Title: The Child Safety in Cars International Collaborative Study: Early findings and lessons learned

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Keywords: naturalistic observation study, naturalistic driving study, NDS, child restraint systems, child occupant behaviour, child occupant positions, out-of-position, child occupant-related driver distraction, Kinect

Introduction

It is well known that in the rear seat of cars, child occupants slouch, sleep, and interact with electronic devices, toys and other passengers. Our previous findings from a pilot study showed that child occupants rarely remain in an optimal position for the efficient functioning of their child restraint systems (CRS) throughout the duration of their journey (Charlton et al., 2010). Such behaviours may not only affect restraint effectiveness in terms of injury prevention but may also have a negative influence on driver performance and distraction (Koppel et al., 2011). Moreover, children's seating posture and out-of-position (OOP) status and particularly the quantification of their head position has important implications for design of test programs using anthropomorphic test devices (ATD) intended to mimic the human occupant. Importantly, solutions that might arise from evaluations based on real-world pre-crash positions of child occupants vs. conventional in-position ATDs may lead to different design specifications of rear seat restraint systems and energy management features of the vehicle interior. To advance our understanding of child occupant's real-world travel, we designed the first international large-scale naturalistic driving study (NDS) of children in cars. Key objectives of the project include: (i) the documentation of the natural behaviour of child occupants during real-world car trips, including the circumstances which promote/reduce their OOP status; (ii) the identification of the impact of children's OOP status on injury outcomes; (iii) the assessment of parent knowledge, attitudes and practice in relation to child occupant and driver safety in cars; and (iv) the determination of the child occupant behaviours which contribute to driver distraction.

This paper provides insights and lessons learned from the implementation of an NDS which included child occupants. Issues include legal, logistical and technical matters during implementation as well as the management and analysis of complex, confidential, qualitative data generated from the NDS. This information will be useful for other research teams who are considering applying NDS methods to study child occupant behaviour.

Methods

Forty-two volunteer families (including 82 children), with at least one child aged between 1 and 8 years (in a Forward Facing CRS or booster seat) drove an instrumented study car for 2 weeks. Child occupants used their regular CRS which was installed and checked for appropriateness by qualified CRS fitters. Families/drivers were advised to use the vehicle in the same manner they would normally use their own vehicle. In addition to a conventional data acquisition system and video cameras, a Microsoft Kinect™ system comprising an RGB camera and depth sensor was installed in one of the study vehicles. The Kinect™ system provided quantitative 3D motion capture of the rear seat child occupants. Continuous collection of in-vehicle data and vehicle dynamics allowed for the derivation of measures including the behaviour of child occupants and other occupants with whom they interact, head position and posture of rear seat occupants, driver behaviour (e.g., where they are looking), vehicle dynamics (e.g., speed, lane position, headway). Data collection was completed in October 2014.

Results and Discussion

The study generated approximately 690 hours (3 terabytes) of data. Participating families completed 1651 trips. Most trips were undertaken by a female driver and during daylight hours. Child occupants' behaviour, affect, OOP status (seating posture relative to ideal), and in-vehicle factors (e.g., number of occupants, seating allocation) were determined by manual review of in-vehicle videos. Child occupants' head position coordinates were extracted through a combination of manual and automated processes from Kinect™ images (Arbogast et al., 2016, Loeb et al, 2016). Child-related driver distraction was analysed by applying novel machine learning solutions and imaging techniques to the driver video to measure frequency and duration of off-road glances and physiological metrics indicative of driver cognitive load (Kuo et al., 2014; 2015). Current activities include sled tests to examine the injury implications of child occupants' head positions identified in the NDS component (Arbogast et al., 2016). In addition, a survey of parents was conducted to explore how the safety culture and attitudes of families influence their safe travel in cars (Cross et al., Submitted). These components of the study are the focus of other publications and are not discussed here.

NDS are increasingly being conducted to provide insights into driver and occupant behaviour during real-world, everyday trips by recording details of driver, occupants, vehicle and surroundings through unobtrusive data gathering equipment and without experimental control. NDS generate 'big data' which is defined as large amounts of data which requires new technologies and architectures so that it becomes possible to extract value from it (Marx, 2013). 'Big data' has put forward many challenges due to its various properties like volume (size), velocity (size/time) and variety (Laney, 2001), as well as its complexity (nested/hierarchical structure, qualitative video). Although the Children in Cars dataset may not strictly meet all 'big data' criteria, the sensitive nature and complexity of our data renders many existing analytical solutions unfeasible.

