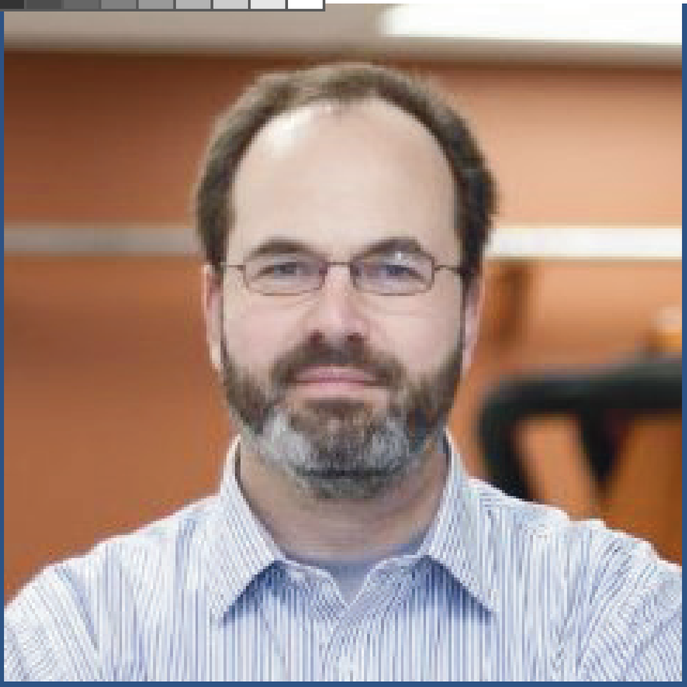
Association for the Advancement of Automotive Medicine

2019 AAAM 63rd Annual Scientific Conference

15 – 18 October 2019
Madrid Spain

Comillas Pontifical University
Universidad Pontificia Comillas

SAFETY WITHOUT BORDERS



Welcome from the AAAM President

Welcome to the 63rd Annual Scientific Conference of the Association for the Advancement of Automotive Medicine (AAAM). !Bienvenido a Madrid! We have an exciting program in store for you!

This year's scientific conference offers outstanding content and unmatched networking opportunities for those with the shared passion of eliminating road traffic injuries worldwide. We'll officially get the conference underway on Tuesday, 15 October with the Student Symposium and Welcome Reception in the evening. We are also offering a pre-conference workshop on Understanding AIS: Practical Information for Analyzing Injuries using AIS Codes that will be held Tuesday afternoon.

Wednesday through Friday are packed with a record-number of outstanding research sessions, including the two exceptional keynote speakers our Scientific Program Committee has secured – Dr. Mark Rosekind, Chief Safety Innovation Officer, Zoox and Prof. Dr. Ir. J.S.H.M. Wismans (Jac), President, SAFETEQ, and Visiting Professor, Chalmers University. On Wednesday and Thursday afternoons, we are debuting AAAM's Special Interest Group's Special Sessions on Automated Vehicles and Road Safety in Low- and Middle-Income Countries. We hope the addition of these important programs enhance your conference experience. I encourage all of you to attend the membership meeting on Wednesday for AAAM updates on membership, AIS, program initiatives, and to learn about opportunities for YOU to get involved. Don't miss the Recognition Dinner on Thursday evening honoring those who have contributed significantly to AAAM's mission of road safety.

And if you desire MORE knowledge and information, join us after the conclusion of the formal presentations on Friday for an optional tour of the Emergency Services Coordination Center of Madrid – SAMUR-Protección Civil – Spain's equivalent of U.S. 911-system operations.

Thank you for joining us at our 63rd Annual Scientific Conference! I hope you enjoy your conference experience.

Joel D. Stitzel, PhD
AAAM President

Scientific Program Committee

Thank you to the members of the Scientific Program Committee (SPC) for their work on planning the 2019 Conference.

Matthew R. Maltese, PhD (Chair)
Jacobo Antona Makoshi, PhD.
Aditya Belwadi, MS, PhD (Vice Chair, Annual Program Subcommittee)
Timothy L. Brown, PhD
Kerry A. Danelson, PhD
Richard J. Frampton, PhD
Hampton C. Gabler, PhD
F. Scott Gayzik, PhD (Chair, Student Program Subcommittee)
Emily Gu, MS
Jason J. Hallman, PhD (Chair, Annual Program Subcommittee)
Hans W. Hauschild, MS
Hamed Joodaki, PhD
Francisco J. Lopez-Valdes, PhD
Dennis J. Maiman, MD, PhD
Julie A. Mansfield, MS, PhD
Gary Milavetz, PharmD
Bingbing Nie
Jennifer A. Oxley, PhD
Daniel Perez-Rapela, MS
Anuj K. Pradhan
Bahram Ravani, PhD
Matthew Reed, PhD
Jonathan D. Rupp, PhD
John D. Struble, MS
Damien L. Subit, PhD
Ashley A. Weaver, PhD (Immediate Past Chair, Annual Program Subcommittee)
Jennifer L. Yaek, PhD, PE (Chair, Education Program Subcommittee)

Conference Schedule

Tuesday, 15 October 2019

Student Symposium - 9:00 AM - 5:30 PM

Sponsored by Nissan Motor Company

AAAM guests staying at the Courtyard Madrid Princesa may enjoy breakfast at the hotel in Moncloa I+II prior to their arrival at the conference.

Events for the conference will be held at Comillas Pontifical University unless otherwise noted.

8:30AM	**Registration Open**
9:00AM - 9:10AM	**Welcome: F. Scott Gayzik, PhD** - *Perez del Pulgar (Alberto Aguilera 25, 1st floor)*
9:10AM - 10:10AM	**Student Presentations: Tools for Vehicle Safety Evaluation** Session Moderators: Valentina Gracia, PhD and Derek Jones, MSE, BS
9:10AM - 9:30AM	**Predicted Benefit of Lane Departure Warning Systems for Cross-Centerline Head-on Crashes using a Multi-Vehicle Dynamics Model** *Luke E. Riexinger, Virginia Tech, Blacksburg, VA*
9:30AM - 9:50AM	**Optimal Child Restraint Design to Reduce the Propensity for Misuse** *Bianca Albanese, University of New South Wales, Australia*
9:50AM - 10:10AM	**Estimation of Fiber Angles in Intercostal Muscles from Cadaveric Thoraces** *Yuliia Sedneiva, Paris Tech & Université, Lyon, France*
10:10AM - 10:30AM	**Break**
10:30AM - 11:30AM	**Student Presentations: Field Data Analysis** Session Moderators: John J. Combest, BS and Elizabeth Krebs, MD, MS
10:30AM - 10:50AM	**Release of State-Level Driver's License and Crash Records for Use in Scientific Research: A US Legal Mapping Study** *Rania Mansour, Children's Hospital of Philadelphia, PA, USA*
10:50AM - 11:10AM	**Prevalence of Alcohol-Related Traffic Injuries in Patients Presenting to the Emergency Department of Chuk** *Joseph Niyonzima, University of Rwanda, Centre Hospitalier Universitaire de Kigal*
11:10AM - 11:30AM	**Data Mining Techniques for the Prediction of the Severity of Traffic Accidents in Cartagena, Colombia** *Holman Ospina-Mateus, Universidad Tecnológicade Bolívar, Cartagena, Columbia*
11:30AM - 1:00PM	**Lunch** - *Courtyard Madrid Princesa, Moncloa I+II*

1:00PM - 4:30PM	***Pre-Conference Workshop:*** **Understanding AIS: Practical Information for Analyzing Injuries using AIS Codes** *Kathryn Loftis, PhD, CAISS and Kathy Cookman, BS, CSTR, CAISS, EMT-P, FMNP - Seminary Room IIT (Santa Cruz de Marcenado 26, ground level)*
1:00PM - 2:00PM	**Student Presentations: Vulnerable Road Users** Session Moderators: Allison Curry, PhD, MPH and Julia Muehlbauer
1:00PM - 1:20PM	**Linking Age-Related Decline to Driver Behavior at Signalized Intersections** *Ashirwad Barnwal, Iowa State University, Ames, IA, USA*
1:20PM - 1:40PM	**The Influence of Child, Parent, and Context Factors on Child Passenger Safety** *Emma S. Goodman, University of Alabama, Birmingham, USA*
1:40PM - 2:00PM	**Examining the Potential for AEB Mitigation of U.S. Vehicle-Bicycle Crashes** *Samantha Haus, Virginia Tech, Blacksburg, VA, USA*
2:00PM - 2:20PM	**Break**
2:20PM - 3:20PM	**Student Presentations: Crash Analysis and Prevention** Session Moderators: Sjaan Koppel, PhD and William Decker
2:20PM - 2:40PM	**Predicting Crashes with Safe Systems Surrogates Obtained from Video Analytics – Implications for Evaluation of Safety Treatments** *Alireza Jafari Anarkooli, Ryerson University, Toronto, Canada*
2:40PM - 3:00PM	**Test Scenario Generation for ADAS & Automated Driving using UK Crash Data** *Simon Perveen, Coventry University, Coventry, UK*
3:00PM - 3:20 PM	**Differentiating Culpable and Non-Culpable Drivers in Fatal and Serious Injury Collisions Using Geodemographic Data** *James Nunn, Loughborough University, Loughborough, UK*
3:20PM - 3:30 PM	**Closing**
3:30PM - 5:30PM	**Mentoring Session** - *Room 201 (Alberto Aguilera 25, 2nd floor)*
5:30PM - 6:30PM	**Break**
6:30PM	**Welcome Reception** - *Hotel Emperador, Room: Climate Terrace* *Gran Via, 53 Madrid*

Wednesday, 16 October 2019

Main Conference 8:00 AM – 5:00 PM - Comillas Pontifical University

AAAM guests staying at the Courtyard Madrid Princesa may enjoy breakfast at the hotel in Moncloa I+II prior to their arrival at the conference.

Full Paper abstracts can be found by number in the back of the program. Numbers in a ● Green circle indicate that the article is already available electronically at Traffic Injury Prevention: www.tandfonline.com/toc/gcpi20/current.

**Short Communications abstract can be found in the separate program attachment.*

7:30AM	**Registration Open**
8:00AM - 8:15AM	**Welcome Address** - *Sala Conferencias (Alberto Aguilera 23, ground level)* Joel D. Stitzel, PhD and Jason J. Hallman, PhD
8:15AM - 9:15AM	**Keynote Address: Living Safety: Attitudes, Actions, and Innovation** **Mark R. Rosekind, PhD** Chief Safety Innovation Officer, Zoox Inc., USA
9:15AM - 10:25AM	**Integrated Safety** *Session Moderators: F. Scott Gayzik, PhD, Wake Forest University School of Medicine & Emily Gu, Delta V Biomechanics*
9:15AM -9:35AM	1 **Adapting Load Limiter Deployment for Frontal Crash Diversity** Author: Karthikeyan Ekambaram, *Coventry University* Co-Authors: Richard Frampton; Lisa Jackson
9:35AM - 9:55AM	2 **Comparison across Vehicles of Passenger Head Kinematics in Abrupt Vehicle Maneuvers** Author: Matthew Reed, *University of Michigan - Ann Arbor* Co-Authors: Shelia Ebert; Monica Jones; Byong-keon Park
9:55AM - 10:15AM	3 **Comparison of Control Strategies for the Cervical Muscles of an Average Female Head-Neck Finite Element Model** Author: I Putu Alit Putra, MEng, *Chalmers University of Technology* Co-Authors: Johan Iraeus; Robert Thomson; Mats Svensson; Astrid Linder; Fusako Sato
10:15AM - 10:25AM	*** Feasibility Study of a Safe Sled Environment for Reclined Frontal Deceleration Tests with Human Volunteers** Author: Julia Muehlbauer, *Ludwig-Maximilian University (LMU)* Co-Authors: Sylvia Schick; Dustin Draper; Francisco J. Lopez-Valdes; Loannis Symeonidis; Hellas Steffen Peldschus
10:25AM - 10:40AM	**Break**

