ROAD SAFETY ON ELDERLY DRIVERS: AN EXPERIMENTAL HUMAN FACTORS ANALYSIS.

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ABSTRACT

The aim of the present paper is to identify which manoeuvres and driving conditions elderly drivers experience more difficulty with and to determine the relationship between some of the more significant manoeuvres and the human factors involved, in particular those relating to the perception of external stimuli and the task of driving a vehicle.
A significant sample of over 65 year olds was chosen to examine the driving behaviour of the elderly. They were asked to complete a questionnaire containing 70 questions requesting information of a general nature, about their health status and their behaviour when turning into traffic, changing lanes and overtaking, driving at night.
The data were analysed using exploration techniques in order to identify significant relationships among the variables found to be most meaningful. The analysis allowed to test a method for determining the driving behaviour of the elderly with a view to pinpointing the most significant safety-related aspects.

KEY WORDS

RAD SAFETY / ELDERLY DRIVERS / HUMAN FACTORS

1. INTRODUCTION

Over the last few years, increasing attention has been focused on active safety issues and in particular on the driving behaviour of over 65 year olds. Today an increasingly larger percentage of elderly drivers take to the roads as they lead longer and healthier lives.
At the same time, different studies have shown that the physical conditions, driving habits and the behaviour when negotiating certain manoeuvres change with age. Mental capacity, physical abilities and concentration diminishes with age and this can increases the likelihood of elderly drivers having an accident due to human error. Usually older drivers have “more cautious” behaviour due to their long experience behind the wheel and the awareness of potential dangers.
The objective of this paper is to identify which manoeuvres and driving conditions involve higher risk for elderly drivers and to attempt to establish a relationship between the perception of external stimuli and the driver’s decision.
Previous research on elderly drivers in Italy has shown that they experience more difficulty when turning across oncoming traffic, changing lanes, merging with main traffic streams, night driving, driving with poor visibility (for example during rain). Based on the results of this research we have studied these specific manoeuvres, with a view to gaining a better understanding of the difficulties they experience and their relation with human factors.
We surveyed 160 individuals over the age of 65 administering a questionnaire to discern this age groups driving behaviour. The survey contained 75 questions regarding background information, medical history, behaviour during different manoeuvres and night driving.

The data has been analysed using both traditional (ANOVA) and multidimensional (Multiple Correspondences Analysis and Cluster) analyses, for the purpose of understanding the relationships between the most significant variables.
The study shows the characteristics of each manoeuvre to which respondents assigned a high difficulty rating in the questionnaire. This information will form the basis of work for subsequent research investigations using driver simulation systems for the ultimate goal of devising measures to be introduced in an attempt to reduce the risk of elderly drivers making mistakes .

2. STATE OF THE ART

For people of all ages, and especially for older people, driving a car has become a necessity in everyday mobility to meet personal needs and social obligations. Elderly drivers appear to be more prone to accidents than middle aged and younger drivers, despite the fact that they do not use the car as frequently. They represent a particular class of drivers, that can be regarded as “weak” compared to other age groups. Analysis of numerous studies has shown that elderly drivers are generally more cautious, due to their longer experience, but at the same time they constitute a greater potential danger. Diminished visual acuity, cognitive and sensory impairments also accentuate the risk.
The physical abilities of drivers change as they age and consequently their attitudes, values and societal influences. In some cases they have years of driving experience and feel they are able to drive safely, but will not admit that their behaviour is not unchangeable. The aging process generally impairs the ability of drivers to drive a car safely.
Over the last few decades, the number of elderly drivers on the road has increased rapidly and is expected to continue to rise in the future. The reason for this is longer life expectancy and healthier over 65’s. .
These drivers are the main focus of attention for two different reasons: the fact that they are at higher risk and that older people are more likely to be injured in a crash than younger people. Analysis focuses on determining the relationship of confidence in and self-rating of driving ability especially for: each other, driving patterns, adverse driving events and driving performance. These analyses show that the elderly have certain physical limitations and changes in road design might well improve safety.
In the United States the above considerations are prompting researchers to seek new ways to enhance road safety. In some states license renewal intervals for drivers over a certain age, typically 65 or 70 years old, are longer than in others. However, numerous States are trying to change this procedure, introducing shorter intervals for license renewal for drivers over 65 or 70 years old.
Elderly drivers experience difficulties when negotiating certain manoeuvres especially when they have to judge the distance between their car and another, or when they have to change lanes. Why do elderly drivers encounter problems at intersections when they appear to be able to cope with other traffic situations comparatively well? There are two reasons. The first concerns their health conditions especially their sight. With age vision deteriorates, changing focus becomes more difficult, peripheral vision deteriorates and visual acuity diminishes, and cognitive impairment can have an affect on vision and focusing on traffic, road signs and markings.
Numerous surveys have shown that there are gender differences in elderly drivers’ behaviour. The accident rate differs for men and women, especially for certain manoeuvres, for example turning across traffic, changing lane, and judging distances. One study reported higher accident rates among elderly women.

