Note: Hyperlinks from the contents to the relevant text sections

VISUAL FUNCTIONS AND TRAFFIC ACCIDENTS.

A Danish study based on 359 motor vehicle accidents resulting in human injury, with case reports.

By K. E. Alsbirk, M.D.

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A Danish study based on 359 motor vehicle accidents resulting in human injury, with case reports

By K.E. Alsbirk, Department of Ophthalmology, Aarhus University Hospital, and Institute of Forensic Medicine, University of Aarhus, Denmark.

ABSTRACT.
Purpose and methods: A descriptive and analytical study of visual functions in Danish drivers involved in automobile accidents has been performed. A total of 562 active (i.e. not passengers) road users, aged ≥ years 10 involved in 359 car accidents resulting in human injury in the police district of Aarhus county (284,000 inhabitants) was registered: 405 car drivers (156 aged ≥ 50 years) and 157 unprotected road users were included. The participation rate was 76%. The non-responders' vision was evaluated through contact to ophthalmologists or general practitioners. In this way vision data was obtained in 93% of the study group. A control group of 138 randomly selected active car drivers, aged ≥ 50 years, were correspondingly examined with a participation rate of 83%. If available, police reports were studied in all relevant accidents. A case/control study was performed in 204 drivers (91 cases and 113 controls), aged ≥ 50 years. Eighty-two vision/accident relevant case reports and 24 accident reports on medical conditions are published separately, 43 illustrated.

Results and discussion: Among the investigated car drivers involved in accidents, 1.6% aged < 50 years had a corrected visual acuity below the legal level at the time of the accidents. Correspondingly, the proportions were 8% in 50-69-year-old persons and 25% in drivers aged ≥ 70 years. No significant differences could be demonstrated on visual parameters between males and females, although a longer period since last visual test was found in males ($p< 0.01$). In twelve out of 14 drivers (86%) with unilateral reduction of visual acuity, being involved in intersection accidents, the collision happened from the side with impaired vision ($p< 0.02$). Eleven of such bumpings (79%) took place from the left side ($p< 0.06$). A renewal of optical correction was sufficient to legalise the driver's vision in 15 of 17 accident drivers with visual acuity at (2) or below (15) the legal limit (88%, 95% confidence interval (CI):[64%-99%]. Tested binocularly, correspondingly 9 out of 10 drivers (90%) with visual acuity below 0.5 achieved legal vision after today's standard by new glasses. In 16 % [CI: 10-23%] of the accident involved drivers aged ≥ 50 years, an acute or chronic medical condition, including significant visual problems, was estimated to be of contributory importance for the accidents.

Multiple logistic regression analyses with vision/accident risk estimates were carried out on 204 drivers aged ≥ 50 years (the case/control study) with correction for age, sex, annual driving, daily alcohol consumption, percentage of urban and professional driving, and visual reaction time. Traffic accident risk was found to be significantly associated with quality of vision. Illustratively each accident is further individually evaluated for such an association. Contrast sensitivity (odds ratio (OR) = 1.99, [CI: 1.3-3.1], $p= 0.003$), and to a less degree unilaterally reduced visual acuity (OR=5.21,[CI: 1.3-20.6], $p= 0.02$), and binocular visual acuity (OR= 4.35, [CI: 1.1-17.5], $p= 0.03$) seemed to be important test variables. Binocular visual acuity was identified as a stronger risk indicator than monocularly tested visual acuity (OR= 3.65, [CI: 0.9-15.6], $p= 0.08$). It can not be ruled out that stereopsis (OR= 2.15, [CI: 1.0-4.7], $p= 0.05$) and the time interval since last visual test (OR= 1.55, [CI: 0.97-2.5], $p= 0.07$) are critical factors. No association was found with central or paracentral visual field defects, visual field defects tested a.m. Donders, colour vision defects or refraction. Several visual variables tested were found mutually associated. The health consequences of accidents with driver's visual acuity at or below the lawful limit did not differ from the main group of accidents. A vision/accident association is cautiously estimated as probable in 430 [216-761] traffic accidents with human injury in Denmark per year, or one per day.

Conclusions: Elderly drivers' compensation for their increasing visual problems in the form of a change in driving behaviour is not fully adequate. One way to reduce the problem may be to perform more efficient and consistent re-testing of drivers' vision at appropriate intervals and with adequate procedures. Due to the fast growing population of elderly drivers world-wide, this seems increasingly relevant. Furthermore, when applied to relevant age groups, a screening program may to some extent function as a valuable health prophylaxis, including prevention of diseases and blindness. The implementation of such steps in individual countries, however, is a question of health politics.

For selected group of drivers at doubt, modern visual attenuation test methods such as useful field of view and/or interactive driving simulators might be useful in the future.

Key words: vision, driving, traffic accidents, legislation, Denmark, visual function, case reports, Epidemiology, motor vehicle accidents, human injury.

Preface and acknowledgements

As a medical student, I was deeply inspired by the late Professor Dr. med. Jørgen B. Dalgaard, Institute of Forensic Medicine, University of Aarhus, and his indefatigable work for the prevention of traffic accident tragedies.

As a young doctor, working in the department of neurosurgery in the seventies, I was strongly affected by the many severely injured victims of road traffic accidents, including children. One of them, a male driver, had lost his wife and teen-age daughter in a serious car accident. In November, in dim light, one municipal district salted the sporadically icy roads whereas the neighbouring district did not! Might the possibly reduced vision of the driver in question be one of several aetiologies contributing to this familiar catastrophe? - It was never investigated!

In the department of ophthalmology my interest has been reinforced, partly by meeting patients with very bad vision, who were still active car drivers, partly by treating the severe eye-lesions caused by traffic accidents of which the majority could have been prevented by simple measures such as the use of seat belts.

These experiences made research in traffic ophthalmology very challenging and has motivated the present investigation.

This study has been performed at the Department of Ophthalmology, University of Aarhus, Denmark, in close cooperation with the Institute of Forensic Medicine, University of Aarhus, and with permission from the Regional Committee of Medical Ethics.

The first constructive idea for the project was suggested to me by my colleague and friend, Jens Elmeros, M.D., Aalborg.

I am grateful for the kind advice, critical discussions, patience and support from my adviser, the late Professor Dr. med. Jørgen B. Dalgaard, The Institute of Forensic Medicine, University of Aarhus, and from Professor Dr. med. Niels Ehlers, Department of Ophthalmology, Aarhus University Hospital, for placing the facilities of the eye clinic at my disposal for the project.

It would have been impossible to accomplish a comprehensive study like this without the co-operative help from several extramural institutions and persons:

The epidemiological design and other aspects have been discussed with Senior Lecturer Svend Juul, M.D., Institute of Social Medicine, University of Aarhus, whose critical and constructive advice has been of major importance for the design of the study. Senior Lecturer, M. Sc. Anders Holst Andersen, Department of Statistics, University of Aarhus, has been a helpful consultant in the statistical evaluations of the results. Professor Lic. Sc. Michael Væth, Department of Biostatistics, University of Aarhus, has performed a later logistic regression analysis. To achieve detailed information on the accident data, I asked for and obtained the co-operation of the Aarhus Police Department. The late director of police, Erik Christensen, gave me the optimum conditions for conducting the project and paid consideration to the medical, professional secrecy of the author. In the follow- up phase, the same conditions were kindly offered to me by vice-director of police, P. Stampe Degn.

The staff of the police department has been very helpful in providing me with the relevant police reports. I would like to thank secretary Karen Nielsen, Aarhus Police Department, for faithfully and systematically informing me on the relevant traffic accidents. For the collection of a control group of randomly selected active car drivers I especially wish to express gratitude to the late assistant Mrs. Kaja Falkenvig for her kind and effective assistance.

At the Ministry of Justice and the Ministry of Traffic and Communication I have been met with positive interest and support, for which I am very grateful.

Furthermore, I am indebted to a number of persons:

The heads of the two casualty wards in Aarhus, Dr. med. Ole Helmig and Jørgen Sommer, M.D., for their kind co-operation, effectively and systematically administered by the secretaries Laila Pedersen and Lene Plagborg, for which I am very grateful;

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Ph.D. Gevene Hertz for the English translation of the summary chapter.

I wish to direct special thanks to my brother and colleague, Dr. med. Poul Helge Alsbirk for his very patient, detailed, critical and constructive revision of the manuscript; The late Dr. med. C. J. Møllenbach for giving important contributions to the history of the Danish legislation, and the late consultant Ib Boesen, M.D., The National Board of Health, for his important supply of legislative aspects in the EU;

The late Dr. med. Viggo Clemmesen for his important help in making contact to ophthalmologists worldwide; Dr.

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My colleagues in general practices and eye specialists' practices, who were asked to provide information concerning the non-responders, for positive co- operation and support;

Several colleagues for having shown interest in the project by looking for relevant literature;

My chiefs and colleagues at the departments of ophthalmology in Aarhus, Vejle, Aalborg, and Sønderborg for co-operatively supporting my periodic need for leave from my clinical work.

I also wish to thank all probands involved in the accidents and the control persons for their confident and positive contribution in making the conclusions of this study valid. They have offered the project a lot of time, inconvenience and good will.

This study would not have been possible to perform without economic support. I wish to thank: Augustinusfonden; the Danish Association for the Blind; the Danish Medical Research Council; Landsforeningen "Værn om Synet"; Nordisk Gjenforsikrings Jubilæumsfond; Rådet for Bedre Synspleje; Sparekassen Bikubens Fond; Sparekassen SDS Fond; Sygekassernes Helsefond; Vognmand Johannes Rasmussen, Svebølle og hustrus Fond; Åge og Ulla Filtenborgs Fond, and Synoptikfonden for their generous financial support.

Last, but not least, I wish to thank my ex-wife Vibeke, who lovingly has provided me with the demanding but decisive family back-up for the project. My three children, Jakob, Thomas, and Ditte, to whom this work is dedicated, have given me remarkable patience, love and even help in busy periods.

It has been my primary intention with this study to take part in the prevention of tragedies in road traffic accidents. From a humanistic and medical point of view, this rather comprehensive work will definitely have been worth the while, if it contributes to the hindrance of just one serious road traffic accident resulting in human injury.

Also, from an economical point of view, the research project seems justified, if just one serious traffic accident is prevented.

Høruphav, Denmark, May 1st. 1999.

Knud Erik Alsbirk

Addendum.

The manuscript has now been made available as a PDF-file for the internet!

It is found on the following internet address :

http://www.retsmedicin.au.dk/publikationer/afhandlinger

A printout version is available from the author (at the price of 25 €, 200 N kr. or 190 D kr. + postage).

The Institute of Forensic Medicine, University of Aarhus, Denmark is kindly thanked for their positive help in letting the manuscript become available on the homepage of the institute.

Bergen, Norway, March 1.st . 2008

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1. Introduction

Traffic accidents today constitute a heavy load in most societies in the world, whether seen from a humanistic, health, social or an economical point of view.

Research on the role of the increasing number of aged car drivers in modern traffic has been in demand (e.g. Nordisk Trafiksikkerheds Råd, 1990, Schieber 1994).

1.1. Demographic background

From the statistical reports, we know that the elderly population is the fastest growing age group in the Western hemisphere and will go on increasing in most European countries (Fig. 1.1) (OECD 1985). The Scandinavian countries are no exception as estimated by Strengell (1986) (Fig. 1.2). Although

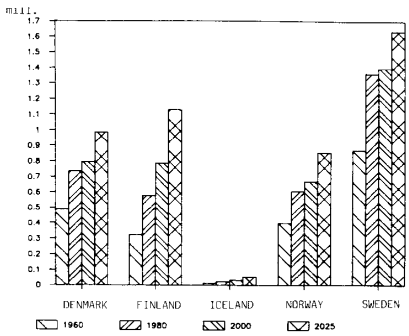

Fig. 1.2. The actual and predicted number of > 65-year-old individuals in the Scandinavian countries 1960-2025 (Strengell 1986).

a temporary stagnation is probable for the rest of the century, the proportion of elderly individuals will increase again.

Furthermore, the proportion of car drivers in the countries in question has changed radically. Figure 1.3 shows that in Sweden in 1954 10% of the male population owned a car at the age of 50, decreasing to approx. 5% at the age of 70. In 1983, 60% of the male population aged 50 owned a car, decreasing to 35% at the age of 70 (Wictorsson 1984).

The proportion of 65 year old male Swedes who owned a car has risen from

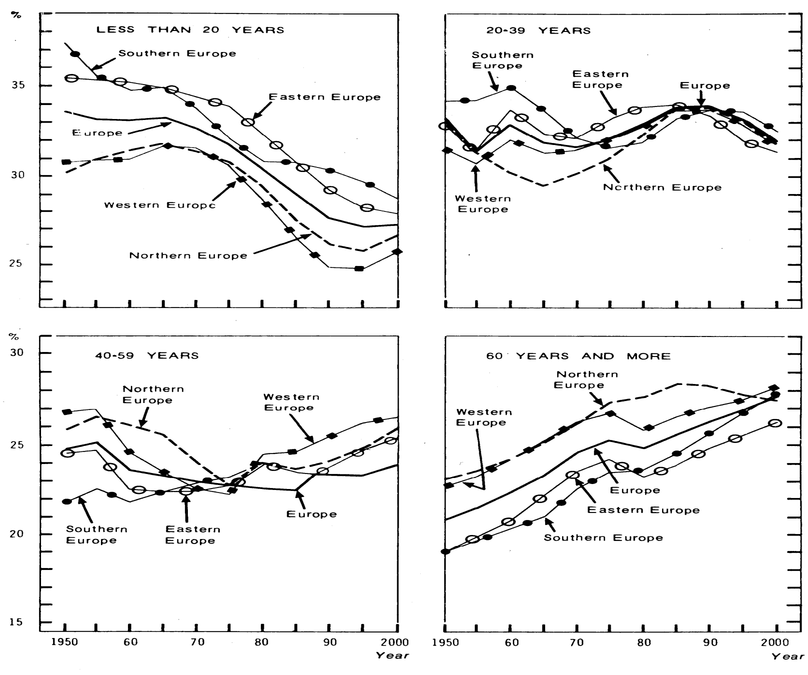

Fig. 1.1. Trends in the distribution of age groups in Europe and within the European regions: 1950-2000 (OECD 1985).

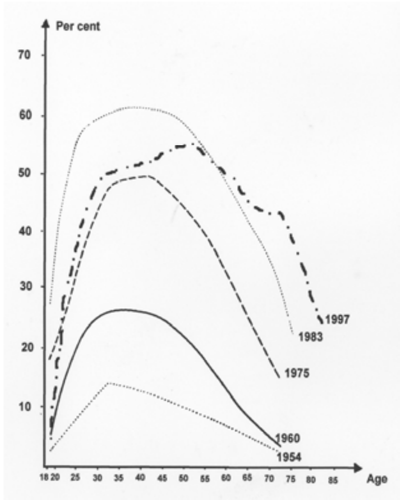

Fig. 1.3. Rate (in per cent) of male car owners in Sweden according to age , 1954, 1960, 1975, 1983 and 1997. (Wiktorsson 1984, with 1998 update, personal communication).

7% in 1965 to 45% in 1997 (Wiktorsson, personal communication).

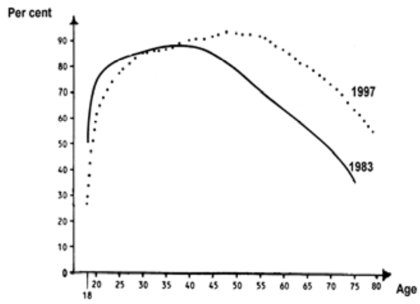

Fig. 1.4. Rate (in per cent) of holders of a driver's license according to age , Sweden 1983 and 1998 (Wiktorsson 1984 with 1997 update, personal communication).

Fig. 1.4 shows the frequency of holders of a driver's license in different age groups in Sweden in 1983 and 1997 (Wictorsson 1984 and 1998, personal communication), a country in which elderly drivers' vision is *not* compulsory retested. Today, a driver's license, as shown, is more common in the elderly population than was the case in 1983. In Sweden, until the year 2000, the transport by private cars is estimated to increase with 30% while public transport will decrease with 25% (Transportforskningsberedningen, 1984). The same tendency is seen in Denmark (Andersen 1985). From these facts it can be concluded that with a great deal of probability there will be a rapidly increasing proportion of active elderly car drivers in the coming decades, as presumed by Holmberg (1986), (Fig. 1.5).

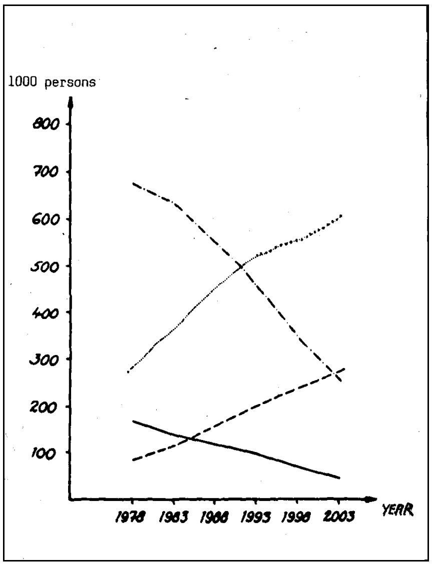

Fig. 1.5. *Holders of a driver's license and access to car in the age group > 65 in Sweden, actual and predicted No. in thousands (Holmberg 1986).*

.-.-.-.- *No car, no driver's license,*

\- - - - *No car, driver's license,*

—— *Car, no driver's license,*

.... *Car, driver's license.*

During the time it has taken this elderly generation of car drivers to grow up, the Danish law concerning visual tests for drivers and the traffic situation has radically changed. Before 1966, all drivers had to have their health status, including their vision re-tested every 5th year. After June 1966, however, a health examination was no longer mandatory until age 70 (except for professional drivers of public transport vehicles and drivers suffering from certain diseases such as diabetes, epilepsy, etc.). Since 1997, a new lorry driver's license is valid until 50 years of age, and thereafter for 5 years (cf. Chapter1.22)

How do these facts relate to the present and future traffic safety in Denmark? The present investigation is an attempt to answer this question.

1.2. Legislative background

1.2.1. International aspects

To a certain extent there has been a general agreement concerning the legislation on limits or cut-off points for drivers' central visual acuity and their visual field in relation to obtaining a driver's license in most US and European states (Zaidel & Hocherman 1986). On the other hand, much disagreement exists concerning appropriate intervals for the re-testing of the drivers' vision.

The *visual standards for driving* in various countries have been reviewed by Charmann (1985): In most countries there is a general agreement as to passing monocular test- standards for corrected static visual acuity = 6/12 in at least one eye, (e.g. EU and Norway), the demands being normally higher for the last eye in functionally one eyed drivers than for drivers with two good eyes. An important difference is the use of the "numberplate test", which is a binocular test that has been used in the UK since 1935 (Plenty, 1985, Mars and Keightley, 1990) and in some earlier Commonwealth countries (e.g. the UK, Cyprus, Hong Kong, Mauritius).

In Hungary a one-eyed person cannot obtain a driver's licence (exemption is granted to persons having lost their vision after having obtained a driver's licence) (Ottovay, personal communication).

The *methods for static visual acuity testing* vary from the use of Snellen's chart to vision-screeners of various kinds.

Big variations exist concerning *legislation on colour vision defects.* Most tests are performed as simple discrimination tests between well defined colours. Greece, Italy, Belgium, Columbia, Japan, the USA (42 states), Australia (Queensland), Poland, Austria, and Hungary are such examples. In the two latter countries, protanopes and achromates are excluded. Canada, Sweden, and Hungary require normal colour vision for bus drivers (Vingrys and Cole, 1986). This variation reflects the disagreement in the role of colour defects in traffic accidents as reviewed by Verriest et al. (1980).

The political changes in East Europe since 1989 have further confused the picture of legislation.

Demands for *visual field testing* vary: In some countries this is tested only in horizontal extents by hand. Other methods are examination by a visual field screener, by a bowl perimeter (e.g. Belgium and Queensland), and by Donder's confronting test (e.g. Denmark). In UK the minimal visual field for safe driving is a field of at least 120° in the horizontal meridian and 20° above and beneath the fixation point as measured by a Goldmann Perimetry using the III-4e settings (or equivalent) (Elkington, 1995).

Depth perception is tested in West Germany and in the USA (31states).
Most tests of drivers' vision are conducted by optometrically untrained personnel. In Greece and Italy an ophthalmologist has to perform the vision testing. In a few countries individuals with night blindness, high levels of ametropia and aphakia are excluded.

In general, in spite of these differences, the standards for corrected static visual acuity are very similar. Contrary to this, *the standards for re-testing* differ heavily: Table 1.1 lists the raw rules for a re-testing of vision in various countries around the world.

These differences are based more on tradition than on tangible evidence. Zaidel and Hocherman (1986) have investigated the effect of license renewal for elderly Israeli drivers aged 65 and up. Out of 10.937 tested drivers, 48% showed no abnormal findings. Eighteen percent showed visual problems, correctable by glasses, and 34% were further evaluated by the Medical Institute of Road Safety. Only 10% out of these needed further medical intervention. In summary, 25% of the applicants were requested to wear spectacles while driving. Seven percent of all elderly drivers started wearing glasses when driving as a consequence of the tests. In spite of these findings, the authors concluded: "It is doubtful whether compulsory and costly medical examinations under the threat of losing a driving license are the appropriate context for diagnostic, preventive public health medicine".

On the other hand, Nelson et al. (1992) found, in a registration survey, a significantly lower (p=0.04) rate for fatal crash involvements in 10 US states with re-testing of vision each 4-5 years compared to 9 states without retesting. This conclusion was confirmed by Levy et al. (1995).

Hills and Burg (1977) and Macdonald (1985) have found that accident rates correlate better with dynamic than static visual acuity of the drivers. However, devices developed for the purpose of *dynamic visual acuity* testing (DVA) have not been evaluated thoroughly, (Henderson and Burg 1974) and these methods have not yet been widely used.

Hills and Burg (1977) found no significant association between accident rates and poor visual performance in young and middle-aged drivers. From age 55- to 70 years, however, a weak but significant association was shown. For drivers aged ≥ 55 years the association between the two parameters, static and dynamic visual acuity, was very close. Byrnes (1962) found that static visual acuity correlates well with lower angular velocities and found no reasons to test other than static visual acuity (v. a.) for application of a driver's license.

Modern methods, such as useful field of view (Ball and Owsley, 1993) and driving simulators, will be discussed in chapter 5.4.

Hedin (1980) concluded that elderly drivers avoid difficult driving situations compensating for the deterioration with age. He found that the gain of re-testing the visual capacity of elderly drivers has not yet been proven and if re-testing is considered, it should be restricted to drivers ≥ 65 years of age. Aldman (1982) found that the differences concerning the visual requirements for car drivers within the Scandinavian countries ought to be minimal. The Swedish medical association has recommended that professional drivers should be re-tested at 65, 67, 69, and every year from age 70 until 75 years (Andreasson, 1984). For private drivers re-testing is recommended at age 65, 70, and then every 3rd year for medical reasons.

As can be seen from table 1.1, Sweden, apparently, is one of the countries with the least restrictive rules for re-testing drivers' vision. This has a historical background (Andreasson, 1994). Recently, Hakemies-Blomquist et al. (1996) argued against re-test of elderly drivers, which is still Swedish politic. But it must be emphasized that in Sweden most elderly people have medical check-ups annually for general health reasons. The physicians are obliged to inform the licensing authorities of any pathologies detected likely to affect driving capacity. Publications con-

Table 1.1. Standards for re-testing drivers' vision and health. (Alsbirk 1999)

REGIONS:	*PRIVATE DRIVERS:*		*BUSSES, TAXIS, ETC:*	
	AGE:	INTERVALS:	AGE:	INTERVALS:
SCANDINAVIAN COUNTRIES:				
Denmark	>70 :	4,3,2,1 year(s)	>21 :	5 years
Finland *	>18 :	at 45 and 60 years, since: 5 years.	>45 :	5 years until age 70.
Iceland (all) *	>70 :	4,3,2,1 year(s) (as Denmark)	>20 :	10 years
Norway	>70 :	max 5 years	>18 :	10 years
Sweden *	>18 :	-	>65 :	10 years (no requirements for taxes).
EUROPE:				
Austria		-	>18 :	5 years (Bus: 3 years)
Belgium		-	>21 :	3 years
Estonia ****)	>18:	2 years, since 10 years		
France		-	>18 :	5 years
			>60 :	2 years
			>76 :	1 year
Germany		-	>21 :	5 years (bus + taxi only)
Greece	>65 :	3 years	>65 :	5 years
Hungary*	16-50 :	5 years	16-50 :	5 years
	50-65 :	3 years (>65: 2 years)	50-65 :	3 years (>65: 2 years)
Ireland	>18 :	3 years	>18 :	3 years
	>70 :	1 year	>70 :	1 year
Israel	>65 :	2 years	>65 :	2 years
Italy	>18 :	10 years	>18 :	5 years
	>50 :	5 years	>65 :	2 years
Lithuania ****)	>18 :	5 years.		
	>55 (♀) and >60 (♂): 3 years.			
Luxemburg	>50 :	10 years, > 70: 3 years	<50 :	10 years, >50 : 5 years
The Netherlands ****)	>18 :	10 years, >65: 5 years	>18 :	5 years
Poland ****)		-	>55:	at age 60 and 63, since each year.
Russia ****)	>18:	10 years		
Spain ****)	>18 :	10 years	>21 :	5 years
	>45 :	5 years	>50 :	3 years
	>70 :	2 years	>60 :	2 years until age 70.
Switzerland ****)	>70 :	2 years	>50 :	5 years
UK	>70 :	3 years	>45 :	5 years (>60 : 3 years)
OUTSIDE EUROPE:				
Australia **)	>70-80 :	1 year	18-60 :	3-6 years
Canada**)	>80 :	1 year	<65 :	3 years (>65: 1 year)
Japan*	:	3 years	:	3 years
Jordan*, healthy persons	:	10 years	:	?
Liberia	>18 :	1 year	>18 :	1 year
Mauritius		at 60		at 60
New Zealand	>50 :	5 years	>18 :	1 year
			>70 :	1 year
South Korea*	:	5 years	:	3 years
USA***)	>21 :	2-6 years	>21 :	2-6 years
C.I.S.*)	:	5 years	:	3 years
(males/fem.)	>60/55 :	2 years	>60/55 :	2 years

Remarks:
*) Personal communications (see text).
**) Variable in different parts of the nations.
***) Variable. Re-test of vision in 31 States (Graca 1986).
****) CIECA, 1998.
Other references: see text.
Empty boxes: no information.

cerning estimates on the frequency of testing the drivers' vision on these occasions have not been found.

Correspondingly, according to section 12 of the Danish Practice of Medicine Act, Danish physicians have the same duty to report, but only if the patients will not accept the decision concerning non fulfilment of conditions for a driver's license. As shown by Juhl (1984), this reporting has been very heterogeneous and inconsequent. The Danish law and its background will be described in details in chapter 1.2.2.

The legal aspects and the ethical problems of the physician's duty to warn their patients of medical risk conditions have been reviewed by Gregory (1982). On the basis of a California study of 20,000 drivers, it was emphasized that when physicians examined, listened to, and reported their medically impaired driving patients, the accident rates were low compared to a control group of non examined drivers.

In his editorial, based on a California court decision, Tennenhouse (1984) concludes that "the physician who fails to warn a patient about the danger of driving is endangering not only the patient but every one else on the road". It is emphasized that ophthalmologists are probably liable for the patients as well as for other persons, who are injured as a result of the ophthalmologists not having warned patients with a dangerous visual impairment. Proofs of the physicians having given this warning could be a brief note in the medical record such as: "warned against driving".

In Denmark the National Board of Health (Sundhedsstyrelsen 1981) has stressed that breaking the 12th section of the Danish Practice of Medicine Act can lead to penalty. As proofs, notes in the medical records are recommended.

1.2.2. The Danish situation in a historical perspective, including recent EU legislation

The first official report on the legislative problems in relation to visual needs in car driving is an application from the Danish Ophthalmological Society to the Ministry of Justice (D.O.S. 1909). Referring to "La Societé d'Ophtalmologie de Paris", the Society recommended:

- Visual fields should be normal in both eyes.
- Requirements for visual acuity without corrections should be at least half on one eye and a quarter on the other eye.
- Because of changes in vision with increasing age, investigations should take place within certain yearly intervals.

These basic recommendations for visual acuity and investigations of car drivers were not far from the requirements for sailors (Stadfeldt, 1906).

The Minister replied that on the basis of the current experiences such investigations of the drivers' visual capacity could not be required (Bendtzen & Høgsbro 1909), at least for the time being.

This is easier to comprehend, when one considers the fact that in Denmark at that time there were very few vehicles.

Table 1.2 Registered horse and motor vehicles in Copenhagen 1903 -1939 (Ahlmann-Olsen 1942).

YEAR:	INHABITANTS:	TRAMS: HORSE	TRAMS: El	BUS: HORSE	BUS: MOTOR	HACKNEY-COACH HORSE:	HACKNEY-COACH MOTOR:	TAXI: HORSE:	TAXI: MOTOR:	MOTOR LORRIES & VANS:	MOTOR-CYCLES:	PRIVATE MOTOR CARS:	MOTOR VEHICLES SUM:	INHABITANTS PER MOTOR VEHICLE:
1903:	412.100	19	296	34	-	76	-	428	2	-	20	35	108	3815
1909:	447.500	4	325	32	-	27	-	236	176	23	383	96	678	660
1919:	542.600	-	426	-	13	26	3	24	426	1863	2412	2678	7392	73
1929:	610.900	-	411	-	59	-	20	1	1398	5118	4751	8671	19405	31
1939:	698.805	-	454	-	89	-	2	-	998	7082	6658	5565	30402	30

Table 1.2 shows the traffic in Copenhagen from 1903, when the first Danish automobile was registered, up to World War II (Ahlmann-Olsen, 1942).

However, already on June 1, 1910, the first Danish law regarding general health requirements for motor drivers was passed. The visual requirements for the driver were vaguely expressed in terms like "He is in possession of the requisite ability of vision" - without any further specifications (Zahle, 1910). These were defined half a year later by the National Board of Health like this: "Visual acuity with corrections should be at least 6/12 in one eye and at least 6/24 in the second eye. Visual field tested by hand should be normal" (Sundhedsstyrelsen 1910).

Three years later it was stated that the maximum interval before requiring a new medical certificate for a driver's license was 5 years (Bülow, 1913).

From the owners of automobiles the question was raised whether *one-eyed persons* could have a driver's license. After a discussions in the Danish Ophthalmological Society (Schou, 1917), it was recommended that one-eyed persons should not be allowed to drive a motor vehicle. - The argument was the risk of getting foreign bodies into the remaining eye. In the same discussion an upper limit for myopia (- 4.0 D) was recommended by the Society.

The National Board of Health (Sundhedsstyrelsen 1919) confirmed that vision with correction should be at least 6/12 on one eye and at least 6/24 on the other eye. A normal visual field, tested by hand, and absence of hemeralopia (night blindness) were further required.

The National Board of Health received many applications for a driver's license from persons with various handicaps. In 1923 (Sundhedsstyrelsen) it was recommended (as a guide) that one-eyed persons could obtain a driver's license on the following conditions: The applicant should have been one-eyed for at least half a year and the other eye should be without diseases or visual field defects. Visual acuity should be at least 6/12 without correction.

Nine years later this was confirmed and tightened up by the Ministry of Justice (Justitsministeriet 1932). The visual acuity of the remaining eye should be 6/9 or better *without correction*. This exception for one eyed drivers, however, was not allowed for drivers with a license for occupational transport of persons.

Not until 1950 was this legislation for the visual needs of the remaining eye changed. Then it was requested that this eye should be healthy, visual acuity should not be less than 6/9 *without or with correction* and the condition should have been stationary for at least half a year (Justitsministeriet 1950). Still, for professional transport of persons, it was not allowed to drive with one eye only.

In 1966 the Danish law concerning intervals for health controls was changed (Folketingsdebat 1966 a).

With reference to Sweden, Western Germany, and France it was proposed to change the rules so that the first mandatory health control after the primary investigation was postponed to the age of 70 for private drivers instead of once every five years. The argument was primarily economically based (Folketingsdebat 1966 b). No more than 2 per one thousand of the candidates for a renewal of the driver's license had been met with a refusal, according to prevailing rules.

The Executive Committee of the Danish Medical Association had warned against such an extension of the health investigation intervals. Some debate took place in the Danish Medical Journal (Christiansen, 1966 and Weber, 1966), and the co-founders of the Danish Society of Traffic Medicine (Dalgaard, personal communication) as well as the Danish Ophthalmological Society (Westerlund 1966) found the change inadvisable.

The Danish National Board of Health was asked, and responded (Folketingsdebat, 1966 a) that a reform in the direction of intervals of 10 years or more between health controls could be re-commended under the following conditions:

1) No acceptance of change in examination procedure the first time.

2) Only drivers with a "blank health certificate" at the first health control were included in the change of law, and

3) drivers with a license for occupational transport were not included in the change (occupational transport was defined as occupational transport of persons).

Furthermore, the 12th section in the Danish Practice of Medicine Act was emphasized (Folketingsdebat 1966 a) together with the 15th section of the Road Traffic Act, stating that only drivers being able to drive in a safe way are allowed to drive.

The Danish Liberal and Social Liberal Party proposed an age limit of 60 instead of 70 years, but they were outvoted. Important, maybe decisive in the debate (Folketingsdebat 1966 b), was a Swedish investigation (Herner et al. 1966) in which 44,255 registered accidents from Western Sweden were analysed. Of these only 41 (0.9‰) were found to be caused by *sudden* illness of the driver of the motor vehicle, and only 19 were estimated as preventable by previous medical examination (chronic medical conditions, including impaired vision of the involved partners, could not be estimated from this investigation).

Another important liberalization was the allowance for one-eyed drivers to drive a taxi. Cases concerning such applicants for bus driving licenses should be put to the National Board of Health. The law was signed on June 8, 1966 (Nielsen 1966). It was adjusted in 1979 with no changes to the visual requirements for drivers. However, from 1967, no clear recommendation was given concerning the accepted time interval of a temporary driving ban for a sudden one-eyed condition. Today, such an interval is individually estimated: it should have "existed for sufficiently long time to allow adaptation" (Rosenberg and Goldschmidt, 1976). It can be concluded, as a kind of paradox, that until 1996, the legislation concerning visual ability and the re-testing of the driver's vision in Denmark have been liberalized during a period in which traffic intensity has increased significantly (fig 1.6).

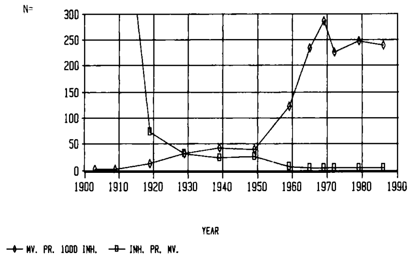

Fig. 1.6. *Development of traffic density 1903 -1985, Copenhagen (based on information from the Danish Statistical Department) Motor vehicles per 1000 Inh. , Inhabitants per MV (K.E. Alsbirk, 1999).*

At the meeting of the *Danish Society of Traffic Medicine* (1979) it was concluded and recommended that:

1. The term "*occupational drivers"* should include all drivers of heavy vehicles, lorries etc. > 3500 kilos. These drivers were proposed to be re-tested every 5th year like drivers of occupational transport of persons.

2. The visual test for young drivers from 18 to 20 years of age could be followed by a solemn declaration and should not necessarily be performed by a physician.

3. Referring to the visual changes and the possibility of diseases it was proposed that all holders of a driver's license should undergo a medical examination at 50 to 55 years of age and after then every 5th year, motivated mainly because of the need of vision control.

Latest changes (1996).

In the *European Union (the EU),* of which Denmark is a member, a more uniform legislation concerning a driver's health condition has been approved. The primary proposals (Rådet for de Europæiske Fælles-skaber 1980) have been revised, and the final changes (De Europæiske Fællesskabers Tidende, 1991, Færdselsstyrelsen, 1997, Trafik-

ministeriet, 1997) were implemented in Denmark on July 1st, 1996:
As far as the *visual limits* are concerned the proposals concern two main groups of drivers:
Group I drivers: M.C. and cars < 3500 kilo: (class A+B).
Group II drivers: Cars, lorries, busses, and long vehicles > 3500 kilos (class C+D+E), drivers of category B with commercial passenger services.

Re. group I: Static visual acuity with correction should be ≥ 0.5 (until 1989, ≥ 0.6 was proposed) when using both eyes simultaneously. Visual field shall exceed 120 degrees horizontally.

For *one-eyed drivers*, meaning visual acuity below 0.1, or a total loss of visual function in one eye, or use of only one eye (e.g. in the case of diplopia), the remaining eye must have a visual acuity of at least 0.6 (or 3 of 4 signs in 6/9 Snellen line), if necessary with corrective lenses. A consultant medical authority must certify that this condition has existed for a sufficiently long period to allow adaptation. The horizontal visual field must be unrestricted. The driving license will be valid until age 75. Applicants for a first-time license or drivers aged > 75 must undergo periodical medical examinations as may be prescribed by national legislation. In Denmark at age 70, at age 75 and thereafter with two-year intervals. From age 80 examination is required with one-year intervals.

Re. group II: Applicants must have binocular vision with a visual acuity (corrected) of at least 0.8 (or all signs in the 6/9 Snellen line and at least 2 in the 6/6 line) in the better eye and at least 0.5 in the worse eye. The uncorrected visual acuity shall exceed 0.05. The minimum acuity (0.8/0.5) must be achieved either by means of glasses ≤ 8 D or with the aid of contact lenses or intraocular lenses. Visual acuity without optical correction (glasses or contact lenses) must exceed 6/120 (0.05) on each eye. The correction should be well tolerated. Defective binocular visual field or diplopia will not be accepted. The drivers must undergo periodic examinations as may be prescribed by national laws. For drivers with *commercial transport of persons*, a drivers licence is valid for a period of 5 years. For *truck drivers*, the license is valid until 50 year of age, and thereafter for 5 years. (For those with such a license older than from March 11th 1997, this is still valid until age 70).

Thus for group II a radical change took place since a good vision is now required in *both* eyes. Functionally *one-eyed individuals* will not be allowed a driver's license for occupational transport of persons in the future. *Provisional rules* for one-eyed holders of such licenses are as follows: One eyed bus-drivers can not have their group II license renewed. For taxi licences or driving school teacher licenses from before July 1st 1996, however, such drivers may continue with visual demands as for group I.

The requirements for group II drivers have been debated in the European Commission. At a workshop in Brussels 1997 and -98, it was decided to recommend a change of Annex III point 6.3 of Directive 91/438/EEC of 29 July 1991 in the following way: As long as the uncorrected visual acuity of both eyes is at least 0.05, a visual acuity of 0.8 binocularly should be sufficient. The field of vision has to be normal (CIECA, 1999).

Intraocular lenses will not be considered as corrective lenses. This is also the case concerning previous *refractive surgery* for ametropia or astigmatism.

1.3. Literature review of epidemiological aspects

1.3.1. Traffic accident risks and general diseases

The relationship between medical conditions and traffic accident risks has been studied by several authors. In this context it is important to distinguish between *acute* and *chronic* medical conditions, the latter group including visual impairment. Norman (1960) found that the assessment of fitness to drive may be difficult in the case of people who have multiple disabilities, but in general the effects of such disabilities and of aging are additive.