10:40AM - 11:55AM	**Automated Vehicle Safety** *Session Moderators: Matthew Maltese, PhD, Children's Hospital of Philadelphia & Jason Hallman, PhD, Collaborative Safety Research Center, Toyota Motor North America*
10:40AM - 11:00AM	4 **Seating Configuration and Position Preferences in Fully Automated Vehicles** Author: Sjaan Koppel, PhD, *Monash University Accident Research Centre* Co-Authors: Jesús R. Jiménez-Octavio; Katarina Bohman; David Logan; Wassim Raphael; Leonardo Augusto Quintana Jimenez; Francisco J. Lopez-Valdes
11:00AM - 11:20AM	5 **Submarining Sensitivity across Varied Anthropometry in Autonomous Driving System Environment** Author: Katarzyna Rawska, *University of Virginia, Center for Applied Biomechanics* Co-Authors: Bronislaw Gepner; Jason Kerrigan; Shubham Kulkarni; Daniel Perez-Rapela; Kalle Chastain; Junjun Zhu; Rachel Richardson; Jason Forman
11:20AM - 11:40AM	6 **Prospective Assessment of the Effectiveness of Autonomous Emergency Braking in Car-to-Cyclist accidents in France** Author: Henri Chajmowicz, *GIE Renault / PSA (LAB)* Co-Authors: Sophie Cuny; Jacques Saade
11:40AM - 11:50AM	*** Age and Gender Differences in Emergency Takeover from Automated to Manual Driving on Simulator** Author: Helen Loeb, Ph.D., *Children's Hospital of Philadelphia* Co-Authors: Aditya Belwadi; Jalal Maheshwari; Saniyah Shaikh
11:50AM - 11:55AM	**Effectiveness of Path Prediction of Automated Vehicle in Curve Driving** Author: Hongyang Xia, *South China University of Technology* Co-Author: Jiqing Chen; Zhaolin Liu; Fengchong Lan
11:55AM - 1:25PM	**Lunch** - *Courtyard Madrid Princesa, Moncloa I+II*
1:25PM - 2:55PM	**Special Session: Automated Vehicles, presented by Automated Vehicles Special Interest Group** - *Sala Conferencias (Alberto Aguilera 23, ground level)* Speakers: Dr. Mark Rosekind, *Zoox Inc.;* Ola Bostrom, *Veoneer;* Lorrie Walker, *SafeKids International;* Megan Smirti Ryerson, *University of Pennsylvania*
2:55PM - 3:10PM	**Break & Poster Discussions**
3:10PM - 4:00PM	**Children and Aging 1** *Session Moderators: Matthew Reed, PhD, University Of Michigan - Ann Arbor & Timothy Brown, PhD, University of Iowa*
3:10PM - 3:30PM	7 **Linking Age-Related Cognitive and Visual Decline to Real-World Risk Exposure** Author: Jennifer Merickel, PhD, *University of Nebraska Medical Center* Co-Authors: Robin High; Jeffrey Dawson; Matthew Rizzo
3:30PM - 3:50PM	8 **Characterization of the Motion of Booster Seated Children during Simulated In-Vehicle Pre-Crash Maneuvers** Author: Valentina Graci, PhD, *Children's Hospital of Philadelphia* Co-Authors: Ethan Douglas; Thomas Seacrist; Jason Kerrigan; Julie Mansfield; John Bolte; Rini Sherony; Jason Hallman

3:50PM - 3:55PM	**A Pilot Study Evaluating the 3-Point and 4-Point Restraint System for Pediatric Occupants in Non-Standard Seating Positions** Author: Jalaj Maheshwari, *The Children's Hospital of Philadelphia* Co-Author: Aditya Belwadi
3:55PM - 4:00PM	**Associations between Graduated Driver Licensing Restrictions and Delay in Driving Licensure among U.S. High School Students** Author: James Fell, MS, *NORC at the University of Chicago* Co-Authors: Federico Vaca; Eduardo Romano; Denise Haynie; Bruce Simons-Morton
4:00PM - 5:00PM	**Annual Business Meeting**
7:00PM - 9:00PM	**Student Social: Trivia Night -** *La Zamorana, Calle de Galileo, 21, 28015 Madrid, Spain (10 minute walk from the University. Meet in the lobby of the Courtyard Madrid Princesa at 6:50PM.)*

Thank you to our supporters

AAAM thanks the following companies for their generous support of our Annual Meeting. Their contributions enable AAAM to build a more dynamic conference.

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Thursday, 17 October 2019

Main Conference 8:00 AM – 5:15 PM - Comillas Pontifical University

AAAM guests staying at the Courtyard Madrid Princesa may enjoy breakfast at the hotel in Moncloa I+II prior to their arrival at the conference.

Full Paper abstracts can be found by number in the back of the program. Numbers in a Green circle indicate that the article is already available electronically at Traffic Injury Prevention: www.tandfonline.com/toc/gcpi20/current.

**Short Communications abstract can be found in the separate program attachment.*

7:30AM	**Registration Open**
8:00AM - 9:00AM	**Keynote Address: Global Challenges for Road Safety in the Next Decade** **Jac Wismans, PhD, SAFETEQ**
9:00AM - 10:20AM	**Driving Impairment** *Session Moderators: Rini Sherony, MS, Collaborative Safety Research Center, Toyota Motor North America & R. Shayn Martin, MD, Wake Forest University School of Medicine*
9:00AM - 9:20AM	9 **Quantifying Vehicle Control from Physiology in Type 1 Diabetes** Author: Pranamesh Chakraborty, *Iowa State University* Co-Authors: Jennifer Merickel; Viraj Shah; Anuj Sharma; Chinmay Hegde; Cyrus Desouza; Andjela Drincic; Pujitha Gunaratne; Matthew Rizzo
9:20AM - 9:30AM	*** Correlation of EEG Biomarkers of Cannabis with Measured Driving Impairment** Author: Timothy Brown, PhD, *University of Iowa* Co-Author: Marissa McConnell; Greg Rupp; Amir Meghdadi; Christian Richard; Rose Schmitt; Gary Gaffney; Gary Milavetz; Chris Berka
9:30AM - 9:40AM	*** Neurocognitive and Behavioral Markers in DUI Recidivists** Author: Claudio Terranova, *Legal Medicine and Toxicology University of Padova* Co-Authors: Mariaelena Tagliabue; PadovaGiorgia Cona; Evelyn Gianfranchi; Laura Di Pietra; Giulio Vidotto; Massimo Montisci
9:40AM - 9:50AM	*** Impaired Driving: A Case Report. Pickup Truck Centerline Crossover Collision with Medium-Size Bus on US Highway 83, Concan, Texas, United States** Author: Mary Pat McKay, MD, MPPH, *National Transportation Safety Board* Co-Authors: Kristin Poland; Donald Karol; Rafael Marshall; Ronald Kaminski
9:50AM - 10:00AM	*** Variability of Baseline Vehicle Control among Sober Young Adult Cannabis Users: A Simulator-Based Exploratory Study** Author: Timothy Brown, PhD, *University of Iowa* Co-Authors: Barbara Banz; Kaigang Li; Deepa Camenga; Federico Vaca; Gary Gaffney; Gary Milavetz

10:00AM - 10:05AM	**The Disparate Burden of Alcohol-Related Fatal Crashes Among Young Latino Drivers** Author: James Fell, MS, *NORC at the University of Chicago* Co-Authors: Federico Vaca; Eduardo Romano; Bruce Simons-Morton; Kaigang Li
10:05AM - 10:10AM	**Predicting DUI Decisions of Different Drivers in Different Legal Environments: Investigating Differential Deterrence** Author: Jie Yao, *Harbin Institute of Technology (Shenzhen)*
10:10AM - 10:15AM	**Glossary on Drug Use and Driving Safety** Author: Pau Mota, *Federation International de l'Automobile* Co-Authors: Maria Segui; Gerard Saillant; Prisca Mauriello; Rebeca Abajas
10:15AM - 10:20AM	**Driving after Cannabis Use and Compensatory Driving Behaviors among Current Cannabis Users in Colorado** Author: Ashley Brooks-Russell, PhD, *University of Colorado Anschutz Medical Campus* Co-Authors: Timothy Brown; Anna Malin Rapp-Olsson; Kyle Friedman; Michael Kosnett
10:20AM - 10:35AM	**Break**
10:35AM - 11:40AM	**Low- and Middle-Income Countries** *Session Moderators: Jennifer A. Oxley, PhD, Monash University Accident Research & Ashley A. Weaver, PhD, Wake Forest School of Medicine*
10:35AM - 10:55AM	10 **Risk Factors Associated with Boda-Boda (motorcycle) Accidents in Kampala, Uganda** Author: Siya Aggrey, *Makerere University* Co-Authors: Benard Ssentongo; Abila Derrick Bary; Arthur Kato; Howard Onyuth; Denis Mutekanga; Isaac Ongom; Edimand Aryampika; Akim Tafadzwa Lukwa
10:55AM - 11:05AM	*** Who Is More Vulnerable In Crashes between Motorized 2-Wheelers and Pedestrians?** Author: Aravinthkumar Jayaraman, *JP Research India Private Limited* Co-Authors: Jigar Soni
11:05AM - 11:15AM	*** Crash Patterns in Two Chinese Secondary Cities, with Comparisons to Drink Driving Crash Patterns in the United States** Author: Ted Miller, PhD, *Pacific Institute for Research & Evaluation* Co-Authors: Bina Ali; David Swedler; Joel Grube; Mallie J. Paschall; Christopher Ringwalt
11:15AM - 11:25AM	*** Compliance of Commercial Motorcyclists with Road Safety Measures in a Nigerian Metropolitan City** Author: Omoseye Ogunkeyede, MBBCH, MPH, MWACP, *University College Hospital* Co-Author: AKayode Osungbade

11:25AM - 11:30AM	**Data-Driven Prehospital Training to Decrease Motorcycle Crash Deaths in a Sub-Saharan African Urban Center** Author: Ashley Rosenberg, MD, *Virginia Commonwealth University Health Systems* Co-Authors: Fraterne Uwinshuti; Myles Dworkin; Vizir Nsengimana; Eugenie Kankidi; Mediatrice Niyonsaba; Jean Marie Uwitonze; Ignace Kabagema; theophile Dushime; Sudha Jayaraman; Elizabeth Krebs
11:30AM - 11:35PM	**Differential Mental Representation of Warning Traffic Signs In Latin-America** Author: Jose Vilchez, PhD, *Universidad de Cuenca*
11:35AM - 1:10PM	**Lunch with Committees & Special Interest Groups** - *Courtyard Madrid Princesa, Moncloa I+II*
1:10PM - 2:40PM	**Special Session: Road Safety in Low- and Middle-Income Countries, presented by LMIC Special Interest Group** - *Sala Conferencias (Alberto Aguilera 23, ground level)* *Speakers: Jac Wismans, PhD, SAFETEQ; Eric Howard, AM, Strategic Road Safety Advisory Services; Marilyn J. Bull, MD, Riley Hospital for Children at IU Health Services*
2:40PM - 3:30PM	**Vulnerable Road Users and Trauma Analysis 1** *Session Moderators: Francisco Lopez-Valdes, PhD, Comillas Ponitical University & Gary Milavetz, PharmD, University of Iowa*
2:40PM - 3:00PM	11 **Vehicle-Pedestrian Crash Analysis for Head Injury Safety** Author: Tarek Morsy, *Coventry University* Co-Authors: Omid Razmkhah; Karthikeyan Ekambaram
3:00PM - 3:05PM	**Evaluation of a Triage Algorithm to Establish the Need for Partial Trauma Team Activation** Author: Javier Sainz Cabrejas, *H. Universitario 12 Octubre* Co-Authors: Carlos García Fuentes; Rosana Ashbaugh Lavesiera; Juan Carlos Montejo González; Mario Chico Fernández
3:05PM - 3:10PM	**Trends and Epidemiology in Road Traffic Accidents in Patients Who Requires Hospital Admission in the Intensive Care Trauma Center (Level 1 Trauma Center)** Author: Rosana Ashbaugh Lavesiera, *H. Universitario 12 Octubre* Co-Authors: Javier Sainz Cabrejas; Carlos García Fuentes; Mario Chico- Fernández
3:10PM - 3:15PM	**Comparison of Epidemiology and Injury Profile among Injured Patients Involved In Incidents by Special Purpose Vehicle** Author: Sang-Chul Kim, *Chungbuk National University Hospital* Co-Authors: Hyun Seok Choi; Young Min Kim; Jin Seok Lee; Seong Je Go; Jin Young Lee; Hae Ju Lee; Yeon-il Choo
3:15PM - 3:20PM	**Attention Capture in Hazard Prediction in Driving and Its Relation with the Effect of Driving Experience** Author: Candida Castro, *University of Granada* Co-Authors: Ismael Muela; Pedro Garcia-Fernandez

