# The older adult road user: recommendations for driver assistance

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**Abstract**

The number of older road users is getting increasingly larger in Europe. Therefore policy makers pay more attention to the abilities and limitations of this group of road users. Providing accessible and comfortable assistance and safety functions for mobility is a key challenge in the objective of extending autonomy, independency, safety and a good quality of life. In this paper an outlook is given on the action plan describing the recommendations for the European Commission. The preferred mode of transport for older road users is car driving as long as they can drive safely. In-car technology could help them maintain driving longer and safer. A cooperative Automatic Emergency braking system (C-AEB) was developed to improve bicycle collision avoidance for older drivers. Two Human Machine Interfaces were designed and evaluated with a usability test including both young and older drivers. Results showed a tendency for older drivers to prefer earlier warnings than younger drivers.

*Keywords:* Ageing; Road Users; Driving; Human Machine Interface; Cooperative Systems

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## 1. Aim

Access to transport in older age is key in the objective of extending autonomy, independency, safety and a good quality of life. In this paper an outlook is given on the action plan describing the recommendations for the European Commission. New technologies for older drivers could help them moving safely through traffic. In-car systems can make driving easier for elderly by compensating for their reduced capabilities and help overcome limitations associated with ageing (Davidse, 2005). This would enable older drivers to keep their driver's license longer, decreasing their accident involvement and enhancing traffic safety. At the same time however these new technologies could add to task complexity and demand which can cause unfavourable effects like increased workload, distraction, behavioural adaptation and a decrease in situational awareness. It is known that with older age deterioration of the brain begins primarily at frontal regions (Raz, 2000). These deteriorations could influence the capability to perform in complex multitask situation such as driving with in-car devices and decision making on complex intersections. To successfully assist the elderly road user it is essential that new technologies have an optimized human-machine interface (HMI) that takes in consideration the functional decline associated with ageing. This study describes a cooperative Automatic Emergency braking system (C-AEB) was developed to improve bicycle collision avoidance for older drivers. Two Human Machine Interfaces were designed and evaluated with a usability test including both young and older drivers.

## 2. Profiles of Older People

Current predictions show that the share of people aged 65 years or over in the total European population is projected to increase from 17.5% to 29.5% in 2060 (EUROSTAT, 2014). Moreover, the number of people aged 80 years or over is expected to grow from 4.8% to 12%. In order to keep older people actively involved in daily activities, it is vital that they are able to travel safely. These demographic changes produce considerable challenges for future transportation systems and place new and growing demands on transport systems. On the whole, older people who drive will prefer to continue doing so for as long as possible and will also expect to have access to alternative transport modes that meet their individual needs, especially as they approach 80 years of age. Compared to other modes of travel like walking and cycling the physical demand of driving is the lowest while cognitive demand is relatively high because of the velocity. Older road users are considered vulnerable road users (VRUs) together with children, pedestrians and cyclists, who have a higher risk of being involved in traffic accidents.

Future transport systems and services will play an essential role in supporting independent, healthy ageing. The EU GOAL project (Growing Older, stAying mobiLe) aimed at comprising current knowledge and identifying research gaps in order to develop an action plan for innovative solutions to fulfill the transport needs of an ageing society.

When evaluating current developments of solutions, it is vital to gain comprehensive insight into the characteristics of the group of older people. Basically, the group is merely defined by age but includes a wide range of different characteristics, comprising highly dissimilar types like physically fit and active seniors as well as frail and immobile seniors suffering from physical or mental limitations. In order to thoroughly provide for the specific, heterogeneous requirements of older people, the GOAL project has developed distinguishable and internally cohesive profiles of older people. The profiles of older people resulting from this work represent typical combinations of mobility-related characteristics. The development of these profiles required the inclusion of different information sources. An initial identification of common sets of characteristics in the older population in Europe has been derived from statistical cluster analysis based on a cross-national panel database comprising data on health, socio-economic status and social and family networks of more than 55,000 individuals from 20 European countries aged 50 or over: the SHARE database (Survey of Health, Ageing and Retirement in Europe). These first types have been advanced by adding information on physical and mental barriers, regional and socio-demographic differences, transport, life satisfaction and living environment collected from more than 70 relevant international publications, studies and reports. Finally, remaining relevant aspects have been addressed in two small-scale trans-national surveys (among older people as such and among experts and intermediaries working with older people).

