The importance of precise sight correction for safe driving

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THE IMPORTANCE OF PRECISE SIGHT CORRECTION FOR SAFE DRIVING

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The research project presented herein is designed to investigate the importance of visual perception for safe driving.
To what extent can inadequate vision be the cause of an accident? What is the optimal visual acuity for safe driving? Does the current driving test suit its purpose? Do Italian motorists possess the minimum sight requirements prescribed by the Road Code for holders of a driving license? Can visual skills that are most appropriate to assess fitness for driving be defined?
Answers to these queries were sought by a research project focused on analysing statistical data of accidents, international scientific literature on the visual process and road safety. A new and more appropriate eye examination protocol was also designed to study visual skills involved; this eye test was administered to a sample of over 1,000 drivers at the Optometrics Centre, Università degli Studi di Milano Bicocca and, lastly, the data collected was processed.
The following pages present a summary of the study's outcome.

Road accidents
Road accidents are an issue that concerns the whole world today. They are provenly one of the chief causes of death in Italy. As reported by the WHO in *World Report on Road Traffic Injury Prevention* (2006)[1], 1.2 million people die in a road accident and ca 50 million are yearly injured in road accidents throughout the world. Narrowing the field of study to Europe, the report *Youth and Road Safety* (2007)[2] published by the WHO Europe declares that 127,000 people die in road accidents every year, while 2 million cases have requested either admission to hospital or medical assistance. We cannot neglect the fact that the WHO's European Region counts 32,000 youth aged under 25 years killed in road accidents every year. To judge by estimates, cars have killed more people since they were invented than all the wars fought over the same period (including World War 1 and 2).
The survey focused on the European Union reported that 1.3 million road accidents yearly cause 40,000 deaths and 1.7 million injured people. Considering this data, the European Union published the White Book on 13 September 2001, setting the ambitious goal of reducing road deaths to half the current number by 2010. The decision issued from the European Union's belief that the enforcement of appropriate regulations concerning prevention and

1 Racioppi, 2006 (http://www.iss.it/binary/sicu/cont/Cap.%201 -10.1141 384947.pdf)
2 World Health Organization, *Youth and road safety,* and *Youth and road safety in Europe,* 2007.

road safety had been underestimated, and that they could, instead, lead to a drop in the number of road accidents recorded in every country. We must mention that the mortality rate viewed by country presents considerable variations for reasons that have as yet to be clearly defined. Italy is one of the countries that is most affected by the problem; as a matter of fact data published by the *European Transport Safety Council* in May 2007 reported a mean mortality rate associated with road accidents of ca 13% above the European average, which is equivalent to ca 900 deaths more than the mean yearly incidence.
The latest survey published by the ISTAT in cooperation with the ACI[3] says that Italy **daily** records an average of **633 road accidents** that kill 14 people and injure 893.
Considering the many categories of road transport, **cars** account for 66.5% of vehicles involved in road accidents, and the percentage rises if we only study accidents between vehicles. **Motorised two-wheeled vehicles** involved in accidents number 21.4% of all vehicles, comprising mopeds (8.6%) and motorcycles (12.8%); practically 1 accident on 5 involves a two-wheeled vehicle. Lastly, **goods transport vehicles** account for 6.8% of vehicles involved in accidents.
The ISTAT has also estimated that social costs of road accidents for the year 2007 amounted to **30,386 million euro,** which is ca **2% of the GDP** for the same year.[4]

The causes of road accidents: the role played by vision
Studies conducted on driving behaviours have found that driving is a very complex task, which entails the interaction of three main factors: Man-Environment-Vehicle (MEV). Therefore, driving safety can only be ensured when this dynamic interaction maintains a balance that mostly depends on the driver's appropriate actions and reactions.
The ISTAT/ACI 2008 report[3] declares that the causes of road accidents can be catalogued in two macrodimensions: *Presumed circumstances related to the motorist's driving behaviour* and *Circumstances related to the motorist's psychological and physical condition.* Concerning the latter, Table 1 reports both ascertained and presumed causes of road accidents[3], and their percentages, with special reference to *causes directly blamed* on the poor perception of the vehicle's driver (highlighted in blue), such as failure to use corrective lenses or glare-related reasons, and *causes indirectly blamed* on a poor visual process (highlighted in red).
Highlighted data reveals a remarkable percentage of accidents caused by these circumstances: 59.13% of accidents can be blamed more or less directly on causes associated with poor sight.

[3] ISTAT/ACI Report – *Incidenti stradali anno 2007,* Rome, 2008.