3:20PM - 3:25PM	**Artificial Intelligence Technology for Real Time Injury Prediction in Motor Crash Accident** Author: Itay Bengad, *MDGo* Co-Author: Gilad Avrashi
3:25PM - 3:30PM	**Vision Zero: Preventing Pedestrian Injury and Death** Author: Jodi Raymond, MPH, *Riley Hospital for Children at IU Health* Co-Authors: Joseph O'Neil; Thomas Rouse; Teresa Bell; Peter Jenkins; Lewis Jacobson; Clark Simons; Kim Irwin; Ashley Vetor
3:30PM - 3:45PM	**Break & Poster Discussions**
3:45PM - 5:05PM	**Parallel Sessions**
	1) Vehicle Safety and Ratings - *Polavieja (Alberto Aguilera 23, ground level)* *Session Moderators: Jennifer Yaek, PhD, Exponent & Thomas R. Hartka, MD, MS, University of Virginia*
3:45PM - 4:05PM	12 **Factors Associated with Chest Injuries to Front Seat Occupants in Frontal Impacts** Author: Karthikeyan Ekambaram, *Coventry University* Co-Authors: Richard Frampton; James Lenard
4:05PM - 4:25PM	13 **Pelvis Injury Risk Curves in Side Impacts at Different AIS Severities from Human Cadaver Experiments** Author: Narayan Yoganandan, *Medical College of Wisconsin* Co-Authors: John Humm; Frank Pintar; Somers Jeffery; Anjishnu Banerjee
4:25PM - 4:45PM	14 **Fatal Side Impact Crash Scenarios for Rear Seat and Seat Belt Restrained Occupants from Vulnerable Population** Author: Seth Fein, *Children's Hospital of Philadelphia* Co-Authors: Jessica Jermakian; Kristy Arbogast; Matthew Maltese
4:45PM - 4:55PM	*** Suitability of Enhanced Head Injury Criteria for Vehicle Rating** Author: Marc van Slagmaat, *Autoliv France* Co-Authors: Matthew B. Panzer; Bengt Pipkorn; Becky Mueller
4:55PM - 5:05PM	*** Safer Vehicles and Technology for Older Adults** Author: Jennie Oxley, *Monash University* Co-Authors: David Logan; Sjaan Koppel; Judith Charlton; Steve O'Hern; Lynn Meuleners
	2) Biomechanics - *Sala Conferencias (Alberto Aguilera 23, ground level)* *Session Moderators: Jason L. Forman, PhD, University of Virginia, Center for Applied Biomechanics & Emily Thomas, PhD, Consumer Reports*
3:45PM - 4:05PM	15 **Head Injury Metric Response in Finite Element ATDs and a Human Body Model in Multidirectional Loading Regimess** Author: Derek Jones, MS, *Wake Forest University* Co-Authors: James Gaewsky; Jeffrey Somers; F. Scott Gayzik; Ashley Weaver; Joel Stitzel

4:05PM - 4:25PM	16 **Detailed Subject-Specific FE Rib Modelling for Fracture Prediction** Author: Johan Iraeus, *Chalmers University of Technology* Co-Authors: Bengt Pipkorn; Linus Lundin; Simon Storm; Amanda Agnew; Andrew Kemper; Sven Holcombe; Yun-Seok Kang
4:25PM - 4:45PM	17 **Validated Thoracic Vertebrae and Costovertebral Joints Increase Biofidelity of a Human Body Model in Omnidirectional Hub Impacts** Author: F. Scott Gayzik, PhD, *Wake Forest University School of Medicine* Co-Authors: Jazmine Aira; Berkan Guleyupoglu; Derek Jones; Bharath Koya; Matthew Davis
4:45PM - 4:55PM	*** Determination of Compression-Based Injury Variables in Far-Side Sled Impact Tests From Chestband Information** Author: Yuvaraj Purushothaman, *Vellore Institute of Technology* Co-Authors: John Humm; Davidson Jebasselan; Narayan Yoganandhan
4:55PM - 5:05PM	*** Effect Of the Q10 Dummy Upgrade Kit in UN Regulation No. 129 Front and Side Impact Tests** Author: Costandinos Visvikis, *CYBEX GmbH* Co-Authors: Christoph Thurn; Thomas Müller
5:05PM - 6:30PM	**Break**
6:30PM	**AAAM Recognition Dinner** - *Casino de Madrid, Alcalá Calle de Alcalá, 15, 28014 Madrid, Spain*
	Dress code for dinner: Jacket and tie for gentlemen. Business formal for women.

Pick the Best Poster

View the poster displays and vote for your favorite. Place the AAAM wooden coin in the box with poster of your choice. The outstanding poster presenter will be announced at the Recognition Dinner on Thursday evening.

CAST YOUR VOTE BEFORE 5:15 PM Thursday, 17 October.

Want to win Apple AirPods or a $50 Amazon Gift Card?

Complete an evaluation after each session and return to the AAAM Registration Desk for a raffle ticket. One raffle ticket is earned for each evaluation that is returned. A $50 Amazon Gift Card will be raffled at the end of the day on Wednesday and Thursday (using raffle tickets for those days only). The Apple AirPods will be raffled off at the conclusion of Friday's sessions.

Winner must be present to obtain the prize and must produce the winning ticket. [AAAM is not responsible for lost tickets. The gift card cannot be exchanged.]

Friday, 18 October 2019

Main Conference 8:00 AM – 12:00 PM - Comillas Pontifical University

AAAM guests staying at the Courtyard Madrid Princesa may enjoy breakfast at the hotel in Moncloa I+II prior to their arrival at the conference.

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7:30AM	Registration Open
8:00AM - 9:00AM	**Children and Aging 2** *Session Moderators: Sjaan Koppel, PhD, Monash University Accident Research Centre & Aditya Belwadi, PhD, The Children's Hospital of Philadelphia*
8:00AM - 8:20AM	18 **Age-Based Differences in the Disability of Extremity Injuries in Pediatric and Adult Occupants** Author: Michaela Gaffley, MD, *Wake Forest School of Medicine* Co-Authors: Ashley Weaver; Jennifer Talton; Ryan Barnard; Joel Stitzel; Mark Zonfrillo
8:20AM - 8:40AM	19 **A Comparison of Seat Belt Fit and Comfort Experience between Older Adults and Younger Front Seat Passengers in Cars** Author: Katarina Bohman, PhD, *Volvo Cars* Co-Authors: Anna-Lisa Osvalder; Svante Alfredsson; Robin Ankartoft
8:40AM - 8:50AM	*** Responses of the Scaled Pediatric Human Body Model in Rear- and Forward- Facing Child Seats in Simulated Frontal Motor Vehicle Crashes** Author: Aditya Belwadi, PhD, *The Children's Hospital of Philadelphia* Co-Authors: Shreyas Sarfare; Sophie Tushak; Jalaj Maheshwari; Srihari Menon
8:50AM - 9:00AM	*** Sarcopenia and Osteosarcopenia in Seriously Injured Motor Vehicle Crash Occupants** Author: Ashley Weaver, PhD, *Wake Forest School of Medicine* Co-Authors: Casey Costa; Josh Tan; Lisa Maez; Xin Ye; Joel Stitzel; Leon Lenchik
9:00AM - 10:10AM	**Vulnerable Road Users and Trauma Analysis 2** *Session Moderators: Richard Frampton, PhD, Loughborough University & Kathryn Loftis, PhD, CAISS, AAAM*
9:00AM - 9:20AM	20 **Accuracy of Algorithms to Predict Injury Severity in Older Adults for Trauma Triage** Author: Thomas Hartka, MD, MS, *University of Virginia* Co-Authors: Christina Gancayco; Miranda Chase; Ashley Weaver; Timothy McMurry

9:20AM - 9:40AM	21 **Evaluation of Finite Element Human Body Models for use in a Standardized Protocol for Pedestrian Safety Assessment** Author: William Decker, MS, *Wake Forest University Center for Injury Biomechanics* Co-Authors: Bharath Koya; Wansoo Pak; Costin D. Untaroiu; F. Scott Gayzik
9:40AM - 9:50AM	*** Catalyzing Traffic Safety Advancements via Data Linkage: Development of the New Jersey Safety and Health Outcomes (NJ-SHO) Data Warehouse** Author: Allison Curry, PhD, MPH, *Children's Hospital of Philadelphia, Univ. of Pennsylvania*
9:50AM - 10:00AM	*** Comparing Consequences of Using Two Different Definitions for Body Regions on Priority Setting for the Improvement of Personal Protective Equipment for Powered Two Wheelers** Author: Sylvia Schick, Dr., M.P.H., CAISS, *Ludwig-Maximilians-University Munich, LMU* Co-Authors: Simone Piantini; Marcus Wisch; Julie Brown
10:00AM - 10:10AM	*** Analysis of Swedish and Dutch Accident Data on Cyclist Injuries in Cyclist-Car * Collisions** Author: Christoph Leo, *Graz University of Technology - Vehicle Safety Institute* Co-Author: Corina Klug
10:10AM - 10:25AM	**Break**
10:25AM - 11:35AM	**Infrastructure and Policy** *Session Moderators: H. Clay Gabler, PhD, Virginia Tech & Valentina Graci, PhD, Children's Hospital of Philadelphia*
10:25AM - 10:45AM	22 **Billboard Impacts on Crashes on a Suburban Highway: Comparing Three Periods - Billboards Present, Removed, and then Returned** Author: Victoria Gitelman, *Transportation Research Institute* Co-Authors: Etti Doveh; David Zaidel
10:45AM - 11:05AM	23 **Underutilized Strategies in Traffic Safety: Results of a Nationally Representative Survey** Author: James Fell, MS, *NORC at the University of Chicago*
11:05AM - 11:25AM	24 **A Driving Simulator Study for the Evaluation of the Effectiveness of Perceptual Treatments in Reducing Speeds Approaching a Sharp Curve of a Rural Road** Author: Alessandro Calvi, *Roma Tre University* Co-Authors: Fabrizio D'Amico; Luca Bianchini Ciampoli; Chiara Ferrante
11:25AM - 11:35AM	*** Low Speed Limits in Residential Areas in Melbourne** Author: Brian Fildes, PhD, *Monash University Accident Research Centre* Co-Authors: Brendan Lawrence; Jennifer Oxley
11:35AM - 12:00PM	**Closing Remarks** *Marylin J. Bull, MD and Jason J. Hallman, PhD*
12:00PM	**Adjourn**
2:00PM - 5:00PM	**Optional Tour - Emergency Services Coordination Center of Madrid (SAMUR-Proteccion Civil)** - *Meet outside of the lobby of the Courtyard Madrid Princesa at 1:45PM.*

Wednesday Abstracts

Abstracts

1 Adapting Load Limiter Deployment for Frontal Crash Diversity

AKarthikeyan Ekambaram[1], Richard Frampton[2], Lisa Jackson[2]

1. Coventry University

2. Loughborough University

Objective: Crash research clearly shows that thoracic injuries in frontal impacts are still an issue, especially for older occupants in lower speed crashes. This aim of this study was to explore the basic concept of adapting the seat belt force limiting threshold to individual occupant and crash characteristics, and thereby improving chest protection.

Methods: Numerical simulations were conducted with a MADYMO ellipsoid model to examine the effect of different force limiter thresholds on chest injury risk in frontal impacts. Driver and front passenger numerical models were developed for a 5th, 50th and 95th percentile Hybrid III ATD. Force limiting was varied between 2, 3, 4 and 6 kN, in five frontal impact scenarios, representing as wide a range of real frontal crash conditions as possible. Simulated thoracic injury risk predictions were converted into injury probability values using AIS 2+ age dependent thoracic risk curves. Benefits for a weighted real-world crash sample were quantified using the predicted relative AIS 2+ risk reduction, and based on occupant seating position, impact scenario, occupant size and occupant age.

Data Sources: UK RAIDS-CCIS crash injury data 2000 - 2018.

Results: Simulation showed that, for both the 50th and 95th percentile ATD in both front seating positions, a 2kN threshold provided the best chest protection in low severity impacts, without increasing the risk to other body regions. In high severity impacts, a low load actuation threshold allowed the driver ATD to move dangerously close to the vehicle interior, but there appeared to be some benefit for the 50th percentile front passenger ATD. Low load actuation showed no benefit for the 5th percentile driver ATD. Low load actuation showed chest injury reduction potential for the 50th percentile front seat passenger ATD but not for the driver, in EuroNCAP type frontal crashes. Applying the AIS 2+ risk reduction findings to the crash data sample, showed that 33% of the front seat occupants who had sustained AIS 2+ seat belt related chest injuries would have received less severe chest injury if all vehicles could have selected more appropriate force limiting.

Significance of Results: The basic concept of adaptive load limiting appears to hold some potential, especially since more lower speed crashes and more older car users are forecast for future traffic environments. Refinement of the concept would necessarily involve integration with other safety systems and perhaps the employment of more sophisticated human body models.

2 Comparison across Vehicles of Passenger Head Kinematics in Abrupt Vehicle Maneuvers

Matthew Reed, Sheila Ebert, Monica Jones, Byoung-keon Park

University of Michigan - Ann Arbor

Objective: Studies of vehicle occupant motions in response to abrupt vehicle maneuvers have demonstrated movements that may result in changes in the level of protection for the occupant if a crash subsequently occurs. The previous studies have typically used a single vehicle. The current study considers whether the patterns of occupant movement are different across passenger vehicle types.

