

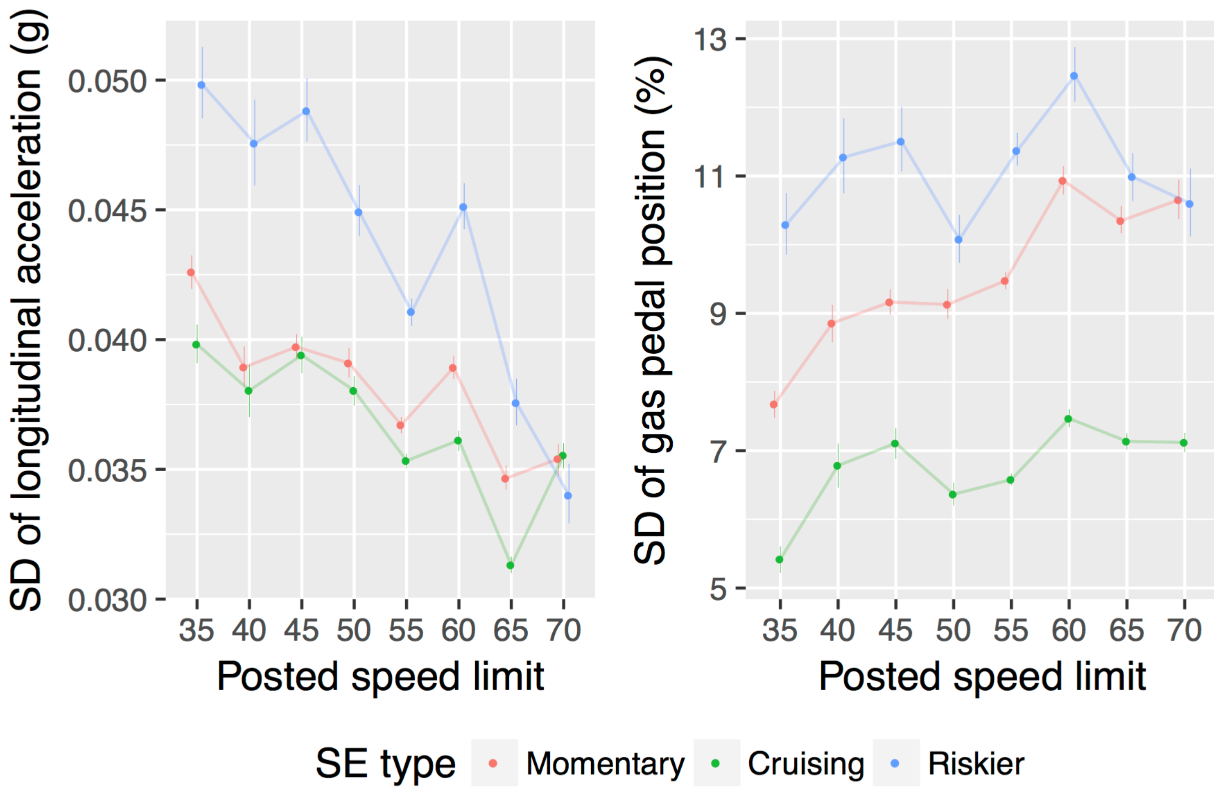

Figure 48. Standard Deviation of Longitudinal Acceleration and Gas Pedal Position across Posted Speed Limit for each type of speeding.

As the previous figures have shown, the characteristics of SEs differed across PSL in ways that were consistent with their underlying behavioral explanations. The driving conditions represented by different PSL roadways clearly influenced the characteristics of each SE type. One question is how did PSL influence the relative frequency of each type of SE? For example, since Riskier SEs had more unsafe characteristics, it is possible that speeders compensated by engaging in Riskier speeding less often on lower-PSL roadways (where hazards are more common) than on higher-PSL roadways.

Figure 49 shows the relative frequency of SEs within each SE type across PSL. The proportions plotted across PSL for a particular SE type add up to one. Because FFEs were more common on higher-PSL roadways, the count of each type of SE was divided by the count of FFEs at each PSL. This generally accounted for differences in FFE exposure across PSL.

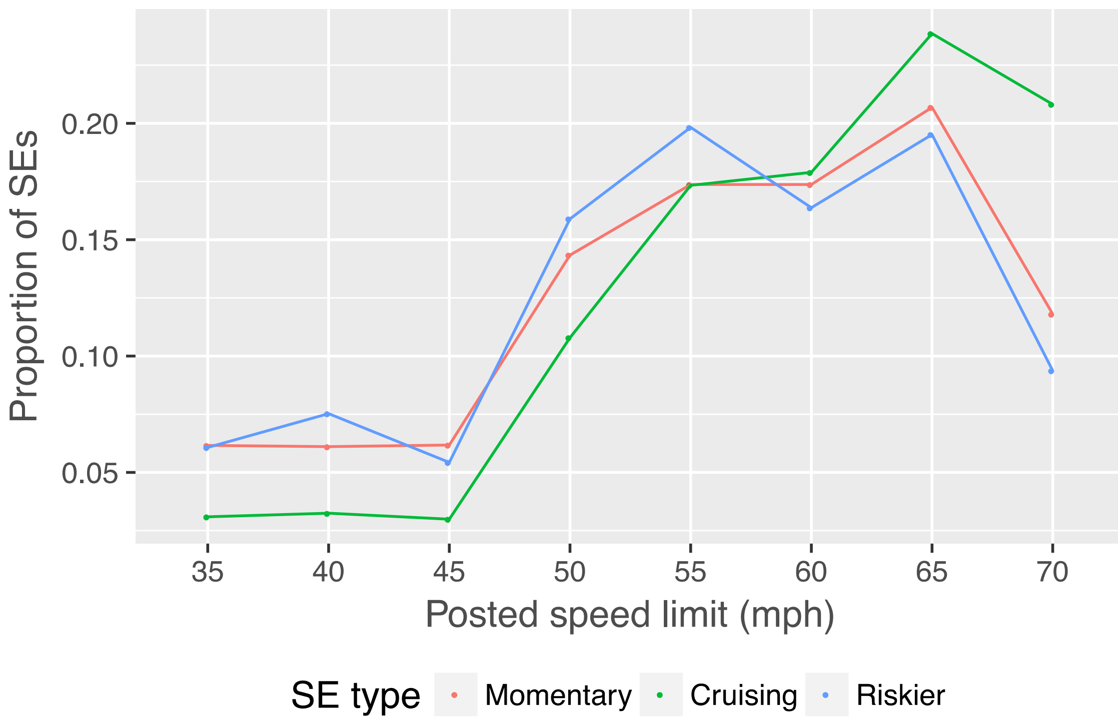

Figure 49. Proportion of each SEs across PSL for each type of Speeding. SE counts are normalized by FFE counts.

The most prominent pattern in Figure 49 is that, within each type of SE, speeding was less common on lower speed roadways. This could suggest that drivers were less likely to speed on roadways with a greater potential for hazards. Although this pattern is consistent with the notion described above that drivers engaged in less Riskier speeding to offset risk, the findings do not provide clear confirmation of this because the same pattern occurred for the other types of speeding—even more so for Cruising.

An alternative explanation for this pattern is that since FFE durations were generally shorter on lower PSL roadways, the corresponding opportunities may have been less accommodating of speeding overall, resulting in relatively lower frequencies. However, duration alone probably does not explain this pattern. Specifically, Momentary SEs were substantially shorter than Riskier SEs, which should have made them easier to "fit" within the shorter FFEs on lower-PSL roadways--and consequently more prevalent. However, there is no consistent difference in the relative frequency of Momentary and Riskier SEs on lower-PSL roadways. In fact, these types show almost the same relative distribution across all PSL levels. It is unclear why these frequencies are so similar. If Momentary SEs are shorter and less risky, they might be more balanced across all PSLs than Riskier SEs. Instead, the two types vary in sync, which suggests that roadway factors reflected by PSL influenced the relative frequency of these types of SEs in similar ways.

Relative to Momentary and Riskier SEs, Cruising SEs exhibited a slightly different pattern across PSL. Specifically, the relative differences in SE frequencies between lower and higher PSL roadways was greatest for Cruising speeding. This suggests that it may be harder to engage in SEs that have low speed variability on lower PSL roadways. With a higher density of potential hazards and access points on lower PSL roadways, speeding may have to be brief (i.e., Momentary speeding), or it may have greater swings in speed because of the complexity of driving on these roads (i.e., Cruising speeding).

The findings from this section indicate that SEs are clearly influenced by roadway conditions. This is not surprising given the differences in TCDs, potential hazards, and duration of the opportunities to speed on different PSL roadways. Speeding of all types was relatively less frequent on 35-45 mph roadways. However, when it did occur, it involved the highest maximum speed exceedances, especially for Riskier SEs. A key safety-relevant finding was that speeding episodes did not have characteristics that were noticeably less risky on lower PSL roadways.

Differences in SEs Across Time of Day and Month of Year

Figure 50 shows plots of the frequency of each type of SE across time of day and month of year. Note that these graphs are slightly different than the corresponding time and month plots in earlier chapters. Specifically, the graphs in previous chapter plotted the proportion of speeding time, whereas the graphs below are based on simple counts within each bin. Showing simple counts eliminates bias across SE types in the proportion calculation caused by the systematically different durations.

There were no meaningful differences for speeding type across time of day. Although it was likely that the "quality" of opportunities to speed changed throughout the day based on traffic levels, the time of the trip mostly affected the frequency of all SE types, rather than favoring one type over another. All types of speeding occurred at night, although at lower levels. This suggests that although driver curtailed their risk at night, they did not do so discriminately—either because they did not perceive a difference in risk between SE types or because they were unaware that they were curtailing their speeding in the first place. A similar pattern occurred for month of year. While the frequency dropped in the winter months, it did so for all SE types.

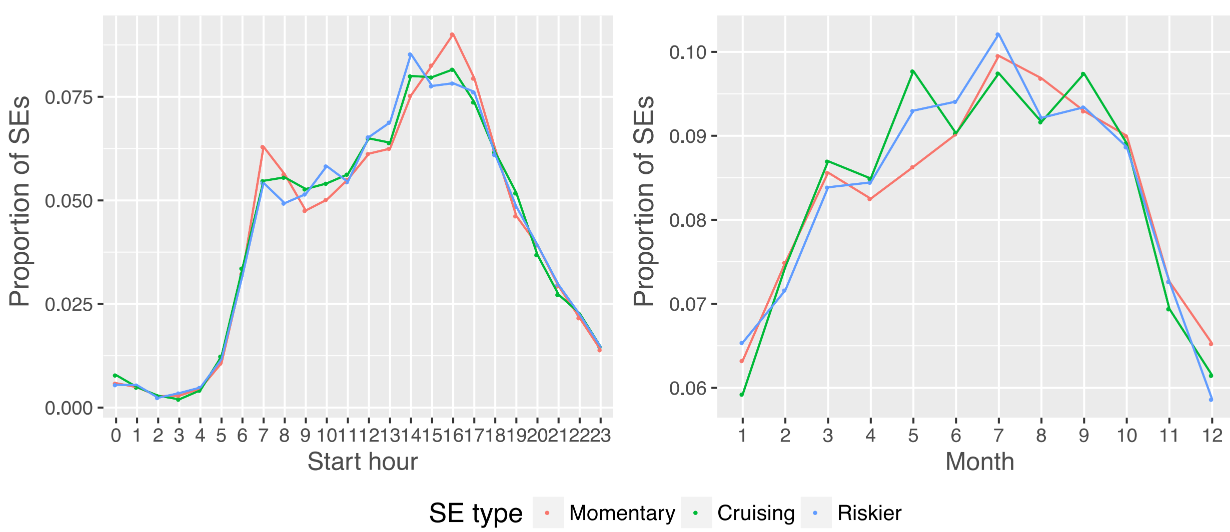

Figure 50. Proportion of each SEs across trip start hour and trip month for each type of Speeding.

Discussion

The Cluster Analysis of SEs conducted on variables that represented key dimensions of speeding divided the SEs into three interpretable types of speeding. The three types mapped closely to some of the types of speeding identified in the earlier MfS analysis that used a different dataset (Richard, Divekar, & Brown, 2016). The key aspects of the three types of speeding are summarized below.

Momentary Speeding: This type of speeding was typically comprised of a brief increase then decrease in speed. This type speeding could be unintentional, or it may occur in the service of a short-term tactical objective, such as making a lane change or passing another vehicle. These SEs most closely matched a cluster identified as "Casual" speeding in the previous analysis (Richard, Divekar, & Brown, 2016). The 25-35 second duration is likely too long for this type of SE to reflect incidental speeding that can occur because of normal fluctuations in vehicle speed (Richard, Divekar, & Brown, 2016). In contrast, Momentary speeding could reflect a variety of different driving behaviors or situations, such as making lane changes or passing other vehicles. It could also reflect the influence of local topography, such as being accelerated by gravity on a downhill grade. Another possibility is that it reflects brief inattention to the vehicle's speed, possibly while platooned with other fast-moving traffic. The key behavioral implication is that it seems to reflect neither a deliberate intent to speed in a sustained way, nor cautious attention to diligently keep below 10 mph above the PSL. Because of the multitude of possible causes, the term "Casual Speeding" places too much emphasis on driver-specific causes, which downplays likely influence of roadway and situational factors. Thus, the "Momentary Speeding" label better captures the transient nature of these SEs, especially since the short duration is the defining attribute of this type of speeding.

