Title: Naturalistic Observation of Children in Cars: An International Partnership

Authors: Charlton, J.L.[1], Koppel, S.,[1] Cross, S.,[1] Kuo, J.[1], Rudin-Brown, C.,[2] Arbogast, K.[3], Loeb, H.[3], Eby, D.,[4] Bohman, K.,[5] Svensson, M.,[6], Jakobsson, L.[6,7] & Stockman, I.[6].

Affiliations: 1. Monash University Accident Research Centre, Monash University, Melbourne, Australia; 2. Human Factors North, Inc, Canada; 3. The Children's Hospital of Philadelphia Research Institute, USA; 4. University of Michigan Transportation Research Institute, USA; 5. Autoliv Development; 6. Chalmers University of Technology; 7. Volvo Car Corporation, Sweden

Please address all correspondence to Judith L. Charlton:

Telephone: +61 3 99051903

Email: Judith.charlton@monash.edu

ABSTRACT

It is well known that in the rear seat of cars, small children squirm, slide, slump, sleep, play and interact with their fellow passengers. Our previous findings from a pilot study show that children rarely remain in an optimal position for the efficient functioning of their restraint systems throughout the duration of their journey. Such behaviours may not only affect restraint effectiveness but may also have a negative influence on driver performance and distraction. Moreover, quantification of children's position and out-of-position (OOP) status (i.e., their actual position relative to the ideal position for which the technology was designed) has important implications for design of test programs using anthropomorphic test devices (ATD) intended to mimic the human occupant. For example, understanding true pre-crash positions may lead to different design specifications of rear seat restraint systems and energy management features of the vehicle interior compared with the kinds of solutions that might arise from evaluations with an in-position ATD. This paper builds on our preliminary research findings and describes the design of the first international large-scale study of children in cars which uses innovative methods to observe and quantify the positions of child occupants in cars and identify the injury effects of OOP status and its impact on driver distraction. The study will facilitate a paradigm-shifting advance in child occupant protection – from the concept of safety technology designed to protect an ideally positioned occupant to the concept of dynamic restraint systems that maintain optimal restraint over a range of expected child positions/movements in a vehicle. Outcomes of the research will directly inform the design of future restraints for children, the development of appropriate crash test procedures that account for natural positions of child occupants, and the development of community awareness messages to improve the safety of children.

AIMS & BACKGROUND

Despite recent advances in motor vehicle and child restraint system (CRS) design, motor vehicle crashes remain the leading cause of child death in Australia[1] and in most OECD countries[2]. This is a significant public health problem and the societal costs of child crash injuries are substantial, with motor vehicle crashes ranked in the top five most costly causes of injury and death among children aged 14 years and younger in the state of Victoria, Australia ($22 million)[3]. Existing evidence suggests that CRS and booster seats offer a high level of crash protection during an impact, potentially reducing injury by 70 percent compared with unrestrained children[4-6]. In addition, while adult seatbelts are safer than no restraint, they offer suboptimal protection to children compared to CRS or booster seats[7-11]. However, it is also clear that inappropriate and incorrect usage rates of CRS and booster seats, particularly amongst older children, are high[12-16].The consequences of incorrect and inappropriate use of restraints can seriously reduce or nullify the safety benefits of these devices[17-19]. Research also suggests that children's restraint practices may distract the driver/parent and lead to increased risk of involvement in a crash[20-22].

The broad aims of the proposed project are to reduce fatal and serious injuries to children in motor vehicle crashes through advances in design of vehicles and restraint systems and through targeted safety education strategies. The project brings together a multidisciplinary team from engineering, injury biomechanics and behavioural safety science and uses novel, naturalistic driving methods and covert video-recording techniques to observe child occupant and driver behaviour during everyday travel. The approach represents a fundamental shift in the principles of protecting children in motor vehicle crashes.