In total, five internally cohesive profiles have been identified and elaborated. The profiles include specifications concerning demographics, physical and mental health, social life, living environment, mobility-related aspects as well as transition points (life-changing events causing transitions in the profile affiliation).
Figure 1 illustrates the five profiles in relation to two substantial characteristics: age and level of activity.

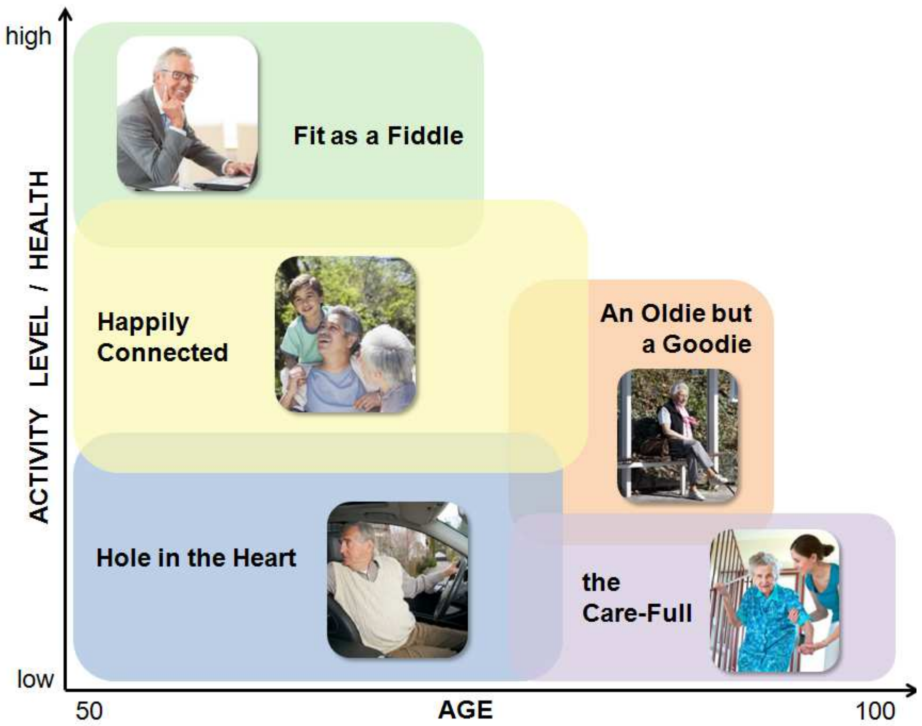


Fig.1. Profiles of Older people by age and activity level.

The youngest, healthiest and most active group is denoted *Fit as a Fiddle (FF)*. The profile named *the Care-Full (CF)* contains the frail, impaired and immobile very old ones, who are dependent on the help of others. The members of the profile *an Oldie but a Goodie (OG)* are quite mobile and independent despite their old age. Persons in the *Happily Connected (HC)* group are fit, active and satisfied elderly with excellent social networks, and the profile *Hole in the Heart (HH)* includes older people suffering from mental as well as severe physical problems at younger ages. The comparison of the profiles reveals important facts that constitute the necessity of developing solutions which are targeted to the specific needs of different types of older people. For example, as financial resources are strongly linked with employment, two "younger" profiles (FF and HC) have no problems to make ends meet. For the "young" HH group, however, the financial situation is worse, where many are retired, unemployed or chronically ill. Although health is generally closely related to age, members of the OG profile are still relatively healthy until high ages and the HH group has to face health problems at younger ages. Eyesight and hearing related problems as well as dementia and Alzheimer's can be observed in the OG and the CF groups. Worse (physical and mental) health conditions can be found in the CF profile, they depend on others for their mobility. In general, driving is rated as very important among all profiles. The lowest car dependency can be observed in the OG profile, where the public transport usage is comparably more frequent and most trips are done on foot. Gender-related differences in private transport are distinct in the HC and to some extent in the OG group, where men are the drivers and women the passengers.

The five profiles were used to evaluate the state of the art literature and the gaps in knowledge about older adults in traffic and the needs of older adults regarding mobility for all modalities i.e. walking cycling, public transport and driving. Seven research actions were defined that need to be addressed because of the considerable transport challenges we face by the growth of the older people population in the coming decades. The seven research actions should be taken forward immediately if we are to understand and exploit the opportunities to enable older people to enjoy safe, sustainable and socially satisfying lifestyles.

