AAAM 64th Annual Scientific Conference

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Full Paper Abstracts

Tuesday, October 13th, 2020

3:30 PM - 4:40 PM: Non-Standard Seating and Simulations

Tuesday, October 13th, 2020, 3:30 PM - 3:45 PM EST

Submarining Sensitivity Across Varied Seat Configurations in Autonomous Driving System Environment

Author: Katarzyna Rawska, University of Virginia, Center for Applied Biomechanics

Co-Authors: Bronislaw Gepner, University of Virginia, David Moreau, University of Virginia, Center for Applied Biomechanics, Jason Kerrigan, University of Virginia, Center for Applied Biomechanics

Proposed Title: Submarining Sensitivity Across Varied Seat Configurations in Autonomous Driving System Environment.

Research question / objective: Self-driving technology will bring novelty in vehicle interior design and allow for wide variety of occupant seating choices. Thus, vehicle safety systems may be challenged to protect occupants over a wider range of potential postures. For reclined occupants, the risk of pelvis submarining under the lap-belt substantially increases with the increase of the seatback angle. This study aims to investigate the effects of seat cushion angle on submarining risk and injury prediction metrics for reclined occupants in frontal crashes.

Methods: Vehicle environment frontal crash Finite Element (FE) simulations were performed with the two simplified Global Human Body Model Consortium (GHBMC) occupant models: small female and midsize male. Occupant restraints consisted of a frontal airbag, a seatback-integrated 3-point belt with a lap belt anchor pre-tensioner, and a retractor pre-tensioner and force limiter. For each simulation, parameters including seat cushion angle (3, 8, 13 deg), seatback recline angle (0, 10, 20, 30 deg), and knee bolster position relative to the occupant (baseline and no knee bolster) were varied. A full-factorial simulation matrix was performed using the USNCAP 56 km/h frontal crash pulse (without vehicle deformation). Occupant kinematics data was extracted from each simulation to investigate how changes in seat cushion angle, anthropometry, seatback angle, and knee bolster position would affect submarining across all forty-eight simulated cases. Data Sources: Forty-eight full-vehicle FE frontal crash simulations with GHBMC occupant models.
Results: Overall, the 5th female model was more likely to submarine when compared to the male occupant model. The threshold for submarining was also affected by the seat cushion angle and recline angle. Additionally, increasing the occupant-to-knee bolster distance resulted in more submarining cases. The lowest threshold of 10 deg seatback recline angle with 8 deg seat cushion angle was identified for small female, and 10 deg with 13deg seat cushion angle for mid-size male occupant. The lap belt position and pelvis orientation were good predictors of submarining. The results further show an increased lumbar flexion load with increased seat recline angle, seat cushion angle as well as occupant-to-knee bolster distance.
Significance of Results: Submarining may be a major challenge to overcome for reclined occupants in autonomous driving systems (ADS). This study shows that seat cushion angle plays a role in restraining occupants in recline scenarios but it is not sufficient to prevent submarining without additional countermeasures.

Tuesday, October 13th, 2020, 3:45 PM - 4:00 PM EST

Prevalence of Non-Nominal Seat Positions and Postures Among Front-Seat Passengers

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Co-Authors: Sheila Ebert, University of Michigan - Ann Arbor; Monica Jones, University Of Michigan - Ann Arbor; Jason Hallman PhD, Toyota Technical Center USA

Objective: Recent studies have suggested that crash injury risk can be elevated if the occupant is in a posture different from the postures used with anthropomorphic test devices (ATDs) in crash testing. The prospect of driverless road vehicles has also increased interest in passenger postures. The objective of this study was to address a dearth of data concerning front-seat passenger postures through a naturalistic study.
Methods: Video cameras were installed in the passenger cabins of 57 passenger cars and SUVs. The video data, along with vehicle acceleration and location data, were downloaded after the vehicles were operated as usual by their owners for two weeks. A novel method was used to track seat position and seat back angle in the video.
Data Sources: Passenger postures were manually coded using a custom video coding tool for 237 unique front-seat passengers in 2347 trips. A total of 9450 frames were coded. Seat position relative to full rear and seat back angle in degrees from vertical were calculated for each coded frame. On average, one frame was sampled for each five minutes of passenger travel.
Results: The median trip duration was 12 minutes and the overall distribution of trip durations was similar to national statistics. The passenger was female in about 70% of observations. The head was rotated left or right in 35% of frames, and the torso was rotated left or right about 15% of the time and pitched forward in almost 10% of frames. The thighs were lifted off the front edge of the seat due to the feet being shifted rearward about 40% of the time. One leg was crossed over the other about 8% of the time.
The front passenger seat was rearward of the mid-track position typically used in ATD testing more than 90% of the time and was full-rear on the track about 25% of the time. The mean seat back angle was 25 degrees. The seatback angle was greater than 30 degrees about 10% of time but greater than 35 degrees in fewer than 0.1% of frames.
Significance of results: The data indicate that front-seat passenger postures differ from the nominal postures used in ATD testing a substantial proportion of the time. The seat is most often positioned toward the rear of the track, but highly reclined postures are rare. These results provide guidance for prioritizing the assessment of safety system performance for non-nominal postures.

Tuesday, October 13th, 2020, 4:10 PM - 4:25 PM EST

Evaluation of Users' Experience and Posture in a Rotated Swivel Seat Configuration

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Co-Authors: Ronja Örtlund, Volvo Cars; Gustav Kumlin Groth, Volvo Cars; Pernilla Nurbo, Volvo Cars
Lotta Jakobsson, Volvo Cars

Research Question / Objective: In fully autonomous vehicles, the driver is no longer needed to be engaged in driving and thereby becomes a passenger. This opens up the possibility for more flexible vehicle interior configurations. There is a need to understand how seat configuration can address users' preference and comfort, and still choose a safe sitting posture. This study aims to evaluate the users' experience in a rotated seat in terms of interaction with the other front seat occupant and overall perceived comfort.
Methods: A static user study was conducted, using a stationary Ford Transit with two front seats facing rearwards (figure 1). The seats were mounted on a swivel plate which allowed inboard rotation positions of 10° and 20°. An Ipad was mounted in front of the seats. The test lasted for 40 minutes, and in total 26 participants took part in pairs knowing each other with either a stature of short, or tall. Three seating configurations were evaluated with a questionnaire; 0° and 10° and 20° inboard rotated position of both seats. The test pairs spent 5 min in each configuration talking to each other and 5 min watching a film.
Data Sources: A user study with 26 participants' experience was evaluated through structured interviews and comfort scales. A front view camera collected pictures every 2 seconds during the whole session, capturing sitting postures.
Results: 100% of the short participants and 85% of the tall participants preferred to sit in any rotated seating configuration when watching the film. The rotated position was perceived as very comfortable, due to lower tension in back and neck. 92% of the short participants and 65% of the tall participants preferred any rotated configuration when conversing with each other. Generally, the short participants preferred 20° rotation, while the tall participants preferred 10° rotation due to interference between their legs and/or feet. Leg interference was common for tall participants in 20° rotation (figure 2), and it was perceived as very uncomfortable. Various strategies were used to avoid leg/feet contact, including stretching the legs to keep them away from contact or rotating the legs outboards. The rotated positions were perceived to improve the contact during

conversation, since it facilitated eye contact requiring less rotation of head and upper body. Still, the occupant would easily have an overview of the road.

Significance of results: This study shows that rotated seating configuration is a desired seating configuration in fully autonomous vehicles for individuals who know each other. Furthermore, it reveals the reasons behind the preferences and the extent of desired seat rotation. By understanding how occupant position and posture can be influenced by offering various seat configurations, the occupant can be nudged into a comfortable position that is also safe. These results can be used when further develop restraint systems for fully autonomous vehicles.

Tuesday, October 13th, 2020, 4:25 PM - 4:40 PM EST

Understanding Factors Related to Users' Preferences in the Selection of Vehicle Seating Configurations and Positions in Fully Automated Vehicles

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Research question/Objective: To understand the anthropometric and driving factors that determine user preferences in the selection of vehicle seating configurations and positions across different travelling scenarios involving a fully automated vehicle (FAV).

Methods: Participants completed an online survey in which they were asked to imagine traveling in a FAV across seven hypothetical travelling scenarios. In addition to demographic questions, participants were asked about their anthropometric characteristics, and also about their previous driving experience. Specifically, participants were asked to select between five different seating configurations and four positions within the FAV for each travelling scenario (see Figure 1). The study describes the sample, as well as the multinomial regression analyses that were conducted to understand the significance of potential influential variables in the preferences. All analyses were performed controlling for participants age and gender. This study was approved by the relevant Ethics committees from participating institutions.

Data Sources: Online survey. Participants were recruited through social media platforms up to October 2019. Results 730 participants (387 women, 339 men) completed the online survey. Participants resided in Australia (34.5%), Spain (12.6%), Sweden (13.8%), Lebanon (30.1%), Colombia (3.0%) and several other countries (5.9%). The height and weight distributions of the participants are shown in Figure 2. Three independent height and weight groups were created (low, medium, high) for the multinomial analyses.

