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SAFE Move for older drivers: A French-Swedish research initiative to keep the balance between safety and mobility

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ABSTRACT: Faced with the aging of the population, it is crucial for older drivers to keep driving in order to ensure their mobility and autonomy in daily life as long as possible. Driving is an important aspect of maintaining mobility and independence in older adults. Driving is a complex task, requiring a range of visual, psychomotor and cognitive abilities. As people aged, a number of physical and cognitive changes, as well as health problems, may affect driving ability. The regulation of driving activity according to one's actual motor, visual and cognitive state is crucial for continuing to drive in a safe manner, for maintaining mobility and autonomy and for reducing accident risk. The SafeMove project is based on the hypothesis that a correct estimation of one's driving ability is necessary to drive safely in older drivers. A review of the literature on self-assessment of situations/scenarios that are challenging for older drivers was carried out. Two cohort studies were conducted (Sweden and France) to identify determinants of driving regulation, i.e. factors leading to under- and overestimation of cognitive performances and driving ability. On-road tests with a sub-set (approx. 40) of the respondents were performed in Sweden and will be performed in France. These results will together with a review of older driver training literature be used for the design of driving simulator-based training (DSBT) curricula which will primarily be evaluated with volunteers from the on-road tests. Furthermore, a current state-of-the-art and literature review of critical driving assistance systems for older drivers was carried out with the objective develop a Driver-Vehicle Interaction System (DVIS) to monitor and control assistance systems according to driver's needs. The presentation will give an overview of the whole project.

KEY WORDS: older drivers, driver training, driver support systems, mobility, safety

1. Introduction

There has been tremendous growth in the older population in developed countries and this trend is expected to continue. In France, according to demographic forecasts, a third of the population will be 65 or over in 2030. As a consequence, the number of older people who drive increased dramatically during recent decades. The vast majority of aged people use cars to ensure their mobility, and driving is necessary for their autonomy.

This paper presents a joint Swedish-French project on older drivers called SafeMove which started in 2012 and will end by mid-2015. The project is a result from a collaborative effort made by SAFER in Sweden and MOVEO in France.

The project is coordinated by VTI and IFSTAR and involves 3 Swedish and 6 French partners from industry and research.

- identifying determinants for driving regulation, i.e. factors leading to under- and overestimation of cognitive performances and driving ability.
- developing and evaluating a driving simulator based training (DSBT) curriculum.
- adapting driver assistance systems with the aim to prolong active driving for older drivers.

The problem addressed by SafeMove can be depicted as in Fig. 1. The assumption under investigation is that driver training and/or driver assistance system can promote safe mobility for both over and under estimators.

2. Project outline

2.1. Objectives

The aim of the SafeMove project is to promote safe mobility for older (+70 y) drivers by:



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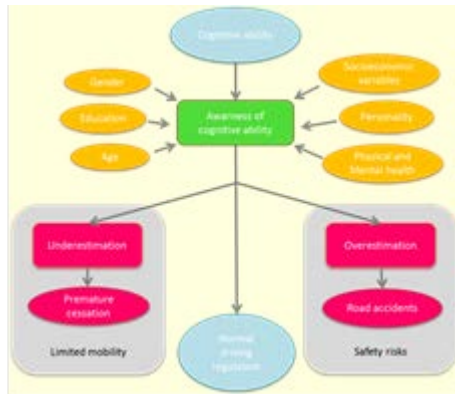


Fig. 1 Relations between perceived cognitive ability and outcome in terms of safe mobility

2.2. Three subprojects

The SafeMove project consists of three subprojects:

1. Determinants of driving regulation in older drivers
2. Simulator based assessment and training of older drivers
3. Driver monitoring functions for adaptive assistance for older drivers

Both Swedish and French partners are involved in all three sub-projects. Initially, literature reviews have been carried out in each of the sub-projects. A specific problem related to simulator based training, simulator sickness, has also been addressed in the second sub-project. The results achieved so far will be reported here.

3. Determinants of driving regulation in older drivers

3.1 Literature review.

A literature review was conducted with the aim to collect information about the characteristics of the most frequent accidents and incidents among older drivers. Forty-four papers out of 1130 identified searching 10 different databases were deemed relevant for the review.