1.3.1.1. Acute medical conditions

Herner, Smedbys and Ysander (1966), in a registration survey from Gothenburg, Sweden, found that among 44,255 police and hospital registered accidents, only 41 (1 ‰) were definitely or probably caused by a sudden illness of the driver. Epilepsy (12), myocardial infarction (7), and loss of consciousness (12) were classified as the most important. Three were due to diabetic hypoglycaemia. In only 19 of the 41 cases (1/2 ‰) previous medical examinations were assumed to have indicated unfit drivers. This survey played a very central role in the reform of the Danish law in 1966 concerning the intervals of medical examination of drivers, cf. above (Folketingsdebat 1966 b). The aspects of chronic medical conditions, including vision, were not studied in this survey. The results concerning acute medical conditions in relation to traffic accident risks have been confirmed by Naughton, Pepler, and Waller (1985), indicating a very low traffic accident risk caused by acute medical conditions.

1.3.1.2. Chronic medical conditions

Waller (1965), in a comprehensive epidemiological survey with control groups, compared 2672 individuals with chronic medical conditions and 922 controls. On the average, drivers with diabetes, epilepsy, cardiovascular disorders, alcoholism and mental illnesses were involved in twice as many accidents as the controls per 1 million miles of driving (accident rate). (All the differences were significant at the 1%. level). In a data register survey comparing 39,242 medically restricted drivers with 1.6 million licensed Washington drivers, Crancer and Mc Murrey (1968) found that patients with diabetes, fainting and epilepsy had small but significantly higher accident rates than a control group. Persons with special license registration due to visual deterioration (307) had the same accident rates as the age/sex matched control groups. In a study in which a total of 1440 drivers in four register investigations were compared to 1440 controls, Ysander (1970) found that "drivers with chronic diseases do not appear to constitute an increased risk in traffic compared to a control group of drivers, identical with respect to sex, age, annual driving distance and driving license period". -This may be due to the annual medical check-up of elderly patients in Sweden (author's comment). In a Danish autopsy study of 229 traffic killed car drivers, Dalgaard (1977) found that among 189 drivers < 70 years of age, 6.2% had traffic relevant diseases including < 1% with known, registered visual problems. Among 40 drivers aged ≥ 70, 31 had traffic relevant diseases, 12 of whom (30%) were registered as weak sighted.

In an epidemiological study of 1768 woman aged 71 years or older, 62% were current drivers while 19% had stopped driving. Medical conditions and co-morbidity influenced the driving patterns (Forrest et al, 1997).

1.3.1.3. Diabetes

Hartmann (1964) investigated diabetic drivers. As opposed to Ysander (1970), he found that "the accident potential of diabetic drivers is distinctly raised above the normal", mostly caused by the obviously poor general physical condition of the patients. Campbell and Ellis (1969) found that diabetic drivers had an increased traffic accident risk by a factor 1.7 compared to an age matched control group. The frequency of accident and major conviction repeaters appeared to be three times the proportion found in the control group. De Klerk and Armstrong (1983) studied 72 admissions after road crashes among 8623 diabetic patients admitted to hospital in Western Australia. Although no overall difference was found, male diabetic road users < 55 years were significantly over-represented by a factor 1.7 ($p < 0.01$). Out of these the male drivers (N=17) were over-represented by a factor 2.8 ($p < 0.01$) and the male pedestrians x 4.7 ($p < 0.01$). Dalgaard and Arnold (1985) studied 159 medico-legal autopsies in diabetic patients. Of these 41 died as a result of traffic accidents. Ten were drivers of motor vehicles and 3 of the accidents were estimated as being possibly induced by hypoglycemia. Data concerning the drivers' vision and retinal status were only sparsely available.

Dionne et al. (1995) in a Canadian study analysed truck drivers' accident risks. After correction for age and driving experience, diabetic drivers had more accidents than drivers in good health. On the other hand McGwin et al. (1999) performed a case-control study among 249 at-fault crash-involved drivers, 454 non-crash-involved drivers and 198 not-at-fault crash- involved drivers. They did not find evidence that older diabetic drivers, aged 65 and above are at increased risk for automobile crashes. Hypoglycaemia and visual impairment are the principal problems in relation to driving among diabetic patients (Frier, 1994). Hypoglycaemia in itself causes no detectable impairment of visual acuity, but a highly significant deterioration in the speed of visual information pro-cessing and in contrast-sensitivity (McCrimmon et al, 1996). Loss of visual fields from retinal ischaemia and from pan-photocoagula-tion may influence the visual field significantly (Pearson et al, 1998) and give problems with dark adaptation and, as a consequence, driving at night. Diabetic cataract like other cataracts is associated with significant headlight glare.

- In conclusion, it seems motivated that diabetic patients need special monitoring for keeping their drivers license.

1.3.1.4. Neurological diseases

Taylor (1983) reported that hypogly-caemic diabetic insulin dependent patients were responsible for 17% of 1300 police reported accidents in which the driver collapsed at the wheel. In 38% a witnessed grand mal seizure occurred and in 23% blackouts. All kinds of heart conditions accounted for 10% and strokes for 8%. Twelve percent of the accidents were due to a first time seizure. Among the others, 70% had not declared their condition in relation to their driving license! With respect to epilepsy, Juul-Jensen (1963) found that among 969 adult patients with convulsions a driver's license was of importance in 175 cases (18.1%). The license had been revoked in 86 patients, but the revocation in Denmark was found to be rather arbitrary, and many were still car drivers even though they still had seizures. Ysander (1966) found that 84 physically disabled drivers did not cause increased hazards in traffic compared to a control group, with the exception of drivers with a loss of function to the right arm and leg. Juhl (1984) found that neurological disorders were the most frequent reason for reporting a driver to the National Health Service, followed by visual problems. Lings (1987) studied 193 patients with neurological conditions (Parkinson's disease (28), paraparesis inferior (52), and hemi-paresis (67 right-sided and 46 left-sided)). These patients were examined by means of a mock car. Although the method was rather low in sensitivity, it was possible to show that patients with Parkinson's disease had significantly reduced abilities in strength and speed of movements, reaction time and, most importantly, had more incorrect reactions. Patients with paraparesis inferior reacted more slowly and those with apoplexia cere-bri coped far worse than the controls in almost all functions. Very often they completely failed to react to given signals. Jensen & Lings (1987), in an investigation of 105 patients with cerebral haemorrhage and hemiparesis, found that less than 10 % of the patients were fit for driving. This was estimated on the basis of neuropsychological investigations and by the use of a mock car. Patients with a right hemispheric lesion were more disabled, had lower spatial perception and had more problems in realizing their own handicap than those with a left hemispheric lesion.

- Thus patients with various neurologic conditions, like diabetic patients, need special attention in relation to evaluating their traffic ability.

In "Medical Aspects of Fitness to drive", Raffle (1985) sums up that "the available evidence suggests that medical conditions of drivers, with the exception of the effects of alcohol, are not an important factor in road accidents causing injury to other road users. Omitting temporary factors such as tiredness and emotional factors, medical conditions are a major cause in substantially less than 1% (probably 1-2 per thousand) of such accidents". However, he adds: "This should not be regarded as ground for complacency".

Conclusion: Although it is universally known that "the human factor" is by far the most dominant in the aetiology of traffic accidents (Rumar, 1986), acute and chronic medical conditions only seem to constitute a minor part of the problem.

However, only a few of the studies on chronic medical conditions, including diabetes, have been focused on the visual ability. This might be due to the problems in systematically collecting visual data in relation to traffic accidents.

1.3.2. The importance of age (with a special view on vision aspects).

Apart from the visual acuity deterioration resulting from age and general diseases, *the ageing process itself* acts as a confounding factor in the

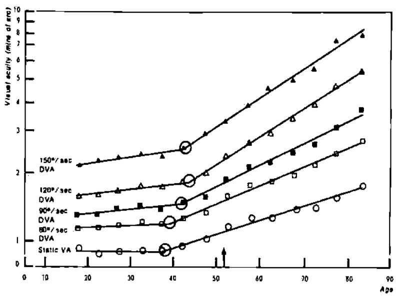

Fig. 1.7. *The variation of static (lower curve), and dynamic visual acuity (DVA) with age (California data, Hills 1985).*

study of the epidemiology of traffic ability. No individual theory satisfactorily explains the biological mechanisms of ageing, which is a complex phenomenon (Merry, 1986). Hills (1975) found that various aspects of drivers' visual performance do change with age. From age 45 static, and especially dynamic visual acuity decreases (fig 1.7.).

As documented in chapter 1.1, the number and proportion of drivers >65 years will increase in the next decades.

In Sweden it is estimated that the number of these individuals having a car and a driving license will be twice as large in the year 2003 in comparison with the year 1978 (Holmberg 1985).

In a registration survey Ysander & Herner (1976) mailed 406 drivers > 60 and 126 drivers around 40 years of age questionnaire. Approx. 67 % responded. Among drivers between age 65 and 69, 24% had voluntarily given up driving, and after 75 years of age 51% had stopped. Elderly drivers avoided driving in darkness, on icy roads and in unknown cities, and their annual distance of driving was shorter than in the younger control group. No significant difference was found between the two groups in a three year accident - and offence rate, based on data from the licensing authorities. Mourant & Mourant (1979) by visual laboratory testing examined 13 elderly drivers (60-70 y.) and compared them to 10 young drivers (21-29 y.). The elderly drivers required more time to acquire the minimum information needed for vehicle control, revealed longer eye travelling distances, longer "eye open times" and visual search times than the younger drivers. On the other hand, they drove more slowly when night driving, which altogether indicated lower basic capacities but also more cautious driving than the controls. Brühning & Harms (1983) found that elderly car-drivers had a higher accident risk than the middle-aged. This tendency was even more pronounced in night accidents and in bad visibility caused by the weather. The reaction decreases - and the reduction of vision in darkness as well as susceptibility to glare in bright light increase with age (Ruth 1986).

Häkkinnen (1984) investigated 546 randomly selected elderly persons (age >65) in Finland. Of 370 women 4% of were still active drivers versus 38% out 176 males. The number of active drivers (males and females) declined with age, being 5% after age 75. In standard light conditions 98% of the drivers had an optimally corrected visual acuity at or above the level of minimum visual requirement in Finland (0.8 or 0.7 in the better eye/ 0.3 in the worse eye). Ten per cent of the drivers did not fulfil the license requirements for difficult lightning conditions, 15% experienced subjective symptoms of glare, and 9% avoided night driving.

Brainin (1980) found more accidents per mile driven in drivers around 65 years and older than in drivers aged 25 to 44 years. Failure to yield right of way and to obey signs and signals, along with turning at intersections were particular problems for these drivers. As a consequence he proposed a special education programme for elderly drivers. Hvoslef (1986) showed that from age 65 years the traffic accident rate is almost doubled and it increases further with age compared to that of middle aged drivers (Fig. 1.8), but not compared to the level of the young drivers!

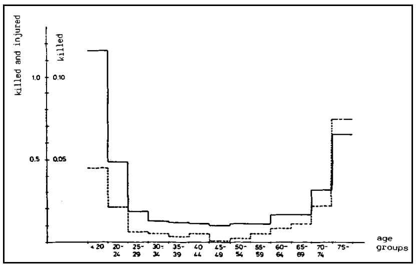

Fig. 1.8. *Killed and injured drivers per 1 million km in different age groups (quoted by Hvoslef 1986).*
——— = killed and injured
-------- = killed.

The same trends have been found in a Swedish (Wiktorsson 1984) and a Danish investigation (Danmarks Statistik 1982), which together with many other international investigations (Williams, 1989, review by Graca, 1986) makes these findings general.

In a regional study in Sweden, Wiktorsson (1985) found a significant over- representation of drivers >65 in: a) turn-off manoeuvre accidents ($p< 0.001$), b) accidents in which the drivers failed to yield the right of way ($p<-0.001$), and c) red light accidents in daylight ($p< 0.05$), compared to a control group of middle aged drivers aged 35 to 54. Visual functions in these manoeuvres and age groups might have been of relevance but they were not investigated in the study.

Ball et al (1988) searched for a more relevant test than visual field in evaluating drivers problems. The useful field of view (UFOV) is defined as the visual area in which information can be acquired within one eye fixation. This field is reduced in size as a cause of age. The method has later proved to be of increasing importance since the UFOV is significantly associated to crash involvement in car drivers cf. chapter 1.3.3.2.

Kline et al. (1992) interviewed 397 drivers aged 22-92. The visual problems increased with age in five different visual dimensions: unexpected vehicles, vehicle speed, dim displays, windshield problems, and sign reading. Several of these problems were related to types of vehicle-accidents more common among older drivers. Szlyk et al (1995) investigated 107 drivers in an interactive driving simulator study. Older drivers had poorer driving related skills measured with the simulator, which also was suggested in an earlier investigation (Szlyk et al, 1993), but they did not seem to have higher on-road accident rates than the younger group. Perryman et al. (1996) found fewer steering and eye-movement excursions but more frequent drifts across the centreline in elderly than in younger drivers. These drove faster and executed more breaking applications. The motorvehicle operational performance was related to reduced visual spatial-attenuation reduction and the useful field of view (UFOV) was associated with the normal ageing process. A restricted UFOV seems associated with age related effects of restricted head movements (Isler et al., 1997), which might be of importance in elderly drivers' involvement in intersection accidents.

Wiseman and Souder (1996) found that risk factors for elderly drivers are problems with vision and reaction time, intellectual impairment, a poor safety record, alcohol abuse, use of certain medications, poor attentional skills, impaired executive functions, and a family report of driving problems. Most of these factors can be identified with a careful history, physical examination, in-office tests of cognitive function and alcohol use, and an interview with family members.

Besides, Johansson (1997), cf. chapter 1.3.3.2, in a Swedish study found that cognitive impairment seems to be a very important risk factor for older drivers in road traffic accidents. In Sweden no routine health controls of elderly drivers is mandatory (Vägverket, 1998).

A multicentre study in the Nordic countries comprised 2039 traffic accidents with human injury, involving drivers aged $\geq$ 65 (Nordisk Trafiksikkerheds Råd, 1990). It was concluded that the layout of the physical environments as well as the older drivers' functional ability contribute to the accidents. No conclusions could be made on the role of drivers' vision, since such information was missing. The need for future research in this field was stressed. Also Klein (1991) searched for more epidemiological research on risk for traffic safety in patients with age-related eye diseases.

In the report "Traffic safety of elderly road users" (OECD, 1985), the over-representation of elderly road users has been documented (fig. 1.9 and 1.10). But it was emphasised that "18 to 20-year-old drivers are responsible for 23% of the evaluated accidents as opposed to the 4% for which the 65 to 84-year-old drivers are considered responsible". Elderly drivers have more accidents per mileage compared to middle aged drivers; the average consequences of elderly drivers' accidents are more serious and the same drivers are more often legally responsible for the accidents. These facts were more or less confirmed in a Finish investigation (Hakamies-Blomquist, 1990) in which 144 fatal accidents with drivers aged $\geq$ 65 were compared to corresponding accidents with drivers aged 26-40. Young male drivers <26 years, however, were again seen as a far more dangerous problem for traffic safety.

In a later Finnish study on insurance data, Mannan and Ernvall (1996) found that elderly drivers aged 75 and above had a factor 5 (men) to 10 (women) increased accident risk compared to drivers aged 60 to 64. This surplus was even more pronounced in crossroads accidents.

Freemann (1972) warned against too hard restrictions on the driving of the elderly drivers. He found that drivers below age 35 were responsible for 60% of motor vehicle fatalities. As he stated: "There is insufficient evidence to incriminate the elderly as driving hazards or to assign responsibility to them for accidents out of proportions to their licensed numbers".

Realizing that the problem is primarily the young and inexperienced drivers, Laberge-Nodeau et al.(1983) have studied the effect of instituting intensive education among high school pupils. Unfortunately, such a program has failed to show significant effect on traffic fatalities in the young age group of drivers. Renwick et al.(1982) found a four fold increase in the motor vehicle accident death rate in the age groups 15 to 19 and found that alcohol was a major contributory factor.

At the 4th Scandinavian Congress on Traffic Medicine, Rumar (1986 a) concluded that the handicaps of the elderly road users are of a physiological and cognitive character. These limitations are partly compensated for, mainly by increased caution. The elderly driver more often chooses: 1) another mode of transportation than driving, 2) a longer and less difficult route, 3) to drive in low

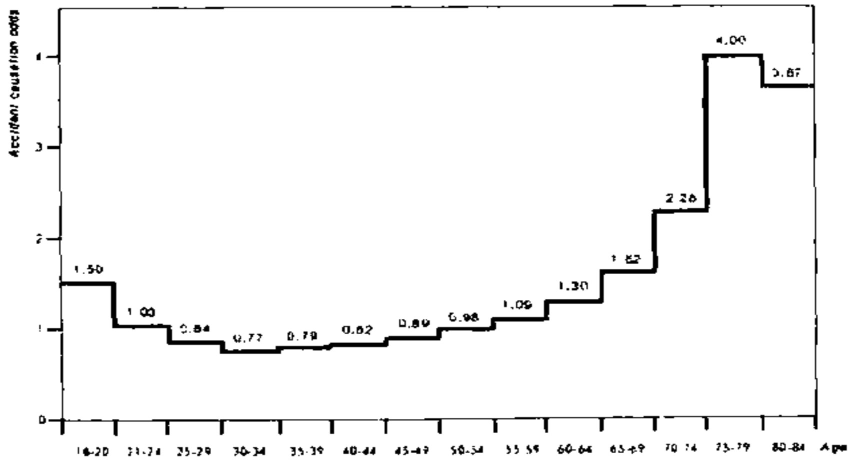

Fig. 1.9. Frequency of convictions for failing to give way according to age of driver (1971-1975 data) (OECD report 1985 p.102).

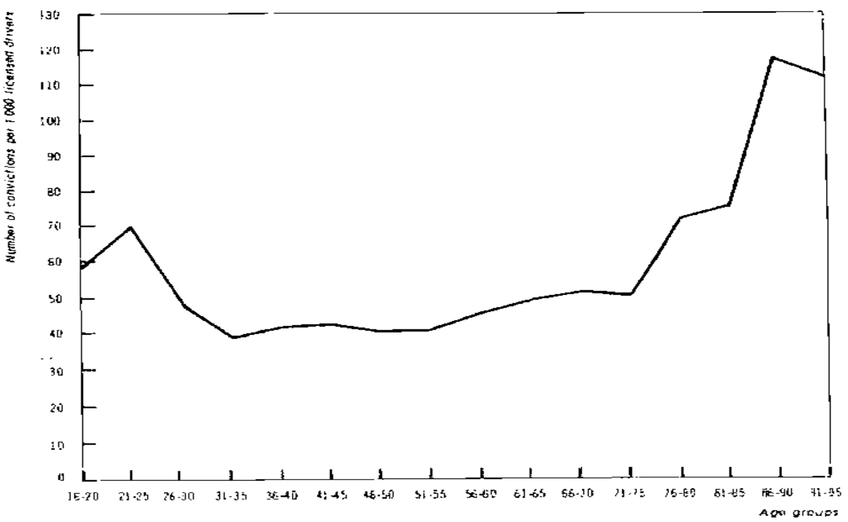

Fig. 1.10.*Causation odds for car into car injury accidents according to age of driver (OECD report 1985 p.102).*

traffic periods, or 4) to lower his speed. The elderly driver is especially handicapped in unfamiliar situations and even more so in dense traffic and night traffic. New complex and dynamic incidents which require immediate decision and action seem to cause most problems. However, in familiar situations, which can be predicted, his reactions are often faster than those of a young driver.

As a consequence of an increasing worldwide population of elderly drivers, efforts have been made to identify alternative vision test procedures and new fields of research have been addressed (Shinar and Schieber 1991). Drivers' vision and visual assessment have been identified as one of six major categories of high priority research and need for developments (Schieber 1994).

Conclusion

The young and, to a lesser degree, the elderly drivers are dominant in traffic accidents compared to the middle aged group. The reasons are totally different: In the young group alcohol, lack of driving experience, psychology etc. are main factors and this group generally possesses brilliant health parameters, including visual ability. As opposed to this, in the elderly group of drivers, the health factors dominate in relation to traffic accidents. Important factors seem to be: reaction time, increasing visual problems with age, and over-representation of being involved in complicated intersection accidents.

Therefore, when analysing visual problems in relation to traffic accidents, it is of the utmost importance to adjust for the age factor.

1.3.3. Visual factors and road safety

As Rumar (1986a) puts it: "Vision is no doubt the most important information input channel for a driver. Most visual functions decline considerably from the age of about 45". Byrnes (1962) estimated that 90% of the sensory information reaching the driver's brain is visual. Admitting that the information relevant to driving predominantly is visual, Sivak (1996), however, has found no evidence for this precise percentage in the literature.

1.3.3.1. Reviews.

The literature on the relationship between drivers' visual performance and traffic safety is comprehensive and has been reviewed by a number of authors:

Smeed (1953), Miles (1956), Goldstein (1964), Norman (1962), Richard (1963), Burg (1968), Gramberg-Danielsen (1967), Henderson & Burg (1974), Levitt (1975), Shinar (1977), Glad (1977), Hills (1980), Davison (1978), Hedin 1980), Hales (1982), Humphriss (1983), North (1985, -87 and -93), Harms (1986), Taylor (1987 and 1993), Keltner & Johnson (1987 and 1992), Lewandowski (1995), Shipp &

Penchansky (1995), Wilkinson ME (1998) and van Rijn & Völker-Dieben (meta- analysis, 1999).

Davison (1978) reviewed 39 studies concerning the static visual acuity and driving ability. In 19 studies he found a "weak" positive association, in 3 studies the association was "strong", and in 17 studies no relationship was found. He concludes that "the evidence would suggest that the association between visual acuity and accidents is statistically significant for older rather than for younger drivers and that drivers with a particularly poor recent accident record are more likely to have poor vision". Further: "Those studies using large sample sizes (over 2000 drivers) have, without exception, produced relatively weak positive associations (despite very high levels of statistical significance in some cases) and usually only for certain subsamples of drivers (older and/or "accident repeater" drivers)".

Goldstein (1964), who reviewed 69 research reports on every aspect of human factors in driving between 1938 and 1956, concluded that "apparently, not many drivers become involved in accidents because of visual deficiencies per se." *Humphriss* (1983) divided the literature in 1) earlier, more qualitative research reports giving an impression of a relationship between subnormal vision and road accidents, and 2) recent, more quantitative studies with rather mixed results.

Henderson and Burg (l974) performed an intensive literature review on 18 different visual parameters and found a great need for additional research in most areas. Based on their review they found the following visual parameters important for driving: Static visual acuity, dynamic visual acuity, visual field, glare sensitivity, movements in depth, angular move-ments, saccadic pursuit, and steady fixations as well as overall visual performances at low levels of illumination. Colour vision was not seen to be important for driving.

The authors found that one reason for the lack of relationship between visual ability and accidents could be that all the persons tested had a driver's license, and therefore generally a good visual ability. This might also be due to frequent examinations in most USA states (author's comment). The same bias has been suggested by *Burg* (1968), *Gramberg-Danielsen* (1967), and *Hedin* (1980). If more persons with bad vision had been tested, a closer association might have been found. Drivers with good and medium visual ability showed the same accident rate. Not until the vision was very poor did the accident rate increase steeply (cf. fig 1.11).

Generally, most of the reviews support the statement by *Taylor* (1987): "It is true that something like 95% of the sensory input into the brain in the act of driving or riding comes from vision. Carefully constructed scientific studies have, however, failed to show that poor vision is an important cause of road traffic accidents". *Van Rijn et al. (1999)* in a meta analysis concludes that static visual acuity is a well evaluated test, but it has a low criterion validity with a relative risk of 1.3 [1.19 - 1.45]. “Alternative” tests, such as Useful Field of View, are promising and may display relative risk much higher than classical Snellen acuity and visual field tests. However evaluation until now has been based upon relatively small samples and has to be confirmed.

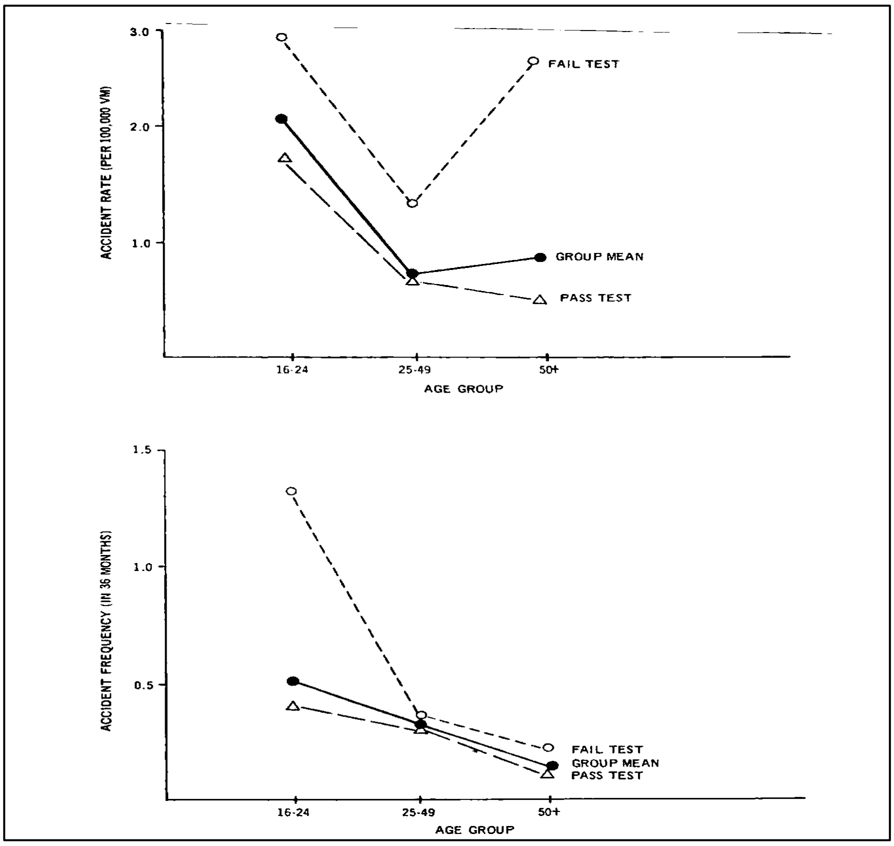

Fig. 1.11. *Effects on accident statistics using the Central Angular Movement Threshold Test as a screening tool. Cut-off score = 32 minutes of arc/second (Henderson and Burg, 1974). VM = Vehicle Miles.*

Some of the historically most important studies and other relevant studies have been listed in table 1.3.

A more detailed summary of these studies have been published in chronologically order. Since the type and conclusions of the studies differ, it has been attempted to focus on the design in each study. The individual studies are mentioned in chronological sequence.

1.3.3.2. Separate studies

Visual factors and road safety, a literature review.

Lauer et al. (1939) examined vision and driving records in 1014 commercial drivers. Age was the chief influencing factor. Higher visual acuity was found to be related to fewer accidents. High astigmatism tended to be related to accidents. No marked relations was found between accidents and colour blindness.

Brody (1941), in a study of accident repeaters, found that 4 out of 26 (16%) had an acuity of less than 20/30 in the better eye, and 20/50 in the worse eye. In a control group of non-accident repeaters, 2 out of 28 (7%) were below the limit. This difference was not significant.

Fletcher (1949) in an investigation from 1939 found that in 200 drivers with good driving records, 1% failed the visual tests, whereas in 321 drivers with bad records, (i.e. involved in fatal or at least 3 major injury accidents) statistically significant more drivers (5%) failed the visual tests. In a later study, the same author (*Fletcher* 1947) found that in one third of 103 fatal crossroads accidents, one of the drivers had a unilateral visual deficiency (e.g. v.a. ≤ 20/40). In 90% of these, the accident happened on the same side as the impaired vision. In a comparative study of personal characteristics in 2 groups of 100 accident repeaters and 100 accident free drivers, the *ENO- foundation* (1948) found that binocular visual acuity, the depth perception, and ocular muscle balance were better in the accident free group. No difference could be demonstrated between the two groups with respect to visual fields or the rate of dark adaptation.

Davey (1956) demonstrated that in experimental conditions simple driving tasks can be performed safely when the vision is considerably blurred, but if the driver is required to respond to traffic signs, the standard of driving deteriorates rapidly at the 0.33-0.25 level of blur.

Sachsenweger and Nothaass (1961) analysed 4011 traffic accidents in Leipzig. Out of 110 car and tram drivers to blame, 7 did not fulfill the visual legal demands (6.4%). One had constricted visual field caused by glaucoma. Only in this patient a causal association between vision and the traffic accident was presumed.

Hager (1963), in a survey from Rostock, examined 342 blamable drivers involved in traffic accidents and compared them to 2236 control persons registered in the city eye clinic. The author concludes that 1) a significant under-representation of drivers with legal visual functions was found in the accident group (68%) compared to the control group (81%), 2) in the accident group, functionally one eyed-drivers (worse eye below 0.1) were significantly over represented (13.7% versus 5.4%) as were 3) colour blind drivers (8.5% versus 4.6%), the difference being most pronounced among protanopes (3.5% in the accident group versus 1.1% in the control group). By simple chi-square-testing of the published tables, the differences were significant (p values between 0.05 and 0.001). No data exists concerning age and sex distribution. The study has been criticised by *Jahn* (1963) with respect to the method of selection of the two groups of drivers.

TABLE 1.3: Literature on vision and traffic ability (epidemiological aspects). (Alsbirk 1999).

Author:	Year:	Proband group, type of drivers:	N=	No of accid.:	Control group?	N =	Remarks:
Lauer et al.	1939	Commercial drivers	1014		(within)		v. screening
Brody	1941	Accident repeaters	26	132	Non accident repeaters	28	
Fletcher	1942	Drivers with poor driving records	321		Good driving records	200	
Fletcher	1948	Fatal crossroad accidents	103	103			
ENO-Foundation	1948	Accident repeaters	100		Accident free drivers	100	
Danielson	1957	Drivers	680		(within)		acc.hist.
Davey	1956	Drivers in experimental conditions	40				
Sachsenweger & Nothaass	1961	Blamable accident involved drivers	110	4011			
Hager	1963	"Guilty" accident involved drivers	342		Eye clinic driving pt.s	2236	
Cashell	1968	Accident involved drivers	50		Non-accident involved	30	v. screening
Gramberg-Danielsen	1966	Bus and tram conductors	1701	?	(within)		5. y.a.rates.
Burg	1967	Drivers license applicants	14215	5200	(within)		3. y.a.rates.
Keeney	1968	Multiple crash risk drivers	991		eye clinic driving pt.s	21000	
Heinsius	1969	Bus drivers	4135	348	(within)		
Gramberg-Danielsen	1971	Accident involved and drunk drivers	2649	1073	(control group)	728	
Liesmaa	1973	Dangerous drivers	167	-	(control group)	854	
Henderson & Burg	1973	Truck and bus drivers	236		(within)		3. y. a. rates
Henderson & Burg	1974	Car drivers	669		(within)		3. y. a. rates
von Heb-streit	1974	Blamable accident involved drivers	1921		(within*)		v. screening
Council & Allen	1974	Drivers license applicants	37372		(within)		
Shinar	1977	Car drivers	890		(within)		acc. hist.
Clayton	1976	Accident involved road users	348	210	(within)	110	tested
Hofstetter	1976	Volunteer driver screening	13786		(within)		1. y. a. freq.
Fishmann et al.	1981	Drivers with retinitis rigmentosa	42	32	family of patients	875	3. y. a. freq.
Davison	1980	"Garage study"	1368		(within)		v. screening
Backmann	1983	Occupational drivers	633				health survey
Johnson and Keltner	1983	D.l.applicants.v. field.	8767		(within)		3. y. a. rates.
Harms, Kröner, Danheim	1984	Drivers with illegal vision in private eye clinics (MC)	471		(within)		1 week MC.
von Hebenstreit	1984	Experienced occupational drivers	668	881	(within)		acc. hist.
Golding	1984	Accident involved drivers	2111		"road side study"	2073	v. screening
Davison	1985	"Road side study" (MC)	1000		(within)		3 + 10 y. a. h.
Quimby et al.	1986	Accident involved drivers	288		(within)		3 + 5. y. a. r.
Humphriss	1987	A. Drivers with illegal v.a.	666				v. screening
		B. Employed drivers	933				v. screening
		(Accident involved)	196		(not acc.involved)	*(170)*	v. screening
Rogers et al.	1987	Prof. drivers' licence applicants	16465		(within)		2 y. a. h.
Szlyk et. al	1992	Drivers with retinitis pigmentosa	21		matched in age/sex distr.	31	accident fr.
Gresset et al.	1994	Accident involved drivers	1440		(within- insurance records)	2636	accid. hist.
Mc Closkey	1994	Accident involved drivers aged ≥ 64	235		(optometrists records)	448	
Johansson	1997	Drivers guilty of crashes	23		Matched	37	v. screening
Lachenmayr	1998	Accident involved drivers	754		matched	250	v. screening
Owsley et al.	1998	Cohort study	294		matched (within)		UFOV 3.y. a..r.
Ivers et al.	1999	Cross-sectional study	2379				v. screening
Alsbirk	1999	Accident involved drivers	405	359	matched in age/sex distr.	138	v. screening

*) A= "Visual accidents", N= 975. B="Non visual accidents", N= 946. (See text)
Notes: MC = multi center study. UFOV = useful field of view . 3.y.a.r/ 3.y.a.h.= 3 year accident rates/history (see text).

Cashell (1966) compared 30 accident involved drivers with an age and driving experience matched control group of another 30 drivers. On this basis, no significant difference in visual impairment was found between the two groups.

Gramberg-Danielsen (1966) examined 1117 bus drivers and 584 tram conductors. Drivers with a vision between 0.66 and 0.75 on both eyes had the same accident rate as drivers with a full vision. The accident rates decreased with increasing age until age 55. In a later multi-centre survey, the same author (*Gramberg-Danielsen* 1971) studied the visual acuity of 1728 randomly selected drivers (road side study) and of 1576 drivers with their license withdrawn because of alcohol intoxication while driving. These two groups were compared to accident involved drivers with or without alcohol intoxication (N=1073). In the last two convicted groups, the tests were performed 6 months and one year after the actual episodes. In all three groups less than 1% had binocular visual acuity < 0.8 when tested. It was concluded that a relationship between visual acuity and accident involvement could not be proven.

In a study by *Burg* (1968), among 14,215 out of 17,500 volunteer California driver's license applicants, young drivers were found to have the highest accident and conviction rates followed by elderly drivers, compared to middle aged drivers having the lowest rates.

No difference was found between the two sexes. Among vision variables, dynamic visual acuity (DVA) was by far the factor that most consistently and closely correlated with driving records, followed by static acuity, field of vision and glare recovery. In a re-analysis 10 years later (*Hills and Burg*, 1977) an age stratification of the material was performed. From this re-analysis it was concluded that significant but weak associations were found between static and dynamic visual acuity versus accident rates among elderly drivers > 54. Furthermore, a good correlation was found between dynamic and static visual acuity.

Burg's and Hill's investigations are among the studies most often referred to. The accident records have been evaluated as being rather precise, obtained through the records of the insurance companies. The authors stated that for an individual driver, the accident prediction value of visual acuity tests remained very low.

It should be emphasized, however, that these investigations have been performed among volunteer driver's license applicants. An important aspect may be the fact that these findings may not directly reflect the visual performance *on the scene* in relation to the reported 5200 traffic accidents.

Keeney (1968 and 1974) in a risk driver re-examination study (N= 2,375,528) found pathological conditions which might constitute reduced driver capability about 20 times more frequently than on pre-license examinations. Out of the 2-3% drivers who had their license cancelled for medical reasons, only 3.8% were rejected because of visual defects. Among 991 multiple crash injury drivers, monocularity was found to be over-represented by a factor 4, and this group caused greater risks of driving failure from the impaired side.

In a survey of 4135 bus drivers involved in 348 traffic accidents, *Heinsius* (1969) found no significant difference in accident frequency (8-10.6%) in 3 different visual acuity groups. Age stratification analyses were not performed.

Liesmaa (1973) investigated drivers in Finland, selected from a police car at the road side. "Dangerous" drivers were stopped and their vision examined (N=167). Compared to a control group of 854 drivers, a highly significant ($p< 0.001$) increased frequency of drivers with visual acuity below the requirements and of functionally monocular drivers was found among the dangerous drivers.

Henderson and Burg (l973) examined 236 truck and bus drivers and found positive correlation between driving records and dynamic tests of visual perception, but not static visual acuity tests. In a later survey *(Henderson and Burg* l974), the authors tested visual performances in 669 licensed car drivers and compared these findings with the 3 year accident rates. Drivers with good and medium visual performances (= pass test group) had a similar 3 year accident rate. The small group of drivers, who failed the visual test, had poor driving records (cf. fig. 1.11). The differences between groups that failed or passed the test were greatest for the old age groups when comparing the accident rates as accidents per loo,ooo miles. With respect to the overall 3 year accident frequency, the impact of dynamic visual performance was seen to be much greater for the young drivers. On the basis of their analysis, the following visual parameters were found to be of importance to driving: static and dynamic acuity, perception or angular movement and movement in depth, useful visual field, ability to perceive under conditions of glare and/or low levels of illumination and, ability to detect events occurring in the visual environments rapidly and accurately.

Council and Allen (1974), in this driver's license applicant screening, examined 52.397 drivers by horizontal dynamic visual field testing. In only 4.2 per cent the horizontal visual field was less than 140°. Less tha 1% had a visual field $\leq 120°$ and less than 1 ‰ $\leq$ 90°. Only in two drivers (<0.05 ‰) the visual fields were below 50°. In general, drivers with limited visual fields did not seem to be over- represented in accidents, but those with limited fields had significantly more side impact collisions than the compared group ($p < 0.01$).

In an "on the scene" study of 210 accidents with 348 involved road users, *Clayton* (1976) obtained information on visual acuity in 110 (31.6%). Poor static acuity below 6/12 and incidence of visual defects in the causation of road accidents were found to be less than 5%. No information on the large group of non-responders was published.

Hofstetter (1976) analysed a material of 13.786 volunteer drivers, screened by 4 different visual test instruments in a multi-centre optometrist study. A proper age stratification was made for the analyses. The proportion of drivers involved in two or more accidents within the last 12 months was significantly higher ($p = 0.001$) among drivers with visual acuity below the lower quartile compared to drivers with visual acuity above the median score. No significant difference was found in the group of drivers with $\leq$ 1 accident within the last year.

Shinar (1977): In a vision screening of 890 car drivers, static visual acuity in different illuminations was found to be the methodologically most reliable test, whereas the tests most consistently related to accidents were: tests for dynamic visual acuity, static acuity under low levels of illumination (specifically associated with night time accidents), and central angular movements. From the literature review and from his results, the author recommended that periodic re-examinations of drivers below 40-50 of age should be eliminated and instead intensified in elderly drivers as well as in "problem drivers". Since the probability of detecting significant visual deficiencies in the young applicants is extremely small, he proposed that visual testing of beginner drivers possibly could be administered by the high school drivers' education programme.