Results: below correspond only to the scenario of riding alone in the car, but all scenarios will be included in the full publication. Configuration 3 was the preferred seating configuration for almost 74% of the participants, followed by Configuration 2 (13%). When weight was included in the models, participants height was not significant (p-value equal to 0.05) in their preferences for seating configuration. The medium weight group (60 kg- 89 kg) was less inclined to choose Configuration 1 over Configuration 3 (p-value less than 0.05), as was the tallest group (p less than 0.10). Within Configuration 5, the medium weight group preferred position Cover position A (p-value less than 0.05), but preferred position A over positions B and D (p-value less than 0.05). Despite more than 50% of the participants reporting experiencing motion sickness at some point when travelling in a vehicle, this experience did not significantly influence their preferred seating configuration (Configuration 3), nor the chosen seating position within their preferred configuration (i.e., tended (p-value less than 0.10) to choose position C over position A in Configuration 3).

Significance of results: This study follows up previous work which describes data that has shown differences in participants preferences for seating configurations and positions depending on age, sex and country. In addition, while increasing the sample size, the current study analyses other factors, such as anthropometry, motion sickness susceptibility or exposure to traffic that might be associated to choosing one seating configuration and position over others. As these factors are directly related to the likelihood of sustaining injuries in the event of a motor vehicle crash, the information included here provides important insights regarding the potential risk factors for occupants in FAV.

Wednesday, October 14th, 2020, 11:30 AM - 11:45 PM EST

Booster Cushion Design Effects on Child Occupant Kinematics and Loading Assessed Using the PIPER 6-year-old HBM and the Q10 ATD in Frontal Impacts

Author: Katarina Bohman PhD, Volvo Cars
Co-Authors: Jonas Östh PhD, Volvo Cars; Lotta Jakobsson PhD, Volvo Cars; Maria Wimmerstedt, Volvo Cars; Helena Wallin, Volvo Cars; Isabelle Stockman PhD, Volvo Cars
Research Question / Objective: Boosters are used to adapt the children's height to the vehicle restraint systems. In addition to the essential of providing a boost in height, other design characteristics may also influence crash performance. The aim was to compare different booster cushion designs and their effect on dummy kinematics and loading with the Q10 ATD and the PIPER 6y in frontal impacts.
Methods: Three different booster cushion designs (booster A, B and C) were evaluated in the 50km/h EuroNCAP MPDB impact configuration, using a static angle of 14° in linear sled test and 6 DOF kinematics in simulations. The Q10/PIPER 6y was positioned on the right rear seat in two different passenger cars, and the crash pulse resulted in an inboard motion. Boosters A had the lowest guides, while Booster C had the highest. Booster B had the lowest sitting height and deformed during the crash. Shoulder belt routing above or under the guides was evaluated, as well as the influence of tethered booster attachments versus only seat belt attachments.
Data sources: Three sled tests with Q10. 12 simulations with the PIPER 6y.
Results: Shoulder belt routing above or under the guide influenced initial shoulder belt position on shoulder and wrapping around lower torso. The overall kinematics of the Q10 showed a delayed lap belt interaction when restrained on booster B. This resulted in larger pelvis displacement with limited torso pitch and higher neck tension (1.8kN), compared to booster A (1.4kN), which had an early pelvis engagement resulting in an earlier torso pitch and therefore lower neck tension. For booster C, the shoulder belt slipped off the shoulder, resulting in increased torso motion and lower neck tension (1.1kN). No head impact occurred. In the simulations with the PIPER 6y, booster A and booster B showed similar initial belt-fit but a different dynamic behaviour, similar findings as in the sled tests. The simulations confirmed the delayed pelvis interaction, resulting in a forward motion of the pelvis and torso with a consequence of a delayed torso pitch and increased neck tension. The option to allow to the shoulder belt to be placed above the guide, provides a more stable shoulder belt position, especially for taller children. This mitigates the risk of shoulder belt slip off. Furthermore, it is essential the design of the guides is considered, to maintain a good wrapping around the lower torso.

Significance of results: Boosters with similar initial static belt fit can result in different dynamic performance during crash, due to the design of the boosters. Across two different child sizes, using an ATD and a HBM, in two different vehicle types, consistent sensitivity to the different booster designs were seen. The findings provide guidance for design of the cushion part of the booster. The results in this study are essential for the understanding of booster to vehicle interaction for real world safety applications. Note: Parts of the study were presented at the conference Protection of Children in Cars, in Munich, December 2019.

Wednesday, October 14th, 2020, 11:30 AM - 1:25 PM:
Vulnerable Population

Wednesday, October 14th, 2020, 11:45 AM - 12:00 PM EST
Should Airbags Be Deactivated for Wheelchair-Seated Drivers?
Author: Jingwen Hu, University of Michigan Transportation Research Institute
Co-Authors: Nichole Orton, University of Michigan Transportation Research Institute; Miriam Manary, University of Michigan Transportation Research Institute; Kyle Boyle, University of Michigan Transportation Research Institute; Lawrence Schneider, University of Michigan Transportation Research Institute

Objective: Field data analyses have shown significant benefit from driver airbag for occupant protection in frontal crashes. However, current federal motor vehicle safety standards allow deactivation of airbags in personal vehicles modified for use by wheelchair users. Consequently, vehicle modifiers almost always permanently deactivate airbags for wheelchair-seated drivers. The objective of this study was conduct sled tests and computational simulations to answer whether driver airbags should be deactivated for drivers seated in wheelchairs.
Methods: Five sled tests were conducted under a 48-kph 20-g frontal crash pulse all with driver airbag. Parameters varied in those tests included seat-belt fit (good, poor, and unbelted), airbag deployment time (proper and late), and occupant size (midsize male and small female HIII ATDs). The sled test results were used to validate a set of MADYMO models simulating wheelchair-seated occupant impact responses in various frontal crash conditions. A parametric study with a total of 28 MADYMO simulations were then conducted to investigate the airbag

effects on occupant injury risks with varied occupant size, belt fit, and impact angle (0, 15, and 30 deg).

Data Source: The 2006 Chrysler Town-and-Country minivan was selected as the nominal vehicle environment, and a surrogate wheelchair with a docking tie-down system was used for all sled tests. Volunteer data were used to position the midsize male and small female ATDs relative to the steering wheel. ATD injury measures for the head, neck, chest, and lower extremities were recorded in each test, and were used for MADYMO model validation. The same injury measures were also collected in each parametric simulation to evaluate the effect of airbag deployment on occupant protection.

Results: The sled tests showed potential safety concerns for wheelchair-seated drivers with a poor belt fit or without a belt. Specifically, the unbelted midsize male ATD sustained high femur forces and the small female ATD with poor belt fit sustained high chest deflections. The parametric simulations showed that airbag generally improved the protection for wheelchair-seated drivers. It is especially useful for unbelted wheelchair-seated drivers, and is also helpful for reducing the head and neck injury risks regardless of the belt condition, occupant size, and impact angle.

Significance of Results: This is the first study using sled tests and computational simulations to investigate the effects of airbag deployment on injury risks of wheelchair-seated drivers. Overall, the results showed little basis for concern that the energy of deploying a driver airbag in today's vehicles will cause serious-to-fatal injuries to drivers seated in wheelchairs. The results of this study therefore support the idea that driver airbags generally offer tangible safety benefits for a wide range of drivers seated in wheelchairs, just as they do for drivers in vehicle seats.

Wednesday, October 14th, 2020, 12:30 PM - 12:45 PM

Health Status and Quality of Life Among Road Users with Permanent Medical Impairment Several Years After the Crash

Author: Helena Stigson, Folksam

Co-Author: Anders Kullgren, Folksam

Research Question / Objective: Improvements in road infrastructure and vehicle safety have been achieved in many countries during the last decades. As the number of fatalities have

dropped, the consequences of non-fatal injuries have been brought into focus. Therefore, the objective was to investigate self-reported health status several years after the crash for road-users that sustained injuries resulting in permanent medical impairment.

Methods: Self-administered questionnaires using instruments to measure different dimensions of health e.g. depression, physical function, pain interference, sleep and ability to participate in activities. The response rate was 29%, a total of 2078 responses were received from the 7174 road-users with permanent medical impairment that received the questionnaire.

Data Sources: The injured road-users were identified from insurance policy holders of the Folksam Insurance Group. While the injury data were obtained from hospital records, each road-user answered a questionnaire regarding health status and quality of life to obtain additional information regarding how the health had been affected by the crash.

Results: In total 85% were still suffering from the injuries several years after the crash (8-18 year after the crash, in average 13 years). Road-users with head injuries as well as injuries to the nerves were affected to a higher extent. Furthermore, road-users with injures to the spine were having highest pain interference. A dislocation was in general causing more problem than a fracture to the extremities. Older road users reported that they in general were feeling worse than younger road-users. Although, younger had the greatest change in physical activity when comparing before and after the crash. Before the crash 64% were physical active. The corresponding figure was 34% after the crash. The higher permeant medical impairment the higher affected health several years after the crash.

Significance of results: In 2008, the Swedish Transport Administration changed the definition of serious injuries to be injuries leading to permanent medical impairment. This definition is based on insurance data to classify if an injured road-user still had residual symptoms three years after a crash. This study shows how that the classification correlate with self-reported physical activity and quality of life. To understand the long-term consequences of road traffic injuries, it is important to gain knowledge of different aspects of health loss.

