



SAFE AND SOUND

PAVING THE WAY

2017
Annual Report

CChIPS | Center for Child Injury Prevention Studies

PARTNERING FOR SAFETY

Welcome to the CChIPS 2016-2017 Project Year!

The Center for Child Injury Prevention Studies (CChIPS) takes a unique approach to child safety research. For over a decade, CChIPS has been a hub of innovation and collaboration for industry members and academic researchers committed to improving the safety of children and adolescents.

A Message from Our Directors



Kristy Arbogast, PhD, John H. Bolte IV, PhD,
and Flaura Winston, MD, PhD, co-directors, CChIPS

Founded in 2005 by the National Science Foundation (NSF), CChIPS' unique partnership includes research sites at the Children's Hospital of Philadelphia (CHOP) Research Institute and The Ohio State University (OSU), and our Industry Advisory Board (IAB) comprises 22 member organizations from industry, advocacy, and government agencies.

In 2016-2017, the IAB funded 13 completed research projects, bringing the Center's 12 year total to more than 130 completed projects across the Center's five-domain research agenda. This multitude of projects has fostered the development of multiple lines of research, including crash avoidance and autonomous vehicles; vehicle restraint performance; child restraint design and performance; consumer/driver behavior; and crash test dummy biofidelity.

In this Annual Report, you will find highlights of live conversations held with our principal investigators about their CChIPS projects, where they discuss a range of topics including project aims, results, and industry relevance. We hope that this report allows the expertise,

passion, and dedication of our CHOP and OSU-based research scientists to shine through. These conversations also illuminate just how important a role our IAB members play in the research process and the iterative process that makes CChIPS research so unique.

- Industry Advisory Board Members: Page 2
- Financial Update: Pages 3-4
- 2016-2017 Project Highlights: Pages 5-18
- Supplemental Research Funding: Pages 19-20

The Center's research portfolio is continually evolving to address current challenges and emerging issues. CChIPS is also committed to the ongoing engagement of its stakeholders and to the translation of rigorous science into action with measurable impact. At the annual Advances in Child Injury Prevention (ACIP) Conference, held in Plymouth, MI in November 2016, attendees from over 30 companies came to hear experts from academic, policy, and advocacy institutions share their latest research on occupant safety and other road traffic injury topics related to children and adolescents.

In addition, CChIPS – through its parent center at CHOP, the Center for Injury Research and Prevention – utilizes a team of outreach and communication experts who focus on translating CChIPS research findings into appropriate messages and materials designed to reach target audiences. This includes digital communication strategies to share information such as the cchips.research.chop.edu website, which saw a 33 percent increase in site visits in calendar year 2016.

We look forward to sharing many more achievements with you in the future.

IAB MEMBER COMPANIES



◆ Founding IAB Member Company ★ 2016 ACIP Conference Sponsor – Gold ★ 2016 ACIP Conference Sponsor – Silver

CChIPS Mission Statement

The CChIPS mission is to advance the safety of children, youth, and young adults by facilitating scientific inquiry into childhood and young adult injuries and to translate these findings into commercial applications and educational programs for preventing future injuries.

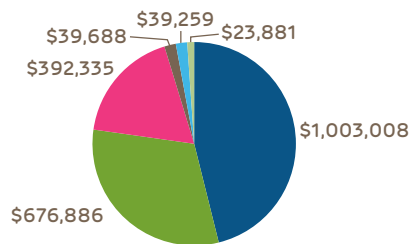
For current IAB membership, please visit cchips.research.chop.edu.

FUNDING THE RESEARCH

CChIPS is made possible through a grant from the National Science Foundation (NSF), as well as sponsorships from its Industry Advisory Board (IAB) member companies. The IAB is comprised of leaders in industry, small business, nonprofits, and government agencies that engage in and value scientific research and development to improve child safety. Every year, each member company contributes an annual membership fee and receives a seat on the IAB, full voting rights, and early access to and involvement in the research portfolio chosen by the Board. Recognizing the importance of small businesses, government and non-profit agencies in achieving the child safety mission, these organizations can become a part of the Board for a reduced annual fee, with commensurate reductions in benefits; government agencies are non-voting with all other rights intact. One key role of the IAB is project mentorship. This ongoing involvement helps to ensure rapid translation of research results into new products, policies and programs. Membership in CChIPS has fostered industry and small business commitment to the CChIPS mission and spurred innovation. To become a member or to sponsor research with CChIPS investigators, please contact us at cchips@email.chop.edu.



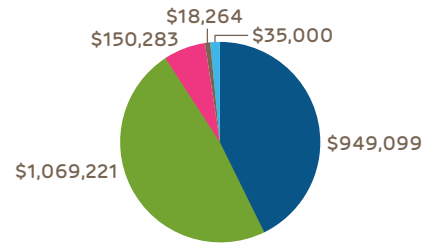
REVENUE FOR 2017



- IAB Member Companies' Contributions
- Additional Member Company Contributions
- NSF Supplemental Funding
- Meeting Revenue
- Directors Discretionary
- NSF Center Award

*Total Revenue: \$2,175,057

EXPENDITURES FOR 2017



- Projects Awarded (IAB Funding)
- Projects Awarded (Additional Member Company Contributions and Supplemental Funding)
- Admin/Operating/Evaluator Expenses
- Meeting Expenses (ACIP & IAB Meetings)
- Marketing Expenses


Total Expenditures: \$2,221,867

*Gap represents decrease in NSF grant support as CChIPS moves into final funding phase for a "mature" center. Membership fee increases in 2017-2018 will bridge this gap.

HOW DO WE CALCULATE THE CCHIPS ROI?

The CChIPS Industry Advisory Board (IAB) has three different membership types tied to varying annual fees:


Large Business
\$50,000


Government/Nonprofit
\$25,000


Small Business
\$15,000

22 Members

\$865,000 in research funds
excluding supplemental funds

The research pool funded 16 projects in 2016-2017, which fall within five interest areas. Projects are often categorized in more than one area.


Child Restraint
Design and
Performance

8 Projects

\$748,789*




Consumer/Driver
Behavior

7 Projects

\$574,946*





Crash Avoidance
& Autonomous
Vehicles

3 Projects

\$349,170*




Vehicle Restraint
Performance

8 Projects

\$923,640*




Dummy
Biofidelity

2 Projects

\$188,563*



What Does the CChIPS ROI Look Like for One Member?

In 2016-2017, a large business  with an interest in vehicle restraint performance  contributed \$50,000 for access to research valued at \$923,640.

* These values include the cost of individual projects coupled with the institutional indirect rates from academic partners to more accurately represent the actual cost of conducting research.

RESEARCH IN ACTION:

2016-2017 Project Highlights

To make the CChIPS research portfolio more accessible to a broad audience with a range of professional backgrounds and expertise, we asked our principal investigators to tell us about their projects. We hope you enjoy the highlights from these conversations. Full abstracts for each project are available on the [CChIPS website](#). Detailed technical reports are made available to IAB member companies, and findings from the majority of projects are published in the peer-reviewed literature.

PROJECT INTEREST AREAS

The CChIPS research portfolio can be categorized by five interest areas below. Look for these icons next to each project summary.



