Title: Will automated driving technologies obsolete today's effective restraint systems?

Authors:
- Damien Subit, Ecole Nationale Supérieure d'Arts et Métiers, Institut de Biomécanique Humaine Georges Charpak, Paris, France
- Philippe Vézin, Institut Français des Sciences et Technologies des Transports, de l'Amenagement et des Réseaux, Département Transport Santé Sécurité, Bron, France
- Sébastien Laporte, Ecole Nationale Supérieure d'Arts et Métiers, Institut de Biomécanique Humaine Georges Charpak, Paris, France
- Baptiste Sandoz, Ecole Nationale Supérieure d'Arts et Métiers, Institut de Biomécanique Humaine Georges Charpak, Paris, France

Abstract: Autonomous driving will trigger a shift in the epidemiology of road traffic injuries that is raising concerns for public health and requires the design of new strategies for the protection of vehicle occupants. Indeed, today’s effective protection systems were developed for crashes caused primarily by human errors, and they may be ineffective or even injurious in the new typology of crashes that will arise with the increasing level of automation in vehicles. There is a need to continuously analyze and forecast vehicles behavior on roads as automated driving technologies spread and get updated, to design effective countermeasures and address ethical and public health challenges.

Keywords: road traffic injuries, automated driving technology, epidemiology, occupant protection

Road traffic injuries (RTI) in industrialized countries are a topic of great concern, as these potentially debilitating or fatal injuries are seen as preventable. The reduction of the severity and frequency of RTI triggers much debate about which technologies and policies could lead to safer driving behaviors[1]. Automated driving technologies (ADT) that assist vehicle drivers or take over the driving tasks are expected to implement better decisions than humans do and make the road safer. To attain this goal, new models for exposure and risk assessment for RTI are needed.

EXPECTATIONS FROM AUTOMATED DRIVING TECHNOLOGIES

The capability of ADT is an unprecedented change in the automotive transportation landscape that triggers two concurrent expectations:

- the '*Safety Expectation*': Crashes caused by human errors will be prevented. There is potential for a colossal gain in the reduction of RTI as human error is the primary cause in 94 % of crashes today (bit.ly/29kcWKA),
- the '*Better Traffic Expectation*': Algorithms will ensure that vehicles obey traffic rules, and adjust their behavior to increase road throughput and decrease travel time. They will trigger a dramatic change in traffic patterns that will lead to less congestion, increase comfort for road users, and allow vehicle occupants to better exploit the time spent in a car.

Both expectations are formulated by projecting the benefits of ADT in today's environment and neglecting the structural changes to traffic that ADT will bring. For instance, the *Safety Expectation* is based upon the assumption that vehicles equipped with ADT will drive like humans do, minus the human driving errors, in the same road and traffic environment, which is fundamentally in conflict with the *Better Traffic Expectation*. Indeed, today, both expectations cannot be met simultaneously, as the safety strategies that are currently available to protect road users are effective for today's human driven traffic conditions, not for an environment where the *Better Traffic Expectation* is met. This incompatibility will probably hold true for a significant period of time, while the level of automation increases in the vehicle fleet. The underlying reason is that safety systems in today's vehicles are designed based on the retrospective analysis of accident data, *i.e.* from accidents prominently caused by human errors, in vehicles controlled by humans. Changes in vehicle driving technologies will affect vehicle flow and traffic patterns[3], and lead to a new epidemiology of RTI: indeed, ADT are expected to greatly change road traffic accident scenarios[4], by means of (1) a reduction in the vehicle energy prior to a crash thanks to better braking ability, (2) the capability to prevent accidents by the execution of avoidance maneuvers, and (3) a better knowledge of the vehicle surroundings and road infrastructure. Therefore, there is a risk that the safety systems designed for human driven vehicles may be ineffective, or even injurious, in vehicle equipped with ADT as the automation of driving tasks increases. In short, tomorrow's road safety technology cannot be designed based upon yesterday's accident scenarios.

HOW ARE COUNTERMEASURES DEVELOPED FOR TODAY'S VEHICLES?