These are the research actions;

1 Develop databases on walking and cycling behaviour by older people
2) Identify motivators for walking and cycling for older people
3) Investigate the transition behaviour from car to other modalities
4) Develop methodologies to assess the benefits of public transport accessibility measures
5) Identify the requirements for travel information and social media suitable for older people
6) Assess the impact and potential of future technology for the older driver
7) Develop driving screening and assessment tools and programs

**3. New technology and the older driver**

Driving was rated as important and the preferred mode of transport for all profiles. One of the research actions (6) emphasizes the potential of future cooperative technology for the older driver in order to assist the driver and increase road safety. Cooperative mobility will change the way we currently drive our cars: the vision of cooperative mobility is that in-car and on road sensors will support the road user while driving, as an addition to the limited cognitive capacity and perception of the human being. For example, drivers can only respond to what they observe in their direct surroundings and need time to make decisions. With the help of direct vehicle to vehicle or vehicle to infrastructure communication, more information can be exchanged quicker than humans would be capable of. Anticipating communication systems have the potential to influence individual vehicles and drivers and even traffic streams, which will make the traffic system more safe, efficient and comfortable, with less traffic jams and emissions. Such technological developments of cooperative driving in conjunction with developments for (semi)automated driving will change the nature of the driving task considerably. It is necessary that older drivers are taken into account by making sure they are able to cope with this technology and that their needs are considered when these functionalities are being developed. Key to this assistance of the older driver with cooperative technology will be the level and type of  automation and the Human Machine Interface (HMI) design of the interface for the driver.

In the EU project VRUITS (improving the safety and mobility of Vulnerable Road Users through Intelligent Transport Systems) project, TNO evaluated two types of Human Machine Interface (HMI) for a cooperative automated emergency braking (C-AEB) system. Current automated emergency braking (AEB) systems operate using forward-looking environmental perception sensors. These sensors do not provide sufficient information about objects in obstructed sight scenarios and beyond the sensor field-of-view. Furthermore, these sensors perform poorly when crossing scenarios are considered, because the sensors do not provide accurate lateral motion information. These type of scenarios are specifically important when vulnerable road users (VRUs) are considered like cyclists, pedestrians, children and older road users. TNO has developed a C-AEB with the focus on improved bicycle collision avoidance, which enhances current sensor based AEB systems by fusing them with wireless communication. The goal is to improve safety performance by providing early object detection, improved lateral tracking and reliable object classification. The technology is developed based on ITS-G5 wireless communication (ETSI, 2009), GPS, motion sensors, radar and camera sensors, information fusion, object tracking and AEB control algorithms. The C-AEB system identifies a bicycle object in the direct vicinity of the host vehicle and determines whether this bicycle object is on collision course with the host vehicle. If the collision risk is large the system will warn the driver several seconds before a collision is expected (visual, audible, seatbelt pre-tensioner) and subsequently, if no manual braking is applied, actuate the vehicle by automated braking to prevent a collision. The timing of the warnings is based on the Time-To-Collision (TTC). Two variants of HMI warnings have been evaluated in a usability study(Table 1). Variant 1 consists only of a warning phase and an intervention phase, and does not provide much information on the situational traffic context. In variant 2 the warning starts with an information phase and the whole warning procedure is more explicit concerning the (critical) traffic situation.  Assumption was that by allowing older drivers more time and by giving them a warning that does not rely on memory retrieval they would prefer variant 2 over variant 1.

Table 1: Two HMI variants of the C-AEB system. TTC=time-to-collision

| ***Phase*** | ***Variant 1*** | ***Variant 2*** |
|---|---|---|
| Inform | - | TTC = 3 sec |
| | | Warning sound “watch out, bicyclist!” |
| | | Display: traffic sign |
| Warn | TTC = 1.4 sec | TTC = 1.8 sec |
| | Deceleration = -3m/s$^2$ | Deceleration = -3m/s$^2$ |
| | Pre-tensioning of seatbelt | Pre-tensioning of seatbelt |
| | Warning sound “beep, beep” | Warning sound “ping, ping” |
| | Display: [Brake] | Display: traffic sign |
| Intervene | TTC = 0.8 sec | TTC = 0.8 sec |
| | Deceleration = -6 m/s$^2$ | Deceleration = -6 m/s$^2$ |
| | Seatbelt still tensioned | Seatbelt still tensioned |
| | No warning sound | No warning sound |
| | Display: [Brake] | Display: traffic sign |

## 4. Method

### *4.1 Participants*

38 participants took part in the study, including 20 young drivers (52.6%; average age 26,85 years , SD = 1,3); and 18 older drivers (47.4%;average age 67,0 years ,SD = 1,8). All older drivers fitted the GOAL profile FF due to a requirement of physical fitness by the ethical committee, in particular absence of neck and back problems. The distribution of men and women was respectively 65.8% and 34.2%.

