Protecting children and youth in cars: highlighting non-nominal cases and the user experience

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INTRODUCTION

Child occupant protection research remains a critical need for industry, academia, government and safety advocacy organizations. While reductions in fatalities and serious injuries in high-income countries have been achieved, motor vehicle crashes remain a leading cause of death and disability for children and adolescents and as a result, represent a public health priority (Kahane, 2016). To facilitate international coordination and sharing of knowledge around this topic, the fifth biennial international workshop on Child Occupant Protection was convened in September 2017, bringing together worldwide leaders in the fields of child occupant protection, human factors, behavioral science, biomechanics, and auto safety to critically review the state-of-knowledge in the field and identify high-priority research topics and strategize toward their implementation.

Significant advances have been made over the last two decades in the biomechanics of child occupant protection such that there is great understanding on how to protect an in-position, properly positioned, restrained child occupant (Crandall et al., 2013; Yogandandan, Nahum and Melvin, 2014). However, because the global burden of child occupant injuries and fatalities remain large, the field is in need of an expanded perspective and thus the focus of the meeting was on the experience of the mobility system user as it influences safety.

Ongoing changes in the nature of mobility have the potential to affect children and youth in motor vehicles, with society moving towards car sharing, carpooling, ride hailing (e.g Uber) and automated cars. Society is redefining "public" transportation; to date, these modes have primarily been used by adults, but they are increasingly being used by children/families. Already today, when children are travelling in taxis or in other vehicles that do not belong to their families, there is a challenge to ensure that they travel safe due to access to age-appropriate child restraint systems. This challenge will grow as the nature of mobility changes and more trips will take place in a vehicle that does not belong to the family. The intense work worldwide on the development of automated vehicle technology will further change the nature of crash injury risk. It is imperative to establish new social norms for protection in these new mobility methods. Research is needed on the effects these changes in mobility will have on younger passengers. We need to understand why consumers do not always choose the right restraint for their child's age, often use that restraint incorrectly, and the range of "user positions" that restrained occupants may assume. We need to ensure that our vehicle and restraint designs are robust to account for this variability.

Summaries of previous workshops were presented at the 2011, 2013 and 2015 Protection of Children in Cars Conferences. The following describes the recommendations that emanated from the 2017 meeting.

PROCESS

A two-day workshop was held in which the first day focused on reflecting on new challenges facing the field - with a focus on the user experience in the context of changing mobility modes and aligning user expectation with optimized safety.

The second half of the workshop was dedicated to a future-oriented perspective and identifying particular challenges facing our society to continue to improve the safety of children in cars. Through this discussion, we identified 4 important questions that we thought were critical to tackle through informed and engaged dialogue from a variety of stakeholders. The questions and initial thoughts of the workshop attendees are as follows.

1. How do we define the value proposition for safety? How to use it to drive design?
2. How do we define the non-nominal cases to focus attention on?
3. How do we make the risk apparent? How do we make safety issues important for people such that they change their behavior?
4. What are the strategies to make it easier for consumers to do the right thing?

The questions and initial thoughts of the workshop attendees are summarized below.

This effort included 19 individuals from diverse organizations and scientific disciplines:

- Behavioral scientists
- Biomechanists
- Human factors including psychology and industrial engineering
- Epidemiologists
- Government researchers
- Physicians
- Auto safety researchers
- Restraint suppliers
- Vehicle manufacturers
- Test centers and rating institutions

A list of attendees is contained in the Appendix.

KEY THEMES

The discussions that align with the above questions are summarized in four themes.

<u>Value proposition for safety</u>

The primary theory that emerged from the workshop is that the concept of "safety" may be too vague for the general consumer to place high value on it. The idea that a given individual will crash and sustain life-altering injuries may be a remote, non-tangible concept that does not necessarily affect that person's day to day activities. Thus their decisions to engage in optimal safety behaviors are driven by the "here and now" of comfort and convenience rather than the far-removed idea of protection in a crash.

Critical to selling safety is packaging its appearance such that it is integrated into something people already value and by tying it to functions that one appreciates daily (like comfort). A value proposition

for safety may be to offer a safe solution that is attractive, accommodating and accessible for everyone. This approach moves safety higher on a person's hierarchy of needs. As a safety community, we may be able to generate user demand for safety but it needs to be safety that works for them via user centered design (see comments below on this concept).

There was debate on whether safety should be a personal decision or removed from the individual consumer via regulations or ratings programs. If remaining a personal decision, two concepts emerged from the discussion. First, make safety a habit so that the decision to engage in safe behaviors is not situational (e.g. needing to find appropriate child restraint when in a taxi); allow consumers to act in their natural way but make the natural behavior safe. Second, allow the consumer to maintain their autonomy of choice by putting safety at "eye level" – e.g. permitting them to make a choice but have that choice be between safe option 1 and safe option 2. These ideas embody the science of nudging – a tactic borrowed from behavioral science and economics which states that positive reinforcement and indirect suggestions for a target behavior are more effective than direct instruction or a legal approach (e.g. Hertwig and Grune-Yanoff, 2017; Peeters and Schuilenburg, 2017).