Wednesday, October 14th, 2020, 12:45 PM - 1:00 PM EST

Pediatric Occupant Human Body Model Kinematic and Kinetic Response Variation to Changes in Seating Posture in Simulated Frontal Impacts - With and Without Automatic Emergency Braking

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Co-Authors: Shreyas Sarfare MS, Children's Hospital of Philadelphia; Clayton Falciani, Children's Hospital of Philadelphia; Aditya Belwadi, The Children's Hospital of Philadelphia

Research Question/Objective: Prior studies have shown that pediatric occupants assume a variety of positions inside vehicles. Current vehicle crash tests do not typically consider changes in posture and alterations in seat belt placement and geometry while evaluating kinematics. From naturalistic studies, it has been shown that children sit out-of-position 70% of the time. Therefore, the study examines the effect of various naturalistic seating positions of children in booster seats exposed to frontal impacts in a full-vehicle environment, with and without the application of pre-crash automatic emergency braking.
Methods: The PIPER 6YO and 10YO pediatric human body models were positioned in booster child restraining seats (CRSs). The 6YO was restrained on a lowback (LBB) and highback (HBB) booster, while the 10YO was positioned on a LBB and in a no-CRS condition. The child models were pre-positioned (gravity settled, seatbelt tensioned) in four naturalistic seating postures: leaning-forward, leaning-inward, leaning-outward, and a pre-submarining position, along with a baseline reference seating position as per FMVSS 213 standards. A 2012 Toyota Camry finite element (FE) model was used as the vehicle environment. A standard 3-point lap-shoulder belt system was modeled to restrain the child and CRS in the left-rear vehicle seat. Two vehicle impact cases were considered: with and without a pre-crash AEB. For with-AEB cases, a pre-crash phase was run to extract postural changes due to the application of AEB. All seating positions were ultimately subjected to a full-frontal barrier impact at 35MPH.
Data Sources: 40 conditions were simulated in LS-DYNA v971(LSTC, CA). Kinematics and kinetics were extracted and compared as per SAEJ211 metrics.
Results: From the set of simulations, it was observed that even though the initial head position pre-crash was different for with-AEB vs. without-AEB cases, the difference in the head positions decreases during the crash phase as the child undergoes excursion. The difference in head positions is less pronounced for the 10YO than for the 6YO child model. These kinematics can be attributed to the head-neck complex model. There is a greater extension in the spine observed in the cases without-AEB as compared to with-AEB. This further leads to believe that the hypothesis that application of AEB leads to greater excursion might not hold true. Further,

shoulder belt slippage was observed for the 6YO leaning-inward on HBB, consistent with other pediatric studies. There are a few limitations to the study. The study only considers frontal impacts. Other principal directions of force and the usage of airbags need to be explored. Further, the tested postures were the most-commonly observed positions in the real-world. Extreme out-of-position postures could lead to differing kinematics. Moreover, the simulation environment needs to be validated with physical test data.
Significance of Results: The data can aid in the future development of restraint geometry, CRS booster designs, vehicle injury mitigation technologies, and anthropomorphic test devices (ATDs).

Wednesday, October 14th, 2020, 1:00 PM - 1:15 PM EST
Vehicle Safety Characteristics in Vulnerable Driver Populations
Author: Kristina Metzger PhD MPH, Children's Hospital of Philadelphia
Co-Authors: Robert Foss PhD, University of North Carolina School of Public Health; Nina Joyce PhD, Brown University School of Public Health; Allison Curry PhD MPH, Children's Hospital of Philadelphia; Emma Sartin PhD, Children's Hospital of Philadelphia

Research Question / Objective: Ensuring vulnerable driver groups, including teen and older drivers, are in the safest vehicles they can afford is an approach recommended by traffic safety organizations like the IIHS to reduce crash injuries. Survey research and analyses of fatal crashes suggest that teen and older drivers drive the least safe vehicles—those that are older, smaller, and lack widely available safety features. However, the field lacks a broader picture of characteristics of the vehicle fleet, and specifically how vehicle characteristics vary for drivers across the age spectrum. We aimed to obtain population-level estimates of vehicle characteristics—including model year, type, weight, engine size, and the presence of safety features—driven by drivers of various ages.
Methods: In prior work we described an expanded application of quasi-induced exposure (QIE) methods; specifically, we borrowed QIE's fundamental assumption—non-responsible drivers involved in "clean" (i.e., one driver at fault) multi-vehicle crashes are reasonably representative of drivers on the road—to estimate drivers' behaviors and their vehicles' characteristics. We utilized this method to estimate the proportion of all vehicles on the road in New Jersey with

specific characteristics as the number of non-responsible drivers in clean multi-vehicle crashes with a vehicle with the characteristic of interest divided by the total number of non-responsible drivers in clean multi-vehicle crashes.

Data Sources: We analyzed data from the New Jersey Safety and Health Outcomes (NJ-SHO) warehouse, a unique linked data source that includes the full history of licensing and police-reported crashes for every NJ driver from 2010-2017. For each crash-involved driver, data included vehicle year, make, model, and Vehicle Information Number (VIN), as well as drivers' age at crash. We used the NHTSA Product Information Catalog and Vehicle Listing (vPIC) platform to decode the VIN of each crash-involved vehicle. We obtained more detailed information from vPIC about the vehicle, including model year, vehicle type, weight, engine size, and presence of safety features.

Results: We identified 995,824 non-responsible drivers in clean multi-vehicle crashes with VIN data available from vPIC (7.3% aged 17-20 years; 28.3% aged 21-34; 54.2% aged 35-64; and 10.3% aged =65). Table 1 shows the distribution of select vehicle characteristics of younger (17-20) and older (=65) drivers compared to middle-aged (35-64) drivers. Younger and older drivers drove vehicles that were older, had less horsepower, and were lighter-weight. These vulnerable driver populations were also more likely to drive passenger cars. Passenger cars of younger and older drivers were as likely as those of middle-aged drivers to have front air bags, but less likely to have side air bags.

Significance of Results: The vehicle fleet of the youngest and oldest drivers included vehicles that may be less safe than those of middle-aged drivers. By better describing vehicle characteristics, we can explore interventions related to environmental changes in vehicle safety among these vulnerable driver populations. This approach is a promising alternative approach to behavior change strategies —which has proven to be relatively ineffective in changing behavior—in reducing injuries of crash-involved drivers.

Thursday, October 15th, 2020, 2:00 PM - 3:25 PM:
Pre-/Post-Crash Research

Thursday, October 15th, 2020, 2:00 PM - 2:15 PM EST
Factors Associated with EMS Transport Decisions for Pediatric Patients after Motor Vehicle Collisions
Author: Thomas Hartka MD, MS, University of Virginia
Co- Author: Federico Vaca MPH, Department of Emergency Medicine and the Yale Developmental Neurocognitive Driving Simulation Research Center
Objective: Prehospital non-transport events occur when emergency medicine service (EMS) providers respond to a scene but the patient is ultimately not transported to a hospital for evaluation. These non-transport events may increase both the medical risk for the patient and the medicolegal risk for EMS. The objective of this study was to determine the factors associated with non-transport of pediatric patients who were involved in a motor vehicle collision (MVC).
Methods: We searched the NEMSIS database using ICD-10 injury codes to identify cases in which EMS responded to a pediatric occupant (age < 18 years) who had been involved in an MVC. We excluded interfacility transports, scene assists, patients who died at the scene, and collisions that occurred outside the US. The outcome of interest was whether or not patients were transported by EMS to a hospital for evaluation. We performed univariate and multivariate analysis to identify risk factors that were associated with non-transport. We also examined the reasons recorded for not transporting patients.
Data Sources: Data were obtained from the National Emergency Medical Services Information System (NEMSIS) from the year 2017. The NEMSIS database is supported by the National Highway Traffic Safety Agency (NHTSA) and collects records at the level of individual EMS responses. Data for each response includes agency information, times of key events, patient demographics, interventions, and disposition.
Results: We identified 23,745 pediatric patients who were evaluated by EMS after an MVC, of which 7,825 (33.0%) were not transported to a hospital for evaluation. In our adjusted analysis, the factors associated with non-transport were response by an ALS provider(s), normal mental status, region of the country, and time of day; sex and age did not significantly change the odds

of non-transport, except patients 1 to 2 years old were slightly more likely to be transported. In cases of non-transport, 2,445 (31.2%) were due to a patient or caregiver refusal and 2,494 (31.9%) were due to patients being released against medical advice. Only 824 (3.5%) of all patients were released based on an established protocol.

Significance of Results: In approximately one-third of cases, pediatric patients were not transported after EMS responded to an MVC. There was considerable variation in transport decisions based on geographic region, provider level, and time of day. The effects of this variation are unknown, but prior work has shown that non-transports do carry some risk for patients and EMS providers. Standardized protocols may be able to decrease this variation. Additionally, most non-transports occurred because patients were release against medical advice or the patient or care-giver refused transport. Only a small number of patients were medically cleared based on an established protocol. Given relatively low injury rates reported in the medical literature, further research is warranted to identify pediatric patients at low risk of injury in order to develop expanded protocols for who can be safely released from the scene of a crash.