To date, vehicle and restraint systems have largely been optimised through laboratory-based (or computational) test programs using crash test dummies or anthropomorphic test devices (ATD) intended to mimic the human occupant. Most of the test protocols evaluate restraint performance with ATDs placed in 'ideal' (upright) positions and, under these conditions, the majority of restraints perform very well. In reality, children do not behave like static, crash test dummies. Recent evidence suggests that real world occupant restraint use bears little resemblance to the ideal, experimental conditions used to test the safety efficacy of restraints. Despite being seated in the correct restraint system for their age and size, an unacceptable number of children die or are seriously injured in real world crashes. Research investigating the mechanisms of injury for children who died as a result of interaction with frontal passenger airbag deployments[23] has demonstrated that rather than seated ideally, these children were inappropriately located close to the airbag when it deployed. This landmark research highlighted the serious injury consequences of children's OOP status. With this information about actual position of child occupants in these crash scenarios, laboratory test procedures that more closely reproduced the real world were designed, and the US federal motor vehicle regulations were upgraded, resulting in improved, safer design airbags for children[23-26]. The experience with frontal airbag-related child deaths demonstrates crucial lines of research needed to inform further advances in the design and testing procedures for child occupant protection technology. Moreover, with airbag fitment migrating to the rear seat zone in many new cars, it is crucial that the effects of OOP of rear seat occupants on injury outcomes are better understood. A primary outcome of the current project will be to use the data collected to develop improved positioning protocols for ATDs in crash tests to better replicate actual positioning of children.

Using a multi-phase, mixed methods approach, the current study will facilitate a paradigm-shifting advance in child occupant protection – from the concept of safety technology designed to protect an ideally positioned occupant as represented by the ATD to the concept of dynamic restraint systems that maintain optimal restraint over a range of expected child movements in a vehicle. The aim of this paper is to describe the methods for the naturalistic observational study component. The key objectives of the observational component are (i) to document the natural behaviour of child passengers during real world car trips, including the circumstances which promote/reduce their OOP status; and (ii) to determine the child behaviours which contribute to driver distraction. Complementing this, the broader program of research will also implement sled test methods to examine the injury implications of children's OOP status, and survey methods to explore how the safety culture and attitudes of families influence their safe travel in cars.

Restraint Effectiveness

CRS are designed to provide specialised protection for child occupants in the event of a crash. Data from the US have demonstrated that, compared with seatbelts alone, CRS reduce the risk of death in children aged 2 to 6 years by 28 percent after excluding cases in which the child restraint was grossly misused[8]. Similarly, Winston et al.[10] reported that once involved in a motor vehicle crash, children aged 2 to 5 years restrained by seatbelts were 3.5 times more likely to sustain a significant injury (RR: 3.5; 95% CI 2.4-5.2) and 4.2 times more likely to sustain a significant head injury (RR: 4.2; 95% CI 2.6-6.7) compared with children restrained by CRS. Durbin et al.[9] reported that, in 4 to 7 year old children, the use of booster seats reduced the risk of head and brain injuries, all internal organ injuries, spinal cord injuries and extremity fractures by 59 percent when compared with seatbelt restraints. An Australian case–control study investigated the injuries sustained by children aged 2 to 8 years following involvement in a motor vehicle crash[17-18]. The authors found no serious or fatal injuries among optimally restrained children, while 30 percent of suboptimally restrained children sustained serious or fatal injuries. These data underscore the importance of age-appropriate restraint use for children.

CRS Use, Misuse and Legislation,

National usage rates of CRS use in Australia is estimated to be relatively high. An observational study conducted in Australia estimated that usage rates exceeded 95 percent[12;28]. However, the survey techniques used to obtain these figures do not allow for accurate estimates of the *quality* of installation of restraints in vehicles, nor the appropriateness of restraint for the child's size[16]. Hence, although compliance estimates are high, these figures belie reported error rates in CRS use, as discussed below.

While research has established that CRS offer a good level of crash protection in the event of a crash[4-6], the effectiveness of CRS is critically dependent on correct installation of the restraint in the vehicle, correct harnessing of the child in the restraint, and use of the appropriate restraint for the child's size. Incorrect and inappropriate fitment and use of restraints may reduce or nullify safety benefits[16;19]. While CRS manufacturers provide adequate instructions for fitment, it is generally acknowledged that installation and use of CRS and boosters is somewhat complicated and prone to error[29]. Indeed, studies show that inappropriate use and misuse of the fitment of CRS is widespread[12;15; 30-34]. Glanvill[33] reported that 69 percent of the 4,600 CRS checked between 1996 and 1999 involved faulty installation and/or use, and a disturbing proportion of these (25%) were judged to be major faults. These figures have been confirmed by Paine and Vertsonis[32], and Koppel and Charlton[12]. Most of these studies have been conducted at child restraint fitment stations where the observation is completed in a stationary vehicle after the family has entered the checkpoint. It is unclear whether these data represent the range of naturalistic misuse conditions seen *during* car trips.