Child Restraint Design and Performance



Consumer/Driver Behavior



Crash Avoidance & Autonomous Vehicles



Vehicle Restraint Performance



Dummy Biofidelity

GLOSSARY OF COMMONLY USED TERMS

ATD – anthropomorphic test device; also known as a crash test dummy

CRS – child restraint systems; including rear- or forward-facing car seats and belt-positioning booster seats

FMVSS 213 – Federal Motor Vehicle Safety Standard used to certify child restraints

LATCH – Lower Anchors and Tethers for Children; a standardized method of attaching child restraints to motor vehicles

NHTSA – National Highway Traffic Safety Administration; an agency of the US Department of Transportation dedicated to saving lives, preventing injuries, and reducing economic costs due to road traffic crashes



EVALUATION OF SIDE IMPACTS WITH A FRONTAL COMPONENT FOR CHILDREN IN CRS (YEAR 3)

Principal Investigator:

Kristy Arbogast, PhD, Children's Hospital of Philadelphia

Project Team Members:

Hans W. Hauschild, MS, Medical College of Wisconsin; **Bruce Kaufmann, MD**, Children's Hospital of Wisconsin & Medical College of Wisconsin; **Matthew R. Maltese, PhD**, Children's Hospital of Philadelphia; **Frank A. Pintar, PhD**, Medical College of Wisconsin; **Narayan Yoganandan, PhD**, Medical College of Wisconsin

Students:

John R. Humm, Medical College of Wisconsin; **Jared Koser**, Milwaukee School of Engineering

IAB Mentors:

Keith Nagelski, Britax Child Safety, Inc.; **Eric Dahle**, Evenflo Company Inc.; **Amanda Taylor**, Federal Aviation Administration; **Neeharika Anatharaju**, FCA US LLC; **Lan Xu**, FCA US LLC; **Mark LaPlante**, Graco Children's Products Inc.; **Jerry Wang**, Humanetics Innovative Solutions Inc.; **Mark Humer**, Lear Corporation; **Sara Seifert**, Minnesota HealthSolutions; **Hiromasa Tanji**, TK Holdings Inc.; **Uwe Meissner**, Technical Advisor

CAN YOU DESCRIBE THIS PROJECT IN A FEW SENTENCES?

Over the course of this multi-year project, we've tested different features of forward-facing CRS and how each provide protection in oblique impacts. This focus is driven by interest in protection in side impact crashes; in the real world those crashes are more likely oblique than directly lateral. In this third year, we focused on examining the performance of the three different lower attachment methods by which CRS are fixed to the vehicle anchor points without the use of vehicle seat belts: standard LATCH (a single flexible LATCH belt routed through a CRS belt path); ISOFIX (a rigid attachment from the CRS to vehicle anchor points); and dual flexible attachments (two small belts secured on either side of the CRS with each attached to the vehicle anchor points).

WHAT DID YOU FIND?

While the ISOFIX rigid attachment provided the best performance, the dual attachment—developed with the support of our car seat manufacturer project mentors—performed similarly to the rigid attachment when used with a top tether. We were able to document a benefit in decreased head excursion, suggesting an advantage to having a two-belt design over the single LATCH belt.



High speed video image of Q3s ATD kinematics at time of maximum excursion in rigid ISOFIX attached FF CRS without a tether. Inch tape line on right side of vehicle seat represents typical door or side structure intrusion.

WHAT DO YOU FIND INTERESTING ABOUT THESE RESULTS?

In the first two years of the study, we saw that the CRS rotated and tipped toward the direction of impact. We hypothesized that only a rigid attachment could prevent this motion but were surprised and excited to see that the dual flexible attachment was a good alternative. This also has implications for what we found in Year One where, because of the rotation of the CRS when attached via a single flexible LATCH belt, the child's head had limited interaction with the side wings. Our finding here in Year Three shows that if we can use the lower attachments to help control that rotation, the side wings can do what they are designed to do—contain and protect the child's head. A second important finding was that across all three years of research, the kinematics of the child seat were improved with the use of the tether.



EVALUATING THE EFFICACY OF BELT POSITIONING BOOSTER DESIGN (HIGH-BACK, LOW-BACK AND HEIGHTLESS BOOSTER) IN FRONTAL AND FAR SIDE OBLIQUE IMPACTS

Principal Investigator:

Aditya Belwadi, PhD, Children’s Hospital of Philadelphia

Project Team Member:

Kristy Arbogast, PhD, Children’s Hospital of Philadelphia

Students:

Evan Bisirri, Drexel University; **Nhat Duong**, Drexel University; **Seth Fein**, University of Pennsylvania; **Jalaj Maheshwari**, University of Pennsylvania

IAB Mentors:

Keith Nagelski, Britax Child Safety, Inc.; **Michael Kulig**, Calspan Corporation; **Emily Thomas**, Consumer Reports; **Eric Dahle**, Evenflo Company Inc.; **Zine Ben Aoun**, FCA US LLC; **Amanda Taylor**, Federal Aviation Administration; **Julie Kleinert**, General Motors Holdings LLC; **Mark LaPlante**, Graco Children’s Products Inc.; **Jerry Wang**, Humanetics Innovative Solutions Inc.; **Russ Davidson**, Lear Corporation; **Mladen Hume**, Lear Corporation; **Eric Veine**, Lear Corporation; **Arjun Yetukuri**, Lear Corporation; **Jon Sumroy**, mifold; **John Combest**, Nissan Motor Company; **Hiromasa Tanji**, TK Holdings Inc.; **Schuyler St. Lawrence**, Toyota USA; **Barbara Birkenshaw**, Volkswagen Group of America, Inc.; **Uwe Meissner**, Technical Advisor

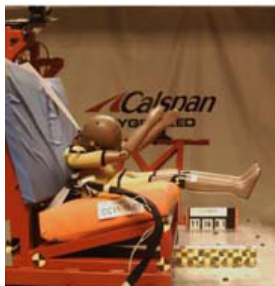
CAN YOU BRIEFLY DESCRIBE YOUR PROJECT?

We were interested in looking at the effect of changes in lap-shoulder belt routing and ATD performance across different types of booster seats. In a new category of child seats, the heightless booster seat, the shoulder belt is pulled down to the level of the child instead of traditionally lifting (“boosting”) the child to the level of the belt. These seats also change the forward position of the lap belt, making it lay flatter on the thighs than on the pelvis. Our basic research objective was to compare ATD performance for various impact types across four child booster/restraint designs: high-back, low-back, inflatable and heightless boosters.

HOW DID YOU ACCOMPLISH THIS, AND WHAT DID YOU FIND?

We conducted 40 sled tests using an instrumented Q6 crash dummy with abdominal pressure sensors and a hip liner in various seating positions, and combined those with computational modeling of the Q6 finite element model. We then explored how performance varied across a number of variables: differences in seating position for the three types of booster seats and across frontal, oblique, and side impacts.

One of the key findings was that across the various seating conditions, all booster seats performed well in terms of ATD kinetics - such as head, chest, and pelvis acceleration - being well within the Injury Assessment Reference Values specified by NHTSA. However, this did not always match up to the kinematics seen in videos of the sled testing and in the computational modeling. That is a very important study finding because it shows a limitation of the dummy capabilities. This is something we are looking to address in year two, which will be one of the first projects to utilize a 6-year-old human body model rather than a dummy.



No Booster



Heightless



HBB



LBB

Comparison of low-back (LBB), high-back (HBB), heightless boosters and a no booster condition in a frontal (0 degree) impact.



