OLDER DRIVERS' PERCEPTION AND ACCEPTANCE OF IN-VEHICLE DEVICES FOR ROAD SAFETY AND TRAFFIC EFFICIENCY

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ABSTRACT. A multitude of new technologies (ranging from guidance systems to speed-limit exceeding systems and to fatigue detection systems) are emerging, many of which are either explicitly targeted to older drivers or expected to benefit them the most. However, these same older drivers are more likely to find adapting to the use of such technologies challenging. Therefore, understanding older drivers' perception of such devices will allow experts to take the necessary steps to ensure their smoother acceptance and complete success of their deployment. Using Greek drivers' data collected within the scope of an extensive recent survey in 23 European countries (the SARTRE-3 dataset), a statistical analysis of the perception of usefulness and acceptance of new technologies by older drivers is presented, indicating that -in this dataset- older drivers are more willing to accept these new technologies. The results of the developed ordered logit models provide insight into the human-factors' aspect of the introduction of advanced technologies with respect to the more sensitive segments of the driver population.

INTRODUCTION

By 2030 people age 65 and older are expected to represent 25 percent of the driving population and 25 percent of fatal crash involvements. As that trend will continue, it is evident that older drivers will be one of the more critical driver population

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segments in the future. A multitude of new technologies (ranging from guidance systems to speed-limit exceeding systems and to fatigue detection systems) are emerging, many of which are either explicitly targeted to older drivers or expected to benefit them the most. However, these same older drivers are more likely to find adapting to the use of such technologies challenging. Therefore, understanding older drivers' perception of such devices will allow experts to take the necessary steps to ensure their smoother acceptance and complete success of their deployment.

Using data collected from Greek drivers within the scope of an extensive recent survey in 23 European countries (the SARTRE-3 dataset), a statistical analysis of the perception and acceptance of new technologies by older drivers is presented. The results of the developed ordered logit models provide insight into the human-factors aspect of the introduction of advanced technologies with respect to the more sensitive segments of the driver population. Specific recommendations about the further seamless acceptance of in-vehicle devices by older drivers conclude the paper.

The first SARTRE survey was carried out from October 1991 to June 1992 in 15 European countries, which consisted at that time of 10 European Union member states and 5 non-European Union countries. In each country a representative sample of about 1,000 vehicle license holders, who actually drove, have been questioned, making a total of 17,430 car drivers. Based on the positive receipt of the conclusions and recommendations of the SARTRE survey (Barjonet et al., 1994), it was decided to perform a follow-up survey. The second step, SARTRE 2, was carried out from October 1996 to April 1997, using the same methods regarding the surveys. For most questions, the questionnaire was similar to the first one but the number of surveyed countries grew to 19 (all EU members at the time, except for Denmark and Luxemburg, plus Switzerland, Czech Republic, Slovakia, Hungary (already in SARTRE 1), and (new in SARTRE 2, Slovenia and Poland).

This research uses data from the third SARTRE survey, which took place between September 2002 and April 2003. Surveyed countries include fourteen of the EU-15, seven of the accession countries, and Switzerland and Croatia. The overall SARTRE 3 results reveal substantial differences in the perception of road risk and self-reported behaviors among European drivers from various age groups (SARTRE, 2004). Younger drivers show a tendency to adopt risk-taking behavior (such as following the vehicle in front too closely, overtaking when just can make it, not giving way to a pedestrian at pedestrian crossings and using a mobile phone while driving), thus helping to explain why younger drivers are more likely to be involved in accidents.

Unsafe driving practices decrease for both sexes as the age increases. Younger drivers also recognize more than their older counterparts the danger implied in their driving style, which can be viewed as a typical characteristic of youthfulness. The perception of driving more dangerously and faster than the others is proportionally higher among the youngest group. Driving under the effects of alcohol seems to be an exception, since it was found that there were no significant differences among younger and older drivers. The likelihood to engage in unsafe driving behavior is influenced by several driver characteristics (gender, age, driving experience, etc).

