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7. Author(s)
Kathy H. Lococo,* Loren Staplin,* Carol A. Martell,† and Kathy J. Sifrit‡

8. Performing Organization Report No.

9. Performing Organization Name and Address
TransAnalytics, LLC
336 West Broad Street
Quakertown, PA 18951

†Highway Safety Research Center, University of North Carolina
730 Martin Luther King, Jr. Blvd.
Chapel Hill, NC 27599-3430

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16. Abstract

This project examined the prevalence of pedal application errors and the driver, vehicle, roadway and/or environmental characteristics associated with pedal misapplication crashes based on a literature review, analysis of news media reports, a panel of driver rehabilitation specialists, analysis of multiple crash databases, and case studies. An analysis of crashes attributed to pedal-related vehicle equipment malfunction, rather than to a driver error, was also carried out based on a media scan.

Available sources provide an estimate of 15 pedal misapplication crashes per month in the United States, but there are limits to the reporting and archiving of these events that could result in underestimation. Analyses of media reports and a State crash database indicated that the drivers in almost two-thirds of such crashes were females. When crash involvement is plotted against driver age a U-shaped function shows significant over-involvement by the youngest (age 16 to 20) and oldest (76 and older) drivers. Driver inattention and distraction were common contributing factors across age groups.

Analysis of news reports examined which vehicle types, makes, and models most often experienced stuck accelerators and other equipment malfunctions in crashes between 2000 and 2010. Passenger cars were by far the most prevalent, and the makes that were most strongly over-represented in relation to their proportion of the U.S. fleet were all domestic.

Besides identifying future research needs, recommendations were to educate physicians about medical conditions associated with pedal misapplications; refer drivers with lower limb sensory loss to driver rehabilitation specialists for evaluation for hand controls; inform the public about how to counteract an unintended acceleration; and provide law enforcement with a practical means of recording information about drivers in pedal misapplication crashes.

17. Key Words
Pedal application errors, pedal misapplication, unintended acceleration, crash analysis, safety, older drivers, novice drivers, driver performance, functional abilities, human factors, medical conditions, driver rehabilitation

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LIST OF ACRONYMS AND ABBREVIATIONS

AMA	American Medical Association
BTSI	brake transmission shift interlock
BTW	behind the wheel
CDRS	Certified Driver Rehabilitation Specialist
DMV	Department of Motor Vehicles
DOT	Department of Transportation
DRS	Driver Rehabilitation Specialist
EDR	event data recorder
GHSP	Governor’s Highway Safety Program
NHTSA	National Highway Traffic Safety Administration
NMVCCS	National Motor Vehicle Crash Causation Survey
NTSB	National Transportation Safety Board
OT	Occupational Therapist
PDI	potentially driver impairing
PVA	public vehicular area

EXECUTIVE SUMMARY

This project examined the prevalence of pedal application errors—specifically, the driver error of mistaking the accelerator pedal for the brake pedal—and the driver, vehicle, roadway, and/or environmental characteristics that are associated with pedal misapplication crashes. Researchers first reviewed the technical literature published between 1980 and 2009, then analyzed news reports about 899 of these crashes in the United States over the past 10 years. The research team conducted two crash analyses, one based on 31 crashes in the National Motor Vehicle Crash Causation Survey (NMVCCS) between 2005 and 2007, plus 2,411 pedal misapplication crashes between 2004 and 2008 contained in the North Carolina State crash database.

A panel of Driver Rehabilitation Specialists (DRSs) provided another perspective. Panelists drew on their clinical experience to discuss the medical conditions and functional deficits, the maneuvers, the locations, and the driving task demands associated with pedal application errors. Researchers conducted case studies of drivers in pedal misapplication crashes, using data mined from the Iowa reexamination database and from one-on-one, unstructured telephone discussions with drivers in North Carolina, to seek additional insights about this phenomenon.

Finally, in a complementary task researchers completed a media scan for crashes attributed to pedal-related vehicle equipment malfunction, rather than to driver error (pedal misapplication).Analyses of these reports described the types of vehicles and specific equipment problems most often implicated in such crashes, and compared the driver age and sex distributions, crash locations, and a range of vehicle characteristics with those describing crashes due to pedal application errors.

The literature review identified sparse evidence of the prevalence of pedal application errors. The studies included were all conducted with driving simulators, so may not reflect real-world driving behavior. Two predictors for pedal error events were identified, however: increasing driver age and impairments in drivers' "executive function."[1] These studies also demonstrated that pedal misapplications could be triggered by sudden changes in the environment that startle drivers.

Analyses based primarily on the results of the media scan and North Carolina crash database analysis provided information about the prevalence of pedal misapplication crashes. The former source yielded reports of 7 to 15 crashes per month, somewhere in the United States The latter source also provided an estimate of less than 1% of all crashes. But media archiving practices dictate that researchers will have access to a diminishing sample (i.e., only the most "newsworthy" stories) the older the source of the data; and, State database analyses are limited by the absence of any codes on police crash reports to indicate that a crash resulted from a pedal misapplication. Thus, there is strong reason to believe that each of these sources produced a significant <u>under</u>estimation of how often drivers mistake the accelerator for the brake, and a crash ensues.

The most consistent finding across data sources was the striking overrepresentation of females in pedal misapplication crashes, relative to their involvement in all types of crashes.

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[1] Executive function describes a variety of loosely related higher-order cognitive processes like initiation, planning, hypothesis generation, cognitive flexibility, decision making, regulation, judgment, feedback utilization, and self-perception that are necessary for effective and contextually appropriate behavior (Daigneault, Joly, & Frigon, 2002).

Females were the drivers in nearly *two-thirds* of the pedal misapplication crashes identified in both crash databases and in the media scan. Possible explanations might include greater exposure by women where these crashes occur most often (parking lots); a poorer “fit” in their cars due to shorter stature, which may increase the likelihood of a pedal application error; or a disproportionately high rate of one or more functional deficits that contribute to pedal errors, such as neuropathy. Explaining this anomaly may be important as a starting point in designing crash countermeasures.

The pedal application error analysis results for driver age were compelling. When the percentage of crash-involved drivers was plotted against 5-year cohorts from 16-to-20 age group to the 76+ group, both the North Carolina database and the news media reports demonstrated a marked U-shaped relationship. Over-involvement in pedal misapplication crashes was especially pronounced among drivers 76 and older in the media. This may reflect the sensational nature of such events that increases the chances that the media will report them, often in multiple outlets. The NMVCCS analysis results did *not* mirror this pattern, instead showing relatively even levels of crash involvement for young, middle-aged, and older drivers; but this should be interpreted with caution as this database excludes crashes in parking lots.

The single factor that may explain over involvement in pedal misapplication crashes at both ends of the driver age distribution is poor executive function. The relevant areas of the brain do not fully develop until young adulthood, and have been shown to decline with advanced age. The participating Driver Rehabilitation Specialists supported this premise, having observed pedal application errors among their clients who perform poorly in clinical tests of executive function. This was not limited to older drivers—panelists reported that young patients with diagnoses of autism and attention-deficit disorder are more prone to these errors, too.

Across age, the most common contributing factor in pedal misapplication crashes was driver inattention, cited in 44% of the North Carolina crashes. Distracted drivers may be more likely to be startled by an unexpected event or traffic situation, and in their panic to stop or slow the vehicle, may press the wrong pedal.

Turning to the news reports of pedal-related vehicle malfunction crashes that were screened to exclude behavioral causes, three findings were most pronounced. First, the striking overrepresentation of female drivers disappeared in such crashes. Next, for a subset of events of particular interest – stuck accelerator crashes – both the youngest and oldest driver age groups again appeared to be at greatest risk. Alternately, both of these groups again may be the most newsworthy for the reporting of such crashes by the popular media. Third, a detailed analysis of vehicle types, makes, and models most often in media reports of equipment malfunction crashes from 2000 to 2010, showed that passenger cars were by far the most prevalent, and the makes that were most strongly over-represented in relation to their proportion of the U.S. fleet were domestic.

Most of the conclusions to be drawn from this project are tentative, pointing to the need for additional research to better understand the reasons for this driver behavior. At the same time, safety benefits may confidently be predicted from educating physicians about the conditions that are associated with pedal misapplications; physicians referring drivers with sensory loss to driver rehabilitation specialists who can evaluate their ability to use hand controls; informing the public about shifting into neutral if a vehicle accelerates unexpectedly; and providing law enforcement with a practical means of recording information about drivers in pedal misapplication crashes, to improve the quality of traffic records for future data analyses.

INTRODUCTION AND BACKGROUND

This section describes the rationale behind the project, highlights the objectives, and provides the reader with a brief overview of the technical approach.

BACKGROUND AND UNDERSTANDING OF THE PROBLEM

The driver performance deficits termed “pedal application errors” gained a degree of notoriety in the 2003 crash in Santa Monica, California, when an older passenger car driver pressed the accelerator instead of the brake, surged into a crowd of shoppers at an outdoor market, and killed 10 pedestrians and injured 63 others. A National Transportation Safety Board (NTSB) investigation of the Santa Monica crash confirmed that the cause of the crash was the driver’s inadvertent acceleration when he intended to brake, and his continuing acceleration through the market due to his faulty belief that his foot was on the brake as he pumped the accelerator. NTSB subsequently performed in-depth investigations of 5 crashes that occurred between 2005 and 2008 involving heavy vehicles in which 2 people were killed and 71 injured, and concluded that pedal misapplication was a factor in all 5 crashes. As indicated by the NTSB (2009), “pedal misapplication can occur in heavy vehicles as well as light vehicles; any vehicle operated by a driver is susceptible to the loss of control caused by human error.”

The media reports newsworthy incidents across the United States on nearly a daily basis, including fatal and injurious crashes; and there is anecdotal evidence that such driver errors resulting in property damage may be relatively commonplace. However, caution must be used in interpreting media data extracted over a certain time period to explain the prevalence of pedal misapplication crashes and the characteristics of the drivers involved, because of competing and complementary issues biasing reporting of pedal misapplication crashes.

One difficulty in precisely documenting the frequency of crashes involving pedal misapplications is that when these events occur on private property or in a parking lot, they may not be reported to the police or be registered as entries in any crash database. In order to identify events captured in police narratives in a crash database, analysts must distinguish narratives that include “pedal” as an element from other crash types with “pedal” as a root term (e.g., pedalcyclist), filter for terms such as “mistake” or “slip,” and then critically review the crash narrative to confirm an event of interest. At this time, no State uses a code to identify crashes associated with pedal application errors.

Ambiguity in the data describing such events also results from a marked inconsistency in the use of the expression “pedal errors.” This expression covers a wide range of behaviors, some related to mechanical issues and others to driver behaviors. Within the latter category, physical as well as cognitive impairments could lead to an unintended acceleration, as could inattention and distraction. Events related to a “set-shift” (i.e., the driver believes he/she is pressing the brake, and when the vehicle accelerates instead of slowing, presses harder) must be distinguished from errors committed when multitasking (an information processing limitation). Similarly, “pedal confusion” may refer to a state of either generalized or episodic confusion. The former would apply to a person who has difficulty using the key or operating the vehicle controls; while the latter might apply to someone who is only temporarily confused, e.g., by a distracting noise or thought. Throughout this report, the terms “pedal application errors,” “pedal misapplications,” and “pedal misapplication crashes” will be used to identify the driver behavior of mistaking the accelerator for the brake pedal.

PROJECT OBJECTIVE

The overall objective of this project was to determine the magnitude of the problem of crashes associated with pedal misapplications. Specific goals included learning how frequently crashes occur as the result of pedal misapplication; whether particular driver groups such as novices or older drivers are overrepresented in such crashes; if certain conditions place drivers at higher risk of pedal misapplication; and the extent of property damage, injuries, and fatalities caused by these errors.

PROJECT SCOPE

Major tasks in this project included:

- A literature review, encompassing searches in the technical peer-reviewed literature as well as in the news media over the past 10-year period. An additional news media search focused on the characteristics of crashes involving brake or accelerator pedal malfunction, for comparison with crashes resulting from pedal misapplication.

- An expert panel meeting with 15 Driver Rehabilitation Specialists (DRSs), to gather information regarding their experience with their clients’ pedal application errors. Specifically, panelists provided descriptions of incidents of clients’ pedal misapplications; driving tasks during which these errors seem most likely to occur; characteristics of drivers most likely to make such errors; and any additional insights regarding pedal application errors.

- Data mining using the National Motor Vehicle Crash Causation Survey (NMVCCS) database and North Carolina’s State crash database.

- Case studies of drivers involved in pedal misapplication crashes in Iowa and North Carolina. Data mining in the Iowa driver reexamination database provided information about the fitness to drive of those involved in such crashes, through their performance on the DMV reexamination tests and resulting license actions. Telephone discussions with crash-involved North Carolina drivers provided information about the driver, vehicle, and situational factors underlying pedal application errors, beyond what might be recorded on crash report forms.

METHODS

LITERATURE REVIEW

This literature review encompassed searches in two domains to determine the magnitude of crashes associated with pedal misapplications, and the driver characteristics and environmental circumstances surrounding these crashes. The peer-reviewed literature included studies describing the frequency, severity, and conditions associated with pedal application errors. Because NHTSA anticipated that little research had been done in this area, the literature review was extended to include reviews of news media reports of crashes related to pedal application errors that have occurred within the United States between January 1, 2000, and February 16, 2010. A second media search examined driver and vehicle characteristics in crashes involving malfunctions of the braking and acceleration systems, for comparison with crashes involving pedal misapplication (driver error). The search methods used to identify peer-reviewed literature and news media reports are described below.

Technical Literature

Researchers performed searches in the ScienceDirect, TRIS, PsycInfo and Dissertation Abstracts databases for literature published between 1980 and 2009, . Since the focus of this project was behavioral errors that lead to these crashes—the driver mistakenly pressing the accelerator, believing it is the brake pedal—literature relating to equipment failure was methodically excluded from the review.

Researchers identified and acquired one report in the ScienceDirect database related specifically to pedal misapplication, using the following keywords: braking; rear-end crash; stop/go decision; brake response time; brake-perception reaction time; pedal confusion; emergency braking; collision warning; time to collision; time to contact; active accelerator pedal; brake reaction time; car following; braking time; reaction time; event uncertainty; and driver reaction times.

The TRIS database provided six relevant reports under the following keywords: driver errors; pedal errors; automotive foot pedals; pedal configuration; brake pedal; unintended acceleration; sudden acceleration incidents; and pedal misapplication.

In the PsycInfo and Dissertation Abstracts databases, researchers identified and acquired four reports using the following keywords: pedal errors; braking task; braking response; pedal hitting errors; pedal actuation errors; design of pedal & floor & seating geometries in automobiles; frequency of accelerator & brake pedal actuation errors during simulated driving; unintended acceleration; and foot placement in driving simulator.

A series of structured Internet searches using keywords along with the names of authors of key reports identified from the three databases identified four relevant reports not identified in the previous searches; these were retrieved for review.

The Internet searches revealed the National Transportation Safety Board (NTSB) as a major source of investigative research on this subject. As reflected in past, recent, and ongoing investigations of pedal application error incidents, especially those involving heavy vehicles and commercial vehicles, the NTSB appears to be the most comprehensive United States-based source of research on crashes in which drivers applied the gas pedal, thinking they were applying the brake pedal. *Pedal misapplication* is the current NTSB terminology for this type of incident.

News Media Reports

The literature review encompassed reviews of news media reports of crashes related to pedal application errors that occurred within the United States between January 2000 and February 2010. Researchers tracked and archived media coverage using primarily the following Web-based tracking databases and tools:

- Google News: Google News is a computer-generated news site that aggregates headlines from news sources worldwide. Specifically, media coverage was tracked using the general search for more recent articles and the news archive search, which provides an easy way to search and explore historical archives.
- LexisNexis News: LexisNexis focuses on the needs of professionals. The University of North Carolina at Chapel Hill provided access to archived articles using the News segment of LexisNexis. This database provides full-text access to general, regional, and international news.
- America's Newspapers: The University of North Carolina at Chapel Hill provided access to America's Newspapers, a comprehensive U.S. newspaper resource that is updated daily. It includes electronic editions of 827 newspapers—with 75% of these sources not available in any other library database.

The project team searched and compiled media "hits" between January 2000 and February 2010 using these databases and the following key phrases.

(Crash OR accident) AND - -

- - Pressed the accelerator instead of the brake
- - Pressed the gas pedal instead of the brake
- - Stepped on the accelerator instead of the brake
- - Stepped on the gas pedal instead of the brake
- - Confused the accelerator for the brake
- - Confused the gas pedal for the brake
- - Confused gas and brake pedal
- - Hit the accelerator by accident (OR mistake)
- - Hit the gas pedal by accident (OR mistake)
- - Mistook the accelerator for the brake
- - Mistook the gas pedal for the brake
- - Hit the wrong pedal

A second search for reports of crashes involving equipment malfunction (brake or accelerator) during the same period used the following terms.

(Crash OR accident) AND - -

- - Stuck accelerator (OR gas pedal OR throttle)
- - Jammed accelerator (OR gas pedal OR throttle)
- - Brakes failed (OR failure)
- - Could not stop car (OR vehicle)
- - Sudden acceleration
- - Unwanted acceleration
- - Runaway car (OR vehicle)
- - Floor mat stuck

Any hits that indicated the crash might have resulted from a pedal misapplication were excluded from this analysis.

DATA MINING

A national crash database (NMVCCS) and a State crash database (North Carolina) provided detailed information about crashes involving pedal misapplications, as well as insight into the frequency, characteristics, and consequences of these driver errors.

National Motor Vehicle Crash Causation Survey (NMVCCS)

NHTSA's National Motor Vehicle Crash Causation Survey is a nationally representative sample of 5,470 crashes that occurred between January 1, 2005, and December 31, 2007 (NHTSA, 2008, July). This sample is limited because of NHTSA's strict guidelines for a crash to qualify for an on-scene investigation and inclusion into the database. Specifically,

- The crash must have occurred between 6 a.m. and midnight.
- The crash must have resulted in a harmful event associated with a vehicle in transport on a trafficway.[2]
- EMS must have been dispatched to the crash scene.
- At least one of the first three crash-involved vehicles must be present at the crash scene when the NMVCCS researcher arrives.
- The police must be present at the scene of the crash when the NMVCCS researcher arrives.
- At least one of the first three vehicles involved in the crash must be a light passenger vehicle that was towed or will be towed due to damage.
- A completed police crash report for this crash must be available.

For qualifying crashes, NMVCCS researchers obtained information from all possible sources: the crash scene, police, drivers, passengers, witnesses, and vehicles. NMVCCS data contains information collected on-scene about the events and associated driver, roadway, environment, and vehicle factors leading up to crashes involving light vehicles. The survey provides in-depth information about the causal chain of a crash: movement prior to the critical crash envelope, the critical pre-crash event, and the critical reason for the critical pre-crash event. The

[2] This criterion results in the exclusion of pedal misapplication crashes occurring in parking lots.

critical reason can be attributed to the driver (distraction, drowsiness, driving too fast, panic), the vehicle (tire/wheels, brakes), roadway, or atmospheric conditions (rain, snow, glare).

NMVCCS used a multistage probability sample design to generate a nationally representative sample of crashes. Each of the 5,470 crashes has been assigned a weight based on the probability of selecting the crash for analysis. The NMVCCS data set contains information about 1,479 additional crashes that are not weighted because they were investigated during the phase-in period (first 6 months of data collection). The data for the 5,470 crashes may be used to determine national estimates, but the NMVCCS manual (Bellis & Page, 2008) states that the 1,479 crashes assigned zero weights should only be used for clinical study and not for determining national estimates.

There is no "pedal application error" field in the NMVCCS data that can be directly queried to provide information on crashes that resulted from pedal misapplications. However, one of the fields contains a narrative description of the crash. Researchers queried this field to identify crashes that may have been caused by the driver pressing the wrong pedal. The query identified crashes with narratives containing the words "instead" OR "mistak" OR "inadver," as well as any of the following words: "pedal" OR "peddle" OR "brak" OR "gas" OR "accel." The query identified 110 potentially relevant crash narratives.

The research team reviewed each crash narrative to determine whether the crash actually resulted from a pedal application error. Of the 110 crashes, 31 were caused by the driver applying the wrong pedal (pedal misapplication) and 2 were the result of the driver's foot slipping from the brake and pressing the accelerator ("slips"). The remaining 77 crashes contained the words "instead," "mistake," or "inadvertent," but they did not relate to a pedal application error, and were therefore excluded from the analysis. For the 31 pedal misapplication crashes, researchers identified the vehicle number associated with the driver who committed each pedal application error. The NMVCCS case number and vehicle number allowed researchers to extract data about the crash for analysis.

North Carolina State Crash Database

North Carolina's crash database was selected because the crash narrative is included as a field in the crash relational database. The field can be searched using inclusive and exclusive terms to identify crashes resulting from pedal application errors, making it possible to easily extract all the attributes for the selected crashes. In addition, this State database contains crashes that occur in parking lots as well as those that occur on-road.

Law enforcement officers use the Crash Report Form DMV-349 to report motor vehicle crashes in North Carolina. A reportable motor vehicle traffic crash must meet at least one of the following criteria (NCDOT, 2006):

- The crash resulted in a fatality, or
- The crash resulted in a non-fatal personal injury, or
- The crash resulted in total property damage amounting to $1,000 or more, or
- The crash resulted in property damage of any amount to a vehicle seized.

In addition, a reportable motor vehicle traffic crash must occur on a trafficway (any land open to the public as a matter of right or custom for moving persons or property from one place to another) or occur after the motor vehicle runs off the roadway but before events are stabilized. Crashes in parking lots are reportable, if they meet the criteria, and are included in the set of crash locations defined as public vehicular areas (PVA). A PVA includes any area that is generally open to and used by the public for vehicular traffic, including by way of illustration and not limitation any drive, driveway, road, roadway, street, alley, or parking lot upon the grounds and premises of:

a. Any public or private hospital, college, university, school, orphanage, church, or any of the institutions, parks or other facilities maintained and supported by the state of North Carolina or any of its subdivisions;

b. Any service station, drive-in theater, supermarket, store, restaurant, or office building, or any other business, residential, or municipal establishment providing parking space for customers, patrons, or the public;

c. Any property owned by the United States and subject to the jurisdiction of the State of North Carolina.

Beach areas used by the public for vehicular traffic as well as any roads opened to vehicular traffic within or leading to a subdivision for use by subdivision residents, their guests, and members of the public, whether or not the subdivision roads have been offered for dedication to the public, are also considered as PVAs. The term “public vehicular area” excludes any private property not generally open to and used by the public. A PVA crash report should contain the same information as if the crash occurred on a roadway.

Some law enforcement officers choose to report crashes that do not meet the State’s criteria for a reportable crash. When this occurs, they check the “non-reportable” block on the crash report form.

As with the NMVCCS data recording forms, the North Carolina DMV-349 does not contain a code box or data element field to indicate when a crash occurred because a driver made a pedal application error. Consequently, there is no “pedal misapplication” field in the North Carolina crash data that can be readily queried to provide information on crashes that resulted from a driver mistakenly pressing the accelerator, thinking that it is the brake. However, one of the fields contains a narrative description of the crash, which we queried to identify crashes that may have been caused by the driver pressing the wrong pedal. The query identified crashes with narratives containing the text strings “instead” OR “mistak” OR “inadver,” in combination with any one of the following text strings: “pedal” OR “peddle” OR “brak” OR “gas” OR “accel.” The query identified 2,930 crashes for the 5-year period 2004-2008.

Researchers reviewed each crash narrative to determine whether the crash actually resulted from a pedal application error. Of the 2,930 crashes, 2,411 were caused by a driver applying the accelerator when he or she intended to apply the brake. Fifty-eight were the result of the driver’s foot slipping from the brake and pressing the accelerator, 47 were the result of the driver pressing the wrong pedal in a vehicle with manual transmission (either clutch or accelerator rather than the brake, or the brake rather than the clutch). Reviewers determined the remaining 414 crashes not to be the result of a pedal misapplication; these 519 incidents were therefore excluded from the present analyses.

For the 2,411 crashes resulting from pedal application errors, researchers used the crash case number and vehicle number to extract data about the driver and the crash for analysis. No crash had more than one driver who made a pedal application error; there was a one-to-one correspondence between drivers and crashes.

DRIVER REHABILITATION SPECIALIST PANEL

The DRS panel supplemented information from the news media accounts and police reports. Panelists provided first-hand accounts of their clients' pedal application errors, including:

- Descriptions of incidents where clients pressed the gas instead of the brake;
- Driving tasks during which these errors seemed most likely to occur;
- Characteristics of drivers most likely to make such errors;
- Strategies to prevent or reduce pedal misapplication errors;
- Further study methods to learn more about pedal misapplications; and
- Additional insights regarding pedal application errors.

The research team selected the panelists through consultation with the NHTSA TOM, and two individuals nationally recognized in this field: Elin Schold-Davis (OTR/L, CDRS) and Susan Pierce (OTR/L, CDRS, SCDM). Fifteen of the 16 panelists were DRSs, while 1 panelist was a human factors researcher with expertise in sudden acceleration issues who has published several papers on the topic. Of the 15 DRSs, 14 were "on-road veterans" with decades of experience sitting in the front seat evaluating a broad range of drivers. The clients included those learning to use left foot accelerators and hand controls, those with early-stage dementia, those recovering from traumatic brain injury and stroke, younger drivers with attention deficit disorder, and medically impaired drivers referred by their State DMV for an evaluation of fitness to drive. The 15th DRS panelist was a neuropsychologist who performs clinical evaluations and training on a simulator, but does not evaluate or train clients on-road (behind the wheel). The panelists are listed below in alphabetical order.

- Leah Belle, CDRS, Driver Rehabilitation Coordinator, Roger C. Peace Rehabilitation Hospital, OT Dept., Greenville, SC.
- Carol Blackburn, OTR/L, CDRS, Adaptive Mobility Services, Inc., Orlando, FL.
- Cyndee Crompton, MS, ORT/L, SCDCM, CDRS, Driver Rehabilitation Services, McLeansville, NC.
- Glenn Digman, OTR/L, CDRS, Coordinator, Driver Training Program, National Rehab Hospital, Washington, DC.
- Rosamond Gianutsos, Ph.D., CDRS, FAAO, Cognitive and Driver Rehab Services, Sunnyside, NY.

- Anne Hegberg, MS, OTR/L, CDRS, Driver Rehab Program, Marianjoy Rehabilitation Hospital, Wheaton, IL.
- Tom Kalina, MS, OTR, CDRS, Bryn Mawr Rehab Hospital, Malvern, PA.
- John (Jerry) Kenny, OTR, CDRS, Health South Rehab Center of Toms River, NJ.
- Desiree Lanford, MOT, OTR/L, CDRS, University of Florida Public Health and Health Professions, Department of Occupational Therapy, Institute for Mobility, Activity, and Participation (I-MAP).
- Miriam Monahan, MS, OTR, Driver Rehabilitation Program, Fletcher Allen Health Care, Colchester, VT.
- Susan Pierce, OTR/L, CDRS, SCDM, Adaptive Mobility Services, Inc., Orlando, FL.
- Richard Schmidt, Ph.D., Human Performance Research, Marina del Rey, CA.
- Elin Schold-Davis, OTR/L, CDRS, AOTA Older Driver Initiative, Sister Kenny Rehabilitation Institute, Minneapolis, MN.
- Michael Shipp, M.Ed., CDRS, Louisiana Tech University, Ruston, LA.
- Donna Stressel, OTR/L, CDI, CDRS, Sunnyview Rehab Hospital, Schenectady, NY.
- Carol Wheatley, OTR/L, CDRS, Good Samaritan Hospital, Baltimore, MD.

The research team provided the panelists with the Literature Review presenting the state of the knowledge on this topic four weeks in advance, and asked that they become familiar with its contents by the meeting date. The 1.5-day meeting was conducted on August 19 and 20, 2010, at a hotel/conference facility in Washington, DC. The meeting agenda and Moderator’s Guide are presented in Appendix A. The meeting was (audio) recorded and transcribed by a professional transcription service.

CASE STUDIES

The purpose of the case studies was to gather detailed information from and about drivers involved in pedal misapplication crashes to fill in the gaps left by the data mining activities and DRS panel meeting conducted in earlier tasks. Researchers sought information about medical conditions and medications; functional ability; use of cruise control prior to the crash; whether drivers use both feet to control the pedals; driver height; use of adaptive equipment; driver positioning in the driver's seat; and any driver distractions at the time of the crash. Researchers collected two types of case study data: detailed data mining in a State license reexamination database, and unstructured one-on-one telephone discussions with drivers involved in recent pedal misapplication crashes.

Case Study Investigation of Drivers Required to Undergo Reexamination Following a Pedal Misapplication Crash (Iowa)

TraCS (traffic and criminal software) data provided by the Iowa DMV to UNC/HSRC for the time period 4/15/2007 to 10/4/2010 identified 414 drivers with pedal misapplication crashes. These data were obtained through a privacy act agreement executed between Iowa DOT and UNC/HSRC. Licensing data were available for 349 of these drivers; the remaining 65 were either unlicensed, or were out-of-State drivers. Research and Driver Safety Analysis staff in the Iowa DOT Office of Driver Services input the license numbers of the 349 drivers into the Iowa Driver Re-examination Database, and identified 95 drivers who had undergone reexamination. The reexamination path was not the same for all drivers under review. Some drivers were required to have an examination by their physician and submit an acceptable medical report in addition to passing the DMV tests (road, written, and, vision) while others were required only to pass the DMV tests. While the team had planned to obtain data describing medical conditions, medications, and adaptive equipment that may have been used by the crash-involved drivers who underwent reexamination, privacy and confidentiality issues precluded the DMV's ability to provide such information, even though the data were de-identified. The DMV was able to provide us with the following data: driver age and sex; reexamination requirements (medical report, vision test, written test, and road test); whether drivers were suspended because they had unacceptable medical reports or failed any of the DMV tests; driver condition (as coded by law enforcement on the crash report); and the license restrictions that were in force at the time of the crash and following the reexamination. The reexamination data were provided to UNC/HSRC, who de-identified the data, and provided a file to the TransAnalytics Project PI for analysis.

One-on-One Unstructured Conversations with Drivers Involved in Recent Pedal Misapplication Crashes (North Carolina)

Data mining in the North Carolina State crash database identified 508 drivers who had a pedal misapplication crash in 2008 (the most recent year for which crash data were available for this study). For this set of 508 drivers, the data previously extracted by UNC/HSRC for analysis included crash database case numbers and driver age, but no other personally identifying information (i.e., no driver license numbers, names, or addresses). North Carolina Department of Transportation statute prohibits sharing of personally identifying data to entities outside of the DOT. However, the North Carolina Governor's Highway Safety Program (GHSP) and the North Carolina Department of Motor Vehicles (DMV) are both part of the North Carolina DOT, and the

DOT statute allows for this information to be shared between the DMV and the GHSP. The GHSP agreed to mail letters to drivers asking the recipients to call the TransAnalytics PI on a toll-free number to participate in an anonymous phone conversation. UNC/HSRC extracted the names and addresses of a subset of the drivers involved in pedal misapplication crashes from the North Carolina State database, and provided this information to the GHSP.

The target sample size for the Case Study was 100 drivers. The research team selected a subset of 226 drivers for the GHSP solicitation to participate in the telephone conversations by eliminating drivers who were unlicensed or had out-of-state licenses, sorting the remaining drivers by age, and choosing every other driver. Appendix B contains the solicitations letter which states that (1) participation is voluntary—drivers' license status would not be affected whether they participate or not—and (2) TransAnalytics would not ask drivers for their names or license numbers, so their responses would remain anonymous. Since the participants remained anonymous, it was not possible to link their responses to their crash data extracted during the earlier data mining task in this project.

When the drivers called TransAnalytics' toll-free number, they were asked to describe as much as they could remember about the crash, and to self-report medical conditions and medications, describe how they use their pedals, and the kind of shoes they were wearing when they crashed. The guide for the unstructured discussions is presented in Appendix C.

RESULTS

LITERATURE REVIEW

The findings from the technical, peer-reviewed literature are summarized in this section. The findings from the media review of pedal misapplication crashes are integrated with the findings from the data mining tasks to facilitate comparisons of specific characteristics across data sources.

NTSB Investigations

The NTSB investigated seven crashes involving both light and heavy vehicles to identify patterns and driver causes of crashes involving pedal misapplications (NTSB, 1998; 2004; 2009). NTSB crash investigations provide detailed information about drivers' medical factors, driving experience, vehicle factors, and environmental factors. These data, obtained through interviews with the drivers and witnesses, medical reports, toxicology tests, and mechanical inspections of the crash-involved vehicles, can provide rich information about the causes of crashes. The investigations involved a transit bus driver (Normandy, Missouri, 1997); a passenger vehicle driver (Santa Monica, California, 2003); a fire truck driver (Asbury Park, New Jersey, 2006) and four school bus drivers (Liberty, Missouri, 2005; Falls Township, Pennsylvania, 2007; Newtown, Pennsylvania, 2008; and Nanuet, New York, 2007).

In all seven crashes, the drivers either reported a loss of braking or were observed by vehicle occupants or witnesses to be unsuccessfully attempting to stop the vehicles; however, investigators found no evidence of braking system failure. The NTSB determined that pedal misapplication was a factor in all seven crashes.

As a result of their investigation of the Falls Township, Newtown, and Asbury Park crashes, all of which began from a parked position, the NTSB recommended that NHTSA require the installation of brake transmission shift interlock (BTSI) systems or equivalent technology in newly manufactured heavy vehicles with automatic transmissions and other transmissions susceptible to unintended acceleration associated with pedal misapplication when starting from a parked position (NTSB, 2009). A BTSI is a technology that forces drivers to have their foot on the brake when shifting out of park, in any key position. A BTSI would not have prevented the Liberty, Nanuet, and Santa Monica crashes, because the vehicles were in motion when the pedal misapplications occurred. Congress required all light vehicles to be equipped with BTSI by September 1, 2010 (Section 2(d) of Public Law 110-189; see FMVSS 114, Final Rule, March 2010); however, there is no requirement for heavy vehicles.

The NTSB used driver and witness statements to determine that the Santa Monica crash was caused by unintended acceleration, initiated by pedal misapplication. The board concluded that the presence of an event data recorder (EDR) in the vehicle would have provided data needed to assess and understand the driver's acceleration, steering, and braking behavior, and its contribution to the crash. As a result of their investigation, the NTSB recommended to NHTSA that once standards for EDRs are developed, their installation should be required in all newly manufactured light-duty vehicles (NTSB, 2004). In August 2006, NHTSA published a final rule (71 FR 51043) that standardized the information EDRs collect and addressed the survivability requirements for EDRs (United States Code of Federal Regulations, Title 49, Part 563). However, this rule does not require vehicles to be equipped with EDRs. The rule only establishes standards for EDRs that manufacturers choose to install. The standards apply to vehicles manufactured on or after September 1, 2010 including passenger cars, multipurpose passenger vehicles, trucks, or buses with a GVWR of 8,500 pounds or less. In the proposed rule, NHTSA predicted that 65% to 90% of new vehicles would be equipped with EDRs.