Legislation on CRS is a powerful mechanism for influencing individuals' behaviour with significant capacity to improve safety practices. In the last decade, there has been widespread adoption of regulations worldwide that mandate CRS and booster seat usage for children up to the age of around 12 years in European and North American jurisdictions (12 years in the United Kingdom; up to 8 years in several states/provinces in the US and Canada) (www.childcarseats.org.uk; www.mto.gov.on.ca; www.iihs.org/laws/ChildRestraint.aspx). Australia has been slower to introduce legislation that requires children to remain in CRS for longer; however, in 2009, national laws were introduced requiring that children must be restrained in an approved CRS with an inbuilt harness, or booster seat with seatbelt, up to the age of seven years. However, recent research suggests that while CRS legislation may increase overall CRS use, it does not necessarily increase correct and appropriate CRS use. For example, Koppel, Charlton and Rudin-Brown[35,36] recently reported that there was no significant improvement in correct and/or appropriate CRS or booster seat use following the new Australian legislation regarding CRS and motor vehicle restraint use for children aged seven years and under.

Implications of Real World Occupant Posture

Anecdotally, human occupants have been observed to assume a wide variety of postures which bear little resemblance to the ideal upright seating positions of ATDs studied under most vehicle crash test conditions. An extensive program of research focusing on the naturalistic behaviours of drivers has shown important findings on drivers' physical movements and behavioural responses *during* the driving process, in advance of an impending crash or near-crash[37]. These results have, in part, led to the rapid development and adoption of crash avoidance technology in new vehicles to counteract unsafe driver behaviours. Based on the field observation studies, laboratory tests of these technologies now more closely replicate actual driving.

For child occupants, however, there have been only a few isolated efforts to describe position and postural changes using naturalistic, observational methods. It is likely that the postures and positions among child occupants are more varied than for adults. Anecdotal reports from parents indicate that children do not sit perfectly still and upright while travelling in vehicles. Children can squirm, slide down, fall asleep, play and attempt to remove their restraints while travelling in their CRS, and therefore will be more likely to be seated away from the preferred design location, or to be considered to be OOP. Research conducted by Christophersen[38] demonstrated that children travelling in CRS exhibited very high levels of appropriate or safe behaviour, whereas children not riding in CRS exhibited very low levels of appropriate behaviour. When CRS were introduced to those children who previously had not used them, the level of appropriate behaviour improved dramatically. These results were maintained at three-month follow-up observations. Christophersen noted that the prevention or reduction of disruptive child behaviour during car travel is an obviously important but previously unreported benefit of the use of CRS. The behaviour of children in various restraint systems was also investigated by Meissner, Stephens and Alfredson[39]. In this study, a hidden camera in study vehicles recorded the child occupants' activity and position in their restraint system. Children were initially placed in the correctly restrained positions for the restraint system involved and then the vehicle was driven for a period of several hours. Results showed that nearly all the children spent less than ten percent of the time optimally restrained, with many children openly demonstrating their dislike for being restrained in their CRS. In apparent contradiction to Christophersen's findings, the authors also reported that older children restrained in booster seats or adult seatbelts had a greater tendency to be OOP compared with younger children. This was thought to be partially due to the less restrictive system (compared with a full harness in the toddler-age forward facing CRS) and partly due to the somewhat increased activity of children of that age. For example, older children were more likely than younger children to move in their CRS and to move the belt in order to explore and search surroundings other than the area within their properly restrained position. Interestingly, the authors noted that children who had had more exposure to the automotive safety or medical field (through parental education) had a greater tendency than those who had not to remain in the correct position in their restraint; however, due to methodological limitations, it is unclear whether the findings are robust and/or representative of the travel posture of all child passengers.