Cruising Speeding: This type of speeding was comprised of longer duration speeding consistent with speed maintenance behavior. Cruising speeding involved longer stretches of speeding that had lower speed variability, low maximum speed, and a generally flat shape. These SEs most closely match a cluster identified as "Cruising" speeding in the previous analysis (Richard, Divekar, & Brown, 2016). Since the SEs in both studies share the same basic characteristics, the term "Cruising" is an applicable label—especially since the label implies speed maintenance. A defining characteristic of Cruising SEs was a high rate of speed reversals per minute. These reversals often represented speed fluctuations around a stationary or drifting set point, which seemed to reflect consistent speed maintenance behavior for much of the SE. Another noteworthy characteristic of Cruising SEs is that they typically lasted for minutes. This means that drivers had ample time to observe the speedometer and become aware that were exceeding the PSL by at least 10 mph. It is likely that this type of speeding reflects a conscious decision by drivers to speed.

It is difficult to determine if Cruising speeding represents a greater safety risk than Momentary speeding. While the longer duration inherently increased exposure risk, there was also evidence of offsetting risk mitigation at the aggregate level. The median SE speed was slightly lower than Momentary speeding, and Cruising speeding was much less likely to occur on lower PSL roadways. Also, the driving conditions required to accommodate the low speed variability in Cruising SEs likely involved straighter, lower-access, and more open roadways where hazards may have been sparser.

Riskier Speeding: This type of speeding was characterized by multiple riskier attributes such as long duration, high maximum speed, and higher speed variability. These SEs were consistent with drivers actively controlling their high speeds. In the previous analysis, this type of speeding was termed "Aggressive Speeding" (Richard, Divekar, & Brown, 2016). The available data fields in the current analysis were slightly different. While the characteristics of Riskier SEs in the current analysis were more "aggressive" than the other types of speeding, the dataset lacked the appropriate variables to identify clear patterns suggesting that this arose specifically from aggressive actions on the driver's part. There was evidence of traffic interactions, but it was not necessarily weaving around traffic. Although the term "Aggressive" may not be completely suitable, the label of "Riskier" speeding does seem appropriate. These SEs had the highest speeds—especially on low PSL roadways, they had relatively long durations, and speed was consistently varying throughout the SE. In particular, on 35 mph roadways, the average maximum speed in Riskier SEs exceeded the PSL by 65%.

In general, the typology described in this chapter likely reflects broad difference in underlying speeding behaviors. A key challenge was that SE were analyzed in aggregate, and there was a lack of detailed situational information from forward video or radar to refine and validate the typology. Thus, the interpretation of the SEs was based primarily on the statistical properties of each type. It was possible to inspect time-series data for many of the SEs, and they were largely consistent with the interpretations; however, there were also many examples of SEs that did not fully match the prototypes or that could have been classified as one of the other types of SEs. As a high-level view of speeding behavior, the current approach met the research objectives, but there is still room for further research efforts to refine the current typology.

Developing valid and meaningful interpretations of the speeding types was important in the current study because the corresponding SEs form the input for the next stage of analysis, which involves identifying different types of speeders. Previous research, and the regression analyses described in earlier chapters, indicate that driver-specific factors influence speeding. If the SE types reflect underlying behaviors that differ in terms of riskiness and safety consequences, then not all drivers may be equally willing to engage in these riskier behaviors. Therefore, drivers should differ in terms of how much and what kinds of speeding they engage in. This premise forms the basis for approach taken to examine speeder types in the next chapter.

Chapter 11 – Typology of Speeder Groups

The previous chapter showed how the SEs observed in the dataset could be categorized into types of speeding that seemed to represent different underlying driver behaviors. Moreover, these behaviors differed in terms of potential safety risk. The primary question addressed in the current chapter is whether these different types of speeding arise because certain types of drivers are inclined to speed in these ways because of their demographics, attitudes, and other traits.

This chapter describes analyses conducted to develop a typology of speeders. The analysis was based on a second cluster analysis conducted to classify individual drivers into different driver types based on their observed speeding behaviors. More specifically, the extent to which drivers engaged in the different types of speeding described in Chapter 10 (i.e., Momentary SEs, Cruising SEs, and Riskier SEs). This chapter aims to answer two research questions:

- Is it possible to develop a meaningful typology of driver groups based their **observed** speeding behavior?
- Do the speeder groups reflect underlying differences in driver demographics, self-reported behaviors, beliefs, and attitudes?

The basic process to achieve the research objectives consisted of several steps. First, a Cluster Analysis was conducted to group driver types using proportion of each speeding types. Second, a Principal Component Analysis was conducted to interpret driver clusters from the previous step. Lastly, various comparisons and evaluations of the driver clusters were conducted by comparing SE statistics and driver-specific attributes across the groups.

Driver Type Analysis: Cluster Analysis and Principal Component Analysis

A cluster analysis was conducted to classify individuals into different driver groups based on their observed speeding patterns (e.g., proportion of each type of speeding as classified from the cluster analysis in the previous chapter). The clustering variables were simply the proportion of FFE time that each driver spent engaged in (a) Momentary Speeding, (b) Cruising Speeding, and (c) Riskier Speeding. Note that 227 drivers (10% of the sample) that had no speeding were excluded from the cluster analysis (but added as a separate non-speeder group later). K-mean clustering was applied to group driver by using the three proportion of SE variables. The four-cluster solution was the most interpretable. Along with the four clusters, an additional cluster was added (Cluster 0), which included the drivers without any speeding.

Figure 51 compares the different driver clusters based on individual drivers' proportion of each type of speeding. Each panel plots a different combination of SEs types. Overall, drivers were concentrated at the low end in terms of the proportion of each type of speeding, and the groups at this end generally appeared to be part of a larger continuum. It is only at higher proportions that greater differentiation seemed to occur among the groups. Drivers in Clusters 0 and 1 engaged in little or no speeding. Drivers in Clusters 2 and 3 engaged in relatively moderate amounts of speeding; however, Cluster 3 drivers had more Cruising speeding. Finally, drivers in Cluster 4 had the most speeding overall, in addition to the highest proportion of Riskier speeding.

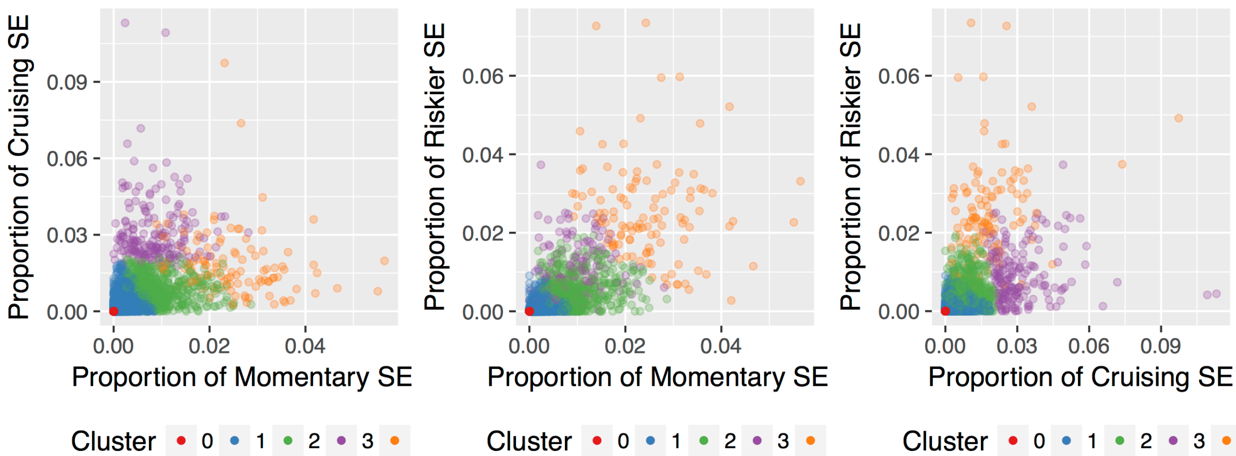

Figure 51. Driver clusters and proportion of each type of speeding.

Figure 52 shows the frequency with which drivers were assigned to different speeder clusters. Over 50% of the drivers were classified as Cluster 1. The two clusters that represented drivers that almost never sped (Cluster 0 & 1), accounted for the majority of drivers (66%). The next most common type of speeding was Cluster 2, which represented 22% of the sample. There was a relatively small number of Cluster 3 (7.8%) and Cluster 4 (4.8%) drivers. A favorable outcome from a safety perspective is that speeder group 4, which engaged in the most Riskier speeding represented just 5% of the total sample.

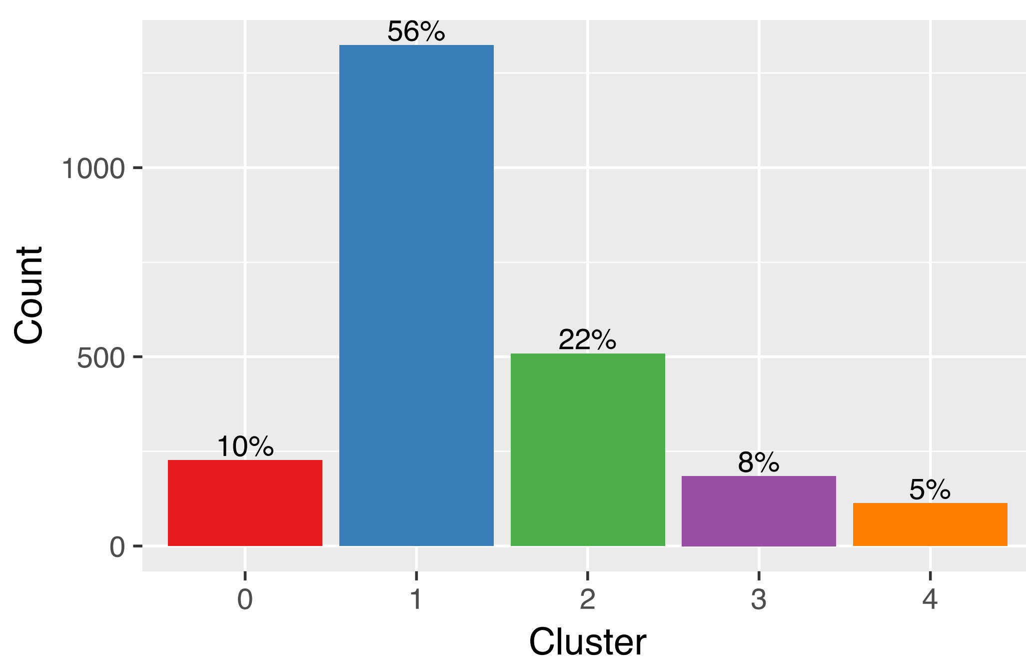

Figure 52. Distribution of drivers based on Cluster Analysis groupings.

A Principal Component Analysis (PCA) was conducted to identify patterns in the data and to help interpret the cluster analysis results. The PCA was run using the same proportion of each SE variables for individual drivers as the cluster analysis. In PCA, the number of distinct principal components is equal to the number of original variables, thus three principal components were identified. Table 14 shows percentage contribution of each speeding type to the three principal components (Dimension 1, Dimension 2, and Dimension 3). The percentage of contribution in Table 14 represents a relative measure of association between each variable and each dimension (the contribution values within a dimension sum to 100). Variables that are positively associated with a dimension are marked with (+), and variables that are negatively associated are marked with (-) in each cell. The first two Principal Components (Dimensions 1 & 2) explained around 90% of the variance in the data (Dimension 1=69% and Dimension 2=20%). Dimension 1 was positively associated with all types of speeding about equally. This suggested that Dimension 1 represented a general component related to the overall amount of any type of speeding. Dimension 2 and Dimension 3 accounted for less variance compared to Dimension 1 (20% and 10% respectively), but they were uniquely associated with specific speeding types. Dimension 2 was only positively correlated with the proportion of Cruising SEs, while Dimension 3 was only positively correlated with the proportion of Riskier SEs.

Table 14. PCA contribution table.