Thursday, October 15th, 2020, 2:15 PM - 2:30 PM EST

Adaptive Restraint Systems Considering Occupant Diversity and Pre-Crash Posture

Author: Kyle Boyle, University of Michigan Transportation Research Institute

Co- Authors: Abeselom Fanta, University of Michigan Transportation Research Institute; Matthew Reed, University of Michigan Transportation Research Institute; Kurt Fischer, ZF; Alex Schroeder, ZF; Angelo Adler, ZF; Jingwen Hu, University of Michigan Transportation Research Institute

Research Question / Objective: To use volunteer data and parametric finite element (FE) human body models to investigate how restraint systems can be designed to adapt to a diverse population and pre-crash posture changes induced by active safety measures.

Methods: Four FE human models were generated by morphing the midsize male GHBMC simplified model into geometries representing a midsize male, midsize female, short obese female (BMI 40 kg/m²), and large obese male (BMI 40 kg/m²). Each human model was positioned in a generic vehicle driver environment using two occupant pre-crash postures based on volunteer test results in abrupt braking events. Optimal restraint designs

were developed individually for the short obese female, midsize male, and large obese male in a 56 km/hr delta-V front crash condition by adding a knee airbag, adjusting the shoulder belt load limit, steering column force, and driver airbag properties (tether length, inflation, and vent size). The optimal designs were then run with each human model and posture combination. Injury risks for the head, neck, chest, and lower extremities were analyzed.

Data Sources: Using age, sex, stature, and BMI, statistical models predicted the bone shape and cortical thickness of ribcage, pelvis, femur, and tibia, as well as the external body shape. These geometry models were developed based on ~500 CT scans and ~200 whole-body surface laser scans. Radial basis function (RBF) techniques were used to morph the baseline model (GHBMC-M50-OS v1.8.4) into the target geometries. The pre-crash postures of these models were based on volunteer tests conducted to quantify the head and torso motions of minimally-aware subjects exposed to an abrupt 1-g braking event. The driver environment model primarily utilized a generic vehicle model developed by Chalmers University which included vehicle interior, driver airbag, and driver seat. Belt restraints including retractor, pre-tensioner, and dynamic locking tongue as well as a knee airbag were provided by ZF.

Results: Human size and shape effects dominated the design optimization results, while the pre-crash-braking induced posture had minimal effects. Some of the safety concerns observed for large occupants include head strike-through the airbag and a conflict between head and chest injuries, which were mitigated by a stiffer restraint system with properly-tuned driver airbag. Low tolerance of chest injuries appeared as a safety concern for female occupants, mitigated by a softer seatbelt and smaller airbag size near the chest. Obese occupants exhibited a higher likelihood of lower extremity injuries indicating a need for a knee airbag. No single restraint solution served well for all occupants at the same time, which indicates restraint adaptability is necessary for accounting for occupant diversity.

Significance of Results: This study investigated the effects of occupant size and shape variability, posture, and restraint design on injury risk for high-speed frontal crashes. The results indicated several interesting injury concerns and helped identify the cause and possible countermeasures that can be used in situations not as well studied as midsized occupants with normal seating postures. Further investigation is needed to confirm and extend the findings of this study.

Thursday, October 15th, 2020, 2:50 PM - 3:05 PM

The Role of Perceived Pedestrian Safety on Designing Safer Built Environments

Author: Carlos Aceves-Gonzalez, Universidad de Guadalajara

Co- Authors: Karthikeyan Ekambaram, Coventry University; John Rey-Galindo, Universidad de Guadalajara; Libertad Rizo-Corona, Universidad de Guadalajara

Research Question / Objective: The objective of this study is to examine the relationship between the characteristics of built environments and perceived risk to improve pedestrian safety in an urban area in Mexico.

Methods: A total of six intersections and ten sidewalk sections were evaluated. This study was divided into two stages. In the first stage, a physical audit of a road section was performed to assess characteristics that may increase the perceived danger/risk of a collision. An observational framework was developed to evaluate road features such as intersections, pedestrian crossings, road markings, sidewalks, traffic lights, illumination, and presence of any obstacles to walking safely, among others. In the second stage, a questionnaire was applied to a group of 299 pedestrians aged between 16 to 77 years. It was aimed to collect road users perception regarding safety risks.

Results: Results from the physical audit found that the presence of several features of the built environment may increase the risk of a pedestrian involving in a collision. Some of the identified problems include the following: there were zebra crossings on all the intersections however the paint markings were worn out due to lack of maintenance, there were several obstacles, including potholes and cracks on the pedestrians' crossings and sidewalks. Also, there was a lack of appropriate signs for other road users while approaching the pedestrian crossings. Meanwhile, approximately 75% of participants, who responded to the questionnaire, raised a concern regarding safety conditions when crossing the intersections or using the sidewalks in the area. Pedestrians identified the following elements as detrimental for the safe use of roads: lack of traffic lights, too much traffic, lack of signs, and parked cars that obstruct visibility. Interestingly, participants also raised issues beyond the physical infrastructure, for instance, lack of respect shown to drivers to pedestrians. Additionally, participants identified the need for some actions for safety improvement. They suggested more than fifteen ideas but the following are the

top five recommendations: 1) Pedestrianisation of the road and widening the sidewalks, 2) (48) to ban parking of cars in the street, 3) removing any obstacles on the walkway at crossing points, 4) installing pedestrian traffic lights, and 5) adding more signs and information.
Significance of results : The study identifies a series of elements of the urban space that might be considered to create a safe environment for pedestrians which is useful for planners, decision-makers, and road users. This is an important finding because pedestrians are the most vulnerable group of road users, and they require specific attention to improve accessibility and their overall safety.

Thursday, October 15th, 2020, 3:05 PM - 3:25 PM

Frequency and Nature of Sightline Obstructions in Left Turn Across Path / Opposite Direction Intersection Crashes

Author: Max Bareiss, Virginia Tech, Graduate Research Engineer
Co- Authors: Ryan Anderson, Virginia Tech; Hampton C. Gabler, Virginia Tech

Research Question / Objective: Previous analyses of intersection active safety systems in the Left Turn Across Path / Opposite Direction (LTAP/OD) crash configuration have shown how strongly sensor sightline obstructions can degrade the performance of these systems. A depiction of these sightline obstructions is given in Figure 1. National retrospective crash databases provide very little information about the presence of temporary obstructions such as moving vehicles, so little is known about the proportion of cases which have sightline obstructions. One promising alternative to retrospective crash databases are naturalistic driving studies (NDS). The objective of this study was to estimate the frequency and characteristics of LTAP/OD crashes and near-crashes which have sightline obstructions using a large-scale NDS.
Methods: LTAP/OD crash and near-crash cases were identified from the Second Strategic Highway Research Program (SHRP 2) dataset. Each case was manually inspected to note the presence of obstructing vehicles at the moment the left turning vehicle began turning. Sightline obstructions were characterized based on intersection and event details such as the presence of turning lanes and traffic control devices, whether the subject vehicle was traveling though or turning, and the vehicle types involved.

Data Sources: The basis for this study was 248 crash and near-crash LTAP/OD events selected from the SHRP 2 study. SHRP 2 was a naturalistic driving study which collected 80 million kilometers of driving from approximately 2,500 participants over a 2.5 year period.
Results: The worst case sightline ratio was defined to be the proportion of cases in a population which had sightline obstructions when the turning vehicle began turning and represented the "worst case" for a vehicle safety system which relies on line of sight. The worst case sightline ratio was computed based on which vehicle was the ego vehicle in the SHRP 2 study and whether a traffic control device was present. In the case where the ego vehicle was the vehicle traveling through the intersection, the worst case sightline ratio was 17% when a traffic light was present and 19% when no traffic control device was present. When the ego vehicle was the turning vehicle, the worst case sightline ratio was 16% in the case where a traffic light was present but 36% in the case where no traffic control device was present.
Significance of Results: These results inform the debate on future sensor modalities for intersection active safety systems in LTAP/OD crashes. Intersection active safety systems have been shown to have reduced effectiveness when sightline obstructions are present. In cases with reduced sightlines, non-line-of-sight sensors, such as vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) technologies, may have higher effectiveness. For cases in this study with a clear line of sight (64-84% of cases), vehicle mounted sensors and V2V/V2I sensors would have similar effectiveness. The non-line-of-sight system would potentially perform better in cases with sightline obstructions (16-36% of cases).

Thursday, October 15th, 2020, 4:00 PM - 5:45 PM:
Biomechanics

Thursday, October 15th, 2020, 4:00 PM - 4:15 PM
Thoracolumbar Spine Kinematics and Injuries in Frontal Impacts with Reclined Occupants
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Objective: Highly automated vehicles may permit alternative seating postures, which could alter occupant kinematics and challenge current restraint designs. One predicted posture is a reclined seated position. While the spine of upright occupants is subjected to flexion during frontal crashes, the orientation of reclined occupants tends to subject the spine to high compressive loads followed by high flexion loads. This study aims to investigate kinematics and mechanisms of loading in the thoracolumbar spine for a reclined seated posture through the use of post-mortem human subjects (PMHS).

Methods: Frontal impact sled tests (50 kph delta-v) were conducted on five adult midsize male PMHS seated with the torso reclined to 50 degrees with respect to the vertical. The PMHS were seated on a semi-rigid seat and restrained by a seat-integrated three-point belt with dual lap-belt pretensioners and a shoulder-belt pretensioner with a 3 kN load-limiter. 3-D kinematic trajectories of five chosen vertebrae, and the pelvis were measured relative to the vehicle buck. Intervertebral pressure transducers were installed at three locations in the lumbar column to detect load timing.