Methods: Data collection was conducted on a closed test track with the same driver for all trials. A passenger sedan, a pickup truck, and a minivan were equipped with inertial measurement units to quantify vehicle dynamics. Twelve men and women with a wide range of body size and age were recruited. Standard and three-dimensional anthropometric measurements were obtained. The primary purpose of the study was obfuscated by telling the participants that the focus was on vehicle ride motion. Participants sat in the right front seat and wore the vehicle belt. The fore-aft position of the seat was adjusted so that the location of the upper belt anchorage (D-ring) with respect to the seat was similar across vehicles. The first event during the test track route was a hard brake (approximately 1 g) to a stop from 35 mph (56 kph). Within the space of approximately 5 minutes the participants also experienced an aggressive lane change, a sharp right turn with simultaneous hard braking, and a second hard braking event. The vehicles were presented in random order for each participant.

Data sources: A Microsoft Kinect v2 sensor was positioned to view the area around the front passenger seat. Head location was tracked using the Kinect data with a novel methodology that fit 3D head scan data to the depth data acquired in the vehicle. The accuracy of the method has been quantified in a previous study by tracking an ATD

head positioned using a manual coordinate digitizer.

Results: Horizontal accelerations were very similar across vehicles, but the vehicle pitch and roll differed. Forward head excursions with respect to the vehicle in braking were not significantly different across vehicles, but lateral movement of the head in the lane-change maneuver was larger in the minivan than in the other vehicles, possibly due to the lack of a center console

Significance of Results: This is the first study to compare occupant kinematics during abrupt vehicle maneuvers across vehicles. The results indicate that vehicle kinematics and interior layout should be considered when assessing the likely pre-crash distribution of occupant posture.

3 Comparison of Control Strategies for the Cervical Muscles of an Average Female Head-Neck Finite Element Model

I Putu Alit Putra[1], Johan Iraeus[1], Robert Thomson[1], Mats Svensson[1], Astrid Linder[1, 2], Fusako Sato[1, 3]

1. Chalmers University of Technology

2. Swedish National Road and Transport Research Institute (VTI)

3. Japan Automobile Research Institute (JARI)

Objective: ViVA OpenHBM is the first open source Human Body Models (HBMs) for crash safety assessment. It represents an average size (50th percentile) female and was created to assess whiplash protection systems in a car. ViVA OpenHBM is a HBM to address the average female which have up to 3 times greater risk to sustain a whiplash injury compared to males. To increase the biofidelity of the current model, further enhancements are being made by implementing muscle reflex response capabilities as cervical muscles alter the head and neck kinematics of the occupant during low-speed rear crashes. Therefore, the objective of this study was to assess how different neck muscle activation control strategies affect head-neck kinematics in low speed rear impacts.

Methods: The VIVA OpenHBM head-neck model, previously validated to PMHS data, was used for this study. To represent the 34 cervical muscles, Hill-type material model with 129 beam elements were used. Two different muscle activation control strategies were implemented: a control strategy to mimic neural feedback from the vestibular system and a control strategy to represent muscle spindle's feedback. To identify control gain values for these controller strategies, parameter calibrations were conducted using optimization. The objective in these optimizations were to match the physical test head linear and angular displacements. Model validation was conducted by comparing head displacements, head accelerations and head to headrest contact times to another set of published-volunteer data. Model performance involved an objective comparison of model and volunteer data.

Data Sources: Volunteer kinematics responses for the calibration were based on published data from 2 female subjects in low-speed rear impact test sitting in the rigid seat, while the data for the validation was based on a published volunteer data set including 8 female subjects in low-speed rear impact test sitting in a laboratory seat. All simulations were conducted using LS-DYNA version 9.2 while calibration simulations were conducted using LS-OPT 5.2.1.

Results: Gain values of the implemented muscle control strategies were successfully identified from calibration simulations. In all muscles control strategies, the onset of muscles activation was observed around 70ms after the start of the impact. Muscles activation changed the head kinematics by reducing both the peak linear and angular displacements, as compared to the model without muscles activation. For the muscle activation model mimicking the human vestibular system, a very good agreement was observed for the horizontal head translation. However, in the vertical direction there was a discrepancy of head kinematic response caused by anterior-posterior buckling of the cervical spine. In the model with a control strategy that represents muscle spindle feedback, improvements in head kinematics were observed in all directions and less cervical spine's buckling was observed. Both strategies captured essential muscle activities occurring in the crash, comparable to the volunteer responses. The control strategy that mimics the human vestibular system had greater head displacements than the volunteers and the head displacements of a control strategy representing muscle spindle feedback were even greater than the previous strategy.

Significance of Results: This study compares two different muscle activation strategies and gives insight into how muscles are recruited in a low severity rear impact. With further development, the results can be used to guide future HBM development and whiplash protection strategies.

4 Seating Configuration and Position Preferences in Fully Automated Vehicles

Sjaan Koppel[1], Jesús R. Jiménez-Octavio[2], Katarina Bohman[3], David Logan[1], Wassim Raphael[4], Leonardo Augusto Quintana Jimenez[5], Francisco J. Lopez-Valdes[2]

1. Monash University Accident Research Centre

2. Pontifical University Comillas

3. Volvo Cars

4. Saint Joseph University

5. Javeriana University

Objective: This study aimed to understand seating configuration and position preferences in a fully automated vehicle (FAV) across seven hypothetical travelling scenarios.

Methods: Participants completed an online survey where they were asked to imagine travelling in a FAV across seven hypothetical travelling scenarios (1: by themselves; 2: with a partner/spouse; 3: with a child occupant(s); 4: with a partner/spouse and child occupant(s); 5) with an older relative(s); 6) with a partner/spouse and older relative(s); and 7) with someone they don't know). For each travelling scenario, participants were asked to select one of five seating configurations and one of four seating positions for themselves and for any additional occupants. Furthermore, participants were asked to indicate any activities that they, and any additional occupants, would engage in during these scenarios, and whether they would be willing to wear a different seatbelt in a FAV while seated in a non forward-facing mode or while reclined.

Results: Five hundred and fifty-two participants (Male = 50.5%; Mean = 36.6 years, SD = 14.0 years, Range = 18 - 78 years) completed the online survey. Most participants resided in Australia (40.9%), Spain (16.5%), Sweden (15.6%), or Lebanon (19.4%). Most participants: held a valid driver's licence (98.9%), had no restrictions on their licence (77.4%), drove on a daily basis (60.0%), had driven between 5,000 and 15,000 km in the previous year (33.2%), and reported that they 'always' or 'almost always' wore their seatbelt while travelling in a motor vehicle (98.2%). Across all seven hypothetical travelling scenarios, participants were most likely to prefer a conventional seating configuration (i.e., all seats facing forward [between 40.0% - 76.3%]). In terms of seating position preferences, participants preferred seating position 'A' (i.e., the conventional driver's seat [between 54.6% - 68.3%]), regardless of with whom they were travelling. When asked about activities that they would engage in during these travelling scenarios, a wide variety of activities was specified. The most common activity while travelling alone was reading (25.0%), followed by listening to music / podcast / radio (13.0%). However, when travelling with other occupants, talking was the most common activity (41.0% - 63.0%) - even to someone they do not know (31.0%). Most participants predicted that they would 'always' or 'almost always' wear their seatbelt when travelling in a FAV (95.9%). Most participants also reported that they would be 'very willing' or 'willing' to wear a different seatbelt configuration in a FAV while seated in a non forward-facing mode or while reclined (73.8%, 80.7%, respectively).

Significance of Results: This study has provided valuable insight regarding seating configuration and position preferences in a FAV, as well as predicted activities and restraint use. Significant differences were found across seating configurations and position preferences depending on age, sex and country for some of the travelling scenarios. Future research will use this information to simulate likely injury outcomes of these preferences in the event of a motor vehicle crash, and provide a basis for the design of occupant protection systems for FAVs in the future

5 Submarining Sensitivity across Varied Anthropometry in Autonomous Driving System Environment

Katarzyna Rawska, Bronislaw Gepner, Jason Kerrigan, Shubham Kulkarni, Daniel Perez-Rapela, Kalle Chastain, Junjun Zhu, Rachel Richardson, Jason Forman

University of Virginia, Center for Applied Biomechanics

Objective: Self-driving technology will bring novelty in occupant seating choices as well in vehicle interior design. Thus, vehicle safety systems may be challenged to protect occupants over a wider range of potential postures and seating choices. For (seat back) reclined occupants, the risk of lap-belt submarining in frontal crashes is substantially increased. This study aims to investigate the effects of occupant size, seat recline angle and knee bolster position 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 three simplified Global Human Body Model Consortium (GHBMC) occupant models: small female, midsize and large male. Additionally, a detailed GHBMC 50th male model was used to compare with selected simplified cases. 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 seatback recline angle (0, 10, 20, 30 deg) and knee bolster position relative to the occupant (baseline, close, far, and no knee bolster) were varied. Impacts were simulated (without vehicle deformation) with the USNCAP 56 km/h frontal crash pulse. Occupant kinematics data was extracted from each simulation in a full-factorial sensitivity study to investigate how changes in anthropometry, seating position, and knee bolster position would affect submarining across all forty simulated case.

Data Sources: Forty full-vehicle FE frontal crash simulations with GHBMC occupant models.

Results: Overall, the 5th female model was more likely to submarine than the two male occupant models. Additionally, increasing the occupant-to-knee bolster distance resulted in more submarining cases. The threshold for submarining was also affected by the seat recline angle. The lowest threshold of 10 deg seatback recline angle was identified for small female, 20 deg for mid-size occupant, and 30 deg for large-size occupant. The lap belt position and pelvis orientation were good predictors of submarining. The results further show an increased lumbar flexion load and higher BRIC values with increased seat recline angle as well as occupant-to-knee bolster distance. The detailed GHBMC model was less prone to submarine than simplified model due to differences in model configuration.

Significance of Results: Submarining may be a major challenge to overcome for reclined occupants in autonomous driving systems (ADS). Further, this study shows that anthropometric variation and position of the knee bolster affect the risk of occupant submarining. Lastly, to our knowledge, this study is the first one to compare three simplified and a detailed GHBMC models in reclined postures.

6 Prospective Assessment of the Effectiveness of Autonomous Emergency Braking in Car-to-Cyclist accidents in France

Henri Chajmowicz[1], Sophie Cuny[2], Jacques Saade[2]

1. GIE Renault / PSA (LAB)

2. CEESAR

Objective: Assessing the effectiveness of an Autonomous Emergency Braking system in car-to-cyclist front collisions (AEB Cyclist), in a prospective and representative way. Giving results in terms of avoided accidents and mitigated injuries. Performing a sensitivity analysis on AEB Cyclist effectiveness with regards to its design parameters.

Methods: The analysis is based on car-to-cyclist real-world collisions gathered from police report in France and weighted for representativeness. In a first step, AEB Cyclist relevant cases involving passenger cars and cyclists were selected and used to build cyclist injury risk curves for fatal, severe and slight injuries. In a second step, accident cases were simulated by means of a car kinematic model involving sensor detection strategies and actuator actions, so as to simulate the effect of AEB. Combining the resulting simulated impact speed distributions, given that the car would be fitted with an AEB, with the injury risk curves allowed to assess the AEB system's effectiveness in terms of lives saved and mitigated injuries. Using Design of Experiments methods, we assessed the sensitivity of this effectiveness with regards to AEB design parameters.

Data Sources: The VOIESUR data base gathered all the fatal accidents that had occurred in France in 2011 and 5% of all accidents resulting in an injury, selected at random. About 8,500 accidents were coded and recorded with information related to the infrastructure, the vehicle, the occupants and the injury. The database is weighted to be representative of the accidental situation of France for year 2011. AEB relevant car to cyclist accidents selected among the database consist of 53 fatally injured, 383 severely injured and 634 slightly injured cyclists

Results: Results cover three areas: - The construction of cyclist injury risks curves with their confidence intervals for fatal, severe and slight injuries. They were built from a polytomous CLOGLOG regression model, using the squared impact speed as an independent variable. - The sensitivity analysis on AEB Cyclist effectiveness showed the influence of the decision algorithm and braking design parameters over the influence of detection parameters (e.g. magnitude of the field of view). - Results nevertheless show an AEB Cyclist effectiveness range from 35% to 59% in fatalities, 14% to 54% in severe injuries and 11% to 42% in slight injuries, depending on the field of view parameters alone, once reference values of the decision algorithm and braking design parameters have been set.

Significance of Results: This paper contains a prospective effectiveness assessment of a system that is the next trend in Advanced Driver Assistance Systems targeting Vulnerable Road Users protection. It is a first of its kind assessment of the potential of AEB cyclist in improving cyclist safety on French roads. A new set of injury risk curves for cyclists, along with their confidence interval curves, is also presented here for the first time. Moreover our paper highlights an original method to calibrate AEB-Cyclist by using Design of Experiments methods.