MEASURING ATD RESPONSES IN CHILD SEATS INSTALLED ACROSS VARYING LOWER LATCH ANCHOR SPACING

Principal Investigator:

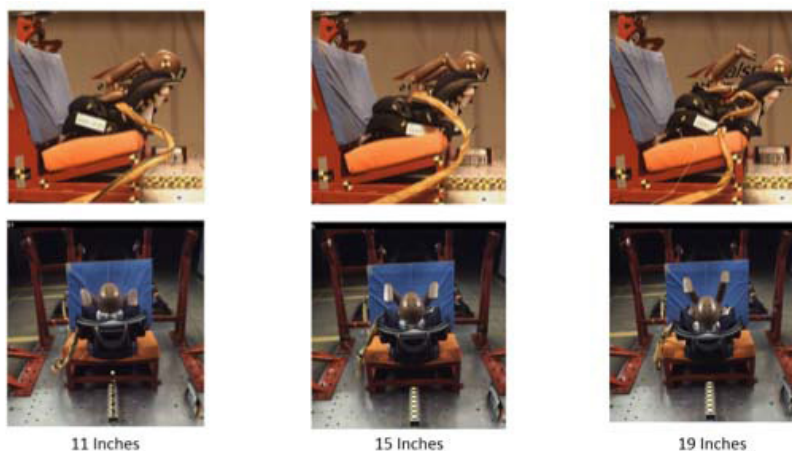
Aditya Belwadi, PhD, Children's Hospital of Philadelphia

Students:

Evan Bisirri, Drexel University; **Nhat Duong**, Drexel University; **Seth Fein**, University of Pennsylvania; **Jalaj Maheshwari**, University of Pennsylvania

IAB Mentors:

Keith Nagelski, Britax Child Safety, Inc.; **Eric Dahle**, Evenflo Company Inc.; **Zine Ben Aoun**, FCA US LLC; **Anthony Rosetto**, FCA US LLC; **Julie Kleinert**, General Motors Holdings LLC; **Mark La Plante**, Graco Children's Products Inc.; **Tim Patrizi**, Graco Children's Products Inc.; **Arjun Yetukuri**, Lear Corporation; **Jon Sumroy**, mifold; **John Combest**, Nissan Motor Company; **Hiromasa Tanji**, TK Holdings Inc.; **Schuyler St. Lawrence**, Toyota USA; **Barbara Birkenshaw**, Volkswagen Group of America; **Uwe Meissner**, Technical Advisor



Comparison of rear-facing infant seats across 11, 15 and 19 inches of lower LATCH anchor spacing.

CAN YOU DESCRIBE THIS PROJECT IN A FEW SENTENCES?

Although research has shown a safety benefit to restraining children in CRS in the center rear seating position, most manufacturers do not allow for this installation with LATCH because of vehicle design constraints. This leads to some parents “borrowing the LATCH,” where they install the CRS in the center rear seating position (that does not have LATCH anchors) by using the LATCH anchors borrowed from the outboard seating positions. To test this “borrowing the LATCH” installation, we compared the standard LATCH spacing (11 inches) with the increased spacing that could occur with “borrowing” (15 and 19 inches) in a series of sled tests: the test matrix included a rear-facing infant seat, rear-facing convertible seat, and a forward-facing seat, with and without top tether in frontal (0 degrees), oblique (30 degrees) and side impacts (80 degrees).

WHAT DID YOU FIND?

Before beginning the project, we were concerned that non-standard, wider LATCH spacing would compromise the safety

of the child occupant. When we analyzed the data, we actually found that the wider anchors resulted in some improved kinetics; the loads decreased and accelerations improved. Think about this: when you go camping, you pitch your tent anchors as wide as possible because if there are any crosswinds, this will make sure that your tent doesn't rotate or flip over. That's exactly what's happening here – as the LATCH anchors widen, even in side impacts, there is reduced rotation or tilting of the CRS. In fact, there is a statistically significant safety benefit to wider anchors.

HOW CAN THESE FINDINGS IMPACT INDUSTRY?

The current recommendation from CRS manufacturers and CPS technicians would be that if the vehicle does not allow for center seating LATCH, then the CRS must be installed in one of the outboard seating positions. Based on the scientific evidence provided by this project, vehicle and CRS manufacturers may consider updating these recommendations and providing additional options to allow for CRS to be installed safely in the rear seating position with LATCH.



PERFORMANCE OF REAR-FACING CHILD RESTRAINT SYSTEMS IN REAR IMPACTS

Principal Investigator:

Julie Bing, MS, The Ohio State University

IAB Mentors:

Keith Nagelski, Britax Child Safety, Inc.; **Emily Thomas**, Consumer Reports; **Eric Dahle**, Evenflo Company Inc.; **Fariba Famili**, FCA US LLC; **Mark LaPlante**, Graco Children's Products Inc.; **Mladen Humer**, Lear Corporation; **Hiromasa Tanji**, TK Holdings Inc.; **Barbara Birkenshaw**, Volkswagen Group of America; **Uwe Meissner**, Technical Advisor

CAN YOU DESCRIBE THIS PROJECT IN A FEW SENTENCES?

The goal of this project was to understand the performance of rear-facing child restraint systems (CRS) in rear impacts, to fill a specific gap in knowledge. The majority of the literature focuses on frontal and side impacts because these are the most common and injurious crash scenarios. However, as best practice is to keep children rear-facing for as long as possible, we wanted to put additional scientific support behind this recommendation. We conducted a series of 12 sled tests at a moderate severity rear impact sled pulse using four different models of rear-facing CRS installed with 12-month-old and 3-year-old ATDs.

WHAT WAS THE MOST SURPRISING FINDING OF THIS PROJECT?

One thing we were expecting to see was excess rearward rotation of the child restraints and resultant head contact of the occupant against the vehicle seat back or head restraint. What we saw was that in our moderate-severity, moderate-speed sled tests, seven out of 12 CRS did not rotate to the point of head contact due to the tension on the seat belt, the lower anchor installation, or anti-rotation devices. In some tests, we either didn't see any head contact at all against the head restraint or seat back, or the contact that was recorded would not lead to a serious injury. We were really happy to see that result.

HOW WERE YOUR FINDINGS RELEVANT TO YOUR INDUSTRY SPONSORS?

In the US, we're lacking a lot of the rear-impact data that many European countries have, as some European standards require rear-impact testing of child restraints. It's an overlooked crash scenario. Even the test benches that we use in the US aren't able to replicate a rear-impact very well because the back of a test bench is different from a vehicle seat. We hope that the industry can look at this study to see what can happen in a realistic crash scenario that more closely mimics a vehicle seat.



During a moderate severity rear-impact, the 12-month-old ATD in this CRS rotated toward the rear of the vehicle seat. Rotation was slowed by the interaction between the CRS base and the vehicle seat, and head contact never occurred.



SURVEY OF CAR SEAT USAGE, KNOWLEDGE, AND ATTITUDES

Principal Investigator:

John Bolte, PhD, The Ohio State University

Project Team Members:

Julie Bing, MS, The Ohio State University;
Arrianna Willis, BS, The Ohio State University

IAB Mentors:

Emily Thomas, Consumer Reports; **Eric Dahle**, Evenflo Company Inc.; **Anthony Rosetto**, FCA US LLC; **Amanda Taylor**, Federal Aviation Administration; **Lorrie Walker**, Safe Kids Worldwide; **Melissa Miles**, State Farm Mutual Automobile Insurance Company; **Uwe Meissner**, Technical Adviser

CAN YOU DESCRIBE THIS PROJECT AND YOUR MOTIVATION FOR PURSUING IT?

This project created a bridge between researchers and the caregivers who use child restraints on a daily basis by asking them to fill out an online survey. As researchers, we work with industry to gain insight and to keep our research relevant, but we felt a little removed from consumers. We hoped this project would help us understand where caregivers are coming from: if they're having issues with child restraint products; if there is anything that we might be missing through our viewpoint of research and industry.