Results: Three PMHS suffered fractures at L1. Combined compression and flexion of the thoracolumbar spine occurred in all tests, but the magnitude of peak flexion varied across the PMHS. During the PMHS' forward excursion, the pelvis rotated anteriorly in two tests and posteriorly in two tests (lap-belt submarining occurred in one). In one test, the pelvis mount interacted with the seat, but did not affect kinematics.

Conclusions: Anterior rotation of the pelvis caused increased extension of the lumbar spine, which exacerbated lumbar compression in two of the PMHS; the one subject whose pelvis kinematic tracking was lost exhibited similar compression kinematics. Posterior rotation of the

pelvis enabled lumbar flexion, which decreased lumbar compression, but lead to lap-belt submarining in one case. Lumbar kinematics for these reclined frontal impacts were sensitive to changes in initial posture of the spine (magnitude of lordosis or kyphosis) and pelvis (pitch angle). To our knowledge, this study is the first to analyze thoracolumbar kinematics and resulting injuries of a reclined seating posture using PMHS.

Thursday, October 15th, 2020, 4:15 PM - 4:30 PM

Simulation-Based Assessment of Injury Risk for an Average Male Motorsport Driver

Author: William Decker, Wake Forest University Center for Injury Biomechanics
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Research Question / Objective: While well protected through a variety of safety countermeasures, motorsports drivers can be exposed to a large variety of crash modes and severities. Computational human body models (HBMs) are currently used to assess occupant safety for the general driving public in production vehicles. A simulation-based approach that incorporates these HBMs in a motorsport environment can provide quantitative data on relative risk for on-track motorsport crashes.

Methods: NASCAR motorsport safety regulations require national series drivers to wear a helmet and use a 7 or 9-point safety belt system with a head and neck restraint device. Unlike a traditional automotive seat, the NASCAR driver environment is driver-customized and form-fitting. Therefore, integrating an HBM into a motorsport environment requires a multi-step process to appropriately represent the driver. A series of representative impacts, developed from real-world crash data, of varying severity (delta-V of 10 - 100 kph) and impact direction (PDOF variability of ~160 degrees) were conducted with the Global Human Body Models Consortium (GHBMC) 50th percentile male simplified occupant (M50-OS). This resulted in 45 total simulations. Kinematic and kinetic data from the human body models were output from each of the simulations and used to calculate injury risk through a variety of criteria, which include abbreviated injury scale (AIS), tibia index, head injury criterion (HIC), and brain injury criteria (BrIC). All simulations were conducted in LS-Dyna R. 9.1.

Data Sources: On-track chassis acceleration crash data was used to model simulated crash pulses.
Results: A multi-step process was developed to integrate the M50-OS into a representative motorsport environment which includes a donned helmet, 7-point safety belt system, HANS device, custom-molded seat, steering wheel, and leg enclosure (Figure 1). Injury risk of the occupant using the previously mentioned injury criteria was calculated for the head, thorax, and lower extremity. Various injury metrics were calculated for a single exemplar 105 kph delta-V impact. These include HIC (236), Bric (0.39), chest compression (32 mm), upper tibia force (1.17 kN), femur force (3.8 kN) and tibia index (as high as 1.2). The greatest associated risk based on these preliminary results for AIS 2+ injury was the chest compression at nearly 40%. The paper will expand upon these results by providing risk estimate variation associated with changes in delta-V and PDOF**.**
Significance of results: This study provides HBM-generated data to determine if particular motorsports crash modes or severities exhibit increased injury risk. Given the custom design of professional motor-sports cockpits and the number of trials presented, it would be difficult to replicate the data generated here via experimental testing**.**

Thursday, October 15th, 2020, 5:00 PM - 5:15 PM EST

Injury patterns within clusters of seriously injured occupants comparing real-world crashes in the US and in the EU

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Objective: The aim of this study is the identification of injury patterns at MAIS3plus level to several body regions and the associated crash characteristics that still occur in the field despite current regulations and consumer test programmes. MAIS3plus injuries are those that need to be analysed to further improve or adapt restraint systems and generate new requirements for vehicle safety.

Method and data: NASS-CDS data from 2000 to 2015 was used. MAIS3plus injured front row occupants older than 14 years, belted, and in passenger cars with model year from 2000 onwards were considered. Body regions were grouped in head-face-neck, thorax, abdomen and pelvis-lower extremities. Using machine learning algorithms, an automated cluster analysis was performed with the data set. Clustering variables included the injury severity to the four body regions, occupant age, vehicle weight, vehicle model year and delta v. Each resulting cluster was examined and logistic regression was carried out to determine the odds of sustaining a particular combination of injuries depending on the collision characteristics within the clusters.
Results: The sample included 1,633 MAIS3plus injured occupants. The clustering algorithm identified five clusters of MAIS3plus injured occupants describing 85 % of the sample variability. Each cluster was named after the parameter that better defines the data in each cluster as follows: elderly cluster, side impact cluster, high delta v cluster, frontal impact cluster and SUV/Pick-up cluster. As an example of the results, the SUV/Pick-up cluster is described here. This cluster contains 359 MAIS3plus injured SUV/Pick-up occupants of all ages who had a collision with delta v below 70 km/h. The injury patterns of the occupants included in this cluster are shown in Figure 1. Each column of the chart represents one body region and each block within the columns represents the injury severity level of each region. MAIS3plus injuries to the thoracic region and to the hip-lower extremities region were the most prevalent in this cluster. The colored curves represent the proportion of occupants of the cluster sustaining an injury of a specific MAIS level per body region and the concurrent injuries in the remaining body regions. Figure 1 shows that 17% of the occupants sustained a MAIS3plus head injury without significant injuries to the other body regions (blue). This injury pattern was mainly caused by oblique lateral nearside impacts with other SUVs/Pick-ups. 14% of the occupants suffered a MAIS3plus injury to the hip-lower extremities region without further injuries in the other body regions (yellow). Lower-extremity injuries were associated with full frontal and oblique center collisions. A further 14% of occupants in this cluster sustained MAIS3plus injuries to the thorax, abdomen and extremities (orange). Full frontal and moderate overlap frontal collisions were the predominant impact configurations. MAIS3plus injuries to the HFN region and to the thorax were sustained by 12% of the occupants in moderate overlap and oblique corner frontal collisions (red).

Significance of results: Detailed analysis of the resulting clusters of MAIS3plus injured occupants show opportunities for further improvement of vehicle safety and could lead to new requirements.

Thursday, October 15th, 2020, 5:15 PM - 5:30 PM EST

Comparison of Injuries in Multiple and Single Event Crashes

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Co- Authors: Timothy McMurry, University of Virginia Department of Public Health Sciences; Sang-Hyun Lee, University of Virginia Center for Applied Biomechanics; Seok-Ho Hong, Hyundai Motor Company; Jason Kerrigan, University of Virginia Center for Applied Biomechanics

Research Question / Objective: Multiple impact crashes result in a quarter to half of all tow-away crashes, MAIS3+ injuries, and driver fatalities. One potential cause of more severe injuries is the occupant becoming out-of-position after an initial minor impact. The objective of this study was to compare injuries for occupants in multiple event (ME) crashes where a minor event preceded a more severe event to occupants in similar single event (SE) crashes. We used field data analyses and finite element (FE) simulations.

Methods: We matched ME crashes where the most severe event occurred subsequent to a less severe event to SE crashes where the SE was similar to the most severe event in the ME crash. Belted front-seat occupants in NASS-CDS years 2000-2015, ages 15+, in vehicles <10 years old, involved in non-rollover ME and SE crashes, were matched based on delta-v, direction of force, general area of damage, horizontal location, survey weight, age, sex, height, weight, and seat position. AIS codes were categorized into 27 groups by body region. Conditional logistic regression was used to compare overall injury risk (MAIS 2+, 3+) and to identify injury groups at increased risk of AIS 2+ injury. A false discovery rate <10% was used to identify significant differences while controlling for multiple comparisons. Four FE simulations were run using two human body models (GHBMC simplified and detailed). The first two simulations reproduced a common multidirectional ME crash scenario, where the second event was the more severe event. The second two simulated SEs with the same crash pulse as the second event of the ME

simulations. Several kinematic and kinetic parameters were considered. Relative injury risks of ME versus SE were computed and compared to those from the field data analysis.
Data Sources: We used NASS-CDS years 2000-2015 for field data analyses and LS-Dyna for FE simulations.
Results: 2,673 ME occupants were identified in cases with complete data on matching covariates. These occupants were matched to 5,226 SE occupants. ME occupants had higher MAIS2+ and MAIS3+ injury risk (ORs: 1.45 and 1.38). Six out of the 27 injury groups had higher injury risk in ME (FDR<0.1; all p-values<0.0027). Increased injury risk was seen in the head (3/6 groups, ORs: 1.55-2.23), as well as soft tissue thorax, lumbar spine, and shoulder (ORs: 1.60-2.21). Occupant kinematics of ME versus SE followed largely different trajectories. Head injury (HIC, BrIC), neck injury (Nij), and thorax injury (strain-based rib fractures) were increased in ME simulations by 1.5- to 3-fold. The detailed and simplified GHBMC models exhibited different kinematics and injury risk across all simulations.
Significance of Results: The field data suggests that a first less severe event appears to make occupants more prone to upper body injuries; this could be because the initial impact puts the occupant out-of-position for the second impact. The simulations coincide with the field data describing substantial risk of head and thorax injuries. Several factors could cause this increase in injury risk, such as improper interaction with restraint systems and airbags.