7 Linking Age-Related Cognitive and Visual Decline to Real-World Risk Exposure

Jennifer Merickel[1], Robin High[1], Jeffrey Dawson[2], Matthew Rizzo[1]

1. University of Nebraska Medical Center

2. University of Iowa

Objective: Our goal is to determine age-related factors that predict older driver risk. Drivers >76 years have among the highest fatal crash rates. Aging impairs abilities needed for safe driving, particularly vision and cognition, increasing crash risk. Environmental factors, like visibility and speed limit, may pose particular risk to impaired older drivers. We monitored real-world older driver vehicle control, in their own vehicles and driving environments, to identify how age-related impairments affect driver safety behaviors and risk.

Methods: We modeled driver vehicle control across environmental and driver covariates. Vehicle control outcomes were computed as acceleration variability (AV, SD) across lateral (AVy) and longitudinal (AVx) axes in 45-second segments (200,578 segments; 24,465 drives; 145,050 miles). Driver covariates were 1) Cognition: composite score from 8 neuropsychological exams relevant to driving and 2) Vision: contrast sensitivity visual acuity (ETDRS-5%, OU), relevant to low-visibility environments. Environmental covariates were 1) Roadway Type: 3 categories from Nebraska GIS speed limit data--a) residential (20-25mph), b) commercial (35-45mph), and c) interstate (>55mph) and 2) Visibility: from US Naval Observatory sunrise-sunset times--a) day (sunrise-sunset) and b) night (sunset-sunrise). We used mixed-effects beta regression models.

Data Sources: Participants were 77 legally licensed, active, older drivers (ages 65-90, mean=75.7). All drivers completed a standardized cognitive and visual assessment battery. A "Black Box" system installed in each driver's own vehicle continuously monitored driver behavior (e.g., GPS, speed, accelerometer) for 3 months.

Results: Overall, daytime environments had higher variability than nighttime and AV decreased with speed. Visual impairments reduced AVx on high-speed, interstate roadways during night driving (B=-0.004, SE<0.001, p<0.0001), which may indicate reduced driver responsiveness to safety-critical environmental changes, driver distraction, and reduced brake/accelerator pedal use. Visually impaired drivers had no at-risk AVx changes in residential and commercial environments (residential: B<0.001, SE=0.194, p=0.999; commercial: B=0.028, SE=0.052, p=0.592). AVy was unaffected by visual impairments, suggesting that impaired vision differentially impacts accelerating/braking behavior--likely from difficulty seeing the forward roadway in low-visibility conditions. Results link visual impairments to low-visibility, high-speed roadways--where rapidly changing driving environments challenge visually impaired drivers--increasing risk of high-speed, severe crashes. Cognitive impairments increased AVx on commercial and interstate roadways (B=0.112, SE=0.01, p<0.001) --indicating harsh braking/accelerating--during night and day driving. Interestingly, drivers with less cognitive impairment had overall higher AVx on residential roads than more impaired drivers (B=0.099, SE=0.009, p<0.001). This may suggest a lack of self-restriction for less cognitively impaired drivers in low-speed, residential environments in which less risk is perceived. Drivers with cognitive impairments also had impaired AVy that mirrored AVx patterns (residential: B=0.009, SE<0.001, p<0.001; commercial/interstate: B=0.003, SE=0.001, p=0.03), and AVy did not change with visibility. This suggests that driver risk from cognitive impairment is linked to roadway type, not visibility, and that cognitive impairments globally affect driver vehicle control (steering and braking/accelerating).

Significance of Results: Results underscore the complexity of mapping visual and cognitive impairments to real-world driver behavior, in-the-context of environment. Individual variation, driver risk acceptance, exposure, and driver strategies likely interact with results. Age-related visual and cognitive declines link to at-risk driver behavior in specific environments. Sensor-based technologies for monitoring real-world safety behavior and outcomes hold promise for developing strategic interventions that mitigate risk and preserve older driver mobility and quality of life. Interventions range from patient and clinician education, public policy, licensure recommendations, and advanced driver-assistance systems.

8 Characterization of the Motion of Booster Seated Children during Simulated In-Vehicle Pre-Crash Maneuvers

Valentina Graci[1], Ethan Douglas[1], Thomas Seacrist[1], Jason Kerrigan[2], Julie Mansfield[3], John Bolte[3], Rini Sherony[4], Jason Hallman[4]

1. Children's Hospital of Philadelphia

2. University of Virginia

3. The Ohio State University

4. Collaborative Safety Research Center, Toyota Motor North

Objective: Pre-crash occupant motion may affect head and trunk position and restraint performance in a subsequent crash, particularly for young children. Others have studied seat belt restrained adult drivers and adult and adolescent passengers in pre-crash maneuvers (Osth et al 2013, Holt et al 2018). For younger children, optimal restraint includes a belt-positioning booster seat which in pre-crash maneuvers may contribute in unique ways to the overall body motion. Therefore, the objective of this study was to quantify booster seated child occupant kinematic, kinetic, and muscle responses during pre-crash maneuvers.

Methods: Vehicle maneuver tests were conducted with a recent model year sedan at the Transportation Research Center Inc. (TRC, East Liberty, Ohio). Three pre-crash vehicle maneuvers were simulated: automated and manual emergency braking (AEB and MEB), constant radius turn (CRT), and oscillatory swerving (SLA). Each maneuver was repeated twice for each participant. Seven 6-8 year old booster-seated children participated in the study and all subjects were seated in the right rear seat. Data Sources Vehicle dynamics (i.e., motion, position, and orientation) were measured with an Inertial and GPS Navigation system (Oxford RT 3003). Kinematic and muscle activity data from human volunteers were collected with an 8-camera 3D motion capture system (Optitrack Prime 13 200Hz, NaturalPoint, Inc.). Photo-reflective markers were placed on participants' head and trunk. Electromyography (EMG, Trigno EMG Wireless Delsys, Inc., 2000 Hz) sensors were placed on bilateral muscles predicted to be most likely involved in bracing behaviorss.

Results: Children demonstrated greater head and trunk velocity in MEB (head 123.7 ± 13.1 cm/s, trunk 77.7 ± 14.1 cm/s) compared to AEB (head 45.31 ± 11.5 cm/s vs trunk 27.1 ± 5.5 cm/s) (p<0.001). Participants also showed greater head motion in MEB (20.1 ± 2.4 cm) vs AEB (15.1 ± 4.8 cm) but the differences were not statistically significant ($p=0.06$). Overall, the booster seats themselves did not move substantially (<3 cm) in the braking maneuvers. During the CRT, participants' head and trunk excursions were equal to 7.5 ± 5.9 cm and 8.4 ± 3.3 cm respectively with the booster seat motion contributing minimally to that movement (<= 3 cm). During SLA, the booster seat moved laterally up to 5 cm in several subjects contributing substantially to peak head (13.7 ± 9.9 cm) and trunk (9.3 ± 6.2 cm) excursion during the maneuver. Booster-seated children also exhibit a different muscle strategy than older age groups (Graci et al 2018) particularly in the lateral acceleration maneuvers: biceps and deltoid muscles, and abdominal and middle trapezii muscles were more active than the sternocleidomastoids during these maneuvers.

Significance of Results: The quantification of booster seat motion, neuromuscular control and the relationship between kinematics and muscle activation in booster seated children in pre-crash maneuvers provides important data on the transition between the pre-crash and crash phase for this younger age group and presents opportunities for interventions that integrate active and passive safety.

Thursday Abstracts

9 Quantifying Vehicle Control from Physiology in Type 1 Diabetes

Pranamesh Chakraborty[1], Jennifer Merickel[2], Viraj Shah[1], Anuj Sharma[1], Chinmay Hegde[1], Cyrus Desouza[2], Andjela Drincic[2], Pujitha Gunaratne[3], Matthew Rizzo[2]

1. Iowa State University

2. University of Nebraska Medical Center

3. Toyota Collaborative Safety Research Center

Objective: Our goal is to measure real-world effects of driver physiology in safety-critical tasks like driving. Drivers with type 1 diabetes (T1D) have an elevated crash risk that is linked abnormal blood glucose (BG): hypoglycemia (BG =70 mg/dL) and hyperglycemia (BG =300 mg/dL). Hypoglycemia, in particular, impairs abilities needed for safe vehicle operation (alertness, judgement, decision-making), and impairments may persist for hours after hypoglycemia resolves. Research is needed to determine 1) the levels of glucose control necessary for safe T1D driving and 2) physiologic patterns that predict T1D driver risk. We address this problem of patient and public safety by taking advantage of advances in sensor-based technologies that permit monitoring of driver behavior and physiology in real-time to discover patterns of at-risk physiology that impair T1D driving.

Data Sources: Drivers (18 T1D, 14 control) were monitored continuously (4-weeks) using in-vehicle sensors (e.g., video, accelerometer, speed) in each driver's own vehicle and wearable continuous glucose monitors (CGMs) that measured each T1D driver's real-time BG

Methods: Driver vehicle control was measured by vehicle acceleration variability (AV) across lateral (AVy, steering) and longitudinal (AVx, braking/accelerating) axes in 45 second segments (N=55,000). Average vehicle speed for each segment was modeled as a covariate of AV. T1D drives were restricted to those with a hypoglycemic episode within 72 hours prior to driving (mean=48.1 h, range: 0-72 h). Mixed-effects linear regression models were used. We tested the hypotheses that 1) T1D drivers would have impaired vehicle control (AV) behavior relative to controls, based on T1D driver physiology while driving, and 2) T1D drivers would show impaired vehicle control with more recent hypoglycemia prior to driving.

Results: We analyzed 3,145 drives (29,930 miles). T1D drivers had significantly higher overall AVx,y compared to control drivers (Bx=0.025, By=0.015, p<0.01)--which is linked to erratic steering or swerving and harsh braking/accelerating--regardless of whether their physiology while driving was normal or abnormal. While all drivers had reduced AV on higher speed roadways, T1D drivers showed greater reduction than control drivers (Bx=-5.624×10-4, By<-3.697×10-4, p<0.001). T1D drivers who had more recent hypoglycemia prior to driving had less overall AVx,y (Bx=1.48×10-4, By=1.4×10-4, p(x)<0.01, p(y)=0.02), which may reflect reduced driver responsiveness to safety-critical environmental changes, driver distraction, and less steering or brake/accelerator pedal use. T1D drivers with more recent hypoglycemia prior to driving had greater reductions in AV in braking/accelerating (AVx) than steering behavior (AVy). State Department of Motor Vehicle records for the 3 years preceding the study showed that at-risk T1D drivers accounted for all crashes (N=3) and 85% of citations (N=13) observed.

Significance of Results: Our novel results show that T1D driver risk can be linked to patterns of at-risk driver physiology, particularly hypoglycemia, and that driver risk can be detected and predicted during and prior to driving. Determining physiologic parameters for models of driver risk permits development of interventions that can operate prior to risk, preserving T1D driver safety, mobility, and quality of life. Sensor-based technologies can be combined with driver-assistance systems to develop in-vehicle technology capable of monitoring and predicting risk from an individual driver's physiology. Combining sensor data and phenotypes of driver behavior can inform patients, caregivers, interventions (education, training, medical), policy, and supportive in-vehicle technology responsive to driver state.

10 Risk Factors Associated with Boda-Boda (motorcycle) Accidents in Kampala, Uganda

Siya Aggrey[1], Benard Ssentongo[1], Abila Derrick Bary[1], Arthur Kato[1], Howard Onyuth[1], Denis Mutekanga[1], Isaac Ongom[1], Edimand Aryampika[1], Akim Tafadzwa Lukwa[2]

1. Makerere University

2. University of Cape Town

Objectives: According to the United Nations, nearly 1.25 million people are killed and up to 50 million people are injured on the world's roads every year. Uganda loses about 10 people daily to road accidents, costing about US$1.2 billion annually which represents about 5% of the GDP. The objective of this study was to identify causal factors that can be associated with boda-boda accidents in Uganda.

Methods: A cross sectional study assessed 200 boda-boda riders in the urban areas of Kampala, Uganda. Interviews using semi-structured questionnaires were administered to all participants. Data collected was entered in excel and imported to STATA for analysis. Multivariate and bivariate analyses were conducted to determine factors that influenced accident risk perception. All variables which were significant at bivariate level and thought to be theoretically important in influencing the outcome variable were included in a logistic regression model. All tests were performed at a significance of P<0.05.

Results: Competition for passengers with other public transport operators (83%), negligence of road safety rules (78%) and inadequate helmet usage (62%) were the main factors perceived to be associated with boda-boda accidents. Other factors identified by the respondents include age of the boda-boda rider (58%) and drug use (56%) (P<0.05). At multivariate analysis, competition for passengers (AOR 17, 95%CI 1.34-26.5) and being in between 18-25 years old (AOR 19, 95%CI 1.42-27.1) remained statistically significant.

Conclusion: This study revealed behavioral factors by all public transporters as the main factors associated with boda-boda accidents in the Urban Kampala. This demonstrates the need for holistic interventions to address such boda-boda accidents in Uganda. Such interventions can be through digitization of transport system for clients to engage remotely with the transport operators, routine refresher trainings of all transport operators and construction of lanes for boda-boda riders.

