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Driver speed selection and crash risk: Insights from the naturalistic driving study

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ABSTRACT

Introduction: This study investigates how speed limits affect driver speed selection, as well as the related crash risk, while controlling for various confounding factors such as traffic volumes and roadway geometry. Data from a naturalistic driving study are used to examine how driver speed selection varies among freeways with different posted speed limits, as well as how the likelihood of crash/near-crash events change with respect to mean speed and standard deviation. *Method:* Regression models are estimated to assess three measures of interest: the average speed of vehicles during the time preceding crash/near-crash and baseline (i.e., normal) driving events; the variation in travel speeds leading up to each event as quantified by the standard deviation in speeds over this period; and the probability of a specific event resulting in a crash/near-crash based on speed selection and other factors. *Results:* Speeds were relatively stable across levels-of-service A and B, within a range of 1.5 mph on average. Speeds were marginally lower (3.3 mph) on freeways posted at 65 mph versus 70 mph. In comparison, speeds were approximately 10.2 to 13.4 mph lower on facilities posted at 55 mph or 60 mph. Speeds were shown to be 2.5 mph lower in rainy weather and 11 mph lower under snow or sleet. *Conclusions:* Significant correlation was observed with respect to speed selection behavior among the same individuals. Mean speeds are shown to increase with speed limits. However, these increases are less pronounced at higher speed limits. Drivers tend to reduce their travel speeds in presence of junctions and work zones, under adverse weather conditions, and particularly under heavy congestion. Crash risk increased with the standard deviation in speed, as well as on vertical curves and ramp junctions, and among the youngest and oldest age groups of drivers.

1. Problem

Speed management has been an extensive focus of traffic safety research dating back to seminal work from the 1960's that showed crash risk (i.e., the probability of being involved in a crash) to be higher among vehicles traveling at speeds either significantly above or below the average speed of traffic (Cirillo, 1968; Solomon, 1964). While the crash risks at lower speeds have been shown to be overstated, various studies have shown increases in average speed and speed variance each tend to be associated with increased crash or fatality rates (Forester, McNown, & Singell, 1984; Fowles & Loeb, 1989; Garber & Ehrhart, 2000; Levy & Asch, 1989; West & Dunn, 1971; Zlatoper, 1991). These results provide support for maximum statutory speed limits, which are posted to inform drivers of the highest speed that is considered safe and reasonable for ideal traffic, road, and weather conditions.

Much of the research to date has focused on high-speed roadways, where the research literature has consistently shown fatalities to increase with higher speed limits. A recent longitudinal study of fatality trends on rural interstates across the United States showed that states with 70-mph maximum limits experienced 31% more fatalities than states with 60 or 65 mph maximum limits, while states with 75 mph limits experienced 54% more fatalities (Davis, Hacker, Savolainen, & Gates, in press). Despite these findings, numerous states have recently increased statutory speed limits on their freeway networks to speeds as high as 85 mph.

Table 1 provides a list of states that have introduced speed limit policy changes from 2011 through 2016.

While research generally suggests safety is negatively impacted by increases in mean speed and speed variance, much of this work has examined speed and crash data at a high-level of aggregation (e.g., statewide or roadway-specific). Research has been more limited as to the effects of speed limits on individual driver behavior. Consequently, it is unclear what the specific factors are that have contributed to the aggregate-level crash trends. This study addresses this gap by utilizing

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Table 1
Changes in speed limit policies by state, 2012–2016.

State	Type of roadway	Prior limit	New limit	Year
Arkansas	Select rural highway	55	60; 65	2012
Indiana	Tollway	55	70	2012
Kentucky	Select US highway	55	65	2012
Texas	Rural freeways; tollway	75; 80	80; 85	2012
Alaska	State highway	55	65	2013
North Carolina	Select rural freeways	65	70	2013
Ohio	Select rural freeways	65	70	2013
Utah	Select rural freeways	75	80	2013
Georgia	Select interstate	55	70	2014
Idaho	Rural freeway	75	80	2014
Illinois	Tollway; select freeways	55; 65	70	2014
Maine	Select interstates	55; 65	60; 70	2014
New Hampshire	Select interstates	65	70	2014
Pennsylvania	Rural freeways	65	70	2014
South Carolina	Select interstates	55	60	2014
Wyoming	Select interstates	75	80	2014
Delaware	Select interstates	55	65	2015
Montana	Rural interstates	75	80	2015
South Dakota	Select interstates	75	80	2015
Wisconsin	Rural interstates	65	70	2015
Maryland	Select interstates	65	70	2015
Nevada	Select freeways	75	80	2015
Kentucky	Select rural highways	55	65	2015
Oregon	Select interstates	55;65c/55t	65c/60t;70c/65t	2016
Washington	Freeways	70c/60t	75c/60t	2016
Michigan	Freeways; state highways	70c/60t; 55	75c/65t; 65	2017

Note: c = passenger car limit; t = truck limit.

naturalistic driving study to examine speed selection behavior and crash risk among individual drivers.