[4] Calculations quantifying deaths, injured people and accidents that caused injuries to people were based on data collected by the ISTAT's survey on "road accidents" and ANIA data on accidents involving only damage to things. The mean social cost for every deceased person amounts to 1,372,832 euro, taking into account healthcare costs, loss of production and compensation for moral damages. The mean cost for every injured person, calculated with the same expenditure items mentioned for the deceased, amounts to 26,316 euro.

CAUSES OF ACCIDENTS	Total	Percentage
Distracted, undecided driving	44,653	15.25
Driving too fast	34,007	11.62
Non specified circumstances	39,626	13.54
Failure to maintain a safe following distance	28,790	9.83
Irregular driving	18,590	6.35
Failure to stop at Stop sign	16,575	5.66
Failure to give- way to vehicles on the right	15,056	5.14
Failure to give way as signalled	16,855	5.76
Irregular turn	9,211	3.15
Driving on the wrong side of the road	6,522	2.23
Irregular overtaking	6,543	2.24
Avoided a vehicle	4,389	1.5
Failure to give a pedestrian right of way at a crossing	5,406	1.85
Failure to comply with traffic lights or traffic police indications	3,019	1.03
Failure to keep to the right side of the carriageway	3,607	1.23
Vehicle bumped into while in an irregular parking position	2,829	0.97
Failure to comply with speed limits	1,713	0.59
Failure to comply with 'no thoroughfare' and 'no entry' signs	1,733	0.59
Person fell out while stepping out of a moving vehicle	1,362	0.47
Avoided an animal	663	0.23
Person fell from vehicle for hanging on to it or bad positioning	794	0.27
Person fell from vehicle as the door opened	856	0.29
Sudden braking with consequences for the passengers	567	0.19
Irregularly drew up alongside other two-wheeled vehicles	512	0.17
The vehicle bumped into had stopped without the prescribed signal	196	0.07
Left the carriageway knocking down the pedestrian	204	0.07
Knocked the pedestrian with the cargo	111	0.04
Headlights were switched on full beam while encountering other vehicles	37	0.01
Exited the driveway incautiously, knocking down a pedestrian	57	0.02
Crossed the level crossing incautiously	8	0
Faulty behaviour of the pedestrian	8,745	2.99
Knocked into an accidental obstacle	4,402	1.5
Avoided an accidental obstacle	2,726	0.93
Avoided holes, etc.	2,232	0.76
The drawbacks of driving	**282,596**	**96.53**
Vehicle defect or breakdown	**1,108**	**0.38**
Abnormal for drink-driving	6,124	2.09
Abnormal for disease in progress	76	0.03
Abnormal for a sudden fainting fit	971	0.33
Abnormal for sleep driving	764	0.26
Abnormal for ingestion of narcotics or psychotropic substances	877	0.3
Failure to use corrective lenses or prosthetic devices	11	0
Dazzled by glare	131	0.04
Exceeded prescribed driving hours	54	0.02
Motorist's abnormal psychological and physical condition	**9,008**	**3.08**

Pedestrian's abnormal psychological and physical condition	**34**	**0.01**
		0
Total causes of accidents	**292,746**	100
Total sight-related causes of accidents	**173,140**	**59.13**

Table 1: Ascertained or presumed causes of road accidents – Year 2007 – ACI-ISTAT 2008

The importance of correct visual perception in preventing accidents was confirmed by the New Road Code, which established the obligation to keep headlights turned on even during daytime driving on the motorway, and by various studies also numbering the one that proved the existence of a link between road accidents and car colour. Cars with sober paintwork, like black, are prone to suffer more accidents (only in the daytime, because colour is not a significant factor at night). The study conducted by the Monash University's Research Centre on Road Accidents, Melbourne (2007)[5], found that cars painted black present a statistically higher risk of accidents, and that "the safest" cars are, instead, the white ones, with a 12% difference, which means that the owner of a black car presents an additional 12% chance of being involved in an accident, compared to owners of a white car. The sight factor's crucial role has been confirmed in this case too.

Data underscores the vital link between accidents and sight, without going into details. The importance of the sight factor (which is at times hard to assess) is often concealed by other aspects that are defined as environmental, but which can also be blamed on sight and entail a higher risk of accidents during night-time driving or when driving in poor visibility conditions.