As explained in the introduction, specific studies concerning elderly drivers have only started to be undertaken in Italy in the last few years. A previous paper analysed the accidents in Sardinia for a period of one year (about 181 accidents, considering only accidents with injuries).
The analysis, for this group of drivers, showed that high risk manoeuvres are: turning across traffic at unsignalized intersections, on-ramping and merging with main stream traffic, changing lanes or turning into main traffic flow, driving at night or in conditions with poor visibility (during rain).

3. METHODOLOGY

The analysis was based on the results of a questionnaire designed to gather information from drivers aged 65 and over and to gain a better understanding of the manoeuvres analysed. The questionnaire was divided into 6 different sections:

1. General background such as age, gender, year driving license was issued, current car type, frequency of vehicle use, etc.;
2. Health and physical conditions, major medical complaints (e.g. high blood pressure or heart disease);
3. Behaviour when on-ramping and merging with main stream traffic;
4. Behaviour when changing lanes in a street with two or more lanes in both directions;
5. Driving behaviour at a 4 armed intersection;
6. Driving at night or in conditions of poor visibility;

In the data analysis, using the following technical explanation, we investigated the relationships between the variable individuals and health conditions or type of manoeuvres in an attempt to understand the relationship between human factors and driving behaviour.
We adopted two different analytic techniques:

- Analysis of Variance (ANOVA) to evaluate the significance of each question with respect to age of the respondents.
- factorial analysis, with the group's analysis, which seeks to explain any proximity or reciprocity in the variables.

The ANOVA indicates significance between two different variables. We will define a null hypothesis and an alternative hypothesis, in this way we can test the null hypothesis that several independent population means are equal.
Two parameters are estimated in the ANOVA: F is the ratio of the mean square and Sig is the probability of obtaining F at least this large when the null hypothesis is true.
In the Multiple Correspondence Analysis and Cluster Analysis we used the *value test* parameter. This parameter enables to evaluate the significance of the variable and the modality observed as a function of the phenomena.
The *value test*, as will be seen in the following, is a parameter for determining the significance level. The variable with high significance has the highest value. In this way it is possible to evaluate the significance for each variable in the phenomena.

3.1. Analysis of variance

Variance is one of the most common measures of variability. It is based on the squared distance between the value of the individual cases and the mean.
We used variance to find the distribution of data with respect to the mean. This method provides interesting information about several independent populations.
We repeated the analysis of variance for the most important variables in the questionnaire. Question No. 1: age of driver -- divided into the following age groups: (1)65-70 years;

(2)71-75 years; (3)76-80 years; (4)over 80 years – was compared with the other most important questions contained in the questionnaire. Statistical analysis was then performed to understand the importance and reality of correct answers given by the drivers. We then found the value of F and the value of Sig. Sig. represents the probability of obtaining F ratio at least when the null hypothesis is true.
When the sample mean varied more than was expected then we rejected the null hypothesis. In every case the null hypothesis was that the frequency of answers corresponding to each variable was the same for each age group. If Sig was less than 0.055 the null hypothesis was true, but for larger values we rejected the null hypothesis.
The following table summarizes the data regarding the value of the mean, F and Sig. We have obtained the results between question No.1, regarding the age of driver, and the other most significant variables corresponding to the question numbers indicated in the first column. The variables in bold are the most important, because they check the null hypothesis. For example for the variable corresponding to question No.9 (use of seatbelt), we can accept the null hypothesis. The four age groups do not differ with respect to the responses (Always, Occasionally, Sometimes, Never and Not Applicable) corresponding to the frequency on using seatbelts. In this case the probability of obtaining an F ratio of 2.809 is only 42 out of 1000. In the variables where the null hypothesis is true, we have plotted the diagram of the mean for each group of answers.