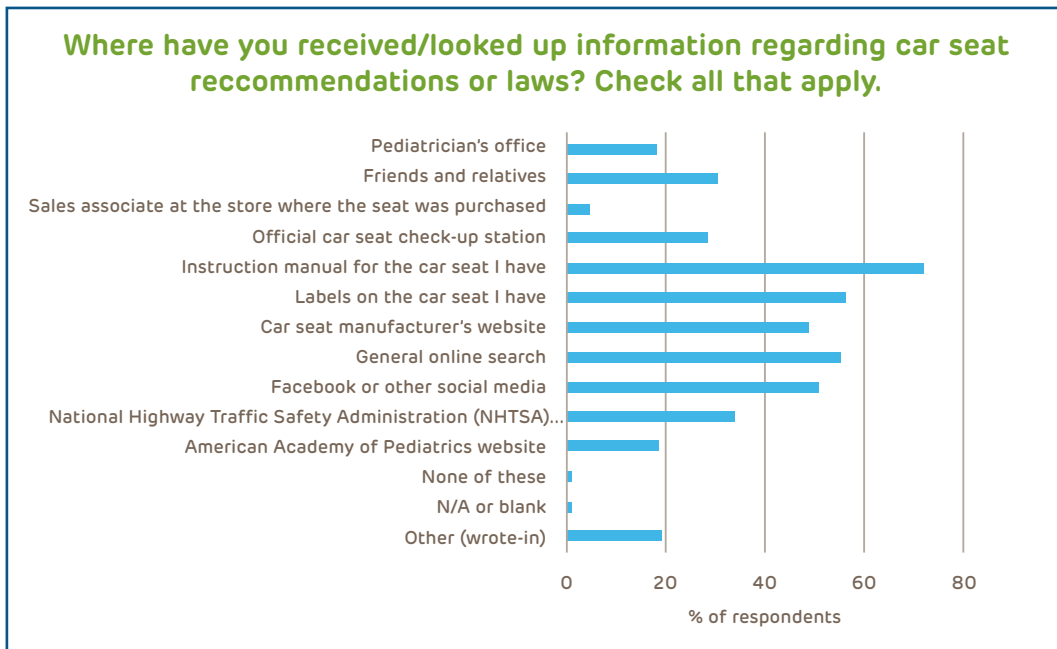
and perceptions of various aspects of child passenger safety. The survey included a few questions about using child restraints on airplanes. This has been looked at somewhat in industry, but a lot of the work up to this point has focused on how CRS fit in the airplane seats – if they are compatible – and how to install them. What was surprising to us was that a lot of parents described the challenges of carrying child restraints through the airport and getting them physically on the airplane because the aisle is not wide enough. We hadn't thought about these things from a crash-safety perspective, but they are still very relevant to the user population.

WHAT WERE YOUR FINDINGS? WAS ANYTHING SURPRISING?

We received 1,120 survey responses to questions spanning the children they regularly transport, the types of car seats used, any difficulties experienced, and their knowledge, attitudes,

WHAT ARE YOUR NEXT STEPS?

We hope to pull new project ideas out of the data that we have collected. Also, the project itself is unique because we are going to keep this survey active for several years; new parents can continue to fill out our survey and give us up-to-date feedback as new products come out.



Results from 1,120 survey respondents identify the most common sources of car safety information and suggest that 1) targeting these sources with accurate and up-to-date information may be a useful education strategy; and 2) increasing pediatrician involvement in car safety appears to be an area for improvement.



ATD LOWER EXTREMITY INTERACTION WITH THE FRONT SEAT BACK DURING SLED TESTS

Principal Investigator:

Laura C. Boucher, PhD, ATC, The Ohio State University

Students:

Saskia Richter, The Ohio State University;

Jared Seidel, The Ohio State University

IAB Mentors:

Julie Kleinert, General Motors Holdings LLC; **Mark Neal**, General Motors Holdings LLC; **Jerry Wang**, Humanetics Innovative Solutions Inc.; **Mladen Humer**, Lear Corporation;

Hiromasa Tanji, TK Holdings Inc.; **Barbara Birkenshaw**, Volkswagen Group of America; **Uwe Meissner**, Technical Adviser

CAN YOU DESCRIBE THIS PROJECT IN A FEW SENTENCES?

We wanted to evaluate how a child’s legs will interact with the vehicle interior when seated in the rear seat during a frontal collision. There’s evidence that legs are getting injured in these crashes, but we’ve never really looked at how they are getting hurt. In this project, we explored this by using a prototype crash test dummy, developed with Humanetics, in the rear seat to assess how the legs are moving and interacting with the front seatback during a simulated crash scenario.

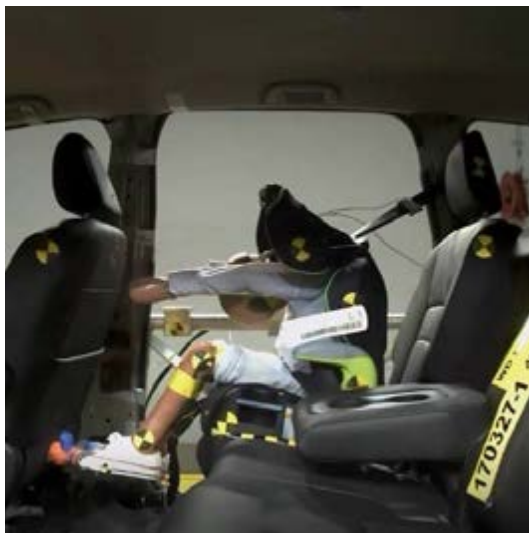
WHAT MOTIVATED YOU TO STUDY THIS TOPIC?

We knew that kids were getting hurt below the knee and in the foot in some crash scenarios, but we didn’t understand how and why. The available 6-year-old child crash test dummy doesn’t have the instrumentation to record load responses below the femur, so in a previous project we worked with Humanetics to develop a dummy that could. Now, we are using this new crash test dummy in a real-world scenario to learn about how kids are getting injured in automobile crashes.

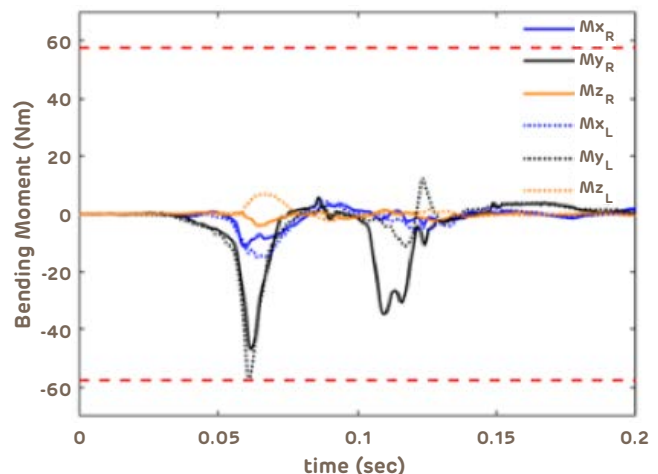
WHAT WAS THE MOST SURPRISING FINDING OF THIS PROJECT?

The most surprising finding was the discovery that there is a lack of standardization in the automotive industry in the materials used to construct the front seatback. It can be really soft or really hard. Our finding is that the material and the amount of space between the front seat and rear seat makes a difference on injury risk. The harder the material is, the higher the chance of injury if the child interacts with that front seatback, whether the child’s legs are in a relaxed position and swing into the seatback or if the child’s feet are touching the front seatback at the time of impact.

We are continuing to learn about rear seat safety of children as well as adults and how the environment can really impact safety. From that standpoint, this project has helped us to come up with questions to take back and explore with industry.