As a result of the NTSB investigations of pedal misapplication in heavy vehicles, the Board reiterated and reclassified a 1999 recommendation to NHTSA to require that all school buses and motorcoaches manufactured after January 1, 2003, be equipped with on-board recording systems that record multiple vehicle parameters, among which are braking input (NTSB, 2009). The Board stated that if these vehicles had been equipped with EDR, the question of the drivers' actions during specific events could be documented, and investigators would have a physical record of specific actions and control inputs.

Prevalence

Using a driving simulator, Rogers and Weirwille (1988) found that serious pedal errors (defined in their study as pressing the wrong pedal or both pedals simultaneously) occurred at a rate of 1 per 4.8 hours of data collection, or 1 per 468 foot movements. They observed a total of 7,008 foot movements resulting in 297 errors during the 72 hours in which data were collected. Of the 297 errors, 15 were serious (i.e., the subject mistook the accelerator for brake, the brake for the accelerator, or pressed both pedals). There were only two incidents where the subject pressed the accelerator instead of the brake. In both cases, the subject recognized and corrected the error immediately (i.e., there were no instances in which the subject persisted in mistaking the accelerator for the brake). The other errors occurred when the driver's foot caught or scuffed a pedal during foot movement. The authors concluded that serious pedal errors occur rarely.

Characteristics of Pedal Misapplication Crashes

Schmidt, Young, Ayres, and Wong (1997) used keywords to search police narratives contained in the North Carolina crash database for pedal error crashes that occurred from 1979 to 1980. They identified 219 crashes for analysis, including pedal application errors and foot slips, where the drivers stated that their foot contacted the accelerator rather than the brake. All these crashes occurred after the driving cycle had begun rather than at the beginning of a driving cycle when a driver shifted from "Park" to "Reverse" or "Drive." The authors indicate this may be the result of brake transmission shift interlocks installed on vehicles to prevent this type of pedal misapplication.

The study classified crashes as occurring either during parking or driving on the road. Of the 219 crashes, only 23 (10.5%) occurred during a parking maneuver. Of these, 14 (61%) occurred while the driver was moving forward, and 9 (39%) when the driver was moving in reverse. Of these 23 parking lot pedal misapplication crashes, 8 occurred because the driver's foot slipped from the brake to the accelerator (none because the foot was slippery or wet) and 15 occurred because the driver hit the wrong pedal. Parking lot crashes were further classified according to whether the scenario was hurried or unhurried based on temporal urgency, as stated in the crash narratives. Of the 19 crashes that could be classified based on the information in the police report, 18 (95%) were unhurried – the driver was not responding to an urgent event.

The majority of the pedal error crashes occurred during driving (196 of 219, or 89%). Of these, 111 (57%) were caused by a foot slip, and 85 (43%) because the driver pressed the wrong pedal. Of the 171 crashes where the scenario could be classified, 117 were unhurried (68%) compared to 54 hurried (32%). The driving circumstances surrounding the pedal error crashes could be classified in 154 of the crashes that occurred during driving (includes slips and wrong pedal instances) as follows: slowing normally (36%); turning (22%); the vehicle was stopped (18%); the driver was distracted (10%); the vehicle was hit by another object (8%); the driver was avoiding an obstacle (6%). In nearly all the crashes that occurred because a driver was avoiding another object or the vehicle was stopped, the cause of the pedal error was a foot slip. In crashes that occurred when the driver was slowing, 76% occurred because of a foot slip and 24% occurred because the driver hit the wrong pedal. All the crashes that occurred when a driver was hit by another object occurred because the driver hit the wrong pedal. In the crashes that occurred during a turning maneuver, the majority (82%) occurred because the driver hit the wrong pedal and 18% were caused by a foot slip.

These findings highlight the fact that pedal application errors may occur more often during the driving cycle than at initial start up, as earlier believed, and may commonly occur under unhurried conditions. Although brake-shift interlocks appear to have been successful in preventing pedal misapplication crashes at the beginning of a driving cycle, they cannot prevent a pedal misapplication crash when the error occurs during the driving cycle. Schmidt et al. (1997) found that pedal errors involving a driver hitting the wrong pedal most often occurred during turning maneuvers and when a driver was presumably startled after hitting (or being hit by) another object.

Rationale for a Human Factors Cause for Unintended Acceleration Events

Schmidt (1989) reviewed the research on movement control from a human factors perspective to examine the relationship between foot placement errors and unintended acceleration, with a specific focus on the following questions:

(1) What is the source of foot placement errors, especially for experienced drivers?
(2) Why would a driver not perceive this error immediately?
(3) Why would the driver persist in pressing the wrong pedal for a sufficient time that a crash could occur, in some cases, for as long as 12 seconds?

Driver Errors in Foot Placement. As noted by Brackett, Pezoldt, Sherrod, and Roush (1989), movement of the foot from one pedal to another is a “blind positioning movement.” Drivers perform this movement without looking at their feet. When controls are not visible to operators, they must rely on proprioception and the kinesthetic senses[3] that provide the ability to discriminate foot position— and the direction, amplitude, and speed of movement — as well as the pressure exerted.

A driver may choose a correct response (e.g., decide to step on the brake) but fail to execute the response effectively (e.g., step on the accelerator by mistake) for a number of reasons. These

[3] Proprioception: sense of position of the limbs and trunk (knowing where your body is in space). Kinesthesis: sense of movement in the limbs and trunk (the experience of movement in your body through space). (Hermans, 2002).

include variation in the force and timing of muscle movements; head and body position; and negative transfer from other vehicles, as described below (Schmidt, 1989).

Variability in producing a foot movement—both the trajectory and endpoint—could result in an error in foot placement. Schmidt (1989) states that almost every braking movement results in the foot contacting the brake pedal, but there is substantial variation in actual placement, because the brake pedal and foot are large and overlap considerably. Variation in movement may be so large that the driver misses the brake pedal completely. If the deviation is to the right, then the driver will strike the accelerator pedal instead of the brake, fully believing that he/she pressed the brake because this was the expectation. The force and timing of muscle movements will affect the variability in foot placement. Foot placement errors mainly originate in the driver's motor system (at functionally low levels of the central nervous system) because of force and time variability in the spinal cord which causes muscles to contract and produce the actions. The more force used, the greater the variability in foot placement, and the faster the movement, the greater the force needed.

With regard to unintended acceleration, the farther the foot is from the intended pedal when the driver initiates a movement toward it, the larger the variable errors will be in hitting the pedal (due to the greater force). When the driver's foot is on the accelerator, the movement distance to the brake is small, and variable errors should be smaller. But when a driver is initiating a driving cycle, the right foot may be in a variety of places prior to shifting from park, all further from the brake than if the foot were on the accelerator as in the driving cycle. Therefore, variable errors in aiming should be larger at the beginning of a driving cycle than after it has begun. Faster movements to contact the brake pedal, are likely to result in increased variation in the movement (due to greater forces). This is particularly relevant when the driver makes a hurried braking response.

Another factor that can affect foot aiming accuracy is head and body position. The driver may shift position and temporarily bias the direction of foot aim rightward when starting the driving cycle (Schmidt, 1989). The result could be a foot movement shifted to the right, enough so that he or she strikes the accelerator instead of the brake, leading to unintended acceleration.

Head position can influence a driver's perception of the spatial position of the (unseen) brake pedal. Moving the head or the eyes can cause large systematic biases in the direction of the aim of the foot. Movements in head position activate proprioceptive receptors in the neck which may in turn, alter the perceived spatial position of the brake pedal with respect to the body, influencing limb placement. In studies cited by Schmidt, errors ranged from 5.7 degrees to the left when the head was rotated to the right, to 4.6 degrees to the right when the head was moved to the left. A driver turning to the left while looking in the left side mirror, or reaching for the seat belt when initiating the driving sequence may bias the perceived position of the brake pedal to the right. This bias could be sufficiently large that the driver could miss the brake and strike the accelerator.

Another source of bias toward the right could be introduced by a change in seating position, disrupting the driver's postural set or orientation to the vehicle when driving is resumed. Although the disruption is temporary, it can be substantial for a few seconds, producing a large bias in aiming. Aiming the postural set to the right, could lead to the driver pressing the accelerator rather than the brake.

Schmidt and Young (1997) note that drivers using cruise control can shift position. When an out-of-position driver tries to slow the vehicle by tapping on the brake to disengage the cruise control, the foot may hit the accelerator by mistake. Also, performance decrements may result when a driver is monitoring rather than controlling a vehicle (as when using cruise control). This has been shown by aircraft pilots who are in a relaxed state using auto-flight controls and then produce excessive control inputs with the wrong foot (e.g., full left rudder instead of right rudder) when startled by turbulence.

Negative transfer from other vehicles can also contribute to bias errors in foot placement. Negative transfer is a decrement in the performance of one task as a result of practice or experience in another task. For example, if a person drives the same car all the time and then drives a different make of vehicle in which the brake pedal is placed relatively more leftward, negative transfer from the customary to the new vehicle could reduce the accuracy of pedal movements. Brackett et al. (1989) report that the body of research on blind positioning movements (or kinesthetic memory) suggests that a person who tries to reproduce learned movement using only kinesthetic memory tends to overshoot short distances and undershoot greater distances. Also, accuracy is diminished if other movements are made with the same limb prior to reproducing the desired movements.

Error Detection. Schmidt (1989) describes a theory of movement perception called "efference copy," that explains why a driver may not detect that he or she has hit the accelerator, rather than the brake as intended. According to this theory, when the central nervous system sends a motor signal (to the right leg/foot) to make a movement, a copy of the motor (efferent) command is sent to another location in the brain that is primarily sensory in nature. The purpose of the efferent copy may be to tell the brain's sensory system what the brain's motor system ordered, to prepare it for actual feedback from the leg/foot. The efference copy is a reference of correctness against which the future movement signals will be compared. To relate this theory to unintended acceleration, because the highest central nervous system levels have correctly ordered a movement toward the brake pedal, under certain circumstances the efference copy may substitute for actual feedback from the leg/foot; this indicates a correct movement (toward the brake pedal) even though the actual movement deviates and contacts the accelerator. This would be consistent with a driver "knowing" his or her foot was on the brake, when it actually pressed the accelerator.

Selective attention may also come into play to explain why a driver does not detect an error in foot placement. Little attention is given to the execution of a foot movement, especially if it is fast, predictable, and well practiced. Once a driver has made a foot movement, selective attention directs attention to other information sources that are more relevant, such as the traffic scene ahead, to plan and make steering movements. When attention is directed to the traffic scene, it is unlikely that the driver will attend to feedback from the foot that it is on the wrong pedal. At the same time, the driver may have a subjective experience (from efference copy) that the foot is on the brake pedal. Depending on the intensity of other stimuli that are holding a driver's attention at the time of a pedal application error and the associated depth of processing, a driver may not notice a difference in how it feels to depress the accelerator compared to how a brake pedal depression feels.

Correcting Errors. Citing Angel and Higgens (1969) and Schmidt and Gordon (1977), Schmidt (1989) states that under laboratory conditions and some practical conditions, people detect errors in limb aiming quickly; depending on situational factors, this can be as fast as 120 ms for a kinesthetic stimulus or 200 ms for a visual or auditory stimulus. Reaction times to initiate a foot movement are approximately 500 ms, plus another 200 ms for the movement of the foot from the accelerator to the brake (Schmidt, 1988). However, numerous cases of unintended acceleration have lasted as long as 12 seconds. Schmidt (1989) points to three conditions that could extend error correction times: hypervigilant reactions (panic), perceptual narrowing, and habitual responses under stress.

Under extreme stress, a panic reaction may occur where a person attends indiscriminately to minor and major threats, frantically searching for a way to escape a perceived hazard. This can temporarily impair cognitive functioning, resulting in impulsive and often poor and dangerous choices. People may freeze, appearing to take no action at all, when they are actually attending to multiple cues in rapid succession without being able to make an effective response. This is a "hypervigilant" state, characterized by three causes: a strong startling stimulus, perception of the stimulus as life threatening, and the sense that a solution must be found immediately. In unintended acceleration events, the strong stimulus is the unexpected, violent acceleration, often accompanied by loud sounds. The driver may perceive this as life threatening, evoking fear for self, passengers, and other drivers and pedestrians. The sense of imminent danger makes it important to find a solution fast. Information processing is impaired as the driver is distracted by what is happening in the environment; he or she does not identify the solution, i.e., to move the foot to the brake, because the driver "knows" the foot is on the brake, so assumes the brakes have failed.

Another effect of stress is perceptual narrowing, or shrinking of the attentional field. The driver focuses on central events and misses peripheral cues (visually and perceptually), as well as potentially effective solutions.

Finally, stress increases the likelihood that a driver, placed under high demand for an effective response, will produce a habitual, well-practiced behavior. When a driver who panics with his/her foot on the accelerator (believing it to be on the brake), responds with hard "braking" or pumping the "brakes," the result is more acceleration, which generates more stress, and more hard "braking."

Driver Age and Sex

Walter, Carr, Weinstock, Sussman, and Pollard (1988) found that middle-aged and older drivers (and particularly female drivers) involved in Audi 5000 sudden acceleration incidents were over-represented compared to drivers in all crashes Nationwide (see Table 1). However, such individuals were also overrepresented as owners and drivers of Audi 5000s. Male and female drivers over age 50 (defined as older drivers by Walter et al.) accounted for 20.8% (males) and 24.3% (females) of the sudden acceleration (SA) incidents reported to NHTSA. By comparison Nationally, older males were involved in 12.2% of all crashes and older females 6.3% (NASS database).

Nationally, males of all ages accounted for 61% of the crashes and females 33% (where sex was reported). In the Audi sudden acceleration crashes, the pattern was reversed, with males accounting for 40% and females 57%. Citing data from the Nationwide Personal Transportation Study (NPTS), Walter et al. note that female drivers took more trips that required frequent starts and stops, which are conditions that increase the opportunity for sudden acceleration incidents, specifically, pedal misapplications following an engine surge (unexpected increase in engine power) associated with the Audi 5000 in the years 1984 to 1986.

Table 1. Age and Sex Associated With Audi 5000 Unintended Accelerations Compared to Age and Sex in All Crashes Nationally. (From Walter et al., 1988)

Age Group	Audi 5000 Unintended Accelerations 1984-1986		NASS Database (All Crashes Nationally) 1984	
	Male	Female	Male	Female
<30	3.5%	5.3%	30.4%	15.6%
30-49	15.5%	27.8%	18.5%	11.4%
50+	20.8%	24.3%	12.2%	6.3%
Total	39.9%	57.4%	61.1%	33.4%

Cognitive Deficits

Citing evidence (Pollard and Sussman, 1989) that unintended acceleration crashes are more likely to involve older drivers and may result from cognitive deficits, Freund, Colgrove, Petrakos, and McLeod (2008) conducted a driving simulator study to determine the extent to which cognitive functions contribute to pedal application errors among older drivers. Freund et al. (2008) liberally defined unintended acceleration events in their study as an inappropriate acceleration *or* a failure to decelerate, when deceleration or a transition from accelerating to braking was required by a demand in the driving situation (e.g., stop sign, vehicular intrusion, pedestrian intrusion). They found that drivers with impairments in executive functioning, as measured using the Clock Drawing Test, were 10 times more likely to experience unintended acceleration events than drivers with normal executive functioning. One-third of the drivers experienced unintended acceleration events, 70% of whom verbalized their inability to slow or stop the vehicle.[4] The number of unintended acceleration events per driver ranged from 1 to 11, and occurred most often in response to a sudden change in environment such as changing traffic lights and intrusions into the driving environment. Drivers 84 or older were 6 times more likely to experience unintended acceleration events.

Freund et al. (2008) conclude that deficits in executive functioning may be an important contributor to pedal application errors and unsafe driving, and recommend that practitioners consider measures of executive function when evaluating patients for their ability to drive safely. Executive function is involved in planning and decision-making, error correction and trouble shooting; drivers rely on this ability in situations requiring novel responses and sequences of

[4] The study authors note that the verbalization of an inability to slow or stop the vehicle suggests that the drivers recognized that deceleration was required but failed to recognize they made an error in pedal choice. These can be interpreted as pedal misapplication unintended acceleration events.

actions, situations that are hazardous or technically challenging, and situations necessitating the resistance to temptation or requiring a course of action that goes against strong habitual response (Norman & Shallice, 1980, cited by Freund et al., 2008). With executive dysfunction, Freund et al. (2008) note that the automatized and procedural skills learned over decades of daily driving are applied in an inflexible manner and thus do not protect the older driver from making errors.

In their simulator study using interactive computer-video scenarios as measures for screening functional aspects of driving performance, Schiff and Oldak (1993) describe a "completely unexpected" observation of unintended acceleration by 2 of the 109 study participants over age 55. The unintended acceleration events occurred in similar driving situations as those reported by Freund et al. (2008) in response to a sudden change in the environment, such as an intrusion by another road user.

Age Differences in Foot Movement

Cantin, Blouin, Simoneau, and Teasdale (2004) showed increased movement variability in the right foot behavior of older versus younger subjects. In a driving simulator study conducted by these researchers, older drivers' right foot movement amplitudes were significantly greater than those of younger drivers (11.55 versus 10.10 cm, respectively), when moving their right foot from the accelerator to the brake to stop at a stop sign or red light. Older drivers also showed significantly greater within-subject variability in foot-movement amplitude (1.37 cm for older drivers versus 0.95 cm for younger drivers). In addition, older drivers made several submovements of the right foot following initial release of the accelerator pedal; younger drivers rarely made such submovements. Submovements were defined as movements greater than 10 cm/s, to differentiate them from small wobbling movements. The average number of submovements made by older subjects was 1.94 compared to 0.44 for younger subjects.

No pedal application errors were observed in the Canton et al. study. While the authors observed that older drivers' right foot movements are more variable that that of younger drivers, they noted that more research is needed to determine if there is a direct relationship between variability in lower limb movement and pedal misapplications. Canton et al. (2004) noted two limitations in their study: the simulated drive required no left turns (due to software limitations), and drivers were not distracted by external events or secondary tasks such as talking to passengers. More complex driving situations, coupled with variable foot movements, may increase the likelihood of pedal application errors.

Driver Unfamiliarity with the Vehicle

Researchers have found that drivers in unfamiliar vehicles (e.g., leased vehicles) have a higher risk of crashes and near-crashes, and make more evasive maneuvers than when they are driving their own vehicles (Lee, Dingus, Klauer, Neale, & Sudweeks, 2005).[5] In this 4-week study using the same driver as his/her own control, the higher risk in a leased vehicle persisted into the fourth and final week of the study, even when exposure differences were taken into account.

[5] Pedal application errors were not a focus of this study, and no mention was made of pedal misapplication as a cause of the evasive maneuvers.

In related work, Pollard and Sussman (1989) reviewed the NHTSA complaint data for vehicles with high reported sudden acceleration incident rates, and found that complaints about unwanted engine power fell substantially with increases in vehicle mileage. They attributed this drop to a decrease in the likelihood of pedal misapplications as drivers became more familiar with their vehicles.

Walter, Carr, Weinstock, Sussman, and Pollard (1988) conducted a study to determine the possible contributions of the vehicle and the driver to the high rate of sudden acceleration incident complaints for the Audi 5000. Between 1978 and 1986, drivers attributed 556 crashes per 100,000 Audi vehicles sold in the United States to unintended acceleration. By comparison, the highest rate for other vehicles was 28 per 100,000 vehicles. Walter et al. compared the Audi 5000's interior seating and pedal arrangements to hundreds of other vehicle models in the U.S. fleet for critical driver-related dimensions. They found significant differences for 20 dimensions, including seat height; knee angle; lateral steering wheel position; knee clearance; brake pedal force, size, height, and travel; and accelerator pedal size and height. Next, Walter et al. (1988) looked at driver experience for the drivers filing a complaint of sudden unintended acceleration for the Audi 5000. They found that 44% of the drivers had less than 6 months' experience with the vehicle, and according to Audi interviews of drivers involved in sudden acceleration incidents, the majority did not own the vehicle or did not drive it regularly. As a means of comparison, an analysis of NHTSA's National Automotive Sampling System (NASS) database indicated that 34% of all drivers involved in crashes nationwide had less than 6 months of experience in the vehicle involved. Walter et al. (1988) concluded that once an unintended acceleration had begun,[6] pedal misapplication resulting from panic, confusion, or unfamiliarity with the Audi 5000 contributed to the severity of the incident.

Pedal Configuration and Vehicle Geometry

As noted by Pollard and Sussman (1989), a driver must be able to distinguish the brake from the accelerator without looking at the pedals. Drivers use sensory cues, which are different for each pedal, to make this distinction. The most significant cues are pedal position (a spatial code) and feel (amount of force to depress the pedal). The direction and curvature of the motion required to operate a pedal are also part of the feel. Drivers may use other spatial reference points such as the transmission hump in distinguishing the pedals. Depending on the type of shoes the driver is wearing, less useful cues include pedal size, shape, angle, surface texture, and contour. Researchers have carried out a number of studies over the past two decades to determine whether the design of the brake-accelerator cluster is associated with crashes involving unintended acceleration or pedal misapplication.

In a sample of 10 make/model/year vehicles[7] with high report rates to NHTSA of sudden acceleration, Pollard and Sussman (1989) found the following characteristics that could increase the probability of a pedal misapplication: (1) relatively close lateral spacing between brake and accelerator; (2) relatively smaller vertical spacing between brake and accelerator, increasing the probability of pressing both pedals simultaneously; (3) relatively long brake-pedal travel resulting

[6] In the Audi 5000, these were due to a failure in the idle-stabilizer system, producing an initial acceleration of 0.3g).
[7] Audi 5000 (1983 and 1985), Buick LeSabre (1985), Cadillac Coupe de Ville (1985), Chevrolet Camaro (1984), Chrysler New Yorker (1984), Mercedes 300E (1986), Mercury Grand Marquis (1984), Nissan 300ZX (1985), and Toyota Cressida (1984).

in a “soft feel,” which makes both pedals feel the same, reducing the chances that an error will be recognized, and permits engine torque to exceed brake torque when both pedals are pressed simultaneously; and (4) a relatively powerful engine, making it more likely a crash will occur before a driver has time to make a correction.

These researchers measured the pedal separation and force deflection in 17 vehicles, some that had high “reported sudden acceleration incidents” (RSAI); those with low RSAI rates were used as a comparison group. All of the tested vehicles with high RSAI rates moved when the drivers applied light to moderate levels of force (less than 50 pounds) with the right foot to both pedals simultaneously, by tilting the foot slightly to the right. Under these conditions, the driver reported that the sensation was similar to stepping on the brake pedal alone, and that the force to stop the vehicle was substantially greater than required for normal stopping. In a wide-open-throttle situation, substantial pedal force (at least 175 pounds) was required to achieve maximum deceleration for some vehicles tested. Pollard and Sussman cite evidence that 50% of all women and a smaller proportion of weaker men cannot provide brake pedal force of more than 175 pounds for a period of 1 to 5 seconds. Most of the reported sudden unintended acceleration incidents Pollard and Sussman reviewed included driver statements concerning the lack of braking effectiveness. The reports frequently indicated that the drivers felt certain they did not press the wrong pedal.

In comparison, test drives in the vehicles with low RSAI rates had pedal arrangements that made it relatively difficult to exert any substantial force on the accelerator while simultaneously pressing the brake with the same foot.

Some vehicles had pedal characteristics that were conducive to pedal misapplications, but had low RSAI rates. Pollard and Sussman noted that these vehicles may have other characteristics that reduce the consequences of a pedal misapplication. For example, the Honda Civic has low engine power and a low noise level.

Walter et al. (1988) found that the Audi accelerator pedal was significantly higher than the accelerator pedal in other vehicles (139.0 mm for the Audi in 1983 and 110.0 mm for the Audi in 1986 versus an average of 71.0 mm for all domestic vehicles). Audi’s brake height, however, was similar to other models (168.0 mm in 1983 and 152.0 mm in 1986 versus an average of 147.3 for all domestic vehicles).

Although Pollard and Sussman (1989) made recommendations to increase the lateral separation of pedals and to raise the brake pedal with respect to the accelerator, they note that these changes would not completely eliminate sudden acceleration incidents, as the majority of automobiles in use at the time the report was prepared had pedal configurations consistent with their recommendations. Also, the test-drive experience indicated that it was not only the static positions of the pedals, but also how they moved with respect to each other and how much engine torque and brake torque were generated at various displacements that could influence the probability of a pedal misapplication.

For the purposes of their study, sudden acceleration was defined as an unintended, unexpected, high-power acceleration from a stationary position or a very low initial speed, accompanied by an apparent loss of braking; typically when shifting from “Park” to “Drive” or

"Reverse." Their recommendation to install automatic brake-shift-interlocks to prevent unintended acceleration had already been adopted or considered by a number of manufacturers[8].

Pollard and Sussman (1989) concluded that human factors play a large role in sudden acceleration problems and that pedal misapplications are the most probable explanation for the majority of such incidents when there is no evidence of throttle sticking or cruise control malfunction—the only two vehicle component failure modes that could result in the wide-open-throttle condition that is characteristic of a sudden acceleration incident report. Their conclusion followed from their study of the fuel systems, braking systems, and driving controls of the 10 vehicle makes/models/years with high RSAI rates as well as measurements of vehicle behavior under simulated fault conditions (on road with the vehicles and bench tests of components). Although they identified certain malfunctions that could cause the throttle to open or stick, these would be readily detectable in a post incident investigation. Cruise control systems are the only vehicle component suspected of initiating a wide-open-throttle condition without the driver pressing the accelerator. Also, for "recent" factory-installed cruise controls (as of the 1989 report) digital circuitry was the norm, so that two or more component failures would have been required to cause an unintended throttle opening. The only other potential cause of the wide-open-throttle condition was the misapplication of a driver's foot. Other malfunctions were found that could cause modest increases in engine power (up to 0.3g), and may be difficult to detect in a post-incident investigation. The researchers stated that the engine power increases (engine surges) were not large enough to cause a sudden acceleration incident, but might startle the driver into a pedal misapplication.

In other studies, no relationship was found between pedal design and unintended acceleration (UA) or pedal misapplication events. In a simulator study using 114 subjects ages 14 to 81, Bracket, Pezoldt, Sherrod, and Roush (1989) found no significant differences in either foot movement time (from accelerator to brake) or pedal application errors (including wrong pedal, both pedals, contacting the pedal with less than half of the foot, and hesitation in foot movements) for three lateral pedal separation configurations. The three configurations included the recommended configuration (3 inches of separation) plus two configurations bracketing the recommended configuration (2 inches and 5.75 inches). Most of the performance errors were observed when foot movements were made from the floor to the pedals, rather than from one pedal to another. High pedal error rates (1 in every 10 foot movements) were found for all three pedal configurations, but this may have been experimentally induced by restricting the pedals from view, allowing no practice trials, starting a large proportion of trials from the vehicle floor rather than from pedal to pedal, and constraining response time.

In the Rogers and Weirwille (1988) study described earlier, the simulator was configured to test the prevalence of pedal application errors as a function of pedal, floor, and seating configuration in four actual automobiles. The four different pedal configurations corresponded to (1) a sport sedan with the brake pedal somewhat above the accelerator; (2) a late-model sport sedan with a floor-hinged accelerator; (3) a full-sized sedan with a wide brake pedal well above a center-hinged accelerator; and (4) a vehicle similar to the sport sedan, but with the brake pedal lowered somewhat so that the vertical separation between the accelerator and brake was smaller. The authors provide

[8] Automatic brake-shift-interlock is now a requirement as part of Federal Motor Vehicle Safety Standard No. 114, effective April 29, 2010.

the specific pedal horizontal separation distance, vertical separation distance, pedal height, and brake pedal width for each configuration in their report. Of particular importance to this literature review is that there were no significant differences between configurations in the incidence of serious pedal application errors observed in the study. The study authors noted that serious errors were very rare, occurring only 15 times throughout the entire experiment. This represents an average rate of occurrence of one serious error per 4.8 hours of data collection or one serious error per 468 foot movements. The authors cautioned that the failure to find significant differences in the occurrence of serious errors among the four configurations may have been the result of sparse data, or a real finding, and noted that it was unlikely that the issue could be resolved using simulation methods.

Trachtman, Schmidt, and Young (2005) identified crashes involving pedal application errors or unintended acceleration (UA) through evaluations of over 4 million crash narratives between 1979 and 1998 in the North Carolina crash database. For UA events, the driver believes that his/her foot was on the brake, denies it was on the accelerator, and believes the vehicle malfunctioned in some way. This happens after startup and shift from park to a drive gear. For pedal error (PE) crashes, the driver is aware of the error and reports it to the police officer. These crashes occur at startup as well as during turning and braking. A narrative search using 19 keywords resulted in 236,231 crash narratives. Each crash report provided the year, make, and model of the involved vehicle. For each crash vehicle make/model/year, either another vehicle of the same make/model/year or a “corporate twin” (a vehicle identical in every respect as the crash vehicle type, except for trim and emblems) was located for measurement. Then, peer vehicles were identified that were not involved in UA or pedal error crashes in the North Carolina database. These peer vehicles were matched with the “corporate twins” on criteria including wheelbase, weight, age, classification, and driver age, but different manufacturer. Various measures were taken to allow a direct comparison of pedal configurations for a group of crash-involved vehicles and a matching group of their uninvolved peers. The sample included 20 UA-involved and 18 pedal-error-involved vehicles, each of which was matched with an uninvolved peer vehicle. Three pedal measurements were made for each vehicle: (1) the separation between the right edge of the brake pedal and the steering wheel centerline, with a positive value being to the right of the steering wheel centerline; (2) the separation of the right edge of the brake pedal and the left edge of the accelerator (the “gap”); and (3) the vertical separation between the two pedals measured along a line perpendicular to the brake pedal surface at rest.

Brake to centerline measurements in this study ranged from -0.12 to 6.27 inches. Across incident type, involved vehicles and peer vehicles had nearly identical brake to steering wheel centerline measures (mean 2.55 in versus 2.65 in). This difference was not significant, nor was the interaction between incident type (UA or PE) and vehicle type (involved versus peer). These findings indicate that location of the brake pedal laterally from the steering wheel centerline was not factor in either UA or PE incidents. The crash involved vehicles had slightly smaller horizontal pedal separation than the peer vehicles (mean 2.44 versus 2.72 in), but this difference was not significant, nor were any differences between the subgroups. This suggests that horizontal separation is not a factor in either PE or UA incidents. Finally, the involved vehicles had slightly larger vertical separation than the peer vehicles (mean 2.62 versus 2.33 in), but this differences failed to reach significance, as did differences between UA and PE vehicles and their peers. Thus, there is no evidence that the vertical separation between the brake pedal and the accelerator pedal was a factor in either UA or PE incidents.

The authors concluded that there is no evidence that vehicles with leftward-biased pedal clusters, or those with a small gap are prone to either UA or PE crashes. Instead, response errors resulting in variability in movement control are likely responsible for pedal misapplications.[9]

Vernoy and Tomerlin (1989) conducted a study to test the hypothesis that misperception of a vehicle's centerline is related to pedal misapplication. Hypothetically, if a driver misperceives the centerline of the vehicle to be to the right of actual center, then during an emergency the driver may place his/her foot to the right of the intended position. Because the accelerator is placed to the right of the brake, drivers may press the accelerator, thinking they are pressing on the brake.

The study compared driver perception of centerline in eight vehicle models. Subjects first completed three trials to identify the centerline of the vehicle by choosing one of 48 LEDs that were projected on a wall approximately 23 feet in front of the subject. Next, they responded to slides projected on the wall instructing them to step on the brake, step on the accelerator, move the shift lever, signal left, or signal right. There were five practice slides, followed by nine slides in each of the two vehicles being compared. Between slide presentations, subjects were instructed to rest their feet flat on the floor. On one slide that presented a stop sign, the experimenter shouted into an intercom "Stop! Hit the brakes!" to simulate a panic stop. Subjects' foot positions on the brake were recorded for each panic stop, and pedal errors were coded as one of two types: (1) foot placement between the pedals or on both pedals; or (2) foot placement on the accelerator. At the end of the session, subjects placed a dot on the dashboard to indicate the center of the vehicle, before exiting the vehicle.

Vernoy and Tomerlin (1989) found that the perceived center of each of the eight vehicles as measured by the outside LEDS was to the right of actual center. The deviation from actual center ranged from 7 to 20 in, and was significantly greater than 0 for all eight vehicles. Similarly, the perceived center of the automobile as measured by inside placement of the adhesive dot showed average deviations to the right of center for each of the eight vehicles, ranging from 0.80 to 2.47 in. The right deviation from center was significantly greater than zero for each of the eight vehicles. Subjects made 26 pedal application errors during the 258 panic stop trials, including 14 where subjects hit the accelerator instead of the brake. There was no significant difference in pedal error rate across the eight vehicles. To test the hypothesis that pedal error was related to the misperceived center of the vehicle, analysts computed correlations between weighted pedal error and both outside and inside center measurements. None of the correlations was significant, indicating no relationship between the misperceived center of the vehicle and pedal application error. In their discussion, the authors noted that real-world error rates were likely lower than observed in the experiment, because they designed the experimental situation to elicit errors through placement of the feet on the floor between foot movements. Most drivers in actual driving situations would place the foot above the brake or accelerator, rather than on the floor. The authors noted that drivers who have a habit of placing their feet flat on the floor between movements, such as in parking and starting situations, and when using cruise control, may be more likely to make these types of errors than drivers who

[9] Potential confounds in the study methodology included: (a) the twin vehicles selected for measurement were not always the same make, model, and year as the crash vehicles; and (b) although the peer vehicles had not been involved in pedal error crashes in North Carolina, they may have been involved in such crashes elsewhere. Therefore, the conclusions regarding pedal geometry of case ("twins") versus comparison ("peer") vehicles should be viewed with some caution.

keep their feet close to the brake or accelerator. This experiment did not test whether misperception of the centerline in a moving vehicle would affect pedal misapplication rate.

The findings of this study are interesting in light of the NTSB's discussions regarding a possible reason for the Santa Monica driver's inadvertent activation of the accelerator (NTSB, 2004). The NTSB report indicated that the driver may have been out of his usual driving position when the crash occurred. This is because moments before the crash, he had parked his car and slid across the vehicle to the passenger side to deposit a letter through the passenger window of his vehicle into a curbside mailbox. Citing Schmidt (1989), the NTSB stated that an error in response execution could result from a driver's head or body being out of position, such that a normal, habitual movement results in an error (in foot placement). Given the widespread misperception of the vehicle centerline (i.e., to the right of the vehicle) noted by Vernoy and Tomerlin, if the Santa Monica driver, upon his return to the driver seat, was positioned farther to the right of center in his vehicle than normal, he may have misestimated the foot movement necessary to hit the brake.