Question Number	Mean Square between group	Mean Square within groups	F	Sig
6	0.217	0.315	0.689	0.560
8	4.275	5.850	0.731	0.535
9	**1.774**	**0.632**	**2.809**	**0.042**
11	0.011	0.032	0.328	0.805
12	**0.809**	**0.242**	**3.341**	**0.021**
14	0.359	0.256	1.405	0.244
15	40.828	20.122	2.029	0.112
17	0.207	0.340	0.609	0.610
18	6.554	3.430	1.911	0.130
19	0.370	0.449	0.823	0.483
20	1.090	1.105	0.986	0.401
32	0.056	0.085	0.658	0.579
34	**1.701**	**0.648**	**2.624**	**0.053**
35	**2.529**	**0.692**	**3.656**	**0.014**
36	1.026	0.477	2.150	0.096
37	1.556	1.243	1.252	0.293
38	1.983	0.859	2.308	0.079
39	0.482	0.851	0.567	0.638
40	0.605	0.545	1.110	0.347
42	3.112	1.832	1.699	0.170
52	**1.583**	**0.510**	**3.105**	**0.028**
53	**2.803**	**0.720**	**3.891**	**0.010**
54	**3.275**	**0.973**	**3.367**	**0.020**
55	**3.104**	**0.812**	**3.824**	**0.011**
56	0.972	0.981	0.990	0.399
57	0.465	0.946	0.492	0.689
58	0.343	1.399	0.245	0.865
59	0.038	0.887	0.042	0.988
60	0.118	0.568	0.207	0.891
61	0.568	0.681	0.834	0.477
62	0.157	1.163	0.135	0.939
63	0.193	0.515	0.374	0.772
64	**1.952**	**0.747**	**2.614**	**0.053**
70	0.606	0.670	0.906	0.440
71	**1.604**	**0.505**	**3.176**	**0.026**
72	1.251	1.001	1.249	0.294
73	1.303	0.752	1.734	0.163

Table 1 - Summary of the Chi-square analysis

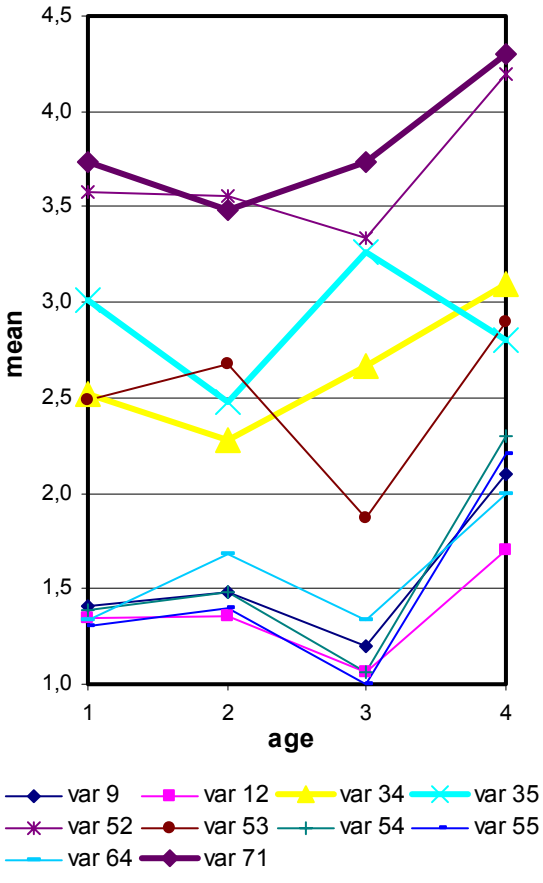

Fig.1 - Relation between age and mean.

The most interesting trends that emerge from Figure 1 concern question No. 35 (inadequate road markings) where the trend is the opposite to the others; No.34 (frequency of motorway driving) and No. 71 (alter route to avoid turning across traffic at unsignalized intersections) because compared to the other answers, here the trend is different for every age group.

4. FACTORIAL ANALYSIS

Because of the complexity of the phenomena examined and the large amount of information analysed, here only the Factorial Analysis concerning sections 1 and 2 of the questionnaire and some significant variables for the type of manoeuvres examined is described. This provides a general picture of driving behaviour in the elderly.
We also examined the behaviour for each manoeuvre. For the sake of brevity we have only included the information pertinent to the present paper.
Having defined the characteristics for elderly drivers, we will now describe the factorial analysis for the group of variables. The goal of multiple correspondence analysis is to try to explain the association between qualitative variables. In this way we obtain indications regarding the basic structure in the observed phenomena This basic structure shows the significance of subspace. The cloud of variables is projected into this subspace. The subspaces are defined with lines or spaces where they are projections by the clouds of data. Choosing the correct subspace, it is possible to minimize the loss of information with respect to the projection.
The following table shows the significance of the variables for the first 7 axes.