Davison and Irving (1980) presented a "garage study" of 1368 drivers. In the complete material, 1% had binocular visual acuity below 6/12. Acuity was found to decline with age, 5% being below 6/12 in drivers aged 65 and above. Sixty-four percent of all drivers had within the previous three years participated in some form of eye test.

Fishmann et al. (1981) found that patients with retinitis pigmentosa were involved in significantly more traffic accidents during a 5-year period than a control group ($p = 0.02$). Especially female patients were over-represented.

In a health screening among 633 professional drivers between the age of 30 and 54, *Backman* (1983) found that 24% had defective distant vision using their usual correction. Nineteen had depth perception below the average, only 1% had defective colour vision and there were no notable limitations in the field of vision. Among 154 delivery drivers, 6% did not meet the demands for obtaining a driver's license.

Johnson & Keltner (1983) reported an incidence of visual field loss in 3.3% of car drivers below the age of 60 and 13% for those older than 65 years, estimated by the use of a Field Master automated visual field screener on 10,000 California volunteers (driver's license applicants). However, only 0.5% of the drivers had a hemianopic field defect or severe visual field destruction. Concerning the association between traffic accident rates and visual field defects the authors found that drivers with binocular visual field loss (N= 196) had accident and conviction rates twice as high as a matched control group ($p< 0.005$). On the other hand, drivers with monocular visual field loss had accidents and conviction rates equivalent ($p> 0.2$) to those of a control group.

Harms, Kröner & Dannheim (1984) conducted a multi-centre survey among 369 West-German ophthalmological practices. It was carried out during a period of one week, revealing 471 patients who drove their cars but did not fulfil the minimum legal requirements for diurnal visual acuity for driving. The median age was 62. In young drivers below 45 years correctable refractive errors were responsible for 85% of the faults. In drivers > age 64 loss of acuity was mainly due to opacities of the lens, which for the major part could not be corrected by spectacles (4% purely refractive errors, 82% cataract alone or in combination with other conditions). Of the drivers with inadequate visual acuity, 2/3 considered their vision to be "sufficient" or "good" for driving, younger drivers being more self-critical than older ones. Only 31% of these drivers, in spite of considering their acuity to be "insufficient", stopped driving at night on their own accord.

In a follow-up study *(Harms & Dietz 1986),* it was estimated that in West Germany at least 350,000 car drivers have insufficient visual acuity. Obligatory testing of visual acuity after traffic accidents was recommended. The duration of inadequate vision for driving varied from 15 to 42 months. Drivers with refractive errors was the largest group, and mainly below 65 years of age (96%). On this basis repeated tests of vision were also recommended for young drivers.

von Hebenstreit (1985) in a study from 1974 tested a random sample of 1921 blameable drivers involved in traffic accidents. These drivers were divided in: A: 975 individuals involved in accidents in which vision might be of importance = "visual accidents" and B: 946 car drivers involved in accidents in which vision seems unimportant = "non- visual accidents". In group A 15.2% had reduced daylight visual acuity (i.e. <0.7) vs. 2.6% in group B (Odds ratio = 6.6, $p< 10^{-6}$, authors calculations).

Harms (1985) has further analysed von Hebenstreits material and concluded that by generalization among 1.1 million blameable drivers in West Germany in 1982, 98,000 had illegal visual acuity (8.9%). He further concluded that the proportion of drivers to blame with visual disturbances was equal to the proportion of drivers being under the influence of alcohol.

von Hebenstreit (1984) later studied 663 professional truck or bus drivers in Bayern with more than 10 years of driving experience. Drivers with visual acuity below 0.7 were more frequently involved in traffic accidents compared to their colleagues with photoptic vision above that level. (v. a. <0.7: 2.52 accidents per driver, and v. a. $\geq$ 0.7: 1.48 accidents per driver; $p< 0.05$). This difference was particularly significant in accidents after 15 years of driving experience ("late accidents"). The conclusions, however, have been questioned by *Schneider* (1986), who in spite of statistical significance found the differences too small. Secondly, it was found that drivers with considerably reduced twilight vision and/or increased susceptibility to glare were more frequently involved in certain types of night accidents than their colleagues fulfilling the requirements for these visual functions.

In a "road side study" of 1000 drivers *Davison* (1985) found significant associations between drivers' accident history (not accident rates) and binocular visual acuity, the associations being strongest for elderly drivers. Hyperphoria has also been found to be over-represented in the group of drivers with accident involvements. In the age group of drivers $\geq$ 55, 3/173 (1.7%) of the drivers were found to have binocular visual acuity < 6/12). The author concludes that a statutory re-testing of the vision of drivers around the age of 50 and periodically thereafter is recommendable. The relationship between the "number plate test acuity" and "Snellen acuity" is found variable and a better standardized acuity test is desired by the author.

Quimby et al. (1986) analysed the visual and perceptual abilities of 370 accident involved drivers, out of which 288 were car drivers. These were volunteers from a group of 2445 individuals involved in 1363 accidents in a 32-month period. No correlation was found between self-reported accident histories and simple "visual or performance tests". Primarily, the study has not been analysed with a stratification for age. No detailed accident information was published, and the frequency of non- responders was unknown. An age and sex matched control group has not been examined. It is concluded that the better the visual acuity, the worse the accident history (which is probably due to the well-known epidemiological fact that *young* drivers have both a good vision and a bad accident history, authors comment). After a secondary age-stratification this difference was eliminated (Maycock 1987, personal communication).

Humphriss (1987): This South African study reports 3 investigations: 1) Among 666 drivers (reported by opticians) who did not fulfil the visual demands for driving 95% were due to refractive errors and another 3.5% could be improved by ophthalmological treatment. 2) Among 933 drivers employed by a large construction company 196 had been involved in traffic accidents and were compared to 170 controls. Significant differences were found in binocular and monocular visual acuity, in depth perception, but also in age distribution (40 being the median age in the accident group and 36 in the control group). A fact that might explain some of the differences found. No difference was found in colour vision and reaction time. 3) In the third study *(Golding 1984)* a group of 2111 accident involved drivers is compared to 2073 controls, tested in another "road side study". 4.5% failed the South African visual requirements in the accident group versus 3.8% in the control group. In the accident group 17% of the drivers with illegal vision still failed the test after being refracted and optically corrected. In the control group, 13% belonged to a "don't care" group who wore glasses for distance at home (for watching television) but did not use them when driving. Eleven per cent were aware that correction should have been used. In the same group the proportion of drivers not fulfilling the visual requirements was significantly over-represented ($p< 0.01$) and their accident rate was significantly higher!

Rogers, Ratz and Janke (1987) compared 2- year accident and conviction rates between 1202 visually impaired (v. a. < 20/40 in one eye) and 15,263 non-impaired Californian heavy-vehicle operators. Only 30% of selected subgroups responded to a questionnaire on driving information. The incidence of total accidents did not significantly differ between non-impaired and moderately (0.1 $\leq$ v. a. < 0.5 in one eye and v. a. $\geq$ 0.5 in the other eye) impaired drivers. Visually impaired drivers had significantly more total accidents (37% more) and total convictions (48% more) than the non-impaired control group, after adjustment for age. "Stronger evidence for the hypothesis was found for the severely impaired (v. a. < 0.1 in one eye) essentially monocular driver. Less evidence was found in its support for visually impaired but binocular drivers".

Paetkau et al (1988) found that among 491 ophthalmologic patients aged 65 and above, 11% of men and 1% of women were driving illegally. As a consequence he recommended regular screening of drivers' vision beginning at age 65.

Owsley et al. (1991) performed examination on "early visual attenuation" and mental status on 53 drivers aged 57-83. This test is known as "the Useful Field of View" *(UFOV)*, defined as the visual area in which information can be acquired within one eye fixation (cf. Ball et al., 1988 and 1990). This area is reduced as a function of age. The UFOV-method evaluates 1) visual processing speed, 2) the ability to divide attention between central and peripheral tasks, and 3) the ability to detect peripheral targets embedded within so-called distraction stimuli. The UFOV test and the "Mattis Organic Mental Status Syndrome Examination" were found to be the best predictors of accident frequency as recorded by the state. Together these tests accounted for 20% of the variation. Twenty-six drivers, not passing the UFOV test, had 4 times more accidents (of any type) and 15 times more intersection accidents than drivers passing the test. In addition the authors found a very low correlation (r= 0.11) between the number of accidents reported by the drivers and the numbers registered on the state records.

Szlyk et al. (1992) compared self reported accident frequency and driving simulator accident rates in 21 subjects with retinitis pigmentosa (RP) and 31 normally sighted control persons. The visual field defects were found to be significantly correlated to both parameters, and logistic regression analyses indicated visual field loss as the primary correlate of automotive accidents within patients with RP.

Ball et al. (1993) tested 294 drivers aged 55-90 years by the useful field of view (UFOV) test (cf. Ball et al, 1988, Owsley 1991, Ball and Owsley 1993). A sensitivity of 89% and a specificity of 81% was found in predicting older drivers' history of crash problems. Thus, older drivers with substantial shrinkage in the UFOV had a 6 time increase in crashes in the previous 5-year period, being unprecedented highly predictive for older drivers' crash risk.

- In a later prospective 3 year follow-up of the cohort (*Owsley et al, 1998*), these findings were confirmed in that drivers having a 40% or greater impairment in UFOV were 2.2 times more likely to incur a crash after adjustment for design variables.

Decina and Staplin (1993) examined 12,400 drivers in Pennsylvania at licence renewal and correlated to crash history. Neither visual acuity nor horizontal visual field were separately significantly associated with crash involvement, whereas the combination of these parameters and contrast sensitivity was so for drivers aged 66 and above, suggesting that contrast sensitivity should be included in the vision screening protocols of drivers.

Gresset and Meyer (1994) compared visual characteristics (information from vehicle insurance boards) in 1400 accident involved drivers with 2636 randomly selected controls. Drivers with minimal visual acuity (6/12-6/15) had the same accident risk as controls, whereas drivers with both minimal visual acuity and lack of binocularity had a moderately higher accident risk than controls.

McCloskey et al. (1994) investigated 235 drivers aged 65 and above out of 312 treated for injuries after a car accident compared with 448 controls. No clear evidence was found that ocular disease or impaired visual acuity increased the risk of an injury collision. The vision was registered by the most recent

general optometry examination record, when available.
The authors recommended more sophisticated test methods such as dynamic visual acuity and useful field of vision.

Wood and Troutbeck (1994) examined driving performance in a sample of young drivers with goggles simulating cataract, binocular visual field restriction and monocular vision, but for all drivers with a binocular visual acuity above 6/12 (legal limit). They found the greatest detriment to driving performance in the simulated cataract group followed by binocular visual field restriction. The monocular condition did not significantly affect driving.

Johanson (1997) compared 37 older drivers (out of 72) guilty of crashes (n=23) or other moving violations (n=14) to 37 matched controls. No difference was found comparing static visual acuity (p= 0.24). Reduced dynamic visual acuity ($p<0.003$) and reduced static visual acuity, tested with tilted Snellen's E ($p<0.02$) were significantly more frequent in the crash group compared to controls. Cognitive impairment was found to be a very important risk factor for older drivers.

Lachenmayr (1998) performed a complete ophthalmological investigation in 754 drivers involved in accidents and compared them to 250 comparable accident-free drivers. Drivers involved in accidents had a statistically significant higher incidence of reduced photoptic visual acuity, mesoptic vision and increased sensitivity to glare. Especially among drivers involved in night-time accidents mesoptic vision and resistance to glare were highly significant worse in the occident group. Many of the drivers involved in accidents assessed their own visual capability as excellent. - The author emphasises the importance of regular ophthalmological check-ups and recommend such tests from age 40.

Owsley et al. (1998) compared 78 drivers aged 55-87 with injurious crash involvement and 101 drivers with non-injurious crashes to 115 controls. Reduced useful field of view (OR: 4.2-17.2) and glaucoma (OR = 3.6, 95% CI,1.0-12.6) was found to be significantly associated with crash involvement

Ivers et al. (1999) performed a cross- sectional survey of 2379 current drivers aged 49 years and older in Blue Mountains, Australia (with left-side driving). A two line difference between eyes in static visual acuity was associated with increased risk of accidents (adjusted prevalence ratio (PR) = 1.6. [1.0-2.4]) as was visual acuity worse than 6/18 in the right eye (PR=2.0 [1.2-3.5]).

1.3.3.3. Danish surveys:

Danish surveys on this connection are very scanty. An unpublished sample of 100 randomly selected drivers (*Damgaard-Jensen* 1948) was referred to by Skjærbæk Olesen (1949). In this random sample, 10% had visual acuity below the legally accepted level, all of whom could by optical correction be corrected to or above the legal limit. The latter author recommended a study on ophthalmological investigation of car drivers involved in traffic accidents.
Kristensen (1988) performed a registration survey in a private eye clinic, covering approximately 25-30,000 inhabitants. In a period of one year he found 28 patients who, in spite of illegal vision, were still driving their cars. Half of them could be optically corrected to legal vision. Another half had age related macular degeneration. Statably, none of them had been involved in traffic accidents with injury and all found their vision sufficient for car driving!
The question of Danish legislative demands in traffic has been debated by Krogh and Tinning in 1995.

1.3.3.4. Scandinavian studies:

Also the remaining *Scandinavian studies* on epidemiological aspects in this field have been easy to survey (*Liesmaa* 1973, *Johanson, 1997). Hjorth et al.* in (1991) performed a task for opticians. They called 294 drivers involved in traffic accidents and a corresponding control group of 294 persons for an investigation. In spite of assurance of anonymity only 18 persons in the case group (6%) and 75 in the control group (26%) participated, making the investigation inconclusive.
Thus, a Danish epidemiological study on the association between visual ability and traffic accidents seems motivated. *Herner, Smedby and Ysander's* investigation on acute medical conditions (1966) did not include visual factors. Their study of decisive importance in the reform of the Danish legislation (see chapter 1.2.2), was based on data collected in 1955 and 1963. Sinc then the traffic intensity has doubled (cf. fig. 1.6) and the number of drivers > 65 has increased too (cf. fig 1.3).

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Apart from these surveys, some casuistic reports and the literature concerning experimental studies on special visual parameters in relation to traffic capability will be covered in relation to the discussion of results (chapter 4 and 5).

1.3.4. Critical comments and conclusions regarding earlier studies

From the studies, listed in table 1.3 some main criticism and conclusions can be drawn: Most of the studies frequently referred to (Burg 1967-78, Council and Allen 1974, Johnson and Keltner 1983), and others (Gresset and Meyer 1994, McCloskey et al, 1994) have been performed by screening a group of persons applying for a driver's license (renewal or first time) or drivers 6 to 12 months after their conviction (Gramberg-Danielsen 1971). Generally, these are situations in which the applicants may be expected to have their visual ability optimized in advance, and it does not necessarily reflect "reality on the road". Thus, as shown by Golding (1984) and Zaidel & Hocherman (1986), a significant proportion of drivers belong to a "don't care group" who use glasses for watching TV but not for driving!
- Only a minor part of the studies have been performed as case/control studies with a randomly selected control group of active car drivers (Fletcher (1949), ENO-foundation (1948), Hager (1963), Cashell (1966), Gramberg-Danielsen (1971), Liesmaa (1973), Johnson & Keltner (1983), Rogers, Ratz and Janke (1987), Szlyk et al. (1992), Gresset and Mayer (1994), McCloskey et al. (1994), Johansson (1997)).

- In some of the earlier studies, (e.g. Heinsius 1969, Crancer and O'Neall, 1969), and indeed also in later ones (e.g. Quimby et al. 1986) the age has not been corrected for.

- As Henderson & Burg (1973, 1974) have mentioned, only a few studies have focused upon the groups of drivers with illegal visual acuity. In later studies as e.g. Harms et al. 1984, Humphriis 1987, no estimates on the association between vision and traffic accidents have been published. Most of the statistics published suffer from the fact that usually too few drivers fulfil all of the following four criteria: 1) belonging to a "low" visual acuity group, 2) being involved in a serious traffic accident, 3) being included as probands in an epidemiological survey on these matters, and 4) being participants in such an investigation.

The registration survey of Rogers et al. (1987) only partly oblige these points of criticism. Information on the drivers mileage is inconclusive and the questionnaire respondent rate being as low as 30%. The authors of this paper found significantly higher accident and conviction rates in the low vision group.

- One important aspect and explanation of the discrepancies found in the international literature might be the significance of the *re-testing intervals* of the drivers' vision cf. table 1.1. The longer the period of driving without compulsory testing, the more drivers can be expected to have poor vision. Since the legislation on this point varies considerably, the international applicability and the conclusions of the single studies should be considered with caution.

- Very few studies reflect a proper analysis of an actual traffic accident situation in relation to visual and epidemiological aspects (Clayton 1976, Quimby et al. 1986).

- The group of *"non-responders"*, in which drivers with impaired vision might be over-represented, is very infrequently elucidated, including the two studies mentioned above. This might be explained by the fact that it is very hard to motivate the drivers as well as to assemble alternative information on these individuals. This is very unfortunate as this group is of the utmost interest, regarding: a) their proportion of the complete material, b) their age and sex characteristics, as well as alternative information on c) their visual and general health status.

The study of *Hjorth et al.*(1991) illustrates the importance of describing the non-responders. After an embarrassing experience such as a traffic accident, only 6% of cases participated, making most observations inconclusive. *Rogers et al.* (1987) had a questionnaire respondent rate of 30% and *Johansson (1997*) of 51%.

- A great number of surveys have been performed by opticians who, whether this is legitimate or not, might be suspected of and prone to bias because of commercial interests.

Conclusions

Although vision is not the most important cause of road traffic accidents, several studies indicate that association seems to exist between insufficient visual ability and traffic accident records in the elderly and the accident repeater groups of drivers. However, the conclusions of the individual studies vary. Test for dynamic visual acuity, early visual attenuation test and "Useful Field of View Test" seem to be better predictors of accident behaviour than classic static visual function tests. Use of interactive driving simulators (Szlyk et al, 1992) is probably a coming test method, at least for drivers with a doubtful visual function in the “grey zone area”. This will be further discussed in chapter 5.4.2.).

1.4. The aim of the study

The purpose of the present investigation was:

1. to describe the pattern of organic visual problems in a population of drivers involved in serious motor vehicle accidents in Denmark;

2. to perform analyses of a possible association between visual capabilities of the drivers and their traffic accident risk;

3. to elucidate the practical and legislative aspects of testing drivers' vision by monocular and binocular technique;

4. to estimate the number of drivers with illegal vision, and the proportion, of which ophthalmologists might be able to assist continuing with legal and safer driving;

5. to estimate the level of seriousness in injury consequence of accidents in which a driver involved had significant visual problems;

6. to illustrate and estimate the role of acute and chronic medical conditions (including vision) in relation to traffic accidents, based on individual accident reports;

7. to present a scientific database concerning practical and legislative aspects of visual factors and accidents.

2. MATERIAL AND STUDY DESIGN

The collection of data had to be performed during several periods mainly grouped in two phases (I and II) with different inclusion criteria. One reason was the author's alternating scientific and clinical appointments. Another reason was that the different phases of data collection had individual purposes:

2.1. Data collection

Collection of data in *phase I* included all active road users, aged ≥ 10, involved in traffic accidents resulting in human injury ("active" means: passengers not included). This phase showed that the visual problems were concentrated among elderly road users. Car drivers were found to be the most important group. Data collection of *phase II* therefore only included car drivers aged ≥ 50 involved in traffic accidents resulting in human injury (IIa) and a control group of car drivers (IIb). The purpose of this phase was to supply the proband material in a relevant age group and to compare the proportion of visual problems in the accident and control groups.

2.1.1. Phase I

The basic *inclusion and exclusion criteria* for a road user to be included are shown in table 2.1.

Remarks:

Re 1. "Active" means passengers not included. Children < 10 years were not investigated, but e.g. a driver involved in such an accident was included. In fact, all drivers, whether injured or not, were included if they were involved in an accident resulting in injured persons.

Re 2. With very few exceptions the police district of Aarhus (cf. figure 2.1) coincides with the hospital districts of the two casualty wards in Aarhus (only 3 patients were referred to neighbouring casualty wards).

Accidents registered by the police and casualty wards as well as those only reported in the casualty wards in Aarhus were included. (Accidents that were registered by the police only were not included).

Re 3. Since the primary aim of the study was to focus on visual problems in car drivers, this selection was done. Thus accidents with or between unprotected road users only, were not included.

Re 4. Phase I started in January 1983, as a pilot project, and continued in February to March 1983 and September to October 1984. These periods were chosen for practical reasons. Since the information on the accidents sometimes arrived with a delay of several days, the exact number of accidents included were unpredictable.

Re 5. and 6. For practical reasons these groups were excluded. The criminals excluded were mostly drivers of stolen cars, "hit and run" drivers etc. In one excluded case, a wife injured her husband by purposely driving into him after a quarrel. Registered drunk drivers and drivers not owning a driver's license, strictly criminals, are included, since they constitute important groups in the field of traffic medicine. The material from phase I gave the basic descriptive information for the demographic analysis.

2.1.2 Phase II

In phase I the most important visual problems appeared in the group of drivers ≥ 50 years of age. It was therefore decided to continue with an investigation of a restricted sample (phase II). This consisted of:

II a) a group of accident involved car drivers, aged ≥ 50, fulfilling the inclusion criteria (table 2.2.). For practical reasons, in this phase only accidents registered by the police as well as a casualty ward were included. These were better registered and consequently easier to contact.

II b) A control group of randomly selected, active drivers ≥ 50. With respect to age and sex, this group was intentionally "matched in frequency" (cf. Rothman, 1986) with the first 69 proband drivers aged ≥ 50 from phase I (table 2.3.). Two controls were selected for each of these first 69 probands (cf. chapter 2.1.2).

Table 2.1. Basic inclusion and exclusion criteria, phase I (Alsbirk, 1999):

Inclusion criteria:
Persons involved in all consecutive accidents in the police district of Århus fulfilling the following criteria:

1. Active road users ≥ 10 years old involved in...
2. Traffic accident with human injury, treated in or referred by casualty wards.
3. One or more car drivers involved in the traffic accident.
4. Periods: January 18th to 25th and February 1st to March 29th 1983 and September 3rd to October 22nd 1984, beginning and stopping at 8.00 a.m.; in total 112 days.

Exclusion criteria:

5. Road users from foreign countries.
6. Certain criminals, see below.

Table 2.2. Inclusion and exclusion criteria, phase II. a (Alsbirk, 1999):

Inclusion criteria:
Automobile drivers involved in police registered accidents in the police district of Århus fulfilling the inclusion criteria 1-4:

1. Drivers, aged ≥ 50 involved in..
2. traffic accident with human injury, treated in or referred by casualty wards.
3. One or more car drivers involved in the traffic accident.
4. Accident period: September 2nd 1985 to January 20th 1986, beginning and stopping at 8.00 a.m.; in total 140 days.

Exclusion criteria:

5. Drivers from foreign countries.
6. Certain criminals (cf. table 2.1).

Table 2.3. Inclusion and exclusion criteria, phase II.b (the control group) (Alsbirk, 1999):

Inclusion criteria:

1. Automobile drivers ≥ 50 year of age from the police district of Århus, randomly selected via records from the driver's license office in Århus (according to the age and sex distribution of the first 69 drivers found in phase I).

Exclusion criteria:

2. Chronic diseases at the time of investigation which made car driving impossible.
3. The driver having not driven a car within the last 2 years.

Fig. 2.1. *Police district of Aarhus (black), 284,000 inh. (5.55% of the Danish population of 5,114,000 inh.), mixed urban and rural*

Phase II a + b were performed within the same period: September 1985 to January 1986.

2.2. Introduction to the study design

Basic demographic patterns in relation to the accidents (type of road users, type of accidents, age and sex distribution, police registration) are described, based on data from phase I (cf. chapter 2.3.).

The descriptive study is based partly on phase I, which included accidents with automobile drivers in all age groups and partly on phase II, including accidents with drivers aged ≥ 50 years (cf. chapter 2.4.).

The analytical (case/control) study is based on 1) proband car drivers, aged ≥ 50 from phase I and IIa and 2) control drivers aged ≥ 50 (phase IIb) (cf. chapter 2.5.).

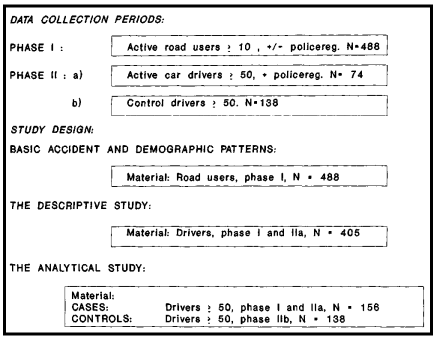

Fig. 2.2. *The raw material and study design. The analysed, restricted material, see text (K.E. Alsbirk, 1999)*

2.3. Basics on the accidents and the study population

Figure 2.2 and table 2.4 show the main characteristics of the study population.

The total number of accidents investigated was 359.

Phase I included 287 consecutive traffic accidents fulfilling the inclusion criteria in table 2.1 in the first two periods. *Phase II* comprised 72 consecutive traffic accidents, restricted according to age, referring to the criteria in table 2.2.

Among the 82 car drivers ≥ 50 years in phase I, 61 (74%) were involved in police registered accidents. Twenty-one (26%) were implicated in non-police registered accidents, reported through casualty wards only. The total period of investigation was 112 +140 days = 252 days. In this period 61 + 74 = 135 police-registered car drivers ≥ 50 were involved.

Table 2.4. The study population: overall data on accidents, persons involved and controls (Alsbirk, 1999).

DATA-COLLECT. PHASE:	*PERIOD:*	*MONTHS:*	*DAYS:*	*TRAFFIC ACCID.:*	*POLICE-REGISTRATION:*	*AGE:*	*UNPROTECTED ROAD-USERS:*	*CAR DRIVERS: CASES: < 50:*	*≥ 50:*	*CONTROLS: ≥ 50:*
I:	1983+84:	1-3 + 9-10	112	287	+/-	>=10	157 **)	249	82 *)	
II:	1985+86:	9-12 + 1	140	72	+	>=50	-	-	74	138
	ALL :		252	359			157	249	156	138
								405		
							562			
								700		

*) Police registered : 61 (74%)
Non-police registered : 21 (26%)

**)		
Bicyclists	:	84 (54%)
Pedestrians	:	35 (22%)
Moped riders	:	25 (16%)
Motor-cyclists	:	13 (8%)
Unprotected road users total	:	*157 (100%)*

2.3.1. *Basic information on the accidents*

2.3.1.1. The type of accidents classified according to involved active participants are figured in fig. 2.3.

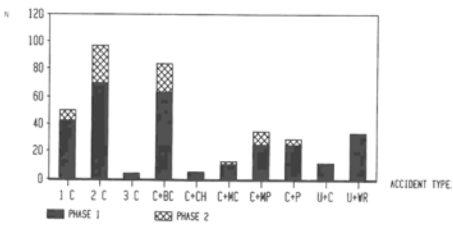

Fig. 2.3. *Participants in 359 traffic accidents (the entire material). C = Car drivers, BC = bicyclists, CH = children, aged < 10, MC = motorcyclists, MP = moped riders, P = pedestrians, U = unknown car drivers, URU= unprotected road users ≥ 10 years. N= no. of accidents, (K.E. Alsbirk, 1999).*

Table 2.5. Distribution of accident types and police registration in phase I material *) (Alsbirk, 1999).

Police registration:	Road users involved: 1 car:	2 cars:	3 cars:	car & bicycle:	car & <10 y.:	car & 1 MC:	car & moped:	car & pedest.:	car & car unknown:	unknown car & u.r.u.**)	total:
+	24	54	2	37	5	9	17	22	0	4	174
-	18	15	2	26	0	1	8	3	11	29	113
Sum	42	69	4	63	5	10	25	25	11	33	287
Pct. police-registration :	57.1%	78.3%	50%	59%	100%	90%	68%	88%	0%	12%	60.6 %

*) cf .table 2.4 and text.
**) u.r.u. : unprotected road user.

Only *phase I* accidents reflect the overall distribution of accidents in focus (i.e. ≥1 car driver involved and personal injury), since in phase II young drivers and accidents *not* registered by the police are excluded. Table 2.5. shows the accidents in *Phase I.*

The accidents have been subdivided according to the type of registration. As can be seen, the proportion of police registration within the groups varies, being most regular in accidents with injured children below 10 years of age (100%) and in accidents which involved motorcyclists (90%) or pedestrians (88%). The average police registration is 61%, indicating that 39% of these accidents (in which a car always was involved) were only known from the casualty wards. The findings reflect that the more serious the accidents, the higher the frequency of police registration. Accidents with two cars (24%) dominate followed by accidents with one car/ one bicycle (22%) and single accidents (15%).

2.3.1.2. When did the accidents happen?

The diurnal occurrence of phase I accidents throughout the seven days of the week can be seen in fig. 2.4 and offers no surprises in relation to existing knowledge.

Further details on the accident circumstances are analysed in chapter 4.2.

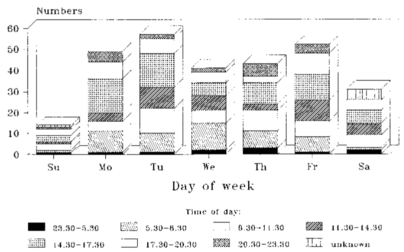

Fig. 2.4. *Time of the accidents. 287 phase I accidents distributed according to weekday and diurnal occurrence (K.E. Alsbirk,1999).*

Table 2.6. Excluded or unknown road users (phase I) (Alsbirk, 1999):
Phase I:

	Children < 10 y.:	Unknown car drivers:	Hit & run drivers:	Foreigners:	All:
Police reg. accidents:	5	1	1	3	10
Non-police reg. :	0	37	5	0	42
Sum :	5	38	6	3	52

Table 2.7. Active road users involved in 359 traffic accidents with human injury (Alsbirk, 1999).

	Car drivers:	Bicyclists:	M.R.:	MC:	Pedestr.:	<10 year:	Unknown:	Hit & run:	Foreigners:	Total:
Phase I (all) :	331	84	25	13	35	5	38	6	3	540
pct.: :	(66.3)	(15.6)	(4.6)	(2.4)	(6.5)	(0.9)	(7.0)	(1.1)	(0.6)	(100)
Included :	331 *)	84	25	13	35	-	-	-	-	488
Phase IIa(all):	100	20	9	3	4	0	0	0	0	136
Included: :	74 **)									74
Phase I+II a :	431	104	34	16	39	5	38	6	3	676
Included :	**405**	**84**	**25**	**13**	**35**	-	-	-	-	**562**

*) all age groups ,
**) age groups ≥ 50 only
M.R.= moped riders.

2.3.2. Excluded and unknown road users

In 44 phase I accidents (15.2%), 52 of the involved road users were either unknown (38 in 35 accidents), "hit and run drivers" (6), below 10 year of age (5) or from a foreign country (3) (Table 2.6).

As could be expected, the "hit and run drivers" and unknown drivers were nearly all involved in the group of accidents not registered by the police.

The total number of active participants (i.e. passengers excluded) in the relevant accidents is listed in table 2.7.

Thus in phase I the total material of 540 active road users involved has been reduced by 52 (9.6%), 488 being the investigated group of road users. In phase II a. only 74 out of 136 road users were included, excluding all unprotected road users (N=36) and drivers of age < 50 (N= 26).

2.3.3. Basic demographic patterns of the study population

Phase I includes all groups of road users in accidents, fulfilling the inclusion criteria. The age and sex distribution can be extracted from this phase:

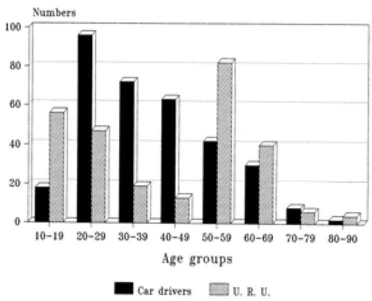

Fig. 2.5. *Age distribution in 287 phase I accidents. N= 488 road users (solid = 331 car drivers, cross-hatched (U.R.U)= 157 unprotected road users) (K.E. Alsbirk, 1999).*

Fig 2.5 shows the *age distribution*. Car drivers were older (median= 37) than the unprotected road users (median= 23), ($p<10^{-7}$, Mann-Whitney rank test). The age and sex distribution of the 331 automobile drivers is seen in fig. 2.6. Males totalled 67% of these drivers.

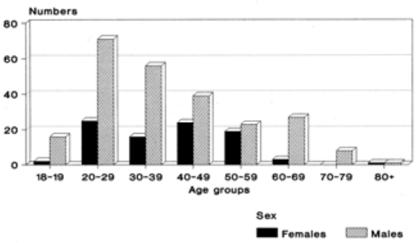

Fig. 2.6. *Age and sex distribution in 331 car drivers involved in accidents (phase I) cf. text (K.E. Alsbirk, 1999).*

The relative distribution of kilometres driven in relation to *age and sex* of car drivers as well as lorry and bus drivers in the background traffic is known from a Danish statistical investigation from 1981 (Danmarks Statistik, Persontransportundersøgelsen, 1982). The *age distributions* in the study populations compared with these background distributions are illustrated in fig. 2.7. In phase I, 269 were car drivers, 45 were lorry and bus drivers and 17 were unclassified.

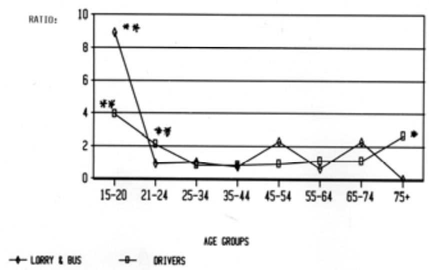

Fig. 2.7. *Study group/background ratios in different age groups.*
■: private car drivers (n=269),
♦: lorry and bus drivers (n=45).
The study population (phase I) compared to the background traffic population. (Danmarks Statistik 1982),
** (p= 0.02), **(p< 0.001), cf. text. and appendix D 1 (K.E. Alsbirk, 1999).*

Generally the findings confirm the age frequencies in accident-involved drivers found in many other materials: the younger age groups of drivers have a highly significant over-representation (by a factor 4-9, p< 0.01, exact estimates). In the age groups 25-74 years, the material corresponded closely to the background data. As far as the elderly car drivers concerned, a slight but significant over-representation was found in the accident group, aged 75 and above (p=0.02).

Driver's sex. The overall female/male ratio in the phase I material of automobile drivers was 90/241 (27.2% females). As mentioned, the proportion is known in the background population in different subgroups of motorists (Danmarks Statistik, 1982). Among drivers of private cars, the fraction of females was 23% (week-ends) - 26% (workdays), estimated on the basis of 1520 interviewed persons. The study proportion of female drivers of private cars involved in traffic accidents with injury (83/254 = 32.7%) is slightly, but significantly elevated (95% limits: 26.9%-38.8%). Setting the average proportion of females in the background driver population to 25%, the odds-ratio is 1.46 (1.09 -1.94), p= 0.014, Fisher's exact.

2.3.4. The non-responders

An important problem in an investigation like the present one is the group of individuals fulfilling the inclusion criteria but *not* participating in the investigation. How many and who are they? (age and sex), where do they live? etc.

The methods used to make this group as small as possible are mentioned in chapter 3.

For a description of the proportion of non-responders, the material has been divided into 4 groups:

Table 2.8. Study population, participants and non-responders (Alsbirk, 1999).

Age		Proband drivers: < 50:	Proband drivers: ≥ 50:	Controls: ≥ 50:	Unprotected road users:	Total:
Investigated	:	187 (75%)	122 (78%)	126 (91%)	130 (83%)	565 (81%)
Non-responders	:	62 (25%)	34 (22%)	12 (9%)	27 (17%)	135 (19%)
Total	:	249 (100%)	156 (100%)	138 (100%)	157 (100%)	700 (100%)
Dead	:	2 (0.8%)	4 (2.5%)	-	3 (2%)	9 (1.3%)
Injured	:	-	1	-	-	1 (0.1%)
Refusals	:	33 (13%)	19 (12%)	9 (7%)	5 (3%)	66 (9.4%)
Other expl.	:	27 (11%)	10 (7%)	3 (2%)	19 (12%)	59 (8.4%)
Non-resp. all	:	62 (25%)	34 (22%)	12 (9%)	27 (17%)	135 (19%)

Car drivers (probands, aged < 50 vs. probands, aged ≥ 50): p= 0.55 (Fisher's exact)
Car drivers (cases, aged ≥50 vs. controls) : p= 0.003 (Fisher's exact)
Car drivers (probands, all) vs. unprotected road users : p= 0.12 (Fisher's exact)

1) Drivers < 50 year.
2) Drivers ≥ 50 year (cases)
3) Drivers ≥ 50 year (control group)
4) Unprotected, accident-involved road users.

As can be seen in table 2.8, the proportion of and reasons for non-responding differed in the 4 groups. The young drivers had the highest frequency of non-responders (25%). However, the difference was not statistically significant(p=0.55).

In the control group this proportion was significantly lower (9%) than in the corresponding proband group of road users (22%) (p< 0.005). The psychological barrier for participating in an investigation apparently is significantly higher when the background is an embarrassing experience. This was also found by Hjorth et al. 1991,

Among the probands the proportion of non-responders in car drivers and unprotected road users did not differ significantly (p=0.12).

Of the accident-involved car drivers 12.5% refused to participate. In this group of drivers the remaining non-responders ("other explanations" 11% < 50, 7% ≥ 50) mostly consisted of foreigners or persons living outside the county (9.3%). For comparison, among the investigated participating drivers, only 2.3% lived outside the county ($p < 10^{-3}$, Fisher's exact). In other words, the frequencies of non-responders were (not surprisingly) dependent on the drivers' address distance from Aarhus. The frequency was 67% in the case of 21 accident involved drivers living outside the county, 23% in the case of 158 drivers from the county but from outside Aarhus and 20% in the case of 226 drivers from Aarhus).

The age and sex distribution of the non-responders as compared to the whole material can be seen in table 2.9.

The age distributions did not differ significantly (p=0.58, Mann-Whitney test). Males were over-represented (p=0.04), but if drivers from outside the county (often males) are excluded, the difference is reduced and non-significant (p=0.23).

Some of the oldest non-responders who refused to participate, expectedly belonged to a group with visual problems. Some of such drivers might be afraid of being advised to stop driving due to vision problems.

Therefore, the frequency of visual problems found in the car drivers investigated is probably minimum estimates compared to the reality on the road of the whole study population. On the other hand, some of the participating probands might belong to a group of persons with visual problems who are especially motivated for an examination by an ophthalmologist.

All possible legal efforts have been used to collect information on the group of non-responders as described in the method chapter (3).

Table 2.10 shows the sources of alternative information. In many cases information on health but not vision could be obtained from the general practitioners. In 7% information on vision was not available. Only 2.3% of the material remained totally unelucidated in respect to health.

The obtained alternative information has been used to characterize the non-responder group. These persons, however have been omitted in the descriptive and analytical study, since the validity of their visual information is inhomogeneous and disputable, see below.

Table 2.9. Age and sex distribution in non-responders and responders (proband group only) (Alsbirk, 1999).