LITERATURE REVIEW

The variability of road-safety trends among age groups is intuitive and well documented. Van den Bossche et al. (2007) introduce a time-series road safety analysis for different age and gender categories of road users. Using Belgian data and appropriate time-series approaches, the authors found that road risk is changing over the age groups according to a U-shaped curve. It was also found that while risk is decreasing over time, the rate varies by age group.

Gish et al. (2002) investigated the driver behavior and performance using an infrared night vision enhancement system (NVES). The authors developed a field experiment with a vehicle equipped with a NVES and groups of younger and older drivers drove the vehicle along a predefined route. The results suggest that performance enhancements are situation-specific. An enhancement of between 60 and 150 m was obtained for pedestrians detected and recognized in the presence of glare but only for younger drivers. In all other conditions, performance either marginally improved with NVES or there was no statistically significant change. Target motion led to significantly higher recognition distances but had no effect on detection distance. Reduced contrast sensitivity and unfamiliar roads were identified as key factors that precluded frequent use of NVES among most of the older drivers. The authors hypothesize that the lower impact to the older drivers is because they did not use the display as much. The perception of older drivers against the system benefits in limiting crashes was also different than younger drivers, with almost half of the older drivers believing that there is little or no crash reduction benefits (while all young drivers thought that there might be some crash reduction benefit).

Karlaftis et al. (2003) report that based on the data collected from SARTRE 2, older drivers tended to self-report that they drive slower than other drivers. This finding is also consistent with previous research according to which younger drivers have the tendency to drive faster compared to older and more experienced drivers.

Pradhan et al. (2003) used eye movements to evaluate the effects of driver age on risk perception in a driver simulator. While the higher fatality rates of younger, inexperienced drivers are often attributed to increased risk taking, in this study the authors check whether the higher fatality rates may be attributed to the relative inability of younger, novice drivers to acquire and assess information relevant to the recognition of inherently risky situations. The results of the study indicate significant age-related differences in driver scanning behavior consistent with the hypotheses. The authors determined that older drivers between the ages of 60 and 75 are much more likely to attend to risk relevant areas than drivers in the younger groups. On the other hand, older drivers experience a decline in their general physiological abilities, such as vision and reaction time, and a reduction in the useful field of view, a measure of visual attention and processing speed. In order to compensate for these problems, older drivers in general are more cautious, for example, following at longer distances or traveling at slower speeds, as well as avoiding risky situations, such as rush hour traffic and nighttime driving.

Noyce and Smith (2003) found (in another study that used driving simulators) that older drivers found protected/permissive left-turn signal displays (in the form of a flashing red indication) confusing.

Romoser et al. (2005) conducted experiments with drivers at least seventy years old who were asked to negotiate scenarios on a driving simulator which were hypothesized to be particularly risky for older adults. If a driver engaged in a risky behavior, he or she was shown what could be done to avoid this risk. In all ten out of ten scenarios, older drivers who received advisement said that they were likely or very likely to modify their driving habits. Moreover, at the end of the experiment older drivers indicated that there were either likely or very likely to increase the frequency of five behaviors regarded as critical to safe driving. Finally, when drivers between the ages of 25 and 55 were evaluated on the same scenarios, they were less than one-third as likely as older drivers to engage in risky behaviors.

Pietras et al. (2005) used an instrumented vehicle and LIDAR speed-range detector to measure the traffic entry judgments of older licensed drivers. The authors found that subjects with visual attention impairment make less safe decisions when entering traffic.

Silverstein et al. (2005) examined the use of a video intervention to increase older drivers' awareness of low-tech vehicle features.

DeRamus (2006) used a fixed-base driving simulator to evaluate the hypothesis that as adults age they scan the roadway to the sides less selectively for potential risks. The author used eye movements to index whether adults 60 years old and older were increasingly less likely to attend to information that signals potential risks. Contrary to hypothesis, the results showed that the oldest subjects (75-79) scan risky areas in the periphery more often than middle-aged (40-50) and middle-old drivers (70-74), but just as often as old (60-69) drivers

Golembiewski et al. (2006) undertook a study to develop standard signing practices, specifically for background color, legend color, underlay color, and pictograph, for electronic toll collection (ETC) toll road signs. One key aspect of this research was to develop some insight into the difference in sign detection and legibility among younger and older drivers, through a laboratory experiment. Consistent with other research involving older drivers, the older participants obtained significantly shorter legibility (though not detection) distances than their younger counterparts. Overall differences ranged from approximately 10% for the guidance information legibility distance to approximately 20% for the pictograph legibility distance. The differences were consistent across combinations of colors and elements.