3.1.1 Results.

Accident statistics and surveys on drivers' confidence in different situations were combined in to one figure (Fig.2) with the aim to show the relation between situations drivers think are difficult and situations where accidents occur. The different combination of confidence or divergence between crash frequency and level of confidence and avoidance may indicate which situations have to be taken into account in order to take preventive actions such as retraining sessions or developing driver assistance systems to reduce the risk associated with certain situations. Color coding has been used to highlight different combinations of driving conditions and driver confidence. Some examples are given below.

Dark pink marks the most safety critical conditions/situations associated with frequent crashes for which older drivers are confident. In this category we find driving alone and doing a left turn for both genders, and also driving in high speed limit roads and at intersections for men only though. Light pink marks driving situations associated with frequent crashes and also associated with a lack of confidence or avoidance, e.g. driving in high speed roads and at intersections for women only.

For both situations women seem to be more aware of the dangerousness of the situation than men. The type of preventive intervention to be done may be then slightly different for both

genders: for men it may consist in alerting them about their dangerousness; for women this may be also the case, but in order to avoid premature driving cessation it may be good to help them to deal with such situations.

The green marked cells should not a priori be considered as especially interesting for accident prevention, but they may be of interest in preventing premature driving cessation, especially among women. However, the different green cells give very crucial information. Dark green cell represent situations associated with infrequent crashes but with a lack of confidence or avoidance, e.g. driving in rain/ bad weather, at night or at night in the rain. It is well known that older drivers, due to changes in the visual system, are struggling to adapt to the glare associated with other cars headlights, making night driving difficult.

Driving conditions and situations	Lack of confidence/Avoided		Confident/Not avoided	No information about confidence/avoidance
Frequent crashes	Women	Men	Women	Men
	- High speed limit roads - Intersections		- Driving alone - Left turn type manoeuvres - High speed limit roads (overtaking, merging) - Intersections	- Going straight forward - At noon/ Afternoon - Rural areas
Infrequent crashes	Women	Men	Women	Men
	- Rain / Bad weather - At night - At night in the rain - Merging		- Overtaking - Merging	- Right-turn type manoeuvres - Backing up - Slowing or stopping
No information about crashes frequency	Women	Men	Women	Men
	- Parallel parking - Changing lane - Busy traffic / Rush hour - Roundabout - Bad road condition - Unfamiliar areas - Long distance		- Unfamiliar areas - Long distance	

Fig. 2 Combined information about crashes frequency and level of confidence/avoidance for driving condition/situation in older drivers

The information compiled in this survey will be used as input to the design of driving simulator based training and driver support systems.

3.2 Swedish cohort study

The following section describes the cohort study conducted in Sweden 2012.

3.2.1. Introduction

According to questions about regulation of driving activity it is interesting to investigate more thoroughly if there are certain determinants of how people interpret driving skills, abilities and the effects on their willingness to regulate driving. The following background notions have been guiding the design of the first subproject of SAFE MOVE and the survey study (postal questionnaire) with an attempt to recognize what the determinants may be. From previous research it was stated that some drivers resume driving prematurely, perhaps because they underestimate their cognitive and driving capacities, which is often the case for women⁽¹⁻⁵⁾. As a consequence, they are not at risk of accident, but they are at risk of social exclusion, and decreased physical and mental health according to low mobility and remoteness from social activities^(6,7). Some drivers are found not able to judge their troubles or deny having reduced ability compared to a younger age. They risk drive in a manner that may overload their real capacity and may become at risk of accidents. This is often the case for men, who are at any age of the population category at higher risk of accidents, even in the course of ageing. Awareness of troubles is then crucial, being an intermediate variable between actual abilities and driving regulation^(8,9). There are reasons to believe that the sensorimotor-transformation process is affected by aging⁽¹⁰⁾. Nevertheless, the processing that links to action is not that clear, and more research is needed in order to understand connection to aging⁽¹¹⁾.



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Physical impairments can be compensated for by technical vehicle adaptations, but cognitive impairments may limit a person's fitness to drive⁽¹²⁾. More research has to be done to better understand factors determining awareness of troubles as well as willingness to change and to analyses which sub-groups are at risk of poor assessment of their cognitive and driving skills. Apart from gender which is a well-known determinant of driving cessation, willingness to change, as well as accident risk, some other variables or drivers characteristics may influence the regulation of driving activity related to cognitive performances.