11 Vehicle-Pedestrian Crash Analysis for Head Injury Safety

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Objective: This paper investigates the influence of pedestrian height when subjected to a Sport Utility Vehicle (SUV) impact and the severity of concurrent injury. The primary focus is to analyse the real-world collision, considering vehicle velocity at the time of contact as well as the SUV front-end-shape which is a crucial factor in the location of impact on the pedestrian body.

Methods: Parametric analysis is conducted using multiple human body models with different heights. Additionally, the average SUV bumper height is taken as a benchmark, and based on the collision result the bumper height is optimised in order to minimise impact effect on the human model, considering their different heights. Furthermore, Kinematic responses of the pedestrian model is analysed using a combination of Finite Element method, HyperWorks, and Multi-body simulation using LS-Dyna. The injury severity on the pedestrian is investigated according to height effects of both the pedestrian and the vehicle bumper. The region of interest in the analysis is the human body model lower extremities, including femur, pelvis and fibula/tibia, in addition to the upper body rotation before impacting on the vehicles bonnet and the head potential to hit either the upper area of the bonnet or the windscreen

Data Sources: Data of average pedestrian heights, in different global regions, is implemented in the simulation of the human model. Also, multiple velocities of the vehicle are included in the parametric study ranging from 20 to 60 m/h in order to investigate how the speed reflects on the pedestrian model impacts on the bonnet.

Significance of Results: The impact velocity of the vehicle is the most critical parameter, influencing the severity of the injury and also the number of regions in the human model affected during the collision. Since injury severity can be reduced through the decrease of vehicle speed at the collision (uncontrolled parameter), the lower extremities and the head are still highly affected during lower speed impact. The second crucial parameter in reducing the impact effect is the height of the SUV front-end. Therefore, based on this paper's investigation the lower front-end-shape of an SUV could significantly minimise the injury severity at the vehicle-pedestrian collision, in addition to that, the angle at which the windscreen is designed could also reduce the head injury. The results shown in this paper reflects a positive potential in SUV front-end-design for safer pedestrian in the event of a vehicle-pedestrian accident.

12 Factors Associated with Chest Injuries to Front Seat Occupants in Frontal Impacts

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Objective: Chest injury, particularly for older occupants, has been a feature of frontal crashes for several decades. This study aimed to provide an update on factors contributing to chest injuries in frontal impacts involving European cars.

Methods: Crash injury data from the UK RAIDS-CCIS were interrogated, focusing on belted front-seat occupants in frontal impacts with air bags, pretensioners and load limiters. Detailed information was available on sample weighting, crash severity (EES), impact configuration and restraint performance. Occupant demographics, injuries and injury severity (AIS98) were matched to the vehicles. Descriptive statistics and appropriate significance tests were used to analyse the data.

Data Sources: UK RAIDS-CCIS crash injury data 2000 - 2018. Sample Size : 2965.

Results: The major factors related to chest injury showed little variation between the oldest and newest vehicle designs. Overall, the chest was the body region most frequently injured at AIS 2+, 3+ and 4+ severities. The rate of AIS 2+ and AIS 3+ chest injury was highest for elderly occupants. However, middle aged occupants also sustained chest injury at significantly higher rates than the young. Elderly occupants sustained their injuries at low mean crash severities, 32 km/h for AIS 2+ and 37 km/h for AIS 3+ injuries. Middle aged occupants sustained their injuries at higher mean speeds (34 km/h for AIS 2+ and 45 km/h for AIS 3+ injuries) but still below levels commonly adopted for crash testing. The front passenger seat, with a higher proportion of elderly females, was more often associated with significant chest injury than the driver seat. Skeletal injury was the most frequent type of AIS 2+ chest injury and more frequent for elderly occupants than for the young and middle-aged. With the increase in the number of rib fractures, the risk of pulmonary complications and organ injuries tended to increase. One interesting exception was that 40% of lung contusions occurred with only 1 or no rib fractures. The major source of chest injury was identified as the seat belt, in the absence of major intrusion. Which implies that an adaptive restraint system could be beneficial. Not only for elderly occupants but also for the middle-aged.

Significance of Results: Results of this study suggest that chest protection at lower impact energies is still an issue, and not only for the elderly, but for middle-aged occupants as well. It is anticipated that future vehicles will contain higher proportions of older occupants and be involved in lower speed crashes. Highlighting the need for crash test assessment using a more biofidelic ATD (THOR-M) with adjusted injury criteria thresholds and at lower impact speeds.

13 Pelvis Injury Risk Curves in Side Impacts at Different AIS Severities from Human Cadaver Experiments

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2. KBRwyle

Objective: Parametric statistical survival modeling (PSSM) is becoming the de facto standard for developing injury risk curves (IRCs) to describe human tolerance in automotive, aviation, and military environments. The original ISO recommendations have been improved to include measures such as the Brier Score Metric (BSM) to determine the hierarchical metrics. Although these novel methods have been applied to some impact environments, IRCs have not been derived for pelvis injuries in side impacts. Aim: reanalyze published data from postmortem human subjects (PMHS), develop IRCs, and determine the metric that best represents the mechanism of pelvic injury in side impacts using the BSM.

Methods: A variety of sled and pendulum tests conducted since the 1980s were examined. Data were censored (right, left, and interval). Variables such as the force and impulse were used to compute statistics such as the Akiake Information Criteria, areas under the receiver operator curves, and Normalized ±95% Confidence Interval Sizes (NCIS), and BSMs, using squared error loss methods. The Weibull (WB) log-normal (LN), and log-logistic (LL) distributions were the potential models for IRCs. Injuries were grouped into the Abbreviated Injury Scale (AIS) severities, AIS 2+ and AIS 3+ categories.

Data Sources: Published data from the Institut National de Recherche sur les Transports et leur Sécurité, the Medical College of Wisconsin, the Organisme National de Sécurité Routière, the University of Heidelberg, University of Michigan Transportation Research Institute, and Wayne State University were used for injuries, injury metrics and IRCs.

Results: Briefly, the WB and LN distributions for the force, and the WB distribution for the impulse were found to be the optimal functions at the AIS 2+ and 3+ severities. For the force at AIS 2+ and AIS 3+ severities, the NCIS ranged from 0.44 to 1.57 and 0.7 to 1.95, and for the impulse: 0.28 to 0.95 and 0.37 to 0.95. The BSMs were consistently lowest for the impulse (5.5 and 10.3 for AIS 3+, and 7.7 and 11.0 for AIS 2+ severities). Individual IRCs together with the ± 95% confidence intervals and NCIS at different risk levels will be given for all cases if accepted for a full-length paper submission.

Significance of Results: Using the PSSMs that accommodate data censoring, to our knowledge, this is the first study to provide IRCs for pelvic injuries in side impacts. The hierarchical identification of the impulse as the best injury predictor using BSM and the different optimal risk functions are also novel. While the present analyses were limited to previous tests, this study underscores the importance of using the impulse as the best metric for describing pelvis injury criteria in lateral impacts. Although risk curves have been developed for the WorldSID device, it may be appropriate to use the impulse metric from matched pair tests to derive dummy-based IRCs. Furthermore, because the THOR is being suggested as a possible additional device for automated vehicle environments due to its differing design from the other device, it may be appropriate to develop THOR-specific injury criteria. Matched-pair tests should be evaluated to develop these dummy-based risk curves for injury assessments and prediction, and the present IRCs serve as the fundamental human-based injury criteria, hitherto not reported in literature.

14 Fatal Side Impact Crash Scenarios for Rear Seat and Seat Belt Restrained Occupants from Vulnerable Population

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Objective: Previous studies have revealed vulnerability of school-age children and older adults in rear seats in motor vehicle crashes. Detailed information about crashes in which these fatalities occur could help improve vehicle and restraint design. The study objective was to identify factors that contribute to serious and fatal injuries in belted rear seat-occupants in side impact crashes in newer model year vehicles.

Methods: Crashes in which there was at least one fatally-injured, restrained rear seat occupant between the ages of 6 and 12 or 55 and older, in a passenger vehicle no older than 10 years at the time of the crash, were identified. Detailed on-scene photographs, autopsy reports, event data recorder and medical records were reviewed by an expert panel to determine mechanism of injury and survivability.

Data Sources: Crashes were identified in FARS based on the stated criteria. Police jurisdictions were contacted for investigative reports, crash photos, and autopsy/medical examiner reports, if available.

Results: Thirty-nine side-impact crashes were analyzed, resulting in 46 fatalities of interest. Fifty-nine percent of fatalities were a result of nearside collisions, though in juvenile cases only 42% were nearside compared to 70% nearside for adult cases. Sixty-one percent of occupants were in vehicles with side airbags, all of which deployed for their position. Of 14 cases with injury data, head and thorax injuries were most common. Impacts with pickup trucks and heavy trucks made up 31% and 22% of all cases, respectively. Roughly two-thirds of crashes were judged as survivable for the fatally injured occupant(s). All but one of the crashes deemed unsurvivable involved juvenile decedents. Further, of those deemed survivable, two-thirds had damage comparable in magnitude to the same vehicles in consumer information crash tests that are considered survivable, evaluated by photo comparison.

Significance of Results: Nearside impacts were more common than farside for adult decedents but not juvenile; in-depth analysis of injury risk for younger occupants in farside vs. nearside crashes is warranted. Head and/or thorax injuries were present in all cases. Side impacts in which younger occupants were killed were more severe than impacts which resulted in the death of an older occupant. However, vehicle damage and intrusion in many fatal impacts for both age cohorts appeared similar to that of consumer information testing. Large pickups and heavy vehicles were the striking vehicle in over half of all fatalities; vehicle designs and crash tests should continue to take this into consideration.

15 Head Injury Metric Response in Finite Element ATDs and a Human Body Model in Multidirectional Loading Regimes

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Objective: The objective of this study was to quantify head injury metric sensitivity of the 50th percentile male Hybrid III, THOR, and Global Human Body Models Consortium simplified occupant (GHBMC M50-OS) to changes in boundary conditions in loading regimes that may be experienced by occupants of highly autonomous vehicles (HAVs) or spaceflight vehicles with nontraditional seating configurations.

Methods: A latin hypercube (LHD) design of experiments (DOE) was employed to develop boundary conditions for 416 unique acceleration profiles. Three previously validated finite element (FE) models of the Hybrid III anthropomorphic test device (ATD), THOR ATD, and GHBMC M50-OS were positioned in an upright 90-90-90° seat and belted with a five-point harness. Acceleration pulses were applied to each of the three occupants in the ±X, Y, and ±Z directions, with peak resultant acceleration magnitudes ranging from 5-20 G and time to peaks ranging from 32.5-120.8 ms with duration 250 ms, resulting in 1,248 simulations. Head injury metrics extracted included peak linear head acceleration, peak rotational head acceleration, head injury criteria (HIC15), and Brain Injury Criteria (BrIC). Injury metric outcomes were regressed against boundary condition parameters using 2nd order multiple polynomial regression, and compared between occupants using matched pairs Wilcoxon signed rank analysis.

Data Sources: 1,248 simulations were generated using the Humanetics Hybrid III, NASA THOR, and GHBMC M50-OS 50th percentile male occupant models using LS-DYNA v.7.1.2 on a high performance computing cluster.

Results: Across the 416 simulations, HIC15 values ranged from 1.0-396.5 (Hybrid III), 1.2-327.9 (THOR), and 0.6-585.6 (GHBMC). BrIC ranged from 0.03-0.95 (Hybrid III), 0.03-1.21 (THOR), and 0.04-0.84 (GHBMC). Wilcoxon signed rank analysis demonstrated significant pair-wise differences between each of the three occupant models for HIC, BrIC, peak linear head acceleration, and peak rotational head acceleration ($p<0.001$) when grouping all simulations. Loading direction sub-analyses were completed, but for brevity results from only two injury metrics are presented here. Quartiles were defined such that rear impact loading was quartile 1 and 4, frontal impact loading, quartile 2 and 3, and vertical (underbody, eyeballs down) loading were in quartile 1 and 2. For HIC15, the largest divergence between GHBMC and the ATDs was observed in simulations with components of both underbody loading and rear impact loading (blue, Figure 1). For other loading regimes, the models preformed more similarly. The three models performed most similarly with respect to BrIC output when loaded in a frontal direction. Both the GHBMC and the Hybrid III produced lower values of BrIC than the THOR on average, with the differences most pronounced in rear impact loading (blue, gray, Figure 2).