Porter et al. (2006) performed an experiment with older drivers to assess whether the failure to check behind while backing up was due to a limited range of motion, or habit. To investigate this, the authors used both a driving course that was completed by the older subjects, and included backing up, and a laboratory session that assessed the flexibility of the neck and trunk. It was concluded that the failure to check behind was a habit for many individuals, rather than due to limitations in flexibility.

Golias et al. (2002) provide broad classifications of advanced driver assistance systems, using safety implications as one of the key dimensions of their analysis. In terms of driver related systems, they consider systems that relate to driver information, driver perception, driver convenience and driver monitoring, while in terms of systems relating more directly to the vehicle, general vehicle control, collision avoidance and vehicle monitoring systems are considered. The systems providing real-time information for the road surface systems as well as those related to adaptive cruise control are ranked at the top impact levels followed by systems related to lane change and merge collision avoidance as well as vision enhancement.

METHODOLOGY

The used data set

In this research, the emphasis is in the self-reported perception of in-vehicle devices for road safety. Data from the Greek drivers has been used. The distribution of age and sex in the data set is shown in Figure 1[5].

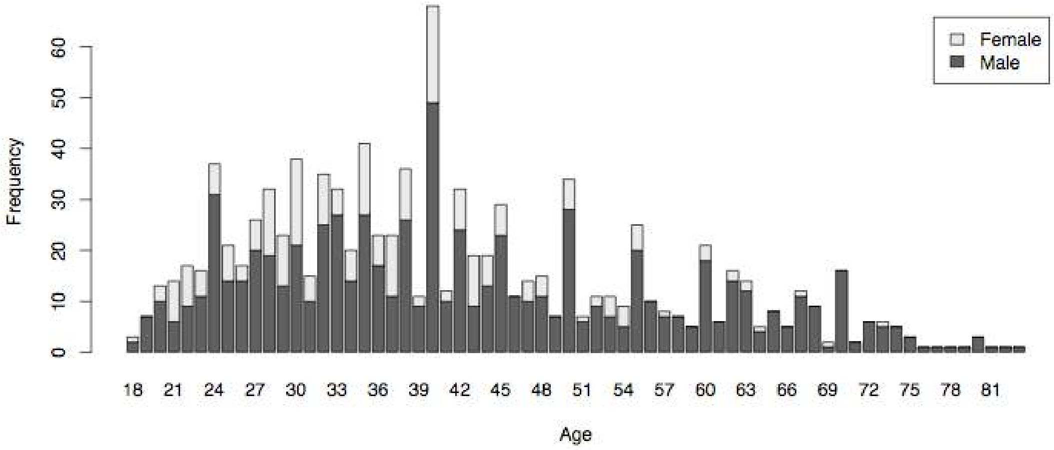

Figure 1. Age and sex distribution in the data set

Figure 2 presents the part of the questionnaire that asked the drivers about their attitude toward technological devices that could improve safety conditions.