Age groups	:	**Non responders: (pct.)**	**Responders: (pct.)**	**Total: (pct.)**
10-19	:	13 (18)	61 (82)	74 (13)
20-29	:	34 (24)	109 (76)	143 (25)
30-39	:	19 (21)	72 (79)	91 (16)
40-49	:	16 (21)	60 (79)	76 (14)
50-59	:	21 (23)	71 (77)	92 (16)
60-69	:	12 (21)	44 (79)	56 (10)
70-80	:	6 (26)	17 (74)	23 (4)
80 +	:	2 (29)	5 (71)	7 (1)
Total	:	123 (21.9)	439 (78.1)	562(100%)

Non-responders vs. responders: z'= 0.54, p=0.58, Mann-Whitney test)

Sex:				
Females	:	26	136	162
Males (pct)	:	97 (79%)	303 (69%)	400 (71%)

(X^2 = 4.1 , d.f.= 1 , p = 0.04)

(From Aarhus county only):				
Females	:	19	94	113
Males (pct)	:	62 (77%)	209 (69%)	271 (70%)

(X^2 = 1.4 , d.f.= 1 , p = 0.23)

2.4. The descriptive study of car driver's vision

This part of the study focuses on *visual parameters in car drivers involved in the accidents.* For the analyses of this data in the descriptive study (as well as the analytical case/ control study), only road users investigated by the author have been included with one exception (cf. p. 95).

According to *table 2.8*, the material analyzed in the descriptive study

Table 2.10. Alternative information on 134 non-responders from the whole study population (Alsbirk, 1999).

aged:		Cases, <50	drivers >=50	controls >=50	unprotected road users:	Total: (pct)
General practitioners	:	38	13	4	12	67 (50%)
Ophthalmologists	:	12	6	2	11	31 (23%)
Others	:	3	13	5	0	21 (16%)
Unknown (pct. of non-r.)	:	9 (15%)	2 (6%)	1 (8%)	4 (15%)	16 (12%)
Non-responders all	:	62 (25%)	34 (22%)	12 (9%)	27 (17%)	135 (19%)
Whole material	:	249	156	138	157	700
Unknown (pct. of all)	:	9 (4.0%)	2 (1.2%)	1 (0.7%)	4 (2.5%)	16 (2.3%)
Information on vision, total	:	*223 (90%)*	*146 (94%)*	*135 (98%)*	*147 (94%)*	*652 (93%)*

consists of the following accident involved road users: 187 car drivers, aged < 50 (participation rate= 75%), 122 car drivers aged ≥ 50 (participation rate= 78%), in total 309.

In the group of *unprotected road users*, 130 persons (83%) were investigated, primarily to elucidate the role of vision in each single accident as thoroughly as possible. They were not directly included in the descriptive study.

2.5. The case/ control study

The purpose of including a control group was to investigate or elucidate whether various visual parameters among car drivers aged ≥ 50 are associated with serious automobile accidents.

As shown in table 2.4, the basic material of drivers ≥ 50 consists of 156 accident-involved drivers *(cases)* and 138 control-drivers. The age and sex of the control group were based on the distribution among the first 69 proband drivers in phase I, drivers from non-police registered accidents included. The subsequent 87 cases turned out to differ from the first 69 with respect to age and sex. (This discrepancy is discussed in chapter 3.1.3). As a consequence, the age distributions of the two groups differed, the median age in the control group (61) being significantly higher than in the accident group (58), (p< 0.005, Mann-Whitney test).

No difference was found in the distribution of sex (p=0.69, Fisher's exact). Age and sex distribution of the raw material is given in fig. 2.8.

Differences between cases and controls in associated non-visual factors as well as possible, mutual associations in visual parameters can be partly adjusted for by means of logistic regression analyses (Foldspang et. al 1986), cf. appendix D2 and chapter 4.3.2.

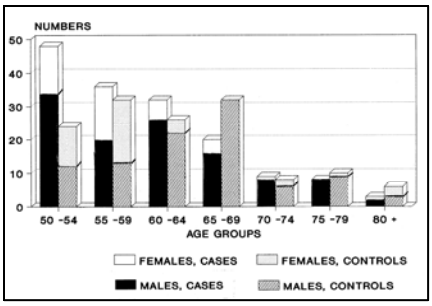

Fig. 2.8. Age and sex distribution in car drivers aged ≥ 50, the case-control study, raw material.

2.5.1. Design variables

The variables age and sex of the drivers have been a fundament for the design of the control-group selection. The present and other studies show that the visual problems in drivers seem to increase significantly with age (cf. table 4.1).

The *"cases"* were all drivers involved in police registered accidents with human injury, aged ≥ 50. The chance of being included as a case in the investigation (i.e. being involved in a serious traffic accident) increases with annual driving (cf. appendix D.2.).

The *"controls"* were selected from the files of the driver's licence office of Aarhus. The chance of being included as a control driver was independent of the amount of annual driving, provided the inclusion criteria were fulfilled.

- Thus drivers' annual driving too is of importance for whether a given person is included in the study as a proband or a control.

In the *logistic regression analyses* with calculations of odds ratio estimates, adjustment for *age, sex and annual driving* (design variables) has been made. In order to avoid heterogeneity in the inclusion criteria of the cases, the computations primarily have been made on the basis of exclusively *police*

Table 2.11. Material, the case/control study (Alsbirk, 1999):

		Drivers, aged > 50: Cases:	Controls:	All:
Basic material	:	156	138	294
Drivers excluded:				
Police-registered non-responders	:	31	12	43
Non-police registered	:	21	1	
Subtotal	:	104	126	230
Excluded due to lack of information on *design variable annual driving*	:	7	-	7
Subtotal	:	97	126	223
Excluded due to lack of information on *confounding factors*	:	6	13	19
Computerized material for individual risk estimates of visual factors	:	91	113	**204 *)**
Excluded due to incomplete visual information	:	4	1	5
Material for the final logistic regression analysis	:	87	112	**199**

*)Due to incomplete visual information, the risk estimates were based on 199 persons in one analysis, 200 in another and 203 in two calculations, cf. table 4.19.

registered accidents. According to table 2.11, this reduced the basic material to 223, (97 probands (cases) and 126 controls).

2.5.2. Confounding factors

Other non-visual risk variables which might be associated to the visual parameters have been investigated. The following of the factors investigated were found to be associated*: daily alcohol consumption, percentage of urban and professional driving, and visual reaction time* (cf. appendix D. 2.). Therefore, these were included in the multivariate analyses as *con-founding factors:*

Information on confounding factors was insufficient in 19 cases. The analytical method including evaluation of design variables and confounders is discussed in appendix D. 2.

2.5.3. The case/control material analysed by logistic regression

The case/control material for the logistic regression analyses was now adjustable for design variables and confounders. According to table 2.11, the study population aged $\geq$ 50 was further reduced to 204 (91 probands and 113 controls) when the visual parameters were *studied separately.*

The various visual parameters investigated are partly interrelated. In the final logistic regression analyses it was intended to calculate unbiased risk-estimates on six visual parameters, when these were *fitted simultaneously in various combinations* (cf. appendix D. 2.). In 5 drivers visual information was incomplete. Therefore the material for this final logistic regression analysis, was reduced to 199 (87 probands and 112 controls).

3. METHODS

Introduction

This chapter will describe 1) the procedure in collecting accident records and of the selection of the control group; 2) the procedure in contacting the probands and accumulating information; and 3) the method of investigation of the road users, including collecting information on the traffic accidents.

3.1. Procedure in collecting the accident records and in control group selection

3.1.1. Phases I and IIa (cf. tables 2.1 and 2.2)

The collection of accident information was based on co-operation with the departments of orthopaedic surgery of the two city hospitals in Aarhus (Aarhus Municipal Hospital and Aarhus County Hospital). These departments at the time of the investigation ran the only two casualty wards of the region.

The staff of the casualty wards was instructed verbally and by written instructions. To ensure that all persons injured or killed in accidents, who met the inclusion criteria, were registered, *one* secretary in each department was designated as responsible for checking the records every day. A copy of the records was sent to the author.

The same procedure was used in an effective co-operation with the police department, where one secretary was designated as responsible for checking and informing about the police registered accidents which fulfilled the inclusion criteria.

It was an agreement that no information obtained during the survey should be returned to the police! Fortunately in phase I (January - March 1983 and September - October 1984), the same three persons were the responsible secretaries during the whole period. In phase IIa (September-October 1985), a new secretary was introduced at one of the casualty wards.

This contact with each office through one responsible person made the co-operation and registration effective and reliable.

3.1.2. Phase IIb, the control group (cf. table 2.3)

Initially the control group of drivers aged $\geq$ 50 was planned to be of the same size, age and sex distribution as the group of proband drivers (cases).

After the data on age and sex distributions were accessible, based on the first 69 (out of 82) drivers in phase I, examination of two control persons were planned for each case.

The years of birth and sex were listed as shown:

e.g.
1933: 6 males 4 females
1934: 4 males 4 females
etc.

In the files of the driver's license office, cards with names of approx. 175,000 drivers were alphabetically ordered. The cards were selected at random throughout the whole alphabet and the first persons fulfilling the listed criteria (concerning year of birth and sex) were included as controls. This gave a list of 138 controls.

If a driver had died, or moved away, or was excluded according to the criteria (cf. table 2..3), a new control person of the same age and sex was selected from the records according to the same principles.

Also this co-operation with the police department went smoothly and effectively.

3.1.3. Problems in age distribution of cases and controls

The collection of probands (accident involved drivers $\geq$ age 50) according to the restricted criteria in table 2.2 continued in parallel with the controls (phase II a). Unfortunately, the age distribution among the first 69 and the following 87 probands differed significantly, (table 3.1) ($p < 0.001$), the last probands being younger than the first because of relatively many drivers between 50-54 and few between the age of 65 and 69. No valid explanation for this disparity was found. One interpretation might be, however, that the first part of phase II a took place in November, December and January, the darkest months of the year. In this period, the elderly drivers are relatively under-represented in the traffic (Rumar 1986a).

As a consequence, the proband group $\geq$ 50 at the end of the investigation turned out to be significantly younger (median =58) than the controls (median = 61).

As mentioned, in the selection procedure of the control group, the age was based on the year of birth. The practical investigation took place 1/2 year later than the list had been accomplished, which contributed to a small deviation in the control group toward a higher age (cf. fig. 2.8. and table 3.1.).

3.2. Procedure in contacting the probands and collecting ophthalmological data

3.2.1. Phase I and IIa

After the records had been collected and registered, a letter was sent to the persons involved in the accidents or (in a few cases) to their relatives. For psychological reasons, based on experience from the pilot period (the first week of the study), it was decided not to send the letter until at least 2 weeks after the accident. The letter, which fulfills the criteria of the Helsinki declarations, is reprinted and translated in appendix A + B. The principles of voluntariness, confidence and the medical professional secrecy of the author were emphasised.

In some cases of accidents, not registered by the police, an injured person could be the only contact person to other active road users involved in

Table 3.1. Age distribution in accident-involved drivers (cases) aged $\geq$ 50 and controls (Alsbirk, 1999).

Accident involved:		Age groups: 50-54:	55-59:	60-64:	65-69:	70-74:	75-80:	80+:	> 55:	Total:
No 1-69	(1):	12	16	13	16	4	5	3	57	69
No 70-156	(2):	36	20	19	4	5	3	0	51	87
Total	(1+2):	48	36	32	20	9	8	3	108	156
Controls*	(3):	24	32	26	32	8	10	6	114	138

(1 versus 2: $z' = 3.83$, $p = 1.28 \times 10^{-4}$, Mann-Whitney test)
(1 + 2 versus 3: $z' = 2.94$, $p = 3.28 \times 10^{-3}$, Mann-Whitney test)

*) Controls were "randomly" selected according to the distribution of age and sex of the first 69 probands from phase II, cf. text.

the accidents who fulfilled the inclusion criteria of the study. A letter of information was sent to these persons in which they were asked to give voluntary information on the involved partners. One reason why some of the accident-involved partners remained unknown was the fact that a few persons involved in accidents did not want to give this kind of information.

In accordance with the letters (cf. appendix A), the proband persons either contacted the author, or they were contacted by telephone by the author after some days - if possible. This procedure gave the persons an opportunity to ask questions etc. The persons who had not been reached by this first contact procedure (approximately 5%) received a further letter one month later. A few of these responded positively. These procedures resulted in an acceptable participating rate of 78-90%, which would not have been reached by letter contact only (assumed to give 30- 40% responders).

3.2.2. Phase IIb (the control group)

Like the accident involved drivers, the control group of drivers was correspondingly sent a letter with information on the investigation which in the case of no response was followed up by a telephone call.

3.2.3 Non-responders

The road users who did not want to participate in person were by telephone asked to give a voluntary interview on general health conditions, vision, and the accident. They were also asked voluntarily to give information about which opticians the examiner could contact for further information. In some cases this procedure gave information concerning health, use of medicine, refraction, visual acuity etc.

In a few cases where a road user could not give information (i.e. severely injured or dead), close relatives were asked the relevant questions, to be answered voluntarily.

3.2.3.1. Alternative information

In the case of *non-responders* the general practitioners were contacted via the health security registration. This was done to collect information on the general health situation and visual acuity data (if possible) of the involved partners.

Since the general practitioners did not always have information from ophthalmologists, the records from the eye department were searched. Furthermore, all eye practitioners in the region where the non-responders lived were contacted to give relevant information if possible.

All medical information was treated confidentially, under professional secrecy, and after the committee of medical ethics had been consulted. In this way, alternative information on vision was sampled from other sources in 86 persons (12%). The visual acuity had often been examined in relation to application for or renewal of a driver's license (as it was the case in other studies, e.g. *Burg and Hill 1967 & 1978).* The validity of such data in relation to the actual visual situation (including use of glasses) "on the road" is disputable. Therefore, in spite of available information, these persons as a rule have been excluded in the analyses of the descriptive as well as the analytical study. The data primarily have been used in order better to characterise the non-responder group.

After these procedures there was still a lack of information on a remaining group (7%, cf. table 2.10) in relation to vision.

An attempt to collect information on this group via contact to the regional opticians was given up after advice from the committee of medical ethics.

3.3. Methods of investigation

The investigation was divided into:
- interviews
- clinical investigation
- study of police reports in selected cases.

Table 3.2. shows this procedure in summary.

The information was registered in a data scheme. The original Danish version is available at the author. The content is listed below, and the procedures in the visual tests described.

Table 3.2. Methods of investigation (Alsbirk, 1999).

I. Interview:	A. History of general diseases.	
	B. History of eye diseases.	
	C. History of traffic accidents.	
II. Collection of objective, clinical data:		
	A. Information from the casualty wards and hospitals.	
	B. Ophthalmological investigation:	
		Visual acuity and refraction.
		Ishihara colour test.
		Visual field by hand (Donders' test).
		Contrast sensitivity (Arden grating).
		Amsler chart for central defects.
		Stereopsis (Titmus test).
		Visual reaction time
		Ophthalmoscopy
	Optional:	
	Intraocular tension	
	Slit lamp investigation	
	Computerized perimetry (Competer)	
	e.t.c.	
III. Study of police reports:		
	Collection of relevant available information in relation to the accidents.	

3.3.0. Contents of the information scheme:

3.3.1. General information

Name, date of birth, sex, address, profession, driver's license information, driving habits for the last 2 years prior to the day of interview (annual driving in kilometres, proportion of professional driving and driving in rural areas), information concerning earlier visual acuity testing, time intervals since last visual test and the source of information.

3.3.2. History of eye diseases

Family histories, earlier diseases, night blindness, colour blindness, diplopia, history of refractive corrections (use of glasses/ contact lenses), and whether these were used at the time of the accident.

3.3.3. History of general diseases

-Earlier known diseases, especially diabetes mellitus, neurological diseases, psychiatric disorders, hypertension.
-regular use of medicine;
-use of medicine before the accident (especially use of psycho tropic drugs);
-regular use of alcohol;
-use of alcohol before the accident;
-information on blood alcohol records.

3.3.4. History of the accidents

-Police record registrations, type of road user, records on possible professional driving;
-Records on time and local information, weather, light, visibility and illumination at the scene of the accident;
-Records on the use of seat belts in the case of car drivers.

3.3.5. The medical consequences of the accidents

-For the persons interviewed and
-for other persons involved, these were categorised as follows (cf. chapter 4.3.):
a. unhurt.
b. treated as outpatients only (slight injury),
c. hospitalised, no injury of CNS *),
d. hospitalised, with CNS injury.
e. killed (i.e. dead within 30 days).
*) CNS = central nervous system.

3.3.6. Ophthalmological examination data

Introduction
In most cases, the interview and the investigation were performed in the Clinic of Ophthalmology at the Municipal Hospital of Aarhus (today: Aarhus University Hospital). Most of the probands were tested within 3 months after the traffic accidents. In a few cases, however, the investigation took place up to one year after, partly because of hesitation or convalescence following the accident and partly for geographical reasons.

In a few cases, the examination and the interview took place in the hospital department where a road user was hospitalised (n=3). Another group of road users (n=15) had to be investigated at home.

The choice of examination procedures:
All psychological and practical efforts have been used to maximise the participation rate. Therefore, as a rule, 45 minutes were set as a maximum for the interview and the clinical investigation. It was the primary purpose of this study to evaluate the quality of vision with the tests used by general practitioners today (whose responsibility it generally is to administer this testing). It was beyond the practical possibilities to make thorough evaluations of new, sophisticated visual examinations. However, some tests not ordinarily employed have been performed and evaluated.

In the following, the methods are listed and motivated:

3.3.6.1. Static visual acuity (monocular and binocular) testing, including classification of visual scores.

As a main rule this was tested by means of a Müller-Wedel projector in 6 m. in dark-room with dim light). In the majority of cases the 0.1 decimal step scaling system (0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.2) had been used. The test signs were alternating letters and ciphers.

In a smaller group, (e.g. in probands tested at home), the Snellen scaling system (6/60 = 0.1, 6/36= 0.17, 6/24 =0.25,6/18= 0.33, 6/12= 0.5, 6/9= 0.67, 6/6= 1.0 and 6/4.5= 1.33) was applied. When the test was performed outside the Department of Ophthalmology, a portable Snellen chart was used, illuminated with available light. None of the investigated road users were tested by both of these systems.

In a few selected cases (i.e. persons involved in accidents happening in back light), the visual acuity was also tested in glare. A Snellen chart, illuminated with 400 lux was used with the sunlight behind the chart. The general criterion for fulfilling a level of vision was the recognition of at least 3 out of 4 signs shown.

Static tests are of fundamental interest, since such methods are used worldwide for the purpose. In most, but not all countries, drivers at the time of the investigation were tested monocularly. In the road traffic, however, drivers perceive binocularly. Today in EU and in Norway, binocular testing of driver's visual acuity is the method used.

The future visual acuity measurement standards have been discussed in the Visual Function Committee of Consilium Ophthalmologicum Universale (Colenbrander, 1988). It was recommended to use or type sizes in steps of a constant ratio (geometric progression) of $1{:}10^{0.1}$ (or 1: 1.2589). This results in single steps of approximately 4:5, three steps results in approximately 1:2 and 10 steps in a factor 10 precisely.

The data collected were:
- a. visual acuity without optical correction;
- b. visual acuity with the optical correction used in the actual traffic accident;
- c. visual acuity with optimal optical correction.
- d. refractive data (the persons refraction and use of glasses or contact lenses in the accident).

*) a), b), and c) tested mono- and binocularly.

Remark: For simplification, results of *monocularly tested visual acuity*, corrected as in the accident (or in the control group: in last driving situation) have been classified according to the Danish rules as at the time of the investigation in 3 subgroups: "illegal", "limit" and "legal" (table 3.3):

Table 3.3. Legislation on visual acuity (v. a.) and driving, (Danish law, until July 1st. 1996) (Alsbirk, 1999). Monocular testing. Definitions:

			V.a. in better eye:	V.a. in fellow eye:
Legal	:		$\geq$ 0.5	$\geq$ 0.25
		or:	$\geq$ 0.67	$\geq$ 0.0
*Limit**	:		= 0.5	= 0.2
		or:	= 0.6	$\leq$ 0.2
Illegal	:		< 0.5	< 0.5
		or:	< 0.6	< 0.2

*) Strictly illegal, but this class is introduced to minimize false classification due to different test systems, see text.

In the following the classification "legal" is defined as the determined level for fulfilling the former visual requirements for a driver's license according to the Danish National Board of Health before July 1st 1996.

The classification "limit" is included as a borderline group to avoid a false classification. In most cases the decimal test system (0.1, 0.2,..1.2) had been used and in others (e.g. in probands tested at home) the Snellen-system (6/60, 6/36, 6/24,6/18, 6/12, 6/9, 6/6). A patient with a visual acuity at the borderline without such an intermediate group might be classified "illegal" in one system and "legal" in the other:

E.g. (visual acuity in right - left eye):

Decimal system:	*Snellen System:*
0.5 - 0.2 (illegal)	6/12 - 6/24 (legal)
0.6 - $\leq$ 0.2 (illegal)	6/9 - $\leq$ 6/24 (legal)

In most comparisons, the small "limit group" of drivers (only two of the accident involved drivers and one of the controls) therefore has been omitted in the statistical calculations.

Concerning *binocular visual acuity* the proportion of drivers with a score below 0.6 and 0.5 has been calculated. The first limit was proposed in the EU until 1989. However, the last limit (0.5) was the final adopted value (cf. p. 12).

3.3.6.2. Visual field testing
a. by hand ad modum Donders (all), tested monocularly; Donders' method is simple and used for the purpose in most countries.

b. by computerised, static perimetry (Competer I, selected cases). The test occasionally was carried out, when a visual field defect was suspected in Donders' screening test or when other clinical findings or facts motivated this (e.g. glaucoma patients). Sufficient time was not available to use this time consuming procedure in each person.

3.3.6.3. Other visual parameters
In the following tests, (a. b. c. and d.), the investigated persons were tested with the required correction for near. Contrast sensitivity, stereopsis and Amsler-chart tests were performed at a distance of 40 cm. with 400 lux direct illumination at the charts.

a. *Titmus stereopsis test,* (scale 40 - 800 seconds of arc).
This test has been selected out of several possibilities (e.g. the TNO test), since it is easy to quantify, generally accepted and mobile. The test divided the drivers into 9 performance categories, Titmus score 8 being the optimal level and score 0 being absolutely without depth perception.

b. *Arden Grading contrast sensitivity*
Contrasts in the surroundings are important visual stimuli, especially in dim light or darkness. Some authors have suggested contrast sensitivity as a relevant visual parameter for drivers (Evans & Ginsburg 1985, Rumar 1981). A persons contrast sensitivity is dependent on the spatial frequencies of the test objects. It is expressed by and the reciprocal of the contrast thresholds. In this study the test is performed as a binocular kinetic threshold estimation by gradually increasing the contrast stimuli (fig. 3.1.).

Fig. 3.1. *Testing contrast-sensitivity (Arden plates), see text. Photo: T. Drasbæk (K.E. Alsbirk, 1999).*

A threshold was assessed for each of 6 spatial frequencies (0.2, 0.4, 0.8, 1.6, 3.2, and 6.4 cycles per degree). These 6 scores were cumulated to simplify the statistical calculations (range 0 - 120), a high sum-score indicating a low contrast sensitivity. Double estimations have been performed in 13 cases, giving a standard deviation of 4.7 threshold scores.

c. *Amsler-Chart test* for central and paracentral visual field defects within 10-12^{o}, tested monocularly. Defects in this important part of the visual field are impossible to detect with Donders method and may be overlooked even in screening programs of computerised perimetry.

d. *Test of visual reaction time (V.R.T.)*
This examination was performed by the use of electronic equipment, (developed in the Institute of Forensic Medicine, the University of Aarhus) with a scale showing 1-10 seconds in steps of 1/100 sec. All tested persons were asked to perform the same standard procedure 10 times: by a red or green signal to press one of two buttons in a distance of 12 cm. (fig 3.2.).
This test is a kind of perception and response test (relevant for traffic situations), reflecting the state of the central nervous system (CNS) rather than being a visual test.

Double estimations have been performed in 14 cases, with a standard deviation of 0.1 second.

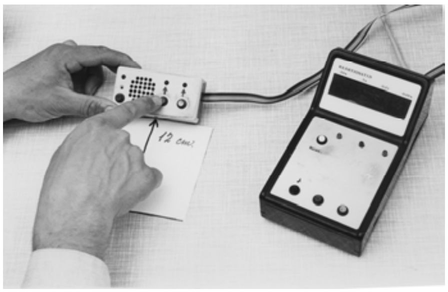

Fig 3.2. *Testing visual reaction time (VRT) (cf. text), Photo O. Jensen. (Alsbirk 1999)*

e. *Ishihara colour test,* tested binocularly in daylight at a distance of approx. 1 m. This mainly qualitative test is normally used to detect and classify congenital colour blindness. It has been included, since in some countries, drivers with certain colour vision defects are excluded from driving (cf. chapter 1.2.1).

f. *Orthoptic screening*
This test was performed as an H-pattern eye motility screening. In suspected cases, the test was extended (see below).

Further, a primary intention was to study dynamic visual acuity and dark adaptation, but for practical reasons this was not possible at the time of investigation. Hills and Burg (1977) have found a close correlation between static and dynamic visual acuity.

3.3.6.4. Ophthalmoscopy
Generally, this was performed as direct ophthalmoscopy without dilatation of the pupils. In an investigation like this, it was regarded as too burdensome for the road users to dilate the pupils. As known, dilatation of the pupils would have made this examination more sensitive. The term "abnormal ophthalmoscopy" was used by presence of pathological findings in the ocular fundus, (e.g. age related macular degenerations, retinal bleeding and infarcts, glaucomatous excavation of the optic disk etc.).

3.3.6.5. Optional
- Slit lamp investigation,
- Applanation tonometry,
- Additional orthoptic tests (Maddox Wing, cover/ uncover test) - Static visual acuity in glare against sunlight.

- Visual field by the use of automated static perimetry (Competer, first model).

3.3.7. Medical signs of general diseases:

As a rule no detailed medical tests (including measuring of blood pressure), neurological examination as well as psychological testing were performed. In one selected case, a CT-scanning was performed. Three patients were referred to neurological examination.

3.3.8. Evaluation of a possible association between visual parameters and accidents

Evidently, such an evaluation cannot be objective. However, it was considered worthwhile to try to estimate such an association in each proband and accident case. This has been attempted. Relevant accident reports and estimations are referred in appendix C. They are not given as scientific results, but as a kind of illustration and a contribution to the discussion.

This final evaluation was based on:

1. an interview of the proband and the involved active partners.
2. Basic accident information from the front page of the police report, concerning: local geography, visibility, time of accident, type of roads, the weather, etc.;
3. a detailed study of the entire police report in selected cases (104 out of 244 accidents registered by the police);
4. optional: inspection in local places of accidents.

3.4. Examination of the control group

In the control group, the same examination procedure as described above was used. However it became more simple since no accident information had to be considered. Instead of visual acuity, corrected as at the time of accident, this parameter was tested with the correction used in relation to the last driving situation.

3.5. Earlier accident records

From the beginning, it was attempted to record accident data from the last five years in all drivers. However, it was the impression that the drivers in many cases belittled earlier accidents. The information thus obtained from car drivers themselves seemed to be very unreliable and inconsistent. This impression has later been supported by the findings of Owsley et al. (1991) and McGwin et al. (1998). A very low correlation (r = 0.11) was found between the number of accidents reported by the drivers and the numbers registered on the state records..

Attempts were made to collect information from the records of the police and insurance company registers, but due to the law of registration, these were in principle not accessible. Therefore, this had to be given up in the meantime.

3.6. Study of police reports

Police reports, if available and after permission from the Ministry of Justice, were studied at the local police department to collect more detailed information on the traffic accidents.

3.7. Data management and statistics

The data obtained were primarily recorded and placed in an SPSS data base but were later transcribed as an ASCII file to the PC data base analysis program "Reflex, the Analyst", (Borland) (Alsbirk, 1987).

Some of the computer formulas used for calculated secondarily derived parameters in the data base are listed in appendix E.

For parametric and non-parametric *statistical analysis*, the program used was "Medstat", (Wulff and Schlichting 1988). For 2 x 2 contingency tables, Fisher's exact probabilities (two sided tests) were usually calculated and in relevant situations odds-ratios were estimated with 95% confidence limits (Foldspang et al. 1986).

N x 2 tables were tested for trends by the use of a Mann-Whitney rank sum test (Wulff and Schlichting, 1988).

For materials with approximately Gaussian distribution (contrast sensitivity scores, optical refraction and visual reaction time) means and standard errors were conventionally calculated.

For the *multiple logistic regression analyses* in the case/control study, programme "Epicure", (Preston, Rubin and Pierce, 1991) was used, cf. chapter 2.6 and appendix D 2.

Other statistical methods used are briefly commented on in appendix D 1.

Two biostatisticians, Associate Professor, M. Sc. Anders Holst Andersen and Professor, Lic. Scient. Michael Væth, Department of Theoretical Statistics, the University of Aarhus, functioned as statistical consultants.

* * *

4. RESULTS

Introduction. In order to present a differentiated analysis, this chapter will be subdivided into various types of aspects, followed by an integrated conclusion of the results observed.

The sequence will be as outlined:

4.1. Visual parameters in relation to the traffic accidents in various subgroups of drivers and types of accidents *(the descriptive study)*.
4.2. Visual parameters in elderly accident-involved drivers compared to a control group *(the case/control study)*.
4.3. Drivers with " borderline" and not optimised visual acuity. - Practical and legislative aspects.
4.4. The medical consequences of the accidents. Comparison of accidents with and without visual problems in the drivers.
4.5. General health parameters found in the study and their relation to the traffic accidents.

Case reports, including an analysis of possible association between traffic accidents and a) visual problems of car drivers and b) various medical conditions are published in appendix C. 2.

4.1. Visual parameters in relation to the traffic accidents in various subgroups of drivers and types of accidents (the descriptive study)

Since the *drivers* are by far the most important, especially in relation to the injury inflicted on other road users, this group will be in focus for a detailed analysis. Furthermore, this group is of the highest importance in relation to legislative perspectives.

Visual factors in drivers in relation to:
1) Driver's age.
2) Driver's sex.
3) Visual reaction time (VRT) and mutual associations between certain visual parameters.
4) Place of accident: a) light conditions, b) visibility conditions, and c) type of roads.
5) Driving parameters: a) annual driving in kilometres; b) urban/rural driving; c) type of driving: 1. private, 2. professional with/without transport of persons.
6) Refraction aspects.

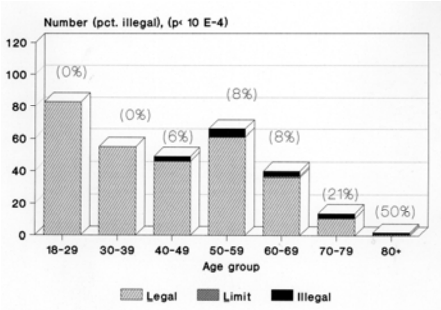

Fig. 4.1. Static visual acuity at the time of the accident, tested monocularly, vs. drivers age and classified in relation to legislative requirements before 1996 (Solid : pct. illegal, p< 10 E -4). (K.E. Alsbirk, 1999).

- The *material* of drivers analysed consists of 309 investigated probands out of 405 (cf. table 2.8). 187 were below 50 and 122 ≥ 50 years of age.

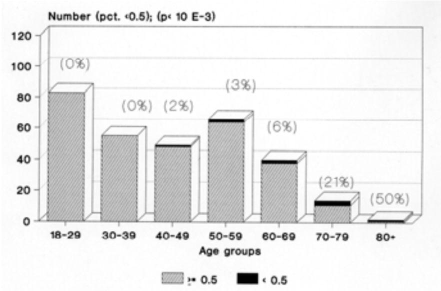

Fig. 4.2. Static binocular visual acuity at the time of the accident vs. age. (Solid: pct < 0.5 in the individual age group, p < 10 E-3) (K.E. Alsbirk, 1999)

4.1.1. Static visual acuity, refraction and contrast sensitivity in relation to age

Age relationship has been studied according to various *static visual acuity* parameters (table 4.1)

In the age group < 50, 3 (1.6%) of the car drivers had illegal visual acuity (in relation to previous Danish legislation) when tested monocularly. One (0.5%) had binocular visual acuity < 0.5 (and 2 (1%) <0.6). From age 50 - 69, drivers with illegal visual acuity numbered 8

Table 4.1. Static visual acuity corrected as at the time of accident in different age groups of investigated drivers (phase I and II combined) (Alsbirk 1999).

a. Monocular test

V.a. in relation to law:	18-29*)	30-39	40-49	50-59	60-69	70-79	80+	Total	Age: Median	(range)
Illegal :	0 (0)	0 (0)	3 (6)	5 (8)	3 (8)	3 (21)	1 (50)	15 (5)	61	(41-80)
Limit :	0 (-)	0 (-)	0 (-)	0 (-)	1 (3)	0 (-)	1 (50)	2 (1)	72	(63-81)
Legal :	83(100)	55(100)	46 (94)	61 (92)	36 (90)	11 (79)	0 (-)	292 (94)	40	(14-78)
Total :	83(100)	55(100)	49(100)	66 (100)	40 (100)	14 (100)	2 (100)	309(100)	85	

Illegal versus legal: z'=3.98, $p<10^{-4}$ (Mann-Whitney test)

b. Binocular test

Binocular visual acuity:	18-29*)	30-39	40-49	50-59	60-69	70-79	80+	Total:	Age: Median	(range)
0.2-0.29 :	0 (-)	0 (-)	0 (1)	0 (0)	1 (3)	1 (7)	1 (50)	3 (1)	75	(67-80)
0.3-0.39 :	0 (-)	0 (-)	0 (1)	0 (0)	1 (3)	1 (7)	0 (-)	2 (1)	69.5	(66-73)
0.4-0.49 :	0 (-)	0 (-)	1 (2)	2 (3)	0 (-)	1 (7)	(-)	4 (1)	52.5	(44-76)
0.5-0.59 :	0 (-)	0 (-)	1 (2)	3 (5)	3 (8)	4 (29)	0 (-)	11 (4)	63	(41-75)
0.6 :	0 (-)	0 (-)	1 (2)	2 (3)	2 (3)	2 (14)	1 (50)	8 (3)	68	(44-88)
0.67-0.9 :	11 (13)	5 (9)	6 (12)	16 (24)	10 (25)	2 (14)	0 (-)	50 (16)	51	(21-77)
1.0-1.1 :	27 (33)	22 (40)	23 (47)	34 (52)	16 (40)	3 (21)	0 (-)	125 (41)	45	(18-78)
1.2· :	45 (54)	28 (51)	17 (35)	9 (14)	7 (18)	0 (-)	(-)	106 (34)	32.5	(14-69)
Total :	83 (100)	55 (100)	49 (100)	66 (100)	40 (100)	14 (100)	2 (100)	309 (100)	42	(14-81)
Median :	1.2	1.2	1.0	1.0	1.0	0.55	0.4	1.0		

<0.5 vs. ≥ 0.5: z'=5.57 , $p< 10^{-6}$ (Mann-Whitney test)

c. Refraction (mean of two eyes):

	18-29*)	30-39	40-49	50-59	60-69	70-79	80+	Total
Mean :	-0.2	-0.5	-0.5	1.2	1.4	0.4	1.4	0.2
N= :	82	55	49	65	40	14	2	307
s.d. :	1.5	1.4	2.0	1.9	1.9	2.2	0.1	1.9
s.e.m. :	0.17	0.19	0.29	0.23	0.30	0.59	0.07	0.11

(age < 50 vs. age ≥ 50: z'= 8.1 , $p<10^{-6}$, Mann-Whitney test).

*) one driver was 14 years old!

(8%). Four (4%) had binocular visual acuity < 0.5 (and 10 (9%) < 0.6). From age 70 and above, 4 (25%) had visual acuity below the Danish limit and binocular visual acuity < 0.5. (8 (50%) had binocular visual acuity below 0.6). cf. fig 4.1 and 4.2.

A highly significant reduction of visual acuity with age, corrected as at the accident, was demonstrated, whether tested monocularly ($p< 10^{-4}$) or binocularly ($p< 10^{-6}$), cf. table 4.1. Thus age is an extremely important factor to adjust for in relation to vision. In the case/control study, driver's age is a so called "design variable" in the multivariate analyses.

Refraction error values increased with age, drivers ≥ 50 being significantly more hyperopic (+ 1.2) than the young drivers (-0.4) ($p<10^{-6}$, cf. table 4.1.c). It must be emphasised, that none of the drivers were tested in cycloplegia, a fact that might partly explain the observed age difference. A secular trend toward myopia in young adults (Fledelius 1988) may be another factor. Further, the *contrastsensitivity* (expressed by its reciprocal value, the contrast threshold) decreases significantly with age ($p< 10^{-6}$) cf. appendix F, table 10.1.

Table 4.3. Visual reaction time (mean of 10 tests), contrast sensitivity and refraction in relation to static visual acuity, tested monocularly (accident-involved drivers, unknown excluded) (Alsbirk 1999).

		Static visual acuity:			
Visual reaction time:		**Illegal**	**Limit**	**Legal**	**Total**
0-0.49	:	0 (0)	0	18 (6)	18
0.5-0.74	:	8 (53)	1	146 (52)	155
0.75-0.99	:	1 (7)	0	94 (33)	95
1.0-1.24	:	4 (27)	1	19 (7)	24
1.25-2.5	:	2 (13)	0	4 (1)	6
Total	:	15 (100)	2	281 (100)	298
Mean:	:	0.92	0.85	0.74	0.75
s.d.:	:	0.38	0.18	0.17	0.17
s.e.m.:	:	(0.1)	(0.13)	(0.01)	(0.01)

Illegal versus legal: (z'=1.22, p· 0.22, Mann-Whitney test)

Contrast sensitivity:					
	(N−)	(13)	(2)	(287)	(302)
(Threshold	-mean	77.2	87	68	68.7
scores)	s.d.	15.9	17.0	8.5	10.4
	s.e.m.:	(4.4)	(12.0)	(0.5)	(0.6)

Illegal versus legal: (z'=2.05, p· 0.04, Mann-Whitney test)

Refraction:	(N=)	(15)	(2)	(290)	(307)
(Diopters)	mean	0.94	1.25	0.2	0.24
	s.d.	1.98	-	1.91	1.93
	s.e.m.	(2.03)	-	(0.11)	(0.11)

Illegal versus legal: (z'=1.61, p=0.11, Mann-Whitney test)

4.1.2. Visual parameters in male and female drivers

As seen in table 4.2, age was comparable in the two sexes (p=0.8). None of the visual factors showed any significant difference. However, a longer period since last visual test was found in males (13% > 10 years vs. 7% in females, p=0.008). In the multivariate analyses of the case/ control study, the driver's sex is also included as a design variable.

Table 4.2. Age and various visual parameters in male and female proband drivers, phase I and II combined (N=309) (Alsbirk 1999).