Driver Workload

Tomerlin and Vernoy (1990) reported on a field study that followed the static tests described by Vernoy and Tomerlin (1989). In this study, 169 subjects were assigned to one of the eight vehicles used in the static tests; subjects who participated in the static tests were assigned to a different vehicle for the field tests. Subjects drove through a short serpentine course, and were directed to one of four areas marked for reversing maneuvers. A researcher sitting in the passenger seat instructed the subject to place the gear lever into Park, shift to Reverse, and back through a parallel line of rubber cones. After the subject shifted into reverse, the researcher opened the accelerator to full throttle using a hand lever, and made observations about the subject's use of the brake pedal and ability to stop the vehicle. One subject hit the accelerator instead of the brake, and continued pressing the accelerator until the car ran off the back of the course and was stopped by the researcher using an ignition kill switch. Four other subjects made partial errors but corrected their mistake. Three of these subjects pressed on both pedals momentarily, and one subject accelerated briefly before applying the brake.

In another study using 130 subjects driving in 3 different passenger cars under 3 different driving situations, Tomerlin (1998) found that experimenter activation of maximum idle speed resulted in confusion by 2 subjects during a reverse-driving test: they applied the accelerator when they meant to brake. Tomerlin and Vernoy (1990) concluded that pedal misapplications can be induced, as shown in the laboratory and field studies, and can be a problem for all automatic transmission cars and all categories of drivers.

Pollard and Sussman (1989) noted that driver workload may influence the likelihood of a pedal misapplication, since unexpected movements of the vehicle may briefly overload and startle the driver, resulting in a control error. The human startle reflex, as initiated by the actions of the vehicle, is controlled by non-cognitive areas of the central nervous system, and may take precedence over conscious efforts to control the vehicle. When a driver is forced to respond more quickly than usual to a stimulus, the likelihood of an error increases. If the idle speed abruptly and unexpectedly jumps, causing even a brief or slight acceleration, a driver who must respond instantly is more likely to partially or entirely miss the brake than a driver making a planned action. Pollard and Sussman (1998) referenced the work of Tomerlin and Vernoy (1990) as evidence that startling a driver (through a surprise acceleration) may result in that driver pressing the accelerator when he or she intended to press the brake.

Schmidt and Young (1997) also provided evidence that startle or surprise stimuli produce errors. When these experimenters unexpectedly tapped the arms of subjects who were performing a two-choice reaction time task (or introduced a “click” via headphones), subjects’ reaction time was quicker, but their response movements were in the wrong direction (Gielen, Schmidt, and van den Heuvel, 1983). Citing Proctor and van Zandt (1994), Schmidt and Young label this phenomenon a speed-accuracy trade off; and when a startling event requires an immediate response, more errors occur in two-choice situations. In addition, startling stimuli (such as loud sounds or bright visual signals) have been associated with more forceful movements, relative to less startling events (Angel, 1973; Ulrich and Mattes, 1996).

NEWS MEDIA AND DATA MINING

Data Limitations

News Media Data. Several issues plague the use of news media reports to determine the incidence of pedal misapplication crashes over time and to describe the characteristics of drivers who make such errors. These include archiving issues, trends in the media, and missing data. With regard to archiving issues, particularly with Google News, the number of archived media hits of any type decreases as the search goes back in time. Newspapers often do not have the capacity on their Web servers to house multiple years of archived stories, so they “weed them out.” Other news databases, such as LexisNexis and NewsBank, continually add new sources over time. For these reasons, a search spanning 10 years will produce more “hits” in the most recent years than in prior years.

A related issue is that not all newspapers archive their stories on the Internet. For example, Google News is limited to publications that archive their news stories on the Internet Other news sources may archive their media on their Web sites, but do not make their archive available to media databases. Publications that operate subscription-based Web sites, such as the Wall Street Journal, often do not provide free full-text versions to Google News users. Similar to the issue with Google, publications may choose not to provide their full-text articles to LexisNexis and America’s Newspapers. For example, America’s Newspapers includes the following National newspapers in their resource: Atlanta Journal-Constitution, Boston Globe, Chicago Sun-Times, Chicago Tribune, Denver Post, Houston Chronicle, Richmond Times-Dispatch, San Francisco Chronicle, St. Louis Post-Dispatch, Washington Post and Washington Times. While this is an impressive list, it does not include every major U.S. National newspaper.

Another factor is competing and/or complementary issues in the media. For example, a high profile crash, such as the “Farmer's Market” crash in California, can raise the visibility of this issue tremendously, leading media across the country to pick up this story and similar stories in their own markets. On the other hand, when there are large competing issues in the media—for example a presidential election—then media outlets might skip “pedal error” stories completely. There may also be a bias in reporting only the most “news worthy” incidents: a pedal misapplication crash involving a middle-aged driver with minor property damage and no injuries will likely not make the news, where crashes involving fatalities, serious injuries, or heavy property damage—especially if teenage or older drivers are involved—probably will.

The final issue surrounding the use of news media in describing pedal misapplication crashes is the amount of missing data. News reports of vehicle crashes vary in the amount of detail provided. Some reports consist of only a few sentences while others describe the crash circumstances in great detail. As a result, the database created using information provided in the news reports was missing a great deal of data characterizing the drivers, their vehicles, the crash locations, the pre-crash maneuvers, and other crash specifics.

Crash Data. Both of the crash databases used in this project (NMVCCS and the North Carolina State crash database) were limited by the lack of a field to identify pedal misapplication crashes. Such crashes could be identified only if: (1) the driver admitted making the error; (2) the reporting officer described the driver's pedal misapplication in the crash narrative field of the crash report form; and (3) our search strategy contained all the phrases (and spellings) that officers may have used to describe the pedal misapplication. There is a strong possibility that a subset of pedal misapplication crashes was not identified, and was included in "all other crash" set; for this reason, our analysis may understimate the prevalence of pedal misapplication crashes.

A further limitation of the NMVCCS data is that it does not include crashes occurring in parking lots. Aside from these missing incidents, and the associated information lost to this analysis, a bias in the ages of the drivers included in the sample drivers who made pedal application errors may be introduced by this limitation. This could happen if drivers in a certain age cohort (e.g., older drivers) are more likely to experience pedal misapplication crashes while performing parking maneuvers than on-road maneuvers. The NMVCCS data also is restricted to crashes involving at least one passenger vehicle needing to be towed from the crash scene, so could be expected to represent a more serious subset of crashes.

An additional limitation of the North Carolina crash database in determining the prevalence of pedal misapplication crashes is the property damage threshold of $1,000. Pedal misapplication crashes that resulted in property damage below $1,000 are not included in the crash database unless they also resulted in a fatality or an injury. Also, crashes that occurred on private property do not meet the State's criteria for a reportable crash; however, some local law enforcement agencies choose to report some crashes on private property. Therefore the private property crashes that are included in the database are an underrepresentation of their actual prevalence.

With these caveats in mind, the following sections describe the prevalence of pedal misapplication crashes and the driver, roadway, and vehicle characteristics associated with these events.

Prevalence of Pedal Misapplication Crashes

The findings from analyses of both the NMVCCS and the North Carolina State Crash Database indicate that pedal misapplication crashes account for less than 1% of *all* crashes. As noted earlier, however, the absence of any codes on police crash reports to indicate that a crash resulted from a pedal misapplication is likely to have caused the prevalence of these incidents to be underestimated. Even if such codes were present, it is unclear whether law enforcement officers, who rely on self-reports of behavior, could accurately and reliably apply them.

The media analysis identified 178 pedal misapplication crashes in 2009. Based on a total of 5,505,000 police-reported crashes in the United States in 2009 (NHTSA, 2010), this represents less than 1% of *all* crashes (.003%). This, too, is likely to be an underestimation, based on archival issues; competing stories; availability of free, full-text articles in news databases; and a bias in reporting of newsworthy-only events.

Table 2 presents the number of pedal misapplication crashes versus all other crashes in North Carolina, by crash type, for the years 2004-2008. Statewide, there were 1,398,034 crashes. Pedal misapplication crashes accounted for 2,411 events, or less than 1% of all crashes (0.2%). This proportion is identical to that uncovered in the weighted analysis of NMVCCS crashes 2005-2007, shown in Table 3, which used the same method of pedal application error identification but is based on a sample of more serious crashes occurring on roadways only.

Table 2. Comparison of Crash Types for Pedal Misapplication Crashes Versus All Other Crashes. (North Carolina State Crash Database, 2004-2008)

Crash Type	Pedal Misapplication Crashes		All Other Crashes	
	Number	Percent	Number	Percent
Missing	2	0.08	377	0.03
On-road - property damage only	653	27.08	718,891	51.51
On-road - fatal	1	0.04	7,114	0.51
On-road - non-fatal injury	395	16.38	384,962	27.58
non-reportable	87	3.61	133,383	9.56
private property	81	3.36	9,278	0.66
PVA* - property damage	980	40.65	125,489	8.99
PVA - non-fatal injury	212	8.79	15,980	1.15
PVA - fatal	0	0	149	0.01
Total	2,411	100	1,395,623	100

*Public Vehicular Area, generally parking lots.

North Carolina data (Table 2) show pedal misapplication crashes resulted in slightly lower proportions of non-fatal injuries compared to *all other* crashes (25.2% versus 28.7%), collapsing across location (PVA and on-road). Pedal misapplication crashes resulted in slightly larger proportions of property-damage-only crashes, compared to *all other* crashes (67.7% versus 60.5%). There was 1 fatality resulting from a pedal misapplication crash (.04%), but the *all other* crash set resulted in 7,263 fatalities (0.5% of the crashes).

Interestingly, nearly half (49.4%) of the pedal misapplication crashes occurred in parking lots or other PVAs, compared to only 10.1% of all other crashes, which may account for the near-absence of fatal crashes among pedal misapplication crashes, compared to *all other* crashes. However, pedal misapplication crashes in parking lots resulted in a larger percentage of non-fatal injuries than *all other* crashes in parking lots (8.79% versus 1.15%). The majority of the non-pedal misapplication crashes occurred on-road (79.6%), compared to only 43.5% of the pedal misapplication crashes. Pedal misapplication crashes occurring on-road resulted in a smaller percentage of non-fatal injuries than *all other* crashes (16.38% versus 27.58%). However, these percentages are affected by the different distributions of on-road crashes. The percentage of on-road pedal misapplication crashes that result in injury or death (37.8%) is about the same as the percentage of *all other* on-road crashes that result in injury or death (35.3%). In contrast, pedal misapplication crashes occurring in parking lots and PVAs are more likely than *all other* crashes to result in injury or death (17.8% versus 11.4%), in part due to pedestrian involvement.

Table 3. Prevalence of Pedal Misapplication Crashes in the NMVCCS Sample 2005-2007 (Weighted).

Data Collection Year	Number and Percentage of Crashes by Type:		Total
	Pedal Misapplication Crashes	All Other Crashes	
2005	865 (0.2%)	399,118 (99.8%)	399,983
2006	1,973 (0.2%)	851,478 (99.8%)	853,451
2007	2,090 (0.2%)	930,662 (99.8%)	932,752
Total	**4,928 (0.2%)**	**2,181,258 (99.8%)**	**2,186,186**

Driver Age

Driver age was available for only 683 of the 899 pedal misapplication crashes identified in the news media and 2,399 of the 2,411 crashes identified in the North Carolina State crash database. Figures D-1 and D-2 in Appendix D present frequency distributions of pedal misapplication crashes by driver age for these two data sources. Due to the small number of crashes identified in the NMVCCS database, NMVCCS findings by age are not included in this discussion. Although the media analysis and the North Carolina crash analysis both show higher crash involvement at both ends of the age distribution, the media analysis showed smaller proportions of younger drivers and larger proportions of older drivers than the North Carolina crash analysis.

Figure 1 shows the Percentage of pedal misapplication crashes involving drivers by 5-year age groupings from the news media analysis (red bars), contrasted against the percentage of licensed drivers in the U.S. population for each age group (green bars).[10] Figure 2 shows the percentage of pedal misapplication crashes involving drivers by 5-year age groupings from the North Carolina crash analysis (red bars), contrasted against the percentage of licensed drivers in North Carolina by age group (green bars).[11] The ratio of the two percentages is presented above each set of bars, providing an indication of the degree to which each age group is represented in

[10] Statistics describing the population of licensed drivers in the United States by age were obtained from Table DL-22 *Highway Statistics* (FHWA), averaged across the years 2000 to 2008 (data for the years 2009 and 2010 were not available on FHWA's Web site as of the time this report was prepared).
[11] Averaged across the years 2004-2008 from Table DL-22 *Highway Statistics* (FHWA).

pedal misapplication crashes versus their representation in the driving population. Ratios greater than one indicate that the group is overrepresented and less than one indicates underrepresentation.

The media analysis (see Figure 1) showed that drivers younger than 20 were overrepresented in pedal misapplication crashes by a factor of 2.38 times their representation in the driving population. Drivers 20 to 64 were underrepresented in pedal misapplication crashes, compared to their proportions in the driving population. Those 65 to 69 were slightly overrepresented, while those age 70 to 74 were represented in crashes involving pedal misapplications at nearly twice their proportion in the driving population (1.90). The risk increased more sharply as age increased, beginning at age 75.For drivers ages 85 and older the relative risk climbed to 12.6.Thus, while pedal misapplication crashes were prevalent among both younger and older drivers, older driver involvement increased sharply in relation to their proportion among the population of licensed drivers.

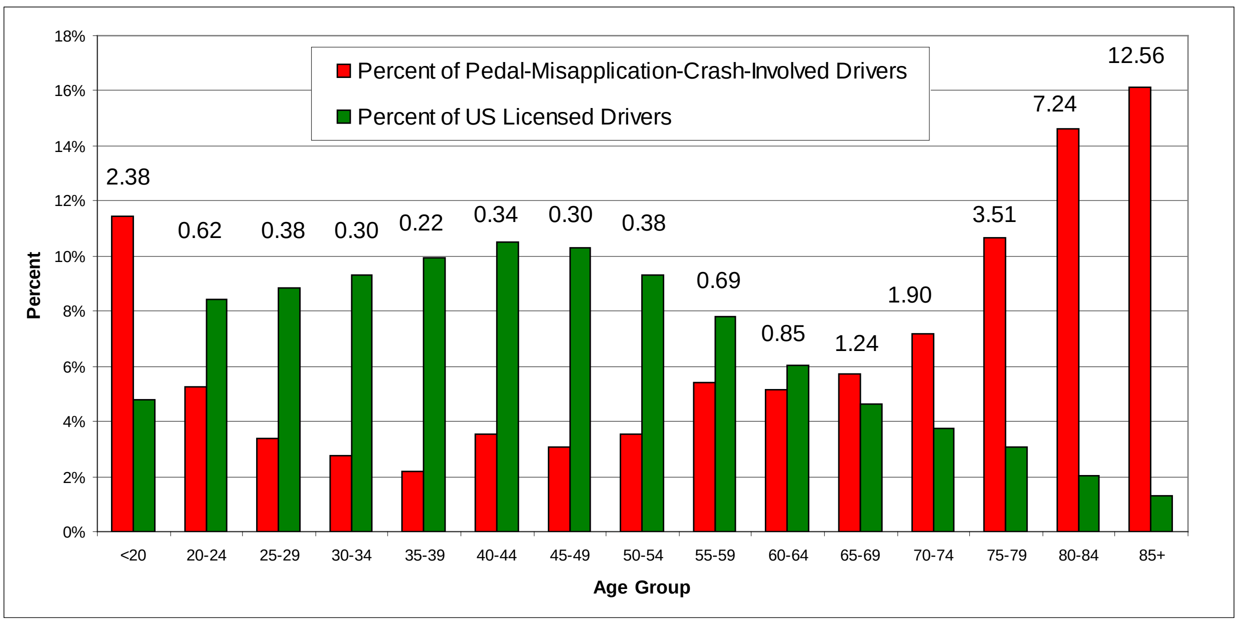

Figure 1. Percentage of Drivers in Pedal Misapplication Crashes Reported by the Media (n=683) in 2000-2010 Versus Percentage of Licensed Drivers in the United States by 5-Year Age Groupings (n= 198,741,423)

The North Carolina crash analysis (see Figure 2) showed that on a per-age-group basis, the percentage of pedal misapplication crashes among the oldest drivers did not approach the level observed in the young novice driver group; however, the *overinvolvement rate* of drivers 85 was nearly equal to that of drivers less than 20 (4.96 and 5.09, respectively). Older driver involvement in pedal misapplication crashes was elevated beginning at 70, in comparison to their proportion in the population of licensed drivers. While the pattern of involvement by 5-year age groups in both analyses followed the same inverted U-shape, the proportion of drivers 75+ identified from the North Carolina crash data was half that identified in the media analysis. The differences in the findings regarding age may be explained by a bias in crash event reporting in the media reflecting what is considered newsworthy. This bias should not exist in police-reported crash data, due to the criteria for reporting crashes.

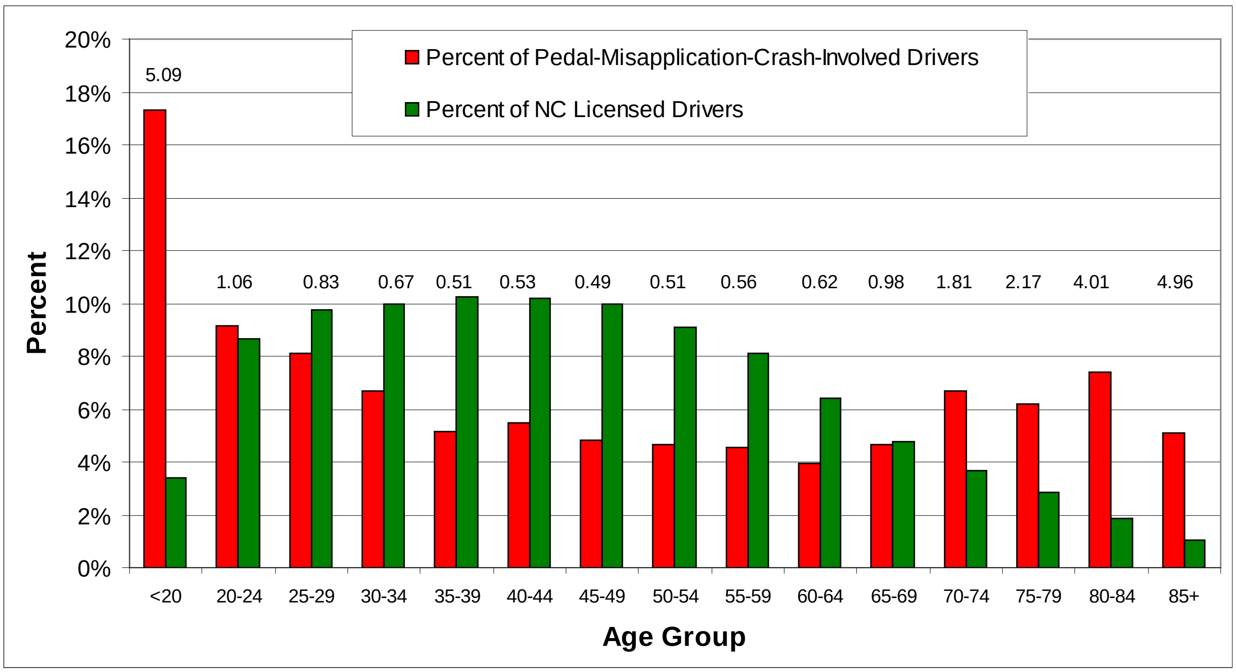

Figure 2. Percentage of Drivers in Pedal Misapplication Crashes (n=2,399) in 2004-2008 Versus Percentage of Licensed Drivers in North Carolina, by 5-Year Age Groupings (n= 6,301,233)

In one of the most striking results of this analysis, Figure 3 shows percentage of drivers in pedal misapplication crashes by 5-year age groupings, contrasted against the proportion of drivers in *all* crashes in North Carolina during the same time period.[12] This figure shows the highest percentage of crashes involving pedal application errors in the 16-20 driver age group and the group 76 and older, accounting for 16.7% and 17.5% of the pedal misapplication crashes, respectively. Looking at *all* crashes (blue bars), the percentage of crash-involved drivers decreased with increasing driver age. Comparisons of driver age in pedal misapplication crashes versus *all* crashes shows higher pedal misapplication crash involvement for the following age groups: younger than

[12] The number of drivers who were in crashes s statewide is larger than the number of crashes statewide, because crashes often involve multiple vehicles/drivers. These data are for all drivers, regardless of fault.

16[13], 16-20, 66-70, 71-75, and 76+. The largest dispairty was for drivers 76 and older. Although they had the smallest representation in *all* crashes (3%), most likely due at least in part to reduced driving exposure, they rival the young-novice drivers in terms of their representation in pedal misapplication crashes (17%).

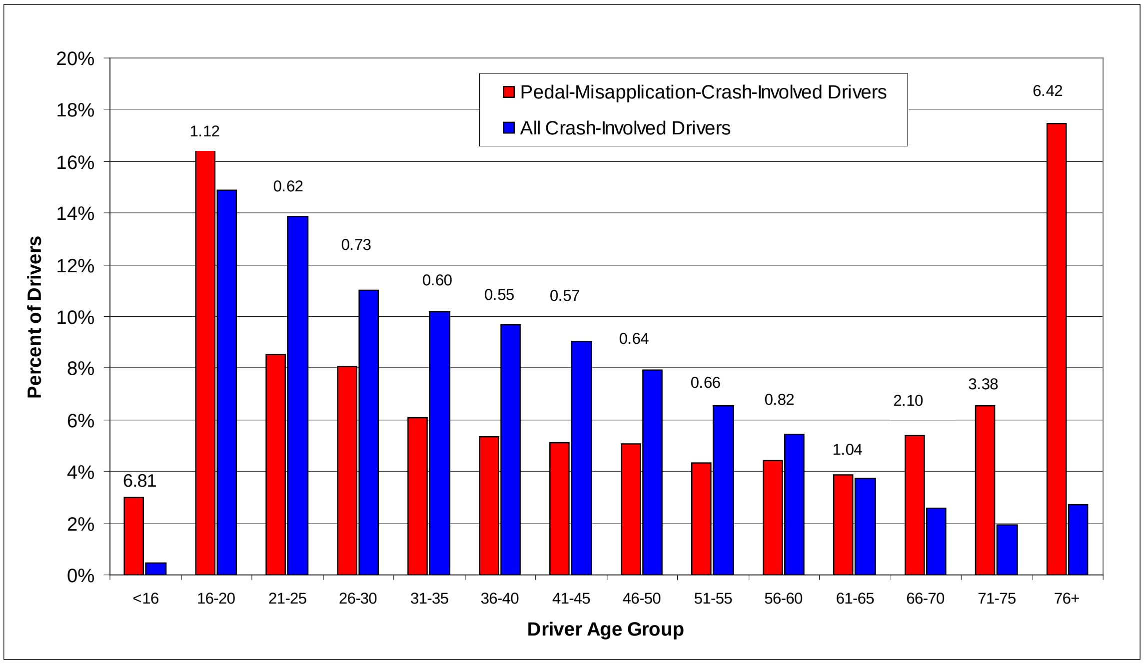

Figure 3. Percentage of Crash-Involved Drivers by 5-Year Age Groupings, for Drivers Who Made Pedal Application Errors (n=2,399) Versus All Drivers in Other Crashes (n=2,228,056)

Driver Sex

Driver sex was not reported in the North Carolina data for 11 of the 2,411 drivers who made pedal application errors. For the remaining 2,400 crashes, males accounted for 37% and females 63%. Table 4 shows that within each of five broad age groups, larger proportions of females than males were involved in pedal misapplication crashes. Statewide crash data for *all* crashes by driver sex for the years 2004 – 2008 show that males accounted for 56% of crashes and females 44%. Thus, female drivers appear to be overrepresented in crashes involving pedal application errors, compared to their representation in *all* crashes.

The findings describing driver sex in pedal misapplication crashes in the NMVCCS analysis (males 35%, females 65%) and the media analysis (males 36%, females 64%) both corroborate the proportions found in the North Carolina data. This is the most consistent finding across the different analyses conducted in this study.

[13] In North Carolina, the minimum age for obtaining a learner's permit is 15.

Table 4. Proportion of Males to Females by Age Group, for Drivers in Pedal Misapplication Crashes.
(North Carolina State Crash Database, 2004-2008, n=2,393)

Driver Age Group	Driver Sex	
	Male	Female
<21	39%	61%
21-35	41%	59%
36-55	32%	68%
56-75	35%	65%
76+	37%	63%

Driver Height

Data describing driver sex in pedal misapplication crashes may be confounded by driver height, as females are generally shorter than males. Certified Driver Rehabilitation Specialists (CDRSs) who participated in the panel meeting in this project stated that because women are smaller than men, their "carfit" in the driver's seat is often worse. Accordingly, we conducted analyses of the heights of drivers involved in pedal misapplication crashes using data extracted from the North Carolina license database. Driver height was available for 772 males and 1,369 females. Figure 4 shows a reasonably normal distribution of driver heights for the total sample of 2,141 drivers in pedal misapplication crashes (collapsing across sex), while Figure 5 segments this distribution according to driver sex.

Descriptive statistics describing driver height by sex as well as across the sample are shown in Table 5.This table includes a summary of anthropometric data collected in the United States on 7,943 males and 9,067 females ages 20 and older (National Health and Nutrition Survey [NHANES] data for the years 1988-1994).The data in this table indicate that the average height of the males and females in the sample of drivers who were involved in pedal misapplication crashes is representative of the average height of males and females in the U.S. population.

Table 5. Driver Height by Sex for Drivers in Pedal Misapplication Crashes Compared With NHANES Anthropometric Data Describing Height by Sex of the U.S. Population.

Statistic	NC Drivers in Pedal Misapplication Crashes 2004 – 2008			NHANES 1988 – 1994 Drivers Age 20+	
	Total	Males	Females	Male	Female
Number of Subjects	2,141	772	1,369	7,943	9,067
Height Range (in)	50-80	60-80	50-75		
Mean Height (in)	66.24	69.7	64.27	69.1	63.7
Standard Deviation Height (in)	3.89	3.25	2.62		
Median (50th Percentile) Height (in)	66	70	64	69.1	63.7
75th Percentile Height (in)	69	72	66	71.0	65.5

The average height—also the median height—of the sample was 66 inches (5 ft and 6 inches). For the crash-involved sample of drivers, 81% of the females were 66 inches or less compared to 16% of the males. The 75th percentile height of a driver involved in a pedal misapplication crash was 69 inches (5 ft and 9 inches); 98% of the females were 69 inches or less,

Figure 4. Distribution of Drivers in Pedal Misapplication Crashes by Height, Across Sex (N=2,141)
(North Carolina State Crash Database, 2004-2008)

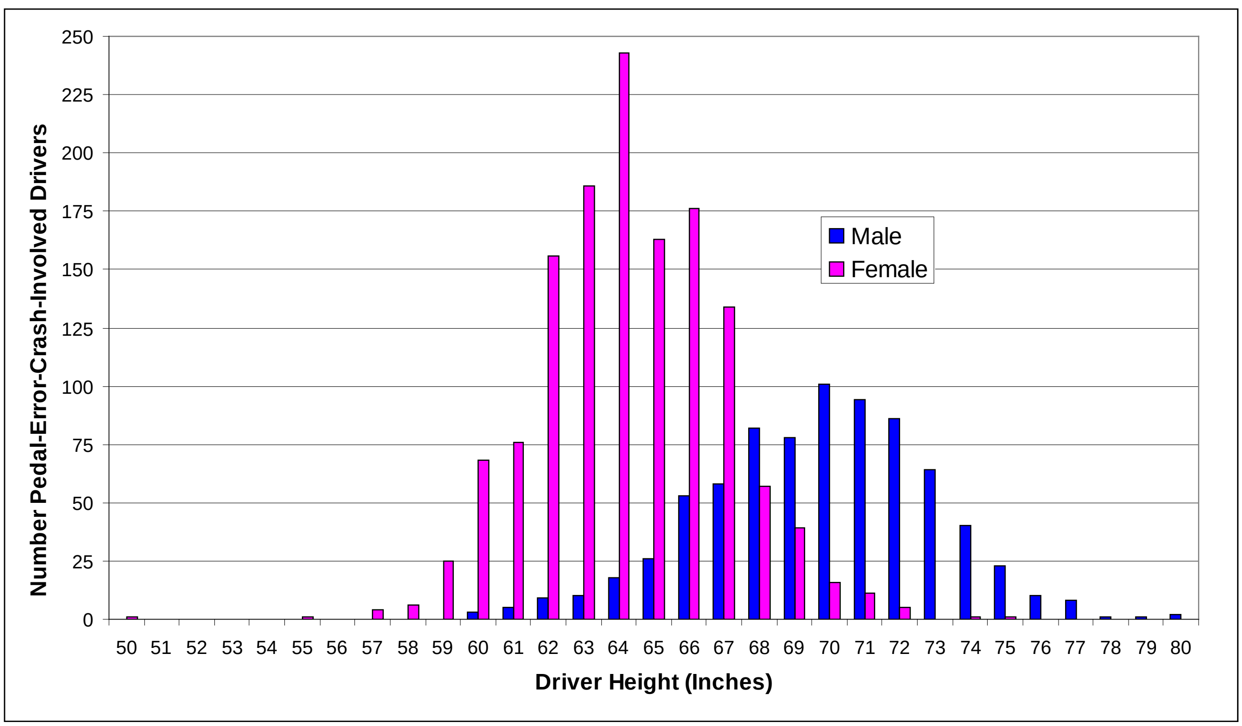

Figure 5. Distribution of Drivers in Pedal Misapplication Crashes by Height and Sex (N=2,141)
(North Carolina State Crash Database, 2004-2008)

compared to 44% of the males. NHANES data indicate that 75% of the female population is 65.5 inches or shorter, while only 10% of the male population is 65.5 inches or shorter.

Thus, short drivers were overrepresented in this sample of drivers involved in pedal misapplication crashes. At the same time, females comprised almost two-thirds (64%) of this sample, suggesting that height (a proxy for driver fit in the vehicle) may be a factor in pedal misapplication crashes involving more females than males. One caution is that height in the driver license file is self-reported, and represents standing height. There are no lower limb driver anthropometric data in the license file that describe "fit" of pedal misapplication crash-involved drivers in their vehicles.

Driver height was not reported in any of the news media reports, and it was available only for 23 of the 31 pedal misapplication crashes identified in NMVCCS.

Driver License Status and Experience at Time of Crash

Table 6 presents the license status for the drivers identified from the North Carolina State crash database, and a descriptive summary of the ages of the drivers with each license type. The date of first licensure was extracted from the license database, and this was used to determine the number of days from first licensure to the pedal misapplication crash. These data were available only for North Carolina drivers with full licenses, permits, graduated driver licenses, and those whose licenses had expired.

For this analysis, experienced drivers were defined as those with four or more years of driving experience. Inexperienced drivers included those with less than four years of driving experience, unlicensed drivers (including those with ID cards only) and ineligible drivers. Using these criteria, there were 1,428 experienced drivers involved in pedal misapplication crashes (63%) and 835 inexperienced drivers involved in pedal misapplication crashes (37%)[14]. The mean age of the experienced drivers was 57.8 years (s.d. = 21.5) and the mean age of the inexperienced drivers was 27.2 years (s.d.=14.1). Males and females were roughly equally represented among the experienced and inexperienced groups (with 39% of the males and 35% of the females classified as inexperienced).

The majority of drivers involved in pedal misapplication crashes were fully licensed in the State of North Carolina (69%). Of these drivers, 83% were experienced and 17% were inexperienced.

[14] Driver experience could not be assessed for 146 drivers with out-of-State licenses (146 drivers) and was missing for 2 drivers with full licenses.

Beginning drivers—those 18 and older with permits to drive in North Carolina, and those 15 to 18 holding a North Carolina graduated driver license (GDL) at any level—accounted for nearly 12% of the drivers who committed pedal application errors.[15] Of these drivers, 6% were experienced and 94% were inexperienced. The 278 beginning drivers ranged in age from 15 to 67 (mean = 21.8, s.d. = 10.1).

Those without licenses (including those holding only an ID card) accounted for another 12% of the crashes resulting from pedal application errors. All were considered inexperienced.

The 27 drivers who allowed their licenses to expire accounted for slightly over 1% of the population of drivers who crashed as a result of a pedal application error. Of these drivers, 22 were experienced (81%) and 5 were inexperienced (19%).

Table 6. License Status of Drivers in Pedal Misapplication Crashes (North Carolina Crash Database Sample)

Type of License at Crash	Number of Drivers	Percent of Sample	Age Range	Mean Age	Standard Deviation Age
Full	1,675	69.47%	18 - 95	54.0	22.6
Out-of-State License	146	6.06%	14 - 97	43.8	22.1
Level 3 Graduated Driver License	34	1.41%	16 - 19	17.4	1.0
Level 2 Graduated Driver License	76	3.15%	16 - 17	16.3	0.5
Level 1 Graduated Driver License	66	2.74%	15 - 28	16.0	1.7
Permit	102	4.23%	18 - 67	31.0	11.8
Expired	27	1.16%	18 - 87	45.7	24.6
ID Card	105	4.36%	13 - 86	30.2	13.7
Unlicensed	179	7.38%	8 - 64	24.2	11.1
Ineligible	1	0.04%	23		
Total	2,411	100.00%			

In the NMVCCS dataset, inexperienced drivers accounted for 6 of the 31 pedal misapplication crashes (19%). Five of the drivers were driving on license permits, and one driver was unlicensed. The ages of the drivers with permits were: 16 (2 drivers), 17, 35, and 41. The unlicensed driver was a female age 55.

[15] GDL Level 1 licenses are limited learner permits for drivers at least 15 but less than 18. However, the license data showed one Level 1 driver was 28. This person most likely had a permit, instead of a GDL 1 license. The remaining Level 1 GDL drivers were 15 to 17. To obtain a Level 1 permit, a driver must complete an approved driver education course and pass the written, signs, and vision tests. GDL Level 2 licenses are limited learner permits for drivers at least 16 but less than 18. To obtain a Level 2 permit, a driver must hold a Level 1 permit for at least 12 months and have no convictions for moving violations or seat belt infractions for the preceding 6 months.
GDL Level 3 licenses are full provisional licenses for drivers 18 or older, who have held a Level 2 limited learner permit for at least 6 months and have no convictions for moving violations or seat belt infractions for the preceding 6 months.

Crash Location

The North Carolina crash analysis findings indicated that 57% of the pedal misapplication crashes were in parking lots or driveways, 42% on roadways, and the remaining 1% at unidentified locations. In the media analysis, 77% of the pedal misapplication crashes were associated with parking lots and driveways, compared to 23% occurring on-road. In both analyses, older drivers were more likely to have been performing a parking maneuver prior to making the pedal application error than other drivers. Although both datasets identified parking lots as the most prevalent crash locations for pedal misapplication crashes, the North Carolina crash analysis, through its inclusion of larger percentages of middle-aged drivers, found a higher proportion of crashes occurring on-road compared to the media analysis (nearly double). Again, this may reflect underreporting of crashes involving younger and middle-aged drivers, and overreporting of older driver crashes by the media.