Axe number	Auto value	Percentage %	Cumulative percentage %
1	0.2945	7.14	7.14
2	0.1865	4.52	11.66
3	0.1701	4.12	15.78
4	0.1265	3.07	18.85
5	0.1076	2.61	21.46
6	0.1034	2.51	23.97
7	0.0993	2.41	26.37

Table 2 - Significance of the first 7 factorial axes with respect to the procedure of SpadN.

The following table describes the first two factorial axes, with the most significance variables obtained from the analysis. Note that for identification we have used the *value-test*[1]. Parameter.

[1] The "value test" is a parameter that allows to estimate the significance level of the modalities against the chosen factorial axes.
The principal underlying data analysis was as follows: for a population of **n** individuals **q** nominal variables are observed. A particular group of $\mathbf{n_k}$ individuals is then identified. The next step is to classify in order of importance the variables that best characterize that group. A variable does not characterize the group if the values of $\mathbf{n_k}$ found appear to have been extracted at random from among the **n** values observed. The more dubious the hypothesis of random extraction the more significant the variable is for characterizing the group.
If $\mathbf{U_{tj}}$ is the coordinate of modality **j** on the axis **at** it is called "*value-test*"

$$u_{ij}\left(\frac{n-1}{n-n_j}\right)^{1/2}$$

where n is the number of individuals analysed and nj the randomly extracted individuals. The "value-test" is in fact a parameter used to measure the significance of the modality and/or variable within the phenomenon being examined.

VARIABLE	V.TEST	MODALITY
drives at night	-7.42	never
avoids driving at night	-6.02	yes
description of health	-4.57	drive lic.+ disease
drives on freeways or roads outside town	-4.15	never
avoids driving at night	-3.65	always
faced with dangerous situations	-2.93	always
C E N T R A L Z O N E		
age	2.25	between 65 and 70
slows down to read signs	2.60	never
alters route to avoid turning	2.95	never
avoids driving at night	3.23	never
drives at night	3.25	sometimes
drives at night	3.85	occasionally
confusion in distinguishing road markings	4.09	sometimes
alters route due to poor lighting	4.29	sometimes
confusion in distinguishing road markings	4.35	never
nervous driving at night	4.56	never
slows down to read road signs	4.71	sometimes
drives on motorways or on roads outside town	5.10	occasionally
alters route due to poor road signs/markings	5.20	never
alters route due to poor lighting	5.80	never

Table 3 - Description of first factorial axis.

VARIABLE	V.TEST	MODALITY
difficulties in turning at unsignalized intersections	-6.96	yes
confusion in distinguishing road markings	-6.02	occasionally
drives at night	-5.88	sometimes
mental overload	-5.81	sometimes
nervous driving at night	-5.79	occasionally
feels other drivers drive too fast	-5.15	occasionally
difficulties judging speed of on-coming traffic	-4.94	occasionally
alters route due to poor lighting	-4.92	always
alters route due to poor road signs/markings	-4.78	occasionally
difficulties turning in day traffic	-4.65	occasionally
C E N T R A L Z O N E		
drives at night	4.19	occasionally
inadequate road markings	4.25	never
difficulties turning in daily traffic	4.38	never
slows down to read signs	4.57	never
alters route to avoid turning	4.95	never
alters route due to poor road signs/markings	4.99	never
alters route due to poor lighting	5.31	never
confusion in distinguishing road markings	5.36	never
difficulties turning at unsignalized intersections	5.50	no
mental overload	6.08	never
nervous driving at night	6.13	never
avoids driving at night	6.37	never

Table 4 - Description of the second factorial axis.

From the analysis of the first factorial axis we can observe the clear contrast between the variables regarding the difficulties in distinguishing road markings or slowing down to read road signs and those for altering the route due to poor lighting and poor road signs/markings.
The second factorial axis shows the contrast between difficulties in turning at unsignalized intersections and the lack of nervousness (or not driving) when driving at night.
For the many single manoeuvres we can show the same results.

The multiple correspondence analysis was followed by cluster analysis which was used to identify the most significant “typical behaviour profiles” of elderly drivers. We identified the 4 homogeneous groups, each characterizing a different behaviour profile, described below.

1. The first group, 34% of the interviewed sample, regards elderly drivers who claimed not to have altered their driving habits as they got older. These individuals enjoy good health and are not affected by external (poor visibility, poor lighting) or internal (heavy traffic, poor roads signs/markings) factors during driving. Moreover drivers in this group declared that they were not required to wear glasses nor to take any other precautions for medical complaints when driving.