	Dimension 1 (69%)	**Dimension 2 (20%)**	**Dimension 3 (11%)**
Proportion of Momentary speeding	34.42 (+)	26.78 (-)	38.80 (-)
Proportion of Cruising speeding	27.46 (+)	68.73 (+)	3.81 (-)
Proportion of Riskier speeding	38.12 (+)	4.49 (-)	57.39 (+)

Figure 53 plots individual drivers within the original driver clusters/groups for the first two principal components (Dimensions 1 & 2), which were the most illustrative dimensions. This figure shows that Driver Clusters 1, 2, and 4 are clearly separated along Dimension 1, which indicates that those three types of drivers can be differentiated simply by the overall amount of speeding for each driver. Cluster 3 overlaps with Clusters 2 and 4 along Dimension 1 but is more distinct from all other Clusters along Dimension 2. This indicates that Cluster 3 can be characterized by intermediate ranges of all types of speeding, but with a higher proportion of Type 2 speeding. Although not shown, Dimension 3 differentiates Cluster 4 from the other clusters. Specifically, drivers in Cluster 4 not only had the greatest amount of speeding overall, but they also had a higher proportion of Riskier SEs.

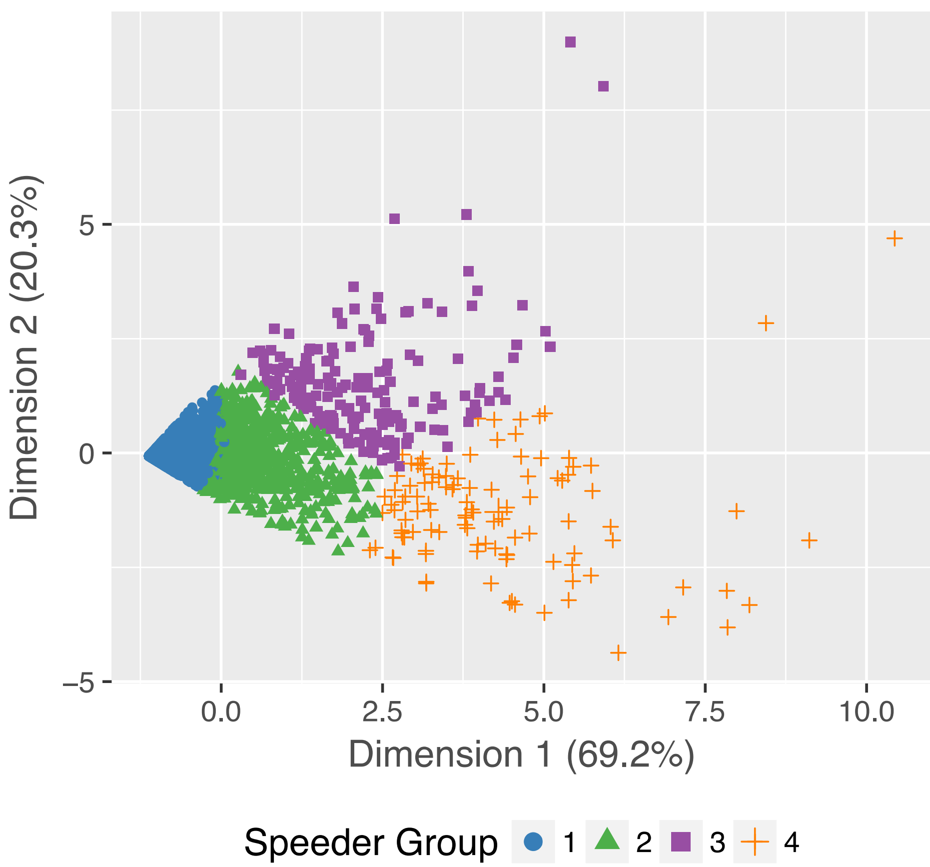

Figure 53. Individual drivers and driver clusters on the first two dimensions in PCA.

The PCA confirmed the basic trends apparent in the cluster analysis findings. Specifically, the amount of speeding was the key determinant of speeder group, accounting for 69% of the variance. This finding is notable because it is consistent with other studies that examined speeder types in which the overall amount of speeding was the key factor for differentiating driver types (e.g., NSSAB and Richard, Divekar, & Brown, 2017). The other two dimensions of the PCA respectively captured relatively higher amounts of Cruising SEs and Riskier SEs, which suggests that there are groups of speeders that differ in terms of the types of speeding they do.

Characteristics of SEs with Speeder Group

This section examines the characteristic of the SEs from each speeder group to identify how they differ regarding their underlying speeding behaviors. Table 15 provides basic descriptive statistics summarizing the SEs associated with the drivers in each group. The first row in the table shows the average proportion of time drivers in each group were speeding (Avg SE proportion). There was a strong increasing trend across the speeder groups. Groups 0 and 1 had little or no speeding (less than 0.5%) within their FFEs. The proportion of time speeding in Group 2 was almost five times higher (2.4%), and almost ten times higher for Group 3. Group 4 speeders had the highest proportion, speeding almost 7% of the time when they had an opportunity to do so. This trend of increasing proportion of speeding underscores the strength of Dimension 1 in the PCA.

The next three rows in Table 15 show the proportion of each SE type within each group. Group 1 had more Momentary speeding and the smallest proportion of Riskier speeding. Group 2 was similar to Group 1, in general, but it included relatively less Momentary and Cruising speeding and more Riskier speeding. Group 3 consisted of similar amount of Riskier speeding compared to Group 2, but had substantially more Cruising speeding at the expense of substantially less Momentary speeding. Group 4 had the highest proportion of Riskier speeding compared to the other speeder groups. There were also interesting similarities across groups. When they sped, Groups 1, 2, and 4 had similar proportions of the Momentary speeding (around 50%). These groups differed primarily in terms of the relative proportion of Cruising and Riskier speeding.

Table 15. Descriptive SE statistics for Speeder Groups.

	Speeder Group 0	Speeder Group 1	Speeder Group 2	Speeder Group 3	Speeder Group 4
Avg SE proportion	NA	0.005	0.024	0.049	0.068
Avg Proportion Momentary SE count	NA	0.55	0.51	0.28	0.48
Avg Proportion Cruising SE count	NA	0.37	0.33	0.57	0.24
Avg Proportion Riskier SE count	NA	0.09	0.16	0.15	0.28
Avg of Total FFE duration (sec)	47,080	70,616	74,716	95,898	74,547
Avg No. Trips per driver	74.15	87.87	87.13	88.76	87.49

Table 15 also shows the average of drivers' total FFE duration within each speeder group. This measure provides an indication of the average level of exposure to opportunities to speed across driver groups. Group 0 had substantially less FFE exposure than the other groups, whereas Group 3 had the most. The remaining groups had approximately the same. The last row of the table shows the average number of trips per driver in each group. This indicated that the low exposure for Group 0 arose in part from fewer trips, but the FFE time per trip was also lower. In contrast, Group 3 had approximately the same average number of trips per driver as Groups 1, 2, and 4, so the average FFE time was longer for Group 3. These patterns suggest that basic trip characteristics were somehow related to the type of speeder.

Figure 54 shows the average maximum speed over PSL (left panel) and average SE duration (right panel) for each speeder group. The pattern regarding average maximum speed over PSL speed reflects the underlying SE characteristics. Speeder group 4 had the highest max exceedance, which was consistent with the higher proportion of Riskier SEs within the group. Drivers in group 1 had the lowest max speeds, which could be due to these drivers having the lowest proportion of

Riskier speeding. The other two groups had similar intermediate values on maximum speed exceedance.

Regarding Average SE duration, Speeder Groups 1 and 2 had the shortest durations. Average SE duration was longer still in Group 4, while Group 3 had the longest durations. The difference in average SE duration between Groups 3 and 4 is an interesting pattern. The analysis of speeding types in the previous chapter indicated that average durations of Cruising SEs were less than 10 seconds longer than Riskier SEs. However, the difference in average duration between Group 3, which contains more Cruising speeding, and Group 4 which contains more Riskier speeding, was substantially greater than 10 seconds. This suggests that Group 3 drivers may have had longer SEs in general, not just a higher proportion of Cruising SEs.

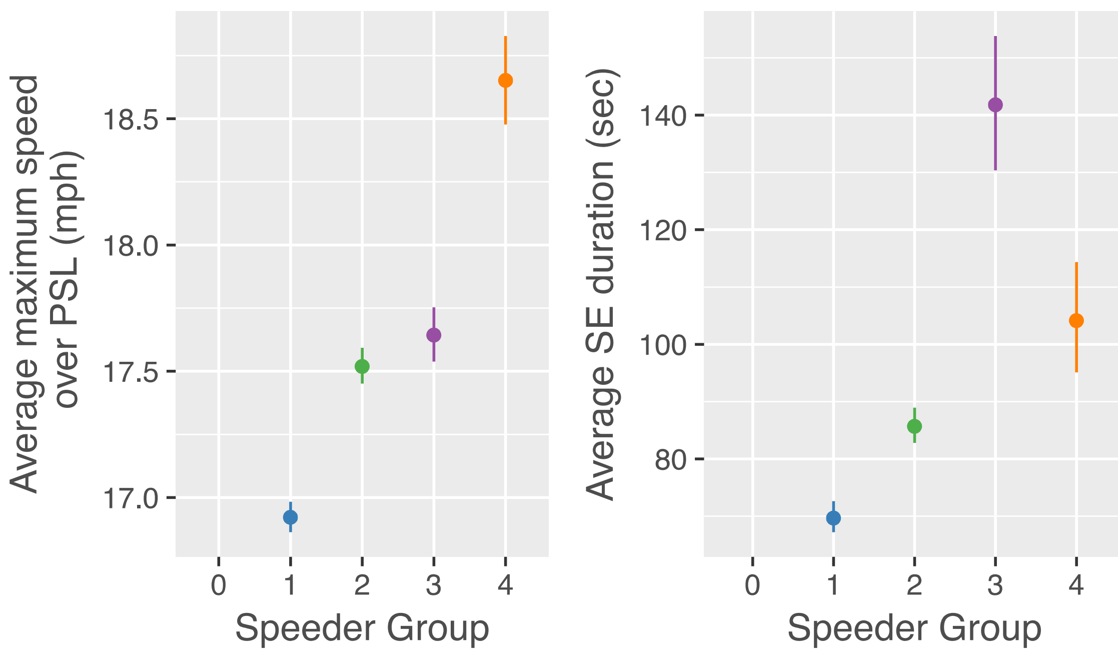

Figure 54. Average maximum speed over PSL and SE duration across Speeder Groups.

Figure 55 shows how the ratio of number of SEs to number of trips was distributed among drivers within each group. Note that the y-axis range shifts across panels to better show the within-group distributions. In general, the distributions shift progressively to higher values from Group 0 to Groups 3 and 4, which indicates a higher frequency of speeding per trip in the later groups. Groups 0, 1, and 2 averaged less than 1 SE every 2 trips, while groups 3 and 4 averaged closer to 1 per trip. The latter groups had similar distributions, which also included a few outlier drivers who had a much higher ratio between SEs and trips (i.e., greater than two).

Figure 55. Distributions of ratio between SE counts and trip counts across Speeder Groups.

Given that driver types were classified by proportion of speeding type, SE characteristics of each speeder group showed the expected patterns. Groups at the low end were labeled based on SE frequency, while groups at the high end were labeled based on their defining SE characteristics. The groups were:

Speeder Group 0: Non-speeders. This group was simple to label since they were not observed speeding in the trip sample; however, it was possible that they had SEs on trips that were not included in the dataset. Nevertheless, this group still appeared to be distinct from Group 1, with substantially fewer trips and lower exposure to FFEs.

Speeder Group 1: Infrequent Speeders. This group almost never sped, but when they did, it mostly involved Momentary SEs. This group also had the smallest proportion of Riskier SEs. It is possible that this group overlaps with the Non-speeders; however, this group is much more like the other speeder groups when it comes to average number of trips and FFE exposure. Infrequent speeders were the most common speeders, comprising just over half of the driver sample. Thus, they represent modal speeding behavior in the current sample.

Speeder Group 2: Occasional Speeders. Speeding was not a rare occurrence for these drivers; they averaged around one SE every two trips and their proportion of speeding was five times higher than the Infrequent Speeder group. Their average SE duration was over 80 seconds long and their average maximum SE speed was greater than 15 mph above the PSL, so these drivers were clearly not speeders by chance. Although half of the SEs associated with this group were Momentary SEs, these drivers had the same proportion of Risker speeding as Group 3.

Speeder Group 3: Long-duration Speeders. This group of speeders had the highest proportion of Cruising speeding, which reflected more deliberate speed maintenance that was well above the PSL. This group stood out from the other groups by having substantially longer average SE durations and greater total exposure to opportunities to speed. The higher FFE exposure levels suggests that these drivers may have engaged in qualitatively different driving overall, so their travel patterns and/or driving environment could have contributed to this speeding behavior. These speeders also had the second highest amount of speeding, which was almost 10 times greater than the modal Infrequent Speeders. The Long-duration speeders may also have experienced elevated safety risk. This is primarily because the long SE durations—which were compounded by the longest FFE times—resulted in the highest levels of speeding exposure. As discussed in Chapter 10, the Cruising SEs may not have riskier characteristics than other SE types, but the extended durations alone may leave drivers more vulnerable to unsafe driving scenarios.