The balance between safety choices being automatic in the vehicle and an active decision of the customer is likely shifting with the increase of autonomous vehicles and the idea that even personal transportation can be viewed as a service industry (e.g. car sharing, car hailing). In these scenarios, the consumer is less in control of deciding which safety features are provided in their vehicle of choice and may [perceive to] be less in control of the vehicle's maneuvers such that the idea that protection should just be part of the vehicle may resonate more loudly. Offering family-oriented options in some autonomous vehicles may be part of the solution when the consumer has time to plan their journey but last-minute trips will remain common and therefore these options should be universal.

Lastly, it is important to note that valuation has cultural variation. This is particular critical as mobility increases worldwide in diverse cultural settings. The packaging of safety with other items of value in the United States or Europe may be fundamentally different from such efforts in East Asia or Latin America. Assessing that valuation by region or locality – both geographic and sociodemographic - is necessary to ensure the selling of safety resonates with the target population.

Definition of non-nominal cases

Traditionally, the approach of restraint design in motor vehicles has been to start with the 50th percentile adult male and optimize the safety system for that occupant. Then, select cases are considered to evaluate any unintended consequences for other size occupants. This approach can also be thought of more broadly – restraints are evaluated primarily with properly positioned ATDs with upright posture and their back against the vehicle seat back. A body of research has shown that occupants assume a variety of common user positions – both preferred due to comfort or activities and forced due to vehicle maneuvers (e.g. Osvalder et al. 2013, Arbogast et al. 2016).

The discussions centered on the urgent need to consider beyond this "nominal" case when developing new safety designs in order to truly achieve a Vision Zero goal of no motor vehicle fatalities and serious injuries. Conceptually, this approach has been happening over the last decade via the idea of personalized protection and adaptive restraints, where information about the size, weight or position of the occupant influences how a seat belt or air bag performs (Hu et al. 2016). Recent advances in human body models – for both children and adults - allow for the morphing of occupant size thus facilitating

this effort (http://www.piper-project.eu/) (Brolin et al. 2014, Beillas et al., 2013, 2014a, 2014b). Personalized safety protection should reduce the proportion of non-nominal cases that are not accounted for.

Several broad concepts emerged from the workshop that build on this idea. First for rear seat occupant protection in particular, our "nominal case" should be different than that for the driver or front passenger position. Safety designs of the rear seat environment should assess the typical rear seat occupant – e.g. in age, size – and focus design efforts on their protection. This would likely result in targeted design for children, adolescents or small adults. This is the same approach taken historically for the front seat; design for the typical and then evaluate unintended consequences for the others. However in this case, the "typical" is not the average adult male.

Second, we introduced the idea that a given test program would define a range of test conditions. This range could encompass a variety of occupant sizes, occupant positions/postures and load cases. Even restrained occupants assume postures that are different from the ATD standard posture, either as a result of common voluntary movement or involuntarily as a result of pre-crash vehicle maneuvers. Investigating the safety consequences of these potential pre-crash postures is an emerging research focus (Bohman et al. in press; Holt et al. 2017). A test program could perform any test within a range of possible postures and positions, thus encouraging designers to be more comprehensive in their approach, resulting in more robust restraint systems. The idea of designing to the test is less limiting if the test conditions are broad. To be fair, many vehicle and restraint designers already include this broad evaluation in their due-care design process; but explicitly tying it to a formal evaluation lends more weight to the results. This flexible approach likely aligns better with consumer information testing programs such as EuroNCAP or Insurance Institute for Highway Safety testing rather than regulations.

Lastly, the workshop participants encouraged a broader vision of non-nominal scenarios to include non-physical concepts such as the state of the occupant (e.g. fatigued, under the influence, distracted) as well as variations in values, priorities and decision-making strategies. Understanding which of these parameters can be quantified and which influence outcomes likely involves a body of fundamental science yet to be explored in the automotive setting (Winston et al. 2016). To this end, engineering disciplines should collaborate with behavioral scientists, cognitive psychologists and human factors specialists in the vehicle safety design team (Larsson and Tingvall, 2013).

How to make risk "tangible" such that people change behavior

Risk is a complicated concept; the perception of risk is an individual's subjective assessment of the probability of an event happening and its associated consequences (Sjöberg et al. 2004). Our perception of risk is influenced by social, cultural, and economic factors. It has been observed that people tolerate substantially more risk and thus risk is a smaller influence on their actions, when they engage in voluntary behavior – e.g. driving a vehicle – versus involuntary events such as environmental hazards (Sjöberg et al. 2004).