2. The second group, 14% of the sample, concerns those individuals who avoid driving at night in spite of the fact that they do not suffer any physical disabilities or do not experience difficulties with certain manoeuvres.
3. The third group, the largest, representing 42% of the sample, consisted of elderly drivers who declared they had difficulties in performing certain manoeuvres. Specifically,. the movements that created most problems ("several times during driving") included the use of the rear view mirror when driving in heavy traffic (hence difficulties in changing focus), and looking at road signs when driving, forcing them to slow down, often suddenly, thus increasing the risk of causing an accident. This group also claimed to experience difficulties in driving in poorly lit streets or in heavy traffic.
4. The fourth group, 10% of the sample, comprised elderly drivers who stated they encountered several difficulties when driving. This group included individuals who altered their route to avoid turning across traffic at junctions, or because of poor lighting or poor road signs or markings. They also found difficulties in driving in normal traffic during the day when they had to negotiate several turns. They had problems reading the signs and also in distinguishing road markings. Sometimes these individuals use prescription drugs or have been advised by a doctor not to drive at all.
5. The table below summarizes table relative to each modality.

CLASSES	SIGNIFICANT VARIABILES (modality)		V-TEST
Some problems when driving (34%)	36.sees signs only at last moment	(sometimes)	2.44
	52.mental overload	(sometimes)	5.51
	53.feels other drivers drive too fast	(occasionally)	4.93
	56.drives at night	(sometimes)	3.73
	57.nervous driving at night	(sometimes)	4.72
	58.poor lighting	(occasionally)	4.73
	59.confusion in distinguishing road markings	(sometimes)	5.53
	60.alters route due to poor lighting	(sometimes)	3.59
	61.alters route due to poor road signs/markings	(sometimes)	3.05
	62.slows down to read road signs	(sometimes, occasionally)	2.77
	70.judging speed on-coming traffic	(sometimes)	4.45
	35.inadequate road markings	(sometimes)	3.77
	73.dangerous situation	(sometimes)	3.45
Occasional difficulties when driving (14%)	8.driving fine over 65 year	(no parking)	2.63
	11.advised by doctor not to drive	(yes)	2.90
	17.drives when taking medication	(sometimes)	3.77
	59.confusion in distinguishing road markings	(occasionally)	3.04
	60.alters route due poor lighting	(sometimes)	4.04
	61.alters route due to poor signs	(occasionally)	3.25
	72.difficulties in turning in normal day traffic	(occasionally)	2.76
	71.alters route to avoid turning	(occasionally)	3.77
Never experiences difficulties when driving (42%)	35.inadequate road signs	(never)	3.79
	37.drives at night	(never)	5.62
	52.mental overload	(never)	4.77
	57.nervous driving at night	(never)	6.84
	58.poor lighting	(never, sometimes)	3.65/4.35
	59.confusion in distinguishing road markings	never)	5.86
	60.alters route due to poor lighting	(never)	6.70
	61.alters route due to poor signs	(never)	5.62
	62.slows down to read signs	(never)	5.70
	63.difficulties at unsignalized intersections	(no)	3.39
	70.judging speed on-coming traffic	(never)	3.89
	71.alters route to avoid turning	(never)	3.02
	72.difficulties turning into traffic during day	(never)	3.78
	73.faced with dangerous situations	(never)	3.05

CLASSES	SIGNIFICANT VARIABILES (modality)		V-TEST
Does not drive at night (10%)	34.drives on motorways or roads outside town	(never)	3.39
	37.avoids driving at night	(always)	3.25
	56.drives at night	(never)	8.22

Table n°5 - Description of homogeneous classes regarding all maneuvers

The findings that emerged from the overall analysis showed that elderly drivers experienced difficulties in performing certain manoeuvres. For this reason a more detailed investigation was conducted in an effort to understand how elderly drivers behaved in specific situations.
For the sake of brevity only the final results of the cluster analysis are reported here. The complete study shows the calculation of the factorial axes and their relative planes.

4.1. Merging from ramp into traffic

Different scenarios were developed for the questionnaire; which envisaged a driver merging into main line traffic from a ramp and viceversa, varying the situation each time (road free, vehicles in the distance, approaching vehicles, vehicles in front).
We divided the data into 5 different groups.