Relevant learnings have included:

- Data capture: i) Logistically easier and more cost efficient to instrument study vehicles rather than participant families' own vehicles – also it allowed researchers to use more sophisticated technology and covert placement of cameras than would otherwise be possible; ii) Need for 'child resistant' hardware, achieved by embedding cameras within the vehicle trim where possible (also serves dual purpose of being discreet), and iii) Systems need to function accurately across multiple scenarios including day/night and variable light conditions and dynamic behaviour of occupants that might compromise the quality of data capture.
- Data analysis: Conventionally, analysis of video recordings of occupants has relied on manual review to code, classify and describe observed behaviours. The sensitive nature of this data prohibits the use of typical crowdsourcing solutions. This study employed a combination of automated algorithmic solutions and selective manual review. This limited the types of behaviour that could be analysed, but allowed us to study those behaviours across the entire dataset. Since camera technology and analysis techniques are constantly evolving, it is important to scan newly available techniques when designing new studies. A particular challenge for analyses involving multiple sensor sources was the need to synchronise data streams.
- Data sharing/storage/transfer: 'Big data' is not new and although current solutions for transferring and storing large amounts of data are adequate on a logistic level, the highly sensitive nature of this dataset due to the capacity to readily identify participants, makes many of these methods unsuitable. Retaining large quantities of sensitive data is typically considered a risky practice, and so workflows involving encryption and time-limited access control have been trialled.
- Data privacy/ethics: The data mining problem - the development of novel analytical methods may uncover behavioural patterns and new data that extend beyond what participants initially consent to (or that researchers were initially aware of). Examples include the inference of driver heart rate and associated physiological measures using imaging photoplethysmography (IPPG), and the development of driver signatures from vehicle data that may overcome de-identification efforts.
- Legal/ethical issues: Any NDS, if large in scale, or long in duration, can generate recordings of private and personal interactions, as well as aberrant, illegal and unsafe behaviours. Protocols to address institutional ethics requirements relating to these issues included (i) a voluntary "stop button" on the vehicle dashboard which participant families were instructed to use should they wish to stop the in-vehicle recording; (ii) the option at the mid- and end-points of data collection for participant families to delete recordings of specific trips; (iii) feedback provided to participating families where persistent behaviours of concern were observed, e.g. unsafe child restraint use (iv) the requirement that participants provide informed consent that, in the unlikely event that a driver was involved in a crash, the video recordings from the study vehicle could be subpoenaed for use as evidence in a court of law; and (v) in the event that a participant was observed to drive in a sustained dangerous manner, or any other illegal activity was recorded, the institution would reserve the right to bring the matter to the attention of its legal advisors or to the police.

NDS are a useful but complex method to gather real-life data. Outcomes of this NDS research will directly inform crash test procedures that account for natural positions of child occupants, and the design of enhanced CRS, vehicle interiors and community awareness messages to improve the safety of children.

Acknowledgements

This research was supported by an Australian Research Council Linkage Scheme awarded to the Monash University Accident Research Centre (MUARC) for the project Child Safety in Cars: An International Collaboration (LP110200334), with partners Autoliv Development AB, Chalmers University of Technology, General Motors-Holden, Pro Quip International, RACV, The Children's Hospital of Philadelphia Research Institute, Transport Accident Commission, University of Michigan Transportation Institute, and VicRoads. The Children's Hospital of Philadelphia involvement in this work was supported by the Center for Child Injury Prevention Studies.

Declaration of Published papers:

Arbogast, K.B., J.Y., Loeb, H., Kuo, J., Koppel, S., Bohman, K., & Charlton, J. L., (2016). Naturalistic driving study of rear seat child occupants: Quantification of head position using a Kinect™ sensor. Traffic Injury Prevention. 17, 168-174.

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Kuo, J., Charlton, J. L., Koppel, S., Rudin-Brown, C. M., & Cross, S. (2016). Modelling driving performance using in-vehicle speech data from a naturalistic driving study. Human Factors. doi: 10.1177/0018720816650565

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