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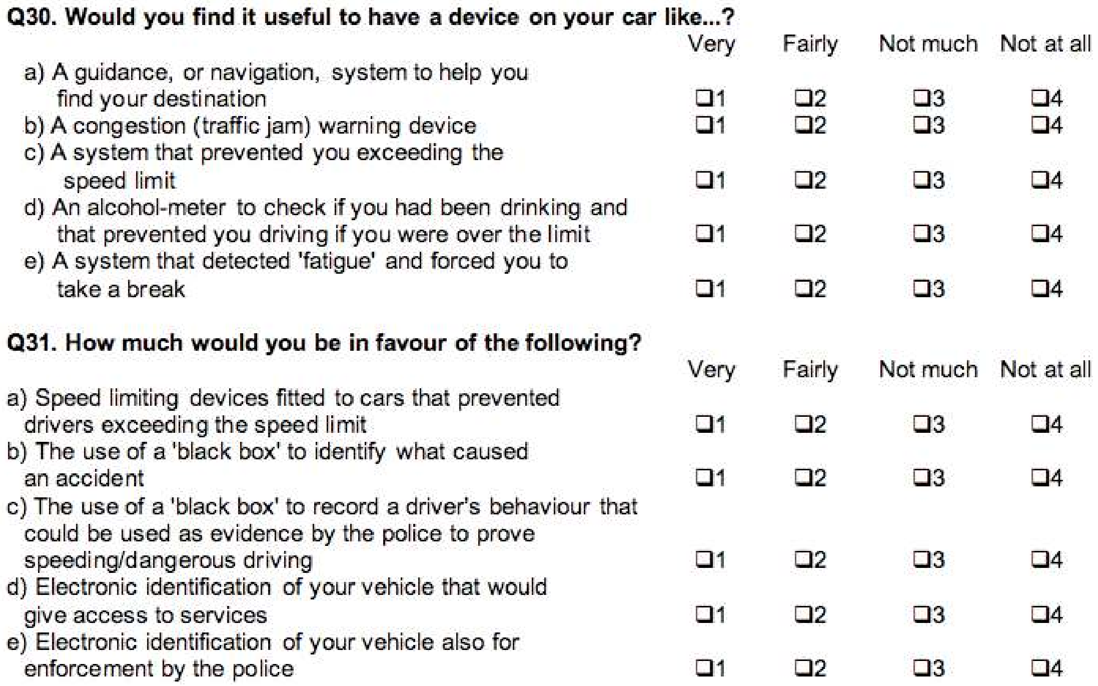
[5] The peaks in the data set occur at round age figures, e.g. 40, 45, 50, are common in such surveys and may be due to rounding errors during self-reporting.



Q30. Would you find it useful to have a device on your car like...?

	Very	Fairly	Not much	Not at all
a) A guidance, or navigation, system to help you find your destination	☐1	☐2	☐3	☐4
b) A congestion (traffic jam) warning device	☐1	☐2	☐3	☐4
c) A system that prevented you exceeding the speed limit	☐1	☐2	☐3	☐4
d) An alcohol-meter to check if you had been drinking and that prevented you driving if you were over the limit	☐1	☐2	☐3	☐4
e) A system that detected 'fatigue' and forced you to take a break	☐1	☐2	☐3	☐4

Q31. How much would you be in favour of the following?

	Very	Fairly	Not much	Not at all
a) Speed limiting devices fitted to cars that prevented drivers exceeding the speed limit	☐1	☐2	☐3	☐4
b) The use of a 'black box' to identify what caused an accident	☐1	☐2	☐3	☐4
c) The use of a 'black box' to record a driver's behaviour that could be used as evidence by the police to prove speeding/dangerous driving	☐1	☐2	☐3	☐4
d) Electronic identification of your vehicle that would give access to services	☐1	☐2	☐3	☐4
e) Electronic identification of your vehicle also for enforcement by the police	☐1	☐2	☐3	☐4

Figure 2. Relevant part of the SARTRE 3 questionnaire

Model formulation

Respondents in surveys are often asked to express their preferences in a rating scale. Such scales are often called Likert scales (Likert, 1932, Richardson, 2002). A multinomial logit model could be specified with each potential response coded as an alternative. However, the ordering of the alternatives violates the independence of the errors for each alternative, and therefore the Independence for Irrelevant Alternatives (IIA) assumption of the logit model. Nested or cross-nested models are one approach to overcoming this issue. Ordered logit models provide another approach that estimates parameter coefficients for the independent variables, as well as intercepts (or threshold values) between the choices.

Figure 3 shows the distribution of the choice probability P as a function of the utility U. Assuming a ranking scale with four levels (like the one used in Figure 2), there are three thresholds or critical values (k1, k2, and k3) that separate the choices (1 through 4). For example, respondents choose the alternative “very useful” if the utility is below k_1, alternative “fairly useful” if the utility is between k_1 and k_2, and so on.