1. Drivers slow down when merging with main line traffic whether a vehicle is approaching, is alongside them or has just passed. These elderly drivers do not have any particular medical complaint or physical disability (21% of the total).
2. These drivers accelerate when merging with traffic. Again the same three positions of vehicles in the main traffic stream are considered (8% of the total).
3. Merging into traffic without changing speed, for all the scenarios developed. In some cases drivers only slow down when merging with a closely approaching vehicle or when another vehicle is traveling alongside, (19% of the total).
4. Merging with traffic changing speed continuously and suddenly, due to insecurity or fear. Some drivers slow down, others brake while others do not change speed at all. This group of respondents complain of muscle pains or mental overload. They also have to wear glasses or contact lenses (19% of the total).
5. Drivers always brake when merging with main traffic stream for all scenarios (33% of the total).

CLASSES	SIGNIFICANT VARIABILES (modality)		V-TEST-
Merge slowing down (21%)	19.muscle pain or fatigue during driving	(never)	2.49
	merging 21:closely approaching vehicle	(slow down)	4.34
	merging 26 :vehicle alongside +vehicle behind	(slow down)	5.31
	merging 27 :closely approaching vehicle+vehicle behind	(slow down)	3.26
	merging 30 : vehicle just passed + closely approaching vehicle	(slow down)	4.40
	merging 29 : vehicle just passed + vehicle behind	(merge)	2.37
Merge forcefully (8%)	2.age driver's license issued	(over 38)	2.63
	merging 21: closely approaching vehicle	(merge)	3.27
	merging 24: vehicle merging from ramp in distance	(merge)	2.58
	merging 27: closely approaching vehicle+vehicle behind	(merge)	5.32
	merging 29: vehicle just passed + vehicle behind	(merge)	2.35
	merging 30: vehicle just passed + closely approaching vehicle	(merge)	6.90

CLASSES	SIGNIFICANT VARIABILES (modality)	V-TEST-
Merge without changing speed (19%)	merging 21: closely approaching vehicle (merge keeping right)	5.04
	merging 23: vehicle just passed (merge keeping right)	3.96
	merging 24: vehicle merging from ramp in distance (merge keeping right	2.55
	merging 27:vehicle just passed+closely approaching vehicle (merge keeping right)	3.31
	merging 28: vehicle alongside-vehicle behind (slow down)	2.53
	merging 29: vehicle just passed + vehicle behind (merge keeping right)	4.32
	)	
Merge changing speed continuously (19%)	18.use mirrors during driving (occasionally)	2.35
	19. muscle pain or fatigue during driving (sometimes)	3.24
	merging 20: vehicle alongside (merge keeping right)	3.70
	merging 25: vehicle merging from ramp alongside (brake)	3.55
	merging 26: vehicle alongside +vehicle behind (merge keeping right)	5.19
	merging 27: closely approaching vehicle+vehicle behind (merge keeping right)	3.64
	merging 30: vehicle just passed+closely approaching vehicle(merge keeping right)	6.39
Merge braking (33%)	merging 20: vehicle alongside (brake)	4.76
	merging 21: closely approaching vehicle (brake)	6.56
	merging 25: vehicle merging from ramp alongside (slow down)	4.10
	merging 26: vehicle alongside +vehicle behind (brake)	6.39
	merging 27: closely approaching vehicle+vehicle behind (brake)	6.08
	merging 28: vehicle alongside-vehicle behind (brake)	3.38
	merging 30: vehicle just passed+closely approaching vehicle (brake)	6.98

Table n°6 - Description of homogeneous classes regarding merging from ramp into traffic

4.2. Changing lanes

Again, different scenarios were tested for changing lanes and respondents were required to answer the questions with the aid of illustrations. Four homogeneous groups have been identified :

1. Drivers who change lanes without changing speed while vehicle approaching in outside lane passes. These drivers do not have particular physical disabilities (large group: 57% of the total).
2. Again drivers change lanes without changing speed while vehicle approaching in outside lane passes. This group differs from the first in that the elderly drivers wear glasses or contact lenses, and have an annual medical check up and eye test (22% of the total).
3. Lane change slowing down. his group includes respondents who declared they had bone or joint problems (14% of the total).
4. Drivers who brake, stop the car and wait until the approaching vehicle has passed before changing lanes. Note, importantly, that the majority of this group of respondents are over 80 years old (9% of the total).

