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1 *Title:* Will automated driving technologies obsolete today's effective restraint systems?
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13 *Abstract:* Autonomous driving will trigger a shift in the epidemiology of road traffic injuries
14 that is raising concerns for public health and requires the design of new strategies for the
15 protection of vehicle occupants. Indeed, today's effective protection systems were developed
16 for crashes caused primarily by human errors, and they may be ineffective or even injurious in
17 the new typology of crashes that will arise with the increasing level of automation in vehicles.
18 There is a need to continuously analyze and forecast vehicles behavior on roads as automated
19 driving technologies spread and get updated, to design effective countermeasures and address
20 ethical and public health challenges.
21

22 *Keywords:* road traffic injuries, automated driving technology, epidemiology, occupant
23 protection
24
25

26 Road traffic injuries (RTI) in industrialized countries are a topic of great concern, as these
27 potentially debilitating or fatal injuries are seen as preventable. The reduction of the severity
28 and frequency of RTI triggers much debate about which technologies and policies could lead
29 to safer driving behaviors¹. Automated driving technologies (ADT) that assist vehicle drivers
30 or take over the driving tasks are expected to implement better decisions than humans do and
31 make the road safer. To attain this goal, new models for exposure and risk assessment for RTI
32 are needed.
33

34 **EXPECTATIONS FROM AUTOMATED DRIVING TECHNOLOGIES**

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

37 - the '*Safety Expectation*': Crashes caused by human errors will be prevented. There is
38 potential for a colossal gain in the reduction of RTI as human error is the primary cause in
39 94 % of crashes today (bit.ly/29kcWKA),
40 - the '*Better Traffic Expectation*': Algorithms will ensure that vehicles obey traffic rules, and
41 adjust their behavior to increase road throughput and decrease travel time. They will trigger a
42 dramatic change in traffic patterns that will lead to less congestion, increase comfort for road
43 users, and allow vehicle occupants to better exploit the time spent in a car.
44 Both expectations are formulated by projecting the benefits of ADT in today's environment
45 and neglecting the structural changes to traffic that ADT will bring. For instance, the *Safety*
46 *Expectation* is based upon the assumption that vehicles equipped with ADT will drive like
47 humans do, minus the human driving errors, in the same road and traffic environment, which
48 is fundamentally in conflict with the *Better Traffic Expectation*. Indeed, today, both
49 expectations cannot be met simultaneously, as the safety strategies that are currently available
50 to protect road users are effective for today's human driven traffic conditions, not for an
51 environment where the *Better Traffic Expectation* is met. This incompatibility will probably
52 hold true for a significant period of time, while the level of automation increases in the
53 vehicle fleet. The underlying reason is that safety systems in today's vehicles are designed
54 based on the retrospective analysis of accident data, *i.e.* from accidents prominently caused by
55 human errors, in vehicles controlled by humans. Changes in vehicle driving technologies will
56 affect vehicle flow and traffic patterns³, and lead to a new epidemiology of RTI: indeed, ADT
57 are expected to greatly change road traffic accident scenarios⁴, by means of (1) a reduction in
58 the vehicle energy prior to a crash thanks to better braking ability, (2) the capability to prevent
59 accidents by the execution of avoidance maneuvers, and (3) a better knowledge of the vehicle
60 surroundings and road infrastructure. Therefore, there is a risk that the safety systems
61 designed for human driven vehicles may be ineffective, or even injurious, in vehicle equipped
62 with ADT as the automation of driving tasks increases. In short, tomorrow's road safety
63 technology cannot be designed based upon yesterday's accident scenarios.

64

65 **HOW ARE COUNTERMEASURES DEVELOPED FOR TODAY'S VEHICLES?**

66 Countermeasures in today's vehicles are tailored to be the most effective in the typical
67 accident scenarios for which new cars have to pass regulatory thresholds for occupant safety
68 to be allowed on public roads. Along the standard accident scenarios, a standard seated
69 position for vehicle occupants is also implemented: today, it is represented by the position of
70 crash-test dummies. Crash-test dummies seat in an upright and forward-facing position, they

71 “look” straight ahead, and have both hands on the steering wheel when they “drive” (figure
72 1(a)). This position is the gold standard for the design and evaluation of countermeasures for
73 occupant protection. All the other seating positions are collectively referred to as “out-of-
74 position”. The effect of countermeasures on out-of-position occupants is an important concern
75 in automotive safety, as countermeasures that are effective in the standard position may be
76 ineffective or even injurious for out-of-position occupants.

77
78 Furthermore, ADT will give occupants more freedom during their ride, and occupants may be
79 out-of-position during part of or all the duration of their trip depending on their vehicle’s level
80 of automation Technologies that allow vehicles to be self-driven on highways are gradually
81 available on luxury vehicles, and the spread of ADT bringing new challenges to safety
82 researchers: as occupants will have the opportunity to change position based on their
83 occupation, the response of the restraint systems will need to be adjusted so that the occupants
84 are efficiently protected⁵. Therefore, there is a risk that existing restraint strategies will be less
85 effective in the new occupant position. Further away, prototypes and designer concepts of
86 fully autonomous vehicles suggest that occupant seating habits will change dramatically to
87 allow vehicle occupants to enjoy more social seating configurations, and various activities
88 (relaxing, reading, or having a meeting, figure 1(b)). The methods currently in place to
89 evaluate the performance of occupant protection systems do not account for the change in
90 occupant seating habits.

91
92 **DESIGNING ROAD TRAFFIC SAFETY WITH THE RIGHT PERFORMANCE**
93 **TARGETS**

94 The possible inadequacy of countermeasure design targets for the actual scenarios of road
95 traffic accident is a fair concern, as they are historical precedents: for instance, epidemiology
96 studies revealed that frontal airbags that were developed to mitigate injuries in high speed
97 accidents increased the risk of injuries when deployed in low-speed accidents, in particular for
98 women⁵. The knowledge of accident causation and injury mechanisms is a prerequisite to
99 develop realistic driving algorithms and protection strategies, and properly address RTI. If the
100 *Better Traffic Expectation* comes true, unknown accident scenarios will arise, and the safety
101 systems proven effective in human driven vehicles may become obsolete, as accident scenarios
102 and occupant activities in the car will be different compared to today’s⁶. Ultimately,
103 retrospective epidemiologic studies may be ineffective to identify accident scenarios, because
104 of its much longer characteristic timescale (several years) compared to the pace at which on-

105 board vehicle software can be upgraded (several times a year, <http://bit.ly/2cH9Ce2>).
106 Identifying meaningful scenarios for both normal driving and traffic conflicts (situations that
107 put road users at risk if the vehicle kinematics is not modified) is a prerequisite for the design
108 of ADT. The trolley problem², that is often used to illustrate the non-trivial decisions that
109 driving algorithms will have to take, has been discussed as too unrealistic and naive⁷, and is
110 therefore inadequate to model what future traffic conflicts will be. Today's challenge is to
111 develop guidelines for the design of future vehicles, while having little information on the
112 environment in which they will evolve.

113

114 **THE NEED TO PREPARE FOR FUTURE ROAD TRAFFIC INJURIES**

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

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126

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(a)



(b)

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

148

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