NMVCCS researchers only investigated crashes that occurred on trafficways; therefore, no crashes occurring in parking lots are included in the entire NMVCCS dataset. The majority of the pedal misapplication crashes in the NMVCCS dataset occurred at non-intersection locations (60%). Intersections were associated with 11% of the crashes, intersection-related locations with 26% of the crashes, and entrance/exit ramps with 3% of the crashes.

Like the NMVCCS findings, the North Carolina State Crash database analyses showed that intersections were the site of 11% of the pedal misapplication crashes identified (6% at four-way intersections and 5% at T-intersections). Intersection-related and exit-ramp locations each accounted for 1% of the crashes in the North Carolina analysis. The majority of crashes that occurred on-road (i.e., not in parking lots) occurred on two-way, undivided roadways (70%). A crosstabulation of number of crashes by number of lanes and roadway configuration for the North Carolina data indicated that the largest proportion of pedal misapplication crashes that occurred on-road were on two-lane roadways with two-way, undivided traffic (35%). The authorized speed limit was not coded for 556 crashes, many of which may have been parking lots. Forty-eight percent of the pedal misapplication crashes identified in the North Carolina crash database were on roadways with speed limits of 25 mph or slower, 33% on roadways with speed limits between 31 and 40 mph, 13% on roadways with posted speeds of 41 to 45 mph, and 6% on roadways with speed limits above 45 mph.

In the media analysis, 7% of the crashes occurred at intersections, 16% occurred on-road at non-intersection locations, and 77% occurred in locations where parking maneuvers are prevalent (64% in commercial parking lots, 5% in residential parking lots, 7% in driveways, and 1% in parking garages). Table 7 presents crash location by driver age group for 656 news reports where both location and driver age were cited. Although commercial parking lots were the most frequent location for crashes resulting from pedal misapplication for every age group, drivers in the two oldest age categories (56 to 75 and 76 and older) had 20 to 25% more crashes in commercial parking lots than drivers 55 and younger, who experienced approximately 50% of their pedal misapplication crashes in these locations. On-road crashes were most prevalent in the 21-to-35 age group (29%) and least prevalent in the 76+ age group (10%). The highest prevalence of intersection crashes occurred in the 36-to-55 age group (13%).

Table 7. Number and Percentage* of Pedal Misapplication Crashes by Location and Driver Age Group (Media Analysis, n=656).

Crash Location	Age Group					
	N	20 or younger	21-35	36-55	56-75	76+
Commercial Parking Lot	416	44 (50%)	33 (47%)	37 (47%)	116 (69%)	186 (74%)
Residential Parking Lot	35	7 (8%)	9 (13%)	4 (5%)	8 (5%)	7 (3%)
Driveway	49	9 (10%)	5 (7%)	7 (9%)	8 (5%)	20 (8%)
On-Road (not intersection)	107	18 (20%)	20 (29%)	19 (24%)	24 (14%)	26 (10%)
Intersection	45	10 (11%)	3 (4%)	10 (13%)	10 (6%)	12 (5%)
Parking Garage	4	0 --	0 --	1 (1%)	1 (1%)	2 (1%)
Total	656	88	70	78	167	253

* Percentages of drivers in each age category (column percents)

Environmental and Roadway Conditions

In North Carolina, the majority of the pedal misapplication crashes (69%) occurred during the daytime (9 a.m. to 6 p.m.), in clear conditions (78%, with an additional 17% under cloudy conditions), and on dry roads (89%). In 77% of the crashes, the roadway was straight and level. In 99% of the crashes, the roadway condition was not considered by the reporting law enforcement officer to be a contributing crash factor. In the news media analysis 77% of the crashes occurred between 9 a.m. and 6 p.m.. In the NMVCCS analysis of pedal misapplication crashes, 56% of the crashes occurred between 9 a.m. and 6 p.m. (and an additional 24% occurred between 6 and 9 p.m.), 71% during daylight, 83% on dry roads, and 66% on straight and level roadways. Thus, roadway and environmental conditions do not appear to be important contributing factors in pedal misapplication crashes.

Table D-1 in Appendix D presents the percentage of crashes by time of day and data source. The differences in proportions of crashes by time of day between the NMVCCS data set and the other two sources may be related to the smaller percentage of older drivers in the NMVCCS dataset (due to the exclusion of parking lot crashes).

Pre-Crash Maneuver

In the North Carolina crash analysis, pedal misapplication crashes were as equally as likely to occur while drivers were traveling straight ahead (39%) as when they were performing a parking maneuver, including backing (39%). Eleven percent occurred during turning maneuvers, and 5% while slowing or stopping. Older drivers (76 and older) were more likely to be performing parking maneuvers than any other maneuver, and more frequently than all other driver age groups, who were more likely to be going straight prior to their pedal misapplications. Drivers younger than 21 were turning in 15% of their pedal misapplication crashes; this is nearly twice the proportion of drivers 36 and older. Drivers 21 to 35 were turning in 13% of their crashes. Table 8 presents the overall distribution of pre-crash vehicle maneuvers, while Table D-2 in Appendix D breaks these data down by driver age group.

Table 8. Pre-Crash Maneuver (North Carolina Crash Database Sample)

Pre-Crash Maneuver	Number	Percent
Going straight ahead	929	39%
Parking	600	25%
Backing (takes priority over other maneuvers)	254	11%
Making right turn	119	5%
Slowing or stopping	116	5%
Making left turn	113	5%
Leaving parked position	75	3%
Starting in roadway (mostly from driveways, public or private)	49	2%
Stopped in travel lane (driver still in vehicle)	27	1%
Parked out of travel lanes	19	1%
Avoiding object in road	15	1%
Making u turn	15	1%
Changing lanes or merging	12	0%
Passing	3	0%
Parked in travel lanes	3	0%
Other	59	2%
Total	2,408	100%

In the news media analysis, parking maneuvers accounted for the largest proportion of the crashes (61%). Other pre-crash maneuvers reported in the news media were turning (9%), going straight (3%), slowing in lane (7%), and startle braking during an avoidance maneuver (20%). Table 9 presents the pre-crash maneuvers identified in the news media crash sample, for the 661 crashes where this information was included in the news report, and Table D-3 in Appendix D presents maneuver frequency by driver age group.

Entering a parking space was associated with the highest percentage of crashes reported by the media, nearly 50%, for all age groups, except for drivers 36 to 55, who experienced only 31% of their crashes while performing this maneuver. For these middle-age drivers, pedal misapplication crashes were most often associated with startle braking following an initial collision or loss of control of their vehicles. Referring back to Table 7, drivers 36 to 55 had the highest percentage of crashes at intersections, compared to other age groups; these are locations where the potential for collisions and the corresponding need for avoidance maneuvers is highest.

Drivers 76 and older had the highest percentage of crashes of all age groups while leaving a parking space (see Table D-3). These older drivers, along with their younger counterparts 56 to 75, also experienced a higher percentage of crashes while turning, than drivers 55 and younger.

The NMVCCS data showed a different pattern of maneuvers due to the exclusion of parking lot crashes: 55% while going straight, 5% while slowing in a traffic lane, 5% while turning, 11% while negotiating curves, and 7% while changing lanes.

Table 9. Pre-Crash Maneuver (News Media Sample)

Pre-Crash Maneuver/Behavior	Number (Percent) of Crashes
Entering parking space	321 (49%)
Leaving parking space	77 (12%)
Turning	58 (9%)
Startle braking following initial collision	51 (8%)
Startle braking following loss of control of vehicle	45 (7%)
Panic stop to avoid collision	27 (4%)
Slowing/stopping for vehicles	24 (4%)
Slowing/stopping for traffic control device	12 (2%)
Slowing/stopping for pedestrians	9 (1%)
Driving in lane	23 (3%)
Parked/still in gear	9 (1%)
Changing lanes	3 (<1%)
Stopped	2 (<1%)
Total	661

Startle or Panic Responses

We read each crash narrative and news article and coded situations where startle or panic was stated or inferred, based on what we learned in earlier project tasks about the contribution of a startling stimulus to a pedal misapplication. The decision to code startle or panic reactions followed from Schmidt's (1989) discussion in the literature review of "hypervigilant reactions or panic to a strong, startling stimulus which seems to be present in unintended acceleration." Other researchers have noted this phenomenon (Freund et al., 2008, Schiff & Oldak, 1993; Schmidt et al., 1997).

The frequency of startle reactions in the analysis sets may be underrepresented due to the lack of detail in many of the crash narratives. The situations we coded in the North Carolina crash database sample included:

- Startle following an initial collision (e.g., the driver reacts to a crash by hitting the wrong pedal).
- Startle following loss of control of the vehicle (e.g., the driver panics when the vehicle skids or drifts out of the lane, and during the recovery the driver hits the gas instead of the brake).
- Panic stop to avoid a collision (e.g., an animal, vehicle, or pedestrian is in the driver's immediate path, and the driver tries to slam on the brakes to avoid a collision).
- Startle following a driver's foot slipping from the brake to the accelerator (e.g., the driver panics after the foot slips off the brake, and while trying to re-contact the brake, hits the accelerator).

Table 10 presents the number of drivers researchers inferred were startled prior to making their pedal application error, by startle type. Other startling situations in this table were: passengers yelling at the driver to stop; behavior of other drivers or pedestrians in the area; panic after the vehicle moved in the wrong direction (driver selected the wrong gear); other drivers blowing their horns; ambulance siren; cell phone ringing; lit cigarette landing between a driver and her seat back; driving on suddenly uneven terrain; a traffic signal suddenly turning red, and the driver panicking to stop in time; and panic following an initial pedal misapplication, followed by continued pressing on the accelerator.

Table 10. Drivers in Startle-Related Pedal Misapplication Crashes, by Startle Type (NC Crash Database Sample)

Startle Type	Number of Drivers	Percent of All Pedal Misapplication Crashes (n=2,411)
Panic stop to avoid a collision	171	7%
Startle following loss of control of the vehicle	135	6%
Startle following an initial collision	94	4%
Other startling situations	46	2%
Startle following a driver's foot slipping from the brake to the accelerator	16	<1%
Total	462	19%

In 19% of the North Carolina pedal misapplication crashes, drivers were described as startled or panicked. According to Schmidt (1989), when drivers are startled or they panic, they perceive the sudden stimulus as being life threatening, requiring an immediate solution. The response is often an attempt to slam on the brake. The faster a foot movement is made and the greater force used in making the movement, the less accurate the targeting, which can lead to a pedal misapplication.

Analysis of startle responses shows that as driver age increased, the number of crashes associated with startle or panic responses decreased. Table 11 contrasts the percentage of crashes associated with startle for each age group with the percentage of that driver age group in the sample. Table 11 reveals that the youngest drivers were overrepresented in startle-related crashes in comparison to their proportion in the sample, while the oldest drivers were underrepresented in startle-related pedal misapplication crashes.

In the media analysis, 20% of the drivers were described as startled or panicked, while 58% of the NMVCCS pedal misapplication crashes were associated with a startle or panic response, based on our review of the crash narratives.

Table 11. Pedal Misapplication Crashes Associated with Startle, By Age Group (North Carolina Crash Database Sample)

Driver Age Group	Number (and Percentage) of Crashes Associated With Startle*	Number (and Percentage) of Drivers in Sample
<21	143 (31%)	473 (20%)
21-35	117 (25%)	545 (23%)
36-55	93 (20%)	477 (20%)
56-75	61 (13%)	485 (20%)
76+	45 (10%)	419 (17%)
All	459	2,399

* Driver age was missing in 3 of the startle-related crashes.

Driver Inattention and Distraction

Officers use up to three fields on the North Carolina crash report to code actions of the driver that may have contributed to the crash. They coded driver contributing circumstances for 2,330 of the 2,411 crashes. Table D-4 in Appendix D presents the frequency that each driver action was coded as either a first, second, or third contributing factor, and the percentage of crashes in which each driver contributing circumstance was a factor.

The most frequent driver contributing factor in the North Carolina crash analysis sample was inattention, recorded in 44% of the pedal misapplication crashes in which a driver contributing factor was coded. Driver inattention was relatively equally prevalent as a contributing factor within each of the five broad age groupings: under 21 (43%), 21 to 35 (44%), 36 to 55 (46%), 56 to 75 (42%), and 76 and older (44%).

Driver distraction was coded by the reporting officers as a first, second, or third contributing factor in 4% of the crashes (see Table D-4). Together, inattention and distraction were coded as contributing factors in nearly half of the crashes resulting from pedal misapplications (48%). As a supplemental analysis, we read each crash narrative to determine the kinds of distraction that may have contributed to the pedal misapplication. We identified descriptions of distraction in 166 of the 2,411 pedal misapplication crashes (7%). These are summarized below by type.

- Looking away (42)
- Reaching for an object (30)
- Passengers (19: generally children, but others included passengers arguing or yelling at the driver)
- Cell phone (13: 2 were dialing, 1 was texting, 8 were talking, 2 were distracted by the phone ringing)
- Adjusting radio or CD player (7)
- Other road user (7)
- Dog in vehicle, in lap or near feet (6)
- Interacting with a curbside device such as entering code into entrance gate (5)
- Insect in vehicle (4)
- Thoughts – preoccupied or upset (4)
- Object in car fell (3)
- Driver dropped object (3)
- Adjusting mirror (2)
- Equipment malfunction (2)
- Eating (1)
- Other (10: e.g., reading map, ambulance siren, something in eye, missed a turn, sneezed)
- Narrative stated driver was distracted, but did not specify the distracter (8)

Table 12 compares the percentage of crashes associated with distraction by age group with the percentage of the age group in the sample. It shows that drivers in the two older age groups (56 to 75 and 76 and older) were underrepresented in distraction-related crashes, and drivers in the two youngest age groups (<21 and21 to 35) were overrepresented in distraction-related crashes, based on their representation in the sample.

Table 12. Drivers in Distraction*-Related Pedal Misapplication Crashes, by Age Group (North Carolina Crash Database Sample)

Driver Age Group	Number (and Percentage) of Crashes Associated With Distraction	Number (and Percentage) of Drivers in Sample
<21	46 (28%)	473 (20%)
21-35	53 (32%)	545 (23%)
36-55	39 (23%)	477 (20%)
56-75	21 (13%)	485 (20%)
76+	7 (4%)	419 (17%)
All	166	2399

* determined through a review of the crash narratives

Driver distraction was reported in 39% of the NMVCCS pedal misapplication crashes. As a point of comparison, inattention and distraction factored in 18% of the crashes in the entire NMVCCS sample (*all* crashes, representing 843,804 crashes nationwide between 2005 and 2007) (NHTSA, 2008, December). Thus, based on the findings from the NMVCCS analyses of pedal misapplication crashes, inattention and distraction factored more prominently in pedal misapplication crashes than in *all* crashes.

Driver distraction was present in 12% of the news media articles that mentioned a driver contributing factor. This may be an underrepresentation, because the news reports varied greatly in the level of detail provided. Drivers 20 and younger, 36 to 55, and 56 to 75 were overrepresented in distraction-related pedal misapplication crashes. Drivers 76 and older were less likely than the other age groups to be reported distracted, and were under-represented in distraction-related pedal misapplication crashes. Drivers 21 to 35 were only slightly more likely to have distraction cited, compared to their representation in all pedal misapplication crashes.

Eight of the news media crash reports indicated that drivers were reaching for something. This included dropped cigarettes and cell phones, something in the back seat, and a tissue. In six crashes, the drivers were talking on cell phones. In six others, drivers were looking away from the road; this included looking at the sides of the road for a parking space, looking at a man in a wheelchair, looking at a spot where the road curves, looking at cars parked along the roadside, reading a sign on a storefront, and simply looking down for a second. In three crashes, drivers were distracted by a conversation with their passengers, one of whom was in the back seat; the driver turned to look at her. Two articles simply stated that the driver was distracted. One driver was distracted by a contact lens popping out, which caused her to look away from the road for a second, after which her passenger screamed, causing her to slam on the “brakes” (actually the accelerator), jump a curb, and drive down a steep bank into a ditch. Other distractions cited in the news reports included: a dog jumping into the driver’s lap, driver sneezing, driver untangling a cord to a microphone, adjusting the radio, holding food and beverage in hand while exiting a drive through, and wandering thoughts.

Driver Out of Position

The research team coded drivers who crash narratives reported were reaching for something in the vehicle, looking left or right, or who had exited their vehicle and re-entered it quickly when it started to roll, or whose seating position was described as unusual, as “out-of-position drivers.” Drivers described as looking left or right were included, based on a human factors theory that head and eye movements can affect the accuracy of foot-aiming movements (Schmidt, 1989). The out-of-position factor overlaps with driver distraction, because drivers looking away from the roadway and reaching for objects are not exclusively directing their attention to the driving task.

Seventy-three of the 2,411 drivers in the North Carolina Crash database sample were coded as out of position (3%). This may be an underestimation, as the team only coded this factor if the reporting officers included a description in the crash narrative. A summary of the driver behaviors that resulted in improper positioning in the driver’s seat included:

- Reaching across the vehicle, or into the back seat, or down into the floorboard area for something the driver dropped (29 drivers);
- Re-entering the vehicle to stop it from rolling, after parking but inadvertently leaving it in gear (21 drivers);
- Looking left or right (10 drivers);
- Looking left and reaching (5 drivers);
- Driving with the driver’s side door open and the left foot out of the door, while moving a vehicle slowly in a parking lot or driveway (3 drivers);
- Driving from the passenger seat or center console area (2 drivers);
- Moving from the passenger seat to the driver’s seat with the vehicle still in gear (1 driver);
- Starting the vehicle from a seating position straddling the center console, not realizing the vehicle was in gear (1 driver); and
- Seat positioned too far back for driver to accurately control the pedals (1 driver).

Ten percent of the pedal application error crash narratives in the NMVCCS analysis described drivers as “out of position,” and 7% of the news media reports (where a driver factor was described) included drivers out of position. The media analysis included 12 pedal misapplication crashes associated with drivers looking or reaching to the sides or rear of the vehicle, 5 with drivers re-entering the vehicle to hit the brake when it began rolling after being parked (but not in Park gear), and 2 with drivers or passengers moving from one seat to another; the driver hit the wrong pedal to stop the vehicle when it began rolling. Drivers 36 to 55 had the largest overrepresentation with this factor, although those 20 and younger and 21 to 35 were somewhat overrepresented compared to their proportion in all pedal misapplication crashes. Drivers in the two oldest age groups were underrepresented on this factor.

Driver Unfamiliarity with the Vehicle

The literature review revealed that drivers unfamiliar with the vehicle were overrepresented in unintended acceleration crashes. This applies to new owners as well as occasional users (e.g., parking lot attendants, rental car patrons). After reading each crash narrative and news article, the research team coded instances where the driver was described as driving an unfamiliar vehicle.

In the news media analysis, 14 of the 266 pedal misapplication crashes that included a driver factor as a contributing cause, cited drivers in unfamiliar vehicles (5%). Reports cited age in 10 of these 14 crashes. Drivers 21 to 35 and 36 to 55 appeared to be overrepresented in pedal misapplication crashes in reports that cited this driver factor, compared to their representation in all pedal misapplication crashes, while drivers 76 and older were underrepresented. Two drivers reported to be unfamiliar with the vehicle were driving rental vehicles (SUVs). Two other drivers were operating newly purchased vehicles, and two were test driving a vehicle for sale. Two crashes occurred when car dealership employees were moving display or newly purchased vehicles in the car dealership lots. One crash occurred at a car wash, when an employee was moving a customer's vehicle. Two drivers new to bus companies (one with 3 weeks experience as a commercial bus driver) were involved in pedal misapplication crashes. One of these crashes involved distraction when the driver tried to untangle a microphone cord while driving. Two drivers in vehicles with adaptive equipment were involved in pedal misapplication crashes. One driver was not handicapped and was unfamiliar with the vehicle's hand controls. The other driver (age 84) was described as unfamiliar with the vehicle's foot controls for the disabled.

The research team uncovered 25 crash records in the North Carolina crash analysis (1%) describing the driver as unfamiliar with the vehicle. Ten involved drivers in cars that belonged to friends or relatives; five were driving rental vehicles (1 was a U-Haul truck, which likely had a different pedal and seating configuration than a standard passenger vehicle); two were not accustomed to driving vehicles with automatic transmissions; two were car-wash attendants; two indicated they were "not accustomed" to the vehicle and one stated that he/she was "not accustomed to the gas and brake pedals in the vehicle." One driver had just purchased the vehicle that week. One driver was parking a vehicle equipped with "handicapped braking equipment" which was unfamiliar to the driver. One driver stated that she was test driving a vehicle that had a gas pedal as big as the brake pedal, so she thought she was hitting the brake when she hit the gas.

There were no pedal misapplication crashes attributed to driver unfamiliarity with the vehicle in the NMVCCS analysis.

Driver Medical Conditions or Functional Impairments

The North Carolina crash reports contain a field for coding the physical condition of the driver at the time of the crash. The selections provided on the form are very general, as shown in Table D-5 in Appendix D. Inspection of Table D-5 indicates that the large majority of drivers (93% across all age groups) were "apparently normal." Slightly higher percentages of drivers in the younger age groups were "apparently normal" drivers (96%) compared to drivers in the oldest age group (90%).

Many of the police narratives contained more detailed information about the drivers than could be coded on the police crash report form. In addition, there appeared to be inaccuracies in the coding of driver physical condition, leading to underrepresentation of medical conditions. For example, of the 2,235 drivers coded as “apparently normal,” review of the crash narratives indicated the presence of medical conditions for 37 drivers, including the following conditions: partial paralysis, casts or splints on the right foot, blacked out, cognitive disorders, multiple sclerosis, medical problems with knees, pain in the right leg, and use of a handicapped parking space (suggesting the presence of a medical or functional condition). Of the 43 drivers coded as “unknown,” 5 were described in the narratives as having the following conditions: seizures, back pain/spasms, dizzy/blacked out, cast on foot, and using a handicapped parking space.

The following medical conditions (or situations suggesting the presence of medical conditions) were uncovered for 77 drivers, following a review of the 2,411 crash narratives in the North Carolina crash analysis.

<u>Handicapped</u>

- 23 drivers: Parked in a “handicapped” parking space (suggesting the driver has a medical condition that warranted parking in such a place). One driver was specifically described as “handicapped.”

<u>Lower Limb Impairments (Loss of Strength, Sensation, Range of Motion)</u>

- 11 drivers: Wearing a cast on the right foot or leg (note: 2 of these drivers were described as driving with the left foot)
- 3 drivers: Brace or splint on foot or leg (note: the driver with a splint on the right knee was described as braking with the left foot)
- 1 driver: recent right leg amputation; wearing prosthesis
- 1 driver: Driving a handicapped-equipped van with a hand brake
- 2 drivers: Prior stroke(s) which resulted in little feeling in the right leg
- 1 driver: Couldn’t feel his foot, as it had fallen asleep.
- 1 driver: Right side of body went numb
- 4 drivers: Difficulty (or unable to) move feet and legs
- 3 drivers: Recent surgery, resulting in diminished foot strength and loss of feeling in legs (note: 1 of these drivers was described as using the left foot to operate the pedals)
- 2 drivers: Multiple sclerosis
- 2 drivers: Medical problem with knees
- 2 drivers: Right leg pain and discomfort (1 described as using left foot for braking)
- 1 driver: Hurt right foot, so was driving with left foot
- 1 driver: Back pain and spasms

<u>Black Out, Loss of Consciousness, Hypoglycemic Reaction</u>

- 4 drivers: Blacked out (1 may have fallen asleep)
- 1 driver: Seizures
- 1 driver: Blood sugar dropped

Cognitive Impairments

- 3 drivers: Cognitive decline or minor mental condition (1 described as confused and not fit to drive; 1 asked for a "pan of bread to blow my nose")
- 2 drivers: Medications /drugs (Prescription narcotics, marijuana)

Other Conditions

- 3 drivers: Sneezed
- 1 driver: Coughing uncontrollably
- 1 driver: Stomach cramps
- 1 driver: Contractions
- 1 driver: Feeling ill and trying to pull over to park
- 1 driver: Unspecified

Combining the two data sources (driver physical condition codes and crash narrative review), at least 163 of the 2,411 drivers with pedal misapplication crashes (6.7% of the sample) had some type of physical or mental impairment, or other medical condition. Also as indicated in Table D-5, 13 drivers were tired; and 25 were impaired by alcohol, drugs, or medications.

In the news media analysis, 75 of the 266 pedal misapplication crashes with descriptions of driver contributing factors included descriptions of medical conditions or medications (28%). News reports of drivers parking in handicapped spaces (associated with 26 crashes) or driving vehicles with handicapped plates (associated with 4 crashes) were coded as having this factor.

There were no drivers 20 or younger who were cited in the news reports as having medical conditions or using medication. Drivers 21 to 35 and 36 to 55 were also underrepresented with this factor, compared to their representation in all pedal misapplication crashes.Not surprisingly drivers 76 and older contributed to the majority of crashes with this driver factor (58%), and were overrepresented in comparison to their proportion in all pedal misapplication crashes.Drivers 56 to 75 were slightly overrepresented as having this factor.

In addition to "handicapped" as described above, specific medical conditions and medications reported in the set of news media crashes were as follows.

- Leg, foot, and hip problems (12 drivers): includes 2 drivers with leg cramps; a driver with cast on the right foot, another with a broken right foot, and one with an injured right foot; a driver with a "neuropathy-related condition" and another with a "condition that causes the feet to go numb;" a driver with a flexible cast on 1 leg; a driver who used a cane and could not lift the right foot when walking; a driver who used orthopedic shoes; a driver with a medical condition that required hand-operated brakes and accelerator; and a driver with a hip problem.
- Black-out (3 drivers)
- Seizure (2 drivers)
- Diabetes (4 drivers)

- Arthritic (2 drivers)
- Heart condition (11 drivers): included a driver who possibly had a heart attack just prior to the crash, 2 drivers with high blood pressure, 1 who had a triple bypass recently, one who had a heart valve installed in recent years, and 1 with heart palpitations after the crash
- Dialysis patients (2 drivers)
- Drivers undergoing chemotherapy treatment (1 driver with breast cancer)
- Early Alzheimer's disease (1 driver)
- Chronic back problem (1 driver who wore support while driving)
- Spinal injury (1 driver)
- Abdominal pain (1 driver)
- Dizzy/faint (1 driver)
- Medical emergency (2 drivers, including one who was "in a trance")
- Disorientation (2 drivers)
- Used oxygen tank (1 driver)
- Medications (7 drivers): included two drivers on medication for high blood pressure; 1 driver taking a painkiller, a tranquilizer, and an antidepressant (Zoloft); a driver taking medication for high cholesterol (Lipitor) and quinine sulfate; 1 driver treated with chemotherapy; 1 driver taking medication for a heart condition (unspecified); and 1 driver using marijuana

In the NMVCCS analysis of pedal misapplication crashes, 29% of the narratives included descriptions of medical conditions and 48% described medications, the majority of which were potentially driver impairing. The NMVCCS researchers coded 7 of the 31 drivers (22.5%) as having a physical factor that may have been relevant to the driver's pre-crash driving behavior. As a point of comparison, in the entire NMVCCS sample (*all* crashes), representing 2,045,577 crashes where driver condition was coded, only 2.4% identified drivers with physical impairments. The medical conditions in the sample of pedal misapplication crash-involved drivers included: previous back injury, high blood pressure (2 drivers), depression (3 drivers), diabetes, poor eyesight, poor circulation in feet, recent heart surgery, allergies, and lack of alertness. A total of 33 medications had been taken by the 15 drivers who had used medication in the 24-hour period prior to their pedal misapplication crash. The number of medications taken per driver ranged from 1 to 7. Eight drivers were taking a single medication, 3 were taking 2 medications, 2 were taking 4 medications, and 2 were taking 7 medications. The medications comprised the following pharmacologic classes: anticoagulants, hypoglycemics, antihypertensives, antidepressants/antianxiety, narcotic analgesics, non-steroidal anti-inflammatory drugs, antipsychotics, anticonvulsants, asthma medications, sedating antihistamines, non-sedating antihistamines, analgesics, proton pump inhibitors, birth control medications, and electrolytes.

Driver fatigue factored in less than 1% of the North Carolina pedal misapplication crashes, 10% of the NMVCCS crashes, and 2% of the news media reported crashes. Alcohol was suspected in less than 1% of the North Carolina pedal misapplication crashes, 3% of the NMVCCS pedal misapplication crashes, and 8% of the news media reports of pedal misapplication crashes.

Vehicle Make and Year

In North Carolina, officers document the vehicle manufacturer (e.g., Chrysler, Ford, etc.) and model year on the crash report form, but they do not record vehicle model. Vehicle make was missing in 17 cases. Table 13 shows the make listed for the remaining 2,397 cases by number and percentage of cases. Pedal misapplication crashes occurred across 43 vehicle makes, most frequently in Fords (16%), Chevrolets (12%), Toyotas (11%), and Hondas (9%). Data describing the composition of the fleet of registered vehicles in North Carolina were not available; however, Table 13 includes data describing the fleet of vehicles in operation in the United States as of April 1, 2010 provided by The Polk Company. Vehicle makes associated with large percentages of pedal misapplication crashes were also largely represented in the U.S. vehicle fleet. In other words, the prevalence of these vehicles in pedal misapplication crashes appears to directly reflect their exposure in the vehicle fleet.

Table 13 also presents the proportion of vehicle makes involved in the media-reported pedal misapplication crashes, in those instances where vehicle make was cited, and the vehicle makes involved in the NMVCCS sample of pedal misapplication crashes. Interestingly, the NMVCCS distribution varied from the overall fleet distribution more than the media distribution, with higher than expected proportions of Hondas, Mitsubishis, and Buicks, and a lower proportion of Fords. At least some of the discrepancy might reflect the vehicle preferences of a generally younger sample of drivers.

Vehicle year was not coded in 22 of the 2,411 pedal misapplication crashes in the North Carolina crash analysis sample. Table D-6 in Appendix D presents the number and percentage of vehicles involved in pedal misapplication crashes by vehicle year, for the remaining 2,389 crashes that occurred between 2004 and 2008. Vehicles produced over 5 decades, from the 1960's to the 2000's, were represented in pedal misapplication crashes occurring between 2004 and 2008.

Each model year from 1966 to 1988 was associated with 1% or less of pedal misapplication crashes; and the most recent years (2008, 2009) as well. From the late 1980s involvement rates climbed gradually to a peak of 8% for the 2003 model year, then declined. Again, these findings are most easily understood in terms of exposure. Like vehicle model, the prevalence of vehicle year in the fleet of vehicles registered in North Carolina was not pursued.

Table 13. Make of Vehicles Involved in Pedal Misapplication Crashes in the North Carolina Crash Analysis, Media Analysis, and NMVCCS, Compared to Vehicle Makes in Operation in the U.S. Fleet

Vehicle Make	Number of Pedal Error Crashes			Percent of Sample			Percent of Vehicle Fleet*
	NC Crash Database	Media	NMVCCS (Weighted)	NC Crash Database	Media	NMVCCS (Weighted)	
Acura	28	5	0	1.17%	1.02%	0.00%	1.04%
Audi	3	0	0	0.13%	0.00%	0.00%	0.44%
BMW	27	3	0	1.13%	0.61%	0.00%	1.37%
Buick	96	29	532	4.02%	5.89%	10.80%	2.72%
Cadillac	48	16	0	2.01%	3.25%	0.00%	1.51%
Chevrolet	290	51	634	12.14%	10.37%	12.87%	15.40%
Chrysler	52	11	440	2.18%	2.24%	8.93%	2.53%
Daewoo	1	1	0	0.04%	0.20%	0.00%	0.05%
Dodge	124	25	0	5.19%	5.08%	0.00%	6.60%
Eagle	3	0	0	0.13%	0.00%	0.00%	0.07%
Ford	384	69	379	16.07%	14.02%	7.69%	16.64%
GMC	36	8	0	1.51%	1.63%	0.00%	2.95%
Honda	220	45	1392	9.21%	9.15%	28.25%	7.15%
Hyundai	20	7	0	0.84%	1.42%	0.00%	1.71%
Infiniti	12	1	0	0.50%	0.20%	0.00%	0.57%
Isuzu	14	4	0	0.59%	0.81%	0.00%	0.32%
Jaguar	4	2	0	0.17%	0.41%	0.00%	0.22%
Jeep	59	15	0	2.47%	3.05%	0.00%	2.67%
Kia	27	3	0	1.13%	0.61%	0.00%	1.03%
Land Rover	6	1	0	0.25%	0.20%	0.00%	0.17%
Lexus	29	7	338	1.21%	1.42%	6.86%	1.36%
Lincoln	33	19	130	1.38%	3.86%	2.64%	1.09%
Maserati	0	1	0	0.00%	0.20%	0.00%	0.01%
Mazda	51	8	0	2.13%	1.63%	0.00%	1.71%
Mercedes	24	13	0	1.00%	2.64%	0.00%	1.36%
Mercury	97	20	0	4.06%	4.07%	0.00%	1.89%
Mini	1	0	0	0.04%	0.00%	0.00%	0.13%
Mitsubishi	45	5	412	1.88%	1.02%	8.36%	1.08%
Nissan/Datsun	145	21	0	6.07%	4.27%	0.00%	4.74%
Oldsmobile	39	15	311	1.63%	3.05%	6.31%	1.55%
Plymouth	23	1	0	0.96%	0.20%	0.00%	0.66%
Pontiac	65	6	0	2.72%	1.22%	0.00%	3.06%
Saturn	19	6	0	0.80%	1.22%	0.00%	1.38%
Subaru	26	12	0	1.09%	2.44%	0.00%	1.13%
Suzuki	16	2	0	0.67%	0.41%	0.00%	0.33%
Toyota	274	52	360	11.47%	10.57%	7.31%	10.41%
Volkswagen	19	5	0	0.80%	1.02%	0.00%	1.52%
Volvo	29	3	0	1.21%	0.61%	0.00%	0.81%
Total	**2389**	**492**	**4928**	**100.00%**	**100.00%**	**100.00%**	**99.38%**

*Data from The Polk Company: 233,871,380 vehicles in operation as of April 1, 2010

Injuries and Fatalities

Crash reporting law enforcement officers in North Carolina use the following definitions to categorize injury severity.