2. Literature review

Numerous studies have examined the relationship between posted speed limits and the frequency and severity of traffic crashes. Much of the research in this area was conducted following the introduction of the 55-mph National Maximum Speed Limit in 1974. Collectively, these studies found that lower speed limits tended to result in safety benefits (Dart, 1977; Deen & Godwin, 1985; Weckesser et al., 1977), which were attributed to lower average speeds and speed variance (Burritt, Moghrabi, & Matthias, 1976). The speed limit issue was revisited by subsequent research and legislation. Additional evaluation studies showed increases in traffic crashes and/or fatalities in states where speed limits had been increased (Baum, Lund, & Wells, 1989; Baum, Wells, & Lund, 1992; Farmer, Retting, & Lund, 1999; Gallaher et al., 1989; Greenstone, 2002; Haselton, Gibby, & Ferrara, 2002; Ledolter & Chan, 1996; McKnight & Klein, 1990; Patterson, Frith, Poveya, & Keallaand, 2002; Upchurch, 1989; Wagenaar, Streff, & Schultz, 1990).

Despite these findings, numerous states have recently increased speed limits on rural freeways, with several additional states considering similar increases as of 2017. In contrast to earlier increases, which were often implemented on a system-wide basis, many of the recent speed limit policy changes have been introduced on specific road segments. In such instances, states have considered a range of factors in determining whether speed limit increases are appropriate at a given location. These factors include the existing mean and 85th percentile speeds, speed variance, and recent crash history.

The American Association of State Highway and Transportation Officials note that driving speeds are affected by the physical characteristics of the road, weather, other vehicles, and the speed limit (AASHTO, 2001). Among these, road design is a principal determinant of driving speeds. Geometric factors tend to have particularly pronounced impacts on crashes. Ultimately, many factors affect speed selection beyond just road geometry and posted limit as shown by prior research in this area (Abdelwahab, Aboul-Ela, & Morrall, 1998; Al-Masaeid, Hammory, & Al-Omari, 1999; Andjus & Maletin, 1998; Emmerson, 1969; Fitzpatrick, Carlson, Brewer, Wooldridge, & Miaou, 2003; Glennon, Neuman, & Leisch, 1985; Islam & Seneviratne, 1994; Kanellaidis, Golias, & Efstathiadis, 1990; Krammes et al., 1993; Lamm & Choueiri, 1987; McLean, 1981; Polus, Fitzpatrick, & Fambro, 2000; Schurr, McCoy, Pesti, & Huff, 2002; Voigt, 1996).

Research has generally shown that speed limit increases result in changes in the observed mean and 85th percentile speeds that are less pronounced than the actual speed limit increases (Brown, Maghsoodloo, & McArdle, 1991; Freedman & Esterlitz, 1990; Lynn & Jernigan, 1992; Ossiander & Cummings, 2002; Parker, 1997; Upchurch, 1989). A meta-analysis of research from European countries and the United States (Wilmot & Khanal, 1999) concludes that drivers ultimately choose their speeds based on perception of safety rather than posted speed limits.

These findings are largely reflective of driver opinions on speed limits. A survey of freeway users found that, on average, respondents drove 11 mph over the speed limit on roads posted 55 mph, 9 mph over the speed limit on roads posted at 65 mph, and 8 mph over the speed limit on roads posted at 70 mph (Mannering, 2007). Research also shows that drivers believe the most influential factors dictating their speed selection are weather conditions, their perception of what speeds are "safe," the posted speed limit, traffic volume levels, and the amount of personal driving experience they have on a particular road (Royal, 2003).

Research into the actual speed selection behavior of individual drivers, along with the resultant impacts on crash risk, has been rather limited. Much of the work to date has utilized aggregate-level crash data. For example, comparisons across states have often focused on measures such as the annual number of traffic fatalities. At this level of analysis, it is difficult to discern the impacts of important disaggregate-level factors, such as roadway geometry. While additional research has examined how the mean and standard deviation in speeds vary across road segments, this level of aggregation also precludes the ability to examine behaviors of individual drivers. When attempting to integrate speed and crash data, additional challenges arise due to the imprecision and latency often associated with the sources of each type of information. As such, it is difficult to infer how the behaviors of individual drivers may vary in response to different speed limits, as well as how these behavioral changes may impact crash risk.

To this end, it is important to gain a greater understanding of how driver speed selection changes in response to changes in the speed limit while controlling for various external (e.g., road geometry) or in-vehicle (e.g., driver distraction) factors. While safety research has historically utilized some combination of police-reported crash data, sensor- or camera-based operational data, human factors data from driving simulators, and so forth, naturalistic driving studies (NDS) have recently become a promising alternative for collecting more detailed data than is possible using these traditional methods (Hutton, Bauer, Fees, & Smiley, 2015). Utilization of such data, particularly the SHRP 2 NDS data, provides researchers with an opportunity to analyze actual behaviors and situations that contribute to crash events as opposed to relying on post-crash accounts from police crash report forms. Recently, several studies have exploited NDS data to investigate important behavioral issues affecting traffic safety. Simons-Morton et al. utilized the NDS data to analyze teenage drivers' behavior, finding them to be nearly four times more likely to be involved in crash or near-crash events as compared with adults (Simons-Morton et al., 2015). Several NDS studies have also shown high-risk behaviors, such as speeding, to be more prevalent among adolescents as compared with adults (Hallmark, Tyner, Oneyear, Carney, & McGehee, 2015; Simons-Morton et al., 2015). This study builds upon prior work and investigates a robust set of characteristics related to drivers, vehicles, the roadway, and the environment.

3. Data

The second Strategic Highway Research Program (SHRP 2) Safety Data provides unique resources to investigate the nature of the speed-

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