Thursday, October 15th, 2020, 5:30 PM - 5:45 PM EST
Evaluation of Low Speed Limits in Residential Areas in Melbourne, Australia
Author: Brian Fildes PhD, Monash University, Professor
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Evaluation of Low Speed Limits in Residential Areas in Melbourne, Australia

Introduction: Two of the five Pillars of the United Nations (UN) Decade of Action focus on road safety management and safer roads. Safe speeds are also identified as a key element in a safe system approach to road safety. WHO (2004) identified speed as a key risk factor in road traffic collisions by an increased risk of a road crash, as well as the severity of the injuries that result from the crash.

Research Question / Objective: Local residential streets in Melbourne, Australia are typically posted as 50 km/h or 40 km/h (25 mph). Given their residential status and the high movement of pedestrians, children, cyclists, etc, a trial of a reduction from 40 km/h to 30 km/h (19 mph) in a particular region of an inner municipality was introduced in September 2018 and evaluated after 12 months. It was expected that vehicle speeds would subsequently be reduced and local residents would support this road safety initiative.

Methods A before and after study design was employed to evaluate the safety benefits of the trial. A traffic survey company was engaged to install and measure speeds at 100 selected sites in the trial area. Similar speed measures were also employed at an adjacent control region where speed limits were kept at the current 40 km/h (25 mph) limit. In addition, two surveys were undertaken before and after the trial involving residential attitudes to the lower speed limit along with other related questions. Demographic data were also collected in the survey questionnaire. The survey was undertaken in both the treated and control regions.

Data Sources: Data included both quantitative speed measures as well as qualitative community survey data. Speed data were collected over 7-days including both weekdays and weekends. Over one-million speeds were measured over peak and off-peak periods and the treatment effect was modelled using a Generalised Linear Modelling method. More than 500 survey responses were collected using an on-line survey format and analysed using bivariate statistical tests.

Results: The findings showed a small but meaningful reduction of 1.1% in average speed overall, which was not significant. However, examining the reduction in percent of vehicles exceeding 30 km/h (19 mph) was 2.3%, exceeding 40 km/h (25 mph) was 28% and a 25% reduction in exceeding 50 km/h (31 mph) in the treatment area. Curiously, speed reductions were also observed in the control region, suggesting a carry-over effect of the treatment effect into the adjacent control region. After adjusting for this, modelling showed an important 11% and 7% reduction in the odds of exceeding 40 km/h and 50 km/h after the treatment, respectively. Among other findings, the survey results further showed an increase in support for the lower speed limit from 44% to more than 51%.

Significance of results: While crash reductions could not be measures in such a trial, the potential injury savings were estimated as a 4% reduction in the risk of a pedestrian injury from identifying the difference in cumulative risk before and after intervention from a traditional published serious injury risk curve.

Friday, October 16th, 2020

Real World & Database Analysis

Friday, October 16th, 2020, 10:15 AM - 10:30 AM

Characteristics of Pedestrian Injuries Caused Due to Impacts with Powered Two Wheelers in India

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Objective: This study aims to understand the nature of injuries, its severity and the sources of injuries sustained by pedestrians involved in crashes with Powered Two Wheelers (PTW) in India. Further, the study aims to understand the injury pattern, injury outcome and injury mechanism of the pedestrian based on the contact location of the Pedestrian on the PTW**.**

Methods: Field data from 1st May 2011 to 31st March 2019 from the Road Accident Sampling System - India (RASSI) database was considered for the study. RASSI data, which is a sample of crashes investigated in-depth on Indian roads, include sampling weights developed to extrapolate national estimates for India. For this study, analyses were performed using both weighted and unweighted RASSI data. A sample of 57 crashes between pedestrians and PTW was analysed to determine the characteristics of injuries sustained by pedestrians, pedestrian orientation at the time of impact and the PTW Contact Zone (PCZ) or the area of PTW contacting the pedestrian. The PCZs were classified into three types and the risk of sustaining Maximum Abbreviated Injury Scale (MAIS) injury to the head was examined for each of the three PCZs. The injury mechanism of the pedestrian across the three PCZs was analysed.

Results: The results of both weighted and unweighted RASSI data were consistent. Majority of the fatal pedestrians (67%) sustained MAIS3+ head injury and majority of the non-fatal pedestrians (52%) sustained MAIS2+ lower extremity injury. The risk of AIS3+/fatal head injury is notably higher (86%) when pedestrians were struck from behind while walking along the road, compared to when pedestrians were struck from the sides while crossing the road (36%). Of the

three PCZs, about 80% of the pedestrians contacting PCZ-1 (front corner on either sides) sustained fatal head injuries while only 5% contacting PCZ-2 (center of the PTW front end) sustained fatal head injuries. About 40% contacting PCZ-3 (combination of PCZ-1 and PCZ-2) sustained fatal head injuries. Of all AIS3+ head injuries, 88% were associated with ground contact. Of all the AIS2+ lower extremity injuries, 96% of them were associated with contacting the front-end parts of the PTW.

Conclusions: The in-depth crash investigation data shows that head injuries account for most of the pedestrian fatalities in crashes with PTWs and lower extremity injuries account for most of the non-fatal injuries. Head injuries are associated with ground contact and lower extremity injuries are associated with contacting front-end parts of PTW. Pedestrians contacting the corner of the PTWs are highly prone to MAIS3+ head injuries whereas pedestrians contacting the center of the PTWs are less prone to MAIS3+ head injuries. This difference is predominantly because of the varied injury mechanisms seen across PCZs. This study highlights the injury patterns, injury sources and injury mechanism of the pedestrians involved in crashes with PTW.

Friday, October 16th, 2020, 10:30 AM - 10:45 AM

A Predictive Model to Analyze The Risk Factors of Traumatic Brain Injury in Elderly Occupants on Motor Vehicle Crashes Based on Korean In-Depth Accidents Study(KIDAS) Database

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Traumatic brain injury (TBI), also known as intracranial injury, occurs when an external force injures the brain. TBI can be classified based on severity, mechanism, or other features. The age groups most at risk for TBI are children ages five to nine and adults over age 80, and the highest rates of death and hospitalization due to TBI are in people over age 65. This study aimed to analyze the risk factors of traumatic brain injury in elderly occupants on motor vehicle crashes.

We defined the elderly occupants were more than 65 years old. Damage to the vehicle was presented using the CDC (Collision Deformation Classification) code by evaluation of photo-images of the damaged vehicle, and a trauma score was used for evaluation of the severity of the patient's injury. In specially, TBI was defined when AIS code related to head, except for damage to other structures such as the scalp and skull. A logistic regression model was used to identify risk factors affecting the TBI to elderly occupants and a predictive model was constructed. We performed this study retrospectively and gathered the whole data under the KIDAS investigation system. Among 3,697 patients who visited the emergency room in the regional emergency medical center due to motor vehicle crashes from 2011 to 2018, we analyzed data on 1,243 TBI patients. The rate of the TBI occupants in elderly group was 11.3%. The rate of the injured with side collision and rollover were higher in elderly group(20.4%, 18.4%) than in non-elderly one (17.1%, 11.4%). The rate of the injured with non-alert mental status (V,P,U) was each higher in elderly group (16.3%, 11.6%, 9.3%) than in non-elderly one (5.3%, 1.4%, 1.4%), respectively. By the multiple logistic regression analysis (?2=4.764, p-value: 0.783, Hosmer & Lemeshow Test), the probability of the TBI was 1.01 times higher as the age increased by one year (OR=1.010, 95% CI: 1.000-1.020). Also, the probability of the TBI in the elderly in the rear-end collision was 2.05 times higher related to the frontal collision (OR=2.045, 95% CI: 1.235-3.387). In the elderly, related to the CE zone 1, CE zone 2 was 1.65 times higher (OR=1.645, 95% CI: 1.123-2.410) and CE zone 3 was 2.35 times higher (OR=2.347, 95% CI: 1.299-4.242) respectively. This study was meaningful in that it approached several indicators that affected the occurrence of TBI. In addition, it was performed to determine the TBI in age, collision type, and crush extent by the logistic regression analysis. For in-depth study, it would be necessary more factors about the vehicle damage, the environment, and the human injury.

Friday, October 16th, 2020, 11:05 AM - 11:20 AM

Injury Risk Curves in Far-Side Motor Vehicle Crash by AIS Level, Body Region and Injury Code

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Objective: To develop injury risk curves as a function of velocity for occupants in far-side motor vehicle crash (MVC) by AIS level, body region, and specific AIS codes that commonly occur in this crash mode. Data sources: The National Automotive Sampling System-Crashworthiness Data System (NASS-CDS) years 2000-2015 and Crash Injury Research and Engineering Network (CIREN) years 2005-2016 databases were queried, resulting in 5024 non-weighted far-side crashes.