CLASSES	SIGNIFICANT VARIABILES (modality)	V-TEST
Wait to pass (57%)	14.eye test (no)	3.03
	change lane 41: vehicles outside lane (wait pass)	8.19
	change lane 42: approaching vehicle outside lane (wait pass)	7.95
	change lane 45: approaching vehicles outside lane+car behind (wait pass)	5.76
	change lane 48: approaching vehicle nearside lane+car behind (change lanes)	2.76
Wait to pass and wear glasses (20%)	12.annual medical check up (yes)	2.72
	14.annual eye test (yes)	3.49
	18.wear glasses during driving (sometimes)	2.66
	change lane 45: vehicles outside lane+car behind (wait pass)	2.91
	change lane 46: approaching vehicle outside lane+car behind (wait pass)	2.39

CLASSES	SIGNIFICANT VARIABILES (modality)		V-TEST
Slow down (14%)	15.description health problems	(joints/bones)	2.57
	change lane 41 vehicles outside lane	(slow down)	6.48
	change lane 42 approaching vehicle outside lane	(slow down)	7.33
	change lane 45 vehicles outside lane+car behind	(slow down)	7.59
	change lane 46 approaching vehicle outside lane+car behind	(slow down)	5.28
Brake and then stop (9%)	1.age	(over 80)	2.67
	2.age driver's license first issued	(34-38)	3.39
	change lane 41 vehicles outside lane	(brake and stop)	3.02
	change lane 42 approaching vehicle outside lane	(brake and stop)	3.14
	change lane 45 vehicles outside lane+car behind	(brake and stop)	4.27
	change lane 48:approaching vehicle nearside lane+car behind	(brake and stop)	3.14

Table n°7 - Description of homogeneous classes regarding changing lanes

4.3. Turning across on-coming traffic

In this case different scenarios were developed for turning across on-coming traffic. We identified 6 homogeneous groups:

1. The manoeuvre is completed without difficulties when the on-coming vehicle is at some distance. Elderly drivers who admitted to suffering from bone or joint problems also responded in the same fashion (24% of the total).
2. Again respondents in this group do not experience difficulties when the on-coming vehicle is at some distance even when the driver wears glasses or contact lenses or drives under the influence of medication. The age of this group is younger (65-70 years). (10% of the total).
3. In this case the driver first stops the car and then proceeds to turn without difficulty. This happens both when one or a line of on-coming cars are approaching (27% of the total).
4. Again the manoeuvre is completed in two phases: the driver first stops the car and then proceeds to turn with difficulty. This group is composed largely of over 80 year-olds who wear glasses or contact lenses when driving and have periodic medical check-ups (14% of the total).
5. The driver slows down but does not stop the car even when on-coming vehicles are approaching. In this case drivers' age is younger (71-75 years) compared to the other groups where difficulties were encountered in performing this manoeuvre (9% of the total).
6. In the last case, the driver accelerates to turn across in-coming traffic even when approaching vehicles are near (16% of the total).

CLASSES	SIGNIFICANT VARIABILES (modality)		V-TEST-
No difficulties (24%)	2.age driver's license first issued	(24-28)	3.91
	12.annual medical check-up	(no)	4.63
	14.eye test	(no)	6.56
	15.description health problems	(joints/bones)	2.76
	18.wears glasses for driving	(not prescribed)	4.41
	turning across traffic 67: vehicle approaching from distance	(accelerate)	3.05
No difficulties – wears glasses (10%)	1.age	(65-70)	2.89
	2. age driver's license first issued	(18-23)	2.97
	17.drives under influence of medication	(sometimes)	3.89
	18.wears glasses for driving	(occasionally)	3.84

Stops and then proceeds to turn with no difficulties (27%)	2. age driver's license first issued	(18-23)	2.65
	12. annual medical check-up	(yes)	2.54
	14. eye test	(yes)	4.36
	17. drives under influence of medication	(never)	3.61
	63.difficuties turning at unsignalized intersection	(no)	2.93
	turning across traffic 64: on-coming car approaching	(stop and then proceed)	4.36
	turning across traffic 65: line of cars approaching	(stop and then proceed)	3.30
	turning across traffic 66: car approaching+car behind	(stop and then proceed)	5.45
Stop and proceed to turn with difficulties (14%)	1.age	(76-80)	3.59
	6.frequency of car use	(once/twice a week)	3.13
	12.annual medical check-up	(yes)	2.50
	18. wears glasses for driving	(always)	4.77
	63.difficulties in turning across on-coming traffic	(no)	5.00
	turning across traffic 64: on-coming car approaching	(stop and then proceed)	3.18
Slow down (9%)	1.age	(71-75)	2.41
	turning across traffic 64: on-coming car approaching	(slow down)	6.84
	12. annual medical check-up	(yes)	2.64
	turning across traffic 65: line of cars approaching	(slow down)	5.11
	turning across traffic 66: car approaching+car behind	(slow down)	6.40
Accelerate (16%)	t turning across traffic 64: on-coming car approaching	(accelerate)	8.30
	turning across traffic 65: line of cars approaching	(accelerate)	7.46
	turning across traffic 66: car approaching+car behind	(accelerate)	8.60
	turning across traffic 67: vehicle approaching from a distance	(accelerate)	3.61

Table n°8 - Description of homogeneous classes regarding turning across on-coming traffic

4.4. Night driving

To analyse driving behaviour at night, respondents were asked a series of questions about general behaviour when driving at night. In this case, unlike the other sections, we did not test specific manoeuvres. Four specific groups were identified.