Visual perception (studies and theories)

Over the years perception has been the focus of many studies on road safety (see Pocaterra R., 2004; 2007, 2008[6]). The psychologist explains that the individual interacts with the environment by receiving stimuli from the world, and processing them as they strike his sensory organs. Cognitive sciences report that 80% of information from the environment reaches the brain by passing through the visual channel.

No social behaviour is foreign to this paradigm but, most likely, driving behaviour is the one that fully concretises this approach: driving is a social behaviour (Albanese A., 2001[7]), and the implementation of appropriate driving styles presupposes the skill to correctly and rapidly interpret the operating framework.

This process is not as banal as it may seem, since it involves many simultaneous factors needing analysis. The first element is the **visual** one, and the quality of vision depends on:

- the degree of environmental brightness (daytime and night-time driving, with fog, mist, rain);

5 http://www.monash.edu.au/muarc/reports/muarc263.pdf

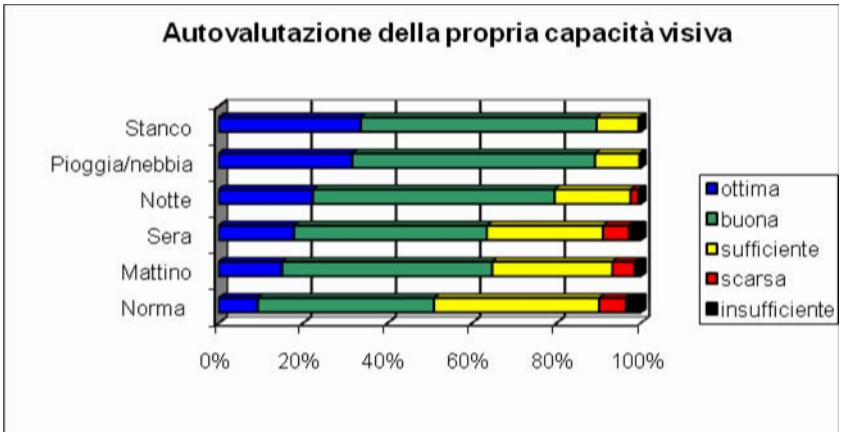
6 Pocaterra R. (edited by), *Giovani e sicurezza stradale,* Angeli, Milan, 2004; Pocaterra, R., Colombo, S., (edited by), *Ragazzi al volante,* Milan, Bruno Mondadori, 2007; Pocaterra, R., Dacquino, MT. (edited by), *Guidiamo la strada,* Milan, Fondazione IARD, 2008.

7 Albanese A. (edited by), *Percezione visiva e sicurezza stradale,* Milan, CUEM, 2001.

- the characteristics of the object to be observed (good background contrast);
- the transparency of the eye medium (aging, ocular diseases);
- the resolution of the optical system (visual acuity, uncorrected or poorly corrected refractive condition);
- the correct function of sensory cells;
- the adequate skill to process collected data.

Other elements involved are **psychological factors** (mood, degree of rest, intake of psychoactive agents – ranging from coffee to "commonplace" drugs, and even alcohol and drugs – and stressful conditions can affect driving performance); **social factors** that can distract the motorist's attention and influence his driving style; and **environmental factors** induced by the environmental and weather conditions, by road conditions and by the vehicle's irregular performance.

The driving environment is a very special framework because it is changeable, inconsistent and packed with the unforeseen. And yet, data collected in recent years[8] depicts a population of Italians, whose awareness of all factors involved in driving behaviour is poor.
Specifically (figure 1), the survey conducted by ABACUS-SOFRES (2000)[8] underscores a total lack of awareness that visual difficulties increase as light conditions change. This data, associated with other observations that emerged during the study[9], indicates a worrying lack of information in Italian motorists concerning the role played by sight as a decisive factor for road safety.



Self-assessed visual skills

Tired	
Rain/fog	Excellent
Night	Good
Evening	Fair
Morning	Poor
Normal	Very poor

Figure 1: Self-assessed visual skills[10] [Source ABACUS SOFRES 2000, Sample: 1,064 motorists]

This approach is confirmed by subsequent studies (Albanese A., 2001, Pocaterra R. 2004): the essential role played by visual perception is acknowledged,

[8] See Abacus-Sofres, 2000, Albanese A., 2001; Albanese, *et all.,* 200; Albanese A., Pocaterra R., 2002 and 2003; Pocaterra R. 2002.

[9] The Abacus-Sofres (2000) survey reports that the Italiani analysed consider sharp reflexes and good brakes as the essential factor for safe driving.