More recently, van Rooij et al.[40] had parents photograph the seating positions of 10 children aged one to three years in harness-type restraints on drives of varying lengths. This study confirmed the earlier results, showing that few children remained seated in an ideal position. For example, children slouched, tilted and turned their head, resting it on the side-support of the CRS. Extreme positions such as leaning forward, removing from the harness or holding feet were also observed. In the second part of their study, common poses and some extreme poses were simulated in a computer crash model in order to investigate the potential increase of injury risk associated with these OOP situations. Evaluation of the simulated crash responses of various common OOPs observed in the first phase of the study revealed an increased risk of injury compared with the standard/prescribed body position. High lateral neck loads were observed in head tilted positions, while children incorrectly restrained without the shoulder harness sustained increased magnitude head excursion; both situations indicative of a poor crash outcome. The authors concluded that virtual testing, where the occupants can be positioned in a wider range of postures, is a valuable tool to predict trends in situations that more closely represent the actual automotive environment.

While these previous studies documented the need for direct observation of children in vehicles to define actual seated positions and use of restraints, the studies were very limited in terms of small sample sizes, restricted ages or restraint types; were non-standardized (e.g., single camera placement limited the ability to map positioning in three-dimensions); were largely qualitative; and the data collected lacked the quantitative detail needed to improve test protocols. Hence it remains unclear whether the observed behaviours are typical of those expected when children are travelling with their own parents in a 'naturalistic' setting and over many trips.

Child Occupants and Driver Distraction

In addition to leading to elevated crash injury risks, children's behaviours and OOP status observed by Christophersen[38], Meissner et al.[39] and van Rooij et al.[40] also have the potential to lead to driver distraction. Driver distraction is the diversion of attention away from activities critical for safe driving towards a competing activity[41] and is a leading cause of traffic fatalities and serious injuries worldwide, with an estimated one-quarter of vehicle crashes resulting from the driver being inattentive or distracted[42]. Despite an intuitive link between children's inappropriate position/behaviour and the attention demanded of a parent, there is limited research examining the influence of child occupant behaviour on driver distraction and/or driving performance.

In the first naturalistic driving study on this topic, Stutts and colleagues[20] studied 70 volunteer drivers and reported on their exposure to potential distractions and the effects of these distractions on driving performance. The authors observed three hours of randomly selected data per participant and coded a taxonomy of driver distractions (talking on mobile phone, eating, tuning radio, etc.), contextual variables (whether vehicle stopped or moving, road type, traffic level, etc.) and observable measures of driver performance (eyes directed inside or outside vehicle, hands on or off steering wheel, and vehicle position in travel lane). The most common distractions in terms of overall event durations were eating and drinking, distractions inside the vehicle (reaching or looking for an object, manipulating vehicle controls, etc.), and distractions outside the vehicle (often unidentified). There were a total of 243 recorded instances of drivers being distracted by other occupants in the vehicle, most often by babies (n=114) or children (n=81), but also by other adults in the vehicle (n=48). Children were found to be about four times and infants almost eight times more likely than adults to be a source of distraction to the driver, based on the number of distracting events per hour of driving. Therefore, efforts to quantify and rectify suboptimal positions of child occupants may not only *reduce the risk of serious injury* to the child in a crash but may also play a crucial role in *avoiding a crash*, by reducing the distractions presented to the driver.

Our previous research examined the OOP effects of two different booster seat designs: one with large head and torso side supports vs. one with small head side supports and no torso side supports. Results showed that the booster design with large side head supports resulted more often in seating positions where the head and shoulder were not in contact with the booster's back. In both boosters, children were positioned with their head leaning forward in front of the head side supports for more than half the time43. Additionally, we compared the sitting postures and comfort experience of children using an integrated booster cushion and a high-back booster. Notably, children's activities and perceived discomfort influenced the selection of sitting posture and seatbelt positions44. We have also undertaken studies to evaluate the posture, movement and position of children relative to the seatbelt restraint (with and without a booster seat) under controlled braking and swerving manoeuvres on a closed-circuit test track45;46. This research highlighted the importance of capturing contextual variables such as restraint type and driving context, in these naturalistic studies.

In 2007, we undertook a small-scale naturalistic observational study of 12 families (19 drivers and 25 child passengers aged 1- 8 years), aimed at examining the feasibility of observing child occupant behaviour in passenger cars during real world car trips47. A study vehicle was equipped with video recording system and a data analysis and coding system developed. Families drove the instrumented 'study vehicle' on their regular trips for 3 weeks. Video-recordings were analysed for 92 trips undertaken by 12 families (including 25 children and 19 drivers), and children's OOP status was defined as positions out of the protective zone provided by the CRS structure or otherwise away from the optimal/preferred location within the CRS or vehicle restraint system. Two key findings emerged from this preliminary research: First, the analysis of child posture showed that children were OOP around 70 percent of the time during trips48. This suggests suboptimal restraint positioning for a significant proportion of children's travel leading to serious implications for restraint effectiveness in the event of a crash. Secondly, children accounted for almost 20 percent of all potentially distracting activities/events49 and drivers interacted with children more than 12 times as often as with their mobile phones22.