Methods: Inclusion criteria were: far-side impact (general area of damage "left" or "right"; PDOF 40-140º or 220-320º), driver or right front passenger, age >16, case sample weight >0, valid AIS code, lateral delta-v >0, belted or unbelted, side airbag (deployed, nondeployed or missing), number of impacts (=1 or >1), injury status coded. For each case, occupant age, sex, and metadata were collected: vehicle model year, vehicle body type, lateral delta-v, PDOF, multiple impacts, belt use, seat position, object contacted, striking vehicle body type, maximum crush extent, and side airbag deployment. Weights were calculated for far-side CIREN cases from similar NASS-CDS cases using a minimal Euclidean distance based on case attributes. Multivariate logistic regression was used to develop injury risk curves for AIS 2+ through 5+ injuries, AIS 2+ injuries by body region (head, thorax, and lower extremity), and for each of the 10 most frequent far-side AIS 2+ injuries. Significant covariates were determined by backwards elimination (p<0.05).

Results: For AIS 2+ through 5+ injury, greater lateral delta-v was associated with greater injury risk (OR's: 2.30-3.46 per 11.9 kph increase) and belt use was associated with lower risk (OR's: 0.04-0.18 with belt use) (Fig. 1). Injury risk increased as maximum CDC extent increased for AIS 2+ to 4+ injury (OR's:1.40-1.63 per unit increase in CDC). AIS 3+ injury risk was increased for more frontal PDOFs and narrow objects (OR: 1.02 (for more frontal impacts), 6.23 (narrow objects)). Multiple impacts were significant predictors of increased AIS 4+ and 5+ injury risk (OR's: 2.77 and 7.04). For AIS 2+, in all body regions, lateral delta-v and maximum crush extent were positively associated with increased injury risk. Age was positively associated with increased injury risk for the thorax and lower extremity. Belt use lowered the risk of head and thorax injury (Fig. 2). Lateral delta-v

had the greatest effect on predicting thorax injuries (OR 3.12 per 11.9 kph delta-v increase). For the 10 most frequent injuries, increased lateral delta-v, un-belted status, and greater maximum CDC extent significantly increased risk in 6 of 10 injuries. Side airbag deployment was not a significant covariate for the injury risk models.

Significance of Results: These risk curves expand upon previous literature to provide a more comprehensive view of contributors to injury risk in far-side MVCs. Additionally, if interiors of highly automated vehicles (HAVs) are designed to place fewer countermeasures in the path of motion of the occupant following crash, the far-side crash mode may serve as a preview of the types of injury patterns that will result from HAV crash. These findings are based on the latest available CIREN and NASS data.

Friday, October 16th, 2020, 11:20 AM - 11:35 AM

Expansion of NASS/CDS for Characterizing Run-Off-Road Crashes

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Introduction: Run-off-road crashes represent one-third of all annual crash fatalities in the US. The National Automotive Sampling System Crashworthiness Data System (NASS/CDS) is a dataset which may be used to understand the nature of these run-off-road crashes and injury outcomes. Despite the wealth of coded data available about the vehicle and driver in NASS/CDS, it lacks coded information about the roadside environment and the off-road trajectory of the vehicle which are crucial for characterizing run-off-road crashes. This information would be useful for guardrail design, lane departure warning (LDW) benefits estimation, residual safety problems, performance of current safety hardware, lane marking inventory, LDW test procedure development, radius of curvature characterization, and effectiveness of ESC in road departures.

Research Objective: The purpose of this paper is to demonstrate a methodology for expanding of data available in NASS/CDS for run-off-road crashes into an auxiliary database and validate reconstruction methods with EDR.

Data Sources: All run-off-road crashes in NASS/CDS which occurred from 2011 to 2015 were eligible for analysis.

Methods: Three types of variables, observed, measured, and reconstructed, were extracted from NASS/CDS and compiled into the National Cooperative Safety Research Program (NCHRP) 17-43 database. Observed variables were primarily coded from the scene photographs and included information such as the lane markings, and shape of the roadside cross-section. The research team extracted the measured variables such as the path of the vehicle, road dimensions, and roadside object positions in run-off-road crashes from the scaled scene diagrams using computer aided design (CAD) software. The reconstructed variables used the vehicle characteristics, WinSMASH delta-v, roadside object characteristics, and the vehicle path to estimate the vehicle impact speed and road departure speed. The general strategy for crash reconstructions was to start from final rest where the energy was known to be zero. Then, working backward along each trajectory segment and impact, energy was added to the system. Based on the absorbed energy, the impact and departure speeds were estimated (Figure 1). In the NCHRP 17-43 database, there were 97 cases with reconstructed impact speeds and pre-crash speeds captured by an associated event data recorder (EDR). There were 73 cases with reconstructed departure speeds and pre-crash speeds captured by an associated EDR. The reconstructed impact speed was compared to the last recorded pre-crash speed and the reconstructed departure speed was compared to the first recorded pre-crash speed.

Results: Overall, there were 1,581 cases representing 510,154 run-off-road crashes from NASS/CDS included in the NCHRP 17-43 database. The reconstructed impact speed was on average 14% lower than the EDR impact speed (Figure 2). Most of this error can be attributed to the known 13% underestimation of the delta-v using WinSMASH. The reconstructed departure speed performed better, underestimating the EDR departure speed by 2%.

Significance of Results: The NCHRP 17-43 database has particular potential for evaluating roadside injury criteria, lane departure warning systems, and lane keeping systems. The dataset is continuing to be developed for run-off-road crashes in the Crashworthiness Investigation Sampling System (CISS) the successor to NASS/CDS.

Friday, October 16th, 2020, 12:00 PM - 1:35 PM:
Human Factors, Alcohol and Drug Use

Friday, October 16th, 2020, 12:00 PM - 12:15 PM
Health Status and Quality of Life Among Road Users with Permanent Medical Impairment Several Years After the Crash

Friday, October 16th, 2020, 12:15 PM - 12:30 PM
Secondary Task Performance While Driving: The Impacts of Cannabis and Low Levels of Alcohol
Author: Ryan Miller, Grinnell College
Co-Authors: Timothy Brown PhD, National Advanced Driving Simulator, University of Iowa; Seoyeon (Stella) Lee, Grinnell College; Ishaan Tibrewal, Grinnell College; Gary Gaffeny, University of Iowa; Gary Milavetz, University of Iowa; Rebecca Hartman, Monroe County Forensic Toxicology Laboratory; Marilyn Huestis, Huestis & Smith Toxicology, LLC

Research Question / Objective: This research aims to assess driver performance during secondary tasks performed while driving under the influence of cannabis with and without alcohol. We consider 3 divided attention tasks, evaluating changes in driving behavior and task performance in response to cannabis/alcohol dosing.
Methods: Healthy cannabis using adults ages 21-55 participated in 6 sessions, receiving combinations of cannabis (placebo/low THC/high THC) and alcohol (placebo/active) in randomized order, separated by washout periods of at least one week. In each session, after dosing, subjects participated in simulator drives with the route including repeated instances of 3 secondary tasks: a side-mirror task where participants had 5 seconds to react to a red triangle appearing in one of their side-mirrors, an artist-search task where participants had 10 seconds to select a specified artist from a navigable menu on the vehicle's console, and a message-reading task where participants had 10 seconds to read aloud a message displayed on the vehicle's console. Driving measures during each task period were compared an equal duration control period occurring just prior to the task. These paired differences, in response to blood THC and

BAC, were modeled using mixed effects regression models. Task completion was modeled using mixed effects logistic regression. Each model included covariates to adjust for road segment and task-specific difficulty factors.

Data Sources: Data were collected by the University of Iowa National Advanced Driving Simulator (NADS-1), a full vehicle cab simulator with a 360° horizontal field of view with a motion base that provides realistic motion feedback. NADS-1 records a comprehensive record of driver inputs and vehicle states that are processed and stored as 60 Hz time-series. Blood THC was determined from samples collected at approximately 0.17, 0.42, 1.4, and 2.3 hours post drive using a previously-published method where 0.5mL blood was protein precipitated with ice-cold acetonitrile, and supernatants diluted, and solid-phase extracted. THC and BAC at every point in the drive were interpolated using individual power curves derived from these four measurements.

Results: Blood THC predicted increased odds of failing to complete the artist-search task (OR 1.09, $p = 0.046$) and increased odds of selecting at least one incorrect response (OR 1.10, $p = 0.041$), while BAC was not associated with task performance. Drivers under all conditions slowed their speed during secondary tasks, but higher THC associated with greater declines in speed during the side-mirror task ($p = 0.020$). Lane departures were observed to be more common in the active cannabis/alcohol conditions.

Significance of results: With many states passing marijuana legislation, it is essential to explore the impacts that acute cannabis use may have on various aspects of driving performance, including divided-attention tasks such as those considered in this research. This research provides evidence that divided attention is an area of concern following acute cannabis use. This raises significant safety concerns as evidenced by the increase in lane departures during secondary task performance. This work contributes to a growing body of research aimed at quantifying the effects of cannabis on driving.