Speeder Group 4: High Speeders. This group's label reflects the fact that these drivers had the highest proportion of speeding, the highest maximum speeds above the PSL, and the highest proportions of the Riskier 3 SEs. Their proportion of speeding time was over 13 times greater than the modal Infrequent speeders. Even relative to the next-highest Long-duration speeders, High speeders had 50% more speeding overall, and twice as high a proportion of Riskier SEs. These drivers were clearly at the high end regarding the riskiness of their speeding behaviors.

This initial analysis formed the starting point for taking a closer look at the notion that there were different types speeders within the SHRP2 dataset. The cluster analysis of speeder groups suggested that drivers could be differentiated based on their actual speeding behavior (i.e., different SE types). A key question is whether these behaviors reflect differences in driver attitudes, beliefs, and other driver-specific factors. The driver-specific regression analysis from Chapter 7 suggested that this was the case at a high-level, since driver-specific factors were predictive of the overall amount of speeding across drivers. The analyses in the rest of this chapter examined this issue from a more practical perspective. Specifically, the analyses investigated if there were sub-types of drivers that engaged in riskier driving and who shared specific attitudes, beliefs, and behavior related to speeding. If so, it could provide new avenues for identifying at-risk individuals and targeting their specific beliefs and attitudes towards speeding with safety countermeasures.

The following sections examine the relationship between the driver types and the driver assessment questionnaire data that participants completed at the outset of their SHRP2 study participation. The reason for examining these variables was to determine if the behavior-based differences in speeding also correspond to driver traits that indicate greater acceptance of risky speeding behaviors.

Driver Type Analysis: Speeder Group Evaluation (Demographic Factors)

The previous section showed how the SEs associated with the speeder groups differed. This section expands the investigation of speeder groups to examine how the demographic characteristics of drivers vary across the groups. Figure 56 shows the composition of each speeder group based on age category. There were two noteworthy patterns. The most prominent was the strong age trend that was consistent with the notion that younger drivers were more likely to engage in risker driving behaviors. The other side of this pattern was that it was the oldest drivers in the sample that were the most likely to avoid speeding—a pattern that was not evident in the middle age range.

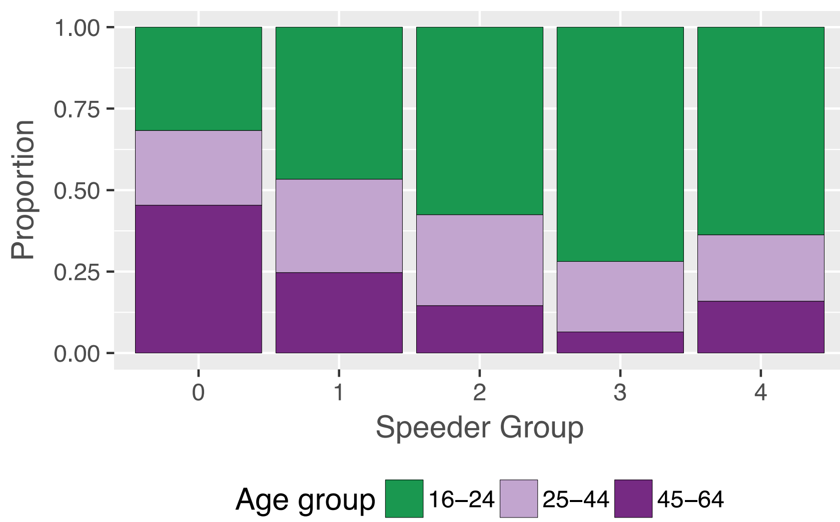

Figure 56. Proportion of age groups across Speeder Groups. Group numbers correspond to the following: Non-speeders = 0, Infrequent speeders = 1, Occasional speeders = 2, Long-duration speeders = 3, High speeders = 4.

The 16-24 years old group spans a wide range of cognitive and emotional variability (e.g., Dahl, 2004). Their travel patterns may also differ, since teenagers are still in school. To better understand age differences at the young end, the 16-24 group was split into two subgroups for subsequent analyses: (a) 16-19 teen drivers and 20-24 young-adult drivers. Figure 57 shows the age compositions of the groups based on the new age categories. The proportions for the older age groups were the same as in Figure 56. Figure 57 reveals an interesting pattern regarding the younger drivers. The proportion of teen drivers was relatively consistent across speeder groups, with perhaps a small increasing trend across speeder groups. In contrast, the proportion of young adult drivers increased steadily from the Non-speeder to the Long-duration speeder groups. This indicates that the age trend involving younger drivers apparent in the previous Figure 56 appears to occur primarily because of the distribution of young adults.

The Occasional and High speeders showed similar age compositions. Both groups had age categories that were somewhat more balanced compared to the others. However, given that their SE characteristics were substantially different, it must be that other driver-specific traits, or speeding opportunities differentiated Occasional and High speeders, since age differences did not.

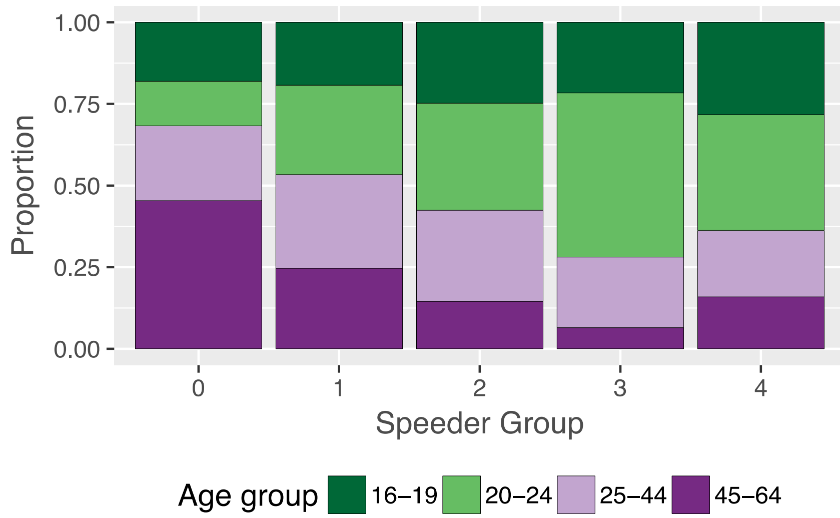

Figure 57. Proportion of the revised age categories across Speeder Groups. Group numbers correspond to the following: Non-speeders = 0, Infrequent speeders = 1, Occasional speeders = 2, Long-duration speeders = 3, High speeders = 4.

Gender was not a factor in group composition. The percentages of males and females was essentially the same in all speeder groups. Even when breaking out gender by age, the distributions were almost the same. (see Figure 58). The stereotypical view of speeding being a young male problem was not consistent with the data patterns in the current dataset.

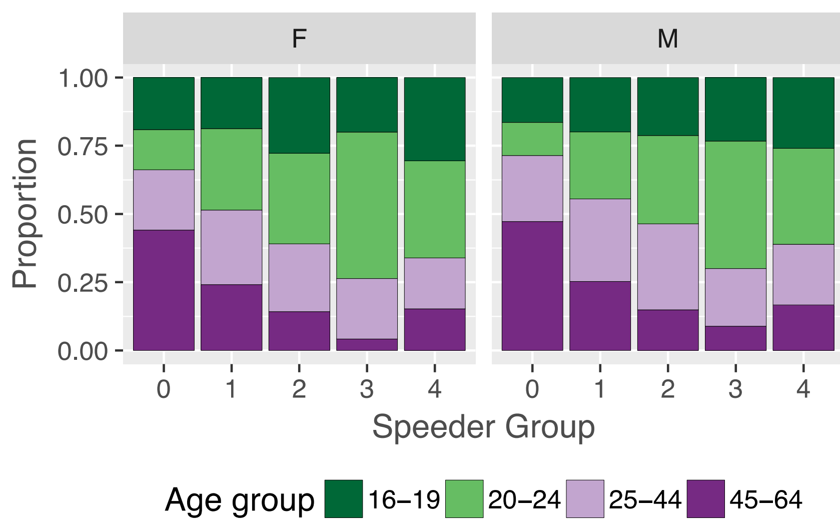

Figure 58. Proportion of the revised age groups across Speeder Groups and gender groups. Group numbers correspond to the following: Non-speeders = 0, Infrequent speeders = 1, Occasional speeders = 2, Long-duration speeders = 3, High speeders = 4.

Figure 59 shows self-reported responses to four demographic questions across the driver groups. These include marital status, annual income, education level, and annual mileage. In each graph, there were differences apparent across speeder group. For marital status, the proportion of single participants increased steadily up to the Long-duration and High speeder groups, while the proportion married decreased. For education, the proportion of drivers with college degrees or some college increased steadily across groups, which mirrors the levels of young adults (20-24) within these groups. Annual income showed a similar pattern; the proportion of participants that reported the lowest income bracket increased steadily across groups. The data patterns in all three of these cases could be attributed to age differences across the groups.

The exception to the latent age-related pattern was self-reported annual mileage. Although there was a high degree of variability, Long-duration and High speeders reported higher mileage. For Long-duration speeders, this was consistent with the higher total FFE duration, but there was no obvious explanation for High speeders.

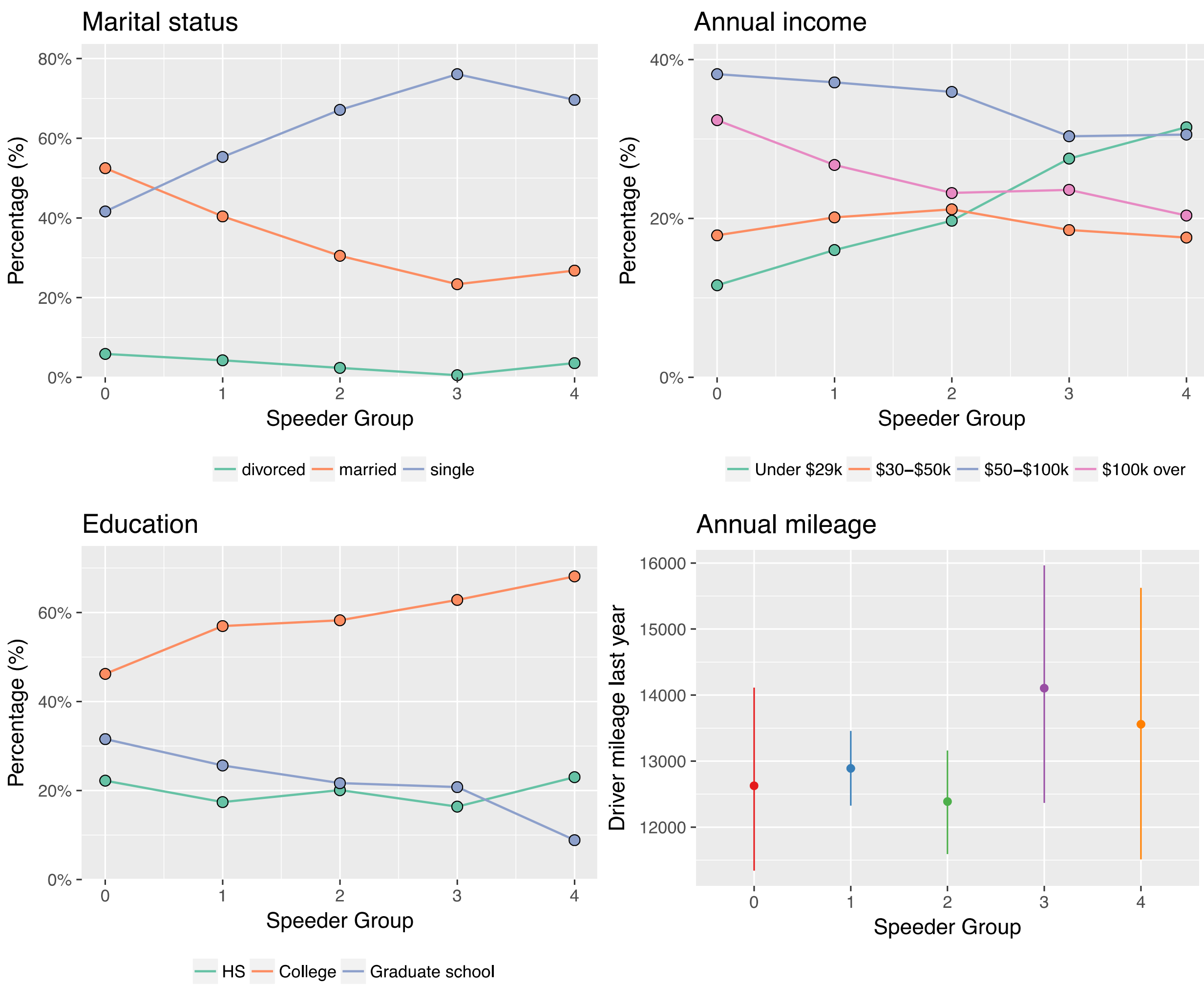

Figure 59. Comparisons of Speeder Groups in marital status, annual income, education level, and driver mileage. Group numbers correspond to the following: Non-speeders = 0, Infrequent speeders = 1, Occasional speeders = 2, Long-duration speeders = 3, High speeders = 4.