Together, these findings highlight the potential to identify and develop solutions to counteract this behaviour including vehicle-based, child-restraint designs and behavioural approaches to improve child occupant protection and minimise driver distraction in the event of a crash.

Findings from the preliminary research were based on a small sample of trips for twelve families. Based on these initial findings, a larger study has been initiated with more comprehensive data collection and analyses to explore further: the effects of child age, restraint type, number of child passengers, use of entertainment systems, driving conditions and other potential confounding variables on OOP status and its potential to distract the driver. Two PhD candidates (Cross and Kuo) have joined the research team. Their respective research responsibilities are:

- To use the naturalistic driving observation data and the results of an online survey to identify the predictors of OOP status and to identify the ways in which OOP travel can be minimised using behavioural and engineering techniques, and
- To use the naturalistic driving observation data and vehicle data to investigate the influence of children's behaviour on driver performance and distraction and to identify strategies to improve children's behaviour and restraint status during travel to minimise driver distraction.

The current study builds on previous preliminary research, using leading edge naturalistic driving methods and covert video-recording techniques to observe child occupant and driver behaviour during normal day-to-day trips. The objective of this paper is to describe the methodology of the naturalistic observational study of child passengers during real world car trips.

METHODS

Participants

Fifty volunteer families (including approximately 100 children) are being recruited. Participants (drivers) are being included in the study if they:

- have at least one child aged between 1 and 8 years, who usually travels in a CRS or booster seat in the rear row/s of their vehicle;
- have no more than three child passengers who regularly travel in the rear row/s of their vehicle;
- hold a valid and full car driver's licence valid in the State of Victoria, Australia;
- are aged over 25 years;
- drive on average, at least 100 kilometres per week with their child/children in the car (accumulated in one vehicle);
- live within a 50 kilometre radius from Monash University, Clayton in Victoria, Australia;
- have normal hearing and vision (glasses and contact lenses may be worn);
- have no known medical conditions that may affect their driving (e.g. epilepsy, dementia, or other serious neurological disorders); and
- have no known problems with substance abuse (alcohol, drugs etc).

Regular passengers (defined as any person who travels in their vehicle on one or more journeys on a weekly basis on average) are also included as participants in the study, following acquisition of appropriate signed consent.

Recruitment

Families are being recruited using a variety of strategies including through respondents for a related on-line child safety survey50, Royal Automobile Club of Victoria (RACV) websites and magazine, social media and word-of-mouth methods.

Vehicle Instrumentation and Data Collection

Two luxury model family sedans with automatic transmission have been instrumented to collect data on driver and occupant behaviour as well as vehicle-based data. The study vehicles have been fitted with video cameras and recording system, and a vehicle data acquisition unit. In addition, a Microsoft Kinect™ system comprising an RGB camera and depth sensor was installed in one of the study vehicles, providing 3D motion capture of the rear seat outboard occupants.

The conventional video system comprises eight cameras, strategically positioned to gain an overall view of the forward road scene and the interior of the cabin with minimal disruption to the driver's view and concealed so as not to be obvious to the vehicle occupants. The cameras provide views of the child occupants (both front and lateral views), the driver and a restricted view of the front seat passenger, and the roadway. Cameras have been located in the vehicle interior as described below:

- Camera 1 is located behind the centre internal rear-view mirror, providing a view of the forward road/traffic;
- Camera 2 is embedded in the internal rear-view mirror (behind an opening, 10mm in diameter), providing a view of the driver and the front seat passenger;
- Camera 3 is embedded in the front cabin light enclosure, providing a view of the steering wheel, centre radio console, and the driver's lap;
- Cameras 4 and 5 are positioned in the interior roof of the vehicle, within the DVD player/interior light cavity, providing a frontal view of child passengers;
- Cameras 6 and 7 are embedded in the handle above the door in the rear passenger compartment (one on left, one on right), providing a lateral view of child passengers;
- Camera 8 is located in the rear parcel shelf, providing a view of the road/traffic to the rear.