As such, utilizing fear of a negative outcome in the setting of automotive safety may not be the most effective approach. Ideally we want individuals to develop positive habits. A habit is routine behavior that is repeated and occurs subconsciously. This is in contrast to a deliberate weighing of risk and the potential for negative outcome that influences behavior; this scenario is more likely to be affected by situational variability.

Two key aspects were discussed regarding development of good safety habits: the cue to the target behavior and the reward or incentive for doing it. In order to increase the likelihood the target behavior develops, the vehicle design must prompt for it in a "front and center" manner. See above for the discussion about having safety at eye-level so that a positive choice is more obvious. There should be a function that acts to increase the likelihood of the behavior and there should be design features than enable that function. For example, if we want people to use a top tether for child restraints, the tether needs to be made visible and its attachment in the vehicle obvious. Sometimes the target behavior is one step removed (i.e. the "target" is changing the behavior they are doing that is preventing them from doing the real target), thus it is important to determine exactly what behavior you want to achieve.

Gamification has been shown to be an efficient strategy, providing benefits for good behavior and the transition of a new behavior to a habit can be accelerated by incentive schemes (Pereira et al. 2014; Steinberger et al. 2017). These approaches have not necessarily been utilized in automotive safety to a large extent. Rather the approach has been to just define the desired behavior and punish via warnings and legal consequences when errors and violations occur. We should include the discipline of behavioral economics which studies the "effects of psychological, social, cognitive, and emotional factors on the economic decisions of individuals" to understand how best to structure such incentive or gamified programs (https://en.wikipedia.org/wiki/Behavioral_economics).

How to make it easier for consumers to do the right thing

The last theme of the workshop was focused on tangible strategies to facilitate good safety behaviors from consumers. Because human error is the main cause of crashes, safety interventions – technological, regulatory, legal and educational – have been directed towards reducing human error (Singh, 2015). We as a safety community need to expand this narrative and understand how to better merge typical behavior with best practice. Make the message simple and positive: highlight a few instructions and make it easy to do them reasonably well instead of conveying "this is so complicated".

To do this, we need to expand the scope of expertise involved in design for safety. Human factors, behavioral science and ergonomics experts need to conduct comfort studies with validated tools. New child restraint designs should be more forgiving systems that understand how the environment is actually used and design from that starting point. Real occupants do not necessarily position themselves like ATD test positions. Perhaps restraint designs that encourage people to conform to test positions should actually be viewed from the opposite perspective – quantify how real occupants behave and design restraints to make that typical behavior safe.

This human and activity-centered design approach has been used in many other areas of transportation but not to a large degree in personal transportation. Design should be conducted with salience in mind considering not only innovative technology but ensuring that technology is discoverable, that is, "visible" to the user. Smarter sensors can be implemented in the vehicle to give positive feedback when the target behavior is achieved and making it difficult or uncomfortable to do it wrong. However, it is not just implementation of technology; advance work must be done to consider what we will do with the information. How will either the human or the vehicle process the data to improve outcomes? Again, the emergence of autonomous technology and new mobility modes provide the opportunity to introduce new concepts that may have previously been unacceptable in traditional personal transport.

CONCLUSIONS

The panel of experts convened for the Gothenburg workshop focused their attention on the user experience in order to lay out a roadmap for reaching a state where no fatalities and serious injuries to children and youth occur on our roads. In this Vision Zero concept, the transportation system must be forgiving and robust for a wide range of road users in a range of conditions. In sum, vehicle restraint design should be human-centered, inclusive and universal and encompass variations in both the traits of the occupant (e.g. size, BMI, age) as well as the states of those occupants (e.g. postures, distraction, shifting priorities). Nudging occupants towards good safety habits requires incorporation of other disciplines – human factors, behavioral science, cognitive psychology – into automotive design. The heterogeneity of the occupant – vehicle relationship that is emerging with automation and new mobility modes likely provide greater opportunity to customize protection and optimize safety.

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WORKSHOP ATTENDEES

Specific attendees of the workshop are listed below. All contributed greatly to the discussion at the workshop and the formation of the concepts described in this manuscript.

- Kristy Arbogast, PhD – Children's Hospital of Philadelphia, University of Pennsylvania
- Katarina Bohman, PhD – former: Autoliv Research, current: Volvo Car Corporation/SAFER
- John Bolte IV, PhD – The Ohio State University
- Karin Brolin, PhD – Chalmers University of Technology, SAFER
- Julie Brown, PhD - Neuroscience Research Australia
- Jason Forman, PhD – University of Virginia
- Lotta Jakobsson, PhD – Volvo Car Corporation, Chalmers University of Technology, SAFER
- Jessica Jermakian, ScD – Insurance Institute for Highway Safety
- Sjaan Koppel, PhD - Monash University Accident Research Centre
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