The last demographic factor examined was site. Figure 60 shows the proportion of each speeder group by site. Washington and New York had the highest proportion of Non-speeders and Infrequent speeders. These sites also had the lowest proportions of Long-duration and High speeders. In contrast, Florida and Pennsylvania showed the opposite pattern. These sites had the smallest proportion of Non-speeders and Infrequent speeders, and the largest proportions of Long-duration and High speeders. The two remaining sites had intermediate proportions of different groups, some on the higher end and others on the lower end. It is unclear at this point what factors may account for these differences, and there are no obvious differences in terms of characteristics of the road network or potential cultural differences to explain the data pattern in Figure 60.

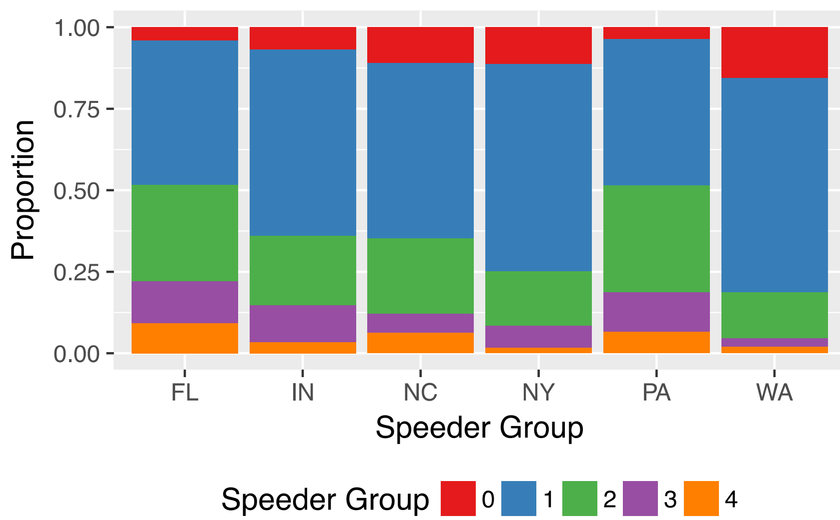

Figure 60. Compositions of Speeder Groups across sites. Group numbers correspond to the following: Non-speeders = 0, Infrequent speeders = 1, Occasional speeders = 2, Long-duration speeders = 3, High speeders = 4.

The investigation of drivers' demographic characteristics (e.g., age, gender, etc.) indicated clear differences across speeder groups. The most prominent trend was the increasing proportion of young adults and decreasing proportion of older drivers across the groups that reflected progressively riskier speeding. This age trend likely accounts for most of other demographic differences, except for site differences. Also, the proportion of teen drivers did not vary greatly across speeder groups, so it is possible that other factors determine speeding behaviors in this age group.

Driver Behaviors, Attitudes, and Beliefs

This part of the analysis examined the extent to which driver behaviors, attitudes, and beliefs towards speeding and other risky actions were related to speeder type. Driver responses from the enrollment questionnaires were summarized across speeder group.

Figure 61 shows self-reported number of violations and number of crashes for past three years. There were clear trends across speeder group. The proportion of 1 and 2+ violations increased across groups, and there was a corresponding decrease in the proportion of drivers reporting zero violations. This pattern mirrors the steady increase in the amount of speeding across groups, although the violations were not necessarily speeding related. The same trends were apparent with self-reported crashes. The trends in violations and crashes provide some validation of the notion that the speeder groups differ in terms of risky driving behaviors.

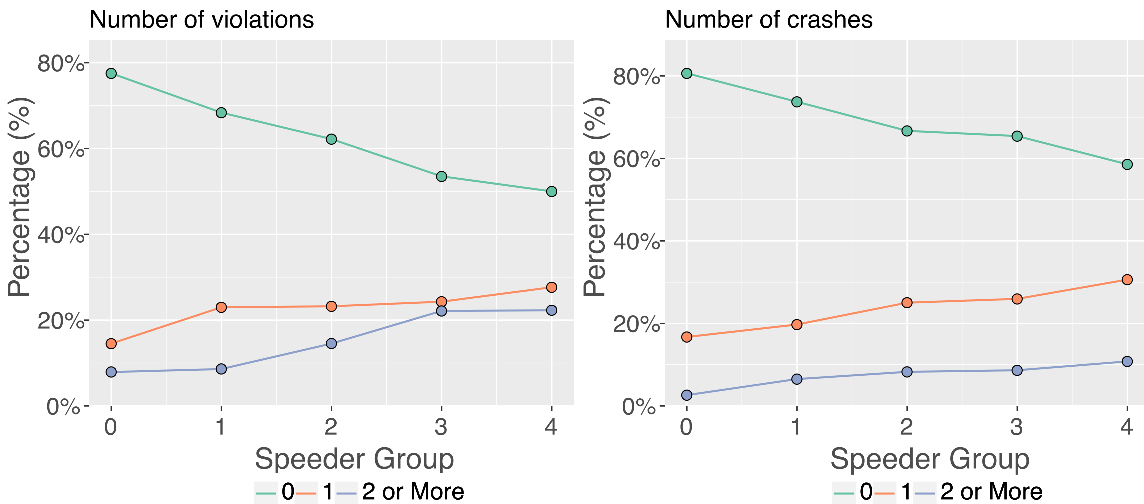

Figure 61. Percentage of drivers reporting 0, 1, or 2 violations and crashes across Speeder Groups. Group numbers correspond to the following: Non-speeders = 0, Infrequent speeders = 1, Occasional speeders = 2, Long-duration speeders = 3, High speeders = 4.

Figure 62 shows the relationship between the speeder groups and how drivers were categorized based on their responses on the Driver Behavior Questionnaire (DBQ). DBQ category assignment was based on the extent to which drivers reported engaging in driving behaviors reflecting "aggressive violations," "violations," "errors," and "lapses" (Reason et al., 1990). Based on the pattern of their responses, drivers were categorized into one of four groups: "Aggressive" (risk takers), "Casual" (about safety risk), "Careful", and "Inattentive" drivers. For the "Casual" and "Inattentive" DBQ types in Figure 62, there was little change across the speeder groups. However, a clear pattern emerged for the two DBQ types that represented opposite ends of risk-taking spectrum. Specifically, the proportion of drivers categorized as "Aggressive" increased steadily from groups Non-speeders to Long-duration speeders, while the proportion of drivers categorized as "Careful" decreased. The High-speeder group was an exception to this pattern. This group contained similar proportions to the Occasional speeder group. These findings suggest that the behavior-based speeder typology also captures high-level differences in self-reported driving behaviors related to risk.

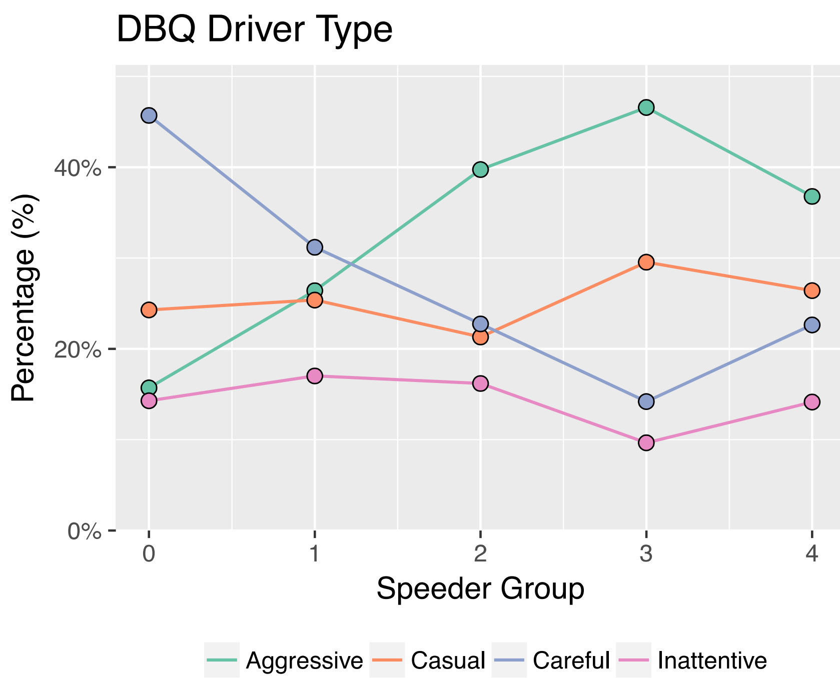

Figure 62. Percentage of DBQ driver types across Speeder Groups. Group numbers correspond to the following: Non-speeders = 0, Infrequent speeders = 1, Occasional speeders = 2, Long-duration speeders = 3, High speeders = 4.

Figure 63 shows the relationship between the speeder groups and summarized driver responses to a battery of risk-perception questions. Specifically, drivers were categorized into different "Risk Affinity" types based on patterns in their risk perception scores. This yielded four types of drivers, those that were: "Risk averse", had a "Low Risk" appetite, were "Casual" in their risk acceptance, and "Risk Inclined." These groups were categorical and not linearly separated. The pattern of results somewhat mirrored those of the DBQ driver types. The proportion of drivers that were "Risk Inclined" increased with speeder group, with no difference between Long-duration and High speeders. In contrast, the proportion of drivers that were "Low Risk" showed the opposite pattern. Note that the "Risk Averse" group was too uncommon to show meaningful changes across speeder group. These findings provided additional evidence that the behavior-based speeder typology also captured differences in self-reported driving behaviors related to risk.

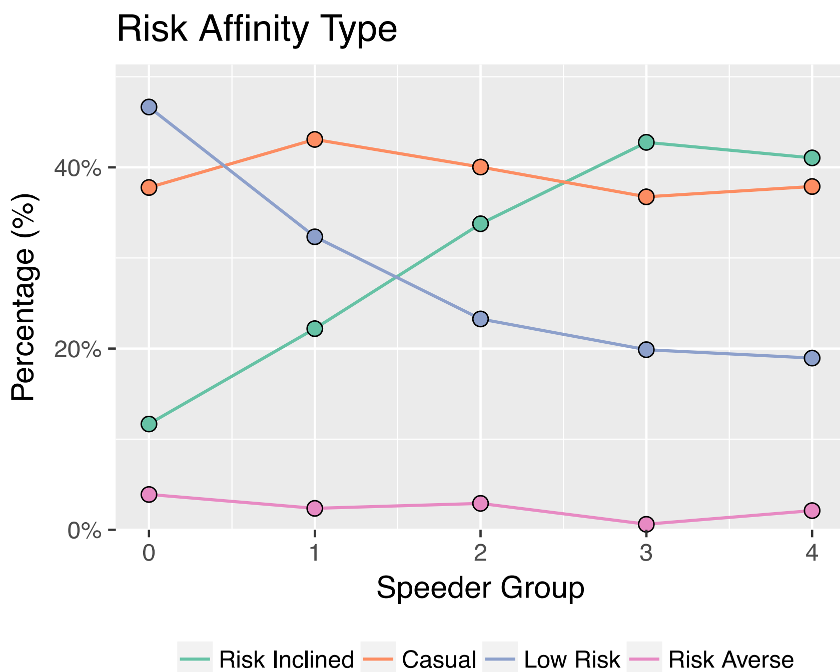

Figure 63. Percentage of driver Risk Affinity type across Speeder Groups. Group numbers correspond to the following: Non-speeders = 0, Infrequent speeders = 1, Occasional speeders = 2, Long-duration speeders = 3, High speeders = 4.

Figure 64 shows the relationship between the speeder groups and the average Sensation Seeking Score for drivers in each group. The pattern is similar to the DBQ and risk perception graphs. There is a steadily increasing trend up to the Long-duration and High speeder groups, which have comparable scores.

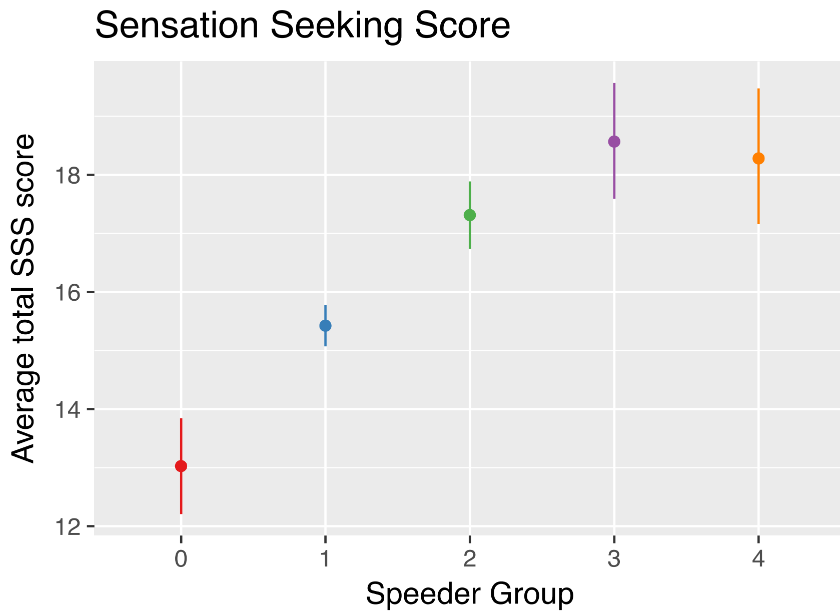

Figure 64. Average Sensation Seeking Score across Speeder Group. Group numbers correspond to the following: Non-speeders = 0, Infrequent speeders = 1, Occasional speeders = 2, Long-duration speeders = 3, High speeders = 4.