Test 1: Seat Forward, Legs Relaxed, Wood Seatback Tibia Movement



Sled test simulating a frontal collision using FMVSS 213 pulse (left). The blue and pink chalk marks reveal the feet hit the lower front seatback, forcing the ankles into plantar flexion. The figure on the right depicts the tibia moment response from this sled test, indicating values almost exceed injury threshold (red-dashed lines).



DYNAMIC TOP TETHER LOADS IN VARIOUS ANCHOR LOCATIONS IN SIDE IMPACTS

Principal Investigator:

Yun Seok Kang, PhD, The Ohio State University

Project Team Members:

Hyun Jung Kwon, PhD, The Ohio State University;

Rakshit Ramachandra, PhD, The Ohio State University

Student:

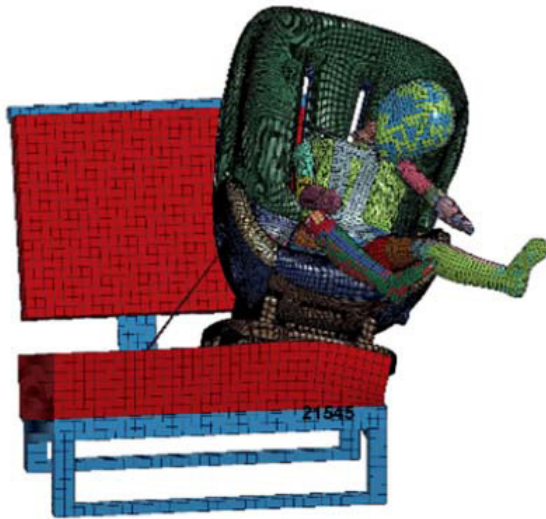
Jared Seidel, The Ohio State University

IAB Mentors:

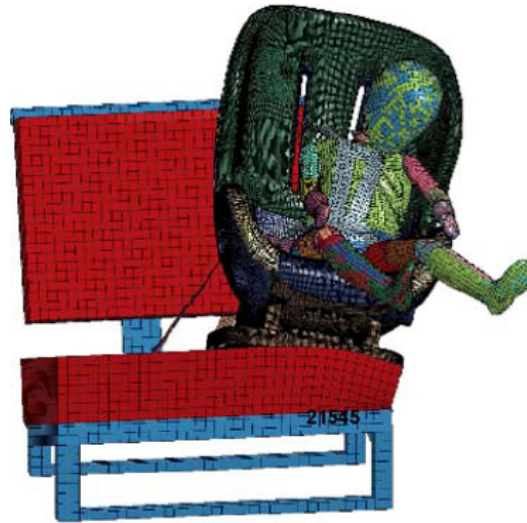
Keith Nagelski, Britax Child Safety, Inc.; **Eric Dahle**, Evenflo

Company Inc.; **Julie Kleinert**, General Motors Holdings LLC;

Barbara Birkenshaw, Volkswagen Group of America



(a) Far side lateral impact with no top tether



(b) Far side lateral impact with top tether

The images show that the top tether reduced head excursion and CRS rotation in far-side lateral impact (10 degrees from the pure lateral impact).

WHAT IS THE BACKGROUND FOR THIS PROJECT?

LATCH is a standardized method of attaching child seats to vehicle seats. The top tether provides an excellent safety advantage when used properly, by reducing forward displacement of the child's head and, therefore, reducing the likelihood for injury. However, the effectiveness of top tether location on the dynamic load in a side impact scenario has not been thoroughly pursued, so this became the aim of our project.

HOW DID YOU INVESTIGATE THIS?

We wanted to see the effect of various parameters, such as seat stiffness, CRS design, and seat contour, on top tether loads. We created a finite element model that could simulate side impact conditions using the FMVSS 213 side impact test bench and a forward-facing CRS with a Q3S ATD model. We used a LATCH system to attach the CRS and measured lower anchor and top tether loads. We also recorded ATD kinematics for the simulation. Then we performed a

parametric study to find out which parameters affect the top tether load, as well as the lower anchor force. We found that the top tether reduced lower anchor loads in both lateral and oblique impacts and that the top tether reduced CRS rotation and lateral head excursion of the ATD head in various testing conditions.

WHAT ARE THE NEXT STEPS FOR THIS AREA OF RESEARCH?

With the completion of this project and previous CChIPS research, we now have information on the importance of top tethers for the side impact and frontal impact scenarios. Next steps should involve merging this information to quantify the maximum force or maximum load on the top tether – the “worst case scenario” that can be applied to the top tether during impact. This information can be utilized by CRS and vehicle manufacturers to ensure these maximum loads are not exceeded and child occupants are optimally protected.



THE ROLE OF VEHICLE SEAT CUSHION STIFFNESS AND LENGTH IN CRS PERFORMANCE

Principal Investigator:

Yun Seok Kang, PhD, The Ohio State University

Co-Principal Investigator:

Julie Bing, MS, The Ohio State University

Students:

Laura Jurewicz, The Ohio State University;
Yadetsie Zaragoza-Rivera, The Ohio State University

IAB Mentors:

Russ Davidson, Lear Corporation; **Mladen Humer**, Lear Corporation; **Arjun Yetukuri**, Lear Corporation

CAN YOU DESCRIBE THIS PROJECT IN A FEW SENTENCES?

The wide variety of rear seat occupant sizes makes it challenging to optimize the seat parameters because the optimal solution for one population may be different from another's. Recent work has shown that shortening seat cushion length is better for the older child and small adult population. However, the shorter, thicker cushion may negatively affect the youngest rear seat occupants who ride in a CRS. Our goal was to investigate whether the seat cushion plays a role in CRS performance and if seat stiffness and length can be optimized to best support our youngest vehicle occupants restrained in CRS. Sled tests were conducted with three different levels of cushion stiffness and two different seat lengths, utilizing three types of CRS with size-appropriate ATDs.

WHAT WERE YOUR FINDINGS? DID ANYTHING SURPRISE YOU?

We found that rear-facing CRS installed on short vehicle seats experienced more rotation. In addition, differences in CRS performance across vehicle seats were less obvious for other types of CRS, although forward-facing CRS appeared to benefit slightly from the shorter seat cushion. We also found that the belt-positioning booster performed better on the longer seat cushion. However, surprisingly, none of the CRS appeared to be very sensitive to the variations of seat cushion stiffness.

HOW CAN THESE FINDINGS HELP TO IMPROVE CHILD SAFETY IN MOTOR VEHICLES?

We hope that manufacturers can better understand seat cushion length and stiffness in order to design a universally safe rear seat that can mitigate injuries for all potential passengers.



Booster seat occupant in a frontal impact, using a seat cushion shortened by the addition of the blue spacer.



DRIVING ANALYTICS: COMPARISON OF TEEN AND ADULT NATURALISTIC CAR-FOLLOWING PATTERNS (YEAR 2)

Principal Investigator

Helen Loeb, PhD, Children’s Hospital of Philadelphia

Co-Principal Investigator

Thomas Seacrist, MBE, Children’s Hospital of Philadelphia

Students:

Ethan Douglas, University of Pennsylvania; **Ayya Elzarka**, University of Pennsylvania; **Charles Gottlieb**, Jack M. Barrack Hebrew Academy; **Leora Haber**, Princeton University; **Elaine Huang**, Lafayette College; **Abe Kashem**, University of Pennsylvania; **Taryn McKinney**, University of Pennsylvania; **James Megariotis**, Drexel University; **Danielle Mendoza**, Widener University; **Abhiti Prabahar**, University of Pennsylvania; **Adin Solomon**, Jack M. Barrack Hebrew Academy

IAB Mentors:

Zine Ben Aoun, FCA US LLC; **MaryAnn Beebe**, General Motors Holdings LLC; **Julie Kleinert**, General Motors Holdings LLC; **Mark Neal**, General Motors Holdings LLC; **Melissa Miles**, State Farm Mutual Automobile Insurance Company; **Uwe Meissner**, Technical Advisor

WHAT WERE YOU LOOKING TO ACCOMPLISH DURING THIS PROJECT?