All camera cables are connected to the data acquisition unit stored in the boot/trunk of the vehicle. The video recording system is operated by a microcontroller, programmed to allow for automatic start-up (within 60 seconds of vehicle 'ignition on'). The recording system can also be de-activated manually by means of the driver pressing a (red) button on the dash behind the steering wheel. This feature was necessary to satisfy ethics requirements and allows drivers to opt out of the study temporarily by shutting down the recording system for any reason at the start of a trip or whilst driving.

In addition to conventional data acquisition system and video cameras, the Microsoft Kinect™ system, composed of an RGB camera and depth sensor, has been installed into one of the two vehicle environments to provide 3D motion capture of the rear seat outboard occupants. The depth sensor consists of an infrared laser projector combined with a monochrome CMOS sensor, which captures motion data in 3D under any ambient light conditions. The data streams are being utilized to provide the 3D location (relative to the sensor) of the head, neck, and shoulders of up to two seated rear row occupants.

Vehicle-based data are being recorded using a GPS-based VBOX™ data acquisition system (DAS) providing accurate position data and information on vehicle speed and braking. Additionally, Mobileye™, a camera-based, multi-purpose, sensor has been installed, providing data on unintentional lane departures, unsafe following distances (headway), imminent collisions and speed limit signs. Data from the Kinect, Mobileye and video camera systems are synchronised with the VBOX data by matching the time stamps on each data stream.

Procedures

Participants are being asked to drive the instrumented 'study vehicle' on their regular trips for a period of two weeks. An $80 fuel voucher is provided to each family as partial recompense for their participation.

Prior to the commencement of each 2-week observation period, the study vehicle is serviced, cleaned, filled with petrol, photographed (i.e., standard inspection photos), and fitted with a new memory card for data storage. Handover of the study vehicle occurs at the participants' house at a briefing session conducted by members of the research team. At this time, parents' informed consent is being obtained in accordance with Institutional Ethics Committee requirements. Parents also complete a brief questionnaire including demographic information, travel patterns, driving behaviour, and children's car travel behaviour. Participant(s) are briefed about the operation of the vehicle and the recording equipment (placement of cameras and what images the cameras will record, how the system is activated/deactivated, how to turn cameras on/off). A written summary of this information is also provided. A CRS fitting specialist attends the briefing session to ensure that all CRS are fitted correctly and, where possible, checks each child in their restraint system and advises parents about any inappropriate usage. All children use their regular CRS, booster seat or seatbelt. Participant(s) are taken for a pilot drive in the study vehicle and are instructed to drive the vehicle as they would normally drive their own vehicle (including safely and responsibly).

Contact is made with participants mid-way through the study period to monitor and address any practical issues and to indicate if there are any trip recordings that they wish to have deleted for any reason (an institutional ethics requirement). At the end of the 2-week observational period, the study vehicle is collected from the participant's house by members of the research team and participants' CRS are fitted back into the family's vehicle by a CRS fitting specialist.

Data coding and analyses

Data is continuously collected, including: video data from the camera, quantitative position data from the Kinect, and vehicle dynamics data from the VBOX. The video data is then coded to get child behaviour and vehicle occupants with whom they interact, driver behaviour, and driver interactions with the road users and road infrastructure. Variables of interest are summarised below.

Child-related	Duration/nature of OOP events; magnitude of OOP; in-vehicle activities; restraint type
Driver-related	Driver looking behaviour; hands off steering wheel; engagement in secondary behaviour
Vehicle-based	Speed, braking, lane position, headway, trip distance/duration
Traffic/environment	Traffic conditions/volume during journey; road type/class
Other	Identification of driver (e.g. parent: mother/father); presence of front-seat passenger; number of children in vehicle

In our pilot studies described above, analyses of video data to quantify position and posture were conducted manually and were labour intensive. In the current study we are developing a data analysis protocol including automation of children's head/torso position and driver looking behaviour (using Kinect and computer vision algorithms). We will explore strategies to identify triggers in the quantitative position data such that an analyst could be directed to a specific epoch in the video stream to extract the behavioural context. The primary objectives of the data analysis will be to: (i) quantify how often and to what degree the child occupant is in a non-ideal (OOP) position; and (ii) to describe and quantify child-related driver distraction.