CLASSES	SIGNIFICANT VARIABILES (modality)		V-TEST
Minor difficulties (31%)	2.age driver's license first issued	(24-28)	2.66
	56.night driving	(sometimes)	8.08
	57.nervousness during night driving	(sometimes, occasionally)	4.59/3.07
	58.poor lighting	(occasionally)	6.28
	59.confusion in distinguishing road markings	(sometimes, occasionally)	3.48/3.57
	60.alters route due to poor lighting	(occasionally)	3.36
	61.alters route due to poor road signs/markings	(occasionally)	3.22
	62.slows down to read road signs	(occasionally)	2.43
Major difficulties (8%)	15.description health problems	(joints/bones)	2.44
	57.nervousness during night driving	(occasionally)	2.92
	62.slowsdown to read road signs	(always)	3.06
	61.alters route due to poor road signs/markings	(occasionally)	4.09
No difficulties (42%)	0.gender	(male)	2.76
	2. age driver's license first issued	(18-23)	4.17
	6.frequency of car use	(daily 3-5d)	2.93
	56.night driving	(occasionally, always)	7.01/2.94
	57.nervousness during night driving	(never)	6.71
	58.poor lighting	(sometimes)	7.41
	59. confusion in distinguishing road markings	(never)	5.95
	60.alters route due to poor lighting	(never)	5.23
	61.alters route due to poor road signs/markings	(never)	4.91
	62.slows down to read road signs	(never)	2.81
Do not drive at night (19%)	56.night driving	(never)	7.98

Table n°9 - Description of homogeneous classes regarding night driving

1. These drivers have minor difficulties when driving at night. Drivers who sometimes have trouble seeing on poorly lit streets also responded in the same fashion. Sometimes they feel apprehensive or nervous about driving at night (31% of the total).
2. In this case the drivers experience greater difficulties with night driving and suffer health problems especially with bones and joints (8% of the total).
3. This group declared they had no problems driving at night. These drivers usually use the car daily. They do not have any difficulties changing lanes and they do not alter their route because of poor street lighting (42% of the total).
4. This group of drivers choose not to drive at night (19% of the total).

5. CONCLUSIONS

Some interesting aspects emerged from the analysis, briefly summarized below.

1. Elderly drivers are disturbed by vehicles travelling behind them, creating difficulties in negotiating certain manoeuvres. The reason for this is that they have to keep looking into the rear-view and side mirrors to monitor the position of the vehicle behind, thus taking their eyes off the road. This is particularly true of manoeuvres such as merging into main stream traffic and changing lanes, when it is essential to be able to quickly judge the distance from the other vehicle or vehicles.
2. For elderly drivers it proved very difficult to check the rear- and side-view mirrors' blind spot, precisely because of diminished ability and difficulties in rapid head movements.
3. A lot of drivers choose to change their habits to avoid driving at night or when visibility is poor. Driving in these conditions affects the visual field, increasing the risk of an accident happening.

The findings of the above analysis revealed that certain factors have a significant influence on elderly drivers' behaviour, in particular their eyesight. In fact one of the major difficulties that elderly drivers experience is judging the distance and speed of objects in different positions and travelling at different speeds. This is confirmed by the fact that the questionnaire respondents reported difficulties using the rear view or side mirrors; in distinguishing road and lane markings; in judging the distance of approaching vehicles or vehicles travelling behind them, in making out obstacles or shapes when driving at night or in conditions of poor visibility.

One of the major difficulties encountered by elderly drivers is perceiving objects outside the cone of vision, as this requires them to constantly change focus.

Consequently, the aspects associated with dynamic visual acuity, that is the ability to correctly recognize moving objects and judge distances, and with night-seeing ability of elderly drivers need to be properly evaluated.

Future research directions envisage the use of driving simulators to reproduce situations similar to those described in the present paper, so as to assess variations in elderly drivers' performance in different driving situations.

The ultimate aim of this work is to try to introduce suitable measures in Italy for assessing the driving ability of the elderly upon application for license renewal. These measures could include visual acuity tests that could result in restrictions for elderly drivers, for example only driving during the day, or staying off motorways or heavily trafficked routes.

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