Significance of Results: With the advent of novel seating postures that may be employed in HAVs (e.g. reclined, supine, oblique/lateral-facing), occupants may experience high energy crashes that load the occupant in directions not traditionally observed in motor vehicle crashes (e.g. rear, vertical). The response of ATDs to these non-frontal impacts is unknown compared to human body models (HBMs), which are designed to be biofidelic omnidirectionally; only select comparisons, typically in frontal and side impacts, have been made between these models. Since repeat physical testing on such a large scale is usually cost-prohibitive, understanding the expected difference between ATDs and HBMs will help ensure restraint systems are not under-designed based on ATD models. Furthermore, the inclusion of the HBM elucidates significant areas of difference between ATDs and human subjects.

16 Detailed Subject-Specific FE Rib Modelling for Fracture Prediction

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2. Autoliv Development

3. ÅF Industry

4. The Ohio State University

5. Virginia Tech

6. University of Michigan **Objective**: Current state of the art human body models (HBMs) can predict the number of fractured ribs, but it has not been proven that they can also predict fracture location. If secondary soft tissue injuries such as lung or liver lacerations resulting from rib fractures should be modelled and predicted by HBMs, it is important to first predict rib fracture locations. Currently, the level of anatomical detail and model complexity required to accurately capture fracture location is unknown. This leads to the research questions for this study: can subject-specific finite element (FE) rib models, based on state-of-the-art clinical CT combined with material data from coupon testing, accurately predict rib fracture location? To what extent can the rib model be simplified and still capture rib fracture location?

Methods: High resolution clinical CT data was used to generate detailed subject-specific geometry for twelve sixth rib FE models. The cortical bone periosteal and endosteal surfaces and thickness were estimated based on a previously calibrated cortical bone mapping algorithm. In a first step both the cortical and the trabecular bone were modelled using a hexa-block algorithm resulting in a high-quality hex mesh. The cortical bone for each rib was assigned subject-specific material data based on tension coupon tests, while the trabecular bone material parameters were assigned based on a statistical model mapping the CT estimated density to stiffness. Isotropic material models were used for both the cortical and trabecular bone. The capability of the FE model to predict fracture location was carried out by subjecting each rib to a dynamic anterior-posterior rib bending test. The rib model predictions were directly compared to the results from physical tests. The force-displacement time history, strain measurements at four locations, rotation of the rib ends and fracture location were compared. Rib fracture location in the FE model was estimated as the position for the element with the highest first principle strain at the time corresponding to rib fracture in the physical test. Modelling the progressive damage of the actual fracture of the rib was not included in this study.

Data Sources: Detailed data from 12 anterior-posterior rib bending tests, including force and strain time history data, high resolution clinical CT data, and material coupon test data.

Results: For seven out of the twelve ribs the model accurately predicted the fracture locations. For the same seven ribs there was agreement (a CORA score above 0.75) between the predicted and measured force-displacement curve. For the other five rib models neither the force-displacement curves nor the fracture location were accurately predicted. It was observed that the stress-strain response for the coupon test for these five ribs showed significantly lower Young's modulus, yield stress, and elongation at fracture compared to the other seven ribs. It can be hypothesized that the difference between the two groups can be attributed to cortical bone heterogeneity (e.g., porosity) which could influence material test results as well as the cortical bone mapping algorithm.

Significance of Results: This study provides guidelines for further enhancements of rib modelling for accurate fracture location prediction in HBMs, and is a necessary step to enable modelling of soft tissue injuries resulting from rib fractures.

17 Validated Thoracic Vertebrae and Costovertebral Joints Increase Biofidelity of a Human Body Model in Omnidirectional Hub Impacts

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Objective: A recent emphasis on non-traditional seating and omnidirectional PDOFs has motivated the need for deformable representation of the thoracic spine (t-spine) in human body models. The goal of this study was to develop and validate a deformable t-spine for the Global Human Body Models Consortium (GHBMC) M50-O (average male occupant) human model, and to demonstrate improved biofidelity.

Methods: Eleven functional spinal units (FSU) were developed with deformable vertebrae. Cortical and trabecular bone were modeled as shell and solid elements with a plastic-kinematic constitutive model employing commensurate properties for each. Spinal and costovertebral joint ligaments were added to each unit as elastic spring beams with properties from the biomechanical literature (Chazal et al. 1985, Pintar et al. 1986). Intervertebral disk meshes were added with annulus fibrosus and nucleus pulposus regions matching literature descriptions (Pooni et al. 1986; Fig.1). The radiate ligament was modeled with shell elements. FSUs were subjected to quasi-static loads per Panjabi et. al. (1976) in 6 degrees of freedom for a total of 99 FSU simulations. Stiffness values were calculated for each moment (Nm/deg) and translational force (N/μm). Updated CV joints of ribs 2, 6 and 10 were subjected to moments along 3 axes per Duprey et. al. (2010). The response was optimized by maximum force and laxity in the ligaments. Fifteen CV joint validation cases were run. In both cases, updated models were compared to the baseline approach which employed rigid bodies and joint-like behavior. The deformable t-spine and CV joints were integrated into the full GHBMC M50-O model v. 5.0 and 3 matched cases were run (updated vs. baseline): (1) a rear pendulum impact per Forman et. al. (2015) at speeds up to 5.5 m/s. (2) a lateral shoulder impact per Koh et al. 2005 at 4.5 m/s. (3) a chest impact per Kroell et al. 1972 at 6.7 m/s. Objective evaluation protocols were used to evaluate the time history response vs. experimental data and an average was obtained from all output signals for each full body simulation.

Data Sources: Literature descriptions of experiments for FSUs and CV joints (Panjabi et al. and Duprey et al.), and full body PMHS experiments (Koh et al., Forman et al. and Kroell et al.). The GHBMC M50-O 50th percentile male occupant model, modified with updated t-spine mesh furnished via GHBMC collaborators. Simulations were conducted using LS-Dyna v7.1.2.

Results: All FSU responses showed reduced stiffness vs. baseline. Tension, extension, torsion and lateral bending became more compliant than the experimental data. Like the experimental results, no trend was observed for joint response by level. CV joints showed good biofidelity. The response at ribs 2 and 6 were closer to the rib level data than baseline while rib 10 closely matched experimental rib 10 data. Objective evaluation scores of full body tests indicated unchanged performance in frontal impact and a ~25% improvement in biofidelity in posterior and lateral hub impacts.

Significance of Results: CV joint validation has not been previously published in any human model and together with FSU validation yielded notable improvements in lateral and rear impacts at the full body level. A hierarchical validation of the spine will increase confidence in out of position occupant simulations. Future work will focus on localized injury criteria made possible by the introduction of a deformable representation of the t-spine anatomy.

Friday Abstracts

18 Age-Based Differences in the Disability of Extremity Injuries in Pediatric and Adult Occupants

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Objective: The objective was to develop a disability-based metric for motor vehicle crash (MVC) upper and lower extremity injuries and to compare the functional outcomes between children and adults.

Methods: Disability risk (DR) was quantified using Functional Independence Measure (FIM) scores within the National Trauma Data Bank—Research Data System (NTDB-RDS) for the top 95% most frequently occurring Abbreviated Injury Scale (AIS) 3 extremity injuries (22 unique injuries). Pediatric (7-18 years), young adult (19-45 years), middle-aged (46-65 years) and older adult (66+ years) MVC occupants with FIM scores and at least one of the 22 extremity injuries were included. DR was calculated for each injury as the proportion of occupants who were disabled out of those that sustained the injury. A maximum AIS-adjusted disability risk (DRMAIS) was also calculated for each injury which excluded occupants with more severe AIS 4+ co-injuries.

Data Sources: The top 95% most frequently occurring AIS 3 extremity injuries were selected from the National Automotive Sampling System-Crashworthiness Data System years 2000-2011. Disability was quantified from 8,587 pediatric, 23,966 young adult, 22,249 middle-aged, and 6,102 older adult MVC occupants in NTDB-RDS v7.1 (2008).

Results: Locomotion impairment was the most frequent type of disability across all age groups. DR and DRMAIS of the AIS 3 extremity injuries ranged from 0.05 to 1.00 (5-100% disability risk). Disability risk increased with age, with DRMAIS increasing from 24.5±9.0% (mean±SD) in pediatrics to 30.2±6.4% in young adults, 39.7±7.1% in middle-aged adults, and 59.7±13.2% in older adults. DRMAIS for each pediatric injury is plotted against the DRMAIS of that injury for the young adult, middle-aged, and older adult age groups in Figure 1, indicating lower overall disability in pediatrics compared to adults. Pediatric DRMAIS was moderately correlated with DRMAIS of young adult (R-squared=0.52), middle-aged (R-squared=0.56), and older adult (R-squared=0.32) occupants. DRMAIS for upper extremity fractures differed significantly between age groups ($p<0.001$), with higher disability in older adults, followed by middle-aged adults. Pair-wise significant differences in upper extremity fracture DRMAIS existed between all age groups ($p=0.001$), except for the pediatric versus young adult comparison. DRMAIS for pelvis, hip, shaft, and other lower extremity fractures differed significantly between age groups (all $p<0.01$). Older adult DRMAIS was significantly higher for these lower extremity fracture types, when compared to each of the younger age groups. DRMAIS for hip and lower extremity shaft fractures was also significantly higher in middle-aged compared to pediatric and young adult occupants ($p<0.009$). The maximum AIS-adjusted mortality risk (MRMAIS, proportion of fatalities amongst MAIS 3 occupants sustaining the injury) was not correlated with DRMAIS for extremity injuries in pediatric, young adult, middle-aged, and older adult occupants (all R-squared<0.01). As shown in Figure 2, the disability associated with each extremity injury was higher than the mortality risk. DRMAIS ranged from 5-49% in pediatrics and 19-100% in adults, while MRMAIS ranged from 0-7% in pediatrics and 0-17% in adults.

Significance of Results: Older adults had significantly greater disability than each of the other age groups for upper and lower extremity injuries sustained in MVCs. Lower disability rates in children may stem from their increased physiological capacity for bone healing and relative lack of osteoarthritic and other bone disease. The disability metrics developed in this study can supplement AIS and other severity-based metrics by accounting for the age-specific functional implications of MVC extremity injuries.

19 A Comparison of Seat Belt Fit and Comfort Experience between Older Adults and Younger Front Seat Passengers in Cars

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Objective: The purpose was to study the aging effect on seat belt fit and perceived comfort by comparing elderly and younger occupants in the front seat of a passenger vehicle.

Methods: A user study was performed in the front seat of a large passenger vehicle in a laboratory environment. Each participant first entered the vehicle and buckled up, in a pre-defined seat position. Then they adjusted the seat to their preferred seating position, and buckled up again. No driving occurred. Anthropometric data was collected of height, weight, waist and hip circumferences; photographs and measurements were taken of seat/seatbelt positions, belt fit and posture; and structured interviews were conducted regarding perception of the two tested scenarios, and also previous experience and awareness of seat belt usage and discomfort as passengers in cars.

Data Sources: Data from 11 elderly (72-81 years, 6 men and 5 women, average BMI 29 for men and 25 for women) and 11 younger participants (25-30 years, 6 men and 5 women, average BMI of 27 for men and 26 for women) was collected.

Results: Poor belt fit included shoulder belt far out on the shoulder, close to neck or lap belt over the abdomen. Four out of 11 elderly had poor belt fit in the pre-defined position and in the preferred position five elderly had poor belt fit. Only one of them showed safety awareness and recognized the poor belt fit in the preferred position. In the younger group, one out of 11 had poor belt fit in the pre-defined position and two in the preferred position. Both of these acknowledged the poor belt fit. Elderly participants with more pronounced kyphotic posture, got the upper part of the shoulder belt closer positioned to the suprasternal notch, compared to younger participants. Elderly were more likely to have the lower part of the shoulder belt higher up on the abdomen compared to the younger participants. Also participants with higher BMI were more likely to have the shoulder belt higher up on the abdomen, independent of age and gender. When the shoulder belt was positioned higher up on the abdomen, the upper portion of the shoulder belt was routed closer to the neck. Elderly preferred to sit higher up, more upright and forward to achieve a good field of vision, compared to the younger participants. Three elderly and one young participant sometimes brought add-on accessories to improve comfort when riding in a car. These included cushions to either increase sitting height or support the lumbar spine.

Significance of Results: The change in body posture due to aging influences seatbelt fit and experienced discomfort. The elderly were less aware of safety related to seat belt fit and less explorative when it comes to adjusting the seat. These findings should be taken into account when designing restraint systems in future vehicles, to ensure safety for all ages of occupants.

20 Accuracy of Algorithms to Predict Injury Severity in Older Adults for Trauma Triage

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Objective: Older adults make up a rapidly increasing proportion of motor vehicle occupants and previous studies have demonstrated that this population is more susceptible to traumatic injuries. The CDC recommends that patients anticipated to have severe injuries (Injury Severity Score = 16) be transported to a trauma center. The recommended target rate for undertriage is less than 5% (not transporting a severely injured patient to a trauma center) and no greater than 50% for overtriage (transporting a less severely injured patient to a trauma center). Several regression-based algorithms for injury prediction have been developed in order to predict severe injury in occupants involved in a motor vehicle collision (MVC). The objective of this study to was to determine if the accuracy of regression-based injury severity prediction algorithms decreases for older adults.