We used data from the federal SHRP2 database, where 3,000 vehicles were instrumented and continuously recorded for two years, to compare teen and adult driving behavior. As helpful a tool as driving simulators are, they cannot capture everything that would be happening in the on-road environment. This is where naturalistic driving comes in, so we can understand how people drive in the real world. For this study, the frequency of crashes and near-crashes were compared for teen drivers ages 16 to 19 and adult drivers ages 35 to 54. Crashes included all types, except for rear-end, which we studied in year one.

WHAT MOTIVATED YOU TO STUDY THIS TOPIC?

In a previous comparative study of teens vs. adults using the driving simulator, we found that in an emergency situation many novice teen drivers demonstrated suboptimal braking performance: On average, teen drivers braked at half the

pressure of adult drivers and some teens either missed the brake pedal or pressed the throttle. After finding this on the simulator, we were interested to see if the same thing was happening on the road: In an emergency, when do teens actually brake, and how much do they brake?

WHAT WERE YOUR FINDINGS?

When we accounted for all crashes, and not just those that were reported to the police and were therefore likely to be more serious, teens crashed 10 times more than adults in rear-ends and 6 times more than adults in road departures. This is significantly more than what is typically reported in the literature. Also, we found that in nearly all of the SHRP2 crashes where an air bag deployed, a teen was behind the wheel, suggesting teens are overwhelmingly represented in serious crashes. While more research is needed, this type of information can help auto manufacturers determine the types of Advanced Driver Assistance Systems (ADAS) that may be helpful for vulnerable teen drivers.



A subset from the SHRP2 database consisting of 355 crashes and 252 near crashes for novice teen drivers, and 180 crashes and 253 near crashes for experienced adult drivers was analyzed.



EMERGENCY AUTONOMOUS TO MANUAL TAKEOVER IN DRIVING SIMULATOR: TEEN VS. ADULT DRIVERS

Principal Investigator:

Helen Loeb, PhD, Children's Hospital of Philadelphia

Co-Principal Investigator:

Aditya Belwadi, PhD, Children's Hospital of Philadelphia

Students:

Charles Gottlieb, Jack M. Barrack Hebrew Academy; **Somil Govani**, University of Pennsylvania; **Saniyah Shaikh**, University of Pennsylvania; **Michelle Shen**, University of Pennsylvania; **Adin Solomon**, Jack M. Barrack Hebrew Academy

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Top Left: Driver in the seat without hands on the wheel (View 1); **Top Right:** Two-Way scene; **Bottom Left:** Driver in the seat without hands on the wheel (View 2); **Bottom Right:** Foot under the pedal while in autonomous mode

WHY DID YOU THINK IT WAS IMPORTANT TO STUDY THIS TOPIC?

With the emergence of self-driving vehicles, there are a lot of unknowns about how the transition is made from manual mode to autonomous mode and back to manual mode. Currently, even if a driver activates the autopilot, he should be paying attention to take over control of the vehicle if needed. We have seen a number of YouTube videos where the autopilot fails and an immediate takeover is required to avoid a crash.

For this project, we used these scenarios to replicate this experience within the safety confines of the advanced driving simulator at CHOP. We compared teens ages 16 to 19 and adults ages 35 to 54 to really understand how driving experience plays a role when reacting to an emergency. We also asked participants to complete pre- and post-drive surveys, to see if their experience in the simulator changed any of their opinions on interacting with self-driving technology.

WHAT DID THE RESULTS INDICATE?

In this pilot study with a small sample size of 8 teens and 4 adults we found some surprising early results: The female participants were better able to avoid crashing than were the male participants, and more teen participants experienced simulated crashes than did adult participants. We'll be leveraging these methods in year two with at least 36 participants, so it will be very interesting to see if the results remain consistent with a larger sample size.

WHAT ARE YOUR GOALS FOR YEAR TWO?

In addition to testing more participants, there will be a few tweaks to the methodology. One important change will be a brand new steering wheel on the driving simulator, so we will know precisely where drivers place their hands. We are also considering adding a warning alert to signal that the vehicle is going to take over, to better replicate the experience in a real vehicle.



MATURATION OF DRIVING SKILL FROM TEEN TO YOUNG ADULT TO EXPERIENCED ADULT USING SHRP2 NATURALISTIC DATA

Principal Investigator:

Thomas Seacrist, MBE, Children’s Hospital of Philadelphia

Project Team Member:

Helen Loeb, PhD, Children’s Hospital of Philadelphia

Students:

Ethan Douglas, University of Pennsylvania; **Ayya Elzarka**, University of Pennsylvania; **Charles Gottlieb**, Jack M. Barrack Hebrew Academy; **Leora Haber**, Princeton University; **Abe Kashem**, University of Pennsylvania; **Taryn McKinney**, University of Pennsylvania; **James Megariotis**, Drexel University; **Danielle Mendoza**, Widener University; **Adin Solomon**, Jack M. Barrack Hebrew Academy

IAB Mentors:

Douglas Longhitano, American Honda Motor Co., Inc.; **Zine Ben Aoun**, FCA US LLC; **Melissa Miles**, State Farm Mutual Automobile Insurance Company; **Schuyler St. Lawrence**, Toyota USA; **Uwe Meissner**, Technical Advisor

CAN YOU DESCRIBE THIS PROJECT IN A FEW SENTENCES?

To date, there have been a lot of studies focused on novice teens and comparing them to experienced adults. Limited research has focused on specifically examining the transition from the unskilled, novice stage to that experienced stage. We wanted to see what errors persisted between the novice group into the young adult age range, and also what errors they have developed skills and corrected for that are similar to the experienced adult. The long-term goal is to identify what next steps are needed in training young adult drivers to address their specific skill deficits.

WHAT WAS THE MOST SURPRISING FINDING?

I think the most surprising finding was that crash risk decreased in this age group overall, but when you looked at specific types of crashes, the changes weren’t as linear. For example, by the time teens reached the young adult age

range, rear-end crashes had decreased significantly and were more in line with that of experienced adults, so they likely addressed problems regarding distance perception and knowing when and how hard to break. But when you look at other types of crashes, such as run-off roads and intersections, their crash risk is higher compared to both the novice teens and experienced adults, so there are some unique crash types for this particular age group.

HOW WERE YOUR FINDINGS RELEVANT TO YOUR INDUSTRY SPONSORS?

Unlike novice teens, where typically a parent would purchase a car, these young adults are in the workforce and are starting to purchase their own vehicles. This research makes it possible to target the types of vehicles that they are purchasing and to design Advanced Driver Assistance Systems specifically tailored to their most common crash types.

Group	Age (yrs)	N	Miles	Crashes	Crash Rate
Novice Teens	16-19	550	4,205,474	87	20.7
Young Adults	20-24	748	7,691,129	121	15.7
Experienced Adults	35-54	591	5,651,315	15	2.7

Comparison of the miles driven, crashes, and crash rates among novice teens, young adults, and experienced adults.



