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A review of risk factors associated with elderly, truck and office worker drivers for automated driving applications

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1. Introduction

Road traffic fatalities and injuries pose a severe threat to public health, since they are the eighth cause of mortality worldwide, with about 1.3 million deaths and many more (20-50 million) suffering non-fatal injuries each year [1]. According to studies, human error is responsible for up to 94% of vehicle accidents [2]. The remaining percentage was due to a mix of factors concerning road environment and vehicle [3]. The aforementioned finding reveals that the human factor component has a substantial role in the accident occurrence; in other words, humans are responsible for the majority of crashes. As a result, the human element, as well as other road and vehicle environment components, should be thoroughly explored in order to mitigate and diminish road accident injuries and fatalities. For that purpose, this research aims to identify risk factors that affect driving performance and road safety.

When intelligent transportation systems will become more widely available in the future, human factor, congestion, and energy efficiency will be improved [4]. A key part of intelligent transportation systems will be Autonomous Vehicles (AVs) and their safety should be investigated, in this direction, the key principles for "safety through automation" were proposed by the Forum of European Road Safety Research Institutes (FERSI). Specifically, the necessity of "Human-Centred Design", in which all conceivable user profiles should be considered while developing AVs, is a vital principle for automation safety. Furthermore, "Human-Centred Design" encompasses safe communication among road users as well as safe interactions with vulnerable road users [5], emphasizing the importance of the human component in AV design. For that purpose, the assessment focused on three specific "use case" drivers or personas: the elderly, truck, and office worker drivers. Specifically, this study focuses on three groups of users: elderly, truck, and office worker (i.e., working and driving simultaneously; feasible at higher levels of automation) drivers, with the goal of identifying risk factors that affect road safety and driving performance. This review also aims to highlight the risk factors that should be taken into account in future safety analyses of AD applications. The examined risk factors were then explored in terms of how they might be extended and altered at various future AD levels, as well as which risk factors should be incorporated in future AD safety analyses.

2. Methodology

As mentioned previously, this analysis includes and reviews risk factors by focusing on three specific driver personas. The research was undertaken within the EU H2020 HADRIAN project, which aims to develop a novel Human Machine Interface (HMI) that would offer seamless interaction (titled "fluid") between the driver and the automated vehicle. The “use case” drivers are inspired by the HADRIAN project as well.

The literature search was conducted on the most popular databases with published studies, the majority of which were published in peer-reviewed journals. Scopus, Science Direct, and Google Scholar were used to find papers primarily from Europe and the United States, published after 2005, using particular search terms and priority criteria. All findings from the Safety Cube DSS; a European Road Safety Decision Support System, were also used. As previously stated, the initial step in the literature review process was a search of the top databases. The next stage was to review the title and abstract and determine whether they were appropriate. The third phase required that the results are statistically significant and the methodology be rational and reasonable in order for a

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study to be included in the final table (this criterion was met with most papers, as most of them were judged by peer review). In total, more than 100 studies were included in the full-text review, with about 300 being screened.

3. Analysis and Results

The findings through the literature review, namely risk factors for each use case, are provided in this section. The detected factors were separated into three categories: elderly, truck, and office worker drivers. These use case drivers were inspired by research undertaken as part of the EU H2020 HADRIAN project, as previously stated. The literature research identified many risk factors that have a substantial impact on driving safety and performance, which are presented in the following table and are discussed in the full-text review. The factors are organized in three columns in Table 1. Each column indicates a different use case.

In addition, as shown in Table 1, the acquired factors were divided into two or three categories depending on the use case. In the case of older drivers, the factors were divided into three categories: age-related impairments, age-related medical conditions, and age-related medication. The adopted categorization is based on the structure of an ElderSafe report from the European Commission [6] and a published review [7]. Furthermore, truck driver risk factors are divided into the following categories: i) Driver-related Factors, ii) Work-related Conditions, and iii) Driving Conditions. Furthermore, factors affecting office workers are classified as follows: i) Working-related Conditions, and ii) Driver Behaviour. The categorization was done in such a way that the examined criteria were divided into as few specialized categories as feasible, while still taking into account the three basic elements of the driving task: human, traffic environment, and vehicle.

Table 1: Reviewed Factors

1. Elderly Drivers	2. Truck Drivers	3. Office Worker Drivers
1.1 Age-related Impairments: • Mental Workload • Inattention • Distraction • Reaction Time • Fatigue • Cognitive Functions • Headway & Speed • Joint Flexibility • Vision • Emotions	2.1 Driver-related Factors: • Age • Driving Experience • Distraction/ Inattention	3.1 Working-related Conditions: • Distraction • Inattention • Stress • Fatigue
1.2 Age-related medical conditions	2.2 Work-related Conditions: • Fatigue • Working Hours • Sleep Duration • Sleep Disorders • Nighttime Driving • Obesity • Heavy Vehicle Configuration (Single Or Double Type Of Trailer) • Company's Safety Policy	3.2 Driver Behaviour: • Speeding • Risk-Taking
1.3 Age-Related Medication	2.3 Driving Conditions: • Road Type	