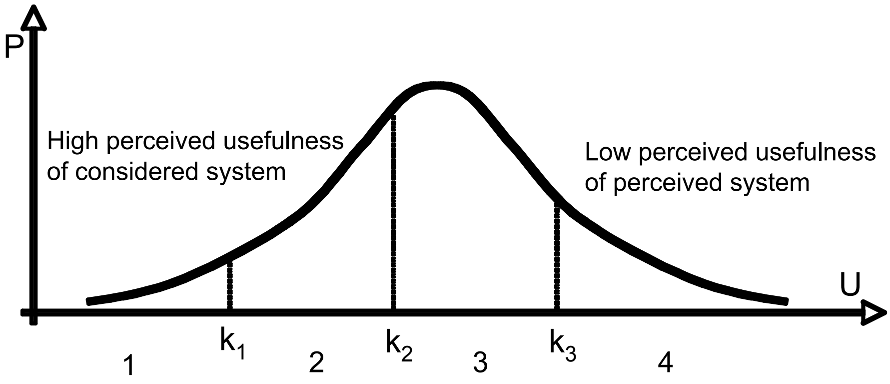


Figure 3. Distribution of the respondents' preference (adapted from Train, 2002)

Modeling involves inherent tradeoffs of complexity versus performance. The addition of appropriate terms in a model can improve its performance; similarly, more elaborate model structures may be better able to model complicated processes. On the other hand, parsimonious models have lower data and computational requirements and thus can be more easily applied. Rigorous statistical tests and appropriate goodness-of-fit measures are available to ensure that additional variables and elaborate modeling techniques are indeed appropriate.

MODEL ESTIMATION RESULTS

Ordered logit models, in which the ordered response is used directly as the dependent variable, are used in this research. In each model, the response variable takes numerical values between 1 and 4, with 1 indicating the highest perceived usefulness of the considered system, and 4 indicating the lowest perceived usefulness of that system.

Socioeconomic characteristics have been used as the explanatory variables. Age has been classified into five groups (<30, 30-39, 40-49, 50-59, 60+), while sex has been modeled as a binary variable (male, female). The youngest age group has been used as the reference level for the Age variable, while male has been used as the reference level for the Sex variable. Based on statistical significance tests, where appropriate these groups have been merged. For example, if no statistically significant difference could be found in the results between the age groups <30 and 30-39, then the two groups were joined into a group <39. For example, in the model estimated for the perceived usefulness for guidance or navigation systems (Table 1), the age groups below 60 years did not show statistically significant difference, and have therefore been merged to a single level <60, which is used as the reference level. Similarly, no statistically significant difference in perception was evidenced among male and female respondents, and therefore the gender variable has been omitted.

The lowest retained age group was used as the basis for the factors. By using factors (instead of ordinal parameters), the model specification allows for capturing non-linear effects. All models were estimated using the R Software for Statistical Computing, Version 2.6.0 (R Development Core Team, 2007) with the MASS package (Venables and Ripley, 2002).

The values of the thresholds (or intercepts) do not have a very clear interpretation and aid in defining the breadth of each of the responses. Naturally, their values should be consistent with their interpretational ordering, i.e. k_1 have the lowest value. Considering that the response of "most useful" has been coded as 1 and "least useful" has been coded as 4, the interpretation of the model coefficients is straightforward. In particular, lower coefficient values imply that the respondents in that group perceive the system in question as more useful. Using Table 1 as an example, it appears that older drivers perceive a guidance or navigation device to help them find their destination more useful that the other segments of the population (which do not show any statistically significant difference among them). Furthermore, there is no statistically significant difference in the perception of such devices among male or female respondents.

Table 1. Model estimation results for guidance or navigation system

	Guidance or navigation system	
Intercept	**Est. coef.**	***t-value***
k_1	-0.4705	*-6.689*
k_2	1.1675	*14.717*
k_3	2.0324	*19.575*
Variable	**Est. coef.**	***t-value***
Age <60	---	---
Age >= 60	**-0.3035**	***-1.788***
Number of observations	974	
Residual deviance	2396.791	
Akaike Information Criterion (AIC)	2404.791	

The results in Table 2 indicate that the perceived usefulness of a system preventing exceeding of speed limit increases with age. Furthermore, female drivers find such a system even more useful than their male counterparts. The results in Tables 3 provide the model estimation results for the perceived usefulness for a system detecting blood alcohol levels and preventing drivers with high alcohol levels from driving, while in Table 4 the results for a fatigue detection system are illustrated. In both cases, older and female drivers are more likely to find these systems useful.