ADVANCED AUTOMATIC CRASH NOTIFICATION FOR CHILDREN (YEAR 4)

Co-Principal Investigator:

Ashley Weaver, PhD, Wake Forest University

Co-Principal Investigator:

Joel Stitzel, PhD, Wake Forest University

Project Team Members:

Ryan Barnard, MS, Wake Forest University;

Jennifer Talton, MS, Wake Forest University

Student:

Samantha Schoell, Wake Forest University

IAB Mentors:

Douglas Longhitano, American Honda Motor Co., Inc.; Eric Dahle, Evenflo Company Inc.; John Combest, Nissan Technical Center North America Inc.; Hiromasa Tanji, TK Holdings Inc.; Dan Robertson, Toyota USA; Uwe Meissner, Technical Advisor

CAN YOU DESCRIBE THIS PROJECT IN A FEW SENTENCES?

The purpose of our project was to develop an advanced automatic crash notification (AACN) algorithm that can use data from a vehicle's black box to predict the risk of a child's injuries following a crash and recommend a triage decision. Triage is getting a person to the right place at the right time for the right treatment. We know that good triage improves patient outcomes. This algorithm predicts whether a child needs to go to a level one or two trauma center for treatment, or whether he or she could be transported to a non-trauma center.

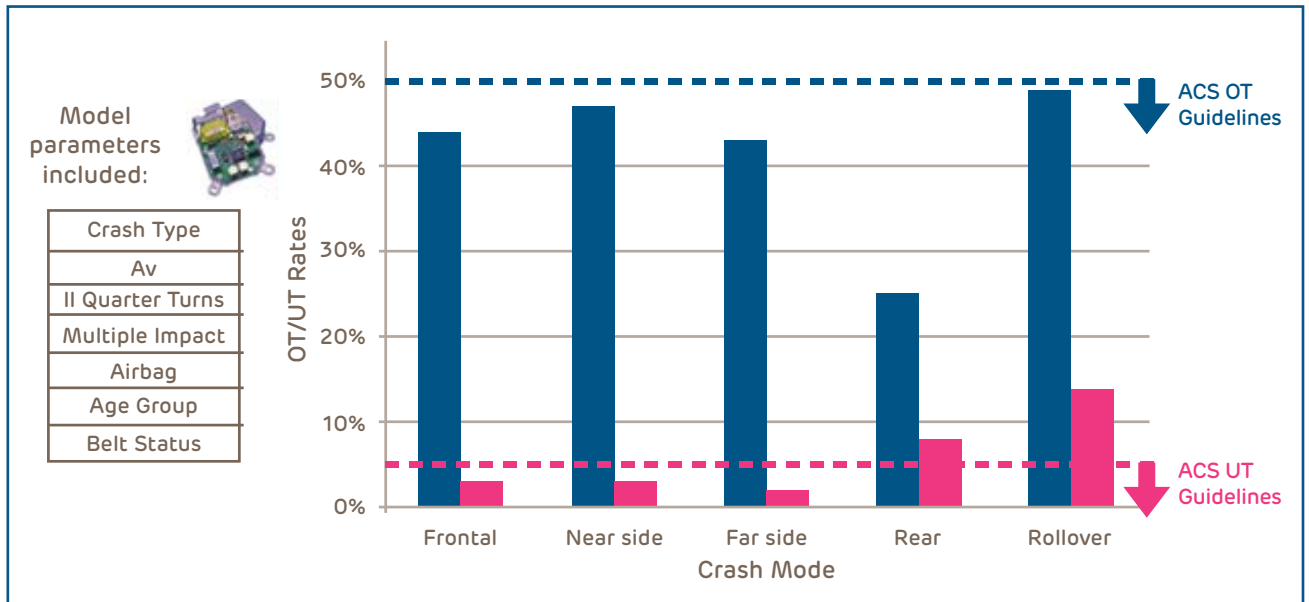
IS YOUR PROJECT FILLING A GAP IN TRIAGE, IN TERMS OF CHILD SAFETY?

While algorithms have been designed for adults, this is the only known AACN algorithm developed specifically for children. We know that children's injury patterns change as they grow and develop. They get different types and severities of injuries,

so we thought it was important to develop an algorithm that specifically addresses the unique patterns of injuries that children sustain in crashes.

WHAT DISTINGUISHES THIS YEAR FROM THE PRIOR THREE YEARS OF THIS PROJECT?

In the project's first year, we divided children into developmental age groups based on the types of injuries they sustained. In years two and three, we focused on using large hospital and trauma crash data sets, along with survey data from expert physicians and EMS personnel, to quantify different facets of injuries. In year four, we incorporated injury facet quantifications, scores that we developed, and crash characteristics to finalize an algorithm that predicts the risk of injury and recommends a triage decision for a child. The next step will be pursuing wide-scale implementation throughout the US to help improve injury outcomes for pediatric motor vehicle occupants.



Summary of over triage (OT) and under triage (UT) by crash mode for the pediatric AACN algorithm including the model parameters of crash type; delta-v; number of quarter turns, multiple impact; air bag; age group; and belt status. The pediatric AACN algorithm was optimized in order to minimize UT and OT rates with the goal of producing UT rates < 5% and OT rates < 50% as recommended by the American College of Surgeons (ACS).



ACTIVE SAFETY NEEDS FOR TEEN DRIVERS: IMPRESSIONS, PERCEIVED NEED, AND INTERVENTION PREFERENCES

Co-Principal Investigator:

Eve Weiss, MS, Children's Hospital of Philadelphia

Co-Principal Investigator:

Thomas Seacrist, MBE, Children's Hospital of Philadelphia

Project Team Member:

Megan Fisher-Thiel, MPH, Children's Hospital of Philadelphia

Student:

Chloe Hannan, West Chester University; **Nahida Sultana**, Drexel University; **Benjamin Varone**, The College of New Jersey

IAB Mentor:

Melissa Miles, State Farm Mutual Automobile Insurance



Study methods included focus groups, in which teens shared their perspectives on how the advent of active safety technologies might affect their driving skills and behaviors, and, ultimately, their safety on the road.

CAN YOU BRIEFLY DESCRIBE THIS PROJECT?

We wanted to understand how teens and parents are responding to the advent of automated cars, particularly the Advanced Driver Assistance System (ADAS) technologies, such as forward collision warnings, blind spot warnings, and lane keeping assist. Because teen drivers ages 16 to 19 and young adult drivers ages 20 to 24 are at the highest risk for motor vehicle crashes, these technologies have the potential to help keep them and others safe on the road. However, there hasn't been a lot of research on the teen population because ADAS technologies are still somewhat new. We conducted three teen focus groups and two parent focus groups to better understand perceptions about ADAS, whether or not teens and parents are interested in using them, and what barriers might exist to their use.

WHAT WERE SOME OF YOUR FINDINGS?

An assumption we had going in was that the teenagers would fully embrace ADAS technologies without thinking critically about them. We were surprised to hear almost the opposite.

Because teens were so familiar with technology, they understood that it may have the potential to malfunction. They were really excited about the ADAS potential, but understood technology cannot always be depended upon and the driver should always stay engaged.

WHAT'S NEXT FOR THIS LINE OF RESEARCH?

We will be conducting a national survey of 1,000 teens and 1,000 parents based on the findings from the focus groups. Our aim is to dive deeper into some of the issues identified in the focus groups to learn more about the teen driving behaviors; choices that teen drivers make; their perceptions about emerging ADAS technologies; and how we might overcome potential challenges in order to make automated safety features more useful to the people they're meant to help.