The older population is heterogeneous, related to health, cognitive state and experience. It is particularly crucial to study how factors as gender, socio economic status, educational level, personality and family situation influence the way older drivers regulate their driving habits. These factors can be analyzed to identify potential new subgroups with regard to self-estimations of cognitive ability, driving abilities and driving habits.

In the first part of the SAFE MOVE project a literature review showed different combinations of convergence or divergence between crash frequency and level of confidence and avoidance.

3.2.2. Aim of the study

The aim of the survey study in Sweden was to design, distribute and analyses a postal questionnaire that would collect health questions (frequent pathologies affecting vision, hearing, cognitive capacity and physical function), driving habits and use of cars (frequency, distance driven, other available modes of transport), traffic situations judged as difficult or dangerous, avoidance strategies of such situations, type of car used, equipment in terms of ADAS systems and frequency of use or this equipment. Also, accidents in the two previous years was asked for, and self-estimation of their cognitive functioning and self-estimate of their driving abilities.

3.2.3. Target group

Persons fulfilling these criteria formed our target population:

- Born in 1941 or earlier (aged 70 years or more in the year of 2011)
- Living in the county of Västra Götaland, Sweden
- Holder of a drivers' license for category B, passenger car
- Still driving a car.

The total population which met the first three criteria above, comprised 143 389 individuals. A random sample of 3 000 individuals was drawn from the driving license register. After one reminder, 1 962 questionnaires were returned (about 65 %). Data collection period was 13th September to 31st October 2012. Since the focus was on active car drivers in this study, those who had ceased to drive were asked to answer only the first three questions and then return the questionnaire. This finally resulted in a target group comprising 1 362 active drivers.

3.2.3. Findings

The overall picture of an old driver emerging from this study is a driver who enjoys car driving, often uses the car and is not particularly occupied by thoughts about driving cessation. There is possibly a bias in this picture of the older drivers which may be due to the fact that those who are the most interested in car driving also were most interested in this study and thus answering the questionnaire.

There are several "truths" about older drives reported in the literature that can be questioned in the light of the present study. Sometimes it is said that older people also drive old cars, a phenomena that was not supported by our questionnaire data. According to the reported year models, older people in this study drive the same cars as old/young drivers generally do in Sweden.

The changes of driving behavior that often are attributed to ageing drivers, e.g. they choose to drive slower, less frequently and with shorter distances, are applicable only to a minority of the drivers in present study. Most of the respondents did not change their driving at all when it comes to these three specified dimensions; even some changed it in an opposite way that it usually has been reported in the literature.

The typical gender differences still exist, e.g. women stop driving at a lower age, drove less frequently than men. Women from this cohort (70+) passed their driving license latter than men. Also 2012, the number of license holders has increased among women to reach 47.5% compared to men 52.5%. The difference still remains but seems to vanish in a near future.

Analyses from this study confirm that not only health status is the reason to stop driving; also if a person is confident or less confident (un-confident) in the context of car driving may result in driving cessation. According to previous research confidence or un-confidence can be seen in terms of avoidance of certain situations and conditions, for example driving on unfamiliar roads, darkness, rain, snow, parking in small spaces. These aspects are also present in our study. However, in the present study we were also interested to find out more about those who seem to have adequate confidence. We can state that a majority of the participants in our cohort seem to have adequate confidence.

Knowledge of the challenging situations and conditions for older drivers is a good ground for further research and efforts to maintaining safe mobility for older adults, also findings about those who seem to have adequate confidence and can analyses their ability and restrict driving in an appropriate way. Findings may indicate situations to be taken into account in order to take preventive actions such as retraining sessions or developing driver assistance systems to reduce the risk associated with certain situations.