4. Discussion

The obtained risk factors from this study are listed in Table 1, and the extensive findings can be found in the full-text review. The driving task will still involve human inputs and interventions at intermediate SAE automation levels (i.e., SAE levels 2, 3) prior to highly automated (i.e., SAE levels 4, 5) [8]. Apart from the Take-Over Request (TOR), there will be areas of the commuting routes where AD will not be available and the drivers will have to drive manually at these two AD levels. As a result, the studied risk factors will be present in these manual driving sections, and AV manufacturers could work on eliminating or minimizing these risk factors with technical assistance. However, AV manufacturers should place a greater emphasis on elderly drivers, as AD will appeal to them more if the majority of the journey is self-driven. TORs (transition from automated to manual driving), which will be a new task for AV users and will connect automated and manual driving, should be investigated more thoroughly in terms of risk factors because human factors will still be present during TORs.

More specifically, all of the risk factors will be present during TORs. However, their impact on accident risk and driving performance will redistribute, necessitating more investigation into how the risk factors discovered would affect accident risk and driving performance during TORs. Regardless of the use case driver, special attention and research should be given to the following risk considerations during TORs:

- **Distraction**: During the TORs, drivers are more likely to be distracted and inattentive. This is because when AD is activated, AVs would allow the driver to be distracted by NDRTs. As a result, the drivers would glance at their laptop, smartphone, or tablet, prior to TORs, rather than outside the vehicle [9].
- **Inattention**: Drivers will be more prone, for the same reason as distraction, to be distracted and inattentive during the TORs by thinking about open issues and liabilities.
- **Stress**: Emotions of stress are likely to be a risk factor in all use cases, since people will experience stress that is unrelated to driving activities, which necessitates more investigation. According to the literature, emotions have a considerable impact on driving performance and the likelihood of an accident [10]–[13].
- **Fatigue**: For the drivers, fatigue will be a major risk factor. AVs will allow users to fall asleep when operating in AD because they will not have to be engaged with the driving activity, and in combination with the fact that the driver may become tired or perhaps fall asleep easier compared to low SAE levels since they are not engaged to the driving task. Fatigue is a serious concern for driver safety as predicts more road accidents [14], [15].
- **Driving Experience**: In urgent requests, driving experience will be a determining element in the overall execution of the TOR maneuver. The driving experience will be a determining factor, for instance, if the driver evaluated all relevant information in the driving environment before taking control, and consequently for the duration of perception or reaction.

There are no human interventions at SAE levels 4 and 5, hence the reviewed risk factors do not exist. As a result, when building autonomous driving concepts, the human aspect, which is responsible for 65-95 percent of accidents [2], [3], will be decreased and, to some extent, removed. The removal of accident risk would be achieved by removing humans from the activity of driving, according to an ideal hypothesis for AD [16], [17]. A more reasonable assumption is that human error will be replaced by accidents caused by malfunctioning automated technologies [5]. As a result, when these levels become available, another form of analysis (e.g., AD mechanical failure) will be required to assess accident risk.

With technology aid like driver monitoring or a system that intervenes with driving corrections, AV manufacturers might focus on minimizing or even eliminating these risk factors, especially for AD up to SAE level 3. Even at AD levels 2 and 3, the human factor should be studied in order to mitigate and reduce its impact on road accident fatalities. For that purpose, safer AD systems could be achieved by minimizing or even eliminating the human factor, which is responsible for up to 94 percent of traffic accidents [2]. It is an opportunity to lower risk factors associated with automated driving, particularly at the stage when automation will be introduced more dynamically into the traffic mix, in order to achieve higher AV market penetration rates. Furthermore, as previously said, AV manufacturers should place a greater emphasis on elderly drivers because driving will be more appealing to them. In order to achieve safer AD systems, different driving profiles should be examined and treated differently. This is in line with the literature and FERSI main principle of "Human-Centred Design" [5] which suggests that while developing AVs, all conceivable user profiles should be addressed.

5. Conclusions

This research identified risk factors that affect road safety and driving performance, with a particular focus on three groups of users: elderly drivers, truck drivers, and office workers drivers (i.e., working and driving simultaneously; feasible at higher levels of automation). The goal of this review was to identify the risk factors that should be taken into account in future safety analyses. Table 1 lists the risk factors discovered throughout this study. The risk factors were then divided into distinct categories. Following that, the examined risk variables are discussed in terms of how they might be extended and altered at various future AD levels, as well as what risk factors should be incorporated in future AD safety analyses. The HADRIAN project, like any other HMI stakeholder, could use the current review to highlight risk factors assisting in developing a human-centered assessment approach that will analyze how humans interact with alternative HMI setups. Overall, there is no direct link between risk factors and the likelihood of an accident or recorded traffic accidents. Researchers can quickly identify missing parts of the literature and directives for their future research in the full-text work. In the full-text work, future research recommendations were given, and researchers might then focus on filling in the gaps that this work did not address because this study is not flawless. Finally, the risk factors examined could help stakeholders make a safer transition to autonomous and manual driving for all road users.

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