SUPPLEMENTAL RESEARCH FUNDING

AWARE: ACCELERATING MINORITY ENTREPRENEURS IN HEALTHCARE

Principal Investigator:
Linda Fleisher, PhD, MPH

Funder:
National Science Foundation (NSF)

The goal of this pilot project is to better understand the challenges faced by women and minority entrepreneurs and explore ways to improve their access to funding opportunities through SBIR/STTR, an NSF program aimed to stimulate research & development innovation among small businesses. AWARE's long-term goal is to significantly increase successful grant applications from women- and minority-owned businesses and connect minority entrepreneurs with existing sources of support to level the playing field.

ACTIVE SAFETY TECHNOLOGY AND TEEN DRIVERS

Principal Investigators:
Eve Weiss, MS and Thomas Seacrist, MBE

Funder:
State Farm Mutual Automobile Insurance Company

State Farm Mutual Automobile Insurance Company provided additional funding support for this CChIPS project, which aims to understand teen and parent needs and perceptions around the advent of Advanced Driver Assistance Systems in motor vehicles. Please see page 18 of this report for a full project description.

ADVANCED AUTOMATIC CRASH NOTIFICATION FOR CHILDREN

Principal Investigators:
Joel Stitzel, PhD and Ashley Weaver, PhD

Funder:
Toyota USA

This multi-year project's goal was to create scoring systems to better classify motor vehicle crash-related injuries in children in order to improve clinical triage algorithms. Toyota USA contributed a second CChIPS membership to the research funding pool in order to continue supporting external investigators from Wake Forest University in this project; a full description of the fourth and final project year is included on page 17 of this report.

CHILD RESTRAINT INNOVATION PROJECTS

Principal Investigator:
Aditya Belwadi, PhD

Funder:
National Institutes of Health

This line of research encompasses several Small Business Innovation Research Grant (SBIR)-funded projects conducted in partnership with CChIPS IAB member Minnesota HealthSolutions. The common long-term goal is developing and evaluating novel methods of installing child restraints or ensuring the child occupant is restrained securely in the child seat.

LOW ACCELERATION TIME EXTENDED EVENTS (LATE)

Principal Investigator:
Kristy Arbogast, PhD

Funder:
TK Holdings Inc.



The LATE project aims to quantify the movement of passengers of different ages during pre-crash avoidance maneuvers. Many crash protocols involve a vehicle hitting an object head on or directly from the side. This approach is not wholly representative of typical real world crashes where the driver sees the hazard and swerves to either avoid contact or minimize damage. CChIPS researchers from CHOP, Drexel University and University of Virginia have collaborated to create a sled (see image) that mimics vehicle swerving. This multi-year line of research seeks to define how occupants move as a result of this swerving and how vehicle restraints interact with the occupant during these maneuvers before a crash ever occurs.

MOTION AND MUSCLE ACTIVATION OF YOUNG VOLUNTEERS IN EVASIVE VEHICLE MANEUVERS

Principal Investigator:
Kristy Arbogast, PhD

Funder:
Toyota Collaborative Safety Research Center

This project builds on the above described LATE project and examines responses of rear seat occupants to emergency maneuvers in a real vehicle rather than in a laboratory setting. In partnership with The Ohio State University Injury Biomechanics Research Center and the University of Virginia Center for Applied Biomechanics, the research team will conduct an on-road (test track) assessment using professional drivers where video, electromyography (EMG, a measure of muscle activity), and motion capture data will be captured on rear seat restrained occupants age 6 years and older. The goal is to optimize vehicle restraint and seat design to provide protection in these common real-world scenarios.

RESEARCH EXPERIENCES FOR UNDERGRADUATES

Principal Investigators:
Flaura Winston, MD, PhD and Thomas Seacrist, MBE

Funder:
National Science Foundation (NSF)

The Center for Injury Research and Prevention (CIRP) at CHOP was awarded an NSF REU Injury Science Site grant, with an emphasis on providing research experiences to racial and ethnic minorities who are underrepresented in research, students with disabilities, and students from STEM-limited schools with limited internship opportunities and no available doctorate program. In our fifth summer offering this program, we received nearly 400 applications for eight REU internship positions. The diverse group of student scholars selected from schools across the country spent the summer working with CIRP researchers, receiving mentorship and hands-on research experience as well as formal training in research ethics, research methodology, and the presentation of research findings. Several students also had the opportunity to shadow clinicians at CHOP, one of the nation's top children's hospitals. Several of these students worked on CChIPS projects with CChIPS faculty.



CIRP Training Manager Carol Murray, MSS, MLSP (far left) and Training Director Thomas Seacrist, MBE (far right) pose with members of the 2017 CIRP REU cohort and other CIRP summer trainees.

PREPARING FUTURE INDUSTRY SCIENTISTS

The CChIPS site at The Ohio State University has been a leader in student development in injury biomechanics via the annual Injury Biomechanics Symposium (IBS). The IBS stimulates and rewards strong injury biomechanics research among trainees by providing a welcoming atmosphere for novice researchers to present original work in a non-threatening environment. In May 2017, it hosted more than 115 attendees including 27 student presenters from 12 universities. Among the presenters were Christine Holt, a PhD candidate at Drexel University working on the LATE project (*see project summary on page 20*) and Nhat Duong, a CHOP student-intern who presented on his work with Dr. Aditya Belwadi on the efficacy of belt-positioning booster seats in frontal and far side oblique impact (*see project summary on page 7*).



CChIPS Co-Director John Bolte, PhD provides welcoming remarks at the 2017 Injury Biomechanics Symposium.



Nhat Duong and Christine Holt (first and second from left) are pictured with fellow oral presenters.

What's Next From CChIPS

The CChIPS IAB has provided continuation funding to multiple projects to deepen its understanding of scientific questions of interest to industry and academia. Many of CChIPS' 2017-2018 projects are continuing work from previous years, including:

- Aditya Belwadi is in Year 2 of his Evaluating the Efficacy of Belt Positioning Booster Design (High-back, Low-back and Heightless Booster) in Frontal and Far Side Oblique Impacts project (Year 1 is detailed on page 7 of this report).
- Helen Loeb is in Year 2 of her Emergency Autonomous to Manual Takeover in Driving Simulator: Teen vs. Adult Drivers project (Year 1 is detailed on page 15 of this report).
- John Bolte will continue a line of CChIPS research into the unique safety needs of children restrained on airplanes with standard and inflatable seat belts.

For a sneak peek of next year's 2017-2018 research projects, please visit the CChIPS website!



Join us for the next Advances in Child Injury Prevention (ACIP) Conference in May 2018. Check the [CChIPS website](#) and [Research in Action blog](#) for updates on the agenda and registration information.

CChIPS: A Unique Consortium

The Center for Child Injury Prevention Studies (CChIPS) would like to thank the Industry Advisory Board (IAB) members, our member companies, and the National Science Foundation (NSF) for their generous support and insight.

Our vital work would also not be possible without the generosity of our academic, corporate, and government collaborators. Many thanks to Children's Hospital of Philadelphia; The Ohio State University; University of Pennsylvania; Wake Forest University; Drexel University; University of Virginia; and Medical College of Wisconsin for providing CChIPS with forward-thinking scientists committed to making the world a safer place for children and adolescents.

Be Part of a Safer Future

Additional partnerships are needed to successfully and efficiently reduce the burden of child injury. CChIPS looks to broaden its membership by adding new companies and other organizations vested in child safety and seeks to expand its scientific collaboration by linking with new academic partners. If your organization is interested in being part of this exciting movement to address a significant societal problem, please contact us at cchips@email.chop.edu.

Acknowledgements

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