		Males: (n=221)	Females: (n=88)	p =	(statistical method):
Age, (median)	:	41	42	0.82	(Mann-Whitney test *)
Visual parameters:					
Monocularly tested visual acuity (% illegal)	:	5.5%	3.4%	0.66	(Fisher's exact)
Binocular visual acuity (pct. < 0.5)	:	4.1%	0%	0.43	(Mann-Whitney test)
Contrast thresholds (median values)	:	68	67.5	0.48	(Mann-Whitney test)
Unilaterally reduced visual acuity (cf. text)	:	8.1%	5.6%	0.63	(Fisher's exact).
Stereopsis (≥ 80 sec. of arc.)	:	36%	41%	0.88	(Mann-Whitney test)
Years since last visual test(pct. >10 y.)	:	13.3%	6.8%	0.008	(Mann-Whitney test)
Central visual field defects (pct.)	:	11.4%	5.7%	0.19	(Fisher's exact)
Visual field defects a.m. Donders (pct.)	:	2.3%	2.3%	1.0	(Fisher's exact)
Residual visual capacity (pct. ≥ 0.25)	:	24%	21%	0.42	(Mann-Whitney test)
Refraction, median	:	0	0	0.09	(Mann-Whitney test)

*) A Mann-Whitney test has been applied, when more than two classes were compared.

4.1.3. Static visual acuity in relation to visual reaction time (VRT) and mutual associations between certain visual parameters

One might expect that drivers with illegal visual acuity to some extent were the same as those with longer visual reaction time. This hypothesis is only partly confirmed, since the mean *visual reaction time (VRT)* was not significantly prolonged in drivers with illegal visual acuity as compared to those with legal vision (p= 0.22, cf. table 4.3).

The *contrast thresholds* were significantly elevated (i.e. lower sensitivity) in the group of drivers with illegal visual acuity. This group of drivers is older than the rest (cf. table 4.1).

VRT as well as contrast thresholds from age 40 increase significantly with age (cf. appendix F, table 10.1 and 10.2).

No significant difference was found in *refraction,* although the illegal drivers tended to be slightly more hyperopic, again reflecting their higher age, cf. table 4.1.

Thus *high age* obviously is an important main factor.

Concerning *acquired colour vision defects* and *macular degenerations*, it is a question of age association too. Among the 27 drivers, with abnormal colour vision, tested by Ishihara test, this finding was so far unknown to the drivers in 17 (63%).

Table 4.4. Central and paracentral defects (monocularly tested) in 17 drivers involved in accidents with hitherto unknown colour vision defects (binocularly tested) *) (Alsbirk 1999).

Recently discovered colour vision defects:

a.Amsler chart:		-	+	?	Total
Normal	:	241 (89)	12 (71)	24	277
Abnormal	:	25 (9)	5 (29)		30
Unknown	:	2 (7)	0		2
Total	:	268 (100)	17 (100)	24	309

Odds-ratio = 4.1 (1.3-12.3), p =0.047 (Fisher's exact*)

b.Ophthal-moscopy: pathology?		-	+	?	Total
No	:	223 (83)	8 (47)	21	252
Yes	:	43 (16)	9 (53)	3	55
Unknown	:	2	(1)	0	82
Total	:	268 (100)	17 (100)	24	309

Odds-ratio = 5.9 (2.1-16.0), p =0.002 (Fisher's exact*)

*)known values tested.

Drivers with central and paracentral defects, detected by means of the Amsler chart as well as drivers with pathological ophthalmoscopy findings in the posterior pole were significantly over-represented in this group (table 4.4). Thus among drivers, the acquired colour vision defects are mainly caused by age related macular degenerations. This is a well known fact in the elderly population in general.

Conclusions: This study confirms a generally known trend, that visual problems increase with age, also in a group of drivers having been involved in serious traffic accidents.

For many of the visual parameters investigated, some mutual associations were found, due to several, partly inter-related visual problems in the same drivers. High age in these drivers was often an important main factor.

This is further analysed in the logistic regression analyses of the case/control study.

4.1.4. Place of accident

4.1..4.1. Accident circumstances

Basic information on the accidents has been given in chapter 2.3. Not all details can be covered by this study, but such information as concerns visibility, weather and place of the accident were registered. This is of relevance as *background information* when the accidents involving the low vision group of drivers are put into focus.

Table 4.5. Lighting conditions at the scene of accidents (N=359) in relation to various external factors (Alsbirk 1999).

		Darkness:	Twilight:	Daylight:	Unknown:	Total:
Distribution	:	89	31	228	11	359
(pct.)		(24.8)	(8.6)	(63.5)	(3.1)	(100)
(pct. in columns -vertical)						
Visibility:						
Reduced	:	19 (21)	3 (10)	19 (9)		41 (11.4)
Normal	:	67 (75)	28 (90)	206 (90)		301 (83.8)
Unknown	:	3 (3)	0 -	3 (1)	11	17 (4.7)
Total	:	89(100)	31(100)	228(100)	11	359 (100)
(Visibility reduced vs. normal: z'= 3.08, p< 0.01, Mann-Whitney test)						
Weather:						
No fall of rain	:	53 (60)	22 (71)	178 (78)		253 (70.5)
Rain	:	22 (25)	8 (26)	40 (17)		70 (19.5)
Fog	:	5 (6)	0	2 (1)		7 (1.9)
Snow	:	6 (7)	1 (3)	5 (2)		12 (3.3)
Unknown	:	3 (3)	0 (-)	3 (1)	11	17 (4.7)
Total	:	89(100)	31(100)	228(100)	11	359 (100)
(Snow, fog, rain vs. no fall of rain: z'= 3.13, p< 0.01, Mann-Whitney test)						
District of accident:						
Urban district	:	64 (72)	27 (87)	198 (87)	4	293 (81.6)
Rural district	:	23 (26)	4 (13)	30 (13)	2	59 (16.4)
Unknown	:	2 (2)	0	0	5	7 (1.9)
Total	:	89(100)	31(100)	228(100)	11	359 (100)
(Urban vs. rural district: z'= 2.59, p< 0.01, Mann-Whitney test)						
Scene of accident :						
Densely built	:	34 (38)	19 (61)	114 (50)	1	68 (18.9)
Lightly -	:	21 (24)	6 (19)	61 (27)	2	90 (25.1)
Scattered -	:	32 (36)	6 (19)	52 (23)	2	92 (25.6)
Unknown	:	2 (2)	0	1 -	6	9 (2.5)
Total	:	89(100)	31(100)	228(100)	11	359 (100)
(Dense vs. scattered builded: z' = 2.06, p< 0.05, Mann-Whitney test)						
Type of roads:						
4 way crossroads	:	22 (25)	16 (52)	83 (36)	0	121 (33.7)
Other crossroads	:	14 (16)	8 (26)	57 (25)	1	80 (22.3)
Entrance/exit	:	2 (2)	1 (3)	15 (7)	-	18 (5.0)
Curved road	:	12 (13)	1 (3)	11 (5)	-	24 (6.7)
Straight road	:	36 (40)	5 (16)	54 (24)	1	96 (26.7)
Other types	:	1 (1)	0	6 (3)	0	7 (2.0)
Unknown	:	2 (2)	0	1 -	9	12 (3.6)
Total	:	89(100)	31(100)	228(100)	11	359 (100)
(Intersections vs. straight/curved ways: z'= 3.38, p< 0.001, Mann-Whitney test)						

In table 4.5, data concerning 1) visibility, 2) weather, 3) place of accident, 4) type of ribbon development and 5) type of roads are listed and analysed in relation to the actual lighting conditions (darkness, twilight and daylight).

Of a total of 359 accidents, 25% happened in rain, fog or snow. The visibility was estimated as reduced in 11.4%. Four out of five (81.6%) of the accidents happened in urban areas. Sixty-one percent happened in some kind of road intersections. As can be seen, 25% out of all accidents happened in darkness, 8.6% in twilight and 63.5% in daylight (3% unknown).

Accidents connected with reduced visibility, rain, fog or snow were significantly more common in darkness than in daylight. The same trend was found in accidents in rural areas and in scenes with scattered or no buildings and accidents happening in curved or straight ways. In only about half of the 120 accidents in twilight or darkness was the road illumination on the scene characterised as good by the police or (in non-police reported accidents) the road users (table 4.6).

Table 4.6. Road illumination in 120 accidents in twilight or darkness.
(as estimated by police or the involved road users, Alsbirk 1999).

Lighting conditions	:	**Darkness:** (pct)	**Twilight:** (pct)	**Total:** (pct)
No illumination	:	20 (22)	5 (16)	25 (21)
Illumination on, good	:	45 (51)	12 (39)	57 (48)
Illumination on, bad	:	17 (19)	4 (13)	21 (18)
Illumination not on	:	4 (4)	7 (23)	11 (9)
Unknown	:	3 (3)	3 (10)	6 (5)
Total	:	89 (100)	31 (100)	120 (100)

4.1.4.2. Lighting and visibility

To estimate the influence of external factors on the visual perceptive process at the time of the accident an analysis has been performed in relation to such parameters. In the tables 4.7 to 4.12 the lighting and visibility conditions as well as the type of roads have been related to various relevant visual parameters in the drivers.

No significant difference in visual parameters investigated could be found in the accidents happening in *darkness, twilight or daylight* (table 4.7). The median age of the phase I drivers with accidents in darkness (32.5) was insignificantly lower than in twilight (38) and significantly lower than in daylight (39), ($p < 0.05$, Mann-Whitney test). Focussing on the visibility at the scene of the accident, the analysis showed some interesting points. The *median age* of the phase I drivers involved in accidents with reduced visibility was significantly lower (30) than the rest (37), ($p< 0.05$, Mann-Whitney test). These observations suggest that elderly drivers prefer to stay at home under bad visibility conditions as well as in darkness.

In table 4.8., some visual variables have been analysed in relation to the visibility:

The drivers involved in accidents with reduced visibility (partly due to fog, rain, snow etc.) had a myopic average *refraction* of -0.66. This was significantly (p=0.01) and about one diopter lower than in the group of clear visibility accidents (+0.37). After corrections for age, however, this difference was only present in drivers aged ≥60 ($p< 0.05$).

No significant differences were found between the drivers with respect to *the possessing of glasses* (p=0.84) and in that case, the *use of glasses* (p=0.92, Fisher's exact test).

Static visual acuity and stereopsis, tended to be slightly better in drivers involved in accidents with reduced visibility, although not to a significant degree (cf. table 4.8). The same trend was found regarding *contrastsensitivity,* (p= 0.2) as well as *unilaterally reduced visual acuity* (i.e. visual acuity < 0.25 in the worse eye and ≥ 0.4 in the fellow eye), (odds-ratio = 3.3, (0.5 - 22.4) and *central visual field defects* (odds- ratio = 1.3, (0.4- 4.5)).

Looking at the *"residual visual capacity"* (the difference between

Table 4.7. Lighting conditions at the scene of accident in relation to visual factors of the involved drivers (Alsbirk 1999):

		Lighting: Darkness	Twilight	Daylight	Total
Static visual acuity					
Illegal	:	3 (4)	0 (0)	12 (6)	15
Limit	:	1 (1)	0 (-)	1 (.5)	2
Legal	:	69 (95)	29 (100)	194 (94)	292
Total	:	73 (100)	29 (100)	207 (100)	309
(Illegal vs. legal: z'=0.91, p=0.36, Mann-Whitney test)					
Stereopsis, Titmus test (sec. of arc.)					
≥80	:	33 (45)	5 (17)	77 (37)	115
<80	:	39 (53)	22 (75)	125 (60)	286
Unknown	:	1 (1)	2 (7)	5 (2)	8
Total	:	73 (100)	29 (100)	207(100)	309
(≥ 80 vs. < 80: z'=0.48, p> 0.6, Mann-Whitney test)					
Contrast sensitivity (threshold scores)					
0-40	:	0 (-)	0 (-)	5 (2)	5 (2)
50-74	:	49 (67)	22 (76)	149 (72)	220 (71)
75+	:	22 (30)	6 (21)	49 (24)	77 (25)
Unknown	:	2 (3)	1 (3)	4 (2)	7 (2)
Total	:	73 (100)	29 (100)	207(100)	309 (100)
Mean	:	70	68	69	69
s.d.	:	10.3	7.9	10.1	10.0
(s.e.m.)	:	(1.2)	(1.5)	(0.7)	(0.6)

Darkness vs. twilight: z'= 1.42, p=0.16, (Mann-Whitney test)
darkness vs. daylight: z'= 0.96, p=0.3, Mann-Whitney test).

Refraction (diopters, unknown excluded):

		Darkness	Twilight	Daylight	Total
(N=)	:	(72)	(29)	(206)	(307)
mean	:	0.14	0.07	0.7	0.24
s.d.	:	1.84	1.35	2.01	1.92
s.e.m.	:	0.21	0.25	0.14	0.11

Darkness vs. twilight: z'= 0.22, p=0.82, (Mann-Whitney test)
darkness vs. daylight: z'= 0.91, p=0.36, Mann-Whitney test).

Table 4.8. Visibility at the scene of the accident in relation to the drivers' vision: (Alsbirk 1999).

		Visibility: Reduced	Clear	Total
Refraction: (Diopters)				
mean	:	- 0.66	0.37	0.24
(N=):	:	(38)	(271)	(309)
s.d.:	:	1.75	1.91	1.92
(s.e.m.)	:	(0.28)	(0.12)	(0.11)
(Reduced visibility vs. clear: z'= 2.5, p=0.01, Mann-Whitney test)				
Visual acuity:				
Illegal	:	1 (3)	14 (5)	15 (5)
Limit	:	0 (-)	2 (1)	2 (1)
Legal	:	37 (97)	255 (94)	292 (94)
Total	:	38 (100)	271 (100)	309 (100)
(Illegal vs. legal: Odds-ratio = 2.0 (0.3-15.3), p= 0.85, Fisher's exact)				
Binocular visual< 0.5	:	1 (3)	8 (3)	9 (3)
acuity >=0.5	:	37 (97)	263 (97)	300 (97)
Total	:	38(100)	271 (100)	309 (100)
(clear vs. reduced: ≥ 0.5: z' = 1.93, p= 0.054, Mann-Whitney test)				
Stereopsis (sec. of arc.)				
≥80	:	10 (26)	105 (39)	91 (37)
<80	:	27 (71)	159 (59)	213 (60)
Unknown	:	1 (3)	7 (3)	8 (3)
Total	:	38(100)	271 (100)	309 (100)
(≥80 vs. < 80 : z' = 1.18, p= 0.18, Mann-Whitney test).				
Contrast sensitivity (threshold scores, unknown excluded)	:			
mean	:	66.0	69.3	68.8
(N)	:	(38)	(264)	(302)
s.d.	:	8.7	10.1	10.0
(s.e.m.)	:	(1.4)	(0.62)	(0.57)
(Reduced visibility vs. clear: z'= 1.27, p=0.2, Mann-Whitney test).				

Table 4.9. Residual visual capacity* of drivers in relation to visibility. (Alsbirk 1999).

Residual visual capacity :		Visibility: Reduced:	Normal:	Total:
0-0.19	:	36 (95)	200 (74)	236 (76)
0.2-0.39	:	1 (3)	47 (17)	48 (16)
0.4-0.59	:	0 (-)	14 (5)	14 (5)
0.6-0.79	:	1 (3)	9 (3)	10 (3)
0.8-1.0	:	1 (-)	1 (0)	1 (0)
Total	:	38 (100)	271(100)	309 (100)
Mean	:	0.04	0.11	

(Visibility reduced vs. normal: z'= 2.77, p< 0.01 , Mann-Whitney test).

*) Optimum binocular visual acuity minus binocular v. a. at the time of the accident.

binocular visual acuity at the accident and after optimal correction), this parameter turned out to be significantly larger in the drivers involved in accidents with a good visibility (table 4.9). The difference was still present after corrections for age in drivers aged 30-59 (p=0.05, Mann-Whitney test), doubtful below age 30 (p= 0.07) but eliminated above age 60 (p= 0.84).

Conclusion: No correlation could be demonstrated between the investigated visual parameters in relation to lighting conditions at the time of accident.

The results show that when involved in accidents with reduced visibility, the drivers were significantly younger with a tendency to correspondingly better visual functions. Additionally they seemed to have more adequate optical corrections and to be more myopic than in accidents in clear visibility.

4.1.4.3. Type of roads

One could expect that drivers involved in accidents in *road intersections* had more visual problems than drivers involved in accidents in *straight or curved roads.*

However, when these two groups are compared, no significant difference in *static visual acuity* is found, whether tested monocularly or binocularly (table 4.10). Neither did the driver's refraction (p>= 0.7) differ. The fraction of drivers with *central visual defects* tended to be insignificantly higher in intersection accidents (11.7% vs. 5.6%, p= 0.07), as were the drivers with reduced contrastsensitivity (p= 0.06). Also the proportion of drivers with unilaterally reduced visual acuity was elevated (7.6% vs. 2.8%, p=0.17), although insignificantly.

Focussing upon the subgroup of intersection accidents in which the drivers had *unilateral visual reduction* (<0.25 in the worse eye and ≥ 0.4 in the fellow eye) reveals 17 accidents (15+2, see below), analysed in table 4.11. This is based on the accident case histories summarised in table 4.12.

Two cases (II-V-574 and II-V-937) did not strictly fulfil the inclusion criteria for the descriptive study having not being examined personally by the author. Yet, since the visual information are safe, based on ophthalmologists investigations, they are (as an exemption) included in these small analyses.

In 65% the collisions happened from the left side, in 18% from the right side, and in 17% from the front. Fourteen were side collisions. Twelve of these (86%) happened on the same side as the visual defect of the driver, and only 2 (14%) on the opposite side (Odds ratio = 6). This difference is statistically significant, (p=0.013 double-sided binomial test).

Eleven (79%) of the same 14 side collisions happened from the left side (p= 0.06, double-sided binomial test).

Table 4.11. Seventeen crossroads accidents in which the involved drivers had a unilateral visual defect *) (Alsbirk 1999).

a. Side of visual defect:

	Collision side: Right:	Left:	Front:	Total:
Right :	3 (100%)	2 (18%)	0	5
Left :	0 -	9 (82%)	3	12
Total :	3 (18%)	11 (65%)	3 (17%)	17 (100%)

(Collision in left side vs. right side: p = 0.057, Exact binomial, two tail test).

b. Collision side in relation to visual defect:

	Observed:	Expected:	Relative risk:
Same side :	12 (86%)	7	6
Opposite side:	2 (14%)	7	1
Total :	14 (100%)	14	

(Same side vs. opposite side: Odds ratio = 6, p = 0.013, Exact binomial, two tailed test).

*) cf. Table 4.12. In two accidents the visual information was based on investigations by general ophthalmologists.

Table 4.10. Type of roads at the scene of accident in relation to visual parameters of the driver (N=309 accident-involved drivers). Statistical tests: accidents at intersections vs. straight and curved ways (Alsbirk 1999).

	Type of roads: Intersections:	Straight roads:	Curved roads:	Misc.:	Total:
Static visual acuity:					
Illegal	10 (5)	4 (5)	1 (5)	0	15 (5)
Limit	2 (1)	0 (-)	0 (-)	0	1 (1)
Legal	185 (94)	81 (95)	21 (96)	5	292 (94)
Total	197 (100)	85 (100)	22 (100)	5	309 (100)
(Illegal vs. legal: Odds-ratio= 1.1 (0.36-3.13), p=1.0, Fisher's exact)					
Binocular visual acuity:					
<0.5	6 (3)	2 (2)	1 (5)	0	9 (3)
>=0.5	191 (97)	83 (98)	21 (95)	5	300 (97)
Total:	197 (100)	85 (100)	22 (100)	5	309 (100)
	(p= 1.0, Fisher's exact)				
Central defects (Amsler charts)					
Abnormal	23 (12)	5 (6)	1 (5)	1	30 (10)
Normal	173 (88)	79 (93)	21 (95)	4	277 (90)
Unknown	1 (1)	1 (1)	0 (0)	0	2 (1)
Total	197 (100)	85 (100)	22 (100)	5	309 (100)
(Abnormal vs. normal: Odds-ratio= 2.7 (1.0-6.9), p= 0.07, Fisher's exact)					
Unilaterally reduced v. a.; ***v. a. in worse eye:***					
<0.25 (doub. sided)**	3 (1)	1 (1)	1 (4)	0	5 (2)
<0.25 (one sided)***	15 (7)	3 (3)	0 (0)	0	18 (6)
>0.25	179 (91)	81 (95)	21 (96)	5	286 (93)
Total	197 (100)	85 (100)	22 (100)	5	309 (100)
** (v. a.: < 0.25/ <0.4); *** (v. a.: <0.25/ ≥ 0.4)					
(One sided vs.≥ 0.25: Odds-ratio= 2.85 (0.85-2.85), p= 0.14, Fisher's exact)					
Refraction (Diopters) mean:	0.21	0.29	0.07	1.2	0.24
(N=):	(195)	(85)	(22)	(5)	(307)
s.d. :	1.97	1.90	1.41	1.85	1.92
s.e.m.:	0.10	0.59	0.3	0.82	0.11
	(z'= 0.37, p = 0.7, Mann-Whitney test)				
Contrast sensitivity: (threshold scores)					
mean:	68.2	79.0	69.3	74.8	68.8
(N=):	(194)	(82)	(21)	(5)	(302)
s.d. :	10.2	9.6	8.8	10.0	10.0
s.e.m.:	0.73	1.01	1.9	4.38	0.57
	(z'=1.89, p= 0.06, Mann-Whitney test).				

Table 4.12. Drivers with unilateral visual impairment involved in crossroads accidents (N=17, two of them* based on information from general ophthalmologist) (Alsbirk 1999).

CASE No. (**)	Sex/ age:	Accident v.a o dxt/o. sin:	Side of Collision:	(Relation)	Estimated association: (***)	Stereo opsis : (****)	Ophthalmological and other visual findings:
I-V-64	M-58	0.4/ 0.05	left	(same)	probable	0	Recently left branch vein thrombosis with scotoma.
I-VM-929	M-76	0.4/ 0.2	front	-	probable	1	Bilat. cat./a.m.d. *****, right paracentral scotoma.
I-V-991	M-81	0.5/ 0.2	left	(same)	probable	3	Uncorrected hyperopia, cataract, misty darkness.
II-V-91	F-56	0.5/ <0.05	left	(same)	possible	2	Severe left side amblyopia.
II-V-115	F-41	0.1/ 0.67	right	(same)	possible	2	Severe right side amblyopia due to excessive myopia
II-V-338	M-63	0.5/ 0.2	left/front	(same)	possible	8	Uncorrected hyperopia.
II-V-397	M-50	1.0/ <0.05	left	(same)	possible	0	Left side amblyopia (astigmatism).
II-V-399	M-55	0.1/ 0.4	left	(oppos.)	possible	0	Right side amblyopia and bilateral corneal scars.
II-V-499	M-62	0.5/ 0.05	left	(same)	possible	0	Left amblyopia, no glasses, ext. visual obstruction.
II-V-574*	M-41	-LP/ 1.25	right	(same)	possible	0	Right side amaurosis (due to retinal detachment).
II-V-598	M-64	0.8/ <0.05	left	(same)	possible	0	Left side amblyopia.
II-V-926	F-51	0.8/ 0.1	left	(same)	possible	0	Left amblyopia and traum. cataract (in childhood).
II-V-937*	M-56	<0.05/ 0.7	right	(same)	possible	0	Right side amblyopia.
II-V-949	F-56	0.7/ 0.2	left	(same)	possible	0	Left side amblyopia and ext. visual obstruction.
III-V-453	F-20	0.1/ 0.9	left	(oppos.)	none	0	Right side amblyopia.
III-V-540	M-44	1.0/ 0.1	front	-	none	8	Uncorrected hyperopic astigmatism.
IV-VMA-301	M-43	1.0/ 0.2	front	-	none	3	Left side amblyopia, tired and drunk.

**) Cf. appendix C for classification and details.
***) Overall estimates on the vision/ accident association, not necessarily related to the unilateral impairment, cf. appendix C.
****) Modified Titmus score (0-8. 0= no stereopsis, 8 = full stereopsis).
*****) cat.= cataract, a. m. d.= age related macular degeneration.

Discussion: In this analysis, the restricted, small sub-sample of accidents fulfilling both criteria 1) unilaterally reduced visual acuity; and 2) involved in a crossroads accident, might be of importance. The p-value 0.14 (cf. table 4.10) can *not* be taken as evidence that driving with unilateral visual reduction is of no importance in intersection accidents when compared with straight/ curved road accidents (such a conclusion could be a type II error). The results shown in table 4.11 may indicate a relationship, also supported by the six-fold, significant increase in crossroads accidents happening on the impaired side of functionally one-eyed drivers and other studies (cf. chapter 5.2.2.3.4).

4.1.5. Driving parameters

To study which category of drivers has visual problems, the visual parameters have been correlated to 1) annual driving distance and place of driving, as well as 2) type of driving.

In most drivers aged > 50, the *annual driving distance* was known. The drivers with illegal visual acuity were those drivers with the shortest annual median driving distance (p <0.01, cf. table 4.13). The same drivers also seemed to have an (insignificantly) higher proportion of urban driving (p= 0.1). The contrastsensitivity was not associated with the driver's annual driving distance.

The driver's *type of driving* in relation to the accident was categorised.

Table 4.14. Type of driving in relation to drivers' vision (Alsbirk 1999).

Static visual acuity:	Private	Professional drivers: transport of persons -	Professional drivers: transport of persons +	Miscel-laneous	Total
Illegal	13 (5)	1 (3)	0	1	15
Limit	2 (1)	0 (-)	0	0	2
Legal	226 (93)	32 (97)	22 (100)	12	292
Total	241 (100)	33 (100)	22 (100)	13	309

Private vs. professional and legal vs. illegal:
Odds-ratio= 3.1 (0.4-24.3), p= 0.45, (Fisher's exact).

Table 4.13. Driving parameters in relation to drivers' vision (120 accident-involved drivers age >50) (Alsbirk 1999).

Static visual acuity:	Annual driving: 0-9.999	10.000-19.999	20.000+	Total	Median (range)	%Urban driving:
Illegal	7 (21)	5 (12)	0 (-)	12	8000 (500- 15000)	69%
Limit	1 (3)	0 (-)	1 (2)	2	12500 (3000-22000)	85%
Legal	26 (76)	37 (88)	43 (98)	106	16000 (800-100000)	55%
Total :	34(100)	42 (100)	44 (100)	120	15000 (500-100000)	57%

Illegal vs. legal: z'= 3.05, p= 0.002, (Mann-Whitney test)
Pct. urban driving: Illegal vs. legal: z'= 1.64, p= 0.10, (Mann-Whitney test)

Contrast sensitivity:					
(Threshold-	Mean	: 75.2	72.7	73.45	73.7
scores)	(N=)	: (339)	(40)	(44)	(117)
	s.d.	: 13.4	8.6	8.6	10.3
	s.e.m.	: 2.33	1.3	1.3	0.95

(<10.000 vs. ≥ 10.000: z'= 0.07, p=0.95, Mann-Whitney test) (<20.000 vs. ≥ 20.000: z'= 0.53, p= 0.6, Mann-Whitney test)

Professional drivers tended to have better visual parameters than private drivers, and the optimum level was found in the drivers occupied with professional transport of persons. The differences, however, were not statistically different (table 4.14), possibly due to small subsamples.

4.1.6. Refraction aspects.

The refraction of the drivers was analysed in relation to a) age (table 4.1.c.), b) static visual acuity at the accident (table 4.3); c) lighting conditions (table 4.7); d) visibility conditions (table 4.8); and e) type of roads (table 4.10) at the place of the accident.

In relation to *visibility,* a significant difference in refraction was found, indicating that drivers involved in accidents with reduced visibility (rain, snow and fog) showed a refraction on the average one diopter more in the myopic direction than the rest (table 4.8, cf. chapter 4.1.4.2.). After adjusting for age, the difference was still significant from age 60, but not below that age. In relation to the other parameters examined, no significant difference in refraction was found between the involved drivers.

In table 4.15, *nine drivers with hyperopia* ≥ 1.5 diopter and with *binocular visual acuity at the accident* ≤ *0.5* have been in focus.

As shown above, out of this subgroup of drivers only one had legal visual acuity, classified according to former Danish rules (cf. table 4.1). Two did not use their glasses, three only had glasses for reading, and three had insufficiently corrected glasses. In only one case (I-V-141) legal visual acuity was not obtainable, due to mature cataract and age related macular degenerations, and this driver was referred to cataract surgery.

Correspondingly, among *6 myopic drivers* with a refractive error ≤ -0.5 D (mean of two eyes) and accident *binocular visual acuity* ≤*0.5*, 5 had illegal visual acuity according to previous Danish legislation. Optimally corrected, all achieved legal visual acuity (table 4.16).

Table 4.17: Use of optical corrections for driving in 309 accident drivers (Alsbirk 1999).

Accident visual acuity in rel. to law:		Use of correction for distance: Had none:	Possessed, did not use:	Possessed, used:	Unknown:	Total (pct):
Illegal	:	4 (27)	3 (20)	8 (53)	0	15 (100)
Limit	:	2	0	0	0	2
Legal	:	155 (53)	26 (9)	110 (38)	1	292 (100)
Total	:	161 (52)	29 (9)	118 (38)	1	309 (100)

Illegal vs. legal:
1) ownership of distance glasses: p= 0.08 (Fisher's exact)
2) use of glasses, when possessed: p= 0.75 (Fisher's exact)

4.1.6.1. Drivers' use of correction

Since many drivers with ametropia were found to have been driving without correction, this has been further analysed. 48% had correction for distance, half of these used bifocal glasses, 36% had no optical correction and 18% used reading glasses only. Two per cent used contact lenses.

Table 4.17 shows that car drivers with illegal visual acuity at the time of accident to a higher extent had glasses for distance (73% versus 47% in legal drivers, p= 0.08). In the illegal group of drivers, having corrections for distance, 3/11 (27%) did not use their glasses, versus 26/136 (19%) in the legal group of drivers (p= 0.74). None of these differences were statistically significant.

4.1.6.2. Refractive corrections in the low-vision group

Concentrating on the accident-involved drivers with illegal(N=15) or "borderline" visual acuity (N=2) identified 17 drivers, of which 14 were aged ≥50. Optimal optic correction in these groups only left two with illegal visual acuity and one at the limit. Thus among 17 accident drivers with visual acuity at or below the legal limit, 15 (88%, 95% limits 64%-99%) were "legalised" solely by optimising their correction (fig. 4.3).

The two drivers who could not be sufficiently corrected were 1) male, 73, with aphakia, mature cataract and macular degenerations (AMD) (case I-VM-141), and 2) male, 55, with amblyopia and corneal scarring (case II-V-399).

Correspondingly, out of 10 accident-involved drivers with a binocular visual acuity below 0.5, 9 (90%) fulfilled today's EU requirements after prescription of new glasses.

Table 4.15. Nine hyperopic, accident-involved drivers with binocular visual acuity ≤ 0.5 (Alsbirk 1999).

Accident number:	Age: (sex)	Binocular v. a. in the accident	V. a. in relation to former Danish law:	Refraction: (sph. eq.)	Optimal bin.v.a.:	Estimated **) association:
A. Owned only reading glasses:						
II-V-143	67(M)	0.25	illegal	+1.62/+2	1.0	possible
I-V-427	80(M)	0.33	illegal	+1.75/+1.75	0.67	probable
I-V-906	66(M)	0.33	illegal	+2/+1.75	1.0	probable
B. Owned distance glasses but did not use them:						
II-V-953	73(M)	0.5	legal	+1.25/+1.75	1.25	possible
II-V-982	50(M)	0.4	illegal	+3.75/+1.5	1.25	possible
C. Owned and used distance glasses:						
I-V-001	80(M)	0.25	illegal	+1.25/+1.75	0.5	probable
I-V-141	73(M)	0.33	illegal	+9/ ? *	0.33	probable
II-V-399	55(M)	0.4	illegal	+2/+2.25	0.5	possible
II-V-499	61(M)	0.5	illegal	+3/+4.25	1.0	possible

*) Mature cataract.
**) Association between accident and visual factors, cf. appendix C.

Table 4.16. Six myopic, accident involved drivers, with binocular visual acuity ≤ 0.5 (Alsbirk 1999).

Accident number	Age: (sex)	Binocular v. a. in the accident:	V. a. in relation to former Danish law:	Refraction: (sph. eq.)	Optimal bin. v. a.:	Estimated **) association:
A. Had no glasses:						
II-V-913	44(M)	0.4	illegal	-1.5/-1.75	0.67	possible
B. Owned distance glasses but did not use them:						
I-V-064	58(M)	0.5	illegal	-0.75/-0.5	1.25	probable
II-V-535	41(F)	0.5	illegal	-1/-0.75	1.25	possible
C. Owned and used distance glasses:						
I-V-924	75(M)	0.2	illegal	-9 */+2.25	0.8	probable
I-V-929	76(M)	0.4	illegal	-0.5/-2	0.5	probable
III-V-941	73(F)	0.5	legal	-6/-4	0.5	unlikely

*) Myopic cataract in the right eye.
**) Association between accident and visual factors, cf. appendix C.

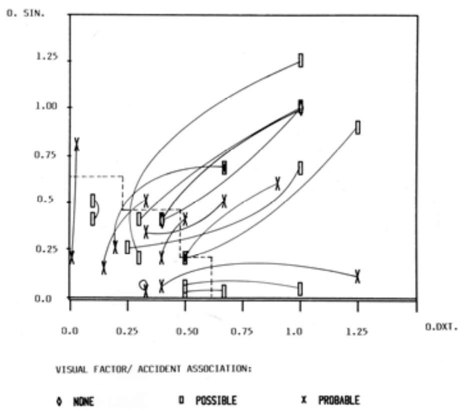

Fig. 4.3. *Improvement of visual acuity (VA) by optic correction in the low vision group of accident involved car drivers with illegal visual acuity (n = 15) or visual acuity at the limit (n = 2) at the time of accident (Age < 50: n = 3, age >= 50: n = 14). Estimates on vision/accident association (cf. appendix C.3.) indicated.*
--------- = lawful limit (before 1996) (K.E. Alsbirk, 1999).

In table 4.18, the diagnoses of the drivers (cases and controls) with illegal visual acuity are listed. As can be seen, insufficiently corrected ametropia was the dominating problem. For details cf. casuistic reports in appendix C 2.

Discussion and conclusion
This part of the study suggests, although not significantly, that drivers with unilaterally reduced visual acuity have special problems at road intersections compared with drivers involved in one-road accidents. In persons with unilateral visual reduction to <0.25, crossroads accidents from the impaired side were 6 times more frequent than accidents happening at the opposite side (p<0.05).

Professional drivers with long driving distances seem to have insignificantly better visual records than private drivers. This might be partly due to the fact that the professional drivers are younger (median age: 39) than the private (median age: 42), although insignificantly (p=0.18, Mann Whitney test). A more relevant explanation might be that regular visual controls each 5th year, as in the case of drivers with professional transport of persons, probably would tend to improve their visual performance.

Of 17 drivers involved in accidents with illegal visual acuity or visual acuity on the limit, according to previous Danish legislation, 15 (88%) could obtain legal vision solely through optical correction.

4.2. Visual parameters in elderly accident-involved drivers compared to a control group: The case/ control study

Introduction
One way to analyse the role of visual factors in a material of accident-involved drivers is to compare the probands with a randomly selected control group of active drivers.

This has been attempted, according to the selection criteria described in the method chapter (3.1.3) by means of the regional records of the driver's license office.

A *matching in frequency* of age and sex was intended among probands and controls $\geq$ 50. Due to the selection procedure or by chance, the distributions of the final basic material (156 probands and 138 controls) varied, cf. chapter 3.

In epidemiological terms, a case/ control study with a control group randomly selected from the background population of active car drivers is called a *case/base study* (Olsen 1988). With a design like this, a calculated *odds ratio* is very close to the relative risk (Foldspang et al, 1986).

4.2.1. Visual variables in the case/control material

To give preliminary estimates on visual variables in the two investigated populations of drivers, some reduction of the material had to be done. Having eliminated the non- responders, drivers involved in non-police registered accidents and drivers with unknown annual driving (a design variable), the two groups were comparable with regard to sex (p=0.57), but not according to age. The control drivers were significantly older (median = 61) than the cases (median = 59), p = 0.045, Mann-Whitney test).

Standardised estimates, (weighted according to the numbers at 5-year intervals in the controls, cf. appendix D. 2.) have been calculated for the two groups in eleven visual variables tested.

In table 4.19 the listed, age standardised visual parameters of these two sub-populations suggest some over-representation of visual problems among accident involved drivers.

Table 4.18: Drivers with illegal visual acuity, cases and controls (Alsbirk 1999).

Case report (cf. Appendix C2):	Sex and age:	Visual acuity at the accident:	Binocular v. a. at the accident	Optimized. v. a.	Refraction **) r. eye / l. eye:	Ophthalmological diagnosis:
a. Cases:						
I-V-1	M-80	0.15/0.15	0.25	0.33/0.5	+1.25/ +1.75	Cataract, AMD *) and hyperopia
III-V-60	M-48	0.4/0.4	0.6	1.0/1.0	+2/+2	Uncorrected hyperopia
I-V-64	M-58	0.4/0.05	0.5	0.67/0.02	-0.75/-0.5	Left side branch vein occlusion
II-V-91	F-56	0.5/0.02	0.5	0.67/0.02	-1.5/ -0.5	Amblyopia and hyperopia
I-VM-141	M-73	0.3/L.P. *)	0.3	0.3/L.P.	+9/-	Aphakia and mature cataract
II-V-143	M-67	0.25/0.25	0.25	1.0/0.67	+1.62/+2	Uncorrected hyperopia
III-V-163	F-58	0.4/0.4	0.5	1.0/1.0	+1/+1	Uncorrected hyperopia
II-V-399	M-55	0.1/0.4	0.4	0.1/0.5	+2/+2.25	Amblyopia, corneal scars and hyperopia
I-V-427	F-80	0.33/0.33	-	0.67/0.5	+1.76/+1.75	Uncorrected hyperopia
I-V-499	M-62	0.5/0.05	0.5	1.0/0.05	-3/+4.25	Amblyopia and astigmatic hyperopia
II-V-535	F-41	0.3/0.4	0.5	1.0/1.0	-1/-0.75	Uncorrected myopia
I-V-906	M-68	0.2/0.25	0.33	0.67/0.67	+2/+1.75	Uncorrected hyperopia
II-V-913	M-44	0.4/0.4	0.5	0.67/0.67	-1.5/-1.75	Uncorrected astigmatic night myopia
I-VM-924	M-75	0.01/0.2	0.2	0.3/0.8	-9/+2.25	Severe cataract , old glasses, DRP *)
I-VM-929	M-76	0.4/0.2	0.4	0.5/0.4	-1.25/-0.5	Cataract, AMD*) and CVI *)
II-VM-982	M-50	0.2/0.3	0.4	1.0/1.25	-3.5/+1.5	Uncorrected hyperopia
b. Controls:						
V-C-743	M-52	0.4/0.3	0.5	1.5/1.5	+1.25/+1.25	Uncorrected hyperopia
V-C-751	M-54	0.05/0.4	0.5	1.0/1.25	-2.5/-1.5	Uncorrected myopia
V-C-788	M-65	0.2/0.2	0.2	1.0/1.0	+1.75/+1.75	Uncorrected hyperopia
V-C-831	M-79	0.05/0.2	0.2	0.2/0.4	+1.75/+2.62	AMD *) and astigmatic hyperopia
V-C-833	M-79	0.3/0.4	0.4	0.9/0.9	+2.4/+2.4	Uncorrected astigmatic hyperopia

*) AMD : age related macular degeneration; DRP: diabetic retinopathy; LP: light perception; CVI: cerebral vascular insult
**) calculated refractive spherical equivalent

4.2.2. Multivariate analyses with separate risk estimates on vision/ accident association (co-author Professor Lic. Sc. Michael Væth).