There is conceptual overlap between the three psychological measures described above, which may contribute to the overall consistency in the pattern of results. Nevertheless, these measures provide converging evidence for the notion that the speeder groups not only reflect difference in risky speeding behavior, but also comparable differences in attitudes and beliefs related to risk.

The next two figures examine driver responses to individual question items related to speeding. Figure 65 shows the distribution of responses to questions about how frequently drivers reported engaging in: (a) driving 10-20 mph above the PSL, (b) driving faster than 20 mph above the PSL, and (c) speeding for thrills. The first two questions map to the speeding behaviors underlying the speeder groups. Speeding episodes were based on driving at least 10 mph above the PSL. In addition, most of the Riskier SEs involved exceeding the PSL by at least 20 mph, whereas speeds in the other types of SEs typically stayed below this level (ranging between 10-20 mph above the PSL). The response patterns across speeder groups reflect these SE differences.

For the question about driving 10-20 mph above the PSL, Non-speeders were the most likely to report never speeding. However, around 5-25% of drivers in the other speeder groups also reported never speeding, which suggest some degree of a social bias effect in the responses. In general, the pattern of responses was similar to the previous pattern regarding risk questions. At both the “Never” and the “Often” ends of the scale, there was a trend towards risker responses across groups, with Long-duration and High speeders showing minimal differences.

The pattern was slightly different in the 20+ mph question. The general trend across groups was similar, but Long-duration and High speeder differed in that the High speeders reported higher proportions of “Often” responses, and lower proportions of “Never” responses. This is consistent with the finding that Riskier SEs—which reached higher speeds over the PSL—were concentrated among High Speeders. These respones also suggest that these speeders demonstrate some degree of awareness of their high speeding. The other difference in the responses to this question is the overall proportion of “Never” responses is much greater across all groups, which is to be expected with this level of speeding.

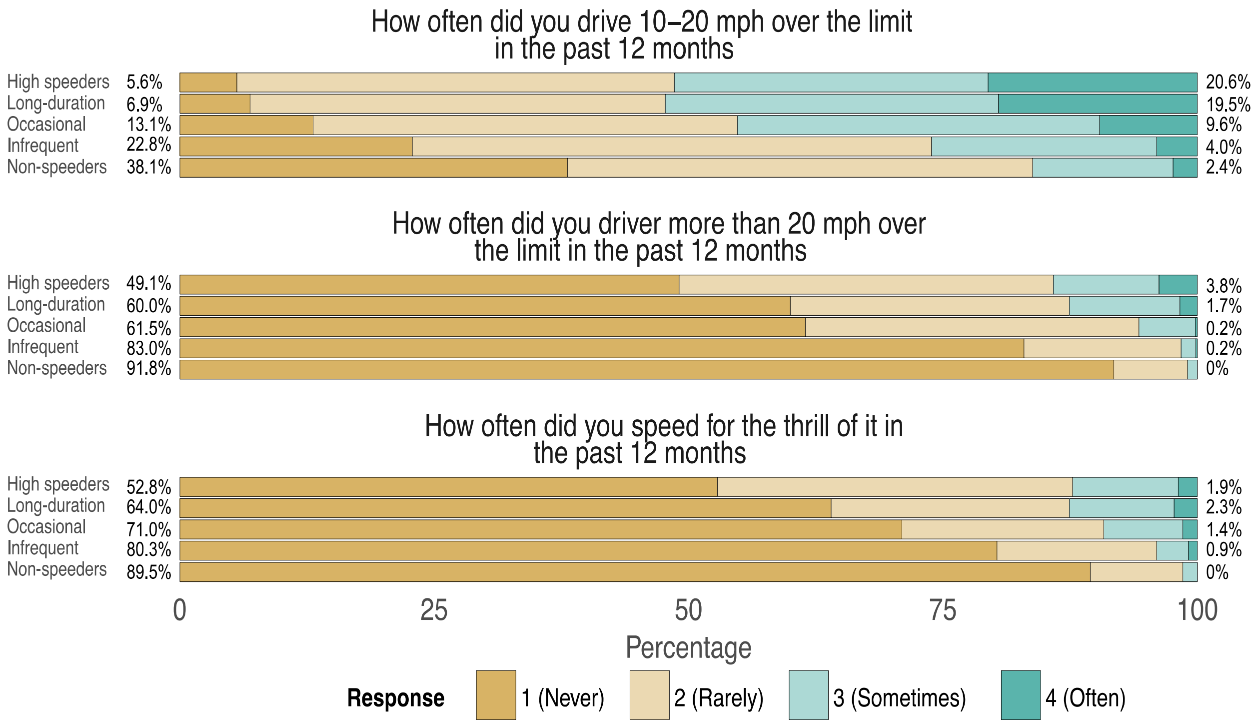

Figure 65. Examples of speed-related risk-taking questions.

The third question about speeding for thrills relates to the previous psychological constructs. It represents a risky, sensational action. The fact that the proportion of “Never” responses is similar to the 20+ question, suggests that most drivers view speeding for thrills as unacceptable driving behavior. The pattern of responses fits the same trend that was observed for the other constructs. The only difference was that the High speeders were less likely to report “Never” engaging in this behavior than the Long-duration speeders.

Figure 66 provides a different take on the behaviors discussed in Figure 65. These questions probed how risky drivers perceived speeding to be. The expected trend across groups was apparent in all of the questions, but only for the “Much Greater Risk” end of the scale. Across questions, drivers generally rated driving less than 20 mph over the PSL as the least risky, and driving more than 20 mph above the PSL as the riskiest. Speeding for thrills had intermediate ratings. Although the High speeder group was the only group to consistently exceed the PSL by 20 mph, there was not much difference in perceived risk between this group and the Long-duration speeder group on the 20+ mph question. It may be that more High Speeders perceived this action to be “No Greater Risk.” However, the percentages were small for this end of the scale and highly variable, so it may not be a reliable finding. Apart from the global differences across questions, the match between perceived risks of speeding to either self-reported and observed behavior appears to be weak.

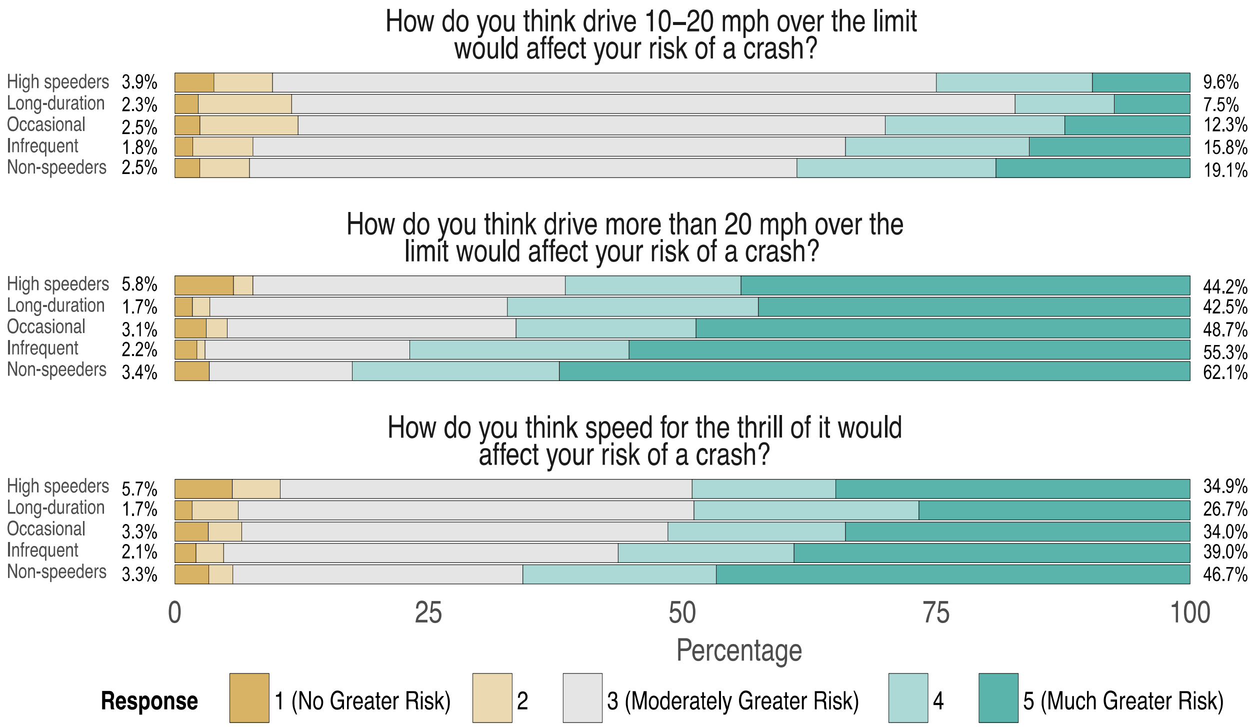

Figure 66. Examples of speed-related risk behavior questions.

The findings discussed in this chapter showed clear differences across the speeder groups. The proportion of: (a) young drivers and (b) drivers that were accepting of risky actions increased steadily across driver groups for several of the measures. However, this pattern broke down for the two groups that represented the riskiest driving behaviors: Long-duration speeders and High speeders. Drivers in these two groups were generally more similar in their characteristics and responses than the other groups. This raises the question of whether these drivers actually represent different speeder types, or whether the underlying differences in their speeding behaviors are merely an artifact of their driving patterns.

To examine this question, two separate logistic regression analyses were conducted for a dataset containing only Long-duration and High speeders. The objective was to find variables that predicted membership in one group versus the other. The first regression model included all the individual question items contained in the DBQ and Risk-Taking questionnaires. The number of drivers included in the analysis was small, so the statistical power was much lower than in previous regression analyses. The results indicated that only two question items differentiated drivers between groups, and neither item was directly related to speeding. Specifically, Long-duration speeders reported "driving sleepy" and "engaging in secondary tasks" more frequently that High speeders. None of the other question items related to riskier behaviors were significant.

The second logistic regression was conducted on the same driver-level predictors that were used in the regression analyses in Chapter 9, which included demographic, driver-specific, and aggregate situational variables. The results of this logistic regression indicated none of psychological constructs, such as DBQ factor or Sensation Seeking, were significant predictors.

However, “years driving” and “some graduate education,” which were proxies for age, were significant and in the expected directions. Other variables that reflected the driving environment were also significant, including site, average FFE duration, and average PSL. The patterns indicated that that Long-duration speeders were associated with longer FFEs and higher PSL roads, whereas the High speeder group contained more older drivers. The speeder groups also differed regarding site, but these effects are difficult to interpret.

Table 16. Coefficient table for Logistic Regression that included situational, demographic, and driver-specific variables.

Predictors	Coefficient	p-value
(Intercept)	6.047	0.005**
FFE duration (average)	-0.002	0.007**
Education (HS/GED vs. Some HS)	0.648	0.319
Education (Some College vs. Some HS)	-0.146	0.773
Education (College vs. Some HS)	-0.003	0.996
Education (Some Grad vs. Some HS)	-1.900	0.023*
Education (Grad vs. Some HS)	-1.296	0.080
Years of driving	0.035	0.014*
ADHD Confidence Index	0.011	0.150
Site (WA vs. NY)	1.1415	0.023*
Site (NC vs. NY)	2.206	0.001***
Site (IN vs. NY)	-0.123	0.854
Site (PA vs. NY)	0.898	0.199
Site (FL vs. NY)	1.406	0.003**
Speed limit (average)	-0.134	0.002**

* $p < .05$, ** $p < .01$, *** $p < .001$

The most notable finding from the regression analyses seems to be that Long-duration and High speeders were not noticeably different in terms of their overall behaviors, attitudes, and beliefs about speeding in the current, albeit, small driver sample. Rather, certain factors reflecting the driving environment were the best predictors for differentiating these speeder groups. This finding leads to the possibility that Long-duration and High speeders could be the same type of speeder, but that differences in their travel patterns and roads driven may cause their proclivity to speed to manifest itself in qualitatively different types of speeding.