### *4.2 Apparatus*

A Toyota Prius was equipped with two on-board sensors (radar, camera) and a sensor (ITS-G5 wireless communication) to identify the dummy bicycle and its placement. The data was transmitted wirelessly consisted of the bicycle position, The radar, camera, communicated bicycle data and vehicle motion data that were fused. The AEB control algorithm is the part of the C-AEB system (Kwakkernaat et al., 2014) and decides to act to avoid the accident by sending a warning signal to the driver or acceleration command to the low level acceleration controller of the vehicle. It uses the output of the risk estimation that takes the fused objects and host vehicle state and estimates if a collision is imminent. Current AEB algorithms (Helbig, 2013) use a three or more phase approach, where the first phase always is the warning phase. Initiation of the different phases are based on estimated Time To Collision (TTC). A similar approach is also followed for the C-AEB algorithm by implementing a three phase algorithm proving a warning, mild braking and strong braking at decreasing levels of TTC. The trajectories of the host vehicle and bicycle are extrapolated over a certain period of time and if in this period of time the TTC is smaller than the limit for the warning or braking phases, the AEB algorithm will warn or brake according to the minimum TTC found in the extrapolation. The warning and the braking phases used here are as follows, warning phase at 4s TTC, deceleration phase 1 with 3 m/s2 at 1.8s TTC and deceleration phase 2 with 6 m/s2 at 0.8s TTC. The visual warnings was a word "BRAKE" or a traffic sign warning for a bicycle (figure 2) A dummy bicycle object was placed at the side of the road.

Fig. 2. Toyota Prius with C-AEB warnings.

### *4.3 Questionnaires*

For the evaluation of the two variants of the HMI two questionnaires were used: The acceptance scale (van der Laan, 1997) and the questionnaire for usability with two additional questions regarding trust and timing. Trust was rated on a visual analogue scale from 0-100 and timing on a 5-point Likert scale ranging from "very early" to "very late". The acceptance scale consisted of nine questions with items scored -2 to +2 on a 5-point Likert scale. Scores where combined to derive the scales on two dimensions: Usefulness and Satisfaction. The questionnaire for usability was translated to Dutch and used to evaluate the participants' favourite variant of the HMI.

### *4.4 Procedure*

Participants where welcomed by the test leader and given general information about C-AEB system. They filled in the informed consent form and a short questionnaire about their physical fitness.  After having seen a short introduction video about the C-AEB system the acceptance questionnaire was given to the participants to assess their expectations about the system. Then, all participants experienced the C-AEB system by driving a practise lap on a piece of road without traffic. For safety reasons, the bicycle object was placed at a fixed position and the participants were instructed to drive towards, but past the standing bicycle at 15 km/h. After the practise lap the participants drove two laps to experience the warnings and braking of the system with HMI variant 1 and 2, respectively. After having experienced the system, the questionnaires were given to evaluate acceptance, trust and timing, and participants rated the usability of their favourite system in the usability questionnaire.

## 5. Results

Table 2 shows how often participants use different transport modes. Most of them drive their cars and bikes on a daily basis.

Table 2 Frequency of mode use

| *Frequency* | *Car [%]* | *Motor [%]* | *Bicycle [%]* | *Public Transport [%]* |
|---|---|---|---|---|
| Never | 0.0 | 86.8 | 2.6 | 15.8 |
| Sometimes | 2.6 | 2.6 | 21.1 | 39.5 |
| Monthly | 7.9 | 0.0 | 2.6 | 21.1 |
| Weekly | 28.9 | 7.9 | 21.1 | 21.1 |
| Daily | 60.5 | 2.6 | 52.6 | 2.6 |

### *5.1 Acceptance scale*

The first Acceptance questionnaire (filled in before driving) showed that both elderly and young drivers score positively on the usefulness scale. With regard to the satisfaction scale, elderly drivers scored positively as well, though younger drivers seem to be more moderate about satisfaction. Statistical analysis confirms this difference. An independent t-test shows a significant difference between elderly and young drivers on the satisfaction scale, $t(34) = -2.18$, $p = 0.04$. Indicating that younger drivers ($\mu = 0.25$) score significantly lower than elderly drivers ($\mu = 0.73$).