Table 2. Model estimation results for a system preventing exceeding of speed limit

	Prevent Exceeding Speed Limit	
Intercept	**Est. coef.**	***t-value***
k_1	-1.3611	*-9.562*
k_2	0.3122	*2.307*
k_3	1.5082	*10.072*
Variable	**Est. coef.**	***t-value***
Age <30	---	---
30<=Age<40	**-0.4006**	***-2.425***
40<=Age<50	**-0.8629**	***-4.922***
50<=Age<60	**-0.8607**	***-4.078***
Age >= 60	**-1.3805**	***-6.540***
Sex: Male	---	---
Sex: Female	**-0.485**	***-3.511***
Number of observations	987	
Residual deviance	2441.126	
Akaike Information Criterion (AIC)	2457.126	

Table 3. Model estimation results for a system preventing drivers above a certain blood alcohol limit from driving

	Alcohol Meter	
Intercept	**Est. coef.**	***t-value***
k_1	-0.7487	*-7.447*
k_2	0.6884	*6.870*
k_3	1.6998	*14.291*
Variable	**Est. coef.**	***t-value***
Age <40	---	---
40<=Age<50	**-0.5195**	***-3.512***
50<=Age<60	**-0.3569**	***-1.897***
Age >= 60	**-0.8208**	***-4.536***
Sex: Male	---	---
Sex: Female	**-0.4346**	***-3.113***
Number of observations	993	
Residual deviance	2462.149	
Akaike Information Criterion (AIC)	2476.149	

Table 4. Model estimation results for a system detecting fatigue and forcing break

	Fatigue Detection	
Intercept	**Est. coef.**	***t-value***
k_1	-1.2133	*-8.688*
k_2	0.2197	*1.638*
k_3	1.4735	*10.027*
Variable	**Est. coef.**	***t-value***
Age <30	---	---
30<=Age<40	**-0.4800**	***-2.914***
40<=Age<50	**-0.8363**	***-4.786***
50<=Age<60	**-0.4155**	***-2.028***
Age >= 60	**-1.1360**	***-5.535***
Sex: Male	---	---
Sex: Female	**-0.2521**	***-1.853***
Number of observations	987	
Residual deviance	2529.228	
Akaike Information Criterion (AIC)	2545.228	

The model estimation results for the ordered logit models relating to how much the respondents would favor the deployment of a series of systems are presented in Tables 5 through 9. Again, in all cases older drivers are expected to be more in favor of such systems, including speed-limiting devices, black boxes to identify accident cause and record driver behavior, and electronic vehicle identification, both for services and enforcement.

Table 5. Model estimation results for speed limiting devices fitted to cars

	In favor of speed limiter	
Intercept	**Est. coef.**	***t-value***
k_1	-1.4572	*-10.028*
k_2	0.4569	*3.315*
k_3	1.4606	*9.703*
Variable	**Est. coef.**	***t-value***
Age <30	---	---
30<=Age<40	**-0.4527**	***-2.689***
40<=Age<50	**-0.8957**	***-5.002***
50<=Age<60	**-0.9445**	***-4.450***
Age >= 60	**-1.3969**	***-6.719***
Sex: Male	---	---
Sex: Female	**-0.4749**	***-3.412***
Number of observations	990	
Residual deviance	2377.240	
Akaike Information Criterion (AIC)	2393.240	

Table 6. Model estimation results for the use of ‘black box’ to identify accident cause

	In favor black box for accident cause	
Intercept	**Est. coef.**	***t-value***
k_1	-0.2445	*-3.300*
k_2	1.3253	*15.215*
k_3	2.6056	*19.236*
Variable	**Est. coef.**	***t-value***
Age <50	---	---
50<=Age<60	**-0.5384**	***-2.846***
Age >= 60	**-0.4841**	***-2.790***
Number of observations	989	
Residual deviance	2271.731	
Akaike Information Criterion (AIC)	2281.731	