- **Killed –** Deaths, which occur within 12 months after the crash
- **Disabling injury (Type A)** - Injury obviously serious enough to prevent the person injured from performing normal activities for at least one day beyond the day of the collision. Examples include massive loss of blood, broken bone, and unconsciousness of more than momentary duration.
- **Evident injury (Type B)** - Obvious injury, other than killed or disabling, which is evident at the scene. Bruises, swelling, limping, soreness, are examples. Class B injury would not necessarily prevent the person from carrying on normal activities.
- **Possible injury (Type C)** - No visible injury, but person complains of pain, or has been momentarily unconscious
- **No injury**
- **Unknown**

The 2,411 pedal misapplication crashes in the North Carolina crash analysis set involved a total of 5,623 road users. This included the 2,411 drivers who made the pedal application errors and the 892 passengers they were transporting, as well as 2,271 occupants of the other vehicles involved in these pedal misapplication crashes, and 49 pedestrians. Injury status was missing for 841 "other road users" (including 3 pedestrians) and 46 "pedal-application-error-vehicle" occupants. Table 14 presents the injury status for the 4,736 road users involved in these crashes, by road user type (pedal misapplication vehicle occupant, other vehicle occupant, pedestrian), where the injury status was known.

The majority of road users involved in North Carolina pedal misapplication crashes (82%, across all road user types) sustained no injuries. Next in prevalence were road users with possible injuries (14%) and evident injuries (4%). Ten road users sustained disabling injuries (less than 1% of the sample), and 1 road user was fatally injured (also less than 1% of the sample). Of importance to this discussion, only 7% of pedestrians involved in pedal misapplication crashes were *not* injured. Although none of the pedestrians was killed, 7% received disabling injuries, 46% evident injuries, and 41% possible injuries.

Table D-7 in Appendix D presents the number and percentage of drivers who were killed or injured (and their injury status), for the 2,367 crashes in the North Carolina analysis where driver age and injury status were known. This table does not include injury data for other occupants in the vehicle, or in other vehicles involved in the crashes. As shown in Table D-7, the majority of the pedal misapplication crashes (85%) resulted in no injury to the driver. The highest percentage of crashes in which there was no driver injury occurred for drivers younger than 21 (87%) and drivers 21 to 35 (88%). As driver age increased, more drivers sustained injuries. There was 1 fatality; this occurred for an 82-year-old driver who died 3 weeks post-crash. In North Carolina, if a death occurs within 12 months of a crash, it is deemed a fatal injury crash.

Table 14. Injury Status of Vehicle Occupants and Pedestrians in Crashes Involving Pedal Misapplications, by Vehicle (North Carolina Crash Database Sample)

Injury Status	Road User Type						All	
	Pedal Misapplication Vehicle		Other Vehicles		Pedestrians			
	N	%	N	%	N	%	N	%
Fatal injury (K)	1	0.03%	0	0.00%	0	0.00%	1	0.02%
Disabling injury (A)	5	0.15%	2	0.14%	3	6.52%	10	0.21%
Evident injury (B)	132	4.05%	33	2.30%	21	45.65%	186	3.93%
Possible injury (C)	347	10.65%	302	21.07%	19	41.30%	668	14.10%
No injury (O)	2,772	85.11%	1,096	76.48%	3	6.52%	3,871	81.74%
Total	3,257	100.00%	1433	100.00%	46	100.00%	4736	100.00%

The number of fatalities was missing from 10 news reports of media-reported pedal misapplication crashes. It may be inferred that for these 10, there were no fatalities, based on "newsworthiness" of deaths in crashes. Adding those 10 crashes to the 781 crashes reported to have no fatalities, pedal misapplication crashes resulted in no fatalities in 791 of 899 cases (88%). The remaining 108 pedal misapplication crashes resulted in 140 fatalities. These numbers include all people killed as a result of the crashes. In 94 crashes, one person was killed. In 10 crashes, two people were killed. One crash resulted in the death of three people, another in the death of four people, another in the death of nine people, and one crash reported in the media resulted in the death of 10 people.

The number of injuries was not mentioned in 78 of the news reports. Researchers removed these 78 crashes from the injury analyses, rather than assume they involved no injuries. Of the remaining 821 crashes, 387 (47%) involved no injuries, while 434 (53%) involved injuries. The total number of injuries reported in the articles describing these 434 crashes was 1,093. In the majority of injury crashes (53%), one person was injured. In 19% of the crashes with injuries, two people were injured. In 11%, three people were injured. In the remaining 17% of the injury crashes, anywhere from four to 23 people were injured. One crash resulted in 60 people being injured.

NMVCCS codes the "Maximum Known Police Reported Injury in Crash," which includes injuries in all vehicles involved in a crash. None of the pedal misapplication crashes recorded in NMVCCS resulted in a fatality. Four crashes (13%) resulted in incapacitating injury,[16] 5 crashes (16%) resulted in non-incapacitating injuries, 11 crashes (36%) resulted in possible injury, and 9 crashes (29%) resulted in no injuries. Injury severity was missing for 2 of the 31 crashes. Table 15 presents the unweighted and weighted frequencies and percentages of crashes by maximum known police reported injury.

[16] Any injury, other than a fatal injury, which prevents the injured person from walking, driving or normally continuing the activities he was capable of performing before the injury occurred is labeled "incapacitating."

Table 15. Pedal Misapplication Crashes, by Maximum Known Police Reported Injury for Each Crash (Unweighted and Weighted NMVCCS Data)

Highest Injury Severity in Crash	Unweighted		Weighted	
	Frequency	Percent	Frequency	Percent
O – No injury	9	29	1,535	31.1
C – Possible injury	11	35.5	1,711	34.7
B – Non-incapacitating injury	5	16.1	996	20.2
A – Incapacitating injury	4	12.9	519	10.5
Unknown if injured	1	3.2	167	3.4
No police accident report obtained	1	3.2	----	-----
Total	**31**	**100**	**4,928**	**100**

Property Damage

To indicate property damage, reporting officers in North Carolina enter property (other than motor vehicles and their loads) that was damaged, identify the owner, and enter an estimate of the dollar damage. Damage to signs, buildings, mailboxes, fences, etc., are included in the estimate.

A summary of the officer-estimated damages for 2,396 crashes is presented in Table 16. Property damage estimates ranged from $25 to $204,000, averaging $7,547. Sixty percent of the crashes resulted in additional damages of $5,000 or less; 23% resulted in damages between $5,001 and $10,000; and 17% over $10,000. To reiterate, these estimates were provided by law enforcement officers, not insurance adjustors.

DRIVER REHABILITATION SPECIALIST PANEL

Driver rehabilitation specialists (DRS) are specially trained professionals who evaluate their clients' ability to operate a vehicle safely by conducting on-road tests in vehicles equipped with a dual braking system. The DRS rides as a passenger in the test vehicle, and may apply the passenger-side brake and take control of the steering, if necessary to prevent a collision or other unsafe maneuver made by their clients.

Pedal Application Error Definition

Early in the discussion, panelists agreed that a pedal misapplication need not result in a full-throttle or high-power acceleration (as in the definition of sudden unintended acceleration applied in the 1980's), in order for it to be considered a pedal misapplication. The pedal application errors observed by the DRSs occurred at low as well as at high speeds, and none of the DRSs allowed the error to continue to full throttle, if a driver failed to correct a pedal misapplication. To frame this discussion, DRSs defined a pedal application error as unintentionally pressing the gas pedal instead of the brake pedal, at any speed, with or without subsequent correction by the driver.

As revealed in the panel discussion, DRSs have observed the following pedal misapplication behaviors: (1) drivers with a wandering foot (termed submovements in the literature) moving between the gas and the brake pedal because they are not sure which pedal to press or where their foot is; (2) the driver who makes a pedal application error but corrects it; and (3) the person who makes a pedal application error and can't recover from it (either at low speed or high speed). They emphasized that pedal misapplications occur along a spectrum, with all levels potentially devastating (whether low-speed or high-speed). The spectrum includes low-speed corrected errors, low-speed sustained errors, high-speed corrected errors, and high-speed sustained errors. Sustained full-throttle acceleration ending in a crash is the most extreme outcome.

Table 16. Pedal Misapplication Crashes by Property Damage Estimates (North Carolina Crash Database Sample)

Additional Property Damage	Number	Percent
Less than $500	37	2%
$500 to $1,000	122	5%
$1,001 to $2,000	411	17%
$2,001 to $3,000	389	16%
$3,001 to $4,000	252	11%
$4,001 to $5,000	211	9%
$5,001 to $6,000	180	8%
$6,001 to $7,000	137	6%
$7,001 to $8,000	99	4%
$8,001 to $9,000	66	3%
$9,001 to $10,000	59	2%
$10,001 to $15,000	186	8%
$15,001 to $20,000	65	3%
$20,001 to $25,000	72	3%
$25,001 to $30,000	22	1%
$30,001 to $35,000	22	1%
$35,001 to $40,000	7	0%
$40,001 to $45,000	21	1%
$45,001 to $50,000	1	0%
$50,001 to $60,000	12	1%
$60,001 to $70,000	8	0%
$70,001 to $80,000	5	0%
$80,001 to $100,000	2	0%
$100,001 to $150,000	8	0%
Greater than $150,000	2	0%
Total	2,396	100%

Prevalence of Pedal Misapplications

The DRSs stated they do not see many pedal application errors occurring on-road, which is likely the result of pre-screening clients in the clinic. DRSs generally reported not allowing clients with sensory problems in their feet to proceed to on-road evaluations; instead, CDRSs evaluated these drivers for their ability to use hand controls. In fact, if a client fails any critical part of the clinical physical or cognitive assessment, the DRSs may not take them on the road.

The 14 participating DRSs who perform on-road evaluations estimated that, collectively, they have seen a total of 380 pedal application errors committed by their clients on the road in the 247 aggregate years of practice represented by this group. This is an average of 1.5 pedal misapplications observed per year, per DRS. Estimates ranged from 5 on-road pedal application errors observed by a DRS with 14 years of experience to 75 on-road pedal application errors observed by a DRS with 20 years of experience. None of the observed pedal misapplications resulted in a crash. The DRSs indicated that the majority of the pedal application errors are corrected by their clients, but there have been instances when the DRSs have intervened, using the instructor brake.

Estimates of pedal misapplications in client population were higher if they include pedal application errors observed in the clinic on the brake reaction-time tester. DRS estimates of observed pedal application errors in the clinic ranged from 11 to 20 per year, per DRS.

The DRSs cautioned that the population of drivers they observe on-road is atypical of the general population, because the clinical pre-screening assessments rule out on-road evaluations for drivers with sensory problems in their feet and those with cognitive impairments more severe than those diagnosed as "mild." The incidence of sensory and cognitive impairment is likely to be higher among the general population, which includes those who have impairments that haven't been diagnosed, and/or haven't been evaluated for their ability to drive safely.

Characteristics of Drivers Who Make Pedal Application Errors

Driver Experience

The DRSs reported observing both novice and experienced drivers making pedal application errors. DRSs commented there are potentially different causes of pedal misapplications for younger (new) versus experienced (older) drivers.

Panelists cautioned that the inexperienced driver group includes new drivers as well as drivers who haven't driven much in the past. Older does not always connote experienced. For example, a number of older women are not experienced drivers. Some have had very little experience because their husbands were the primary drivers; many have only resumed driving following the death of their husbands.

Drivers With Sensory Impairments (Lower Limb)

There was consensus among the DRSs that peripheral neuropathy is of great concern as a potential cause of pedal application errors. DRSs indicated that over the past 10 years, larger percentages of their referred drivers have reported having trouble feeling their pedals. This includes people with knee and hip replacements, chemotherapy, multiple sclerosis, and conditions resulting in foot drop,[17] to name just a few. A panelist referenced an article by a psychiatrist in the practice of pain management and to the Neuropathy Association's Web site (Donovan, 2012). These resources explain that 8 to 9% of Medicare recipients carry neuropathy as either a primary or secondary diagnosis—about *20 million* people—yet neuropathy is one of the least recognized epidemics in the

[17] Foot drop describes the inability to raise the front part of the foot due to weakness or paralysis of the muscles that lift the foot. It is a symptom of an underlying problem and is either temporary or permanent, depending on the cause. National Institute of Neurological Disorders and Stroke: http://www.ninds.nih.gov/disorders/foot_drop/foot_drop.htm

United States. The panelists agreed that many of their clients are unaware that they have a loss of sensation in their feet.

Many medical conditions can cause peripheral neuropathy, and physicians and occupational therapists (OTs) may not test for sensation in the feet of their patients. The DRSs compiled a list of conditions that can cause proprioceptive/sensory deficits that could contribute to a pedal misapplication (see Appendix E). They noted that chemotherapy exacerbates neuropathy.

Members of the panel said that physicians need to be educated about medical conditions that can cause peripheral neuropathy, they need to test their patients for it, and they need to be prepared to discuss the implications of this condition for driving. Panelists recommended that physicians refer their patients with loss of sensation in their feet to driver rehabilitation specialists who can evaluate them to see if they are candidates for driving with hand controls.

One DRS commented that the Santa Monica driver had spinal stenosis, which can cause peripheral neuropathy; but there was no mention in the NTSB report of whether he had problems feeling his feet. The DRS referenced an article by a physician, Dr. William. B. Donovan, who specializes in pain management, and who, himself, is a neuropathy patient (Donovan, 2008). After reading the story of the Santa Monica crash, Dr. Donovan wrote:

> "I contacted several police officers who were familiar with similar cases. They were aware that such older drivers 'confused' the brake with the accelerator. What was surprising was that they all attributed the problem to cognitive, rather than sensory, confusion. When questioned further, they believed it would be unlikely for a police officer to be aware of the existence of peripheral neuropathy. Typically, police officers would pass off the case as being due to senility, pull the driver's license, and submit it to the state licensing agency for re-evaluation."
>
> "I contacted the official responsible for reviewing all the traffic injury reports filed in one of the larger States for almost 30 years. Having suffered from diabetic neuropathy himself, he was familiar with impairment due to peripheral neuropathy. In reviewing tens of thousands of cases, he could recall <u>not one report</u> mentioning this possible cause."

<u>Drivers With Cognitive Impairments</u>

Pedal application errors have been observed by DRSs among their client population that performed poorly in clinical tests with "executive function" tasks (e.g., clock drawing, Trail Making Test). The DRSs were familiar with the concept of sub-movements described in the literature review. Many indicated that they had observed such foot "wandering" in their cognitively impaired older clients.

In addition to sub-movements, one DRS noticed older clients pumping the gas and brake pedals more than their younger clients did. Another DRS pointed out that we really don't know if sub-movements are a negative thing; a study (Cantin et al., 2004) indicated that older drivers made more sub-movements than younger drivers, but no pedal misapplications occurred in that study. However, the literature on target acquisition tasks found more errors in the older subject groups, who also showed longer movement times and more sub-movements. A DRS indicated that it might not be negative to have sub-movements. Another indicated the need to understand the contribution of foot wandering/sub-movements to pedal misapplication, to determine what predicts errors and what is normal.

Panelists reported that another cognitively impaired group that makes pedal misapplications is young drivers with autism spectrum disorders (ASD), including Asperger's syndrome and high-functioning teens with autism, attention-deficit disorder (ADD), and attention deficit hyperactivity disorder (ADHD). Several DRSs indicated that there are many such drivers coming of driving age who need to be taught differently and require more practice than is available in traditional driver education or parent-taught driving. This group (ADD, ADHD and ASD) may slip through the DMV screening cracks because their disabilities are not always visible. Distraction could cause pedal misapplications in the group of young drivers with ADD and ADHD. Adolescents with autism are motorically challenged, so could be at increased risk of pedal application errors. Those with non-verbal learning disabilities might also be more likely to confuse the gas and brake, according to the DRSs.

A DRS working in Washington, DC, said that driver license examiners in DC, Maryland, and Virginia do not allow clients to drive with both feet; nor do they allow anyone to drive with foot pedals who uses a lower extremity prosthesis, an ankle-foot orthosis (AFO), or has any sensory loss in their legs (proprioception or fine touch). Consequently, the population he assesses on the road exhibits very few pedal misapplications. Due to the DMV regulations, clients with the specified lower leg conditions either agree to learn to drive with hand controls or they give up their privilege to drive. Anyone who is evaluated at this facility and diagnosed with a cognitive limitation (brain injury, Alzheimer's, multiple sclerosis, stroke) must return for a second on-road assessment and perform well two times in a row, before being cleared to drive. The pedal application errors this DRS has observed were made by drivers learning how to use adaptive equipment, and novice drivers with cerebral palsy.

Drivers Using Adaptive Equipment

Several DRSs reported having observed pedal misapplications among their clients while they were learning to use adaptive equipment. One DRS who conducts training with a left-foot accelerator and hand controls reported that drivers have been convinced they are on the brake when they are flooring the accelerator; while she had her foot on the instructor's brake telling the driver to let off the gas the driver would still be flooring the accelerator. In her practice, this typically occurs with the more borderline cognitively impaired clients being trained to use adaptive equipment.

One DRS commented that she does not think that people who are properly assessed, properly trained, and have adaptive equipment properly installed are any more likely to have pedal misapplication crashes than the general public. DRSs agreed that their clients must show mastery in using the adaptive equipment before they are released to drive independently.

Female Drivers/Drivers of Short Stature

The DRSs commented that women are smaller and their "fit" in the driver's seat is often poor. Many sit with their hips stretched forward, which can cause leg cramps as well as temporary loss of sensation in their foot and leg. Their vehicles (as opposed to a medical condition) are causing a problem: they are not positioned properly in their seats, and if their legs are cramping or falling asleep, they probably cannot feel the pedals. The panelists who conduct CarFit evaluations[18] said many women do not fit well in vehicles with large seat pans, and older women often do not know how to use the features in their cars (power seat adjustments) to make the fit better. The DRSs have observed women at these events sitting too far away from the steering wheel, sitting too low, reaching for controls, and stretching with their toes.

Short females with small feet need to pick their foot up to move it from the gas to the brake, whereas taller people (or those with bigger feet) can rock their foot (pivot) between the gas and the brake, which provides more control, according to a DRS panelist. Picking up the foot to move it from pedal to pedal also causes more variability in movement than pivoting the foot.

Drivers Who Use Both Feet

DRSs commented that clients who began driving with both feet late in their driving careers have been more likely to make pedal application errors; both-footed driving does not seem to be a problem for those who have driven with both feet all their lives. The DRSs said that clients who start this practice late in life end up pressing both pedals at the same time. Their feet get tired because keeping the foot from pressing the gas pedal requires dorsiflexion. Their feet end up putting more pressure on the gas pedal than they realize, and if their hearing is impaired, they may not hear the engine revving. If they wait at a traffic light with one foot on the brake and the other on the gas (heavy, because their foot is tired), when the light turns green, they take their foot off the brake and they unintentionally accelerate and hit the car in front of them.

DRSs indicate this behavior is prevalent in parking lots, particularly among older drivers who are more cognitively impaired. DRSs notice an evolution from one- to two-footed driving among this population. Drivers start with their left foot on the brake; they shift the car into reverse, and then they put their right foot back on the accelerator and do two-footed driving while backing. They also do it when entering the parking spot, and when starting from a stopped position in the parking lot.

[18] CarFit is an educational program created by the American Society on Aging and developed in collaboration with AAA (American Automobile Association), AARP, and the American Occupational Therapy Association designed to help older drivers find out how well they currently fit their personal vehicle. The program reviews 12 key areas, such as knowing how to properly adjust one's mirrors to minimize blind spots; good foot positioning on the gas and brake pedals to avoid leg fatigue and slowed reaction times; and learning the dangers of sitting closer than 10 inches to the steering wheel/airbag.

Summary of Driver Characteristics

The DRSs indicated three general populations of drivers who make pedal application errors: (1) those with sensory defects in their feet; (2) those with cognitive limitations; and (3) those with no specific medical conditions or functional impairments, but who are influenced by situational factors that overwhelm everything else (inexperience; misfit in the vehicle; new vehicle; distraction).

Situational Factors That May Contribute to Pedal Misapplications

Driving a New or Different Vehicle

The DRS panelists, particularly those who conduct CarFit evaluations, indicated that when drivers purchase new vehicles there typically is only a superficial orientation to the car by salespeople. There are features in new cars that operate differently from older cars, or were not even present in their older vehicles. For example, many drivers of small stature do not realize they have power seats in their new vehicles that can move forward and move higher.

People often do not understand how certain features in their cars work. Automation to increase fuel efficiency may make the car act strangely. It may not accelerate as expected going uphill with the air conditioner on, or the engine may rev for no apparent reason, and people think something is wrong with the car. Car dealers do not explain to customers that the car will normally rev in some situations, and at other times may not speed up immediately when the accelerator is pressed, because the computer program that controls the vehicle enhances fuel efficiency and prevents over-torquing the engine. It confuses drivers when the car does not respond as they expect, and this could contribute to a pedal application error.

Drivers in unfamiliar vehicles may be more likely to make a pedal application error. One DRS evaluated and trained a driver in a sedan, where the driver's legs were positioned out in front of him, and then took him on-road in a van, where he had to pick up his foot to brake, instead of pivoting, because the leg positioning was different. The combination of a different seating posture and leg position resulted in a pedal misapplication (pressing the gas pedal on an approach to a stop sign) requiring DRS intervention. The DRS indicated that it was all she could do to keep the car from running into a house and concluded that you cannot always make a valid judgment of someone's capabilities in one type of vehicle based on their performance in another type.

Other DRSs noted that the pedal application errors that NTSB investigated involved school bus drivers who have a lot of experience as drivers, but (1) the pedal configurations in buses are different than they are in cars, and (2) some of the drivers had recently switched buses. So, even between similar vehicles, the pedal configuration could differ.

Drivers who do not adjust the seats, mirrors, etc., to suit them when they drive vehicles shared with other drivers also may be more at risk of making a pedal misapplication. The DRSs stated that this might be a cohort effect: older women may be more reluctant than younger women to change their husband's settings.

Driver Seating Position

The panelists stated that large seat pans do not work well for smaller drivers. Small-statured drivers sit with their hips stretched forward and may need to stretch with their toes to reach the pedals. This causes leg cramps and may cause their feet to fall asleep. It is stressful for people when they cannot position themselves comfortably in their vehicle. Some women, especially, sit too far away from the steering wheel, sit too low, and need to reach (with their arms and their legs) for everything. Many do not know how to adjust their side mirrors and have no idea that they have a power seat that adjusts seating position in multiple ways.

Cars with bench seats allow people to be "out of position" with respect to foot placement. People who do not wear seat belts may also sit out of position. Some people sit off- center because their seatbelt catches them; they shift it to keep it off their neck, which may move them out of position.

Using cruise control can also cause someone to be "out of position." A DRS explained that the normal foot positioning on the highway without using cruise control is on the gas, so that's the point of reference when it is time to move your foot to brake. In cruise control mode, a driver's foot could be anywhere, so is out of position. The DRSs reported that older people or drivers with multiple sclerosis who have difficulty moving between the gas and brake pedal use cruise control like a hand control to drive in city environments.

Drivers who know they are out of position are also at risk. One DRS gave this example: If you are an older driver and your daughter, who really does not want you to drive much anyway, is sitting beside you, you feel nervous and stressed that she is watching everything you are doing. You do not want to acknowledge your need to reposition; you just want to be natural and get in and drive.

The problem of person-vehicle fit addresses the onset of a pedal application error. Not realizing that you are out of position and thinking your foot is on the brake when it is on the gas explains not correcting the behavior. DRSs pointed to the NTSB's findings that the Santa Monica Farmer's Market driver was likely out of position in the driver's seat after sliding across the seat to deposit a letter in a mailbox on the curb, prior to the pedal misapplication crash sequence.

Distracted Drivers and Unexpected Events

Distractions inside or outside of the vehicle can contribute to pedal application errors. A DRS gave the example of an older woman who performed very well over the entire hour of her first lesson with adaptive equipment (left foot gas pedal), until she pulled into the rehab center parking lot, and saw her grandchildren jumping up and down and being excited about "grandma driving." When she was told to brake, she mistakenly accelerated.

Something unexpected happening in the driving environment can trigger a pedal application error. An event may be unexpected because a driver is distracted, perhaps by engaging in some kind of non-driving activity. Then the traffic light changes, or a car pulls out of a driveway, or another aspect of the traffic situation surprises them, and the result is a pedal misapplication.

Pedal Misapplication Location

Parking Lots

DRSs training clients to use adaptive equipment provided additional insight about the location of pedal misapplications, as evidenced by the following comment:

> "Any of us who've trained people on adaptive equipment know that before I let somebody go with a left-foot accelerator or hand controls, I am spending so much time in parking lots, because if there's going to be an error between gas and brake with any of that adaptive equipment, it's going to happen in a parking lot. That's where the majority of my time is spent at the end of my training with adaptive equipment. I've got to see 20 good parks and back-ups in different congested parking lots, going in and out before I'm ever going to let that person go. That's where it's going to happen; it's going to happen right there in a parking lot."

Similarly, several DRSs said that their final on-road test to ensure that the driver is safe, is the local discount store parking lot, because everyone's lot is "equally crazy" and if a driver is going to exhibit a problem that has not shown up in the lower-level, open-road portion of a test, the parking lot is where it is going to occur.

Twelve of the 14 DRSs who conduct on-road assessments with clients indicated that the majority of the pedal application errors they observed occurred in parking lots. The drivers being evaluated became nervous or anxious when they got close to other cars and there was little room to maneuver. Many foot movements are required in parking lots. Tasks (planning processes and foot movements) are compressed, so the demand for divided attention skills is increased. People need to look over their shoulders more frequently in parking lots and that puts them "out of position" which can lead to pedal application errors.

In reference to the media analysis and crash database report, the DRSs mentioned that pedal misapplication crashes may be more frequent in parking lots because there is less room to recover/correct a pedal application error, given the proximity of cars and other objects. The DRSs hypothesized that many more pedal misapplications may occur on-road than showed up in the media analysis, because drivers corrected, so they did not result in a crash. There is room for correction on-road that is not available in parking lots. In summary, panelists identified three reasons pedal misapplications occur more often in parking lots than on-the road: (1) parking requires multiple pedal movements; (2) parking lots pose greater divided attention requirements; and (3) in the event of a pedal application error, there is less room for recovery.

Finally, several DRSs commented that parking lots are where drivers move from one- to two-footed driving, sometimes without realizing it. They press both pedals, and when they shift out of park and into drive or reverse and then take their foot off the brake, the car can accelerate like a sling shot. Panelists noted that this may happen when the driver is stopped in a parking lot, or when entering or leaving parking spots, with drivers using both feet. Panelists reported observing this in the older driver population, particularly among those with cognitive impairment.

On-Road

Only 2 of the 14 DRSs who conduct on-road assessments and training indicated that most of the pedal misapplications they had observed were on-road (as opposed to in parking lots). Examples were: during a right turn after stopping at a stop sign; in stop-and-go traffic; on the highway; and in cognitively taxing situations that require good divided attention skills. These included neighborhood streets with people and cars on the roadsides, and on a 40-mph roadway where the driver had to respond quickly to traffic signal changes. Other on-road situations where pedal application errors occurred included complicated maneuvers that require the driver to change directions, such as 3-point turns.

One of these DRSs may have a more fit clientele than the others (i.e., more typical of the general population); included among her clients were research participants who were not medical referrals for driving evaluations. This DRS indicated that 75% of the pedal application errors she had observed occurred on-road (and not in parking lots). The other DRS indicated that on-road pedal application errors were most likely to occur when her clients were startled.

During the Final 30 Seconds of a Trip

Panelists noted that pedal application errors were more likely to occur during the final 30 seconds of a driving evaluation. Either something distracted clients at the end of their drives, or they were relieved that the evaluation was over and did not feel the need to concentrate.

When asked whether this might be a consequence of fatigue, the DRSs said, no, it was more of a “let down” response; drivers just did not concentrate as hard at the end because the evaluation was “over.” Another DRS said she has observed 10 to 15% of her clients run the stop sign at the end of their evaluation. These clients performed well on the whole evaluation, until they got to the end. It is the same phenomenon as when pedal application errors occur in the driveway and the garage, where drivers hit their houses. They “relax” from the driving task when they reach home, or at the end of their trip, and that is when a pedal misapplication occurs.

Possible Explanations for Why a Driver Doesn’t Correct a Pedal Misapplication

Cognitive Impairments

As one DRS said, “Regardless of what triggers the behavior, if the driver cannot correct the pedal application error there’s a cognitive reason.” Appendix F contains a list of cognitive impairments generated by the DRSs that may keep people from correcting a pedal misapplication, once one is made. Several are described in detail below.

A DRS stated that borderline cognitively impaired people may be startled when the car does not move as they think it should, then instead of making an appropriate correction to take their foot off the accelerator and apply the brake, they floor the accelerator.

Anxiety decreases driving performance. One DRS described a driver with mild dementia who did fine the entire drive until she forgot the third destination she had planned at the start of the trip. She panicked when she did not know where she was, and made many critical driving errors. Panic is an internal distraction. Another DRS indicated that seniors with dementia find it very stressful to recall a destination and remember how to get to it. This could easily contribute to pedal application errors.

One DRS described a pedal misapplication made by a client who did not perform well on the Trails B test in the clinic (indicating cognitive impairment). This driver was exiting a highway on a ramp with a red traffic light and three cars stopped ahead of him at the light. He began accelerating, and the DRS told him to slow down. He appeared not to hear her, and continued accelerating, appearing confused. He knew he was doing something wrong, but he could not fix it, and became anxious. His anxiety produced more confusion, and continued acceleration. The DRS finally put the car in neutral and took control.

Situationally Induced Cognitive Overload

Set shift impairment—i.e., inability to take the foot off the gas and put it on the brake, because the driver believes it already is on the brake, so pushes harder on the gas—could be considered a transient "cognitive impairment" in the normal (not cognitively impaired) population. In a state of panic, a driver may not be able to recognize and fix a problem. Situationally induced overload results in temporary impairment; it is not chronic cognitive impairment.

Countermeasures

Panelists offered a variety of countermeasures, but noted that they should be matched to the population committing the error: drivers with sensory loss; drivers with cognitive impairments; and drivers without medical conditions who make pedal application errors as a result of situational factors. Some of the countermeasures are obvious, such as for the 8-year-olds who the media analysis identified: do not let children drive. Drivers who have sensory loss in their lower limbs should acquire and learn to use hand controls. For drivers who are cognitively intact, panelists recommended education about how to shift to neutral to stop an unintended acceleration event.

Other countermeasures are less obvious, like educational campaigns directed to physicians and law enforcement officers to increase awareness about medical conditions that can cause neuropathy, and about referring these drivers to driver rehabilitation specialists and the medical review units of the DMV so they can be evaluated for hand controls. Similarly, educational campaigns could raise public awareness of the risks of driving with medical and functional impairments. Countermeasures suggested by the panelists are described in detail below.

Educational Campaigns

Teach the Driving Public to Use Neutral. In a panic situation, some drivers freeze and resort to what they know (i.e., pumping or sustained activation of the pedal that they believe is the brake, but is actually the gas). Panelists stated that drivers need to overlearn solutions that they can implement if their car goes out of control. Specifically, drivers need to know that "neutral is their friend." DRSs said that this should be obvious, but is not taught or practiced in driver education, and it is not in the parent/tutor guides and may not be in driver manuals. One DRS noted that shifting to neutral was not taught in any of five graduate-level courses she took in traffic safety, as part of the requirement for being a driving school instructor; she learned it in a CDRS preparation course.

A concise message that pairs this solution to an unintended acceleration event could be made into a public service announcement (PSA) that is presented on radio and TV to affect the most people. People may think they will harm the transmission if they shift into neutral at full speed, but it will not. *This solution will work for unintended acceleration caused by vehicle malfunctions or by pedal application errors, in situations where there is time to shift the vehicle into neutral before it hits something.*

Not all panelists were convinced that drivers could disengage enough to shift to neutral in a panic situation. Many older adults experience diminished frontal lobe functioning, and the frontal lobe is not fully developed in younger drivers. Others were more hopeful that an educational campaign could result in an overlearned response. DRSs indicated that people who overlearn emergency responses are better able to react correctly in a panic situation. Front-seat passengers could shift the car into neutral for the driver, if the driver freezes. This underscores the importance of this training for everyone, including parents supervising or teaching teens how to drive.

<u>Teach Physicians About the Risks of Peripheral Neuropathy for Driving, How to Test for It, and How to Refer Patients to Driver Rehabilitation Specialists</u>. Physicians need to be aware of the potential effects of peripheral neuropathy on driving safety. Topics that should be included in the educational campaign include medical conditions that can cause peripheral neuropathy, how to test for loss of sensation, and alternatives to foot controls for people with neuropathy. Physicians need to know that they can refer drivers to driver rehabilitation specialists who can evaluate clients for hand controls as remediation. Many doctors think this referral role places them in the position of police officers, and they do not want to be responsible for taking a patient’s license away. Doctors need to understand that their referral to the DRS may help their patient receive additional medical services so they can function better.

A few DRSs noted that this type of information is already covered in the AMA’s *Physician’s Guide to Assessing and Counseling Older Drivers* (Carr, Schwartzberg, Manning, & Sempek, (2010), but others noted that some physicians have not read the AMA guide. There is an AMA information outreach effort, but only a minority of doctors are members of AMA; a majority have not received the information. Panelists recommended continuing outreach efforts for the NHTSA/AMA course to educate physicians about how to screen and counsel older drivers about physical and cognitive problems that can affect safe driving, and educating physicians about referring these drivers to driver rehabilitation specialists for remediation.

<u>Educate DMV Personnel About Hand Controls for Drivers With Peripheral Neuropathy</u>. Along with physicians, DMV staff members need to be educated about hand controls for people with peripheral neuropathy. If a driver has been switched to hand controls by a DRS and goes to a DMV for licensing, the DMV needs to understand why the car has been equipped with hand controls for this person. A DRS said she trained to use hand controls, but the DMV said the driver did not need them. The client had to explain to the DMV license examiner that she could not use her pedals.

<u>Educate Occupational Therapists to Test for Loss of Sensation in the Feet</u>. Panel participants held an occupational therapy (OT) credential in addition to their CDRS credential. They noted that unless OTs are CDRSs, they do not routinely test for loss of sensation in the lower extremities. The panelists commented that OTs generally focus on clients’ arms and PTs (physical therapists) on the legs. PTs routinely test for foot sensation but typically OTs do not.

Continue Efforts to Educate Police About How to Identify and Refer At-Risk Older Drivers. DRSs stated that law enforcement officers need to know how to refer drivers to DMV Medical Review Units for evaluation and remediation of medical and age-related functional impairments. Several DRSs stated that NHTSA has a course addressing this issue, but it should have more exposure. One CDRS who teaches at the police academy in her State indicated that officers avoid referring older drivers.

Teach the General Public About the Dangers of Driving While Impaired. A public education campaign is needed to raise awareness about the dangers of driving with physical or mental impairments, regardless of whether they are caused by age-related functional impairments, medical conditions, or medication use. A similar social norming campaign was successful in reducing drunk driving ("friends don't let friends drive drunk") and increasing seat belt use (*Click It or Ticket* campaigns). Panelists recommended that the public education campaign run parallel to the education campaigns for physicians and police. Targeting social norms makes it easier for physicians and police officers to refer drivers, to the extent a campaign is successful in changing public opinion about the issue of driving with functional or medical impairments.