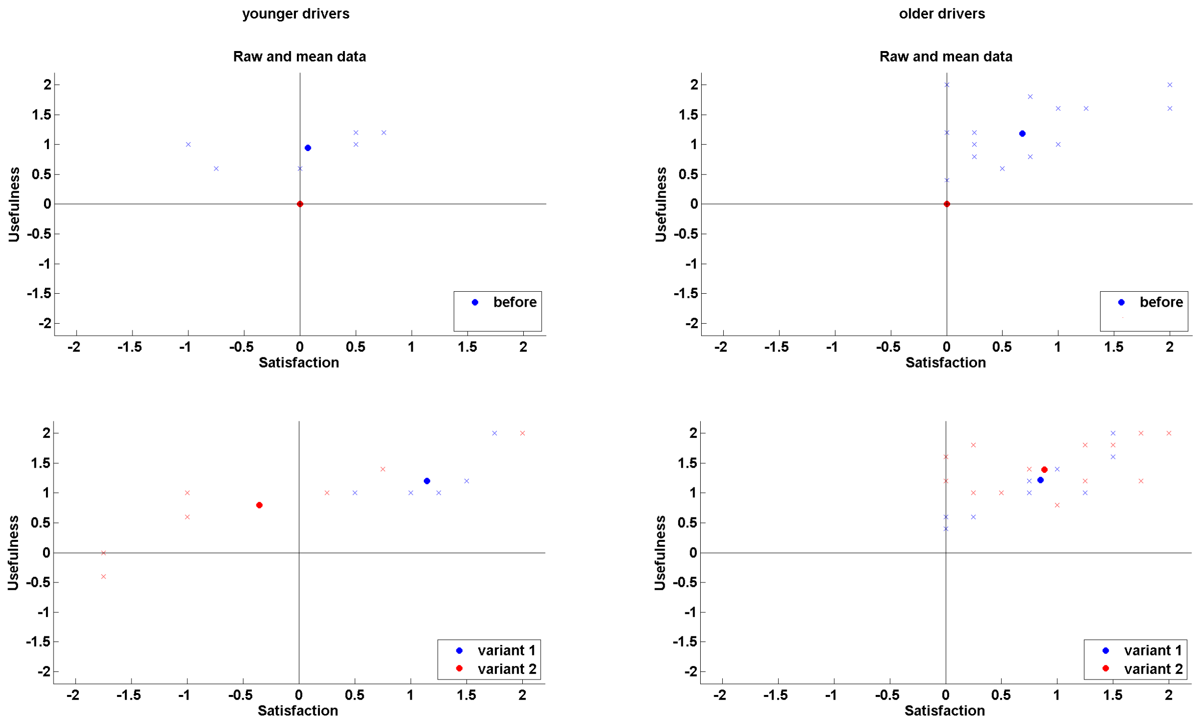


Fig. 3. Acceptance questionnaire (Van der Laan, 1997) after user-tests per age category

Figure 3 shows the scores for usefulness and satisfaction for each variant per age category after experiencing driving with the system. In comparison to the before results, it can be seen that elderly drivers still score positively on both scales for both variants. In contrast to the before results, most younger drivers are also positive on variant 1 for both scales. Though, a part of the younger drivers still judge variant 2 lower on satisfaction.

Repeated measures ANOVA confirms these observations and shows a main effect for variant, $F(4, 31) = 4.99$, $p = 0.00$. In addition, a Bonferroni on satisfaction proves that there is a significant difference between the before condition and the after scores for variant 1 on the satisfaction scale, $p = 0.01$. Indicating that after the user tests drivers are more positive about variant 1 with regard to satisfaction, than before the user tests. Only a trend was found between variant 1 and variant 2 on the satisfaction scale, $p = 0.07$ there was a slight indication that drivers assess variant 1 better than variant 2 for satisfaction. On the usefulness scale no significant differences were found.