Countermeasures in today's vehicles are tailored to be the most effective in the typical accident scenarios for which new cars have to pass regulatory thresholds for occupant safety to be allowed on public roads. Along the standard accident scenarios, a standard seated position for vehicle occupants is also implemented: today, it is represented by the position of crash-test dummies. Crash-test dummies seat in an upright and forward-facing position, they "look" straight ahead, and have both hands on the steering wheel when they "drive" (figure 1(a)). This position is the gold standard for the design and evaluation of countermeasures for occupant protection. All the other seating positions are collectively referred to as "out-of-position". The effect of countermeasures on out-of-position occupants is an important concern in automotive safety, as countermeasures that are effective in the standard position may be ineffective or even injurious for out-of-position occupants.

Furthermore, ADT will give occupants more freedom during their ride, and occupants may be out-of-position during part of or all the duration of their trip depending on their vehicle's level of automation Technologies that allow vehicles to be self-driven on highways are gradually available on luxury vehicles, and the spread of ADT bringing new challenges to safety researchers: as occupants will have the opportunity to change position based on their occupation, the response of the restraint systems will need to be adjusted so that the occupants are efficiently protected[5]. Therefore, there is a risk that existing restraint strategies will be less effective in the new occupant position. Further away, prototypes and designer concepts of fully autonomous vehicles suggest that occupant seating habits will change dramatically to allow vehicle occupants to enjoy more social seating configurations, and various activities (relaxing, reading, or having a meeting, figure 1(b)). The methods currently in place to evaluate the performance of occupant protection systems do not account for the change in occupant seating habits.

DESIGNING ROAD TRAFFIC SAFETY WITH THE RIGHT PERFORMANCE TARGETS

The possible inadequacy of countermeasure design targets for the actual scenarios of road traffic accident is a fair concern, as they are historical precedents: for instance, epidemiology studies revealed that frontal airbags that were developed to mitigate injuries in high speed accidents increased the risk of injuries when deployed in low-speed accidents, in particular for women[5]. The knowledge of accident causation and injury mechanisms is a prerequisite to develop realistic driving algorithms and protection strategies, and properly address RTI. If the *Better Traffic Expectation* comes true, unknown accident scenarios will arise, and the safety systems proven effective in human driven vehicles may become obsolete, as accident scenarios and occupant activities in the car will be different compared to today's[6]. Ultimately, retrospective epidemiologic studies may be ineffective to identify accident scenarios, because of its much longer characteristic timescale (several years) compared to the pace at which onboard vehicle software can be upgraded (several times a year, http://bit.ly/2cH9Ce2). Identifying meaningful scenarios for both normal driving and traffic conflicts (situations that put road users at risk if the vehicle kinematics is not modified) is a prerequisite for the design of ADT. The trolley problem[2], that is often used to illustrate the non-trivial decisions that driving algorithms will have to take, has been discussed as too unrealistic and naive[7], and is therefore inadequate to model what future traffic conflicts will be. Today's challenge is to develop guidelines for the design of future vehicles, while having little information on the environment in which they will evolve.

THE NEED TO PREPARE FOR FUTURE ROAD TRAFFIC INJURIES

ADT are a vivid example of "disruptive technologies" that affect the environment so profoundly that safety researchers and medical professional do not have the tool yet to develop effective intervention strategies to mitigate injuries. Research is indeed needed to design new simulation tools and computational traffic models to anticipate the consequences of changing vehicle behavior onto the epidemiology of RTI, and fully exploit the potential of ADT to protect road users. The limitation in how much today's knowledge can apply to the future of transportation raises important questions about the risks associated to the development of ADT in both traffic conflicts and accident situations. The assessment and management of these risks through evidence-based strategies will define whether and how fast-changing ADT will contribute to improving public health.

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(a) (b)

Figure 1: (a) Anthropomorphic test device in the standard seated posture, (b) Representation of what could be the driver position in a future autonomous vehicle (by the design firm IDEO).

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Fig 1b: IDEO, automobility, http://automobility.ideo.com/ (with permission)