Methods: Data from adults involved in non-rollover MVCs were correlated with severe injury (Injury Severity Score = 16). Regression-based injury risk models were developed using the following variables: age, delta-V, direction of impact, belt status, and number of impacts. Separate models were trained using data from the following age groups: all adults, younger adults (18-54 years), and older adults (55+ and 65+ years). These models were tested against corresponding age groups. The models were compared using the mean receiver operating characteristic area under curve (ROC-AUC) after 1,000 iterations of random sampling with 80% of the data for model training and 20% for model testing. The predicted rates of overtriage were then determined for each group in order to achieve a undertriage rate of 5%. Data Sources: Data was obtained from the National Automotive Sampling System - Crashworthiness Data System (NASS-CDS) from years 2000-2015 (N=16,343 cases).

Results: Of the 16,343 occupants included in this analysis, 20% (3,329) were 55+ years old and 10% (1,763) were 65+ years old. The injury prediction model trained using data from all adults did not perform as well for older adults (ROC-AUC: 18-54 years: 0.880, 95% CI: 0.879-0.880; 55+ years: 0.823, 95% CI: 0.822-0.825; and 65+ years: 0.812, 95% CI: 0.810-0.814). The accuracy of this model decreased significantly in each decade of life [Figure 1]. The performance did not change significantly when age-specific data was used to train the prediction models (ROC-AUC: 18-54 years: 0.879, 95% CI: 0.879-0.880; 55+ years: 0.821, 95% CI: 0.819-0.822; and 65+ years: 0.807, 95% CI: 0.805-0.809) [Figure 2]. With an undertriage rate of 5%, the overtriage rate predicted by these models was 46% for occupants 18-54 years, 64% for occupants 55+ years, and 68% for occupants 65+ years.

Significance of Results: The results of this study indicate that it is more difficult to accurately predict severe injury in older adults involved in an MVC. The injury risk models decreased in accuracy with increasing age and this accuracy is not improved by using age-specific data to train models. This decrease in accuracy is likely due to substantial variations in fragility in older adults. These findings indicate that special care should be taken when using regression-based prediction models to determine the appropriate destination for older occupants. It was not possible to stay below the target 50% rate for overtriage in older adults. Improving these models may require the incorporation more clinical information from emergency medical responders, such as mental status or external injuries.

21 Evaluation of Finite Element Human Body Models for use in a Standardized Protocol for Pedestrian Safety Assessment

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Objective: Finite element human body models (HBMs) must be certified for use within the EuroNCAP pedestrian safety assessment protocol. We demonstrate that the Global Human Body Model Consortium (GHBMC) simplified pedestrian series of HBMs meet all criteria set forth in Technical Bulletin (TB) 024 (v 1.1 Jan., 2019) for model certification. We further explore variation in head contact time (HIT) and location by HBM size and impact speed across 48 full body impact simulations).

Methods: The EuroNCAP Pedestrian Protocol (v. 8.5, Oct. 2018) assesses the overall safety of adult and child pedestrians by outlining a variety of physical tests and finite element simulations using HBMs. These tests are designed to assess the efficacy of vehicle safety technology such as active bonnets. The 50th percentile male simplified pedestrian model (M50-PS, H:175 cm, W:74.5 kg), six-year-old (6YO-PS, H:117 cm, W:23.4 kg), 5th percentile female (F05-PS, H:150 cm, W:50.7 kg), and 95th percentile male (M95-PS, H:190 cm, W:102 kg) were simulated through the suite of cases totaling 48 simulations (12 each). The process gathers three kinematic trajectories and contact force data from designated anatomical locations. The impacting vehicles include a family car (FCR), multi-purpose vehicle (MPV), roadster (RDS), and sports utility vehicle (SUV), each simulated at 30 kph, 40 kph, and 50 kph. Each simulation underwent a 23-point pre-simulation check and post-simulation model response comparison. The posture of all HBMs met criteria consisting of 15 measures. All simulations were conducted in LS-Dyna R. 9.1.

Data Sources: EuroNCAP Technical Bulletin (TB) 024 (v 1.1 Nov., 2019), EuroNCAP Pedestrian Testing Protocol (v 8.5 Nov., 2018). Four publicly available standardized generic vehicles and boundary conditions for each simulation were provided by TU Graz, Vehicle Safety Institute as part of the Coherent Project. Four GHBMC simplified pedestrian models were used.

Results: All simulations normal terminated. For each of the simulations, sagittal plane coordinate histories of the center of the head, 12th thoracic vertebrae, and center of acetabulum were compared with standard corridors and did not exceed the tolerance of 50 mm deviation (Figure 1). Head contact time was also compared with the reference values and did not exceed the tolerance interval of +3.5% and -7%. Comparison of contact forces were required for monitoring purposes only. The head contact time of the models for each simulation were recorded and compared by model size, impact speed, and vehicle geometry (Figure 2). Head contact times varied by roughly 3-fold, were lowest for the child model, and showed the greatest sensitivity for the tallest stature model (M95-PS). As stated in the certification process, other body sizes within a model family qualify for certification if the 50th percentile male model passes, provided that model sizes meet the required posture.

Significance of Results: Vulnerable road users continue to be overly represented in the global health burden of road traffic injuries. When systems with active bonnets are installed, HBMs are required for use in the EuroNCAP pedestrian protocol to determine the hardest to detect occupant. Compliance must be demonstrated by the vehicle manufacturer in-house in accordance with the procedure in TB 024. This study will serve as a benchmark for the compliance of these models within the certification procedure. In addition, the data provided show a range of head contact times anticipated across a broad range of body habitus, impact speeds and vehicle types.

22 Billboard Impacts on Crashes on a Suburban Highway: Comparing Three Periods - Billboards Present, Removed, and then Returned:

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Objective: The objective of this study was to examine the impact of advertisement billboards on crash occurrences on the road while considering two interventions: removing billboards and their subsequent restoration.

Methods: The analysis compared the crash numbers before and after each intervention, on the treatment road sections, while accounting for changes in crash numbers in comparison-group sections (with no or rare billboards), during the same periods. The analysis considered three periods: before - 2006-2007, when billboards were present; during - 2008-July 2009, when billboards were covered or removed; after - September 2009-2012, when billboards were restored. The statistical tool was a refined application of Odds Ratio, with fitting explanatory models to monthly time-series of crash events. Using these models, the annual numbers of crashes "saved" or "added" due to the interventions were estimated. Data Sources: Crash data were extracted from the database of the Ayalon Highway Traffic Control Center which keeps a record of all unusual events occurring on the road including crashes. The analysis examined injury crashes, damage-only crashes and the sum of both.

Results: The results showed that removing the billboards was associated with a decrease of 30% to 40% and restoring the billboards - with an increase of 40% to 50%, in injury crashes on the road. The changes in crash patterns were similar for damage-only, injury and all crashes and when analysed according to daytime versus nighttime or weekdays versus weekends. The estimated savings in crash numbers during the removal period were up to 100 damage-only and 50 injury crashes a year, the estimated crash additions in the after period were up to 120 damage-only and 30 injury crashes a year.

Significance of Results: The study provided empirical evidence on the positive safety impact of removing billboard advertising from the roadsides of a suburban highway and of the negative safety impact of billboard presence. The results were consistent through repeated crash analyses. The stronger impact values observed in the study, compared to previous research, may be related to the road type considered - a heavily-travelled route with a high density of interchanges thus generating higher demands on the driving task; to the high frequency of conspicuous billboards along the roadsides that can hardly be ignored, and to a comprehensive crash database that empowered the statistical analyses.

23 Underutilized Strategies in Traffic Safety: Results of a Nationally Representative Survey

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Introduction: About a third of the US traffic crash fatalities are due to speeding, another third are due to alcohol-impaired driving, while almost half of the drivers and passengers in cars who were killed were not wearing their seat belt. Numerous strategies that are proven effective in reducing crash fatalities have been underutilized. These include: sobriety checkpoints; automated enforcement including speed cameras and red light cameras; lowering the blood alcohol concentration (BAC) limit for driving to .05 g/dL; primary enforcement safety belt and motorcycle helmet use laws; and many others

Objective: Which of these underutilized measures would be favorable to the American public given they are educated on the research of their effectiveness?

Methods and Data Sources: A representative survey of 2,000 U.S. drivers was conducted in October 2018 with 30 questions about these underutilized strategies using the National Opinion Research Center's (NORC's) AmeriSpeak® survey instrument. Our hypothesis was that if the public is in favor of many of these strategies it could change the safety culture in the US and provide the "political will" to implement them and save thousands of lives.

Results:Given a summary of the studies of the effectiveness of these strategies, below are the weighted percentages of respondents in favor of their utilization. The margin of error in these percentages is plus or minus 2.98%. Sobriety Checkpoints: 64.7% were in favor of conducting sobriety checkpoints at least monthly. Speeding: 60.3% were in favor of using speed and red light cameras for automated enforcement. Alcohol-Impaired Driving: When asked if they thought the BAC limit should be lowered to .05 in their state, 49.7% said yes while 49.3% said no. Seat Belt Usage: 82.4% were in favor of a primary seat belt law in their state. In addition, 70.1% were in favor of a law that required all cars to have seat belt reminders that continuously chime until the seat belt is buckled including rear seat passengers. 62.5% were in favor of raising the fine in their state for not using a seat belt from $25 to $100. Speed Limits: 68.6% were in favor of lowering the speed limits by 5 miles per hour in their community if crash studies justify it. Highway Engineering: 72.9% of respondents were in favor of roundabouts replacing the most dangerous intersections in their community. 89.6% were in favor of more rumble strips on certain roads in their community to prevent crossing over the center or lane line.

Significance of Results: The results of this survey indicate that when drivers in the U.S. are given facts about certain countermeasures or strategies to reduce traffic crash fatalities, the majority are in favor of the underutilized strategies. This should be communicated to legislators and highway safety officials in each state who are reluctant to implement some of these strategies. The majority of drivers are in favor of these strategies if they have potential to save lives.

24 A Driving Simulator Study for the Evaluation of the Effectiveness of Perceptual Treatments in Reducing Speeds Approaching a Sharp Curve of a Rural Road

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Objective: Several studies have demonstrated that road crashes are more likely to occur on horizontal curves than on tangent sections because of the increased demands placed on the driver and the vehicle that could lead to a wrong choice of speed and trajectory. To handle this problem and improve road safety, especially that related to speeding and vehicle control along a curve, several in-vehicle systems and road treatments have been developed over the years. Among the various road safety treatments, low-cost perceptual measures are considered an effective tool, as they generally increase the risk perceived by drivers or even alter their speed perception, and consequently cause them to decrease their speed. Their effectiveness has been widely recognized in a number of studies. The overall aim of this study is to investigate the effectiveness of different perceptual treatments in reducing the drivers' approaching speed to two sharp curves (right and left curves). Specifically, this research was aimed at identifying the pavement marking patterns that provide the best improvement in terms of drivers' speed reduction on two curves of an existing two-lane rural road. As the selected curves are currently characterized by a high crash rate (mainly due to speeding behaviour), this study has another goal consisting in identifying the most effective measure to reduce speed and defining its subsequent implementation in the field. It was also decided to investigate possible additional effects of the treatments' colours, as no studies have analysed this topic before, and consequently provide a further contribution to the field-related literature

Method: To achieve the set objectives, a driving simulator study was developed and four speed-reducing measures on curves (chevrons, white peripheral transverse bars, red peripheral transverse bars and optical speed bars) were tested over a randomly selected sample of forty-four drivers. The driving speeds were finally compared to those recorded under a baseline condition (with no treatment applied).

Data Sources: In order to investigate the effectiveness of perceptual treatments in reducing the driver's speed at the approach and along the curves, speed records were taken at six measurement points. In particular, three points were fixed respectively at 300 m, 200 m, and 100 m from the beginning of the curves, whereas the other three points were located at the beginning (B), at the middle point (H) and at the last point (E) of the curves, respectively. Moreover, subjective measures consisting of the driver's static evaluation of desired speed, risk perception and markings comprehension, were collected. Specifically, these measures were based on screen shot pictures that represented the simulated configurations of the treatments.

Results: The outcomes from the tests demonstrated an overall effectiveness of the perceptual treatments. Particularly, the red peripheral transverse bars were found to be the most effective measure in terms of reduction of the driving speeds. In addition, the analysis of the questionnaires yielded valuable information demonstrating the importance of performing driving simulation tests for the evaluation of the effectiveness of perceptual treatments.

Significance of Results: Results confirmed the enormous potential of driving simulators in assessing the viability and design of several speed-reducing measures, thereby allowing the selection of the most effective one in terms of cost reduction and safety promotion, in view of its actual implementation on the field.