Friday, October 16th, 2020, 12:30 PM - 12:45 PM

EEG Biomarkers Acquired During a Short, Straight-line Simulated Drive Predict Impairment from Cannabis Intoxication

Author: Timothy Brown PhD, National Advanced Driving Simulator, University of Iowa

Co-Authors: Amir Meghdadi, Advanced Brain Monitoring Inc.; Christian Richard, Advanced Brain Monitoring Inc.; Marissa McConnell, Advanced Brain Monitoring Inc; Greg Rupp, Advanced Brain Monitoring Inc.; Rose Schmitt, National Advanced Driving Simulator, University of Iowa; Gary Gaffney, National Advanced Driving Simulator, University of Iowa; Gary Milavetz, National Advanced Driving Simulator, University of Iowa; Chris Berka, Advanced Brain Monitoring Inc.

OBJECTIVE

As cannabis use becomes more widely accepted, there is growing interest in its effects on brain function, specifically how it may impact daily functional activities such as driving, operating machinery, and other safety-related tasks. There are currently no validated methods for quantifying impairment from acute cannabis intoxication. The objective of this study was to identify neurophysiological correlates associated with driving simulator performance in subjects who were acutely intoxicated with cannabis. These signatures could help create an EEG-based profile of impairment due to acute cannabis intoxication.

METHODS

Ten participants completed a 3-visit study protocol. Subjects were consented and screened on the first visit. On the 2nd and 3rd visits, subjects were administered 500 mg of either active cannabis with 6.7% delta-9-tetrahydrocannabinol (THC) (dosed), or placebo cannabis with only .009% THC (sober) using a Volcano© Digit Vaporizer (counterbalanced). Following administration of questionnaires and subjective scales, EEG was acquired as subjects completed a series of neurocognitive tasks and a ~45-minute simulated drive. The driving segment of interest for this paper is the final 10-minutes of the drive. During these final 10-minutes, subjects were asked to drive as they normally would on a straight stretch of a rural, two-lane road with posted speed limit of 55 MPH with no other cars or obstacles in either direction.

DATA SOURCES

EEG data was acquired using a STAT X24 wireless sensor headset during a simulated driving scenario from 10 participants during the sober and dosed visits. Frame-by-frame (60 Hz) and average metrics of driving performance (SDLP, speed, etc.) were extracted from the driving simulator. These data were time-synchronized using a common clock.

RESULTS

A within-subjects analysis showed that the standard deviation of lane position (SDLP) was significantly higher during the dosed visit compared to the sober visit (Figure 1). Average speed and standard deviation of speed was not significantly different. Power spectral densities of EEG data were calculated in one-second epochs for all 1 Hz bins and bandwidths from 1-40 Hz. Consistent with our prior findings, in the dosed condition Theta power (4-7 Hz) was significantly decreased while Fast Beta (21-30 Hz) and Gamma (25-40 Hz) power were significantly increased (Figure 2). In the dosed condition, Theta power was inversely correlated with driving performance (as measured by SDLP). Conversely, Fast Beta and Gamma were positively correlated with SDLP. There were no significant correlations between any EEG measure and SDLP in the sober condition.

SIGNIFICANCE

These results, in combination with prior work on the effect of cannabis intoxication during neurocognitive tasks, suggest that neurophysiological signatures associated with acute cannabis intoxication are robust and consistent across tasks. Additionally, these signatures are significantly correlated with impaired performance in a driving simulator. Taken together, EEG data acquired during a short neurocognitive testbed and during a simulated drive may provide specific profiles of impairment associated with acute cannabis intoxication. Further research is needed to establish the impaired cognitive processes associated with these EEG biomarkers.

Friday, October 16th, 2020, 1:05 PM - 1:20 PM

Automatic Collision Notification Availability and Time to a Medical Center Following Vehicle Collision - An Analysis of the 2017 Crash Investigation Sampling System

Author: Russell Griffin PhD, University of Alabama at Birmingham

Co-Author: Jan Jansen, University of Alabama at Birmingham; Shannon Carroll, University of Alabama at Birmingham

Research question / objective: To determine whether occupants of collisions involving at least one vehicle with an available ACN system have quicker times from collision to 1) EMS notification and 2) arrival to a medical center

Methods: Vehicles were categorized as whether ACN was available based on provided data on crash avoidance system availability. An occupant involved in the MVC was categorized as ACN-exposed if at least one vehicle involved in the MVC had ACN available. A Cox proportional hazards model was used to compare the time from collision to both EMS notification and EMS arrival to a medical center. Interactions with time were used to test proportionality by ACN exposure status. In a secondary analysis, a piecewise Cox model was used to examine medical center arrival in 20-minute periods. All analyses were conducted in SAS v9.4 using procedures to account for the weight sampling scheme of the data.

Data Sources: 2017 Crash Investigation Sampling System—the only year for which data is currently available—which is a stratified probability sample of approximately 2000 collisions annually. This system provides data on ACN availability for each involved vehicle in addition to EMS response-related times for each occupants involved in the collision.

Results: A total of 2,034 collisions (weight n: 2,775,512) involving 3,748 vehicles (weighted n: 61;5,065,616) and 4235 occupants (weighted n: 4,987,669) were included. An estimated 546,223 occupants (11.0%) were exposed to ACN. Of the occupants exposed to ACN, an estimated 173,529 (31.8%) were taken to a medical center via EMS transport. The median time to EMS notification was longer for ACN-unexposed (median 3, IQR 1-9 minutes) than ACN-exposed collisions (median 2, IQR 1-5 minutes). There was a significant difference in the hazard of EMS notification by ACN exposure status (HR 1.77, 95% CI 1.10-2.85). Likewise, time to medical center arrival was longer for ACN unexposed (median 43, IQR 32-51 minutes) vs. exposed (median 36, IQR 28-43 minutes) occupants. At any given minute within the first hour post-

MVC, ACN-exposed occupants were nearly twice as likely to arrive at a medical center the following minute compared to ACN-unexposed occupants (HR 1.98, 95% CI 1.38-2.85). This association was strongest for the first 20 minutes post-MVC (HR 6.89, 95% CI 1.27-37.36) and significantly increased for 20-40 minutes post-MVC (HR 1.92, 95% CI 1.19-2.53).
Significance of Results: This is the first study to directly compare EMS response-related times between collisions involving vehicles with and without ACN available. The current data corroborate prior literature reporting quicker EMS notification times among collisions involving ACN-equipped vehicles. This is the first study to find that ACN is also associated to quicker times to medical center arrival—particularly within the first 20 minutes post-MVC—providing supporting evidence on the benefits of ACN in decreasing MVC-related mortality risk by decreasing the time to medical center arrival following a MVC.

Friday, October 16th, 2020, 1:20 PM - 1:35 PM

Using a Wizard-of-Oz Approach to Study Human Factors of Vehicle Automation: A Driving Simulation Evaluation

Author: Ganesh Pai, University of Massachusetts Amherst
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Research Objective: Driving Simulation is commonly used to study human behavior in automated vehicles (AVs). However many complex vehicle behaviors and maneuvers are challenging to realistically simulate. The objective of this study was to evaluate an alternate approach to simulating Automated Vehicles, one that can be used as a more flexible method for the experimental study of human factors of Vehicle Automation.
Methods: A within-subject experiment was conducted on a fixed-based advanced driving simulator to compare a driving simulation algorithm for simulating AVs to a 'wizard-of-Oz' approach. The independent variable was the AV system with two levels: AutoDrive or Wizard. AutoDrive was the simulator algorithm that controlled the AV according to programmed rules. Wizard was the 'wizard-of-oz' approach wherein a human driver (trained research confederate) remotely operated the AV via a parallel networked set of vehicle controls. Participants were kept under the impression that the AV was driven by an algorithm in both

cases. Twenty-four participants drove two drives, one operated by "AutoDrive" and one by "Wizard". Various 'takeover' events were programmed within each drive. Order of presentation of drives was counterbalanced.

Data Sources: The following categories of data were collected: (a) Vehicle data including speed, acceleration, lane position; (b) Driver behavior data including Take Over Response Time/Quality, Reengagement time; (c) Visual gaze data including eyes-off-road time and fixations; and, (d) Surveys measuring Trust, Performance and Safety, and workload (NASA TLX).

Results: Overall, there were no statistically significant differences between the two automation platforms across all the outcome measures. Specifically, the Trust survey revealed no significant difference in participants' scores for the two automation platforms, suggesting equal perceived trust on the differing systems; the Performance and Safety survey also yielded similar results, with participants' scores on both platforms having no significant difference, suggesting similar confidence and perception of safety in on both automation platforms; and, the NASA Task Load Index ratings for both automation platforms showed that they had no significant difference, indicating that a similar workload was induced on the drivers while driving on both platforms. Furthermore, analysis of the participants' visual behavior showed no differences in visual behavior between the platforms, and analyses of speed and lane position variance showed no effect of platform. These results indicate that driver behaviors during automation, during takeover events, and during manual driving, did not differ significantly between the simulation approaches.

Significance of the Results: The study provides evidence supporting the use of a Wizard-of-Oz approach as a viable alternate experimental paradigm to simulate vehicle automation and examine driver behaviors within that context. This potentially broadens the scope of studying driver behavior in AVs since a Wizard of Oz approach can simulate much more complex and dynamic driving situations and environments than traditional available algorithms. This can help gain deeper insight into human performance and deficiencies in their interactions with automated vehicles, as well as provide a more diverse range of scenarios to help design, evaluate, or test automation related design including Human Machine Interfaces.