3.2 On-Road Test in Sweden

Results from the Swedish survey was used to compile a tentative measure which could be used to identify potential under and over estimators (of driving ability) among the respondents. At the end of the questionnaire respondents were asked if they were willing to participate in further research activities and over 170 gave a positive answer. Thus, 40 of these respondents participated in an on-road test in Gothenburg during spring 2013. The participants performed some cognitive tests, e.g. Useful Field of View (UFOV)^(13,14) and Trail Making Test (TMT) prior to the drive. Two versions of the TMT was used; the traditional paper and pencil which measure speed of processing and a newly developed computerized version which include a dynamic aspect of cognition⁽¹⁵⁾. A driving instructor and an occupational therapist were present in the car during the 20 km long drive which took place mainly in urban and suburban environment. Six situations along the route were identified prior to the test as potential probes for testing the drivers' ability to assess his/her own driving performance. The situations were the same for all drivers. Thus, once the driving was complete the drivers were asked to assess his/her own driving performance after looking at video clip from each of the 6 situations on a 5 graded scale ranging from 1 (very bad) to 5 (very good). The driving instructor and the occupational therapist did also rate the drivers' performance at the 6 situations while driving using the same scale as the driver. The results from comparing own to expert assessment of driving performance and the cognitive test will be used to further develop the concept of over and under estimation of driving ability. The participants were also interviewed after the drive in order to capture some more qualitative data. The data are presently being analyzed and some tentative results will be presented at the conference. Common observations and remarks from the instructor include:

1. Speed too high!



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2. Direction indicators not used
3. Incorrect gear shifting
4. Frequent reminders from the instructor
5. Lack of attention – missed signs, lane markings and traffic lights

3.2 French cohort study

A similar cohort study as in Sweden was conducted in France. Basically, the same questions were included in a questionnaire. However, in France the study was conducted as home visits which also included cognitive testing. The cohort study was completed before summer 2013 but it has not yet been analyzed and will be reported later. The cohort study will also be followed by on-road assessment similar to what was done in Sweden.

4. Simulator based assessment and training of older drivers

Driver education and training can be one way to enhance sustained safe mobility for older drivers. Different programs have been used and evaluated in several countries⁽¹⁵⁾. The aim of this sub-project is primarily to develop and evaluate driving simulator based training and to provide some guidelines for mitigation of simulator sickness. However, also the potential in general cognitive training will be investigated in combination with simulator training.

4.1. Literature review

An extensive and updated literature review has been conducted and a report is currently under production. The review covers both traditional training and more recent cognitive training approaches.

4.2. Driving Simulator Based Training Curriculum

Most training programs (refresher course) for older drivers are provided as traditional theoretical education courses⁽¹⁶⁾. However, a demand for more practical training and even driving simulator based training seem to be of great interest to older drivers⁽¹⁷⁾. Thus SafeMove aim to develop and test a driving simulator based training (DSBT) curriculum. The approach applied to develop DSBT curriculum is to utilize the results from the performed literature reviews, the survey (cohort study) and the on-road tests. Furthermore, simulator possibilities and limitations have to be considered which also include consideration of simulator sickness (see below). Thus, a list of possible and potentially useful situations was compiled as follows:

1. Left hand turn, rural or suburban road, on-coming traffic (variable), not 90 degree turn, possible stressors from traffic behind
2. Following a lead vehicle situations at different speeds
3. Passing parked vehicles concealing objects that can be triggered to suddenly appear
4. Pedestrian crossings with or without pedestrians and with and without traffic light
5. Entering a motorway (merging) with varying traffic intensity
6. Cross road with traffic light and oncoming (crossing) traffic
7. "Ordinary" rural road driving under different conditions
8. Lane crossing (motorway) with and without critical situations
9. Slippery conditions, variable friction
10. Roundabouts
11. Road signs (e.g. speed limit, directions)

A set of these situations will be used to compile both assessment and training drives. The ambition is to use the same situations and scenarios for both over and under estimators but difference will be the feedback provided. The experimental approach used will

differ between Sweden and France e.g. in France dedicated cognitive training will be investigated in terms of developing a better self-assessment among driver as a complement to simulator training. In Sweden we will only investigate the potential in simulator based training. In both countries we will focus on the use of small to medium range static simulators.

4.3. Mitigation of simulator adaptation syndrome

Simulator sickness syndrome (SSS), also called simulator adaptation syndrome, could appear when persons are exposed to a virtual environment containing moving objects. SSS is e.g. caused by discordance between visually perceived information and the brain's sense of movement^(18,19,20). However, it is a quite complex phenomenon which is only partly understood. Furthermore, SSS seems to be a more pronounced problem for older drivers^(21,22). Thus, it was deemed important to consider the problem and to find ways to mitigate the problem. A literature survey was conducted and 150 articles were reviewed. Recommendations for mitigation of SSS during simulator training were compiled for older drivers based on the review:

1. Inclusion criteria based on response to a screening questionnaire will be used to explore the motion sickness proneness
2. Precautions will be taken during the pre-drive step (i.e. during the first experience with the driving simulator)
3. Subjects will be supervised to detect early stages of simulator sickness (while it is building up)

Beyond these recommendations, careful design of the driver training scenarios will be applied to minimize the risk for SSS, e.g. avoiding 90 degree turns and frequent speed changes. Later on in the project dedicated simulator experiments will be conducted in order to enhance the knowledge of SSS and how to mitigate it specifically for older drivers.