Discussion of Speeder Groups Analysis

This chapter addressed two research questions about types of speeders. Regarding the first research question, the series of analyses presented above make the case that it is possible to develop a meaningful typology of driver types based their observed speeding behavior.

The cluster analysis conducted to categorize drivers into speeder types was largely effective. Five distinct speeder groups were identified that differed along multiple dimensions. These included:

Non-speeders—these drivers were not observed speeding in the driving sample

Infrequent speeders—this type of speeder was by far the most common, and their limited amount of speeding represented the modal speeder behavior

Occasional speeders—this type of speeder was the second most common, and they engaged in substantially more speeding than Infrequent speeders, but it was a still a relatively small amount

Long-duration speeders—this type of speeder sped more than most other groups and—at an aggregate level—the speeding behavior in this group likely had some degree of elevated safety risk because of the longer SE durations

High speeders—these drivers sped the most overall and engaged in the riskiest speeding behaviors

These groups were clearly distinct based on the amount of speeding, but also in terms of the underlying characteristics of the SEs associated with each group. Long-duration and High speeders appeared to engage in speeding that represented some degree of elevated risk, especially the High speeders. In addition, analyses conducted to address the second research question in this chapter provided converging evidence that the cluster analysis divided drivers into meaningful speeder types.

The second research question in this chapter examined if the types of speeders reflected differences in driver demographics, self-reported behaviors, beliefs, and attitudes. There were clear differences across groups for multiple driver-specific factors. Age appeared to be the most prominent factor. Attitudes and behaviors towards risk also systematically varied across groups; however, it was possible that some of these effects also reflected age differences, since age and attitudes were likely related.

A somewhat unexpected finding regarding age differences was that the trend was not driven by teen drivers, but rather it was driven by the young adult drivers. One possible explanation is that teen drivers likely completed their initial driver training more recently than young adults, and perhaps the safety messages from their driving education was recent enough to still affect their decision-making—at least for many teens. In contrast, young adults had several more years of exposure to situations in which they may have been able to drive fast with probably little or no consequence, which could foster overconfidence in their ability to safely handle speeding. Unfortunately, the SHRP2 dataset does not provide any information about driver training experience to test this hypothesis. Nevertheless, it is still possible that refresher training or messaging targeting young adults could potentially influence their speeding behavior in a positive way.

An unresolved question stemming from the analyses in this chapter involves how the Long-duration and High-speeders are related. Based on the characteristics of the SEs, these groups differed substantially. However, based on their attitudes and self-reported behaviors, there was minimal difference between these drivers. This raises the possibility that broader situational factors, including general travel patterns, could play a greater role in differentiating these two groups. Alternatively, drivers in these groups may still have different traits, but the questionnaire items may not have measured the distinguishing psychological constructs.

Drivers in the riskier speeding groups have different behaviors, risk perceptions, and attitudes towards driving risk. Age and level of maturity likely contribute to these driver traits; however, the important point is that there are differences across groups. Addressing the factors that promote these riskier perspectives could be a way to convert drivers in the higher-risk groups to those in lower-risk groups.

Chapter 12 – Summary and Conclusions

This study had a broad scope and examined multiple aspects of driver speeding behavior. The SHRP2 database provided a substantial driver sample that covered a wide range of driver traits and travel patterns. The nearly 3000 drivers in the sample also completed surveys, which made it possible to identify meaningful trends with several psychological constructs. In addition, the huge sample of trips yielded a substantial number of speeding events that would have otherwise been challenging to record in non-naturalistic settings. Since speeding is situational, it is difficult to predict where and when it will occur (except for SEs that result directly from roadway design). The new perspectives on speeding that emerged from the analyses were only possible because of the breadth of the SHRP2 NDS dataset.

However, despite the richness of the SHRP2 dataset, gaps in essential information related to posted speed limits meant that it was not possible to address the original research questions related to speeding crashes/near crashes. Nevertheless, it was still possible to examine the research questions in the context of speeding behavior. This focus also made it possible to examine speeding in greater detail.

The research activities conducted in this study included defining and obtaining measures for speeding and suitable exposure measures. Regression analyses were then run using these measures to identify situational, demographic, and psychological predictors of the amount of speeding during individual opportunities to speed, and amount of speeding at the driver level. These analyses were expanded to examine the underlying SEs in more detail, to better understand how SEs differ from each other, and to identify what factors and driver behaviors lead to these differences. The subsequent analysis of the speeder groups suggested that the differences in speeding patterns may have reflected underlying differences in specific groups of drivers. The findings obtained at each stage of this research provided new insights about driver speeding behavior, as well as addressing each of the research questions below:

1. What is the relationship between situational factors and speeding?
2. What driver-specific factors predict how much individual drivers speed across all their trips?
3. Can speeding be categorized into different types based on the characteristics of individual speeding episodes?
4. Is it possible to develop a typology of speeder groups that classifies drivers based on their speeding behavior?

What is the relationship between situational factors and speeding?

The analyses found clear relationships between situational factors and speeding, but the specific reasons for these links were unclear. Situational factors were examined using variables that reflected aspects of traffic conditions, environmental/weather factors, and roadway characteristics, but these conditions were not directly measured in the data. The indirect evidence suggested that high levels of traffic appeared to act as a constraint on speeding, and factors representing greater traffic congestion (e.g., daytime and weekday driving) were associated with less speeding. Similarly, FFE duration was a strong predictor of the amount of speeding. FFEs duration may reflect roadway characteristics, but it is also likely that FFE duration is influenced by traffic levels if congestion is high enough to cause periodic slowing to 5 mph below the PSL. Drivers also sped less at night, which suggests that increased risk associated with low light levels may be associated with less speeding—especially since traffic levels are low at these hours. However, situational factors alone did not determine whether drivers sped. While most drivers had plenty of opportunities to speed, only drivers with certain characteristics took advantage of these chances. Thus, suitable situational conditions may have been necessary for speeding to occur, but they were not sufficient in most instances.

Site was also an important situational factor, but it is difficult to understand how site-based factors affected speeding. A limitation in the current study was that there was insufficient time to make use of all the available roadway information, including video data of certain SEs. Consequently, overlapping site-based factors were not disentangled in the current study. For example, the sites contained a mix of urban and rural regions, potential differences in driving culture including regulations and enforcement practices, in addition to differences in weather and lighting. The opportunities to speed also differed across sites, which suggested that the nature of driving also differed. This could arise from a different mix of types of roads, traffic conditions, and topography among other factors. The situational factors associated with site were complex and it was not possible to parse out the different aspects of site on speeding behavior.

While multiple situational factors were associated with different types of speeding, the specific analyses were unable to disentangle the various overlapping effects. To obtain a clearer understanding of just how situational variables account for the observed effects on speeding, it is necessary to conduct further research, specifically by extracting relevant situational data in more detail and more closely examining their relationships to SEs.

What driver-specific factors predict how much individual drivers speed across all their trips?

Both demographic and psychological factors were important predictors of speeding behaviors. The key conclusions regarding each are discussed below.

Influence of demographic factors

Age was the dominant demographic factor affecting speeding. It was a strong predictor of the amount of speeding during FFEs and average amount of speeding across drivers. Age also varied systematically across speeder groups. Older drivers were associated with less speeding overall, which is consistent with expectations. Although younger drivers were associated with more speeding, the pattern was more complicated than expected, and there were differences within the younger age group. Young adults 20-24 made up the highest proportion of drivers in the Long-duration and High speeder groups. In contrast, teen drivers 16-19 were much more evenly distributed across all speeder groups, including Non-speeders and Infrequent speeder groups. At this time, there is no confirmed explanation for why young adults sped more than teen drivers. However, one possibility is that since many teens recently completed their initial driver training, or were still involved in the graduated licensing process, they may still have been influenced by the safety messages learned during driver education.

There were also differences among drivers related to other demographic variables such as education, marital status, and income; however, it is likely that these differences simply reflected age. One noteworthy finding was that gender was not a significant predictor in any of the analyses, and there was clearly no evidence supporting the claim that speeding was predominately a young male problem. Caution should be used when interpreting the demographic results, since the SHRP2 driving sample was not representative of the general driving public. In particular, the sample was more educated, more urban, and comprised mostly of non-Latino Caucasian individuals that were generally safer drivers. Nevertheless, the age effect was strong in all of the analyses conducted, and those findings likely apply outside of the study.

Influence of psychological factors

The psychological measures examined in this study were general psycho-social measures, and they were not developed to examine attitudes, beliefs, and motivations specific to speeding. However, the factors still included psychological constructs such as the DBQ and Sensation Seeking Scale that have been used to examine speeding in previous studies. After conducting Factor Analyses to distill the responses to various test batteries, clear patterns emerged regarding the trends in driver responses. Specifically, drivers who sped more or engaged in riskier speeding behavior were more likely to be accepting safety risk, were inclined towards sensation seeking, and to have a higher proclivity for ADHD. The findings from the driver-level regression model were consistent with several previous studies indicating that driver-specific factors are associated with speeding, such as prior traffic violations (Cleveland, 1959), attitudes towards risk (Corbett, 2000), and sensation seeking (Jonah, Thiessen, and Au-Yeung, 2001).

Another important question was the relationship between age and the psychological constructs. Both factors were related to higher-risk speeding behaviors. Moreover, drivers older than 25 made up progressively larger proportions of the Non-Speeder and Infrequent speeder groups. The key question is how risk-averse attitudes fit in regarding the link between older age and reduced speeding. If older age directly leads to less speeding, then options for countermeasure development may be more limited than if it is mature attitudes that directly lead to less speeding. Specifically, if age-related physiological change is the primary factor leading to risk aversion in both driver attitudes and speeding behavior, then the opportunities to encourage similar attitudes in younger drivers may be ineffective because they may simply be disinclined towards safer behaviors at that age. However, if maturation and driving/life experience in general promote risk-averse attitudes independent of chronological age, then it may be possible to expedite the “maturation” of attitudes and beliefs in younger drivers to encourage them to drive safer.

The distributions teen drivers among the speeder groups may provide some insight regarding this issue. Specifically, teen drivers were more equally distributed across the groups, whereas young adults made up a greater proportion of the riskier speeder groups. Since teen drivers were more likely to have recently competed safe-driver training, it is possible that this education encouraged some of them to retain safer speed behaviors. In contrast, most young adults were likely several years beyond their initial education, so they may have had more time to forget their training and pick up bad driving habits. It may be worth investigating the effectiveness of refresher training for higher-risk speeders. Nevertheless, the link between age, risk-averse attitudes, and speeding needs to be better understood to efficiently apply the findings of this study to driver education countermeasures.

Link to Previous Studies Examining the Influence of Psychological Constructs on Speeding

Another important outcome of this research was confirmation that self-reported frequency of speeding reflected observed behavior with reasonable accuracy. There was some degree of social bias in the self-reports—some speeders reported "never" speeding—but overall, the pattern of responses mapped to the amount of speeding observed across the driver groups. This finding is important because most of the research on driver traits and speeding is based on self-reported frequency of speeding. The confirmation that these patterns reflect real-world driving, in addition to the confirmation that various predictors of speeding such as high DBQ and Sensation Seeking Scores are consistent with previous research, suggests that self-report approaches are valid methods for examining speeding behavior.

Can speeding be categorized into different types based on the characteristics of individual speeding episodes?

The methodological approach in this study made it possible to identify different types of speeding, which yielded new insights about the underlying speeding behaviors. A secondary application of this approach was to shed some insight on how speeding can be defined.

Types of Speeding

After data filtering eliminated SEs related to PSL changes and minimal speed exceedances, the Cluster Analysis identified three basic types of speeding, including the following:

Momentary Speeding was typically comprised of a brief increase then decrease in speed. This type of speeding could have been unintentional, or it may have occurred in the service of a short-term tactical objective, such as making a lane change or passing another vehicle.

Cruising Speeding: This type of speeding was comprised of longer duration speeding consistent with speed maintenance behavior. This type also involved longer stretches of speeding that had lower speed variability, relatively low maximum speed, and a generally flat shape.

Riskier Speeding was characterized by multiple riskier attributes such as a long duration, high maximum speed, and higher speed variability. These SEs were consistent with drivers actively controlling their high speeds, and perhaps driving on the high end of what conditions allowed.

In general, the three types seemed to reflect broad difference in underlying speeding behaviors. However, this claim was based on analysis of aggregate SE characteristics and was unconfirmed in the current study because there was a lack of detailed situational information from forward video or radar to refine and validate the SE types. Consequently, the SE types did not capture the subtle aspects of driver actions leading to particular SEs. Nevertheless, the SEs showed clear statistical differences that were interpretable as certain speeding behaviors. It was also possible to inspect time-series data for many of the SEs, and they were largely consistent with the behavioral interpretations. Moreover, when plotted across PSL, the aggregate characteristics of each SE type systematically varied in ways that were consistent with the explanations. In addition, combining the parameters of the SEs with available information about driving situations made it possible to distinguish these SEs based on relative safety risk. Altogether, this provided a sufficient foundation to use SE type to classify drivers into different speeder groups.