For a detailed analysis with calculations of relative risk estimates, however, the two groups in table 4.19 are not directly comparable. For such calculations, multiple *logistic regression analyses* (Foldspang et. al. 1986) may give less biased odds ratios. For this analysis non-police registered probands were omitted (to minimise heterogeneous inclusion criteria). The basic case/control material now being adjusted for design variables and confounders was restricted according to table 2.11. The choice and analyses of design variables and confounders are discussed in appendix D 2.

Thus 204 drivers (91 cases and 113 controls) aged ≥ 50 made up the material for assessing the visual parameters separately (not corrected for a possible mutual association).

Table 4.19. Age, sex and various visual parameters (age-standardized) in drivers, aged≥ 50, involved in accidents (n= 97) and a control group (n=126) (Alsbirk, 1999).

		Cases: (n=97)	Controls: (n=126)	
Age, (median)	:	59	61	(p= 0.045, Mann-Whitney test)
Sex, (pct. females)	:	25.8%	30.2%	(p= 0.57, Fisher's exact)
Visual parameters:				
Monocularly tested visual acuity (% illegal)	:	9.3%	4.0%	
Binocular visual acuity				
(pct. < 0.6)	:	18.1%	3.9%	
(pct. < 0.5)	:	9.3%	2.4%	
Contrast thresholds (median values)	:	74.7	70.4	
Unilaterally reduced visual acuity (cf. text)	:	15.5%	4.8%	
Reduced stereopsis (≥ 80 sec. of arc.)	:	51.5%	36.3%	
Years since last visual test (%≥10 y.)	:	11.1%	3.2%	
Central visual field defects (pct.)	:	14.8%	7.2%	
Colour vision defect (pct. Ishihara defects)	:	17.9%	8.7%	
Visual field defects a.m. Donders (pct.)	:	4.4%	4.0%	
Residual visual capacity *) (pct.≥ 0.25)	:	31.7%	33.3%	
Refraction (median)	:	+1.12	+0.75	

*) Optimal - minus actual binocular visual acuity.

Table 4.20. Odds-ratios on vision-accident association, with parameters from separate analyses of each visual variable **). N= 204 (Alsbirk, 1999).

n= ***		Visual parameters:	Odds ratio:	95% confidence limits:	p=	Categories considered:
204	1.*	Contrast sensitivity	: 1.99	(1.3 - 3.1)	0.003	10 threshold units
204	2.*	Unilaterally reduced visual acuity (cf. text)	: 5.21	(1.3 - 20.6)	0.02	no/yes
199	3.*	Binocular visual acuity	: 4.35	(1.1 - 17.5)	0.03	≥ 0.6/ < 0.6
199	3.a.	Binocular visual acuity	: 2.76	(0.4 -20.3)	0.31	≥ 0.5/ < 0.5
204	4.*	Stereopsis	: 2.15	(1.0 - 4.7)	0.05	< 80/ ≥ 80 sec. of arc.
204	5.*	Years since last visual test	: 1.55	(0.97 - 2.5)	0.07	5 years
204	6.*	Monocularly tested visual acuity	: 3.65	(0.9 - 15.6)	0.08	legal vs. limit and illegal
204	6.a.	Monocularly tested visual acuity	: 2.73	(0.6 - 12.3)	0.19	legal/illegal
203	7.	Central visual field defects	: 2.31	(0.8 - 7.0)	0.14	no defects/defects
204	8.	Visual field defects a.m. Donders	: 2.1	(0.3 - 14.4)	0.43	defects/no defects.
204	9.	Residual visual capacity	: 1.07	(0.7 - 1.6)	0.76	1 step value.
200	10.	Colour vision defects	: 1.09	(0.4 - 3.3)	0.89	Ishihara defects: no/yes
203	11.	Refraction	: 0.99	(0.8 - 1.2)	0.89	1 diopter

*) Indicates variables used in the final logistic regression analyses (cf. 4.3.2.1.).

**) Odds-ratios for categorized variables estimate the increase in risk associated with the second category. Contrast sensitivity, "years since last visual test", residual visual capacity and refraction were entered in the calculations as continuous variables. The odds-ratios estimate the increase in accident risks corresponding to increase in scores of 10 units for contrast thresholds, 5 years for "years since last visual test", 1 delta step value for residual visual capacity, and one diopter for refraction errors. All estimates are corrected for the effect of design variables and non-visual confounding variables (cf. appendix D2 for details).

***) The sample size in each analysis, after elimination of drivers with incomplete information.

Table 4.21. Odds-ratios on vision-accident association. Accident drivers in various binocular visual acuity groups *). N= 204. (Alsbirk, 1999).

Binocular visual acuity:		Odds ratio:	95% confidence limits:	p=	n=
< 0.6	:	1	-	-	18
0.6 - < 1.0	:	0.29	(0.07 - 1.27)	0.1	67
1.0 - < 1.2	:	0.28	(0.06 - 1.23)	0.09	74
≥ 1.2	:	0.10	(0.02 - 0.47)	0.004	45
					204

*) Optical correction as at the time of accident. Odds-ratios estimate the increase in risk, compared to the first category.

Table 4.20 gives separate odds-ratio estimates on the vision/ accident association. The first 6 of these (indicated with *) were chosen for the final logistic regression analyses, in which a possible mutual association between the individual parameters have been investigated.

As seen, *contrast sensitivity*, is identified as a very important visual parameter. It is followed by *unilaterally reduced visual acuity* and *binocular visual acuity,* (optically corrected as in the accident). These parameters seemed to be the test systems with the most significant association (fig 4.4).

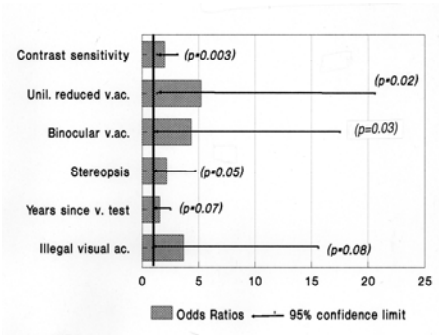

Fig. 4.4. *Odds-ratios on vision / accident association (logistic regression), see text and table 4.20 (K.E. Alsbirk, 1999).*

Various scoring systems for these variables have been analysed. The chosen intervals reflect relevant scores supported by the actual data.

Binocular visual acuity was divided at 0.6, in accordance with the first proposals in the EU, (Kommisionen for de Europæiske Fællesskaber, 1989). The group with binocular visual acuity

≥ 0.6 is rather inhomogeneous, since high scores (≥ 1.2) seem to identify persons with very low risk scores (table 4.21).

Finally, (De Europæiske Fællesskabers Tidende, 1991) the requirements in binocular visual acuity have been relaxed, the decided lower limit being 0.5 (as in Norway, Sweden and several states in USA).

When the test scores are dichotomised and the limit set at 0.5 instead of 0.6, the procedure leaves only 8 persons below this limit. The odds-ratio for these drivers is 2.76 (95% confidence limits 0.4 -20.3), which is not statistically significant (due to the small number). Thus the material is too small to evaluate whether 0.5 or 0.6 is the relevant cut-off point.

The test values "years since last visual test" and "monocularly tested visual acuity", (cf. table 4.20) are not significant at the 0.05 level. However, the individual odds ratios for both variables are relatively high. In such a limited material of drivers, this is a general problem, being reflected also in the wide confidence intervals. Thus the material allows the identification of significant visual variables, but not a very precise estimate on their effect.

4.2.2.1. Logistic regression analyses of mutual associations between visual parameters' risk

An identification of the most important variables is further rendered difficult by their mutual association. The final logistic regression analysis (table 4.22) has been performed on the basis of a restricted material of 199 persons (87 cases and 112 controls), eliminating further 6 drivers with insufficient visual information (cf. table 2.11).

The considered combinations of test scores are briefly commented:

Table *4.22.a* reflects the odds-ratios, when contrast sensitivity and binocular visual acuity are fit together and in *table 4.22.b* the corresponding estimates when contrast sensitivity and unilaterally reduced visual acuity are combined (for all these estimates, p< 0.05). In both situations, the

Table 4.22. Odds-ratios on vision-accident association when parameters are fitted simultaneously in various combinations *). N= 199 (Alsbirk, 1999).

**)	Visual parameter:	Odds ratio:	95% confidence limits:	p=	Categories considered:
a) 1.	Contrast sensitivity	: 1.95	(1.2 - 3.1)	0.004	10 threshold units
3.	Binocular visual acuity	: 5.13	(1.2 - 21.9)	0.03	≥ 0.6/ < 0.6
b) 1.	Contrast sensitivity	: 1.83	(1.2 - 2.9)	0.009	10 threshold units
2.	Unilaterally reduced visual acuity (cf. text)	: 5.21	(1.2 - 23.9)	0.03	no/yes
c) 1.	Contrast sensitivity	: 1.88	(1.2- 2.95)	0.006	10 threshold units
3.	Binocular visual acuity	: 3.09	(0.6 - 15.8)	0.18	≥ 0.6/ < 0.6
2.	Unilaterally reduced visual acuity (cf. text)	: 3.14	(0.6 - 17.7)	0.19	no/yes
d) 1.	Contrast sensitivity	: 1.88	(1.2 - 2.95)	0.006	10 threshold units
3.	Binocular visual acuity	: 5.37	(1.3 - 23.1)	0.024	≥ 0.6/ < 0.6
4.	Stereopsis	: 2.15	(0.5 - 2.4)	0.87	< 80/ ≥80 sec. of arc.
e) 1.	Contrast sensitivity	: 1.8	(1.15 - 2.8)	0.01	10 threshold units
2.	Unilaterally reduced visual acuity (cf. text)	: 4.6	(1.01 - 20.8)	0.048	no/yes
4.	Stereopsis	: 1.7	(0.8 - 3.9)	0.20	< 80/ ≥80 sec. of arc.
f) 1.	Contrast sensitivity	: 1.99	(1.3 - 3.1)	0.003	10 threshold units
5.	Years since last visual test	: 1.64	(1.01 - 2.7)	0.05	5 years
g) 1.	Contrast sensitivity	: 1.99	(1.3 - 3.1)	0.003	10 threshold units
3.	Binocular visual acuity	: 4.18	(0.93 - 18.8)	0.06	≥ 0.6/ < 0.6
5.	Years since last visual test	: 1.51	(0.92 - 2.5)	0.1	5 years
h) 1.	Contrast sensitivity	: 1.92	(1.2 - 3.1)	0.007	10 threshold units
3.	Binocular visual acuity	: 4.48	(0.99 - 20.3)	0.05	≥ 0.6/ < 0.6 2.
4.	Stereopsis	: 1.86	(0.8 - 4.2)	0.14	< 80/ ≥80 sec. of arc.
5.	Years since last visual test	: 1.46	(0.8 - 2.5)	0.15	5 years
i) 1.	Contrast sensitivity	: 1.88	(1.17 - 3.0)	0.009	10 threshold units
5.	Years since last visual test	: 1.48	(0.9- 2.5)	0.14	5 years
3.	Binocular visual acuity	: 5.48	(0.4 - 77.7)	0.21	≥ 0.6/ < 0.6 2.
2.	Unilaterally reduced visual acuity (cf. text)	: 3.80	(0.5 - 30.8)	0.21	no/yes
4.	Stereopsis	: 1.63	(0.7 - 3.8)	0.26	< 80/ ≥80 sec. of arc.
6.	Monocularly tested visual acuity	: 3.07	(0.1 - 80.2)	0.50	legal vs. limit and illegal

*) Odds-ratio estimates: cf. table 4.20, footnote **).

**) Combination of visual variables fit together. Reference numbers refer to table 4.20 for separate risk estimates.

odds-ratios of the other variables are insignificant.

In table 4.22.c it appears that binocular visual acuity and unilaterally reduced visual acuity contain common prognostic information, since they are both insignificant when included in the calculations together.

Table 4.22.d indicates that the influence of stereopsis becomes insignificant when fitted together with contrast sensitivity and binocular visual acuity in combination. Not surprisingly, the same tendency was found when stereopsis was adjusted with contrast sensitivity and unilateral reduction of visual acuity *(table 4.22.e).*

The years since last visual test seem to be of importance when fitted together with contrast sensitivity *(table 4.22.f),* however, the effect is weakened when further combined with binocular visual acuity *(table 4.22.g)* and stereopsis *(table 4.22.h).*

When all six variables are combined, only contrast sensitivity remains as a significant identificator of risk drivers *(table 4.22.i).*

For each of the combined analyses (a-i) in table 4.22, the chi-square test (the deviance change relative to a fit without the variables considered) have been calculated. Thus, p - values on the vision/accident association for each

Table 4.23. Significance of vision/accident associations evaluated by a chi square test for each of the combined logistic regression analyses in table 4.22 (Alsbirk, 1999) .

Analysis (cf. table 4.22)	:	Chi-square:	degrees of freedom:	p = :
a.	:	14.36	2	0.00076
b.	:	14.12	2	0.00086
c.	:	16.03	3	0.00112
d.	:	17.26	3	0.00062
e.	:	15.81	3	0.00124
f.	:	13.53	2	0.00115
g.	:	17.24	3	0.00063
h.	:	19.52	4	0.00062
i.	:	21.09	6	0.00401

combination of visual parameters can be estimated (table 4.23).

For all 9 test combinations, it is clearly confirmed that after control for design variables and confounders, associations exist between the quality of vision and accident risk.

Looking at the separate scores for *contrast sensitivity,* an alternative scaling has been studied (table 4.24).

Table 4.24. Odds-ratios on vision-accident association. Accident drivers in various contrast sensitivity groups *). N= 204 (Alsbirk, 1999).

Contrast sensitivity thresholds:	Odds ratio:	95% confidence limits:	p=	n=
< 67	: 1	-	-	51
67 - 71	: 3.8	(1.3 - 11.4)	0.02	49
72 - 78	: 3.0	(1.0 - 8.9)	0.04	57
≥ 79	: 7.5	(2.4 - 23.4)	0.001	47
				204

*) Odds-ratios estimate the increase in risk, compared to the first category.

Thus, whether tested separately or in combination with 5 other visual parameters, it is confirmed that the higher contrast thresholds (indicating lower contrast sensitivity) seem to identify drivers with a higher accident risk.

Additionally, the results of the logistic regression method have been validated by conditional logistic regression. Furthermore, logistic as well as conditional logistic regression analyses have been applied to an extended material of drivers (non- police registered accident drivers included). These analyses will be briefly commented.

Table 4.25. Odds-ratios on vision-accident association, (conditional logistic regression) from separate analyses of each visual variable *). N= 140 (Alsbirk, 1999).

**)	Visual parameter:	Odds ratio:	95% confidence limits:	p=	Categories considered:
1.	Contrast sensitivity	: 1.79	(1.05 - 3.0)	0.03	10 threshold units
5.	Years since last visual test	: 1.97	(1.1 - 3.6)	0.03	5 years
4.	Stereopsis	: 2.75	(1.1 - 6.9)	0.03	< 80/≥80 sec. of arc.
3.	Binocular visual acuity	: 4.47	(0.8 - 25.4)	0.09	≥ 0.6/ < 0.6
2.	Unilaterally reduced visual acuity (cf. text)	: 3.86	(0.8 - 18.9)	0.1	no/yes
6.	Monocularly tested visual acuity	: 1.57	(0.3 - 8.6)	0.60	legal vs. limit and illegal

*) Odds-ratio estimates: cf. table 4.20, footnote **).
**) Reference numbers refer to table 4.20 for comparison.

4.2.2.2. Conditional logistic regression with a closer case to control matching on age, sex and extent of driving is from a theoretical point of view the optimal analysis. In the actual design, however, a great proportion of persons, according to design variables, are not directly nested and thus comparable cases to controls, and are therefore omitted. This strategy leaves only 140 persons for the analyses. Table 4.25 gives the individual estimates.

The importance of "years since last visual test" and stereopsis is increased, while that of contrast sensitivity is reduced but still significant. The estimates on unilaterally reduced visual acuity and binocular visual acuity are no longer significant and monocularly tested visual acuity is clearly insignificant.

4.2.2.3. Inclusion of non-police registered accidents

These accident drivers were preciously omitted to standardise the inclusion criteria of the probands. However, since they constitute a real part of the true accident population, the visual findings of this group have been compared in the phase I material to those drivers involved in police registered accidents.

Table 4.26 Age, sex and various visual parameters in police registered and non-police registered accident drivers, based on the phase I material (N= 249) (Alsbirk, 1999).

		Police registered: (n=171)	Non- police registered: (n=78)	p =	statistical method:
Age, (median)	:	38	35.5	0.6	(Mann-Whitney test)
Sex, (pct. females)	:	24.6%	39.7%	0.023	(Fisher's exact)
Visual parameters:					
Monocularly tested visual acuity (% illegal)	:	4.7%	5.1%	1.0	(Fisher's exact)
Binocular visual acuity (pct. < 0.5)	:	2.3%	2.6%	0.97	(Mann-Whitney test)
Contrast thresholds (median values)	:	67	65	0.24	(Mann-Whitney test)
Unilaterally reduced visual acuity (cf. text)	:	4.1%	11.5%	0.06	(Fisher's exact).
Stereopsis (≥ 80 sec. of arc.)	:	39%	38%	0.32	(Mann-Whitney test)
Years since last visual test (% ≥10 y.)	:	12.5%	8.9%	0.4	(Mann-Whitney test)
Central visual field defects (pct.)	:	4.7%	20%	0.005	(Fisher's exact)
Colour vision defects	:	4.7%	3.8%	1.0	(Fisher's exact)
Visual field defects a.m. Donders (pct.)	:	1.2%	2.6%	0.74	(Fisher's exact)
Residual visual capacity (pct. ≥ 0.25)	:	21%	23%	0.78	(Mann-Whitney test)
Refraction (median)	:	0	0	0.68	(Mann-Whitney test)

As seen in table 4.26 the age distributions of the two groups were comparable. Significantly more females were observed among non-police registered accident-drivers. By co-incidence unilateral reduction of visual acuity and central visual field defects were found more frequently in this group. In addition to that, no systematic differences were found.

In table 4.27 these drivers have therefore been included in the logistic regression analysis, enlarging the analysed material to 215 persons for the computations.

Estimated separately, all six variables seemed to be of significance, unilateral reduction of visual acuity, binocular visual acuity, contrast sensitivity and stereopsis being of most importance. The significance of contrast sensitivity and unilaterally reduced visual acuity

Table 4.27. Odds-ratios on vision-accident association, (logistic regression, non-police registered drivers included) from separate analyses of each visual variable *) N= 215 (Alsbirk, 1999).

**)	Visual parameter:	Odds ratio:	95% confidence limits:	p=	Categories considered:
2.	Unilaterally reduced visual acuity (cf. text)	: 5.65	(1.6 - 20.4)	0.008	no/yes
3.	Binocular visual acuity	: 5.01	(1.4 - 17.8)	0.013	$\geq$ 0.6/ < 0.6
1.	Contrast sensitivity	: 1.67	(1.1 - 2.5)	0.015	10 threshold units
4.	Stereopsis	: 2.38	(1.2 - 4.8)	0.017	< 80/ $\geq$ 80 sec.of arc.
6.	Monocularly tested visual acuity	: 4.34	(1.1 - 17.1)	0.04	legal/limit and illegal
5.	Years since last visual test	: 1.64	(1.02 - 2.6)	0.04	5 years

*) Odds-ratio estimates: cf. table 4.20, footnote **.
**) Reference numbers refer to table 4.20 for comparison.

Table 4.28. Odds-ratios on vision-accident association, (conditional logistic regression, non-police registered drivers included) from separate analyses of each visual variable *). N= 163 (Alsbirk, 1999).

**)	Visual parameter:	Odds Ratio:	95% confidence limits:	p=	categories considered:
5.	Years since last visual test	: 1.94	(1.06 - 3.6)	0.032	5 years
4.	Stereopsis	: 2.34	(1.07 - 5.1)	0.033	< 80/ $\geq$80 sec. of arc.
2.	Unilaterally reduced visual acuity (cf. text)	: 4.55	(1.1 - 18.8)	0.036	no/yes
3.	Binocular visual acuity	: 4.72	(1.1- 30.2)	0.037	$\geq$ 0.6/ < 0.6
1.	Contrast sensitivity	: 1.45	(0.9 - 2.27)	0.11	10 threshold units
6.	Monocularly tested visual acuity	: 2.69	(0.6 - 11.6)	0.18	legal/limit and illegal

*) Odds-ratio estimates: cf. table 4.20, footnote **.
**) Reference numbers refer to table 4.20 for comparison.

were weakened when the other variables were included in the calculations.

Analysing the same material (non-police registered accident drivers included) by *conditional logistic regression,* 163 drivers could be included in the calculations (table 4.28).

Still, the time interval since last visual test, stereopsis, unilaterally reduced visual acuity and binocular visual acuity seem of significant importance, while contrast sensitivity now looks less critical. Monocularly tested visual acuity constantly appears to be a weak identifier of high risk drivers.

Discussion

As mentioned in chapter 4.2.2.2., the ideal model of analysis would be conditional logistic regression. This, however, due to the present study design, would eliminate as much as 30% of useful information.

The second best model (logistic regression analysis) in which the applied "matching in distribution" is permitted, leaves more material for the calculations. Therefore, greater importance is attached to this model.

Excluding non-police registered accident drivers gives more homogeneous inclusion criteria, but at the same time, it eliminates precious information (7%) in an already relatively limited material.

Conclusions

1. The multiple logistic regression analyses of the case/control study indicate an association between traffic accident risks and the quality of vision.

2. A precise identification of the most important predictors among the visual variables investigated is more problematic since a number of these are mutually interrelated and the material too small to identify several independent risk factors. Certain trends, however, are obvious:

2.1. Contrast sensitivity appears to be an important variable. The information seems rather independent of the other visual parameters tested.

2.2 Unilaterally reduced visual acuity seems to be a significant screening variable, although the importance is reduced when more specific information such as binocular visual acuity is included.

2.3. Binocular visual acuity is demonstrated to rank higher as risk indicator than monocularly tested visual acuity.

2.4 Stereopsis might be a relevant screening indicator, however, the importance is blurred by the influence of other visual variables. Binocular visual acuity is demonstrated as an associated variable and, correspondingly, the expected influence of unilaterally reduced visual acuity is confirmed.

2.5. It can not be ruled out that the number of years since last visual test is of predictive importance - or in more practical terms - of some preventive significance.

4.3. Drivers with "borderline" and not optimised visual acuity. -Practical and legislative aspects

4.3.1. Analysis of drivers' visual acuity, tested by monocular and binocular test

Introduction:

As mentioned in the introductory chapter, a great deal of agreement exists between most countries concerning the requirements for static visual acuity for car drivers but nevertheless differences do exist, and certain kinds of development are taking place. As adverted to in chapter 1.2.2, a new legislation concerning tests of drivers' vision has been implemented in the EU (De Europæiske Fællesskabers Tidende, 1991). The most important change is of a practical kind, namely, that for *drivers of private cars* vision will have to be tested, using both eyes at the same time (binocularly). The limit/cut off point for corrected binocular visual acuity primarily was proposed at a level of 0.6 (Kommissionen for de Europæiske Fællesskaber, 1989). This limit, therefore, has been used in the logistic regression analyses of the case/control study. However, finally for non- monocular drivers, the minimal requirement has been decided reduced to 0.5 as in most other countries (De Europæiske, Fælles-skabers Tidende, 1991). *For professional drivers,* including truck drivers, monocular tests will still be needed, and the requirements in this group have been intensified too: corrected visual acuity of the *worse* eye has to be better than 0.5, excluding one-eyed and most amblyopic drivers. Uncorrected visual acuity must exceed 0.05.

The EU legislation was implemented in Denmark the 1st of July, 1996. Also two of Denmark's neighbouring countries, Norway and Sweden, have introduced binocular tests for driver's vision, the requirements being better than or equal to 0.5. With the radical change from monocular to binocular testing, certain perspectives (which will be analysed in this chapter) arise for drivers with visual acuity close to these limits.

Method and material

In the present investigation, in which 543 drivers were included (405 drivers involved in an accident and 138 controls), information concerning monocular as well as binocular visual acuity were available in 435 participating, investigated drivers (80%). A comparison of these two methods for testing vision has been analysed, independently of the drivers' accident involvement. In tables 4.29 A. and B., the vision at the time of the accident or during normal driving (controls) has been focused upon. In tables 4.30 A. and B. the same relations have been analysed after the visual acuity has been optimised. Accident cases in focus are indicated. They are briefly reported in appendix C. 2.

Table 4. 29. A. Visual acuity, corrected as at the time of accident/during normal driving in 435 car drivers, (known cases and controls) tested by monocular- and binocular test (Alsbirk, 1999).

	Binocular visual acuity				
Monocular test	<0.5	0.5	0.6-0.67	>=0.7	Total tests:
Illegal	12	7*	1****	0	20
Limit	0	1**	1*****	0	2
Legal	0	5***	31	377	413
Total	12	13	33	377	435

Reference to accidents, cf. appendix C.2:
*) I-V-64, II-V-91, II-V-499, II-V-535, III-V-163, V-C-743, and V-C-751.
**) II-V-338
***) I-V-517, II-V-328, II-V-652, II-V-953, and III-V-941.
****) III-V-60.
*****) I-V-991.

B. "Binocular visual gain" in the car drivers by binocular test compared to visual acuity in the better eye at the time of the accident or during normal driving (Alsbirk, 1999).

	Visual acuity in the better eye:					
Visual gain:	<0.4	0.4	0.5	0.6-0.67	>=0.7	Total
<-0.25	0	0	0	0	3	3
-0.25-<0	0	0	0	1	6	7
0-0.09	6	4	8	19	228	265
0.1-0.19	2	5	9	2	45	63
0.2-0.29	0	1	3	3	73	80
0.3+	0	0	1	13	3	17
Total	8	10	21	38	358	435

Results

As seen in table 4.29 A. (visual acuity of the drivers at the time of accident or during normal driving (controls)), twenty car drivers (4.6%) did not fulfil the Danish requirements and 12 (2.8%) were below the EU requirements (0.5). Out of 22 drivers being "at the limit" or not fulfilling the Danish requirements, ten (45%) would have passed according to EU legislation. Reported accidents are indicated.

In table 4.29 B, the "binocular visual gain" (i.e. binocular visual acuity minus visual acuity in the best eye) has been examined. Out of 18 drivers with a visual acuity of <0.5 in the better eye, 6 (33%) had ≥ 0.5 tested binocularly due to the "binocular gain".

After having *optimised* the visual acuity, as registered in table 4.30 A. and B., 3 drivers (0.7%) did not satisfy the Danish legislation and the two of them were also illegal according to the EU- requirements.

None of these two drivers with < 0.5 in the best eye, after corrections, had sufficient "binocular gain" to fulfil the proposed EU requirements (cf. table 4.30 B).

Conclusion

Among the few drivers, not fulfilling the earlier Danish visual requirements for private drivers, only 54% (12/20) would not fulfil the present EU demands. Thus, the results confirm that visual requirements for private driving were eased after the introduction of EU legislation.

After optimal optical correction, the illegal proportion of drivers were reduced from 20 (4.6%) to 3 (0.7%) according to the former Danish rules and from 12 (2.7%) to 2 (0.5%) as per the present EU requirements.

Table 4.30.
A. Optimized visual acuity in 435 car drivers tested by monocular and binocular tests (Alsbirk, 1999).

	Binocular visual acuity				
Monocular test	<0.5	0.5	0.6-0.67	>=0.7	Total
Illegal	2**	1*	0	0	3
Limit	0	0	0	0	0
Legal	0	3***	7	422	432
Total	2	4	7	422	435

Reference to accidents, cf. appendix C.2:
*) II-V-399
**) I-V-141 and V-C-831
***) I-V-001, I-V-929 and III-V-941.

B: "Binocular visual gain" in the car drivers by a binocular test compared to visual acuity in the better eye after optimal correction (Alsbirk, 1999).

	Visual acuity in the better eye					
Visual gain	<0.4	0.4	0.5	0.6-0.67	>=0.7	Total
<-0.25	0	0	0	0	2	2
-0.25-<0	0	0	0	1	5	6
0-0.09	1	1	4	5	292	303
0.1-0.19	0	0	0	0	31	31
0.2-0.29	0	0	0	0	83	83
0.3+	0	0	0	8	2	10
Total	1	1	4	14	415	435

Discussion

In the logistic regression analyses of the case/control study, the proposed 0.6 limit was used. The material of drivers with binocular visual acuity < 0.5 is too small to conclude which of the cut off points 0.5 or 0.6 is the best. Four accident drivers with ultimate corrected binocular visual acuity = 0.5, however, might elucidate this question (cf. table 4.30 A. Two of them were involved in traffic accidents in which visual factors seemed to be important. In one accident, a pedestrian was killed (I-V-929) and in another (I-V-001) a driver with significant cataract was dazzled by the sun.

Seven drivers involved in accidents with illegal visual acuity at the time of accident according to Danish legislation had binocular visual acuity = 0.5 (cf. table 4.29.A). In one of these (I-V-64), vision was estimated as a probable contributing factor and in three (II-V-91, II-V-499 and II-V-535) as a possible factor.

In the multivariate regression analyses, binocular visual acuity seemed to be more associated with accident risk than monocularly tested visual acuity. Moreover, the binocular test method is administratively simpler.

From an ophthalmological point of view, however, things look rather different. - Blindness preventive aspects of monocular testing have to be emphasised. Besides, unilateral reduction of visual acuity, as shown in the case/control study and in chapter 4.1.4.3, seems to imply a certain risk for traffic safety in a small proportion of accidents.

In chapter 5.4.1, advantages and disadvantages in the possible change in procedure will be further discussed.

4.3.2. Analyses of the "residual visual capacity" and the time interval since last visual test

The "residual visual capacity" *(RVC)* means the improvement in binocular visual acuity after optimal optical correction. Corrected from the level as at the time of the traffic accident or in normal driving (controls).

No difference was found on this variable between drivers involved in accidents compared to controls (cf. table 4.19, the case/control study).

In the descriptive study of accident drivers, it was confirmed that static visual acuity is progressively reduced with increasing age (cf. table 4.2). It is therefore pertinent to test whether the residual visual capacity (RVC) was associated with drivers' age.

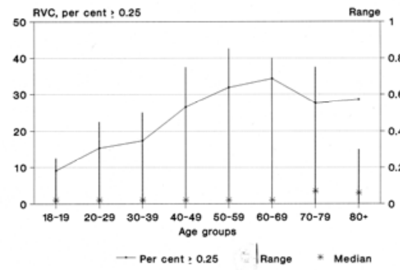

Fig. 4.5. *Residual visual capacity (RVC) vs. age (p=0.001, Mann-Whitney test). N = 435 investigated car drivers. - = percentage of drivers with RVC ≥ 0.25 (K.E. Alsbirk, 1999)*

In fig. 4.5. residual visual capacity is demonstrated to increase significantly with age (N=435, cases and controls pooled, p= 0.001, Mann-Whitney test)). However, the tendency levels out and decreases a little after the compulsory visual test at age 70.

Provided that better binocular visual acuity is associated with lower accident risk (cf. chapter 4.2.), it is of practical

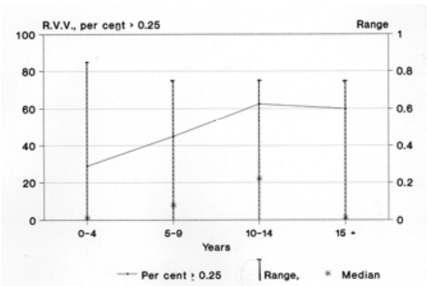

Fig. 4.6. *Residual visual capacity (RVC) vs. years since last visual test. Investigated drivers with a driver's licence ≥ 20 years, N = 253, (z' = 2.80, p= 0.005, Mann-Whitney test) (K.E. Alsbirk, 1999).*

relevance to investigate the association between "residual visual capacity" and the time interval since last visual test. In figure 4.6. the participating drivers (cases and controls pooled) with driver's license for twenty years or more (N= 253) have been the material for such an analysis.

As shown in the figure, a highly significant association can be demonstrated, (p= 0.005, Mann-Whitney test). A corresponding analysis in drivers aged ≥ 50 (N= 248) confirms this association (z' = 3.85, p< 0.001).Thus, not surprisingly, the residual visual capacity is significantly larger in drivers with a longer interval without a visual test.

Concerning the "time interval since last visual test", the case/control study suggests that probands might have been more negligent in relation to visual check-ups than drivers in the control group (p= 0.07, cf. table 4.19). Among drivers aged ≥ 50, fifteen per cent of cases and 7 per cent of controls had their last visual test more than five years ago. The hypothesis of a possible association was partly confirmed when non-police registered drivers were included in the analyses (cf. table 4.26) and when the method of conditional logistic regression was applied (cf. table 4.24 and 4.27). In these 3 analyses an association was suggested, (p< 0.05).

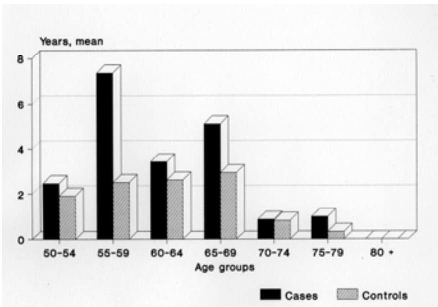

Fig. 4.7. *Average time interval since last visual test vs. age. Investigated drivers aged ≥ 50 (solid = 122 cases, hatched = 126 controls) (K.E. Alsbirk, 1999).*

In fig. 4.7 it is illustrated that this difference (investigated cases and controls, aged ≥ 50) is pronounced, until the compulsory visual test comes in at age 70.

A high value of "residual visual capacity" does not necessarily mean that drivers do not own glasses for distance. In the case/control study no difference was found between the two groups concerning possessing of glasses (p > 0.5). In the investigated groups of cases and controls, aged ≥ 50, 68% and 67%, respectively, possessed glasses for distance. A fairly high proportion of these (19% and 26%, p= 0.4, Fisher's exact) drove the cars without using the distance glasses. However, they used them regularly when watching TV!

Conclusion

The average residual visual capacity increases significantly with age and with the time interval since last visual test. It appears to be only slightly reduced after the age of 70, at which the drivers have to be visually re-tested according to Danish law.

This suggests that:

1) the *decay* in visual acuity (and change in refraction) is common in middle-aged and aged drivers;

2) in most drivers, when tested in relation to the renewal of the driver's license (at age 70 and above) and having visual acuity at or higher than the legal level, the optic correction was not consistently optimised on that occasion, and

3) a significant amount of drivers, aged ≥ 50 (23%), who have glasses for distance, do not regularly use them when driving!

4.4. The medical consequences of the accidents and the use of seat belts

4.4.1. The medical consequences of the accidents

The primary object of the present investigation was to elucidate the visual patterns of the road users in the Danish traffic accident spectrum. The aim was not to perform a thorough analysis of the consequences of the accidents in focus.

However, in order to make some kind of evaluation of the health consequences of the analysed traffic accidents with visual problems in the drivers, a simplified registration in each accident has been included.

It is relevant to examine whether these accidents are unique as regards the medical consequences of the accidents compared to the main group of traffic accidents in the study. It makes it even more relevant if they constitute a group of accidents which to some extent might be preventable.

Background: The Abbreviated Injury Scale (AIS) (AIS-90, 1990) is the established way to classify the severity of human injury in accidents. The use of AIS, however, requires a detailed knowledge of the consequences of what happened to the injured involved road users. Nevertheless, this was not at hand in each case, since it was outside the purpose of the present study.

A simpler classification model "*qualitative accident injury score*", which is easier to manage than the AIS method, has been elaborated in this study:

Methods

In every person implicated in accidents, the injury parameters of the persons involved have been registered according to table 4.31.

The scores are "inclusive", which 'logically' means unions, "either/or" related, since they only register whether one or more persons in the individual accident has had a given severity of injury. This simplification reduces the problems of overlapping, although it makes the accident scores more *qualitative* than quantitative.

It also gives a possibility of classifying all accidents in the four main categories on the basis of the sum scores.

E.g. : One person killed (score = 8), two unhurt (score = 0), and two hospitalised without injury to the central nervous system (CNS), (score = 2) gives a maximum cumulated score =10, the accident being classified as one with at least one killed person (category E).

Thus, in table 4.31 the sum scores of the accidents primarily reflect the most serious consequences of the accidents and are to a lesser extent dependent upon the numbers of injured road users. Further details of the logical computer formulas used can be seen in appendix E.

Material:

According to the principles of a qualitative accident score in table 4.31, the scores in 309 investigated drivers involved in accidents (known from the descriptive study, cf. chapter 4.1) have been analysed in table 4.32.

The distributions of accident sum

Table 4.31. Qualitative accident injury scale: principles for classification of sum scores in each car driver (see text). (Alsbirk, 1999).

Injury classification :	Injured person: Proband	Opposite parts	3rd parts	Score	Max. cumulated score
A. Unhurt	:			0	0
B. Treated as outpatients only (slight injury)	:			1	1
C. Hospitalized, no injury of CNS*.	:			2	2-3
D. Hospitalized, with CNS injury	:			4	4-7
E. Killed	:			8	8-15
				Sum score:	1-15

*) CNS: central nervous system.

scores in different subgroups of car drivers were compared:

1. Drivers with illegal and legal visual acuity, according to a) former Danish legislation and b) the adopted EU- rules of today.

To "test" the method on known associations, the same scores have been investigated by focussing on...

2. drivers involved in accidents registered by the police;

3.a. drivers with a known alcohol concentration in the blood at the time of the accident and,

3.b. drivers who informed that they had consumed more than 1 drink within 6 hours prior to the accident.

Results

The analyses demonstrate that the drivers with a visual problem as regards the estimated qualitative accident scores do not differ from the remaining, whether the focus is on drivers with illegal visual acuity according to former Danish rules (p= 0.82) or the present EU-legislation (p= 0.34).

These accidents have injury scores at least as high as that of accidents in which the drivers had no visual problems.

It is well known that the more serious an accident, the higher is the probability of police registration (cf. table 2.6) and thus the chance of having a blood alcohol test taken. Estimated by the introduced qualitative method, the first relationship is fully confirmed ($p < 10^{-6}$). Further, it could be confirmed that the risk of having a blood alcohol test taken is significantly higher in the most serious accidents ($p < 10^{-5}$, cf. table 4.32.III). Correspondingly, by this method it appeared that accidents involving car drivers, who were under the influence of alcohol, had significantly more serious consequences than the remaining. When analysed 1) according to the known blood alcohol concentration, which was tested in 28 police registered drivers, the p-value was 0.011, (Mann- Whitney test). The present material of drivers with a blood alcohol test taken is too small to make conclusions between different known concentrations of alcohol. When tested 2) according to the intake of drinks during the hours before the accident, registered in the interview, the p-value was < 0.01.