[10] It is clear that the visual process is closely linked with the amount of light present in the environment and that, hence, the answers given by the studied sample disagree entirely with "facts". This leads us to suppose poor awareness of personal skills and a rather lenient self-assessment (over-estimation).

but the importance of frequent testing (mean frequency: every 7 years) is underestimated, and awareness personal visual system characteristics is inadequate. Lack of information concerning the perceptive process' importance for road safety is enhanced by the implementation mode of the fitness test for issue/renewal of the driving license. Only static visual acuity with maximum contrast and colour sensitivity are tested in Italy, though Road Code regulations also required other functions to be investigated, such as binocular vision, night vision and the visual field.

A number of international studies on the subject have declared this fitness protocol outdated, adding the following tests to those already performed: visual acuity in mesopic conditions by evaluating sensitivity to contrast (Wood J.M., Owens A., 2005)[11], glare recovery test, visual-motor skills test, binocular vision test (Sartori S *et al,* 2002) [12], and visual concentration test (Ball K. *et al.* 1993[13]), lastly quantifying the effect of visual and hearing distractions on visual field extension. (Wood J.M. *et al.,* 2006)[14]

Field Research

An analysis protocol designed to examine the various aspects of the motorist's visual skills was drafted on the basis of the mentioned studies. The protocol envisioned a session dedicated to the evaluation of skills prescribed by the Road Code, and the addition of a new session of tests for skills indicated in international literature. Every session produced a performance indicator that was later compared with an Accident Involvement Indicator (AII).[15]

The sample analysed was self-selected by response to invitations sent out to the resident population in Milan's Bicocca district and to employees and students at *Università degli Studi di Milano Bicocca*, whose Optometric Centre implemented the project. The sample group thus obtained presented the typical features of a "self-selected" population[16]. Researchers theoretically expected to study subjects who were keen on road safety, complied with road rules and were rather aware of their visual system's potential.

1,116 people responded to the invitation, and they were analysed in the Optometric Centre's locations; **960** of them were deemed acceptable for data analysis.

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11 Wood J.M., Owens A., "Standard Measures of Visual Acuity do not predict Drivers' recognition Performance under Day or Night conditions", in *Optometry and Vision Science,* vol. 82, No. 8, pp. 698-705, 2005.

12 Sartori S., Pocaterra R., Maffioletti S., Baggio L., "Efficienza Visiva e Sicurezza Stradale: analisi dei processi percettivi e delle dinamiche psicologiche. Parte II", in Rivista Italiana di Optometria., vol. 25, n.3, September 2002.

13 Ball K., Owsley C., Sloane M. E., Roenker D. L., Bruni J. R., "Visual attention problems as a predictor of vehicle crashes in older drivers" in *Investigative Ophthalmology & Visual Science,* vol. 34, No. 11, pp. 3110-23, 1993.

14 Wood J.M., Chaparro A., Hickson L., Thyer N., Carter P., Hancock J., Hoe A., Le I., Sahetapy L., Ybarzabal F., "The effect of Auditory and Visual distracters on the useful field of view: implications for the driving task" in *Investigative Ophthalmology & Visual Science,* vol. 47, No. 10, pp. 4646-4650, 2006.

15 The index was formed using some objective information provided by interviewees, such as the number of accidents experienced, the number of fines received and the number of yearly km travelled multiplied by the years of driving. This index was then pre-tested on a sample of motorists, and subsequently validated with ISTAT data on accidents.

16 A "self-selected" sample comprises all units that spontaneously decide to participate in the survey with no "external" extraction process.

The sample's refractive social, demographic and driving features fully represent the Italian population.

Fitness to drive, as established by the Road Code

Data was analysed starting from visual skills envisaged by the Road Code. These skills are tested during eye examinations for renewal of the license performed every 10 years for A and B-type licences, and every 5 years for other license types. Currently required skills to certify fitness to drive number:

- overall 10/10 vision (14/10 for C, D, E-type licenses); the weaker eye must have at least 2/10 (5/10 for C, D, E-type licenses);
- adequate chromatic sense to rapidly and confidently distinguish colours on road signs;
- normal visual field;
- adequate night-time vision;
- binocular vision.