Figure 4 shows which HMI variants drivers prefer per age group. In both groups drivers prefer variant 2, though especially elderly seem to have a clear preference. The assumption of the chi square test (all expected counts are higher than 5) have been met. However, Pearson Chi-Square was not significant ($p > 0.05$). It can therefore be concluded that age had no effect on the preferred variant.

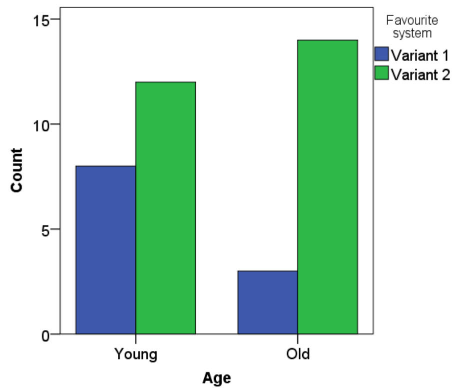


Fig. 4. Drivers favourite system per age category

*5.2 Timing and trust*

Elderly drivers scored the timing of both variants just above a 3, i.e. timing was slightly too late. Younger drivers score variant 1 similar to elderly drivers, though variant 2 got a lower score, indicating that timing was slightly too early. An independent t-test proved that there is indeed a significant difference between elderly ($\mu = 3.33$) and young ($\mu = 2.76$) drivers for variant 2, $t(34) = -2.14$, $p = 0.04$. Elderly score more positive than young drivers for both variants with regard to trust. Elderly drivers trust variant 1 and 2 better then young drivers, with mean scores of respectively $\mu 1 = 84.33$ $\mu 2 = 85.60$ (elderly) and $\mu 1 = 67.38$ and $\mu 2 = 63.10$ (young).An independent t-test shows a significant difference between elderly and young drivers for variant 1, $t(34) = -3.68$, $p = 0.00$ and variant 2, $t(34) = -3.62$, $p = 0.00$.

*5.3 Usability questionnaire*

To determine whether elderly and young people think differently about C-AEB, an ANOVA is performed on each question of the usability questionnaire with age as independent variable. In addition, participants filled in the questionnaires based on their experience with their favourite system. The factor ‘favourite system’ is therefore also included as independent variable in the ANOVA, to check whether participants’ preference was of influence as well. The following paragraph describes the significant comparisons per relevant question, all the other comparisons were not significant with $p > 0.05$.

*System uses notations and conventions that are always clear*

The ANOVA shows a main effect for age, $F(1,32) = 13.71$, $p < 0.01$, and a significant interaction effect $F(1,32) = 4.80$, $p < 0.05$. This indicates that younger drivers ($\mu = 3.71$) judge the system significantly lower on this item than elderly drivers ($\mu = 4.81$). In addition, younger drivers who prefer version 1 ($\mu = 3.25$) score significantly lower than elderly preferring version 1 ($\mu = 5.00$). The difference is smaller between younger ($\mu = 4.17$) and elderly ($\mu = 4.62$) drivers who prefer version 2.

*The potential of user errors in using the system is very small*

The ANOVA shows a main effect for age, $F(1,32) = 4.45$, $p < 0.05$. This indicates that younger drivers ($\mu$ = 3.54) believe to a lesser extent that the potential of user errors in using the system are small, in comparison to elderly drivers ($\mu$ = 4.42).

*The system seems to “know” perfectly what users are doing at all times*

The ANOVA shows a main effect for age, $F(1,33) = 4.48$, $p < 0.05$. This indicates that younger drivers ($\mu$ = 2.46) believe to a lesser extent that the system seems to “know” perfectly what users are doing, in comparison to elderly drivers ($\mu$ = 3.27).

*I trust the system signals and prompts even when I am not sure how it works*

The ANOVA shows a main effect for age, $F(1,33) = 10.43$, $p < 0.01$. This indicates that younger drivers ($\mu$ = 2.85) trust to a lesser extent the system’s signals and prompts, in comparison to elderly drivers ($\mu$ = 4.26).

*The risk of having a road incident is reduced by simply using the system*

The ANOVA shows a main effect for age, $F(1,33) = 5.53$, $p < 0.05$. This indicates that younger drivers ($\mu$ = 3.96) believe to a lesser extent that the risk of having a road incident is reduced by simply using the system, in comparison to elderly drivers ($\mu$ = 4.75).