Table 4.32. Qualitative accident injury sum scores in different types of accident involved car drivers (Alsbirk, 1999):

I. a. Accident visual acuity

Main categories	Sum scores (main categories, cf. table 4.30) 1 (B)	2 (C)	3 (C)	4 (D)	5 (D)	6 (D)	8 (E)	10 (E)	14 (E)	Total	(pct.)	Mean
Illegal	10	3	1	0	0	0	1	0	0	15	(5)	1.80
Limit	2									2	(1)	1.00
Legal	205	45	14	17	2	3	4	1	1	292	(94)	1.67
Total	217	48	15	17	2	3	5	1	1	309	(100)	1.68

(Illegal vs. legal: z'= 0.23, p=0.82, Mann-Whitney test*).

I. b. Accident binocular visual acuity

	1	2	3	4	5	6	8	10	14	Total	(pct.)	Mean
<0.5	5	2	1	0	0	0	1	0	0	9	(3)	2.22
>=0.5	212	46	14	17	2	3	4	1	1	300	(97)	1.66
Total	217	48	15	17	2	3	5	1	1	309	(100)	1.68

(<0.5 vs. > 0.5: z'= 0.96, p=0.34, Mann-Whitney test*).

II. Police registration

	Main categories (cf. table 4.30) B	C	D	E	Total	(pct.)	Mean:
police reg.	134 (62)	58 (92)	20 (91)	7 (100)	219	(71)	1.89
not police. reg.	83 (38)	5 (8)	2 (9)	0	90	(29)	1.14
Total	217(100)	63(100)	22 (100)	7 (100)	309	(100)	1.68

(z' = 5.37, $p < 10^{-6}$, Mann-Whitney test*).

III. Alcohol involved:

a. Blood alcohol

	B	C	D	E	Total	(pct.)	Mean
Unknown (1):	208 (95)	50 (79)	20 (91)	3 (43)	281	(91)	1.52
Negative (2):	3 (1)	4 (6)	1(4.5)	3 (43)	11	(4)	4.55
>0 and >1‰(3):	1 (0.5)	6 (10)	0	1 (6)	8	(3)	3.0
>=1‰ (4):	5 (2)	3 (5)	1(4.5)	0	9	(3)	1.78
Total.	217 (100)	63 (100)	22 (100)	7 (100)	309	(100)	1.68

(1) vs. (2-4): $p < 10^{-5}$; (1+2) vs. (3+4): p= 0.011;
(2) vs. (3+4): p=0.19; (2) vs. (4): p = 0.12; (2+3) vs. (4): p= 0.12, Mann-Whitney test*).

b. Drinks before the accident

	B	C	D	E	Total (pct.)	Mean
0-1:	204 (94)	52 (83)	21 (95)	5 (71)	282 (91)	1.62
2-8:	12 (6)	11 (17)	1 (5)	2 (29)	26 (9)	2.35
Unknown:	1				1	1.00
Total :	217 (100)	63 (100)	22 (100)	7 (100)	309 (100)	1.68

(drinks: <2 vs. ≥2: z'= 2.62, p< 0.01, Mann-Whitney test*).

*) Mann-Whitney test, based on 4 classes of main categories (cf. table 4.31)

Conclusion and discussion

This simplified method of "qualitative accident scores", which is easy to administer, seems to work and is in accordance with known associations.

In the light of this it seems safe to conclude that accident-involved car drivers with significant visual problems are involved in accidents which, with respect to injury consequences, are as serious as the main group of accidents fulfilling the inclusion criteria.

The method seems reliable with respect to comparing different groups of accidents *relatively,* while it is too rough and should not be used when focussing on the absolute and quantitative consequences.

Perspectives

The results emphasised in the conclusion above are of importance when focussing upon the health- and economical "costs" for the possibly preventable subgroup of accidents in which a driver's visual problem might be a contributory factor.

4.4.2 The use of seat belts

The injury-preventing role of seat belts is sufficiently documented (Dalgaard 1977), and also in relation to injuries (Alsbirk and Pedersen, 1983, Johnston and Armstrong, 1986, Cole et al. 1987). One might expect that the accident-involved drivers, being negligent with respect to optical corrections, were more indifferent with respect to the use of seat belts too. Therefore, in the present study all drivers involved in accidents were asked whether they had used seat belts at the time of the accident or not.

Table 4.33 shows that among the accident involved drivers interviewed, 192 of 298 (65%) used their seat belts (95% limits: 59% - 70%). In 12% seat belts were not fitted, in 23% they were fitted but not used, and in 1% the seat belts were defective.

The youngest drivers were the most ignorant group since in the age group <30, only 58% used the seat belt, while from the age 30-49, 61%- and from the age 50, 71% used the seat belt at the time of the accident (z'= 2.37, p< 0.02).

No difference was found on the use of distance glasses (when owned) between drivers using and drivers not using their seat belts, (p= 1.0, Mantel-Haenszel test with control for drivers' age).

For the evaluation of the preventive effect of the seat belts, it is important to know the use of seat belts in accident-involved drivers as well as in a randomly selected group (e.g. from road side studies). In the years 1983-86, the frequency of seat belt usage among car drivers averaged 68% (Danmarks Statistik, 1984-87). This was within the 95% limit of the present accident population (p=0.14, binomial one-tailed exact test).

Conclusion

Drivers being negligent regarding optical correction for driving were not identical to those being careless concerning the use of seat belts.

The present investigation confirms that the proportion of drivers involved in accidents using seat belts was comparable to the findings in road side studies.

In spite of clear evidence of the injury preventive effect of the seat belts, the usage of this simple and effective equipment was disappointingly low. The young drivers obviously had the lowest degree of understanding the established preventive effect.

Table 4.33.

A. Use of seat belts by 309 investigated accident-involved car drivers (Alsbirk, 1999).

Seat belt not fitted	36	(12.1%)
Seat belt fitted, not used	68	(22.8%)
Seat belt used, but defective	2	(0.7%)
Seat belt used, not defective	192	(64.4%)
Unknown	11	
Total:	309	(100%)

B. Use of seat belts by different age groups of 309 accident-involved drivers (Alsbirk, 1999).

	Age groups: 18-29	30-49	50-69	70+	Total
Used	45 (58)	62 (61)	77 (75)	10 (63)	194 (65)
Did not use	33 (42)	39 (39)	26 (25)	6 (37)	104 (35)
Unknown	5	3	3	-	11
Total	83 (100)	104 (100)	106 (100)	16 (100)	309 (100)

(z'=2.37, p< 0.02, Mann-Whitney-test).

C. Use of seat belts by accident-involved drivers in relation to use of glasses at the time of the traffic accidents (Alsbirk, 1999).

Use of distance glasses:	Use of seat belts: Used	Did not use	Unknown	Total
Had none	96 (49)	64 (62)	7	167 (54)
Had, not used	19 (10)	7 (7)	0	26 (8)
Had, used	76 (39)	33 (30)	4	113 (37)
Unknown	3 (1)	0	0	3 (1)
Total	194	104 (100)	11	309 (100)

Use/no use of owned glasses vs. use of seat belts, $X^2 = 0$, d.f. = 1, p=1.0, (Mantel-Haenszel test with control for drivers' age).

5. DISCUSSION.

5.1. Introduction.

The reason for continued research concerning the association between visual factors and road traffic accidents is not only that the conclusions of the majority of studies in this field seem to disagree considerably. In the dynamic world of today and tomorrow, several *changing conditions* prevail:

- A growing proportion of elderly drivers are expected to have or to develop visual problems in the increasing density of modern traffic cf. chapter 1.1. *(demographic evolution);*
- an improvement in possible vision test methods *(methodological development);*
- an increasing potential for surgical and optical relief of visual problems *(health service evolution)*;
- a variation in legislation and "traffic culture", politics and social services *(geographical variation).*

These and other arguments make regional studies relevant from time to time.

The *common denominator* is traffic accidents with all the suffering involved in terms of death, disablement and economic losses.

Traffic accidents are not inevitable. On the contrary, they are preventable by reasonable intervention. The manager of the Global Program for Accident Prevention of the WORLD HEALTH ORGANIZATION has given some statistical background:

In the period from 1970 to 1980, the number of victims of road accidents (as an example) has increased by 50% in Portugal and the former Yugoslavia, whereas in the same period it has decreased by 20% in France and by 40% in Denmark. In some countries up to 20% of all admissions to hospitals are due to road accidents. In 1974 the total costs of road accidents in France were thought to be equivalent to a loss of productivity of 400,000 workers (Romer 1981). Thus, the serious qualitative and quantitative character of road traffic accidents, viewed in a humanistic, health, as well as an economic perspective, is the superior reason for a delineation of the problem as well as for continued research in causality and in preventive measures.

Ophthalmologists' dilemma:

Most ophthalmologists are familiar with the dilemma of being confronted with a patient with a poor visual acuity and at the same time knowing that this same patient is an active motorist.

Often the problem can be solved by giving the patient improved correction for an existing refractive error or by referring the patient to ophthalmic surgery for treatment of unclear media.

If these corrective measures cannot bring the patient's vision above the legal limit, it is the duty of the physician to intervene. According to section 12 of the Danish Practice of Medicine Act, the physician has to:

1) Ask the patient whether he still drives a car and, if this is the case, inform him directly that his vision is not adequate for driving.

2) If the patient will not accept this, it is the physician's duty to inform the patient that it may be necessary to notify the local Medical Officer of Health or the National Health Service, which also functions as a court of appeal for the patient.

Juhl (1984) found a great lack in consistency regarding doctors' necessity for reporting a patient to the Medical Officer of Health. In 1977 and 1978, 13 patients were reported by ophthalmologists. Of the approx. 200 ophthalmologists in Denmark at that time, one reported 7 patients, another reported 2, and four reported 1 patient.

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On the basis of the existing knowledge the following points will be discussed:

The present investigation (5.2); economic and health aspects (5.3) and future perspectives (5.3).

5.2. The present investigation.

The demographic and legislative background of the study has been outlined in chapter I.

5.2.1. The material and study design, methodological aspects:

5.2.1.1. Some characteristics of the present study:

The present study differs from most earlier studies in several aspects:

a. The investigation includes an non-selected series of consecutive road traffic accidents, police-registered as well as non-police-registered. The criteria for relevance and seriousness with respect to health were assured by focussing upon accidents with car drivers involved and accidents in which one or more persons were injured to such an extent that they were admitted to the casualty wards or hospitals.

On the assumption that the hospital and police district of Aarhus (which is a mixture of urban and rural areas) do not differ significantly from the rest of Denmark, the findings may be partly generalised to apply to the country as a whole (cf. chapter 5.3.1.2-3).

b. This is the first *Scandinavian study* in which visual factors are analysed for associations to authentic road traffic accidents. In another study from Finland (Liesmaa, 1973) visual factors were analysed in relation to dangerous pre-accident behaviour of the drivers (cf. p. 20). Other Scandinavian studies have provided important knowledge on a more experimental basis (e.g. Johansson & Rumar, 1967; Berggren, 1970; Åberg & Rumar, 1975; Åberg, 1977; Luoma, 1984; and Lövsund, Hedin and Törnros, 1991). Furthermore, a Danish registration survey from an eye clinic has been published (Kristensen, 1988).

The Scandinavian countries offer excellent facilities for epidemiological studies since the inhabitants are geographically stable, well-registered, and the health service is of a uniform high standard, (Sjölie 1985). This gives a basis for extrapolating findings and frequency estimates to larger population groups.

On the basis of the great variation in legislation, politics and "traffic culture" etc. from country to country, however, such a generalisation on a broad, international scale should be taken with caution. The basic population of this study comprised 284,000 inh. out of 5.1 million = 5.6% of the Danish population.

c. The study includes a *control group of active, randomly selected car drivers.* One reason for the inclusion of a control group was the attempt to make calculations on relative accident risk estimates. Furthermore, access to the drivers' previous accident data in the records of the police and insurance companies was not possible (due to legislation). The information from the interviews on possible previous accident involvement was found to be too unreliable and subjective (also found by Owsley et al., 1991).

d. *Participation* in the study was voluntary and the rate of participation comprised 76% of the accident-involved car drivers, 83% of the unprotected, "weak" road users, and 92% of the control group of drivers. This participation rate is acceptable on the basis of voluntariness. It has been achieved by a rather time consuming procedure which included one or more letter contacts as well as contact by telephone prior to the investigation. Furthermore, the principle of confidence, based on the author's medical, professional secrecy, is considered to be of decisive importance. The study of Hjorth et al. (1991) illustrates the problem of participating in an investigation like this on the background of an embarrassing experience. Only 6% of cases and 26% of controls ($p < 10^{-4}$, Fisher's exact) took part in the visual examinations.

The group of *non-responders* has been described as thoroughly as possible within the limits of the law, leaving only 7% in which ophthalmological data remain unknown.

e. Compared to several other studies (e.g. Council and Allen 1974, Burg 1968, Gramberg-Danielsen 1971, Johnson and Keltner 1983, Rogers et al. 1987, Gresset and Mayer 1995, Lachenmayr 1998), this investigation has a smaller selection of drivers, but, on the other hand, in several aspects it has been more intensive as it offers a profound analysis of 369 road traffic accidents resulting in personal injury. More than one hundred case histories have been published as illustrative documentation, giving the reader the opportunity to draw his own conclusions on the basis of a) a report of vision and b) a short accident report. To highlight the accident situations, a number of sketches have been prepared, in most cases on the basis of the precise drawings in the police reports.

f. The EDP-analysis on a personal computer of the material of 700 persons, each with 90 primary variables and 35 secondarily calculated, derived variables, gave the possibility for detailed cross tabulations and multivariate analyses of relevant associations. In the pre-EDP era, this would have been overwhelming.

g. In order to attain a participating rate as high as possible, the period for examining the drivers was restricted to 45 minutes. For this reason and due to limited economic resources this study, as well as others, has its *limits:* The visual parameters practised in Denmark in relation to driver's license applications had the highest priority. These parameters (static visual acuity by monocular test and visual field examination by hand ad modum Donders) have been supplied only as mentioned in table 3.2. Several parameters of interest were not consistently examined: E.g. dynamic visual acuity, visual acuity in glare, dark adaptation, computerised perimetry etc. For practical reasons the collection of general health parameters was rather superficial, and psychological tests were not obtainable, although this might have been of importance.

Due to limited economical resources only one examiner (the author) performed the investigations in all participating probands. This eliminated inter-observer variation, however, it also implied that the procedure of examination could neither be performed "blind" nor "double blind".

A strict person-to-person matching on age, sex, and annual driving between the cases and the control group of elderly drivers would have been the ideal design. This, however, was not practically obtainable, also due to the limited time available. The collection of data from "controls" started in the same period as the probands in phase II were included in the study according to the inclusion criteria (cf. chapter 2.1).

5.2.1.2. The descriptive study:

For a realistic description of basic demographic patterns, including the different types of road users and accidents, only the material of phase I is used. Phase II consists of a restricted sample, including only car drivers, aged $\geq$ 50, involved in a police registered accident with human injury.

When focussing on *car drivers*, the observations on visual parameters are based on both phase I and phase II material.

In the final generalized compiling of national incidence estimates some corrections have been made as outlined in chapter 5.3.1.

Such generalisations should be limited to regions with comparable legislation, health system and traffic. Most authors who within their regions have performed similar epidemiological investigations have made corresponding estimates (e.g. Keeney, 1974; Gramberg-Danielsen, 1971; Henderson and Burg, 1973-74; Harms, 1985).

5.2.1.3. The analytical study:

Causal associations, which in the individual accidents can only be estimated, may receive support through the use of epidemiological methods.

Analogous problems exist in the estimation of the injury-preventing effect of the seat belt (e.g. Dalgaard, 1977; Alsbirk and Pedersen, 1983) as well as in the accident-provoking effect of alcohol (OECD, 1978; Valverius, 1986).

One important method is to collect information on the frequency of the relevant parameters in the background population. This is possible by the investigation of a control group, randomly selected from the background population - a so-called "case/base study" (Olsen, 1988).

The methodological problems have been mentioned in chapter 2.5 and 3.1.3. These have been partly opposed by performing a logistic regression analysis on a restricted material (cf. chapter 2.5) with control for design variables and certain confounding factors.

As seen in table 1.3, only a part of the studies referred to have used a design including a control group (e.g. Brody, 1941; Fletcher, 1949; ENO-Foundation, 1948; Cashell, 1966; Gramberg-Danielsen, 1971; Liesmaa, 1973; Golding, 1984; Humphriss, 1987; McCloskey et al., 1994; Gresset and Meyer, 1994; Lachenmayr, 1998). Most of these studies, however, differed from the present in several other ways (cf. chapter 1.3.4). E.g. the selection of a control group cannot be said to be strictly sampled at random in an investigation of eye clinic patients or healthy drivers, re-applying for a driver's license (cf. table 1.3). By making a selection from the police records in accordance with the procedure outlined in chapter 3.1.2, this was attempted in the present study. Very few other studies had the probands tested shortly after the accident using the same optical correction.

5.2.1.4. The reliability of the information.

The principles of voluntariness, confidence and emphasis on the author's medical, professional secrecy (cf. appendix 9 A+B) are estimated to have provided the best obtainable conditions and to have been of decisive importance in drawing of a realistic picture of visual problems among car drivers in relation to the accidents.

This basic requirement cannot be assured by testing car drivers applying for a renewal of their driver's license (Burg, 1968; Council and Allen, 1974; Johnson and Keltner, 1983). In one study, a corresponding problem (lack of medical professional secrecy) existed when testing drivers even after a conviction (Gramberg-Danielsen, 1971).

As shown in the present, as well as in other studies (Zaidel and Hocherman, 1986; Humphriis, 1987), many drivers drive without using their distance correction even though they may use it when watching TV! Probably, they also use it when re-applying for a driver's license!

5.2.2. Results.

In the following chapters various aspects found in the analyses of the observations will be discussed. Initially, the importance of age will be considered.

5.2.2.1. Age correlation's and static visual acuity.

The methodological problems in this field, in which age is a confounding factor, have been discussed in chapter 1.3.4.

Looking at drivers below age 50, only 3 out of 187 accident-involved drivers (1.6%) had visual acuity below the legal level, mainly due to myopics driving without the use of their correction. Only one (0.5%) had binocular visual acuity < 0.5. This finding confirms the results of most authors (e.g. Shinar, 1977; Henderson & Burg, 1974; Burg, 1968), that vision seems rather unimportant as an accident-related factor in the case of young drivers, i.e. a re-testing of these drivers' vision would imply low cost/efficiency. Nevertheless, quantitatively speaking, young drivers are of major importance in traffic accidents and a re-testing of

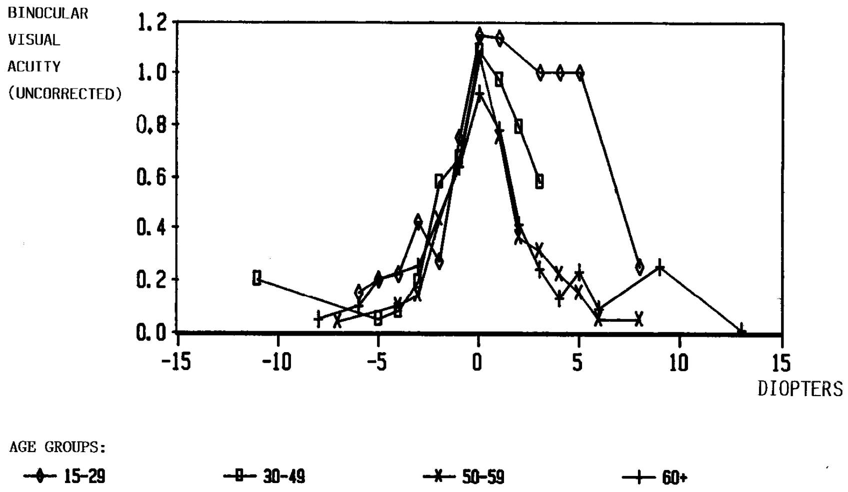

Fig. 5.1. *Uncorrected mean binocular visual acuity vs. refraction groups (diopters, average of two eyes) in 435 car drivers. Age groups indicated. One myopic driver, aged 30-39 had severe anisometropia (-18 and -3) (K.E. Alsbirk, 1999).*

the vision of younger age groups, as well, has been recommended (Harms and Dietz 1987).

In the "intermediate group" from age 50 to 69 the visual findings are intermediate too. Eight in 106 drivers (8%) had un-lawful visual acuity at the time of accident.

In the age group from 70 and above, a significant proportion of accident-involved drivers had illegal visual acuity, being 21% in drivers aged 70-79 (n= 14) and 50% in drivers $\geq$ 80 years (n= 2).

- Thus the proportion of drivers with illegal visual acuity increases significantly with age.

In an English road side study from 1996 among 8000 drivers, 7-10% of the young age group (17-50), failed the number plate test , increasing to 19.3 % for 51-55 year old drivers and 58% in 71-75 year old drivers (Optometry Today, October 1996).

5.2.2.2. Age, uncorrected visual acuity and refraction.

In the total material of investigated drivers, their relationship between uncorrected visual acuity and the refraction was analysed in relation to age. In 467 (86%) of the 543 drivers in the study group (405 probands and 138 controls), binocular visual acuity without correction as well as the mean refraction of the two eyes were known (22 based on information from eye specialists). In fig. 5.1 this relationship is demonstrated.

The curves show the known steep slope in the myopic end, rather independent of the drivers' age, whereas in the hyperopic end, as clearly illustrated, the slope is highly dependent on age: Young drivers compensate well by accommodation, but from age 40 this compensation is significantly reduced, and from age $\geq$ 50 (the age group 50-59 indicated with X) it is highly insufficient. From this age, with a refraction of +2 D or more, the binocular visual acuity without correction as a rule is below 0.5!

The figure disproves a very common misunderstanding that when a person is hyperopic, his/her distant vision is sufficient and glasses are necessary only for reading! This is partly excusable when looking at the common but misleading word for hyperopia: long-sightedness (in Danish correspondingly: "langsynethed").

In the investigated group of drivers, the insufficiently accommodating and often under-corrected group of hyperopic drivers from age 50 and above seems to constitute a significant problem in daily traffic.

5.2.2.3. Visual parameters, other aspects:

5.2.2.3.1. Visual acuity.

As earlier mentioned, the question of how to test car drivers' visual acuity is controversial too. Several authors have not been able to relate reduced *static visual acuity* with accident history, some even conclude that compensation by more careful driving is so efficient that a good vision seems significantly associated with bad accident records! (Quimby et al. 1986). On the contrary, when correcting for the important *age factor* a significant association has been more clearly demonstrated between poor driving records and static visual acuity, although the correlation's are low (accounting for less than 5% of the variation) (Henderson and Burg 1974, Hills and Burg 1977, Davison 1985, Shinar 1977). This was confirmed in the present study. Lachenmayr (1998) found significantly reduced photoptic and mesoptic vision as well as resistance to glare in 754 drivers involved in accidents compared to 250 controls. A normal binocular vision and visual field improve the accuracy of "time before collision" estimation (Cavallo and Laurent 1988). Wood and Troutbeck (1994) in experimental conditions found the greatest detriment to driving performance in a simulated cataract group of young drivers followed by a simulated binocular visual field restriction group. The monocular condition did not significantly affect driving cf. chapter 1.3.3.2. Higgins et al. (1998) examined young drivers' behaviour under experimental conditions with swimmer's goggles modified with calibrated blurring lenses. Acuity degradation produced significant decrements in road sign recognition and road hazard avoidance as well as significant increment in total driving time. Ivers et al. (1999) found association between self reported accidents and a two line reduction of visual acuity (adjusted prevalence rate = 1.6) as well as visual acuity worse than 6/18 in the right eye (PR = 2.0) among 2379 drivers aged 49 and older.

Dynamic visual parameters in several studies have been shown to be more strongly correlated to accident history, e.g. Hills & Burg, (1977), Johansson, (1997). This confirms the hypothesis that traffic accidents are more related to failures in visual perception of a higher order, such as faulty estimation of the speed and of the time necessary to overtake. The quality of visual spatial perception for movable objects clearly decreases in old age and is of importance as to the fitness for driving (Sachsenweger and Sachsenweger, 1987). However, tests for static visual acuity still appear to be more reliable and more realistic to administer so far (Shinar, 1977). Hills & Burg (1977) found a good correlation between dynamic and static visual acuity. Testing of *early visual attenuation* by the method of "useful field of view" (UFOV, a kind of central visual field attention test) seems promising (Owsley et al. 1991, cf. p. 21).

Some of the discrepancies found between the various studies might be explained by their rather *variable legislative background*. The present study was performed in Denmark, in which re-testing of private car drivers below age 70 had not been compulsory since 1966. A surplus of drivers ≥ 50 years involved in traffic accidents had illegal visual acuity compared to a control group, when corrected for age, sex and annual driving. The difference was statistically significant when visual acuity was tested binocularly (cf. chapter 4.2.). The findings suggest that reduced, binocularly tested static visual acuity is a significant co-factor in traffic accidents with odds-ratios between 3 and 5. Although collected in a different way, the results confirm those of von Hebenstreit's (1985), indicating a six or seven fold over-representation of visual problems in drivers involved in the subsample (about 50%) of accidents in which vision was considered to be of relevance.

Other parameters have been indicated as more relevant, but from a *practical* point of view, a testing of static visual acuity is, so far, still the general and realistic way to administer the screening of big groups of drivers all over the world, being even simpler when performed as a binocular test.

It has been questioned whether static visual acuity is relevant at all in traffic accident situations. From a logical or practical point of view some would say that the paracentral and peripheral visual field is more important. Therefore it is surprising that it has been difficult to prove the importance even of this parameter (Council and Allen 1974). As Danielson (1957) stated after testing 680 car drivers: "The quality of the central field is more important than the quality of the peripheral field". He concluded that visual defects seem to be a minor cause of road traffic accidents.

In traffic situations, large contours such as roads, trees, cars, buildings, maybe even persons close up you are distinguishable even with a low level visual acuity. This is even more true in clear and bright visibility conditions. However, in many traffic situations, the visibility conditions are frequently changing and far from optimal (cf. accident I-V-517 and, I-V-991) and it is often the small details in the jumbled traffic picture that are decisive: e.g. the recording/interpretation of eye contact, movements of heads, conditions of the road surfaces (e.g. sporadically icy spots), dark pedestrians and bicyclists, texts in road signals, attitude of children, their playing with toys, balls etc. For this *important current interpretation of small details,* static visual acuity must definitely be of relevance as *a necessary, although not sufficient, condition*. Some other important conditions for the drivers' interpretation of the dynamic traffic picture are: visual field, imagination, alertness, maturity, and experience. The last three factors are not within the scope of this study, but within certain limits they are the parameters by which elderly drivers often compensate for a reduced visual acuity.

Static visual acuity is measured by the estimation of the resolving power of the eye, which is normally about one minute of arch. When practically measuring visual acuity, *distance* turns out to be important. By a visual acuity of 6/24 (=0.25), a person has to be at a distance of 6 metres in order to see the same details as a standard or "normal" person is able to see in 24 metres. Transferred to a dynamic traffic situation this is easy to illustrate: The time interval to ward off an impending traffic situation is a result of the speed as well as the visual acuity of the driver. As an example the corresponding time interval for reacting to an important detail, normally seen in 100 metres, has been calculated for different levels of speed and visual acuity (table 5.1).

As can be seen, *at a fixed speed the time available for a necessary reaction is directly proportional to the static visual acuity*. For important details, normally seen at shorter distances than 100 m (e.g. the interpretation of eye contact, icy surfaces of the roads, small movements and attitudes of children and other unprotected road users etc.) the time available to react is correspondingly reduced. Finally, when considering what to do in order to help

Table 5.1. "Available reaction time" (in seconds) in relation to speed and visual acuity, compared to a standard critical distance of 100 m (Alsbirk, 1999).

Visual acuity:	Distance: (m)	Speed (km/h): 40	60	80	100	120
1.0	- 100:	9.0	6.0	4.5	3.6	3.0
0.8	- 80:	7.2	4.8	3.6	2.9	2.4
0.6	- 60:	5.4	3.6	2.7	2.1	1.8
0.4	- 40:	3.6	2.4	1.8	1.4	1.2
0.2	- 20:	1.8	1.2	0.9	0.7	0.6

a driver with a reduced visual acuity, the static visual acuity is the parameter which still is, and for many years will be, the dominating test used to monitor the gain/ improvements after a new optic correction or an eye operation!

5.2.2.3.2. Optic correction in visually impaired drivers.

For certain visually impaired persons the static visual acuity and visual field represent reciprocal variables when using high power optic correction in front of the eye. Before the era of corneal contact lenses or intraocular lens implantation during cataract operations this was a phenomenon known by many aphakic patients. Achieving a sufficient optic resolution on the retina was "paid for" by a reduced visual field. Due to the heavy glasses a ring scotoma was present (McLemore, 1963; Lachenmayr and Buser, 1994).

A similar phenomenon is found when trying to administer bioptic telescope spectacles for individuals with severely reduced visual acuity. The phenomenon is generally known in the use of binoculars. Kelleher (1979) published his own experiences as the first low vision person in California licensed to drive with a bioptic. Keeney (1974a) and Hames (1976) warned against the use of telescopes when driving. The subject has been reviewed by Barron (1991). Even drivers with a normal visual field drive with a functionally restricted field of vision at high speed. This physiological reduction of the effective binocular visual field is reduced from 200° to 100° at a speed of 20 miles/h, 70° at 40 miles/h and 40° at 60 miles/h. A slightly greater speed brings this *"speed smear"* into the ring scotoma of the bioptic telescopes of the car driver, leaving only about 7° magnification field (Keeney 1974a). Also, Fonda (1983) warned against using bioptic telescopic spectacles for car driving. Later, Fonda (1991) supported this view by finding a factor 1.8 - 3.5 increase in accident rates in drivers using these optics. Baily (1985) argued in favour of bioptic telescopic lenses when combined with a thorough road test of driving skills and under continued monitoring of driving records.

The use of bioptic telescope glasses are not permitted in Denmark. None of the drivers in the present study used them. One driver in the accident group had aphakic correction (I-VM-141) in one eye and mature cataract in his fellow eye. A restricted visual field (ring scotoma) combined with a severe macular degeneration in the aphakic eye probably have been of contributory importance in this accident. On the other hand, in the control group, one driver with bilateral aphakia had driven 13,500 km annually for seven years with aphakic glasses (and without retinal pathology) without being involved in any traffic accident. The German Ophthalmological Society (Lachenmayr and Buser, 1994) recommended that only glasses giving no significant restrictions of the visual field should be accepted. For class II drivers, + and - 8 glasses in the EU is the upper numerical limit.

In addition to his warning against bioptic telescopic spectacles, Fonda (1986) warned against the social consequences of re-testing drivers' vision. On the other hand, the same author (Fonda, 1989) found it safe for some people with a visual field of > 120° to drive with 20/200 (=0.1) visual acuity in daytime at a speed of not more than 40 mph. Like Hames (1976) and Colenbrander & Fletcher (1992), he proposed a limited license and detailed instructions for drivers with visual acuity below the lawful limit.

Today most states in USA offer some type of restricted license to drivers with visual acuity below 20/40, e.g. Washington with a limit at 20/200, (Fishbaugh, 1995). A corresponding practice is applied in Denmark by the Danish National Board of Health in a very limited number of individually evaluated cases applying for the renewal of a driver's license.

5.2.2.3.3. Visual field.

A detailed review on visual field and ergonomics has been published by Verriest et al. (1985). As a consequence of the "speed smear", the peripheral visual fields are especially important at low speeds (Byrnes 1967). Not only is the functional visual field reduced due to speed, but the head movements are also narrowed (Åberg and Rumar 1975). Young drivers with a restricted visual field has (on an experimental basis) been shown to compensate by making large horizontal head movements (Åberg 1977). When testing drivers with real visual field defects in a driving simulator, Lövsund, Hedin and Törnros (1991) showed that only 4 out of 31 drivers compensated sufficiently for their deficiency. McKean and Elkington (1982) described driving problems in a material of 214 glaucoma patients. Twenty-nine percent (N= 61) were still driving. Twenty of these gave up driving, 3 of them due to an accident. Six drivers were diagnosed as a result of problems in driving. In a driving simulator study, Taglia et al (1997) tested 26 glaucoma patients and found that reduced contrast sensitivity was significantly associated with poorer driving parameters.

Spectacle frames can cause visual field defects affecting driver's fitness to drive (Steel et al, 1996).

Visual field defects seem to play a minor role in traffic accidents (Danielson 1957, Council and Allan 1974). However, the last authors found an increased frequency of side collisions in drivers with visual field defects. Johnson and Keltner (1983) found a two-fold increase in accident rates in drivers with homonymous visual field defects (N= 196) by screening 10,000 drivers' license applicants, who volunteered to participate in the screening. Their findings were partly confirmed in a promising test method of "early visual attenuation" by method of *"Useful field of view"* (UFOV) (Ball et al. 1988; Owsley et al.,1991; Ball and Owsley, 1993, cf. p. 21) suggesting a significant increased accident risk in patients with visual attentional disorders. The authors have clearly demonstrated that clinical visual perimetry underestimates peripheral visual field problems in older adults (Ball et al, 1990) compared to the UFOV method. This method was further used by Wood and Troutbeck (1995) in an experimental study with simulated visual impairments among elderly drivers. Significant correlation was found between driving performance, the UFOV-test, and reduced contrast sensitivity. Rizzo and Robin (1996) found reduced sensitivity to signals and increased response times in *both* hemifields in twelve patients with hemianopic defects. Two of these patients were tested in the UFOV test, showing bilateral constriction.

Szlyk et al. (1992) found significant association between visual field defects and the frequency of self-reported accidents as well as *driving simulator accidents* when comparing drivers with retinitis pigmentosa and controls, and when comparing drivers with hemianopic visual field loss and controls (Szlyk et al., 1993). The same method, however, was not associated with accident involvement's for drivers with juvenile macular dystrophies (Stargardts- and cone-rod dystrophies). These drivers had a greater likelihood of being involved in night-time accidents than a control group (Szlyk et al., 1993). In a later driving simulator study (Szlyk et al., 1995) among visually impaired drivers, regression analyses showed that compromised vision and visual field loss predicted real-world accidents in the study population compared to controls. Patients with peripheral vision loss benefit (improvement of 37%) from the use of bioptic amorphic lenses expanding the visual field, when combined with a special rehabilitation programme (Szlyk et al., 1998).

In this study the visual field as a screening procedure has been tested by hand ad modum Donders in the case of all the investigated drivers. An automated perimetry was performed in selected cases (15% in probands and 14 % in controls) by use of the "Competer" perimeter. Such cases were: central defects, retinal disorders, neurological disorders, glaucoma and pathological retinal findings.

Both Council and Allen (1974) and Johnson and Keltner (1983) have found only very few driver's license applicants with large homonymous visual field defects.

In the present descriptive study a corresponding low number was found (0.6%). Heteronymous defects were more common (3%).

Since visual field defects are relatively rare, the numbers found in the present study are too small to draw any conclusions. Referring to table 4.19, no difference was found between the drivers involved in traffic accidents and the control drivers. Bearing the accident cases in mind (cf. appendix C 2) one should *not* conclude, however, that a driver with a given visual field defect is not dangerous in traffic. Accident numbers II-VM 401, II-V-923 and II-VM 979 should be mentioned. Especially in the last case, which is described and illustrated in detail, an old visual field defect due to a skull trauma in childhood might be of importance. In a serious accident, which took place many years ago, three boy scouts were severely injured.

Parisi et al.(1991) reviewed records of 60 patients with homonymous hemianopic field defects. Thirty-four patients (57%) did not meet the visual field requirements for unrestricted licence. Two years later 33% improved and 7% became functionally worse. A two-year follow up of these patients was recommended.

Earlier used Xenon-photocoagulation for diabetic retinopathy was associated with significant visual field test failures, whereas pan retinal photocoagulation (PRP) with 200 micron Argon burns does not appear to jeopardise a driving license (Hulbert and Vernon, 1992). Buckley et al. (1996) for the same reason recommend "just retinal whitening" as the end point for deciding the power of the burns instead of "definite white spots". If both eyes are treated with pan retinal photocoagulation, 12 per cent of diabetics will not pass the UK driving field test (Pearson et al, 1998).

A visual field, artificially restricted to 40 degrees in young, normal subjects significantly reduced driving ability (Wood and Troutbeck, 1992).

Hedin and Lövsund (1986) concluded: "If the abnormal area is located in a part of the visual field relevant for driving, it seems justified to deny the subject a license". New computerised screening methods, easy to perform, are being developed (e.g. Bengtsson & Krakau 1979, Crick & Crick 1981, Hedin, Rumar & Verriest 1981). Today computerised screening programmes are available for personal computers (e.g. Boberg-Ans & Vangsted 1988).

In the future, such non-expensive screening methods will probably become a satisfying supplement to today's very rough and inconsistent screenings by method of Donders, particularly when performed according to the previous Danish recommendations (Sundhedsstyrelsen, 1962). This will be further commented in chapter 5.4.

5.2.2.3.4. Unilaterally reduced visual acuity.

The drivers were classified according to having a unilateral visual reduction or not. The criterion for such a reduction of visual acuity at the time of accident/ during normal driving was: visual acuity in the worse eye < 0.25 (6/24) against $\geq$ 0.4 in the fellow eye. This criterion being chosen as 0.25 was the relevant limit for the worse eye according to the former (until 1996) legislative Danish requirements. With a visual acuity in the worse eye below that value, the requirement for the fellow eye was increased from 6/12 (0.5) to 6/9 (0.67) in many countries, including Denmark. In the present study, drivers with unilateral reduction of visual acuity had a four to five fold increase in accident risk, (p=0.02, cf. chapter 4.2). In the crossroads accidents these drivers were involved in significantly more collisions to the impaired side (86%) than to the opposite side (14%). This does not seem to be a coincidence ($p < 0.05$), but is also suggested, when looking at the relevant accidents (cf. table 4.11). and 4.12 and appendix C. 2). Nevertheless, in such a small sample one should be aware of the possibility of a type I error (a false "positive" result). It is not simple to explain why monolateral amblyopia with an intact peripheral visual field should be important in side collisions.

A number of accidents may elucidate this question: (cases no. I-V-64, I-V-991, II-V-91, II-V-115, II-V-397, II-V-499, II-V-574, II-V-598 and II-V-92, cf. appendix C. 2).

The findings of 11 out of 14 side collisions happening from the left side (79%) vs. 3 (21%) from the right side are close to being statistically significant (p=0.06, double-sided binomial test). If this is not a coincidence, one explanation might be that collisions happening from the left side are approaching from a steeper angle in a country with right-sided traffic. A reduced visual acuity in the left side might be more critical for an adequate perception of a dangerous traffic situation from the left. The steeper the angle, the more critical the reduced visual field of the better, perceiving eye, due to the "nose-barrier", e.g. accident II-V-926 (cf. appendix C. 2).

Ivers et al. (1999) found association between self reported accidents and visual acuity worse than 6/18 in the right eye (PR = 2.0,[1.2-3.5]) among 2379 drivers aged 49 and older. - Since Australia has left-side driving, this corresponds well to the findings in the present study with a surplus of drivers with left-side visual impairment.