The Cluster Analysis of SEs was useful at a high level, but it was not a definitive analysis and classification of speeding types. There were some cases *within* each type where the SE time-series data appeared qualitatively different. For example, cruise control activation yielded a noticeably different time-series than other Cruising SEs. Similarly, the Riskier SEs showed the greatest variation in time-series, ranging from single peaks to repeating high-amplitude undulations, and to different combinations of both. Another consideration is that the variables used to cluster SEs (e.g., duration, magnitude, form, etc.) did not produce distinctive clusters that were clearly demarcated from each other in the parameter space. Consequently, some of the SEs that were far from the center of one cluster, but close to a neighboring cluster probably shared some characteristics in common with SEs of the neighboring cluster. This suggested that while the cluster analysis identified broadly similar SE types, they may still represent a range of unrelated behaviors that occur across SE types.

It is likely that alternative techniques may be more robust at parsing SEs into more homogenous time-series. Nevertheless, since the objective of the current project was to conduct an initial examination on speeding behavior, the high-level differentiation of SEs was suitable for this end. It would be interesting to obtain the video data for different types of SEs to get a more qualitative understanding of the situations in which each occurs. More importantly, this would facilitate identifying recurring driver behaviors that may underlie specific types of speeding. This qualitative exercise would be helpful for differentiating between subtypes of three primary types of speeding.

Definition of Speeding and Speeding Norms

The overall amount of speeding that reached 15 mph above the PSL was relatively low for most drivers. Only 13% of all drivers spent more than 5% of their FFE time speeding based on this definition. Using the driving sample in this study, it is possible to derive some idea of what represents “normal” speeding behavior.

The easiest form of speeding to classify as “normal” speeding comes from SEs excluded from the dataset that exceeded 10 mph but not 15 mph above the PSL. These low-speed SEs were typically less than 20 seconds long. They were also the most common in the current study; 99.8% of drivers had at least one occurrence of these low-speed SEs within their trip sample, and the average number of these SEs per trip was 2.75. The prevalence of this type of SE confirms the common notion that most drivers do not strictly keep to speeds below the PSL. Even if they intended to remain several mph below the PSL, it is likely that drivers would regularly end up driving faster than 10 mph above simply due to normal variations in speed. Thus, while 10 mph above the PSL may serve as a minimum threshold for a definition of speeding, it results in a large number of SEs that probably represent a low safety risk under most driving conditions.

Momentary speeding may also be part of normal speeding, particularly if it arises from tactical maneuvers, such as lane changes and passing actions. It was the most common type of speeding and it occurred at comparable levels across the speeder groups. Since most of the Momentary SEs lasted less than 30 seconds, drivers may be less likely to be caught doing this type of speeding by law enforcement, so Momentary speeding may be less likely to appear in the driving record. Nevertheless, drivers did engage in this type of speeding on lower speed roads, so it may still be beneficial to categorize these SEs as problem speeding. This issue is unresolved at this time and could benefit from additional investigation of the situational factors associated with Momentary speeding.

The two other types of speeding, Cruising and Risker SEs, had higher exposure and kinematic risks that could plausibly be linked to greater safety consequences. The types were uncommon for most drivers, and the combinations of maximum speeds and durations suggest that they do not represent unintentional or accidental speeding. It is reasonable to consider both of these types of SEs as speeding of consequence. This framing further suggests that in addition to speed above the PSL, the duration of an SE may be relevant for the definition of speeding.

Another way to characterize "normal" speeding is by examining the prevalence of speeding in the different speeder groups. Non-speeders, Infrequent speeders, and Occasional speeders comprised 87% of the driver sample. Combined, these groups engaged in speeding on average less than 1% of the time. When they did speed, it primarily involved Momentary speeding with a moderate amount of Cruising speeding. The Riskier SEs, comprised only 0.2 % of total FFE time across all drivers in these three groups. Thus, examining the nature of speeding done by drivers in the lower-risk speeder groups appears to be a reasonable approach for defining normative speeding behavior. The upshot of this is that many normal speeders engaged in a moderate proportion of Cruising speeding, which may represent elevated exposure risk. It is possible that this Cruising speeding is not actually riskier, or that normal speeders are simply unaware that they are increasing their risk. Either possibility or some combination of both may be correct. Examining Cruising SEs in more detailed data could provide some insight into this issue.

Reaching speeds of 15 mph above the PSL may sometimes be unintentional, but it is unlikely to occur if drivers are carefully trying to keep to the speed limit. Thus, the criteria used to sub-set SEs in the current research appeared to strike a reasonable balance between omitting lower-speed SEs that contribute noise in the dataset while still retaining SEs that meaningfully differentiated between different types of speeders and behaviors. This research may have implications for defining speeding in future survey studies about speeding. For example, self-report questions can specifically refer to driving above 15 mph as speeding. However, it may also be possible to develop survey questions around specific behaviors implied by the SE time-series patterns to better differentiate between speeder types. For example, asking drivers about "tailgating and passing vehicles to get around other vehicles that are keeping them from driving as fast as they want" may probe the frequency of Riskier speeding as opposed to other types. Identifying the specific descriptors of the underlying speeding behaviors may require more in-depth analysis of SE characteristics, such as analyzing NDS video data for situational factors, but it could lead to the development of survey questions that better differentiate types of speeders.

Is it possible to develop a typology of speeder groups that classifies drivers based on their speeding behavior?

The Cluster Analysis conducted based on the proportion of each type of speeding for each driver yielded five interpretable speeder groups that differed along multiple dimensions. These included:

Non-speeders—these drivers were not observed speeding in the driving sample.

Infrequent speeders—these speeders were by far the most common, and their limited amount of speeding represented the modal speeder behavior.

Occasional speeders—these speeders were the second most common, and they engaged in substantially more speeding than Infrequent speeders, but it was a still a relatively small amount.

Long-duration speeders—these drivers sped more than most other groups and, at an aggregate level, the speeding behavior in this group likely had some degree of elevated safety risk because of the longer SE durations.

High speeders—these drivers sped the most overall and engaged in the riskiest speeding behaviors.

These groups were clearly distinct based on the overall amount of speeding, but also in terms of the underlying characteristics of the SEs associated with each group. Long-duration and High speeders appeared to engage in speeding that represented some degree of elevated risk, especially the High speeders. In addition, analyses conducted to examine demographic and psychological differences across groups provided converging evidence that the cluster analysis divided drivers into meaningful speeder groups.

Although all groups were distinct in certain ways, it is not totally clear that all of them are functionally different. In particular, Non-speeders were distinct because these individuals drove substantially less than others and had noticeably fewer opportunities to speed. However, from a speeding perspective, there may not be much practical difference between Non-speeders and Infrequent speeders. Non-speeders may still have sped on roadways that were not included in the sample. Nevertheless, these individuals did have different traits compared to the other drivers, so the distinction may still be useful.

The Non-speeders were clearly the most risk-averse of all groups, and they generally reported engaging less often in unsafe behaviors. In contrast, Long-duration and High speeders were the most accepting of risk-taking and unsafe behaviors. Apart from differences in age and driving patterns, the two riskier groups were mostly indistinguishable in terms of psychological and behavioral aspects. It is possible that they reflect the same type of speeder, and that the differences arose from differences in travel patterns and opportunities to speed (e.g., High speeders might have had similar SEs to Long-duration speeders if they just spent more time driving on open roads). It may be possible to examine this hypothesis by comparing the types of roads that each group drove on, or even by comparing the speeding patterns of Long-duration and High speeders on the same roadways. Despite the ambiguities between these groups, the broader differences across speeder groups described in Chapter 11 indicate that the cluster analysis approach was effective in parsing drivers into a meaningful typology of speeders.

Speeder Typologies Across Studies

The clear differences across speeder groups described above provide further evidence that the notion of a speeder typology has merit. The current findings are consistent with previous studies that have examined driver typologies in that they all indicate that driver age and the measure for amount of speeding vary systematically across speeder groups (Schroeder, Kostyniuk, & Mack, 2013, Divekar, & Brown, 2016, Richard et al., 2017). In the studies that examined psychological constructs, riskier speeder groups were also more accepting of speeding and riskier attitudes (Richard, Divekar, & Brown, 2016). Although these studies have examined speeder typologies in different ways, the consistency of the high-level patterns suggests that this approach provides a valid framework for identifying speeders with intrinsic characteristics that make them more likely to be speeders of concern.

Table 17 provides an update to Table 2 in the Introduction that compares the speeder typologies from previous driver-type studies. The findings from the current study (bottom row) bring some clarity to the interpretation of the differences in typology labels across studies. They also indicate that there is probably more similarity across the typologies than was first apparent. Specifically, the current study found that amount of speeding was the key dimension distinguishing the groups. However, at the high end, the characteristics of the speeding behavior were also important. This basic pattern applies to the typologies in the previous studies, after accounting for differences in framing the typologies that arise from the variables used to group drivers. For example, the NASSB typologies did not include psychological constructs as inputs, so amount of speeding serves as the sole grouping dimension.

Another consideration is that the "Occasional" and "Casual" groups across studies share important similarities. These groups differ from the low-end speeders in that they not only have more speeding, but also engage in some level of riskier speeding, hence the label of having a more "casual" attitude towards speeding risks. Given that this middle group of speeders is typically much more common than the higher speeder groups, they may contribute significantly to crashes because the greater number of drivers would yield a greater overall exposure risk. Thus, it may be worthwhile to consider targeting these drivers with safety countermeasures; however, since they typically have different attitudes and beliefs than higher-risk speeders, they would likely benefit more from safety messaging that is specifically targeted at these groups. These messages could reflect the type of speeding that they engage in—perhaps messaging reinforcing the fact that they do not speed much to begin with (e.g., "You're not gain much from speeding"), or that the benefits are small in comparison to the potential safety consequences (e.g., "It's not worth the risk").

Table 17. Comparison of speeder typologies across recent NHTSA studies.

Study	**Basis for Grouping**	**Low-Speeder Group**	**Intermediate-Speeder Group**	**Highest-Speeder Group**
MfS	Occurrence and amount of speeding on a trip	Incidental	- Casual - Occasional	Habitual
MfS Follow-on	Frequency and types of speeding events	Incidental	- Typical - Situational	Deliberate
NSSAB	Self-reported speeding behavior	Non-speeders	Sometimes Speeders	Speeders
Idaho Survey (NSSAB)	Self-reported speeding behavior	Non-speeders	Sometimes Speeders	Speeders
Idaho Survey	Self-reported, Speeding-related attitudes and beliefs	Infrequent	Casual	- Emotional - Aggressive
SHRP2 Analysis	Frequency and types of speeding events	Infrequent	Occasional	- Long-Duration - High Speeders

A key outcome from the focus on a typologies of speeder groups is the recognition that Long-duration and especially High speeders represent a small subset of drivers that are outliers. They differ not only in terms of their riskier speeding behaviors, but also in terms of their attitudes and beliefs towards speeding and risk in general. Indirectly, the typology also suggests that it may be useful to focus countermeasures on certain types of speeding. Speeding at levels that reached 15 mph above the PSL was not a rare behavior. However, the drivers in the riskiest speeder groups engaged in qualitatively different types of speeding, both in terms of amount and nature of the driving. Riskier speeding was defined by it high speed exceedances and large changes in speed, which suggests that the High-speeders who typically engage in this speeding may have been trying to speed as fast as conditions allowed. It would likely require additional research to catalog driver actions during Riskier speeding episodes, but identifying the characteristics to look for could have value for enforcement approaches.

The analysis suggests that if a driver was caught engaging in Risker speeding, chances are that the driver was doing a lot more of this type of speeding, since it was concentrated among High speeders. Thus, if it was possible to encourage a long-term change in a High speeder's driving behavior, it may be an efficient way to reduce the most unsafe type of speeding. The specific approach for affecting this behavioral change is still uncertain; however, the findings from this study point to some of the relevant driver attitudes and beliefs of High speeders, in addition to providing some characteristics to help identify these individuals. The drivers in the riskier groups represent the high-payoff speeders to target with safety countermeasures, and with the growing body of research on speeder typologies, a clearer picture of the specific driver characteristics to target with countermeasures is beginning to emerge. However, more targeted research is needed to identify effective strategies for reducing their speeding.

Final Thoughts

The SHRP2 NDS data provided a speeding dataset that was unprecedented in both its detail and breadth of both drivers and trips. The current study took advantage of these elements to examine many aspects of driver speeding behavior. These analyses used behavior data to confirm several findings expected based on previous self-report studies. The analyses also provided new insights about types of speeding, speeder groups, and a potentially more complex relationship between driver age and speeding. Since this research represented an initial look at speeding in the SHRP2 dataset, many of the more specific questions about speeding and driver behaviors remain unanswered. Nevertheless, the research conducted in this study lay the foundation for examining these issues in more detail.

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DOT HS 812 858
March 2020

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14239-031920-v3