*I easily know if the system is working properly*

The ANOVA shows a main effect for age, $F(1,33) = 8.57$, $p < 0.05$. This indicates that younger drivers ($\mu$ = 2.52) believe to a lesser extent they will easily know if the system is working properly, in comparison to elderly drivers ($\mu$ = 3.83).

*The system increases my awareness on the possible risk I am exposed to*

The ANOVA shows a main effect for age, $F(1,33) = 10.59$, $p < 0.01$. This indicates that younger drivers ($\mu$ = 1.58) believe to a lesser extent the system will increase their awareness on the possible risk they are exposed to, in comparison to elderly drivers ($\mu$ = 3.02).

*I am safer if the system could send me more information on what is happening around me*

The ANOVA shows a significant interaction effect, $F(1,33) = 5.67$, $p < 0.05$. This proves that younger drivers in favour of variant 1 ($\mu$ = 3.00) score significantly lower than elderly drivers who prefer variant 1 ($\mu$ = 4.33). In contrast, younger drivers in favour of version 2 ($\mu$ = 3.33) score better than elderly drivers who prefer version 2 ($\mu$ = 2.71).

*I believe this system keeps me 100% safe only when it is working properly*

The ANOVA shows a main effect for age, $F(1,33) = 7.00$, $p < 0.05$. This indicates that younger drivers ($\mu$ = 1.77) believe to a lesser extent that the system will keep them 100% safe if working properly, in comparison to elderly drivers ($\mu$ = 3.02).

## 6. Discussion and conclusions

The results showed that before driving with the C-AEB, older drivers are more optimistic about satisfaction of the C-AEB than younger drivers. After the user tests younger drivers became more positive about variant 1. Overall variant 2 received very mixed opinions from younger drivers with regard to satisfaction. A possible explanation for more variation between younger drivers is that confident and in-control drivers prefer a minimal version, while drivers that like more support might prefer variant 2. Due to the greater TTC values and spoken text, variant 2 is easier to comprehend and allows more time for decision making and responding. In contrast, all drivers were positive on the usefulness of the system. It therefore seems that the systems functionality is appreciated, though the execution can affect drivers satisfaction.

Older drivers significantly trust the system more than younger drivers. In addition, younger drivers do not believe that the system ensures that they will never have an accident with a bicyclist anymore, that they will always be 100% safe, or that the system always works. Whereas elderly are significantly more positive about these items. So it seems that older drivers are more positive about the usability of the C-AEB.

Most elderly drivers that chose variant 1 indicated that they would be safer if they received more information on what is happening around them. Variant 2 scores better regarding this item. Younger drivers are more neutral with regard to this item. This seems in line with the general understanding that elderly have more difficulties in assessing the traffic situation. In addition, most elderly drivers indicate that they would be safer if they would receive prompts and warnings earlier. To a lesser extent younger drivers indicate this as well. So most drivers prefer a first warning at TTC $\geqslant$ 3 sec. This could also be the main reason why most drivers preferred variant 2.

When asked about the modality of the warnings, drivers were mostly warned by tensioning of the seatbelt, audio warnings and the deceleration of the car were also mentioned as salient warning cues. In contrast, results showed that visual cues were not effective as warning cues in case of emergency braking most participant didn't see the visual warnings. A reasonable explanation could be that an emergency scenario increases drivers' workload and requires much visual attention, such that drivers have little attention to visual in-car information. An emergency scenario therefore requires a haptic and/or audio warning. Specifically, the tensioning of the seatbelt seems to be a useful cue that, not only ensures the drivers safety in case of C-AEB, but also raises the alertness of the driver.

To conclude, variant 2 with earlier warnings was designed to suit the needs of older drivers better. Results indicated that this HMI was preferred by older drivers and also by part of the younger drivers. For an improved version warnings could be prompted even earlier at TTC $\geqslant$ 3 sec this would be advised if it is technologically feasible. The potential of future cooperative technology for the older driver was highlighted. In order to assist the driver and increase road safety cooperative technology will be developed and the driving task will become more automated. Excellent Human Machine Interface design will ensure that older drivers will benefit from this technology whilst not increasing mental workload or decision making time. Furthermore, by acknowledging the different older driver profiles systems could be personalized or adapted to their needs allowing them to drive their car for longer and safer.

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