DRSs suggested that pedal application errors happen more often than they are reported. People back into poles in parking lots and do not report it to the insurance company, because they do not want their rates to increase. DRSs commented that it was important to educate not only the public, but physicians, and others who regularly work with older people, about the importance of minor fender benders as indicators of early dementia.

Other Components of Pedal Application Error Prevention That Could Be Incorporated in Media and Driver Education Campaigns. Panelists suggested incorporating the following elements into campaigns to promote safe driving and in other driver education efforts.

- Educate drivers about the importance of proper seating positioning—being out of position affects where drivers place their feet.
- Educate drivers about the importance of fully learning how to operate their cars, not just how to pass the test.
- Educate drivers about proper footwear for driving (e.g., no flip-flops).
- Educate drivers not to use cell phones when driving because this can cause a distraction that could lead to a pedal misapplication.
- Teach drivers that sometimes drivers are the cause of unintended accelerations, and if the car accelerates out of control, they should take their feet off all pedals, and then if the car continues to accelerate, shift into neutral.

Improvement of Traffic Records

There were two recommendations in this area:

- Add a field on the crash report to code whether a crash involves a pedal application error, so that such crashes can be more easily and accurately identified in future research.

- Develop a checklist for law enforcement officers to use for gathering information about drivers in pedal misapplication crashes (e.g., medical conditions, medications, whether drivers use both feet to control the pedals, distractions, etc.).

CASE STUDIES

Two types of case studies were undertaken in this research. First, researchers reviewed Iowa DMV reexamination data for general information about drivers' fitness to drive based on their reexamination test performance. Second, the research team conducted one-on-one unstructured telephone discussions with North Carolina drivers involved in pedal misapplication crashes in 2008 to uncover more detail about the crash circumstances than was provided in the crash narratives. Interviewers asked drivers about potential contributors to their pedal misapplications, such as medical conditions and use of medications, driving experience, type of footwear, use of cruise control, and familiarity with the vehicle. The findings from the Iowa data exploration activity are presented first, followed by those uncovered in the North Carolina case study telephone discussions.

Case Study Investigation of Drivers Required to Undergo Reexamination After Involvement in a Pedal Misapplication Crash (Iowa)

Of the 349 pedal misapplication crash-involved drivers, 95 were required to undergo reexamination and 254 were not. As shown in Table 17 and Figure 6, the sample of reexamined drivers was older on average than the sample of drivers not reexamined.

Table 17. Summary Statistics Describing Driver Age by Reexamination Requirement, for Iowa Drivers in Pedal Misapplication Crashes (n=349)

Driver Group	Number	Age Range	Average Age	Standard Deviation
Reexamined	95	17-98	80.5	11.3
Not Reexamined*	252	11-95	37.7	22.1

*Age and sex missing for 2 drivers

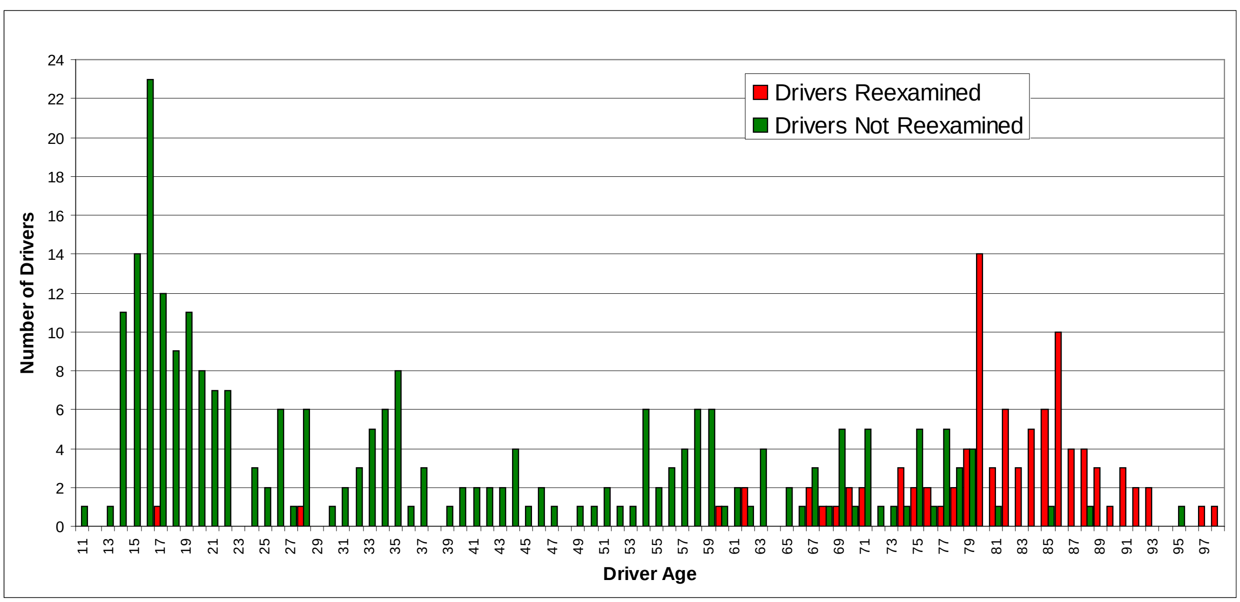

Figure 6. Age Distribution of Drivers With Reexamination Requirement Versus No Reexamination Requirement

Across the sample of 349 drivers, 66% were female. The percentage reflects the earlier findings from the North Carolina crash analysis, the NMVCCS analysis, and the media analysis that females were overrepresented in pedal misapplication crashes. Within the sample of 95 reexamined drivers, 63% were female, and 67% of the 252 drivers not required to undergo reexamination were female.

Due to confidentiality requirements, the Iowa DMV could not provide data to describe medical conditions or functional impairments associated with the pedal misapplication crashes. However, law enforcement officers use a field on the Iowa crash report form to code driver condition at the time of the crash into the one of the following categories: apparently normal; physical impairment; emotional (e.g., depressed, angry, disturbed); illness; asleep, fainted, fatigued; under the influence of alcohol/drugs/medications; other; or unknown. As shown in Table 18, the majority of drivers (85%) were coded as apparently normal. The narrative provided a description for only 2 drivers described as "other," 1 driver was parking in a handicapped spot and another driver had a medical issue that was unspecified in the narrative. The researchers read through each of the 349 crash narratives to uncover evidence of medical conditions, physical impairments, or cognitive impairments. Only 15 narratives contained such descriptions. Two drivers were described as having "medical issues" (no other detail was provided); 11 drivers were described as entering or leaving handicapped parking spaces (with one driver using both feet), 1 driver was "feeling ill;" and one driver was "fatigued from a run."

Table 18. Reported Condition of Iowa Drivers Involved in Pedal Misapplication Crashes, by Reexamination Requirement. (Iowa Sample, n=349)

Driver Condition (Coded by Law Enforcement Officer)	Reexamined Sample Number (%)	Not Reexamined Sample Number (%)
Apparently normal	70 (74%)	227 (90%)
Physical impairment	1 (1%)	1 (0.4%)
Emotional (e.g., depressed, angry, disturbed)	1 (1%)	4 (2%)
Illness	2 (2%)	1 (0.4%)
Asleep, fainted, fatigued, etc.	1 (1%)	2 (0.8%)
Under the influence of alcohol/drugs/medications	0	2 (.8%)
Other (explain in narrative)	16 (17%)	10 (4%)
Unknown	4 (4%)	6 (2%)
Total	95	253

License restrictions in effect, either at the time of the crash or following reevaluation, may indicate deficits in certain functional abilities critical to safe driving. For example, drivers restricted to driving with corrective lenses or during daytime could reasonably be expected to have a visual impairment; those with prostheses or mechanical aids a physical impairment of the upper or lower limbs; those with outside mirror requirements a head/neck/upper body flexibility impairment; and those with speed, roadway, or geographic restrictions a cognitive impairment.

Table 19 presents the number of drivers by restriction type and reexamination status. The number of restrictions is larger than the number of drivers because a driver may be restricted in multiple ways. Nearly half of the drivers not required to undergo reexamination were without restrictions, compared to only 15% of the reexamined sample. Across the full sample, the most prevalent restriction was corrective lenses. Not surprisingly, a higher prevalence of corrective lens restrictions was observed among the reexamination sample, due to the inclusion of a larger percentage of older drivers. Eight percent of the reexamined drivers had a daytime-only restriction; none of the non-reexamined drivers were restricted to daytime. Similarly, only drivers in the reexamination sample had speed and roadway type restrictions (albeit a small percentage). Outside mirror requirements were more prevalent in the reexamination sample. Seven drivers in the reexamination sample and 1 driver in the non-reexamination sample had restrictions on the back of their licenses, which may indicate a geographic restriction (may drive only within a specific radius from home, only on specified roads, or to specified destinations).

Table 19. Restriction Type by Reexamination Requirement for Iowa Drivers in Pedal Misapplication Crashes.

Restriction Type	Reexamined Sample (n=95)	Non-Reexamined Sample (n=254)	Total (n=349)
None	14 (15%)	115 (45%)	129 (37%)
Non-commercial operator permit	0	21 (8%)	21 (6%)
Commercial instruction permit	2 (2%)	0	2 (0.6%)
Except class A & B bus	0	1 (0.4%)	1 (0.3%)
Corrective lenses	69 (73%)	96 (38%)	165 (47%)
Minor’s school license	0	3 (1%)	3 (0.9%)
Left outside mirror	21 (22%)	11 (4%)	32 (9%)
No driving when headlights are required	8 (8%)	0	8 (2%)
Restrictions on the back of the card	7 (7%)	1 (0.4%)	8 (2%)
No interstate or freeway driving	2 (2%)	0	2 (0.6%)
Maximum speed of 35 mph	4 (4%)	0	4 (1%)
SR-22 or SR-23 insurance	1 (1%)	4 (2%)	5 (1%)
Medical report required at renewal	0	1 (0.4%)	1 (0.3%)
Left and right outside mirrors	2 (2%)	6 (2%)	8 (2%)
Intermediate license	0	17 (7%)	17 (5%)

The DMV provided “yes/no” level data indicating whether a medical report was required for the 95 drivers who were required to undergo reexamination; whether drivers passed the written, vision and road tests; and whether their licenses were suspended as a result of the reexamination. The DMV also provided supplemental notes about drivers’ involvement in multiple crashes.

The first finding of interest was that 55 drivers received an “incapable” suspension. This occurs when a driver submits an unacceptable medical report or fails one of the DMV tests (written, vision, or driving). This suggests that these drivers, representing 16% of the sample of drivers (55 of 349) involved in a crash due to a pedal application error, were medically or functionally impaired. The circumstances surrounding these 55 incapable suspensions denoting driver incapacity are described below.

Four of the 55 submitted an unacceptable medical report, resulting in license suspension. These drivers were ages 68, 78, 80, and 85.Twelve drivers voluntarily surrendered their licenses; they were age 62 (2 drivers), 74, 80 (2 drivers), 86 (2 drivers), 89, 90, 91 (2 drivers), and 98.The 74-year-old driver had been involved in 2 crashes in the year of the pedal misapplication crash. One of the 91-year-old drivers had 5 crashes in the 6-year-period prior to the pedal misapplication crash and had 3 reexaminations. Fourteen drivers failed to appear for reexamination tests, resulting in their license suspensions. Their ages were: 17, 60, 79 (2 drivers), 80 (3 drivers), 86 (3 drivers), 87 (2 drivers), 91, and 92. Three of these drivers had 2 crashes (ages 17, 60, and 80). Twenty-four drivers had incapable suspensions because they failed one or more of the DMV tests, as follows: 7 failed the drive test; 4 failed the vision test, 5 failed the written test; 3 failed the written and driving tests; 1 failed the vision and drive test; 1 failed the vision and written test; and 1 failed all three tests. Four of the drivers who failed one or more of the DMV tests were noted as having multiple crashes. The 97-year-old driver who failed the written test had 3 crashes and 2 reexaminations. An 89-year-old driver who failed the written and drive tests was reexamined on two occasions. Another driver (age 84) who failed both the written and drive tests had numerous charged crashes and 2 incapable license suspensions. One driver (age 70) had two crashes. Thus, prior crashes appear to be indicative of future pedal misapplication crashes.

Of the 40 drivers who underwent reexamination and did not receive an incapable suspension, only 1 was noted as having prior crashes—this 88-year-old driver had 3 crashes prior to the pedal misapplication crash. The DMV did not provide data about prior crashes for the 254 drivers with pedal misapplication crashes who were not required to undergo reexamination.

One-On-One Unstructured Conversations with Drivers Involved in Pedal Misapplication Crashes (North Carolina)

Only 10 of the 226 potential case-study drivers identified from the North Carolina data set participated in the unstructured discussions. A brief summary of the pertinent findings is provided below.

Two case study participants were males (age 29 and 67) and 8 were females (age 39, 53, 62, 63, 65, 73, 81, and 85). Five of the 10 drivers (both males and the three oldest females) indicated their crashes were the result of their own errors (either their foot slipped or they hit the wrong pedal). The remaining five drivers maintained that their vehicles must have had an equipment malfunction, because they believe they were pressing the brake; however, their cars continued to accelerate out of control.

None of the drivers was using cruise control, or felt rushed prior to the pedal misapplication. Only one driver indicated she was startled prior to the crash; her vehicle surged forward unexpectedly, which scared her. Three drivers, who were looking to the sides prior to the crash, may have experienced a rightward bias in their foot aim toward the brake, resulting in hitting the gas pedal. One of these drivers was looking at police activity at the side of the roadway, one at the cars parked on both sides of the narrow parking space he was entering, and one at a car backing out of the parking space she planned to turn left into. The driver who was looking at the law enforcement activity at the side of the road was momentarily distracted.

All case study participants indicated that their vehicles were comfortable to drive and that it was easy to reach the pedals and adjust the seating position. The vehicles involved in the crashes were as follows: 1996 Subaru Legacy, 2002 Ford Taurus, 1997 Jeep Grand Cherokee, Subaru Impreza (year unknown), 1994 Lexus LS 430, 2005 Chevrolet Cavalier, 1999 Toyota Camry, 1999 Honda Civic, 2002 Toyota Camry LE, and a 2000 Chevrolet Silverado. The five vehicles believed by the case study participants to have experienced a vehicle malfunction were the Ford Taurus, Jeep Grand Cherokee, Lexus LS 430, Toyota Camry LE, and Toyota Camry.

None of the drivers reported using a prosthesis, or having a cast or splint on their leg or foot at the time of the crash. None reported having a handicap placard, or using adapted driving equipment. Only one of the 10 drivers had had surgery on their hips, knees, or ankles within the 5-year period prior to their crash; this driver had back surgery 5 years prior to her pedal misapplication crash. Two of the 10 drivers stated they had diabetes, and were taking medication to control their blood sugar; but neither wore special diabetic shoes, and neither described any signs of peripheral neuropathy. Only one of the 10 drivers indicated having any symptoms of peripheral neuropathy; this driver stated she had burning sensations in her feet at night. Four drivers (all women) stated they were taking medication for a thyroid condition. Other reported medical conditions included high cholesterol (2 drivers), high blood pressure, bad nerves/panic attacks, prior brain tumor resulting in a single seizure (16 years earlier), arthritis, a heart condition, gout, cataract plus glaucoma, overactive bladder, and attention deficit disorder. One driver stated that she had a hammer toe. Case study drivers reported four specific potentially driver-impairing medications: Tramadol (an opiate analgesic), Carvedilol (a beta blocker), Lamictal (anti-seizure medication), and Oxybutynin (an antispasmodic). All four contain a warning about side effects that may impair thinking and reacting, and advise caution if driving or doing anything that requires alertness. Two of the four medications include an additional caution about driving because of side effects that may impair vision.

Eight of the 10 drivers stated they drive using only the right foot to control the accelerator and brake pedals. The two “2-footed” drivers who said they use the right foot for the accelerator and the left foot for the brake, were both female. These individuals were in the subset of drivers who indicated their crash was due to a vehicle malfunction. One of these drivers said she learned to drive with both feet and has been doing so her entire driving career. The other driver said she uses both feet when reversing her car.

Three of the female drivers reported wearing clogs at the time of their crash. Two of the three were in the subset of drivers who stated their vehicles malfunctioned. Another female indicated wearing low-heeled pumps; this driver also uses both feet to drive. Other footwear at the time of the crash included leather walking shoes, athletic shoes/sneakers (3 drivers), and Van’s (“skateboard shoes”). One driver did not recall the footwear at the time of the crash, but indicated usually wearing flat shoes or low heels when driving.

Both male drivers reported that they were 5 ft, 10 inches tall. Females reported the following heights: 5 ft; 5 ft, 1 in; 5 ft, 4 in; (2 drivers), 5 ft, 4½ in; 5 ft, 5½ in; 5 ft, 6 in; and 5 ft, 9 in. Driving experience ranged from 4 years to 67 years, with 6 of the 10 drivers reporting over 40 years of experience. Driving experience in the vehicle involved in the pedal misapplication crash ranged from 1 year to 12 years.

Although this sample of drivers in pedal misapplication crashes is too small to draw any meaningful conclusions, the information provided by these drivers corroborates some of the findings from earlier tasks, while adding detail not available from any of the other sources.

MEDIA ANALYSIS OF PEDAL-RELATED VEHICLE EQUIPMENT MALFUNCTIONS

A complementary media analysis in this project uncovered 520 reports of crashes where the brakes failed, the accelerator stuck or was trapped by a floor mat, or the vehicle suddenly accelerated for some unknown reason. The principal investigator read each news report and eliminated 68 reports from analysis because of possible driver contributions. For example, reports were eliminated for the following reasons: (1) the report stated that the cause of the acceleration was “unknown and may have been due to driver or vehicle factors;” (2) witnesses stated the driver had been acting strangely prior to the crash; (3) the driver was arrested for driving under the influence of alcohol or appeared drunk; (4) the driver was reportedly taking potentially driver-impairing medications or had symptoms of cognitively-impairing medical condition (e.g., taking opiate analgesics or having hallucinations); or (5) the driver was performing stunt-driving maneuvers.

The resulting analysis set included 452 crashes. These 452 crashes were divided into two groups: 170 crashes where the news report indicated that police or other independent investigation corroborated a driver’s assertion that a vehicle malfunction caused the crash (termed “other-corroborated”); and 282 crashes where the driver stated that the vehicle malfunctioned, and there was no further information confirming or denying the cause (termed “self-report-only”). Given questions about the reliability of the self-report-only data that may reasonably be expected, we present crash characteristics separately for each analysis group.

Another important distinction among these data relates to the type of equipment malfunction. As noted above, different equipment problems can lead to a “pedal-related” crash. Table 20 shows the percentages of crashes in the present analysis set attributed in media reports to a stuck or jammed accelerator (without mention of any floor mat issues); to instances where a floor mat was pressing on the accelerator; to instances of brake failure; and to sudden acceleration events where none of the other problems listed above was mentioned.

As shown, overall stuck accelerators accounted for approximately two-thirds of the crashes (64%) and failed brakes for approximately one-third (32%). Sudden acceleration events and floor mats pressing on the accelerator pedal accounted for just 3% and 2% of the news-reported crashes involving equipment malfunction, respectively.

Table 20 also reveals differences that emerged between analysis groups in the reasons for their pedal-related crashes. Forty-six percent of crashes for the other-corroborated (OC) equipment malfunction group resulted from stuck accelerators, compared to 74% of the crashes for the self-report-only (SRO) group. Brake failure accounted for approximately half (49%) of the crashes in the OC group, but only 21% in the SRO group.

Table 20. Media-Reported Equipment Malfunction Crashes by Malfunction Type and Analysis Group.

Equipment Malfunction Type	Analysis Group				Total	
	Other-Corroborated		Self-Report Only			
	Number	Percent	Number	Percent	Number	Percent
Stuck Accelerator	79	46%	209	74%	288	64%
Sudden Acceleration	1	1%	11	4%	12	3%
Floor Mat Pressing Accelerator	7	4%	2	1%	9	2%
Brakes Failed	83	49%	60	21%	143	32%
Total	170	100%	282	100%	452	100%

Driver Age

Driver age was provided in 126 of the crashes for the OC group and in 194 of the SRO group vehicle malfunction crashes. Table 21 shows descriptive statistics comparing driver age for these analysis groups. On average, drivers in the SRO group were 9 years older than drivers in the OC group.

Table 21. Driver Age by Analysis Group.

Analysis Group	Number	Age Range	Mean Age	Standard Deviation Age	Median Age
Other-Corroborated	126	16 - 100	46	21	44
Self-Report-Only	194	15 - 92	55	23	56
Total	320	15 - 100	51.5	22.6	51

Figure 7 displays the complete distribution of drivers with equipment-related malfunction crashes by driver age and analysis group. Figure 8 sorts these data into 5-year age groupings.

In both analysis groups, drivers younger than 20 accounted for high proportions of equipment malfunction related crashes (10 to 11%). This trend continued for drivers 20-24 in the OC group. The proportion of crash-involved drivers in both analysis groups leveled out from 25 to 39 at 4% to 5%. The proportion of OC group drivers spiked to 14% in the 40 to 44 age group while the proportion in the SRO group remained constant at 4%. The percentage in the OC group remained high between ages 45 and 49 (11%) compared to the SRO group (5%).The SRO group spiked at age 50 to 54 (9%), dropped back to 5% up to age 59, and then showed a gradual increase with increasing age, with the highest proportion among drivers 75 to 79 (almost 12%). The OC group, in comparison, had less than 2% of equipment malfunction crash involved drivers 75 to 79. In general, the OC group had higher percentages of equipment malfunction crash involved drivers up to age 49 while the SRO group had higher percentages for drivers 50 and older.

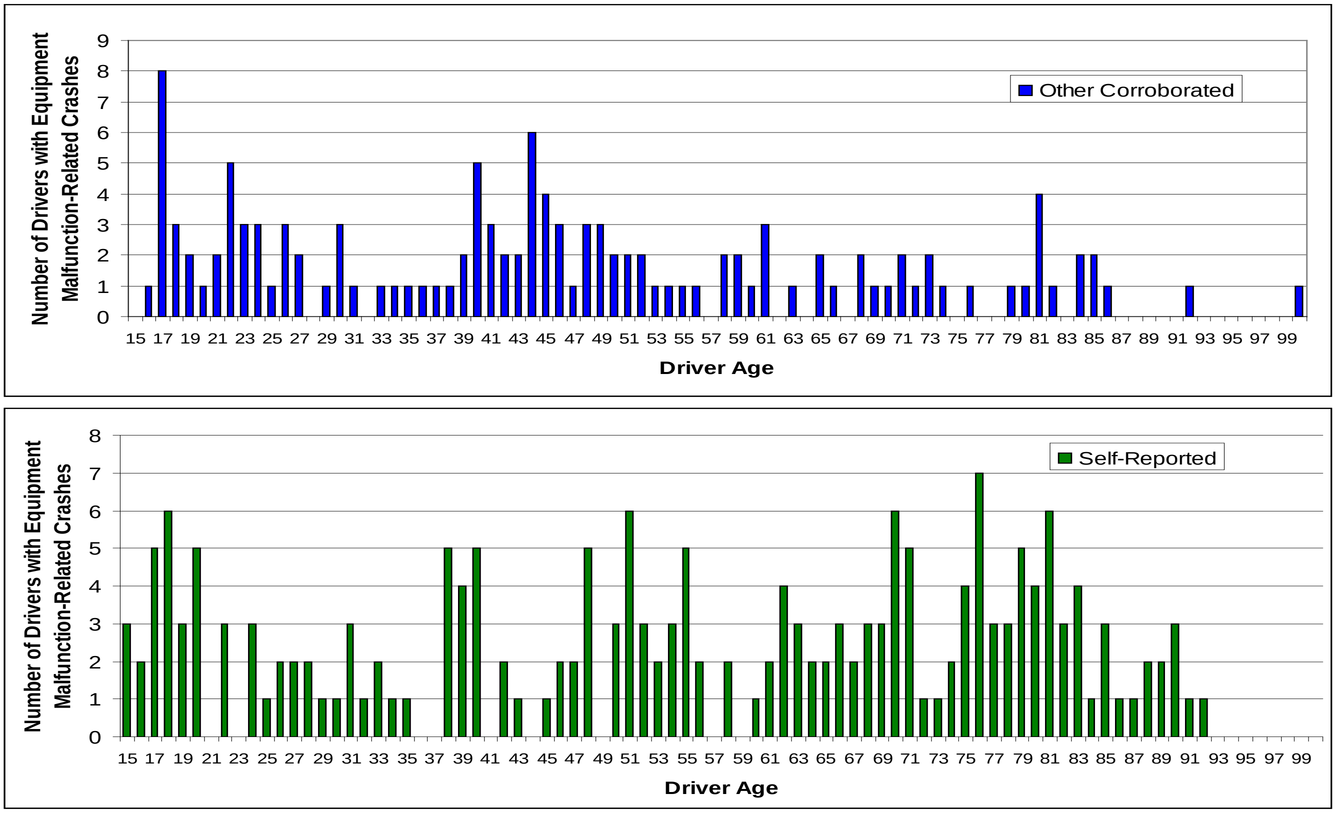

Figure 7. Frequency Distribution by Driver Age and Analysis Group.

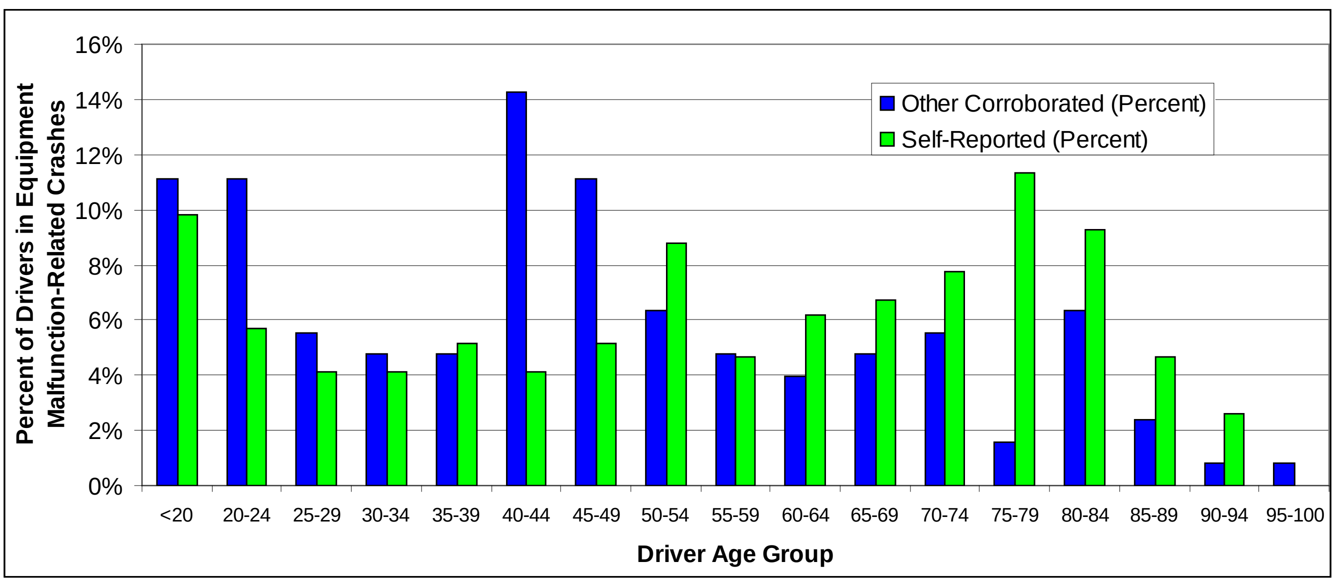

Figure 8. Percentage of Drivers in Equipment-Related Crashes Reported by the Media (n=452) in 2000-2010, by 5-Year Age Groupings and Analysis Group

Because pedal misapplication crashes are often blamed on stuck accelerators, we examined the age distribution of drivers in the stuck accelerator equipment malfunction crashes, then compared it to the age distribution in pedal misapplication crashes uncovered in the earlier media analysis. Figure 9 presents the age distribution for the stuck accelerator equipment malfunction crashes by analysis group for the 207 incidents where the media report provided driver age. Figure 10 collapses across analysis group, to compare the percentage of drivers by age group in media-reported stuck accelerator crashes to those in crashes involving pedal application errors reported in the media, for the same period (2000 to 2010). While not congruent, the patterns in the two types of media reports are broadly similar; to the extent that a bias toward reporting crashes involving older drivers with pedal misapplications was apparent in the earlier analyses, media reports of crashes due to this type of vehicle equipment malfunction may also be affected.

Driver Sex

The news reports identified the sex of 158 of the OC group drivers and 266 of the SRO group drivers. Table 22 presents the percentage of males and females by analysis sample, and across the combined sample. These data show a reversal of the pattern identified in both the media analysis of pedal misapplication crashes and the North Carolina crash database analysis, and are more representative of National crash data (57% males and 43% females) (NHTSA, 2010).

Table 23 presents the breakdown by sex, for the subset of stuck accelerator malfunction crashes only. While the percentage of females in the OC group is higher than their proportion in all equipment malfunction crashes, females were still involved in stuck accelerator crashes at a lower rate than males (42% versus 58%).

Table 22. Driver Sex by Analysis Group, for All Media-Reported Equipment Malfunction Crashes

Analysis Group	Percent Male	Percent Female
Other-Corroborated	61%	39%
Self-Reported	59%	41%
Total	60%	40%

Table 23. Driver Sex by Analysis Group, for Media-Reported Stuck Accelerator Malfunctions Only

Analysis Group	Percent Male	Percent Female
Other-Corroborated	54%	46%
Self-Reported	60%	40%
Total	58%	42%

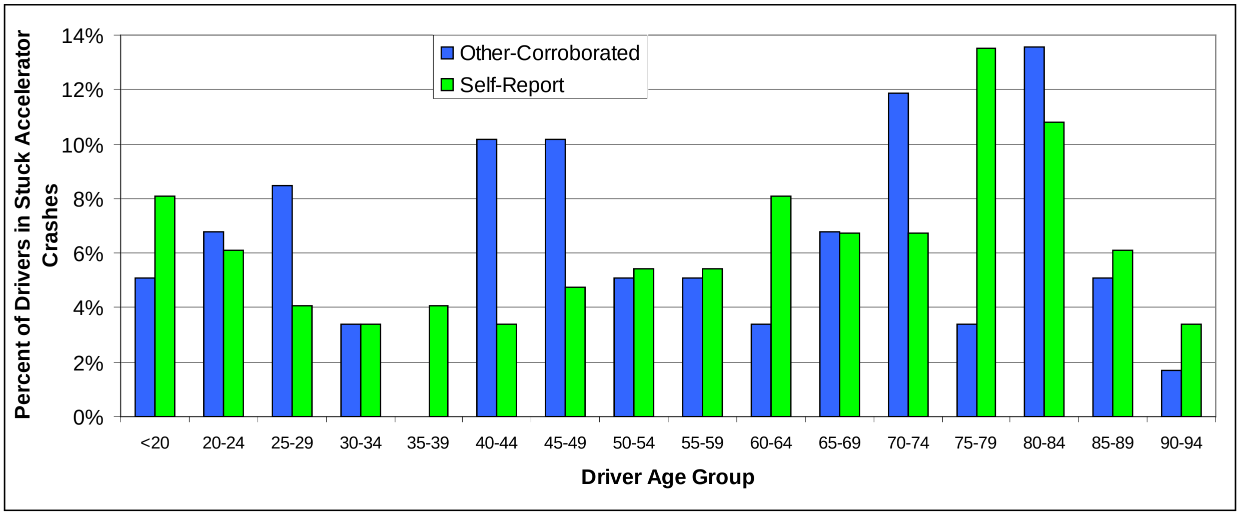

Figure 9. Percentage of Drivers in Equipment-Related Crashes Reported by the Media (n=207) in 2000-2010, by 5-Year Age Groupings and Analysis Group, for Stuck Accelerator Crashes Only

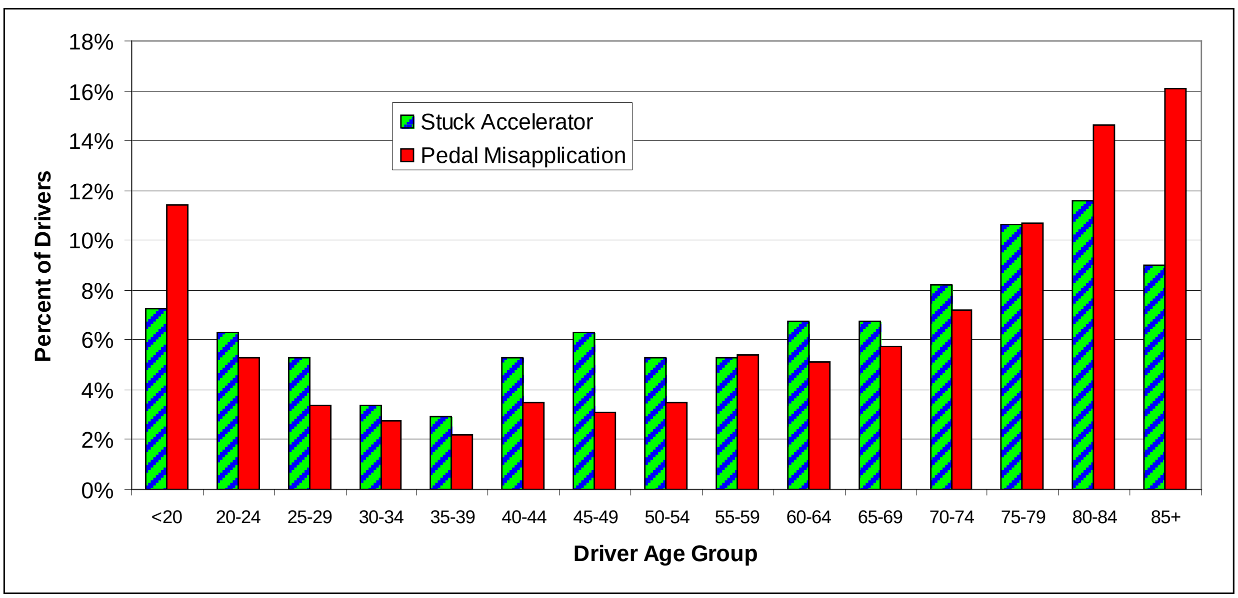

Figure 10. Comparison of Media-Reported Equipment Malfunction Crashes (207 Stuck Accelerator Malfunctions Only) and Media-Reported Pedal Misapplication Crashes (n=683), by Driver Age Group

Further limiting the comparison to passenger cars with stuck accelerators, a greater percentage of crash-involved males than females self-report this problem, 58% to 42%, but for crashes that were corroborated by others the percentage of females slightly exceeded males (52% to 48%). Additional analyses that examine vehicle type are presented below.