Table 7. Model estimation results for the use of a ‘black box’ to record driver behavior

	In favor of black box for speeding	
Intercept	**Est. coef.**	***t-value***
k_1	-0.9613	*-9.511*
k_2	0.3799	*3.917*
k_3	1.4983	*13.362*
Variable	**Est. coef.**	***t-value***
Age <40	---	---
40<=Age<50	**-0.3723**	***-2.514***
50<=Age<60	**-0.4695**	***-2.539***
Age >= 60	**-0.7849**	***-4.452***
Sex: Male	---	---
Sex: Female	**-0.3029**	***-2.239***
Number of observations	983	
Residual deviance	2576.008	
Akaike Information Criterion (AIC)	2590.008	

Table 8. Model estimation results for electronic vehicle identification for services

	In favor of electronic ID for services	
Intercept	**Est. coef.**	***t-value***
k_1	-1.2245	*-11.639*
k_2	0.2429	*2.499*
k_3	1.4692	*13.211*
Variable	**Est. coef.**	***t-value***
Age <40	**---**	**---**
40<=Age<60	**-0.2379**	***-1.847***
Age >= 60	**-0.7525**	***-4.185***
Sex: Male	**---**	**---**
Sex: Female	**-0.0734**	***-0.533***
Number of observations	956	
Residual deviance	2565.669	
Akaike Information Criterion (AIC)	2577.669	

Table 9. Model estimation results for electronic vehicle identification for services and enforcement

	In favor of electronic ID for police enforcement	
Intercept	**Est. coef.**	***t-value***
k_1	-1.4600	*-14.647*
k_2	-0.2208	*-2.545*
k_3	0.9182	*9.987*
Variable	**Est. coef.**	***t-value***
Age <40	**---**	**---**
40<=Age<50	**-0.2969**	***-2.022***
50<=Age<60	**-0.3919**	***-2.118***
Age >= 60	**-0.6211**	***-3.556***
Number of observations	954	
Residual deviance	2625.162	
Akaike Information Criterion (AIC)	2637.162	

An interesting property of the models developed in this section is that they can be used to develop a ranking of the various systems in terms of how useful they are perceived by the older respondents. Figures 4 and 5 provide concise visual representations of the relative perception of age groups against the various systems. For practical reasons, the absolute values of the estimated coefficient are used. Empty cells in these figures correspond to the base or reference cases, for which the value is equal to zero. These figures eloquently demonstrate that with the increase of age, the perception of the usefulness of the various systems increases (Table 4). Similarly, the perception of how much in favor of each system the respondents are increases with age (Table 5). Older drivers (but also the general driver population) find that a system preventing the drivers from exceeding the speed limit would be the most useful, followed by a system detecting fatigue and forcing a break.