The study conducted by this university's Optometric Centre found that the sample group's visual skills did not fully meet Road Code specifications. Data collected is summarised below, underscoring the percentage of subjects with inadequate vision:

1. **18.57% of the sample presented inadequate visual acuity (VA) (even wearing adequate sight correcting devices); of these:**
    a. **16.67% had overall VA under the prescribed requirements;**
    b. **1.90% had single eye VA under the prescribed requirements;**
2. **1.91% of the sample presented inadequate colour vision;**
3. **2.35% of the sample presented an inadequate visual field;**
4. **24.50% of the sample presented inadequate night vision;**
5. **3.19% of the sample presented inadequate binocular vision.**

Inadequate visual skills were expressed (table 2) both with a specific percentage that referred to the total sample population (inadequate %), and with a percentage that highlighted the increase induced by each skill (% of new cases - subjects that were already listed as "inadequate" due to a deficiency detected in previously tested skills), and the overall value of inadequate subjects listed in ascending order (cumulative %). Data revealed that 1/5 of the studied sample group (20.05%) was unfit, at the time of the eye examination, for license renewal, according to criteria enforced in Italy (visual acuity and colour vision test), and required targeted action to restore these basic visual skills. The number of subjects presenting inadequate conditions for license renewal rises if we consider factors that, despite Road Code specifications (i.e. visual field, binocular vision and night-time vision), are not generally investigated during the examination. When this criterion was adopted, one motorist on three (32.17%) of the subjects examined presented *at least one altered visual skill.*

Visual skills	Inadequate %	% of new cases	cumulative %
VA	18.57%	18.57%	18.57%
Colour vision	1.91%	1.48%	20.05%
Visual field	2.35%	1.29%	21.34%
Binocular vision	3.19%	2%	23.34%
Night vision	24.50%	8.83%	32.17%

Table 2: Summary of 'inadequate' visual skills prescribed by the Road Code [Sample: 960 motorists]

Fitness to drive, as specified by international studies

The protocol drafted by *Università degli Studi di Milano Bicocca*'s Optometric Centre also envisaged some tests recommended by international literature to investigate skills associated with a tendency to meet with accidents. These skills are listed below:

- *saccadic mobility* is the visual skill motorists use most for right/left and left/right saccadic explorations to observe and become aware of obstacles on the road and other vehicles;
- *visual concentration* is the skill to continuously use central (foveal) vision; performance standards are proportionate to the degree of weariness and, partly, also to some individual personality traits; evaluating the "ability to use" this visual skill is deemed essential for people with concentration difficulties, such as alcoholics, the elderly and subjects undergoing drug therapy;
- *visual acuity with variable contrast* is an essential skill in case of bad weather and fog; it can be compromised, despite excellent test results for VA with maximum contrast;
- *cognitive disorder:* though the new Road Code allows motorists to use the cell phone while driving, if it has the hand-free feature or earphones, people often find it hard to process multiple data concurrently.

A study of the session focused on additional skills recommended by international literature as useful features for safe driving behaviour found that the reference scene was worse than the one depicted by Road Code criteria. (Table 3)

Visual skills	inadequate %	% of new cases	cumulative %
saccadic mobility	13.84%	13.84%	13.84%
visual concentration	13.59%	10.78%	24.62%
visual acuity with variable contrast	22.93%	16.72%	41.34%
cognitive disorder	32.22%	14.43%	55.77%

Table 3: Summary of 'inadequate' additional visual skills recommended by international literature. [Sample: 960 motorists]

We can notice that 55.77% of the sample presents at least one inadequate area.

Table 4 interfaces results reported in Table 3 and Table 2, which refer to skills prescribed by the Road Code.

	inadequate %	**adequate %**
Skills prescribed by the Road Code	32.17%	67.83%
Additional visual skills (recommended by international literature)	55.77%	44.23%
Combined skills	21.04%	35.13%

Table 4: Summary of overall 'inadequate' visual skills. [Sample: 960 motorists]

Visual skills for driving and the Accident Involvement Indicator (AII)

As already mentioned, an AII calculation has been developed with data that offers an objective picture of the motorist's driving curriculum.

The AII is, hence, a predictor of the risk run by the subject, and it is based on past events that have characterised the motorist's history and the actual number of kilometres yearly travelled[17].