Vehicle Type

Based on the information provided in the news reports we were able to code vehicle type (e.g., passenger car, SUV, tractor trailer) for 165 of the OC group equipment malfunction crashes and 275 of the SRO group crashes. The percentage of vehicle malfunctions by vehicle type and analysis group is shown in Table 24. The category of "other trucks" included fire truck, tow truck, and "truck" (undifferentiated). The "other" bus category included a shuttle bus.

The most prevalent vehicle type was passenger cars (55% of all vehicles), similar to the findings of the media analysis of pedal misapplication crashes (71%). This applied to both analysis groups. There were equal percentages of pickup trucks in both analysis groups (12%); however, this percentage was twice that found in the pedal application errors media analysis (6%). For crashes attributed to equipment malfunctions, the SRO group included higher percentages of SUVs and vans than the OC group; for comparison, the earlier media analysis of pedal misapplication crashes revealed percentages of these vehicle types similar to those of the SRO group in this analysis. However, the OC group included a higher percentage (21%) of heavy vehicles (school/commercial/other buses, tractor trailers, dump trucks, and other trucks) than the SRO group (10%); both of the present analysis groups included more heavy vehicles than were reported in the previous media scan of pedal misapplication crashes (2%).

Table 24. Media-Reported Equipment Malfunction Crashes, by Vehicle Type and Analysis Group

Vehicle Type	Analysis Group		
	Other-Corroborated Equipment Malfunctions	Self-Reported-Only Equipment Malfunctions	Total
Passenger Car	93 (56%)	150 (55%)	243 (55%)
SUV	9 (5%)	40 (15%)	49 (11%)
Van	9 (5%)	21 (8%)	30 (7%)
Pickup Truck	20 (12%)	32 (12%)	52 (12%)
School Bus	3 (2%)	9 (3%)	12 (3%)
Commercial Bus	0	5 (2%)	5 (1%)
Tractor Trailer	15 (9%)	7 (2%)	22 (5%)
Dump Truck	13 (8%)	6 (2%)	19 (4%)
Other Truck	2 (1%)	4 (1%)	6 (1%)
Other Bus	1 (1%)	0	1 (<1%)
Ambulance	0	1 (<1%)	1 (<1%)
Total	165 (100%)	275 (100%)	440 (100%)

Vehicle Make, Model, and Year

Vehicle make was reported in 87 equipment malfunction crashes between 2000-2010 for the OC group and 161 crashes for the SRO group; vehicle model was reported in 56 equipment malfunction crashes for the OC group and 107 crashes for the SRO group; and vehicle year was reported in 65 equipment malfunction crashes for the OC group and 91 crashes for the SRO group. In Table 25 shows only data for only the manufacturers of pedal-related crash-involved vehicles for both analysis groups; for comparison, the percentage of each make in the U.S. fleet (Polk Company, as of April 1, 2010) is also presented.

It appears that certain vehicle makes were overrepresented in media-reported equipment malfunction crashes for one or both analysis groups, in relation to their proportion of the overall fleet: Buick (for the OC group); Ford (both analysis groups); Jeep (SRO group); Mercury (SRO group); Oldsmobile (SRO group); Pontiac (OC group); and Volvo (both analysis groups).Other makes appear to be underrepresented based on their proportion of the current fleet—for example, Toyota, associated with 5% of crashes for the OC group and 6% of crashes for the SRO group.

It is important to note that vehicle make was reported in just slightly more than half of the news reports (248 of 452, or 55%), so the percentages reported in Table 25 may be an underrepresentation of particular vehicle makes in these equipment malfunction crashes.Vehicle make was reported in only 7 of the 66 heavy vehicle crashes linked to equipment malfunctions.

Table 26 presents the vehicle make percentages for just stuck accelerator equipment malfunction crashes, based on 44 OC group crashes and 128 SRO group crashes where vehicle make was included in the news articles. The same patterns are evident in these data as shown previously in Table 25, although percentages for the over-represented makes are slightly higher for the stuck accelerator crashes (e.g., Ford, Jeep, Lincoln, Mercury, and Pontiac).

Tables G-1 and G-2 in Appendix G show the make, model, and year (where reported) for the vehicles involved in equipment malfunction crashes, for the respective analysis groups.

Table 25. Media-Reported Equipment Malfunction Crashes by Vehicle Make and Analysis Group Versus Percentage of Vehicle Makes in Fleet

Vehicle Make	Other-Corroborated		Self-Reported-Only		Total		Percent of Vehicle Fleet*
	Number	Percent	Number	Percent	Number	Percent	
Acura	0	0%	2	1%	2	1%	1.04%
BMW	0	0%	5	3%	5	2%	1.37%
Buick	6	7%	5	3%	11	4%	2.72%
Cadillac	2	2%	4	2%	6	2%	1.51%
Chevrolet	10	11%	23	14%	33	13%	15.40%
Chrysler	1	1%	1	1%	2	1%	2.53%
Dodge	3	3%	12	7%	15	6%	6.60%
Fiat	1	1%	0	0%	1	0%	0%
Ford	27	31%	34	21%	61	25%	16.64%
Freightliner	0	0%	1	1%	1	0%	0.10%
GMC	3	3%	4	2%	7	3%	2.95%
Honda	3	3%	5	3%	8	3%	7.15%
Hyundai	0	0%	1	1%	1	0%	1.71%
International	1	1%	0	0%	1	0%	
Jaguar	1	1%	0	0%	1	0%	0.22%
Jeep	1	1%	10	6%	11	4%	2.67%
Keith-Huber	0	0%	1	1%	1	0%	
Kia	1	1%	2	1%	3	1%	1.03%
Lexus	2	2%	0	0%	2	1%	1.36%
Lincoln	3	3%	4	2%	7	3%	1.09%
Mazda	1	1%	3	2%	4	2%	1.71%
Mercedes Benz	0	0%	3	2%	3	1%	1.36%
Mercury	2	2%	7	4%	9	4%	1.89%
Mitsubishi	1	1%	2	1%	3	1%	1.08%
Nissan	2	2%	2	1%	4	2%	4.74%
Oldsmobile	2	2%	9	6%	11	4%	1.55%
Plymouth	1	1%	1	1%	2	1%	0.66%
Pontiac	5	6%	6	4%	11	4%	3.06%
Saab	0	0%	1	1%	1	0%	0.23%
Toyota	4	5%	10	6%	14	6%	10.41%
Volkswagen	1	1%	0	0%	1	0%	1.52%
Volvo	3	3%	3	2%	6	2%	0.81%

* Data from The RL Polk Company: 233,871,380 vehicles in operation as ofApril 1, 2010.

Table 26. Media-Reported Equipment Malfunction Crashes for Stuck Accelerator Crashes Only, by Vehicle Make and Analysis Group Versus Percentage of Vehicle Makes in Fleet.

Vehicle Make	Other-Corroborated		Self-Reported-Only		Total		Percent of Vehicle Fleet*
	Number	Percent	Number	Percent	Number	Percent	
Acura	0	0%	1	1%	1	0.58%	1.04%
BMW	0	0%	3	2%	3	1.74%	1.37%
Buick	3	7%	1	1%	4	2.33%	2.72%
Cadillac	1	2%	4	3%	5	2.91%	1.51%
Chevrolet	5	11%	20	16%	25	14.53%	15.40%
Chrysler	1	2%	1	1%	2	1.16%	2.53%
Dodge	1	2%	11	9%	12	6.98%	6.60%
Fiat	0	0%	0	0%	0	0%	0%
Ford	16	36%	30	23%	46	26.74%	16.64%
Freightliner	0	0%	0	0%	0	0%	0.10%
GMC	1	2%	3	2%	4	2.33%	2.95%
Honda	1	2%	2	2%	3	1.74%	7.15%
Hyundai	0	0%	0	0%	0	0%	1.71%
International	0	0%	0	0%	0	0%	
Jaguar	1	2%	0	0%	1	0.58%	0.22%
Jeep	1	2%	10	8%	11	6.40%	2.67%
Keith-Huber	0	0%	1	1%	1	0.58%	
Kia	0	0%	2	2%	2	1.16%	1.03%
Lexus	0	0%	0	0%	0	0%	1.36%
Lincoln	3	7%	3	2%	6	3.49%	1.09%
Mazda	0	0%	1	1%	1	0.58%	1.71%
Mercedes Benz	0	0%	1	1%	1	0.58%	1.36%
Mercury	1	2%	7	5%	8	4.65%	1.89%
Mitsubishi	1	2%	2	2%	3	1.74%	1.08%
Nissan	0	0%	2	2%	2	1.16%	4.74%
Oldsmobile	1	2%	8	6%	9	5.23%	1.55%
Plymouth	0	0%	1	1%	1	0.58%	0.66%
Pontiac	3	7%	3	2%	6	3.49%	3.06%
Saab	0	0%	0	0%	0	0%	0.23%
Toyota	2	5%	8	6%	10	5.81%	10.41%
Volkswagen	1	2%	0	0%	1	0.58%	1.52%
Volvo	1	2%	3	2%	4	2.33%	0.81%

* Data from The R. L. Polk Company: 233,871,380 vehicles in operation as of April 1, 2010.

Next, analysts were able to code vehicle type for 440 of the media reports of crashes involving equipment malfunctions, based on the information provided in the news articles. Table 27 sorts the types of equipment malfunctions by analysis group and by vehicle type.

Table 27. Media-Reported Equipment Malfunction Crashes by Malfunction Type, Vehicle Type, and Analysis Group

Equipment Malfunction Type	Vehicle Type	Other-Corroborated		Self-Reported-Only		Total	
		Number	Percent	Number	Percent	Number	Percent
Stuck Accelerator	Commercial Bus	0	0%	2	1%	2	1%
	Dump Truck	1	1%	0	0%	1	0%
	Other Truck	0	0%	3	1%	3	1%
	Passenger Car	54	70%	123	60%	177	63%
	Pickup Truck	12	16%	27	13%	39	14%
	School Bus	0	0%	2	1%	2	1%
	SUV	7	9%	32	16%	39	14%
	Van	3	4%	15	7%	18	6%
	Total	77	100%	204	100%	281	100%
Sudden Acceleration	Passenger Car	1	100%	7	64%	8	67%
	Pickup Truck	0	0%	2	18%	2	17%
	SUV	0	0%	2	18%	2	17%
	Total	1	100%	11	100%	12	100%
Floor Mat Pressing Accelerator	Passenger Car	6	86%	1	50%	7	78%
	SUV	0	0%	1	50%	1	11%
	Van	1	14%	0	0%	1	11%
	Total	7	100%	2	100%	9	100%
Brakes Failed	Ambulance	0	0%	1	2%	1	1%
	Commercial Bus	0	0%	3	5%	3	2%
	Dump Truck	12	15%	6	10%	18	13%
	Other Bus	1	1%	0	0%	1	1%
	Other Truck	2	3%	1	2%	3	2%
	Passenger Car	32	40%	19	33%	51	37%
	Pickup Truck	8	10%	3	5%	11	8%
	School Bus	3	4%	7	12%	10	7%
	SUV	2	3%	5	9%	7	5%
	Tractor Trailer	15	19%	7	12%	22	16%
	Van	5	6%	6	10%	11	8%
	Total	80	100%	58	100%	138	100%

As shown in Table 27, brake failure was the predominant equipment malfunction type associated with heavy vehicles, with tractor trailers accounting for 16% of the brake-failure crashes, dump trucks 13%, school buses 7%, commercial buses 2%, ambulances 1% and other trucks and buses 3%. In contrast, these heavy vehicles were never involved in the crashes involving floor mats pressing on the accelerator or in sudden acceleration event crashes, and in only 3% of the stuck accelerator crashes. Passenger cars were the vehicle type most often involved in equipment malfunction crashes; but were more prevalent in stuck accelerator crashes (63%), sudden acceleration event crashes (67%), and floor mat on accelerator crashes (78%) than in brake failure crashes (37%).

Time of Day

Table 28 presents crash time of day by analysis group for 361 news-reported crashes involving vehicle malfunctions, where time of day was reported. The proportion of crashes by each period was consistent across the OC and SRO analysis groups. The majority of the crashes (71%) occurred between 9 a.m. and 6 p.m.; this was also the case for the media-reported pedal misapplication crashes, where 77% occurred between 9 a.m. and 6 p.m. However, nearly twice the percentage of equipment malfunction crashes occurred between 6 and 9 p.m. (12% versus 7%), and three times as many occurred between midnight and 6 a.m. (9% versus 3%), compared to the pedal misapplication crashes.

Table 28. Media-Reported Equipment Malfunction Crashes, by Time of Day and Analysis Group.

Crash Time	Other-Corroborated	Self-Reported-Only	Total
6 a.m. or earlier	5 (4%)	28 (12%)	33 (9%)
6 – 9 a.m.	13 (10%)	0	13 (4%)
9 a.m. – 12 p.m.	30 (23%)	57 (24%)	87 (24%)
12 – 3 p.m.	27 (21%)	50 (22%)	77 (21%)
3 – 6 p.m.	31 (24%)	62 (27%)	93 (26%)
6 – 9 p.m.	17 (13%)	25 (11%)	42 (12%)
9 p.m. – 12 a.m.	6 (5%)	10 (4%)	16 (4%)
Total	129	232	361

Crash Location

Table 29 presents the location of the equipment malfunction crashes by analysis group for all malfunction types, while Table 30 presents crash location for the subset of stuck accelerator malfunction crashes only. As shown in Table 29, slightly more than half (52%) of the malfunctions (all types) for the OC group occurred on the road (i.e., at non-intersection locations), while only 38% of such crashes happened on-road for the SRO group. Conversely, higher percentages of crashes occurred in parking lots and driveways for the SRO group than for the OC group.

Collapsing across analysis group and crash location, 40% of the pedal-related equipment malfunction crashes occurred in parking lots and driveways, while 60% occurred on-road (including intersections). This is a reversal of the findings for the media-reported pedal misapplication crashes, where 77% occurred in parking lots and driveways and only 23% occurred at roadway/intersection locations.

Table 29. Media-Reported Equipment Malfunction Crashes by Location and Analysis Group (All Malfunction Types)

Crash Location	Other-Corroborated	Self-Reported-Only	Total
Parking Lot	35 (21%)	89 (35%)	124 (30%)
Driveway	15 (9%)	28 (11%)	43 (10%)
On Road (Not at Intersection)	86 (52%)	97 (38%)	183 (44%)
Intersection	27 (16%)	40 (16%)	67 (16%)
Car Wash	1 (<1%)	0	1 (<1%)
Total	164 (100%)	254 (100%)	418 (100%)

Media-reported stuck accelerator crashes produced a different pattern. As shown in Table 30, 55% of these crashes occurred in parking lots and driveways compared to 45% that occurred on-road (including at intersections). This pattern, which was stable across both analysis groups, is quite similar to that observed in the earlier analyses of pedal misapplication crashes, including results from the North Carolina crash database.

Table 30. Media-Reported Equipment Malfunction Crashes by Location and Analysis Group (Stuck Accelerator Malfunctions Only)

Crash Location	Other-Corroborated	Self-Reported-Only	Total
Parking Lot	25 (33%)	79 (42%)	104 (40%)
Driveway	11 (15%)	27 (15%)	38 (15%)
On Road (Not at Intersection)	33 (44%)	62 (33%)	95 (36%)
Intersection	5 (7%)	18 (10%)	23 (9%)
Car Wash	1 (1%)	0	1 (<1%)
Total	75	186	261

DISCUSSION AND CONCLUSIONS

At the beginning of this project, the literature review uncovered two driving simulator studies describing the prevalence of crashes resulting from pedal misapplication, with mixed findings. In one study, drivers pressed the wrong pedal or both pedals simultaneously at a rate of 1 per 4.8 hours of data collection, or once per 468 foot movements (Rogers & Weirwille, 1988). There were only two instances during the 72 simulation hours where the driver pressed the accelerator instead of the brake, and both times, the driver recognized the error and corrected it. However, in another study using drivers 65 and older recruited from a driving evaluation clinic, one-third experienced unintended acceleration events, and 70% of these said they were unable to stop or slow the vehicle (Freund et al., 2008). These events were associated with a sudden change in the environment (e.g., an intrusion); with increasing age (drivers 84 and older were 6 times more likely to exhibit pedal application errors); and with impairments in executive function (impaired drivers showed error rates 10 times higher than drivers with normal executive functioning).

Next, findings from the news media analysis suggested that crashes resulting from pedal misapplications, where the driver mistakes the accelerator pedal for the brake, occur 7 to 15 times each month somewhere in the United States This may be an underestimation, as not all crashes are reported in the news, and not all news reports are entered or maintained in the archives. Similarly, the findings from both the NMVCCS analysis and the North Carolina State Crash Database indicated a low prevalence of pedal misapplication crashes—less than 1% of all crashes—but these sources, too, are less than ideal. Because police crash reports do not include codes to indicate that a crash resulted from a pedal misapplication, researchers cannot query a field in any State or National database for crashes resulting from pedal application errors other than the narrative field. The narrative includes information about pedal misapplications *only* if the driver admits the error *and* the investigating officer includes it in the crash description. However, while the prevalence estimates derived from this project are almost certainly biased toward underrepresentation, the pedal misapplication crashes that were identified and analyzed provided valuable information about the characteristics surrounding these events.

The DRSs participating in the expert panel reported observing, on average, 1.5 pedal misapplications per specialist, per year, in their client population during on-road evaluations. This low number may be the result of pre-screening clients in the clinic to eliminate those with lower limb sensory impairments from on-road testing. None of the pedal misapplications observed by DRSs resulted in a crash, and the majority were corrected by their clients.

The following discussion highlights areas of consistency—while also acknowledging significant disagreement—regarding the characteristics of pedal misapplication crashes as revealed by the literature review, media scan, and the NMVCCS and North Carolina crash database analyses. DRS comments are included wherever pertinent. This section addresses variables where there was strong corroboration of findings across data sources: the *distribution of sex of drivers* in pedal misapplication crashes; the role of *inattention/distraction* in such crashes; the role of *fatigue or impairment*; drivers' *familiarity with the vehicle*; driver *position in the vehicle* and its effect on *foot movement accuracy*; and *situational factors that startle* drivers and may lead to a crash. Two areas in which the present sources appeared to yield more disparate results—*crash location* and the *age distribution* of drivers in pedal misapplication crashes—are then highlighted.

This discussion ends with a focus on contrasts and similarities between the characteristics of crashes involving a pedal misapplication, versus crashes where some type of pedal-related vehicle equipment malfunction was implicated. Conclusions and priorities for continuing investigation follow.

Perhaps the closest agreement among sources was found for data describing the *distribution of sex of drivers* in pedal misapplication crashes. The North Carolina findings (male/female ratio = 37/63 percent) corroborate the proportions in the NMVCCS analysis (male/female ratio = 35/65 percent) and the media analysis (male/female ratio = 36/64 percent). It is apparent that females were overrepresented in pedal misapplication crashes, compared to their representation in *all* crashes.

Driver *inattention* was the most frequently coded driver contributing circumstance in the North Carolina data. This broad indicator of driver error was noted for 44% of the crashes and was relatively equally prevalent across the age groupings of < 21, 21-35, 36-55, 56-75, and 76+. The more specific behavior driver *distraction* was coded as a contributing factor by police in 4% of the North Carolina pedal misapplication crashes, but was revealed in 7% of the crash narratives. Drivers in the two older age groups (56-75 and 76+) were underrepresented in distraction-related crashes compared to their representation in the sample, while drivers in the two youngest age groups (<21 and 21-35) were overrepresented. The most frequently noted distractions were looking away from the road, reaching for an object, passengers, and cell phones. Driver distraction was reported in 39% of the NMVCCS pedal misapplication crashes, and in 12% of the news media articles that mentioned a driver contributing factor. The potential for driver distraction to contribute to pedal misapplications was further underscored by DRS observations that when these errors occurred during driving evaluations, it was commonly during the final 30 seconds, when clients relaxed their concentration on the driving task.

Driver *fatigue* factored in less than 1% of the North Carolina pedal misapplication crashes, 10% of the NMVCCS crashes, and 2% of the news media reported crashes. Impairment due to alcohol also appeared to be a minor factor; this was suspected in less than 1% of the North Carolina pedal misapplication crashes, 3% of the NMVCCS pedal misapplication crashes, and 8% of the news media reports of pedal misapplication crashes.

At the same time, *functional impairment* due to a medical condition or medication use was somewhat more likely to be implicated in pedal misapplication crashes. Approximately 7% of the North Carolina drivers involved in such crashes were so impaired. These included 35 drivers who were specifically described as having impairments in their lower limb functioning, either a loss of sensation, or reductions in strength or mobility; another 23 drivers were described as “handicapped” or parked in handicapped spaces. In the media analysis, 12 of the 75 drivers (16%) with medical conditions had leg, foot, or hip problems, including neuropathy and casts. DRSs concurred that peripheral neuropathy is likely to cause pedal applications errors; they noted that many of their clients were unaware that they had a loss of sensation in their feet. The DRSs also identified cognitive impairment as a likely cause of pedal application errors. In the news media analysis, 28% of the reports that included a driver factor described medical conditions or medications, and in the NMVCCS analysis of pedal misapplication crashes 48% mentioned medications, the majority of which were potentially driver impairing.

The literature review revealed that negative transfer from other vehicles was a factor that may affect foot aiming accuracy (Schmidt, 1989; Lee et al., 2005; Perel, 1983; Pollard & Sussman, 1989; Walter et al., 1988). Driver *unfamiliarity with the vehicle* may contribute to pedal application errors. However, driver unfamiliarity, gleaned through a review of the crash narratives, was associated with only 25 of the 2,411 pedal misapplication crashes in North Carolina (1%), 14 of the subset of 266 crashes in news media reports where a driver factor was mentioned, and none of the NMVCCS pedal misapplication crashes.

Drivers who were *out of position in the vehicle* characterized 3% of the North Carolina pedal misapplication crashes; crash narratives described drivers looking and reaching in the vehicle, resulting in inaccurate movements of the foot from gas to brake. Ten percent of the crash narratives in the NMVCCS analysis described drivers as “out of position,” as did 7% of the subset of news media reports where a driver factor was described. Other changes in head and body position away from front/center can also affect *foot movement accuracy*, as when a driver turns to check over the shoulder before backing out of a parking space. In the media analysis, 19 drivers had their heads or bodies directed away from the forward position when their pedal misapplication crashes occurred. This behavior may help explain the high proportion of pedal misapplication crashes in parking lots, as discussed in the following pages. Complementing these findings, many of the DRS panelists commented about out-of-position drivers. They indicated that small women were often out of position because their “fit” in vehicles with a large seat pan was poor.

Driver age and functional status may also explain variability in foot movement accuracy. In a driving simulator study, Cantin et al. (2004) found increased right foot movement variability in older drivers compared to younger drivers. Also, older drivers made several sub-movements of their right foot after they released the accelerator pedal in preparation for braking. This was rare among younger drivers. The DRSs’ observations of foot “wandering” in their cognitively impaired older clients reinforced these findings. But caution is appropriate as neither the literature review nor the DRS observations tie pedal application errors directly to these (right foot) sub-movements.

Pedal misapplication crashes have also been associated with *situations that startle* drivers. According to Schmidt (1989), when drivers are startled or they panic, they often respond by attempting to slam on the brake, especially if they perceive a sudden stimulus as being life threatening. Faster and more forceful foot movements result in less accuracy, which can lead to a pedal misapplication. In 19% of the North Carolina pedal misapplication crashes, drivers were described as startled or panicked. Drivers younger than 21 were over-represented in startle-related crashes in North Carolina while drivers older than 75 were underrepresented, with respect to their proportions in the sample. The media analysis described 20% of the drivers as startled or panicked. Almost three-fifths (58%) of the NMVCCS pedal misapplication crashes were associated with a startle or panic response, based on the information presented in the crash narratives.

The analyses of *crash location* showed somewhat more disparate results. Analysis of North Carolina pedal misapplication crashes indicated that 57% of the crashes occurred in parking lots and driveways, while roadways accounted for 42%. In the media analysis, 77% of the pedal misapplication crashes occurred in residential parking lots, driveways, and parking garages, compared to 23% occurring on-road. The NMVCCS analysis did not include crashes in parking lots.

As noted earlier, the new media may deem an older driver involved in this type of crash more "newsworthy;" this could lead to the under-reporting of crashes involving younger and middle-aged drivers and the over-reporting of older driver crashes. In both analyses, older drivers were more likely than other drivers to be performing a parking maneuver prior to making a pedal application error. This could explain why the North Carolina crash analysis, which included larger percentages of middle-aged drivers, found more crashes occurring on-road than did the media analysis. The DRSs as a group also indicated most pedal application errors they observed in their clients occurred in parking lots. DRSs noted that their clients manifested one or more impairments that could undermine their driving abilities, so it is to be expected that they would have the greatest difficulty—and experience the greatest number of incidents—in parking lots, where there is less room to recover/correct a pedal misapplication given the proximity of cars and other objects. The DRSs hypothesized that many more pedal misapplications may occur on-road than showed up in the analyses, because drivers corrected the error, so it didn't result in a crash.

The previous findings can be better understood through a more detailed examination of the *age distribution* of drivers involved in pedal misapplication crashes, an area of considerable disparity across data sources. One picture emerges from a consideration of broad age groupings of these drivers revealed in each analysis (see Figure 11). In addition to the apparent under-representation of younger drivers and over-representation of older drivers in the media analysis compared to the North Carolina database analysis, the NMVCCS analysis shows a prevalence of pedal misapplication crashes by drivers age 21-35 that greatly exceeds both other sources.

Another picture emerges when crash involvement is plotted against 5-year age groupings, however (see Figure 12). Even allowing for a media bias toward reporting crashes involving older drivers, a familiar U-shaped curve is now revealed in both the media analysis and the analysis of the North Carolina crash database. And with regard to the North Carolina database analysis, it is important to note that while drivers age 16 to 20 and 76 and older each were involved in 17% of pedal misapplication crashes, the former group was involved in 15% of *all* crashes but the latter group in only 3%. On a proportional basis, this confirms older driver overinvolvement in pedal misapplication crashes.

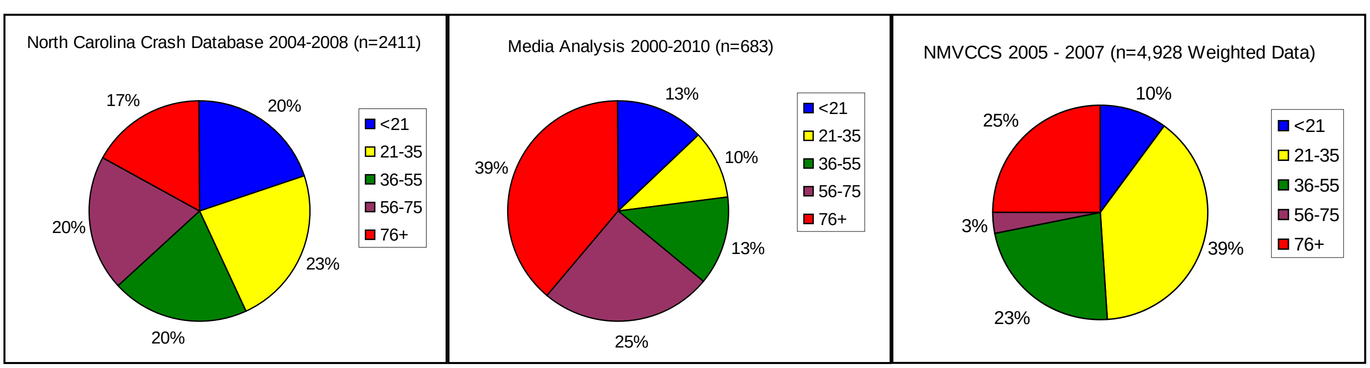

Figure 11. Comparison of Findings for Age, by Data Set

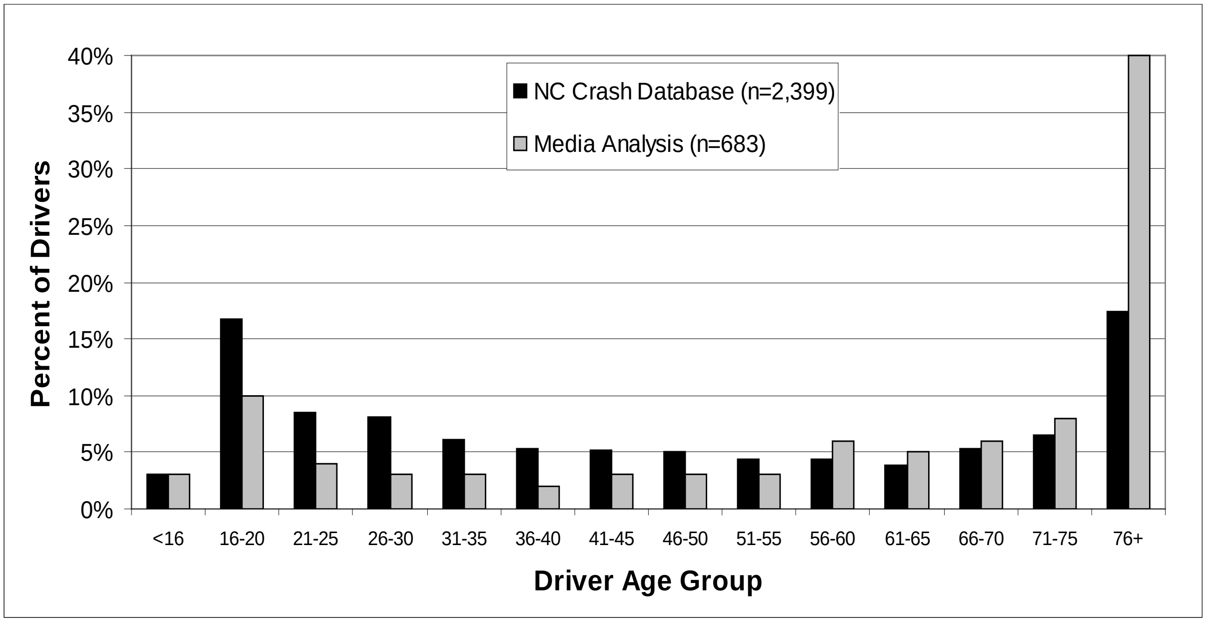

Figure 12. Comparison of North Carolina Crash Database and Media Analysis Findings for Prevalence of Pedal Misapplication Crash Involvement by 5-Year Age Group.

The U-shaped curve relating pedal misapplication crash involvement to driver age raises questions about possible underlying causes. The lack of experience among young/novice drivers certainly cannot be overlooked; this group is still learning simple vehicle control skills, and have not developed the muscle memory, nor the attentional, judgment, and decision making skills that are critical to smooth and safe vehicle operation. In the North Carolina database, 37% of drivers in pedal misapplication crashes had fewer than 4 years of driving experience. In the NMVCCS data, 19% of the drivers were coded as inexperienced, the majority of whom were driving on a permit.

But the factor that best explains overinvolvement in these crashes at both ends of the driver age distribution is poor executive function. The areas of the brain that support executive function are the last to develop, not reaching full maturity until early adulthood (Zelazo, Craik, & Booth, 2003). Corey-Bloom et al. (1996) found that the neuropsychological profiles of older (65 to 74 years old) and very old (85+) individuals could be distinguished almost exclusively by examining performance on executive tasks. Multiple studies have shown a relationship between poor performance on tests of executive function and increased crash risk. Specifically, Freund et al. (2008) found that drivers with deficits in executive functioning had increased pedal application error rates. The DRSs in the current study also reported pedal application errors among their clients who performed poorly in clinical tests of executive function (e.g., clock drawing, Trail-making), and this was not limited to older drivers. Another group they have observed making pedal misapplications includes young drivers with autism, attention-deficit disorder (ADD), and attention deficit hyperactivity disorder (ADHD).

This is a less than satisfactory explanation for the other, overarching finding in these analyses, however, i.e., that women drivers involved in pedal misapplication crashes outnumber men by a margin of roughly 2 to 1, while male drivers account for approximately 60% of *all* crashes. Historically, exposure among male drivers has also been higher, although it is possible that this relationship could reverse for localized settings such as parking lots. It may be possible that women are disproportionately affected by a combination of contributory factors identified herein—shorter stature resulting in poorer "fit" in their cars, and perhaps a greater susceptibility to startle responses—that, together, produce this discrepancy that was documented with such consistency across data sets. A difference in prevalence between sexes in impairing medical conditions or medication use also could merit investigation. All of these remain only unproven hypotheses at this point, begging further study.

The media analysis of pedal-related vehicle malfunction crashes screened to exclude behavioral causes (pedal application errors) and instead focus on crashes attributed to equipment malfunctions yielded several insights. The striking overrepresentation of females versus males disappeared in such crashes. Next, for a subset of events where media attention has been focused most intensively – stuck accelerator crashes – both the youngest and oldest driver age groups again appear to be at greatest risk. Alternatively, both groups may be the most newsworthy, so the media are more likely to report them. The data from the project indicate that the vehicle makes most overrepresented in equipment malfunction crashes from 2000-2010 in relation to their proportion of the U.S. fleet—all are domestic.

It could be argued that, with the exception of the rare incident trumpeted in news reports (e.g., the Santa Monica crash) the consequences of pedal misapplication crashes are usually not severe. In the North Carolina database analysis, only 18% of those involved in a crash involving a pedal application error were injured—but this figure is for all road users, and jumps to 93% for pedestrians involved in such crashes. Still, less than 1% of the North Carolina crash victims received disabling injuries, and only 1 of 4,736 was killed. It is tempting to attribute the low fatality rate to the large proportion of crashes that occurred at low speeds and in parking lots; nearly half of the North Carolina pedal misapplication crashes (48%) occurred on roadways with speed limits of 25 mph or less, and only 6% occurred on roadways with speed limits above 45 mph. These settings are not as benign as these summary statistics might suggest, however. Almost nine percent of the North Carolina pedal misapplication crashes resulting in serious (non-fatal) injuries occurred in parking lots, whereas only slightly over 1% of all non-fatal injurious crashes occurred in such locations. In the media analysis, which included larger percentages of parking lot crashes, 12% resulted in a fatality. In fact, the 108 fatal crashes included in the media analysis claimed the lives of 140 people, and 434 of the media-reported crashes (53%) resulted in more than a thousand injuries. An inescapable conclusion is that whenever pedal misapplication leads to the loss of control of a motor vehicle, and especially in settings where pedestrians are common, the potential for a tragic outcome is high.