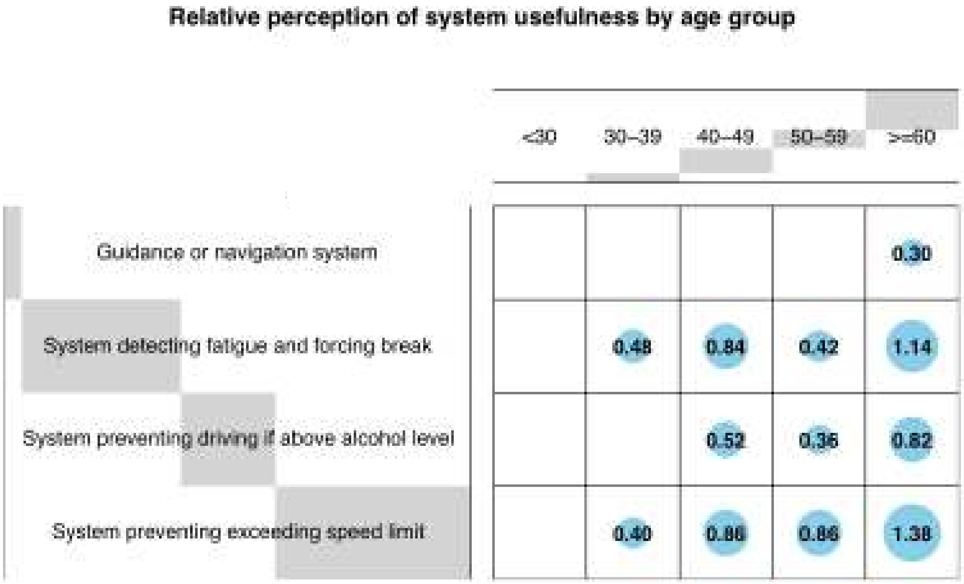


Figure 4. Relative perception of system usefulness by age group

Figure 5 presents similar results for the response in the question of how much in favor of each of the following systems each of the respondents are. The respondents are most in favor of speed limiting devices. From this analysis one can deduce that the systems that the drivers consider most important for the improvement of road safety are those related to the limiting of excessive speed. This is consistent with the perception that excessive speed is responsible for a large part of road traffic accidents.

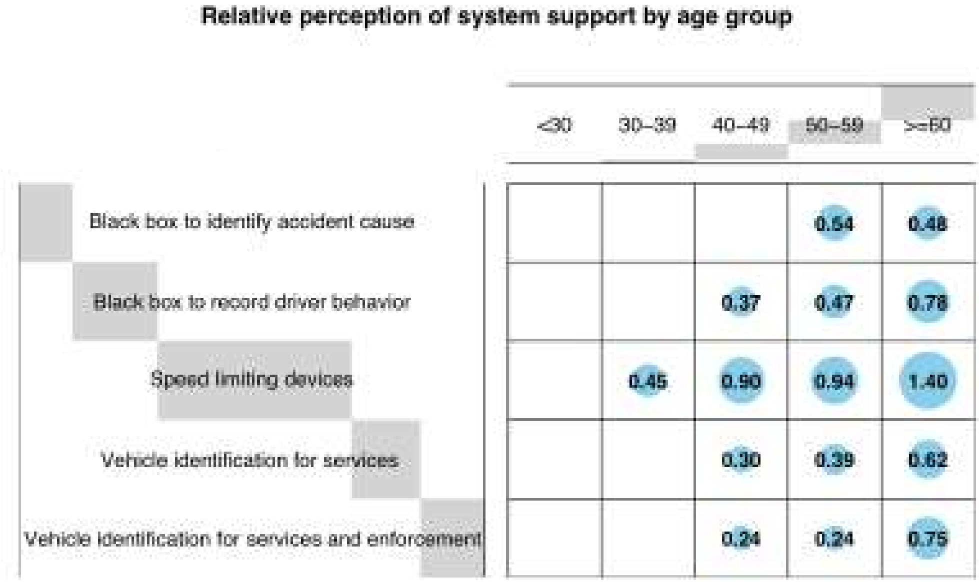


Figure 5. Relative perception of being in favor of each system by age group

CONCLUSION

In this research, ordered logit models have been used to analyze the perception of older drivers (compared to other segments of the population) regarding the acceptance of in-vehicle devices for road safety. The results indicate that older drivers are much more open to such devices. While this might seem an unintuitive finding (considering e.g. that older segments of the population might not be as familiar with new technologies), it can be explained when one considers the more risk-averse behavior of older drivers.

One question that arises from this analysis is whether the respondents really comprehend the details related to the operation of each of the considered systems. Toward this answering this question, further research could include a more detailed questionnaire, focusing on the verification of the respondents' perception of the functionality and the properties of each system. Furthermore, it would be particularly useful if the experimental setup was extended to include field experiments, e.g. using a driving simulator. Such a setup would allow the collection of richer, revealed-preference data about the situation, which are expected to be more reliable than the stated-preference data obtained from this survey.

The findings presented in this paper, should certainly be further validated using driver populations from other countries. If the transferability and generality of these findings is confirmed, however, then it means that older drivers are willing to accept these devices (and to a larger degree than younger segments of the population). This might be a factor that can offset the difficulties that older drivers face when dealing with technology. Furthermore, these findings can be used to target promotional and educational campaigns at the segments of the population, for which they will be most effective.

ACKNOWLEDGEMENTS

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