5. Driver monitoring functions for adaptive assistance for older drivers

5.1. Literature review

A literature review was conducted with the aim to analyze available literature regarding the needs of older drivers in driving assistance functionality and acceptance issues related to supervising/monitoring of driving technology, in order to provide output for future development.

Four databases (Science Direct, TRID, SAE and IEEE) were used to search for articles covering the period from 1999 to 2012. The following key terms were used: older drivers, Advanced Driver Assistance Systems (ADAS), In-Vehicle Information Systems (IVIS), assistance, technology, assist system, crash, driving self-regulation, driving context, traffic conditions, driver distraction, and human-machine interface

More than 60 articles were collected and analyzed for this review. Involved partners established a list of the "TOP 26" high relevance papers which was used to structure the review. Thus, the review report was divided in four chapters.

In the first chapter, most often reported factors influencing the needs and limitations of older drivers regarding the use of ADAS are synthesized as a background. Functional changes due to age and its impact on driving ability were highlighted, both physical and cognitive decline, and how these changes could be compensated for by driving assistance technologies.

In the second chapter, provides an overview of the technology available for ADAS and assistance in order to facilitate the comprehension of the third chapter which reviews recent studies examining the use of ADAS for older drivers. Relevant systems are listed in this chapter: ADAS for: intersections, headway, lateral, and speed control, navigation, parking, night-time driving, and



driver monitoring (driver state). Studies performed on older driver using such systems were reviews. Most of the studies found were done in driving simulators since the penetrating rate of such systems is still quite low for the driving population in general and in particularly for the older drivers. Moreover, the definition of old in identified studies was not as applied in SafeMove (70+). It is common to find studies with drivers 60 or 65 years age old.

The fourth chapter provides a first set of recommendations regarding (i) further investigation of older driver needs and abilities to be implemented through on-road experiments, (ii) identification of the target driving assistance functionalities to be primarily considered in SafeMove for supporting older drivers and (iii) specification of future monitoring functions to be designed during the next steps of the project in order to assist them in their driving activity.

ADAS are designed to assist drivers and even intervene in critical situations and include gradually more sub tasks usually performed by the driver as longitudinal and lateral control, emergency braking. New technical driving aids have the potential to accommodate some of the age related functional changes but these new systems could exceed older drivers' capacities and increase their distraction level. The challenge in SafeMove is to design Driver Monitoring Functions (DMF) liable to support future "adaptive" technologies specifically adapted to older drivers, being able to adjust their assistance to the current driving context and to the specific drivers' characteristics, status, difficulties and help needs at this particular time. This "workload manager" could ideally identify an overloaded or distracted driver and adapt the driving assistance accordingly. The review presented in this report shows the relevance of the SafeMove approach to explore how to design and/or to adapt specific driving assistance systems for different sub-groups of older drivers - from under-confident to overconfident - according to their respective needs in perception, situation awareness, decision-making and action planning.

The review presented here will be complemented with data from a series of focus groups conducted with different subgroups of older drivers in France and in Sweden and by the collection of driving behavior data with an on-road experiment.

6. Conclusions and further work

This paper describes the work done so far in the SafeMove project. The focus is on older active drivers (+70 years) with no documented medical condition which might violate the traffic medicine requirements. Even so there it is expected that some drivers over estimate and some under estimate the ability to drive safely. Under estimators are likely to limit their mobility probably without real reason while over estimators can constitute a safety risk for themselves or other road users. SafeMove aim to provide means to make both over and under estimators better self-assessors and thus promote safe (and sustained) mobility. So far four literature reviews have been performed. Two cohort studies have been completed. On-road tests have been conducted in Sweden and will be conducted in France. The results are not yet ready and will be presented later. Currently, work is focused on developing a driving simulator based training curriculum specifically targeting older drivers who might over or under estimate their ability to drive. Finally, the review of driver assistance systems for older drivers will be followed by focus groups to collect more information about older drivers' needs and preferences concerning driver assistance systems.

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