Pedal application errors thus represent an aberrant driver behavior to which we attach safety concerns, at least in part, due to our aging population that remains overwhelmingly dependent on the private automobile for the activities of daily living. Research is needed to refine our understanding of the relative contributions of cognitive and functional impairments and of vehicle factors such as pedal characteristics and position within the vehicle on the incidence of pedal application errors. To the extent that variance in this behavior can be accounted for in terms of driver and vehicle factors, versus situational factors, countermeasure strategies will emerge that reinforce or expand upon the suggestions of the DRSs in this project. Some strategies merit immediate consideration: educational campaigns that target physicians, law enforcement, and DMVs about the potential for neuropathy to result in pedal application errors, and opportunities to identify, refer, and treat affected drivers. The public should be informed about the simple practice of shifting into neutral gear to counteract an unintended acceleration, regardless of the cause of the unintended acceleration (vehicle or driver). Finally, instituting a checklist for law enforcement to use for gathering information about drivers in pedal misapplication crashes can only lead to an improvement in traffic records that will in turn assist immeasurably in determining the causes of these incidents.

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APPENDIX A: MEETING AGENDA AND MODERATOR'S GUIDE FOR DRIVER REHABILITATION SPECIALIST PANEL

Driver Rehabilitation Specialist Panel Meeting Agenda

Day 1: Thursday, August 19, 2010

12:00 - 1:00 p.m.	Buffet lunch at hotel.
1:00 - 1:30 p.m.	Introduction of Project and Panelists.
1:30 - 2:00 p.m.	Summary of Findings from Literature Review and Analysis of Pedal Misapplication Crashes Reported in the Media 2000-2010.
2:00 - 3:30 p.m.	Panel Discussion
	Topic 1: Incidence of Pedal Misapplications
	Topic 2: Descriptions of Incidents of Clients' Pedal Misapplications
3:30-3:45 p.m.	Break and Afternoon Coffee/Tea Service
3:45 – 5:15 p.m.	Panel Discussion
	Topic 3: Driving Tasks During Which these Errors Seem Most Likely to Occur
	Topic 4: Characteristics of Drivers Most Likely to Make Pedal Application Errors
5:30 p.m.	Adjourn meeting for the day.

Day 2: Friday, August 20, 2010

8:00 -9:00 a.m.	Buffet breakfast at hotel
9:00 – 10:45	Panel Discussion
	Wrap Up Topics Not Completed on Day 1
	Topic 5: Behavioral Countermeasures That May Help Reduce the Incidence of Pedal Application Errors
10:45 – 11:00 a.m.	Break
11:00 – noon	Panel Discussion
	Topic 6: What Kind of Research Might Help Explain the Causes of Pedal Application Errors or Support the Development of Countermeasures That May Prevent or Reduce their Occurrence?
12:00 – 1:00 p.m.	Buffet Lunch at Hotel
1:00 – 3:00 p.m.	Panel Discussion
	Topic 7: Additional Insights Regarding Pedal Application Errors

3:00 Adjourn Meeting

Moderator's Guide For Driver Rehabilitation Specialist Panel

INTRODUCTION (30 MINUTES)

Hello. I am Loren Staplin and this is Kathy Lococo. We are working on a project for NHTSA to learn as much as we can about pedal misapplications—when drivers confuse the gas for the brake pedal. Sometimes this is called pedal application error or pedal confusion.

This is a problem identification study. The overall objective of this project is to find out how frequently crashes occur as the result of pedal misapplication; whether particular driver groups such as novices or older drivers are over-represented in such crashes; if certain conditions place drivers at higher risk of pedal misapplication; and the extent of property damage, injuries, and fatalities caused by these errors. Unfortunately, this project started just before Toyota drivers began having crashes, stating that their accelerator pedals were sticking. For the present NHTSA study, we are focusing only on the driver behavioral problem of mistakenly pressing the gas pedal instead of the brake pedal. We are not focusing on vehicle malfunctions.

You've all presumably looked at the Literature Review and analysis of crashes uncovered in the media over the past 10 years, which answer some of the questions about who has pedal error crashes and when they occur. Kathy will do a quick overview of the findings before we launch into discussions about your personal experiences.

We have asked you to participate in this meeting to learn more about pedal misapplications, as "on road veterans" in the field of driver assessment and rehabilitation, to get your first-hand accounts of your clients' pedal application errors. This is because news media accounts and police reports present only part of the story; there is often more missing data in these reports than what is provided. Also, not all crashes are reported, so the data that we have are likely to be underestimations of the magnitude of the problem. It's difficult to identify crashes caused by pedal misapplication because there is no code for this in crash databases. And when a pedal error crash is identified by searching through the police narrative section of a crash report, little if anything is reported about medical conditions, distractions, and task complexity in these crashes.

The kind of information we're hoping we can learn from this panel includes:

- Descriptions of incidents where your clients pressed the gas instead of the brake.
- Driving tasks during which these errors seem most likely to occur:
  - Entering or leaving parking spaces?
  - Backing up?
  - Distracted?
  - Turning?
  - On-road or in parking lots?
  - Crash avoidance maneuvers?
  - Panic responses following loss of vehicle control?
- Characteristics of drivers most likely to make such errors
  - Older drivers?
  - Drivers with specific medical conditions or functional deficits?
  - Footwear?
  - Using adaptive equipment?
- Whether anything can be done to prevent or reduce pedal misapplication errors.
- Further study methods to learn more about pedal misapplications.

- Additional insights regarding pedal application errors.

I'd like to start by asking each of you introduce yourselves, and briefly describe your work experience.

OVERVIEW OF FINDINGS FROM THE LITERATURE REVIEW AND ANALYSIS OF CRASHES REPORTED IN THE MEDIA (30 MINUTES)

Kathy will get us up to speed with what we've learned so far in this project, and then, we'll turn things over to you, the experts!

PANEL DISCUSSIONS (3 HOURS ON DAY 1 AND 5 HOURS ON DAY 2)

Topic 1: Incidence of Pedal Misapplications

- How many of you have been in a vehicle with a client who mistook the gas for the brake (or viewed a driver in a simulator who made a pedal application error)?

- For those who have, how many clients or incidents have you observed?

- Did any of these incidents lead to a crash?

Topic 2: Descriptions of Incidents of Clients' Pedal Misapplications

For those who have witnessed incidences of pedal misapplications, try to describe each in as much detail as possible, including driver, vehicle, and environmental characteristics.

Topic 3: Driving Tasks During Which these Errors Seem Most Likely to Occur

We've heard the individual stories, which included lots of detail, but now let's try to categorize this information.

- Where are pedal misapplications most likely to occur?
  (e.g., parking lots, on the road, at intersections, in the driver's driveway).

- What was the driver trying to do just prior to the error?
  (e.g., enter or leave a parking space in a parking lot, driveway, or on road; turning at an intersection; slowing down for vehicles ahead that were stopping at an intersection; slowing down for pedestrians crossing the road; recover from a loss of vehicle control; recover from hitting a curb or parking block in a parking lot; recover from a crash; avoid a crash)

- What else was happening inside the vehicle and outside the vehicle just prior to the errors? Try to remember the traffic situation, and pedestrians.

- Was the driver distracted by anything, either inside or outside of the vehicle?

- Did the driver realize he/she had hit the wrong pedal? Did they correct it or did you have to intervene? Did the driver panic and hit the gas again or continue to press on the gas?

- Were the drivers driving their own cars or a vehicle from the rehab or driver training program?

- Other insights into driving tasks associated with pedal misapplications

Topic 4: Characteristics of Drivers Most Likely to Make Pedal Application Errors

Again, we're trying to categorize, if possible, who is mistaking the gas pedal for the brake. Is it generally:

- Older drivers?
- Cognitively impaired drivers?
- Novice drivers?
- Drivers unfamiliar with the vehicle?
- Drivers with medical conditions or taking medications (diabetic neuropathy, broken foot)?
- Young drivers with ADD?
- Drivers learning to use adaptive equipment?
- Any driver/any age who is distracted?
- Drivers startled or trying to make a panic stop?
- Drivers wearing certain kinds of shoes (e.g., diabetes shoes)?
- Two-footed drivers?
- Drivers using cruise control?
- Other insights into driving tasks associated with pedal misapplications

Topic 5: Are There Any Types of Behavioral Countermeasures That May Help Reduce the Incidence of Pedal Application Errors?

Based on the characteristics surrounding pedal misapplication crashes, let's brainstorm about what countermeasures might help reduce or prevent pedal misapplication incidences, or help a driver realize that they've made a pedal application error so they can correct it before they get into a crash.

[Let panelists come up with and discuss their own ideas; if necessary, use the following examples as probes to generate discussion.]

- Education?
- In-Vehicle Warnings? (auditory, visual)
- Sensor on Accelerator and Brake Override?

Topic 6: What Kind of Research Might Help Explain the Causes of Pedal Application Errors or Support the Development of Countermeasures that May Prevent or Reduce their Occurrence?

- Laboratory/simulator studies?
- Instrumented vehicle studies?
- On-road, closed course studies?
- Who should the subjects be?
- What driving situations should be included?
- What environmental situations should be included?

Topic 7: Additional Insights Regarding Pedal Application Errors.

If there are areas that we haven't discussed over the past two days, please share additional thoughts with us.

APPENDIX B:

BODY OF LETTER SENT BY NORTH CAROLINA GOVERNOR'S HIGHWAY SAFETY PROGRAM TO SELECTED DRIVERS WHO HAD PEDAL MISAPPLICATION CRASHES IN 2008.

Dear ________________,

The North Carolina Governor's Highway Safety Program is helping the National Highway Traffic Safety Administration (NHTSA) on a project to learn more about motor vehicle crashes where a person's car seemed to accelerate when they meant it to stop. We have identified over 500 such crashes in North Carolina alone, during the year 2008.

We are asking you to volunteer 15 minutes of your time to participate in a telephone conversation with a researcher about a crash you had in 2008. You are under no obligation to participate in this interview, but we hope that you decide to help. There will be no effect on your license, whether you choose to participate or not.

The company conducting the research for NHTSA is called TransAnalytics. The researcher you talk to will **not** ask you for your name or your driver license number, so the information you provide will remain anonymous. The information discussed during the phone call will be summarized in a report to NHTSA along with information provided by about 100 other North Carolinians. No information from the discussions will be provided to the Department of Motor Vehicles.

Thank you for considering this request to help make our highways safer. The telephone conversations will happen during the month of November. If you have 15 minutes to contribute in November, please call TransAnalytics (toll free) at [redacted]. You will talk with Kathy Lococo. She is available to take your call Monday through Friday, from 10 a.m. to 4 p.m.

APPENDIX C:

DISCUSSION GUIDE FOR ONE-ON-ONE UNSTRUCTURED CONVERSATIONS IN CASE STUDIES ABOUT PEDAL APPLICATION ERRORS

(Revise the wording and order of questions across subjects)

"Thank you for calling. This research is dedicated to learning more about car crashes where the driver means to stop, but the car speeds up instead. Is this what happened to you in your accident a couple of years ago?"

Yes: ______ No: __________

Crash Circumstances

"Now please tell me what you remember about that crash."

(Write what they say, and probe, if possible for the following):

- Location (intersection, parking lot)
- Maneuver (parking, slowing, stopping, changing lanes, crash or obstacle avoidance)
- Use of cruise control
- Pedal Control (one foot, both feet)
- Kind of shoes
- Distractions (passengers, cell phones, eating, drinking smoking, dropped something, reaching, adjusting radio, something outside of vehicle)
- Feeling rushed
- Startled by anything
- Hit wrong pedal, foot slipped, or equipment malfunction

Medical Conditions and Medications

"Please tell me about any medical conditions you have and the kinds of prescription medications and over-the-counter remedies you take."

(List what they say, and probe, if possible for)

- Height
- Handicap placard for car
- Diabetes (and if yes, special shoes for this, and do you wear them when you drive?)
- Foot or leg pain
- Loss of feeling in your feet or legs
- Difficulty moving foot back and forth between gas and brake pedals
- Tingling in your feet or feeling different temperatures in the feet
- Use of medication called neurontin
- Need to look at feet when walking to keep from tripping
- Surgery on hips, knees, or ankles in the past 5 years
- Drive with a brace, cast, or prosthesis on legs
- Cerebral Palsy
- Multiple Sclerosis
- Stroke
- Parkinson's Disease
- Alzheimer's
- Attention Deficit Disorder

"Are any of these medical conditions or medications new? I mean, since the time of your accident?"

Driving Experience

"Tell me about your driving experience: how long you've had a license and how often you drive."

(Write what they say, and probe for miles per year, or trips per day, or number of driving days per week)

What kind of car you were driving when you had the crash?

(Write what they say, and try to get):

- Make
- Model
- Year
- Length of time owned prior to crash
- Automatic or manual transmission
- Adaptive equipment
- Easy to adjust seat position
- Easy to reach pedals
- Comfortable to drive

Closing Comments

"Is there anything else you can tell me about why this crash happened?"

If yes, write what they say:

Thank you again for your time. I've enjoyed hearing your story, and wish you well.

APPENDIX D:

SUPPLEMENTAL DATA FROM THE NORTH CAROLINA CRASH ANALYSIS, MEDIA ANALYSIS, AND NMVCCS ANALYSIS

Figure D-1. Frequency Distribution of Pedal Misapplication Crashes by Driver Age
(News Media Analysis, 2000-2010, n=683)

Figure D-2. Frequency Distribution of Pedal Misapplication Crashes by Driver Age
(North Carolina State Crash Database 2004 – 2008, n=2,399)

Table D-1. Crash Time of Day Associated With Pedal Misapplication Crashes, for North Carolina Crash Database, Media, and NMVCCS Samples

Hour of Crash	Percent of Crashes		
	NC Crash Database	Media	NMVCCS
12 a.m. - 5:59 a.m.	3%	3%	0%
6 a.m. - 8:59 a.m.	9%	10%	14%
9 a.m. - 11:59 a.m.	21%	32%	4%
12 p.m. - 2:59 p.m.	26%	26%	42%
3 p.m. - 5:59 p.m.	22%	19%	10%
6 p.m. - 8:59 p.m.	13%	7%	24%
9 p.m. - 11:59 p.m.	6%	3%	6%

Table D-2. Pre-Crash Maneuver by Driver Age Group (North Carolina Crash Database Sample)

Pre-Crash Maneuver	Driver Age Group										All	
	<21		21-35		36-55		56-75		76+			
	N	%	N	%	N	%	N	%	N	%	N	%
Stopped in travel lane	6	1%	8	1%	5	1%	7	1%	1	0%	27	1%
Parked out of travel lanes	1	0%	4	1%	7	1%	4	1%	2	0%	18	1%
Parked in travel lanes	1	0%	0	0%	1	0%	1	0%	0	0%	3	0%
Going straight ahead	184	39%	235	43%	212	44%	178	37%	118	28%	927	39%
Changing lanes or merging	0	0%	2	0%	4	1%	4	1%	2	0%	12	1%
Passing	1	0%	1	0%	0	0%	1	0%	0	0%	3	0%
Making right turn	34	7%	31	6%	20	4%	19	4%	15	4%	119	5%
Making left turn	38	8%	25	5%	20	4%	14	3%	14	3%	111	5%
Making u turn	1	0%	9	2%	2	0%	2	0%	1	0%	15	1%
Backing	53	11%	33	6%	53	11%	47	10%	68	16%	254	11%
Slowing or stopping	18	4%	39	7%	20	4%	26	5%	12	3%	115	5%
Starting in roadway	10	2%	14	3%	7	1%	13	3%	4	1%	48	2%
Parking	90	19%	115	21%	101	21%	146	30%	146	35%	598	25%
Leaving parked position	15	3%	12	2%	14	3%	13	3%	19	5%	73	3%
Avoiding object in road	5	1%	7	1%	1	0%	1	0%	1	0%	15	1%
Other	15	3%	10	2%	10	2%	8	2%	16	4%	59	2%
All	472	100%	545	100%	477	100%	484	100%	419	100%	2,397	100%

Table D-3. Frequency and Percentage* of Pedal Misapplication Pre-Crash Maneuvers by Age Group (Media Sample)

Pre-Crash Maneuver	Total	Driver Age Group				
		20 or Less	21-35	36-55	56-75	76+
Entering parking space	259	34 (47%)	30 (48%)	20 (31%)	74 (54%)	101 (51%)
Leaving parking space	64	8 (11%)	6 (10%)	8 (12%)	8 (6%)	34 (17%)
Turning	50	6 (8%)	4 (6%)	3 (5%)	16 (12%)	21 (11%)
Driving in lane	17	2 (3%)	2 (3%)	4 (6%)	2 (1%)	7 (4%)
Changing lanes	3	--	--	--	1 (1%)	2 (1%)
Stopped	1	--	--	--	1 (1%)	--
Slowing/stopping for traffic control device, vehicles, or pedestrians	30	3 (4%)	3 (5%)	4 (6%)	6 (4%)	14 (7%)
Startle braking following collision, loss of control of vehicle, or collision avoidance maneuver	111	20 (27%)	18 (29%)	26 (40%)	28 (21%)	19 (10%)
Total	535	73	63	65	136	198

* Percentages of drivers in each age category (column percents)

Table D-4. Frequency With Which Driver Actions Were Coded as a Contributing Factor (either 1st, 2nd, or 3rd), and Percentage of Crashes in Which Driver Actions Contributed to Pedal Misapplication Crashes (North Carolina Crash Database Sample)

Driver Contributing Circumstance	Frequency Driver Action Was Coded as a Contributing Circumstance (Either 1st, 2nd, or 3rd)	Percentage of Crashes* (n=2330)
Inattention	1016	43.6%
Failure to reduce speed	678	29.1%
Other	407	17.5%
Operated vehicle in erratic, reckless, careless, negligent, or aggressive manner	235	10.1%
Improper parking	209	9.0%
Improper backing	177	7.6%
Overcorrected/oversteered	109	4.7%
Driver distracted	102	4.4%
Failed to yield right of way	79	3.4%
Exceeded safe speed for conditions	65	2.8%
Improper turn	51	2.2%
Followed too closely	40	1.7%
Crossed centerline/going wrong way	27	1.2%
Swerved or avoided due to wind, slippery surface, vehicle, object, or non-motorist	26	1.1%
Disregarded stop sign	25	1.1%
Alcohol use	24	1.0%
Disregarded traffic signals	22	0.9%
Exceeded authorized speed limit	22	0.9%
Operated defective equipment	16	0.7%
Visibility obstructed	8	0.3%
Improper lane change	6	0.3%
Drug use	3	0.1%
Disregarded road markings	2	0.1%
Disregarded yield sign	2	0.1%
Other improper passing	2	0.1%
Use of improper lane	2	0.1%
Improper or no signal	1	0.0%
Passed stopped school bus	1	0.0%
Right turn on red	1	0.0%

* Percentages add up to more than 100, because up to three driver contributing factors could be coded per crash

Table D-5. Frequency (and Percentage) of Crashes Associated With Specific Driver Physical Conditions, by Driver Age Group (North Carolina Crash Analysis)

Physical Condition	Driver Age Group										All	
	<21		21-35		36-55		56-75		76+			
	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent
Apparently normal	454	96%	521	96%	435	91%	446	92%	379	90%	2235	93%
Illness	0	0%	1	0%	3	1%	1	0%	2	0%	7	0%
Fatigue	2	0%	3	1%	7	1%	0	0%	1	0%	13	1%
Fell asleep, fainted, loss of consciousness	1	0%	0	0%	2	0%	1	0%	1	0%	5	0%
Impairment due to medications, drugs, alcohol	4	1%	8	1%	8	2%	3	1%	1	0%	25	1%
Medical condition	1	0%	1	0%	8	2%	16	3%	2	0%	28	1%
Other physical impairment	0	0%	2	0%	3	1%	5	1%	13	3%	23	1%
Restriction not complied with	1	0%	0	0%	1	0%	0	0%	1	0%	3	0%
Other	2	0%	3	1%	2	0%	4	1%	6	1%	17	1%
Unknown	7	1%	6	1%	8	2%	8	2%	13	3%	43	2%
All	472	100%	545	100%	477	100%	484	100%	419	100%	2399	100%

Table D-6. Year of Vehicles Driven by Pedal Misapplication Crash-Involved Drivers in North Carolina (2004-2008)

Vehicle Year	Number	Percent
1966	2	<1%
1967	1	<1%
1971	2	<1%
1972	1	<1%
1975	1	<1%
1978	1	<1%
1979	1	<1%
1980	2	<1%
1981	4	<1%
1982	2	<1%
1983	3	<1%
1984	6	<1%
1985	10	<1%
1986	11	<1%
1987	18	1%
1988	30	1%
1989	42	2%
1990	62	3%
1991	61	3%
1992	75	3%
1993	94	4%
1994	103	4%
1995	128	5%
1996	139	6%
1997	163	7%
1998	144	6%
1999	169	7%
2000	168	7%
2001	158	7%
2002	167	7%
2003	181	8%
2004	140	6%
2005	129	5%
2006	82	3%
2007	61	3%
2008	26	1%
2009	2	0%
Total	2,389	100%

Table D-7. Driver Injury Status by Age Group (North Carolina Crash Analysis)

Injury Status	Driver Age Group										All	
	<21		21-35		36-55		56-75		76+			
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Fatal injury (K)	0	0%	0	0%	0	0%	0	0%	1	0%	1	0%
Disabling injury (A)	0	0%	1	0%	2	0%	0	0%	2	0%	5	0%
Evident injury (B)	19	4%	14	3%	17	4%	17	4%	30	7%	97	4%
Possible injury (C)	41	9%	50	9%	51	11%	63	13%	56	14%	261	11%
No injury (O)	407	87%	477	88%	397	85%	398	83%	324	78%	2,003	85%
Total	467	100%	542	100%	467	100%	478	100%	413	100%	2,367	100%

APPENDIX E:

MEDICAL CONDITIONS OR SYMPTOMS LISTED BY THE DRSS THAT CAN CAUSE (OR DESCRIBE) PROPRIOCEPTION OR SENSORY DEFICITS IN THE LEGS

- Peripheral neuropathy*
- Diabetes*
- Multiple sclerosis*
- Proprioceptive/kinesthetic deficits*
- Spinal cord injury*
- Spinal stenosis*
- Nerve disorders (pinched nerves/sciatica)*
- Hip/knee replacement
- Stroke
- Pain in the leg/paresthesia/reflex sympathetic dystrophy
- Vascular diseases
- Pins and needles sensation; numb
- Edema
- Lymphoma
- Cancer/chemotherapy
- Cerebral palsy
- Spina bifida
- Poor healing from cuts/sores
- Parkinson's
- Fatigue
- Foot drop
- Amputation/prosthesis/ankle/foot orthosis
- Muscular dystrophy
- Head injury
- Lower extremity injury (something that severs a nerve, e.g., a gunshot wound or other trauma to the leg that impacts sensation)
- Back pain
- Polio
- Gout
- Gullian-Barré
- Amyotrophic lateral sclerosis (ALS, "Lou Gehrig's disease")
- Arthritis
- Ataxia
- Extensor tone
- Too short/poor positioning in the vehicle seat
- Charcot-Marie-tooth disease (CMT)
- Lyme disease
- Restless legs syndrome
- Leg cramps
- Medications/contraindications
- Radioculopathy

* Received the most ratings by DRSs as being of greatest concern in contributing to loss of sensation in lower extremities.

APPENDIX F:
COGNITIVE IMPAIRMENTS THAT MAY EXPLAIN WHY DRIVERS DO NOT CORRECT A PEDAL APPLICATION ERROR, ONCE ONE IS MADE

- Alzheimer's and memory disorders*
- Parkinson's disease (and other movement disorders)*
- Anxiety*
- Asperger's*
- Cerebral palsy*
- Multiple sclerosis*
- Traumatic brain injury (TBI)*
- Stroke (CVA; right hemisphere/left hemiplegia)*
- Anoxia*
- Transient ischemic attacks (TIA)
- Autism
- Learning disability/ADD (attention-deficit disorder)
- Non-verbal learning disabilities
- Brain tumors and aneurysms
- Spina bifida
- (Over)-medication
- Failure to take medications on schedule
- Huntington's
- Executive function deficit (which is a symptom of many conditions, e.g., anoxia, TBI, dementia)
- Low IQ
- Post-polio
- Muscular dystrophy
- Sleep apnea
- Chronic obstructive pulmonary disease (COPD)
- Post cardiac surgery, cardiac disorders
- Seizure disorder

* Received the most ratings by DRSs as being of greatest concern in contributing to failure to correct a pedal application error.

APPENDIX G: Supporting Tables for Media Analysis of Equipment Malfunction Crashes (asterisks denote missing data for make, model, and/or year)

Table G-1. Make, Model and Year for Other-Corroborated Equipment Malfunction Crashes.

Make Model Year (other Corroborated Equipment Malfunction)	Vehicle Type
* * 1993	Pickup Truck
* * 1997	Pickup Truck
Buick Park Avenue 1991	Passenger Car
Buick * *	Passenger Car
Buick * 1964	Passenger Car
Buick Electra 1980	Passenger Car
Buick LaSabre 2005	Passenger Car
Buick Regal 1986	Passenger Car
Cadillac * *	Passenger Car
Cadillac * 1987	Passenger Car
Chevrolet * *	Passenger Car
Chevrolet * 1963	Pickup Truck
Chevrolet * 1982	Pickup Truck
Chevrolet * 1984	Van
Chevrolet * 1993	Passenger Car
Chevrolet Malibu *	Passenger Car
Chevrolet S-150 1995	Pickup Truck
Chevrolet * 1988	Passenger Car
Chevrolet * 1995	Pickup Truck
Chevrolet * 1997	Passenger Car
Chrysler Concorde 1997	Passenger Car
Dodge 3/4 Ton 1990	Pickup Truck
Dodge Caravan 1989	Van
Dodge Ram 1996	Pickup Truck
Fiat * 1967	Passenger Car
Ford * *	Pickup Truck
Ford * 1977	Dump Truck
Ford * 1990	Passenger Car
Ford * 1993	Passenger Car
Ford * 2006	Pickup Truck
Ford Crown Victoria *	Passenger Car
Ford Crown Victoria 1987	Passenger Car
Ford Crown Victoria 1999	Passenger Car
Ford Crown Victoria 2006	Passenger Car
Ford Econoline 1992	Van
Ford Explorer *	SUV
Ford Explorer 1994	SUV
Ford Escort 1998	Passenger Car
Ford Excursion *	SUV

Make Model Year (other Corroborated Equipment Malfunction)	Vehicle Type
Ford F150 *	Pickup Truck
Ford Focus ZX4 2005	Passenger Car
Ford LTD 1981	Passenger Car
Ford LTD 1983	Passenger Car
Ford Mustang *	Passenger Car
Ford Mustang 1997	Passenger Car
Ford Ranger *	Pickup Truck
Ford Taurus 1992	Passenger Car
Ford Taurus 1992	Passenger Car
Ford Taurus 1992	Passenger Car
Ford Windstar *	Van
GMC Envoy *	SUV
GMC * 1993	Dump Truck
GMC * 2002	SUV
Honda Accord *	Passenger Car
Honda Passport *	Passenger Car
Honda Accord 1994	Passenger Car
International 4700 1999	Dump Truck
Jaguar * *	Passenger Car
Jeep Grand Cherokee 2004	SUV
Kia Sephia *	Passenger Car
Lexus ES350 2007	Passenger Car
Lexus ES350 2009	Passenger Car
Lincoln Navigator *	SUV
Lincoln Town Car 1991	Passenger Car
Lincoln Town Car 2001	Passenger Car
Mazda * 1992	Passenger Car
Mercury * 1997	Passenger Car
Mercury Grand Marquis *	Passenger Car
Mitsubishi Eclipse 1994	Passenger Car
Nissan Maxima 1995	Passenger Car
Nissan Pulsar 1989	Passenger Car
Oldsmobile * 1986	Passenger Car
Oldsmobile Cutlass Supreme 1978	Passenger Car
Plymouth Voyager 1993	Van
Pontiac Bonneville *	Passenger Car
Pontiac Firebird 1994	Passenger Car
Pontiac Grand Am 1986	Passenger Car
Pontiac Grand Am 1991	Passenger Car
Pontiac Grand Prix 2004	Passenger Car
Toyota Camry 1997	Passenger Car
Toyota Corolla 1994	Passenger Car
Toyota Camry 2007	Passenger Car

Make Model Year (other Corroborated Equipment Malfunction)	Vehicle Type
Toyota Tacoma *	Pickup Truck
Volkswagen Passat 2002	Passenger Car
Volvo * *	Passenger Car
Volvo * 1997	Tractor Trailer
Volvo * 2001	Tractor Trailer

Table G-2. Make, Model and Year for Self-Reported-Only Equipment Malfunction Crashes.

Make Model Year (Self-Reported Equipment Malfunction)	Vehicle Type
Acura * *	Passenger Car
Acura MDX *	SUV
BMW * *	Passenger Car
BMW * *	SUV
BMW * *	Passenger Car
BMW * 1989	Passenger Car
BMW X3 2007	SUV
Bouse House * *	Other Truck
Buick * *	Passenger Car
Buick * 1991	Passenger Car
Buick * 1991	Passenger Car
Buick * 1996	Passenger Car
Buick Riviera 1989	Passenger Car
Cadillac * *	Passenger Car
Cadillac * *	Passenger Car
Cadillac * *	Passenger Car
Cadillac * 1988	Passenger Car
Chevrolet * 1979	Pickup Truck
Chevrolet * *	Passenger Car
Chevrolet * 1985	Pickup Truck
Chevrolet * 1996	Pickup Truck
Chevrolet * 2003	Pickup Truck
Chevrolet Blazer 2000	SUV
Chevrolet Caprice 1995	Passenger Car
Chevrolet Cobalt *	Passenger Car
Chevrolet Equinox *	SUV
Chevrolet S-10 *	Pickup Truck
Chevrolet Suburban *	SUV
Chevrolet Tahoe *	SUV
Chevrolet Z28 1980	Passenger Car
Chevrolet Blazer *	SUV
Chevrolet Blazer *	SUV
Chevrolet Celebrity 1988	Passenger Car

Chevrolet Impala *	Passenger Car
Chevrolet Lumina 1992	Passenger Car
Chevrolet Lumina 1994	Passenger Car
Chevrolet S10 *	Pickup Truck
Chevrolet Silverado *	Pickup Truck
Chevrolet Silverado 1999	Pickup Truck
Chrysler Sebring *	Passenger Car
Dodge * 1973	Pickup Truck
Dodge * 1993	Van
Dodge * 2000	Van
Dodge * 2001	Passenger Car
Dodge Durango 2003	SUV
Dodge Intrepid 1995	Passenger Car
Dodge Intrepid 1998	Passenger Car
Dodge Ram *	Pickup Truck
Dodge Ram 1500 *	Pickup Truck
Dodge Ram 1995	Pickup Truck
Dodge Ram Charger *	Pickup Truck
Dodge Stratus 1999	Passenger Car
Ford Aerostar *	Van
Ford Bronco *	SUV
Ford Escape 2005	SUV
Ford Escort *	Passenger Car
Ford Escort 2002	Passenger Car
Ford Explorer *	SUV
Ford Explorer *	SUV
Ford Explorer 1998	SUV
Ford F-150 *	Pickup Truck
Ford F-250 1995	Pickup Truck
Ford F350 *	Pickup Truck
Ford Focus 2000	Passenger Car
Ford Mustang 1966	Passenger Car
Ford Taurus 1995	Passenger Car
Ford * *	Passenger Car
Ford * 1991	Passenger Car
Ford * 1994	Van
Ford Aerostar *	Van
Ford Bronco *	Pickup Truck
Ford Contour *	Passenger Car
Ford Crown Victoria 1989	Passenger Car
Ford Crown Victoria 1989	Passenger Car
Ford Crown Victoria 1999	Passenger Car
Ford Econoline *	Van
Ford Escape 2006	SUV
Ford Expedition 1997	SUV
Ford F-150 *	Pickup Truck

Ford Mustang *	Passenger Car
Ford Mustang 1965	Passenger Car
Ford Taurus *	Passenger Car
Ford Windstar *	Van
Ford Windstar *	Van
Ford Windstar 1998	Van
Freightliner * *	School Bus
GMC * *	Pickup Truck
GMC * 1999	Passenger Car
GMC Sierra 2000	Pickup Truck
GMC Yukon 2006	SUV
Honda * 1995	Passenger Car
Honda Accord *	Passenger Car
Honda Accord *	Passenger Car
Honda Accord 1988	Passenger Car
Honda Passport 1997	Pickup Truck
Hyundai * 2002	Passenger Car
Jeep Cherokee *	SUV
Jeep * *	SUV
Jeep * 1988	SUV
Jeep Cherokee *	SUV
Jeep Cherokee *	SUV
Jeep Cherokee Laredo 1996	SUV
Jeep CJ7 1984	SUV
Jeep Grand Cherokee *	SUV
Jeep Grand Cherokee 2003	SUV
Jeep Liberty 2002	SUV
Kia * 2004	Van
Kia Sephia 1996	Passenger Car
Lincoln Navigator *	SUV
Lincoln Town Car 2001	Passenger Car
Lincoln * 1988	Passenger Car
Lincoln Town Car *	Passenger Car
Mazda * 1999	Pickup Truck
Mazda Protégé *	Passenger Car
Mazda Tribute *	Passenger Car
Mercedes-Benz * *	Passenger Car
Mercedes-Benz * *	SUV
Mercedes-Benz * *	Passenger Car
Mercury Sable 2004	Passenger Car
Mercury * *	Passenger Car
Mercury * 1993	Van
Mercury Cougar 1984	Passenger Car
Mercury Grand Marquis 2002	Passenger Car
Mercury Marquis 1992	Passenger Car
Mercury Tracer 1991	Passenger Car

Mitsubishi Montero 1999	SUV
Mitsubishi Montero 2002	SUV
Nissan * *	Passenger Car
Nissan * 1986	Passenger Car
Oldsmobile * 1984	Passenger Car
Oldsmobile * 1985	Passenger Car
Oldsmobile * 1999	Passenger Car
Oldsmobile 88 1998	Passenger Car
Oldsmobile Cutlass 1983	Passenger Car
Oldsmobile Cutlass 1993	Passenger Car
Oldsmobile Cutlass 1995	Passenger Car
Oldsmobile Cutlass Ciera 1992	Passenger Car
Oldsmobile Regency 1987	Passenger Car
Plymouth * 1971	Passenger Car
Pontiac Bonneville 1994	Passenger Car
Pontiac Grand Am *	Passenger Car
Pontiac Grand Am 1999	Passenger Car
Pontiac Grand Prix *	Passenger Car
Pontiac Grand Prix 1977	Passenger Car
Pontiac Sunbird 1993	Passenger Car
Saab * 2002	Passenger Car
Toyota * 1983	Pickup Truck
Toyota Camry *	Passenger Car
Toyota Camry 2000	Passenger Car
Toyota Tacoma *	Pickup Truck
Toyota * *	Pickup Truck
Toyota * 2006	Passenger Car
Toyota Camry *	Passenger Car
Toyota Corolla *	Passenger Car
Toyota Corolla 1996	Passenger Car
Toyota Prius 2003	Passenger Car
Volvo * 1983	Passenger Car
Volvo 740 GL *	Passenger Car
Volvo 740 Turbo 1987	Passenger Car

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