This indicator can be very useful in building models that link the various subcategories of motorists[18]. **Data (figure 2) reveals a significant correlation between a medium/high AII and sight inadequacy. About 70% of the sample group presenting a driving curriculum that records a moderate number of traffic offences has an inadequate visual system; ca 17% of them was inadequate for both profiles, ca 3% was inadequate to meet Road Code specifications, and ca 50% was inadequate to meet recommendations in international literature.[19]**

[17] The AII (Accident Involvement Index) is calculated with the following formula:

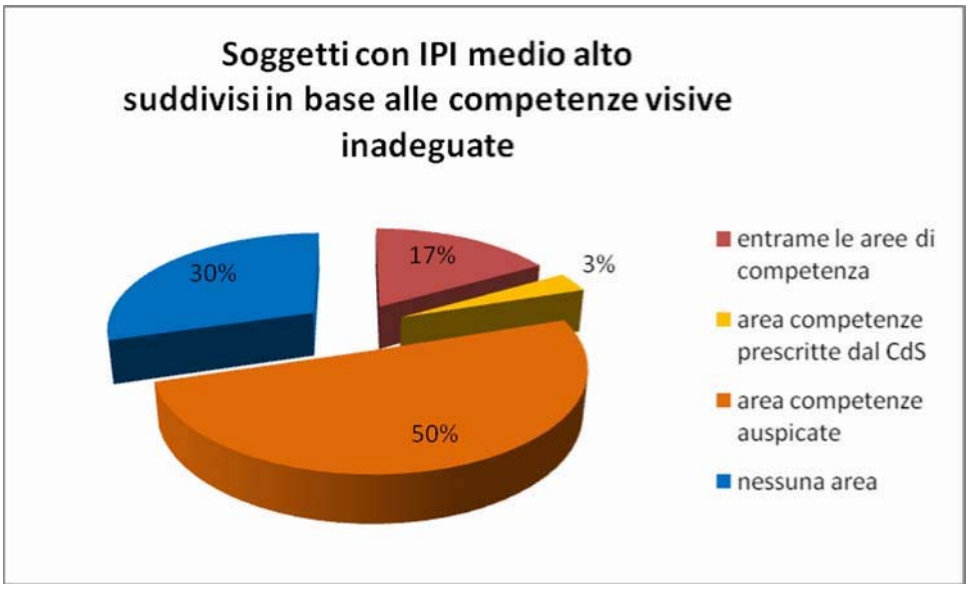
$$AII_{score\ in\ km\ travelled} = \frac{accidents + \frac{fines}{10.83}}{}$$

with

1) "accidents" indicating the number of accidents caused in a lifetime;
2) "fines" indicating the number of traffic offences recorded during the driving career (this value is divided by 10.83, which is the ratio between fines and accidents observed in Italy in 2007; source: ISTAT);
3) "score in km travelled" is a score ranging from 0 to 100 and adopted to classify interviewees on the basis of answers provided to questions on km yearly travelled and years of driving.

[18] The sample population can be divided into one group with a medium/high AII of 13.27% and one group with a medium/low AII of 86.73%. The low frequency of medium/high AII is in line with the analysed sample's profile.

[19] Considering the low number of motorists in this category, this data is not statistically valid. It is reasonable to deem the result as a valid indication.



Subjects presenting medium/high AII divided by inadequate visual skills
- combined skills
- skills prescribed by the Road Code
- recommended skills
- no skills

Figure 2: Classification of the sample group with medium/high AII and inadequate visual skills. [Sample: 170 motorists]

Final considerations

Data processed leads to the conclusions described below.

1. Correlation between road accidents and sight disorders - Collection and classification modes of data published in literature do not provide clear statistical evidence of the two aspects. However, ISTAT data (2008) reveals the presence of a direct causal link with visual perception in 59.13% of cases, and our research study has found sight disorders in ca 70% of motorists with a medium/high AII.

2. Driving test – It is currently unable to screen drivers who possess an adequate visual system for the task. 32.17% of subjects studied do not possess the minimum requisites prescribed by the law to drive the vehicle they own. This failure can be blamed on the examiners' lack of expertise, on a too long interval between renewals (10 years for A and B-type licenses, and 5 years for other license types)[20], on the inadequate or lack of precision in applying the adopted visual protocol, and on the wrong type of sight correction (spectacles or contact lenses) worn by motorists.

3. New and more effective assessment modes for driving license renewal – They are necessary and much hoped for. This indication surfaces both from the study and the review of national and international literature on the subject. The application of the visual protocol proposed in our study indicates that 55.77% of the sample group

[20] This theory is only partly valid. Of subjects who failed to meet eyesight standards prescribed by the Road Code, 43.11% had renewed the license less than three years before the study, and 35.56% had renewed it 4 - 7 years before the study. Hence, it would seem that the time variable has a low influence (21%) on the sample group's inadequacy.

analysed proved to be inadequate concerning these skills. The need to adjust the protocol is also confirmed by the statistically significant correlation between subjects that were inadequate in these visual skills and medium/high All levels (Accident Involvement Indicator).