PRELIMINARY FINDINGS

Data collection commenced in the second half of 2013. At the time of publication of this paper, 42 families were recruited and 8 families have completed their in-vehicle data collection.

Participant Characteristics

For the 42 families recruited to date, the number of children totals 73 (38 males; 35 females) and they range in age from one month to 12 years and one month of age (Mean age =3 years,10 months, SD=29.4 months).

The number of children per family ranged from one to four, with nearly 50 percent of families having at least two children under the age of 16 years (1 child: n = 13; 2 children: n = 23; 3 children: n = 5; 4 children: n =1). Most children used a forward facing child restraint with an integrated harness for their usual car trips (66%), the remaining children used a booster seat with a lap-sash seatbelt (24%) or an adult lap-sash seatbelt (5%).

The participating parents were aged between 32 and 52 years (Mean age = 38.4 years, SD = 4.5 years). Parents were predominantly female (66%) and most (95%) were married (or defacto partnership). Over 48 percent of parents reported that they had achieved a minimum of a university level education and more than half of the parents reported a combined gross household income of $110,000 AUD. Most parents reported that they worked full time (42%) or part time (29%) and nearly 72% of the parents were born in Australia.

Observational data collection

At the time of publication, data collection was complete for 8 families (14 drivers and 16 children). Notwithstanding a small number of technical challenges with some aspects of the auto start-up of the DAS, video and vehicle-based data collection has proceeded seamlessly. Smooth progress has been made on data collection the Kinect data streams: automatic start-up, shut-down, data writing of Kinect color and depth data at 1 frame/sec is advancing well. Some on-going difficulties remain with Kinect system software for conversion of the color and depth data to 3-D skeleton data however a solution to rectify this is underway.

DISCUSSION

This study is the largest naturalistic observational study of its kind focusing on child passengers, their position and its impact on their own safety and the potential for driver distraction. The broad aims of the project are to reduce the incidence of death and serious injury to child vehicle occupants, their families, and other road users by quantifying the positions and posture of children as rear seat occupants of vehicles and their interaction with the driver. Three major components of the study use complementary approaches: a naturalistic observation study of children and drivers in cars (to study both children's position and the potential for driver distraction); a parent survey; and a sled testing program to explore the effects of children's OOP status on injury risk and severity.

Achievements to date demonstrate the feasibility of the equipment and protocol for data collection. Improved, automated methods for quantification of children's OOP and driver distraction which have a high level of accuracy and efficiency are also currently being developed.

A limitation of our methodological approach is the use of a convenience sample for recruitment. However, we will undertake a comparison of relevant demographic, driving and child safety variables for our sample and a larger sample of drivers[50] as well as with population data from the Australian census.

In the next phase of the study, we will use data from the observation phase in controlled sled testing in a laboratory environment to link common OOP postures/behaviours to changes in injury metrics as measured by pediatric ATD. The preliminary crash tests will be conducted at Britax laboratories in Melbourne in order to finalise the protocol and the main tests will be conducted by our research team in Sweden. The expected outcomes of this component of the research will be an improved understanding of the influence of ATD seating position/postures (observed common OOPs) on crash injury outcomes relative to standard dummy seating protocols. Recommendations will be made for improving test protocols, in particular ATD positioning, and restraint system, vehicle design and targeted road safety-related messages for drivers and passengers to improve safety outcomes for child occupants.

The project represents a significant collaborative program of research between Monash University Accident Research Centre, the Center for Injury Research and Prevention at The Children's Hospital of Philadelphia, The University of Michigan Transportation Institute, Chalmers University and key industry partners. The interest of the respective government authorities (VicRoads, TAC), motoring associations (RACV) and strong representation from the automotive, CRS and related industries (GM Holden, Britax, Pro Quip International and Autoliv) is a powerful determinant in guiding the project towards evidence-based solutions for child passenger safety. The motor vehicle and CRS industry project partners have a global presence and this will ensure results are communicated to their worldwide market. The project objectives are strongly aligned with partners' road safety objectives to reduce injuries and fatalities. The combined expertise of these influential partners ensures a tight focus on solutions for design of CRS and motor vehicles to minimise injury to children in the event of a crash.

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