The present observations support the findings of three other studies: Fletcher (1947) found a unilateral reduction of visual acuity (i.e. v.a. ≤ 20/40) in 1/3 of 101 fatal intersectional collisions, 90% happening in the side of the worse eye! Keeney (1968) found a four-fold increased (8%) frequency of one-eyed drivers in a material of 991 drivers with driving problems, compared to a material from a private eye clinic (2%). The same author (Keeney and Garway 1981) has reviewed the literature in this field. Liesmaa (1973) found visual limitations in one eye in 12% of 25 car drivers entering a major road in a dangerous manner.

In 156 out of 382 one-eyed drivers, 192 traffic accidents were recorded during a ten-year period (Schwartz, 1939). The analysis showed that the accidents seemed to be more related to a loss of visual field than to the loss of depth perception .

The question of functionally one-eyed drivers is controversial and has been discussed intensively. In the EU (De Europæiske Fællesskabers Tidende, 1991), a radical change took place for one-eyed drivers since these will now be excluded as taxi, bus and lorry drivers in the future (with the exception of those already having such a license today).

Professional one-eyed drivers were investigated by Gramberg-Danielsen and Repkewitz (1976). No overall increase in accident rate could be demonstrated in these drivers. The same was found in two Swiss studies (Thalmann,1971; Maag and Bullet, 1983). In close traffic situations (e.g. bus drivers in the town and by driving into another car from behind), in which a three dimensional vision is important, one-eyed drivers, however, had slightly more violations. Johnson and Keltner (1983) found no increase in the three year accident rate of voluntarily tested drivers with a unilateral visual field defect.

Wasmund (1982) investigated 53 persons after dilatation of the pupil in one eye. In 64% the induced reduction of visual acuity in the treated eye did not exceed 0.1, in 26% it was 0.2, and in 4 persons (8%) the impairment was worse than 0.2, one was even 0.7. No reduction was found in stereopsis or visual field. The author recommended prohibition against driving after the use of mydriatics due to a risk of sudden diplopia (due to decompensated heterophoria), dazzling (particularly in elderly patients) as well as illusion of perception ("Pulfrich's phenomenon) (Gramberg- Danielsen, 1963). This phenomenon has been reviewed by Diaper (1997). Jude et al. (1998) found that among diabetic patients with legal vision before dilatation 7 % had visual acuity less than 6/9 after dilatation. They recommended to warn the patients and to let them wait at least two hours before driving.
- Instillation of one drop of miotic drug (e.g. Pilocarpine) after such examinations seems reasonable especially in driving patients.

Hedin and Lövsund (1986) tested two monocular drivers in a driving simulator. One of them had a markedly prolonged reaction time in the periphery of the blind side.

In one accident in the present study (I-V-64) a driver had suffered a branch vein thrombosis in his left eye 2 months earlier. In a T-crossroad he overlooked a bicyclist coming from the left side. This accident illustrates the importance of a certain time lag after a sudden acquired monolateral visual defect. In Denmark, drivers with sudden onset of visual loss in one eye is recommended not to drive for up to six months.

Linberg et al. (1988) studied 49 adults with sudden loss of an eye. The proportion of drivers adjusted for driving was 37% within 1 month, 78% within 6 months and 86% within one year. Twelve per cent of 71 enucleated drivers due to choroidal melanomas gave up driving after the operation (Edwards and Schachat, 1991). Fifteen years after the enucleation, 90% (18/20) retained the ability to drive. McKnight et. al. (1991) found monocular drivers significantly deficient in contrast sensitivity, visual acuity under low illumination and glare, and binocular depth perception compared to a control group. However, it was concluded that they did not seem to be significantly worse than binocular drivers in the safety in most day to day driving functions.

The *conclusion* is that unilateral reduction of visual acuity seems to be partly associated to intersection accidents in close traffic situations. The literature and the present investigation reveal rather mixed results concerning the frequency of one eyed drivers in dangerous traffic situations. The present findings support the current "intermediate" legislation of the EU by permitting one-eyed individuals to drive their private cars and by increasing the requirements for taxi, bus and lorry drivers by requiring good vision in *both* eyes (Directorate General 1986). However, the results also put a questionmark against the requirement of only binocular testing of group I car drivers in the EU. This is further discussed below.

5.2.2.3.5. Advantages and disadvantages of testing drivers' vision binocularly according to the present European Union regulative, is evaluated and compared with the former monocular tests. Seen from an administrative point of view, the binocular test has certain advantages. However, from an ophthalmological point of view, particularly with the aim of preventing disease, blindness, or traffic accidents, the binocular test cannot be recommended. The accumulation of drivers with unilateral visual impairment in the accident group supports the tightening of visual standards for the worse eye in drivers of heavy transport (Group II driver's license) or commercial passenger transport. (The more stringent standards have been followed up by also requiring truck drivers to pass a vision test every fifth year from age 50). The same results make somewhat of a case against introducing a binocular vision test.

As discussed in chapter 1.2.2, the present requirements of visual acuity of 0.5 in the worst eye of group II drivers was found too strict (CIECA, 1999).

On the other hand, a modified binocular test in the form of the well-known *number plate test* from England, could be recommended as a screening method, e.g. to be used by police in suspicious cases at the point of accident, analogous to the possible use of the balloon test to screen motorists for possibly being under the influence of alcohol. Being able to read a clean Danish number plate in good illumination at a distance of 26 meters is indicative of satisfying a minimum requirement of a binocular acuity of 0.5 (6/12) cf. p. 74. It should be emphasized that the method is recommended only as a sort of advisory screening method. Furthermore, the method is suitable for drivers in testing themselves.

5.2.2.3.6. Colour vision defects

In the case/control study no significant difference was found between accident involved drivers and the control group (cf. chapter 4.2). A slight over representation is mainly due to more males in the proband group and a surplus of acquired defects caused by macular diseases (cf. table 4.4). The method applied in this investigation (Ishihara charts) is more suitable for testing congenital colour vision defects. It is the most widely used test method in Denmark. Other methods might have been more sensitive for acquired defects, however, sufficient time was not available for a thorough examination of all types of colour vision defects.

The results support the general findings from the literature, viz. that colour vision plays no important role in traffic accidents (Lauer et al. 1939, Norman 1960, Kalberer 1971, Gramberg-Danielsen 1972, Verriest et al. 1980). Verriest et al. (1980) reported an investigation from Dresden in East Germany by Marré. Among 1058 males, protans had twice as many rear-end collisions as normals ($p< 0.005$) and deutans ($p<0.002$). Hager (1963) found a slight but significant over representation of colour blind drivers, but the result was criticised by Jahn (1963) with respect to the selection criteria of the compared drivers.

In one of the present accidents (case no. I-VM-141), acquired defective colour vision in an elderly driver with cataract, aphakia and macular degeneration might have played a contributory role, since the driver did not stop at the red light and overlooked a moped rider. In no other accidents a direct relationship seemed probable.

Although the interpretation of coloured road signals has been made easier for colour blind car drivers by the use of special filters, different *forms* in signal lights (e.g. diamonds, circles, squares, bars) have been proposed as a supplement (Berggren 1970, Verriest et al. 1980 and Whillans and Allen (1991) in order to compensate for their problems.

The rigorous legislation in Poland, where 8% of drivers are disqualified due to colour vision defects (Szymankiewiczowa,1989), does not seem scientifically motivated.

5.2.2.3.7. Central and paracentral visual field defects.

Central defects have been estimated using the monocular method of Amsler charts with correction for near, and by ophthalmoscopy. A two to three fold increase in accident risk was found in drivers aged ≥ 50 with such defects. This, however, was not statistically significant at the 5 % level. Significantly more defects were found in the non-police registered accidents ($p< 0.01$), yet these were omitted in the final logistic regression analyses.

Several accidents illustrate, however, what these findings suggest (e.g. I-V-64, I-VM-141, I-VM-929). In the last of these accidents, a pedestrian, who was killed, was not seen, probably because she was hidden in the paracentral scotoma of the driver's best eye (cf. appendix C 2). This seems to be a suggestive illustration of a known phenomenon. The patients with visual defects do not perceive a "hole" in the visual field but fill it out cerebrally by extrapolating the surroundings into the scotoma. The phenomenon has been vividly self-reported (in Danish) by Wanscher (1982). The paracentral scotomas are detectable by neither visual acuity testing nor Donders' method. Modern computerised perimetry as well as the use of simple Amsler charts might have detected the defect, as was the case in this driver.

Age related maculopathy (AMD) has been shown to be associated with prolonged reaction time (Lovie-Kitchin & Brown 1986). In this study similar results have been found (cf. table 4.3), indicating that *severe* macular degenerations may be part of a general ageing process, making continued car driving risky. On the other hand, it is well known by ophthalmologists that many patients with a slight maculopathy are mentally alert.

Drivers with juvenile macular dystrophies seem to have more accidents at night than controls (Szlyk et al, 1993). Further, drivers with age related macular degenerations (AMD) had poorer performance than controls, when tested in a driving simulator (Szlyk et al, 1995).

The paracentral visual field is of utmost importance for traffic safety. - A car approaching from the opposite direction or a pedestrian in the side of the road will initially appear at the central or paracentral visual field as a small, moving object and will gradually grow and move to the periphery of the visual field. This has been nicely illustrated by Lachenmayr et al. (1994). The authors found that an intact central visual field of at least 20° is requested. The present investigation fully supports this view. This area is somehow corresponding to the age dependent area of “the useful field of view” (UFOV), defined and described by Ball et al. (1988 and 1990). This is further stated in the UK requirements for safe driving (Elkington, 1995): According to the Royal College of Ophthalmologists, homonymeous or bitemporal defects which come close to fixation, whether hemianopic, quadrantanopic, or isolated scotomas should not be accepted as safe for driving.

5.2.2.3.8. Depth perception.

This visual parameter is an indication of the co-operation between the two eyes in the perception of stereopsis, due to the disparity of the two images. Stereo vision depends on a good vision in both eyes. This is of importance for the perception of close objects, and to a lesser extent for objects far away.

As indicated by the ENO-foundation (1948), Thalmann (1971), and Maag & Bullet (1983), reduced depth perception seems to be related to accidents in close traffic. Schiefer et al. (1989) found that distant stereotests seem more sensible than stereotests for near vision. Fleck and Kolling (1996) have developed methods for testing stereopsis at long distance and recommend these methods with regards to driving licenses.

In the present logistic regression analyses study, the drivers with reduced stereopsis low Titmus scores (< 80 seconds of arc.) had a significant (1.6 to 2.7 fold) increase in accident risk. It could be confirmed, as also shown by McKnight et al. (1991), that reduced depth perception seems associated with reduced contrast sensitivity (cf. table 4.22.d.). None of the separate accidents could be directly explained by reduced depth perception, but it might have played a contributory role in accident IV-M-445. This visual parameter is of greater importance in the case of driving into another car from behind, accidents which probably cause more problems to the insurance companies than to the casualty wards.

Reduced depth perception is closely related to unilateral reduction of visual acuity. The accident cases in the present study seem to support the statements by Schwartz (1939), that accidents in functionally one-eyed persons are more due to a loss of visual field than to a loss of depth perception.

5..2.2.3.9. Contrast sensitivity

The perception of contrast is reduced with increasing age (Derefelt et al. 1979, Skalka 1980, Kline et al. 1983, Häkkinen 1984, Auffarth et al., 1994). This has been confirmed in the present study (cf. table 10.1). This parameter, which has been intensively studied by Dreyer (1961), reflects a more overall function than the static visual acuity since it seems related to that part of the visual pathways which are not visible by ophthalmoscopy and which do not affect the gross visual fields (Häkkinen 1984). The highway sign discrimination seems more related to contrast sensitivity than to visual acuity (Evans & Ginsburg, 1985). Contrast sensitivity is lower at night traffic illumination (Rumar 1981). The contrast sensitivity is significantly reduced in glare (Sjöstrand et al. 1987). Patients with cataract, but also - to a lesser degree - pseudophakic patients, have reduced contrast sensitivity compared to non-cataract controls (Eisenmann et al., 1996, Elliot et al., 1996). In darkness, perception of contrast compensates the loss of visual acuity and depth perception as well as chromatic vision (Dubois-Poulsen 1981). Shinar and Gilead (1987) in an experimental study found target detection time for 6 students with high contrast sensitivity less than half of that of 6 low contrast sensitivity control subjects. Reduced contrastsensitivity was associated with difficulty in tasks requiring distance judgements, night driving, and mobility (Rubin et al, 1994). In the same study, visual acuity was found associated with tasks requiring good resolution and adaptation to changing light conditions.

In the multiple logistic regression analyses of the present study, reduced contrast sensitivity appeared to be the visual variable that was most constantly and independently associated with increased accident risks. The same was found in elderly drivers in Pennsylvania by Decina and Staplin (1993), cf. chapter 1.3.3.2. However, the reliability of the kinetic test method used (Arden charts) in this study is not optimal. A standard deviation of 4.7 Arden units as error of measurement in double determinations supports the need for more reliable and valid test methods. Such improvements have been introduced since (Kupersmith et al. 1989, and especially the Pelli-Robson contrast sensitivity chart has been widely implemented (Elliot et al, 1990). Once again one has to compromise between the quality of the method and the time available for an estimation of a persons contrast threshold.

From the accident cases one illustrative example might be mentioned: A sudden dangerous situation in bad light conditions and reduced visibility was not seen by the driver in sufficient time (I-V-517). This was estimated to be due partly to insufficient optical correction, partly to reduced contrast sensitivity (other illustrative accidents are: I-V-991 and II-V-620).

For drivers with visual acuity "on the borderline" and a need for driving in darkness, an optional testing of contrast sensitivity might be practically relevant in selected cases.

5.2.2.3.10. Vision in darkness.

Twenty-five percent of the accidents in this study happened in darkness, 9% in twilight, and 64% in daylight (2% unknown). This is in accordance with the official records (Danmarks Statistik 1985). Relatively, a surplus of accidents happen in darkness. The number of accidents per unit distance travelled is 2 or 3 times higher at night than during the day (Rumar 1981), and the percentage of fatality is 3 times higher in night accidents and contributes world wide to 47% of those killed (Offret 1982, Chevaleraud 1981). Mortimer and Fell (1989) found a slight increase in fatal night-accident involvement among elderly male drivers, compared to middle aged drivers. However, their risk was lower than drivers aged 16-24! The last author has estimated that the drivers' resistance to glare declines through ageing by 50% each 12th year, making detection of objects in environments with weak contrast more critical. The dark adaptation deteriorates with age. The intensity of the light stimulus has to be doubled for each 13 years of age (Domey and McFarland, 1961). This is one important reason why elderly drivers feel unsafe when driving at night. The luminance of the road surface has been shown to be correlated to night accidents. Thus, with a fall of luminance from 2 cd./sqm. to 0.5 cd./sqm. (cd.= candela) the accident probability is increased by a factor 2 (Walraven 1981). To compensate for the qualitative and quantitative visual changes in night driving painted stripes, polarised light projects, retroflective tags etc. have been proposed. Wavy stripes on the side of the road are even more effective by adding an audible signal to the visual (Dubois-Poulsen 1981). White-painting of tunnels will work the same way.

The distance of visibility for car drivers meeting a dark, clothed dummy on non-illuminated roads at night has experimentally, (based on 413 volunteer drivers) been assessed to an average of 23 metres (for 23% of the drivers only 15 metres), corresponding to a safe meeting speed at as low as

25-50 km/h (Johansson & Rumar 1968). The visibility distance for pedestrians is *doubled* by the use of a retroflective tag, being greater than the stopping distance for a car driving 90 km/h (Shinar 1984). Auffarth et al. (1994) found pseudophakic patients 40-50% less suited for night driving than were healthy volunteers with normal eyes. After cataract surgery with intraocular lenses, abnormally low scores for contrast sensitivity was returned to normal values (Pfoff and Werner, 1994). Out of 99 driving patients, 41% had been driving at night before surgery and 80% was driving at night after surgery.

The recall level for warning signals is higher at night (14-18%) than during the day (3-6%), probably due to a higher registration and alertness and less alternative visual inputs (Shinar & Drory 1983). Among 432 lorry drivers involved in night accidents, twenty percent had severely reduced vision in twilight and 25% reduced resistance to glare (v. Hebenstreit 1985). Lachenmayr (1998) found highly significant reduced mesoptic vision and resistance to glare in drivers involved in 261 night time accidents as compared to a control group.

Generally, in the present study, it has not been possible to demonstrate that the limited visual parameters tested were significantly worse in the drivers involved in accidents in darkness or twilight. However, two of the accident cases illustrate that a borderline visual acuity may be critical under difficult light conditions (I-V-517 and I-V-991).

Night myopia (Owens and Leibowitz 1976) is a phenomenon related to accomodation and may be a problem in non-presbyopic persons (Duke Elder, 1970, Charman 1996). The phenomenon might have been of importance in four accidents with drivers aged 26-42 years (II-V-387, II-V-414, II-V-913, and IV-VMA-160). Increased myopic correction worn at night has been shown to help 65% of drivers with night myopia and driving difficulties (Fejer, 1995). Charman (1996) concludes that accuracy in corrections for normal refractive errors is more important during night than day driving conditions due to the greater blur associated with the larger night-time pupil.

An important confounding factor in the epidemiology of night accidents is the influence of alcohol on drivers. From the official accident records (Danmarks Statistik 1985), it is known that 56% of accidents involving road users influenced by alcohol occur in darkness and 6% in twilight. This should be compared with the total number of accidents, of which 28% happen in darkness, 5% in twilight, and 66% in daylight.

Until now it has not been decided to make special tests for night vision in the EU as proposed by Aulhorn and Harms (1970). The Danish solution of requiring a practical test for car drivers with reduced night vision is simple, but it depends on the information given by the driving license applicant. In the future more sophisticated and more easily performed test-methods might contribute to a better screening of drivers with night vision problems (Rumar 1981). However, Sturgis and Osgood (1982) found that "night driving" vision test could be successfully based upon simple measurement of visual acuity at low luminance.

An effect of practise driving at night is demonstrated by the fact that the increase in night time risk is much smaller for professional drivers than for private drivers (Rumar 1981). A night-driving training system was described by Hole (1981).

In decreased visibility elderly drivers (with lower vision) or younger drivers with unfit optical correction may partly compensate by driving less or more carefully.

5.2.2.3.11. Glare

Dazzling is the most harmful visual effect of driving at night (Dubois-Poulsen 1981). The problem increases with age (Chevaleraud 1981, Aulhorn & Harms 1970, Töllner 1984).

For elderly drivers with incipient cataract, driving discomfort is more related to glare than to reduction of visual acuity, as vividly self-reported by Soper (1986). The median difference between indoor and outdoor visual acuity in cataract patients has been estimated to three Snellen lines (Neumann et al. 1988b).

Dynamic visual acuity at night in drivers with simulated mild lens opacities is severely reduced in case of main beam glare (Anderson and Holliday, 1996). Glare seems to be a problem also following modern cataract surgery: as extra-capsular cataract surgery with intraocular lenses (Nadler et al. 1984; Eisenmann et al. 1996; Grosskopf et al. 1998) as well as after refractive surgery (Waring et al. 1985, Applegate et al. 1987). Technical improvements in the field of surgery will probably reduce these problems in the future.

Retinal recovery time after glare is increased by an average of 54% (from 2.03 sec to 3.02 sec) without and with use of tinted spectacles, respectively (Philippe and Ruthstein, 1965).

Glare has not been systematically tested in the present study, only in selected cases. At least 3 accidents illustrate the significant influence of dazzling in car driving (I-V-1, II-V-328, I-V-987). In the first accident, an 80 year-old male overlooked a car coming from a side road in sun glare. His visual acuity dropped from 6/12 till 6/24 when tested in glare, due to incipient cataract. Also, the two other drivers, who overlooked unprotected road users, had incipient cataract, although legal visual acuity judged by an ordinary testing situation. In another accident it was not possible to estimate whether a chronic medical condition or dazzling was the reason for overlooking a traffic light (IV-M-66).

Sophisticated time consuming test methods for glare testing do not seem realistic to perform in Denmark in the case of all driver's license applicants, but applied on selected groups of drivers (e.g. with a visual acuity at the limit with a need for driving at night) such methods may be a step forward. In Germany such tests are recommended, but not legally requested when doubt has been raised concerning drivers' visual acuity (Lachenmayr, 1989). The indication for cataract surgery in car drivers is changing and will probably be easier to decide upon by the use of modern glare testing methods (Sjöstrand et al., 1987; Neumann, 1988a).

Polarized filters in the light projectors as well as in the windscreens have been proposed and partly implemented as a glare reducing technical solution (Rumar 1971, de Boer 1981). Another solution proposed is a regular replacement of worn out windscreens judged by tests for significant microdefects with a "straylight analyser" (Chmielarz et al. 1987; Timmermann 1985).

The role of defect or contaminated windscreens in the present study is difficult to assess. In at least two accidents (II-V-998 and III-V-997) a bad visibility due to this problem seems to have been of contributory importance.

5.2.2.3.12. The importance of using car lights in daytime.

This question has been debated. The legislation in this field vary considerably. Luff et al. (1976) warned against blinding with halogen lights as they increase the internal stress of the drivers. The use of the dipped lights even in daytime, as it is practised in Scandinavian countries today, was opposed by von Bahr (1971) who warned against dazzling. When one considers that 4% of the drivers aged ≥ 50 have visual acuity below the lawful limit, and that unprotected elderly road users in the traffic do not have better visual performance, any effort which increases the visibility of cars even in daylight seems justified. This is supported by the recent estimated findings of 125 fewer accidents in Denmark with 173 injuries (included 10 fatal) prevented annually (Klit Hansen, 1993). The effect appeared to be most effective in collisions of two confronting cars, one turning left in front of the other. Based on evidence of a significant reduction in daytime accident in several countries and states, Lachenmayr (1995) argues for the use of daytime running lights. Today (1998) this is not mandatory in several European countries.

5.2.2.3.13. Refraction, use of optical correction and the time interval since last visual test.

No overall significant difference was found between the cases and controls in the distribution of the drivers' refraction. This is in accordance with the literature. In spite of that, in at least one case, an accident was estimated to be associated with insufficient myopic correction (cf. case no. I-V-950 and additionally table 4.16). The role of night myopia was commented on in chapter 5.2.2.3.10. In several accidents the drivers had insufficiently corrected hyperopia, cf. table 4.15).

The findings of a surplus of elderly myopic drivers involved in accidents with reduced visibility might indicate that in spite of adequate optical correction, myopic glasses may play a role (glare, foreign reflexes, inadequate changing of filter colours) under difficult visual conditions.

On the other hand, the non-use of relevant correction seems to be a significant problem in traffic accidents involving drivers with visual problems. Of practical interest are the 17 drivers with an illegal or "borderline" visual acuity in relation to the accidents. Fifteen of them (88%) achieved legal visual acuity solely by the prescription of new glasses! Tested binocularly 10 drivers involved in accidents had visual acuity below today's legal level of 0.5 (6/12). Nine (90%) of these achieved legal vision by new optical correction.

Such drivers with the greatest "residual visual capacity" were the same as those with the longest *time interval since the last visual test* (cf. figure 4.6).

All the road users were asked when the last visual test was performed. The legislation in many countries, including Denmark, - after the legislatively required primary test - is based on voluntary principles until age 70. The accident involved drivers had been driving for a slightly longer time interval since the last visual testing compared to the control group (cf. table 4.19)

In the logistic regression analyses increasing time intervals did not seem to be significantly associated with increased accident risk. However, when conditional logistic regression analysis was applied and/or non-police registered accident drivers were included, a significant association was found, suggesting a factor 1.4 - 2 increase in accident risk for each 5-year longer time interval since last visual test (cf. table 4.27 and 4.28). In an Australian study (McConnell et al, 1992) 21% of 503 Brisbane drivers had their last vision examination more than five years ago. Eight per cent failed the visual acuity requirements for their class of driving license, and 6% had vision below 6/12. In the present material, 11% of drivers aged ≥ 50 had their last visual test more than 5 years ago (15% of cases and 7 % of controls).

These findings indicate that a statutory retest of drivers' vision will probably reduce the proportion of drivers with low or even illegal visual acuity. Whether this will lead to a reduction in the number of accidents is speculative.

However, the results of the multivariate analyses support the common sense view that the quality of drivers' vision is of importance.

In addition, the results have indicated that the "residual visual capacity" is of significance also in the case of drivers who have been tested at age 70 and above (cf. fig 4.5). From this age the deterioration in visual performances accelerates further. One important reason for that is increasing myopia due to nuclear sclerosis of the lens as a frequent symptom of incipient cataract (cf. the Framingham study, table. 5.7). Thus, if the visual acuity of drivers is just at or above the limit at age 70, it will often lead to an unnecessarily high number of drivers with a visual acuity below the requirements a few years later.

A significant number of drivers (9%) did not use their correction for distance even if they had any (cf. table 4.17). This is in accordance with the findings of Zaidel and Hocherman (1985) as well as Humphriss (1987).

The explanations varied. Some drivers were not aware of having a visual problem in the traffic and were not used to wearing glasses when driving. Others were disturbed by the spectacle frames and felt that their visual field was reduced (as also indicated by Hirschberger & Miedel (1980)). In two cases (II-V-879 and II-VM-973) the spectacle frames may have contributed to the overlooking of unprotected road users. One driver (II-V-612) did not use her glasses when car driving because of problems with the spectacle frames. Another elderly female car-driver miscalculating or overlooking an approaching car (I-V-427) allegedly did not use her correction for cosmetic reasons!

From age 50 the accommodation capacity is reduced to such an extent that the longsighted drivers with a refractive error more than 2 diopters on the average have visual acuity < 0.5 without corrections (cf. fig 5.1). Also the differences between indoor and outdoor visual acuity differ. As mentioned earlier, Neumann et al. (1988b) found a mean reduction corresponding to 3 Snellen lines in cataract patients, when these were tested outdoors.

The best and most direct way to estimate a given driver's visual performance on location of a dangerous traffic situation or an accident is not (as required) to control whether he or she is using their glasses, which in some cases were prescribed many years ago. It seems far more relevant to make a proper vision-screening on the spot (e.g. by the method of the "number plate test", cf. chapter 5.4.2.2.1).

Conclusion: the findings concerning refraction and optical correction support that some kind of obligatory re-testing of drivers' vision will lead to an increased proportion of drivers with legal visual acuity on the roads. This may be assumed, whether judged from known pathophysiological trends or from epidemiological findings.

5.2.2.4. Scenes of accidents and driving parameters.

The suggested findings of a surplus of drivers with unilateral reduction of visual acuity in crossroads accidents (7% vs. 3%) are in accordance with the findings by Fletcher (1947) and Keeney and Garway (1981). In spite of the insignificance p=0.14), this does not seem to be a contingency. It is supported by the findings of significantly more drivers with unilaterally reduced visual acuity in the accident group compared with the control group (cf. chapter 4.2) *and* the significantly increased relative risk (factor 6) for a collision from the impaired side (86%) compared to the opposite side (14%), cf. table 4.11. In his study of 101 randomly selected drivers involved in fatal intersection collisions, Fletcher (1947) found that 33 had monolaterally impaired visual acuity. In 90% of these, the accidents happened in the defective vision side.

- Apart from that, no other significant findings were found in relation to the scene of accidents.

Visually impaired drivers partly compensate by shorter driving distances, supported by the suggestion that drivers with long annual driving distances and professional driving seem to have relatively fewer visual problems than private drivers (cf. table 4.13, and 4.14). This compensation has been mentioned by many authors (e.g. Rumar 1986a, Stutts, 1998). The results also suggest that drivers who have their vision re-tested every 5 years - i.e. those involved in professional transport of persons - have better visual performances: 100% out of 22 such drivers in this study had legally acceptable visual acuity at the time of the accident (cf. table 4.14).

5.2.2.5. Assessing the medical consequences of the accidents in the present study:

An important result of the study is the fact that accidents due to drivers' visual problems seem at least as serious as the main group of road traffic accidents.

In order to estimate the qualitative aspects of accidents due to visual problems of the drivers, a simplified accident score, based on easily accessible data and easy to use in computer programmes, has been developed. The advantage of this score is that it does not require detailed, long-term follow up investigations and collection of data for each accident. This makes it easy to analyse and to classify the traffic accident in relation to a qualitative "scale of seriousness", (cf. table 4.31 and 4.32). The method applied on the data found in this study seems to be useful for such a qualitative comparison of different subgroups of accidents and it has proved to be in accordance with established relationships.

Precaution: For the estimation of quantitative, more detailed and absolute consequences of the traffic accident this method should not be used. The abbreviated injury scale (AIS) score (AAAM 1990) is the method of choice for such estimates. With this precaution the method developed might be used in the classification of certain types of accidents. This could be of practical value when compiling estimates, frequencies and "costs" (medical, social and economic) for large population groups on the basis of regional epidemiological findings.

5.2.3. The case histories:

The observations discussed in chapter 5.2.3.1 and 5.2.3.2. are primarily based on individual evaluations resting on the separate case histories. These findings, published in *appendix C. 2.* should be taken more as illustrative documentation "or soft data" than as “hard” evidence.

5.2.3.1. The estimation of a causal relationship:

In not one accident was it possible to give full evidence of a clear-cut causal relationship, since, as is well known, most traffic accidents are multi-factorial, (e.g. Gramberg Danielsen 1970a, Owsley et al., 1991). Furthermore, it will be almost impossible to prove that an accident would not have happened if the driver had had no visual problems. Therefore, it was intended to approach the problem by giving estimates based on the accident records and the ophthalmological findings in the involved participants. The estimations were discussed with experienced scientists and agreement was reached before a classification was made.

The classification concerning a possible co-association between the accidents and visual problems was made in simple and arbitrary categories: *1. unlikely, 2. possible, 3. probable, and 4. unknown* (definitions, cf. appendix C. 3.). A somewhat similar classification of the human element in a motor vehicle-accident system" was given by Fell (1976). The estimates have been based on a. testimonies from the probands and their adversaries, b. police reports (when available) and c. the objective findings.

A so called *probable* vision/accident co-association was estimated in none of the drivers below age 50, in 5% in accident drivers aged 50-69 and in 38% of drivers aged ≥ 70. This is in accordance with the known increase in incidence of visual problems with age in any elderly population.

From this study it can be confirmed that, as a rule *an automobile accident is a multi-factorial event.* Accident number I-V-129 (for details cf.

appendix C.2) is a typical example of this:

Several witnesses saw that the driver, a male, aged 76, overlooked a pedestrian waiting in the middle of the road. Besides 1) his visual problems, also 2) his earlier left side hemiparesis (with a slightly reduced reaction time), and 3) the behaviour of the pedestrian, who had suffered a cerebral trauma two years before, might have been contributory. In this case, however, neither external obstructions nor defects in the car could be demonstrated.

Another clearly multi-factorial accident is case I-VM-924.

In other words: The potential for a serious traffic accident by an unfortunate coincidence of several circumstances continuously emerges. However, one single factor (e.g. the vision/ the alertness/ the imagination of the driver) may be decisive whether the given potential leads to fending off a collision, a slight injury or a catastrophe.

5.2.3.2. General health parameters

i. Medical conditions: The literature in this field is briefly summarised in chapters 1.3.1 and 1.3.2. In the present study, a higher proportion of accidents with *acute medical conditions* was found (3/359=0.8 %, 95% confidence limits 0.3% - 2.8%) when compared with the findings of Herner, Smedby & Ysander in 1966 (41/ 41,214 = 1 ‰), ($p<0.01$, exact binomial, two-tail test). The findings, however, confirm the results of Herner et al. as well as those of Naughton, Pepler & Waller (1985), viz. that acute medical conditions are of only minimal importance in road traffic accidents with personal injury.

It is more difficult to estimate an association between *chronic medical conditions* and traffic accidents. Table C.8. is an attempt to assemble relevant cases in which a medical condition might have contributed to the accidents. Eleven such cases with chronic medical conditions were found in the age group $\geq$ 50. In the group with visual problems 2 drivers (I-VM-141, I-VM-929) had a relevant chronic medical condition which might be of importance too. In relation to traffic safety, a significant visual problem should also be taken as a chronic medical condition. If one adds to this the drivers with visual problems, which are of probable importance for the accidents (12) and car drivers with acute medical problems (2), a total of 25 (16%) drivers aged $\geq$ 50, who were involved in traffic accidents, had an acute or chronic medical condition of relevance to the accident (95% confidence limits 10-23%). This estimate is moderate since some of the elderly *non-responders* might have had unknown medical problems of importance for the driving ability too.

E.g.:

N-375: Male, 66, with general atherosclerosis including cardiac in-compensation, mistook a motorcyclist for a mopedallist and hit him when turning left. No information available concerning the driver's vision/ use of glasses.

N-470: Male, 51, with intermittent cardiac (atrial) flutter, failed to give way and drove out in front of a car coming from the right, which he overlooked in spite of good view. Information on his visual performance is not available.

N-613: Male, 79, with severe atherosclerosis including cardiac arrhythmia and threatening gangrene of the foot, in treatment with anticoagulation drugs. Coming from a side road he failed to give way to on-coming traffic, miscalculated a car coming from the left and drove out in front of it. Visual acuity (general practitioner's information): 0.67 / 0.67 with intact visual fields. Five months later he died of a stroke.

N-952: Male, 72, with no known general diseases. In a crossroads accident he overlooked a bicyclist coming from the left.

The study is too limited to give indications for isolated medical conditions, but a few important informative cases are mentioned:

- *Diabetes:* One accident-involved driver with diabetes had hypoglycaemia as one of at least three important factors contributing to the accident (I-VM-924). Besides, his visual acuity was 0.2 in the better eye and he was driving in dense fog.
- *Epilepsy and black outs*: Two cases were of importance: 1) a driver (IV-M-206) had a transitoric ischemic attack (TIA) or an epileptic attack in relation to a "single accident". Half a year later he died of a malignant cerebral glioblastoma. 2) A young female (IV-M-455) fainted at the wheel. Earlier she had suffered similar attacks in relation to driving.

Furthermore, some of the drivers with chronic medical conditions overlooked the red light but detailed information about this were not available.

Beside the accident involved drivers, several drivers in the control group had chronic medical conditions. These data, however, are difficult to quantify. When comparing the use of drugs and medicine in the two groups, no significant difference was found (Cf. table C. 10).

Ysander (1970) performed a study of the accident rates of chronically sick, disabled and elderly drivers, which, when compared to a control group showed no significantly increased risk for traffic safety. The results of the present study do not oppose the findings by Ysander omitting the visual factor.

It is difficult to estimate to which extent the accidents in the present study could have been prevented by an earlier medical check-up of the drivers.

ii: Visual reaction time (VRT).

As seen in appendix F, table 10.2, the visual reaction time varies within and between the age groups. A significant increase with age is seen from age 40. Out of ten accident-involved drivers with the most prolonged VRT (2.4%), 9 were older than 60 and 8 older than 70. In two of the accidents in this study a prolonged reaction time might have been of importance (IV-VM-384, IV-M-445). Further, in one accident (IV-VM-979) a VRT-estimate of a driver with Parkinson's disease would probably have given an indication of his driving ability.

For selected cases of elderly drivers, whose traffic ability is questioned, a test for reaction time seems relevant, thus identifying those with a significant prolongation of this value. However, a relatively high cut-off score (above the 97.5% confidence limit, cf. appendix D. 2 and table 10.2) is needed. Besides, standardisation problems for general use must be solved. Davey (1956) suggested that accident-free drivers had a faster reaction time than those who were not accident-free. The age matching in this investigation was unclear.

Richmond and Ebert (1933) emphasized *the importance of the time factor* being included in the estimation procedure of visual acuity testing. He proposed 0.5 sec. observation time as a good standard unit for testing visual acuity in either eye. His proposals, however, were based on 300 navy soldiers and are probably not realistic for drivers above age 70! Luoma (1984) in simulated traffic situations found that a lengthening of fixation time increased the number of correct perceptions. The perceptions were achieved mostly as a result of fixation and to a lesser extent by using the peripheral vision. In relation to traffic situations, Olson and Sivak (1986) found a perception response time of 1.6 sec. from seeing an obstacle until applying the brakes - for young drivers as well as for elderly drivers! Corfitzen (1993) found visual reaction time useful and associated with various level of tiredness, in a road side survey among 120 taxi drivers at night. The same author (Corfitsen 1994) confirmed this association in 240 male nighttime drivers, out of which 106 described themselves as tired (VRT: 0.223 sec.) and 11 very tired (VRT: 0.309 sec.) compared to 123 rested drivers (VRT= 0.189 sec.).

The relation between car drivers' reaction time and age is analogous to the relation between vision and age. As Norman (1960 a) puts it: "It appears that as a man ages in the middle range, his reactions are slower, his hearing diminishes, his eyes-hand co-ordination deteriorates - but he becomes a safer driver". - This, however, can only be confirmed to a certain limit, cf. chapter 1.3.2.

Not only age but also tiredness and the influence of alcohol play a role regarding reaction time. Corfitsen (1982) tested young male drunk drivers and found that the reaction time was significantly prolonged in very tired drivers as compared to normally tired and alert drivers. Correspondingly Owsley (1991) found 3-4 times more accidents in drivers with poor mental status.

iii: Drugs and alcohol: Epidemiological data clearly confirm that the risk of being responsible for a fatal crash injury increases steeply as a function of blood alcohol concentration (OECD 1978). Even small doses of alcohol is known to induce an impairment of the binocular vision, an increase of esophoria and a reduction in the negative fusion ability (Hogan and Linfield 1983, Seedorff 1956). The relationship between 23 different groups of drugs, eye and traffic have been reviewed by Gramberg- Danielsen (1968).

In the present study, data on the influence of alcohol and drugs in relation to traffic accidents have been collected on a systematic basis. However, since the findings are based on interviews, rather than on objective data, they cannot be taken to be as valid as the information on use of medicine and the ophthalmological findings. Table C.8 confirms that alcohol is an important contributory factor in traffic accidents in the case of young drivers (11/249= 4%). It seems less serious in elderly persons' accidents (2/156= 1%), in which medical conditions, including visual problems, seems more important (approximately 16%, cf. appendix C.4).

In spite of aged drivers' larger use of medicine (cf. table C.10), the influence of drugs in connection with traffic accidents seemed more critical in the case of the young drivers (2%, cf. table C.8). Probably these frequencies are under-estimated. This and related aspects will be further discussed in chapter 5.4.1.4.

5.2.4. Visual factors and other relevant parameters not investigated in this study.

As mentioned earlier, it has not been possible to estimate all visual characters. E.g. dark adaptation was omitted, due to limited investigation time. Visual acuity in the presence of glare was only tested unsystematically in selected cases.

One of the more important of the non investigated parameters is *dynamic visual perception,* which is more in accordance with the continuously moving picture in the traffic of today (e.g. Miller & Ludvigh, Hills & Burg 1977, Shinar 1977, Rumar 1981). The examination of "early visual attenuation" by the method of "*useful field of view"* (Owsley et al. 1991, cf. p. 21) is not simple to assess, however it seems promising, showing the hitherto highest association with drivers' accident frequency.

In the driver/vehicle/environment triangle, the *human behaviour* is influenced by several factors, out of which static as well as dynamic visual acuity is only a small but important part.

The personal characteristics of young accident involved drivers are significantly different compared to an age matched group of accident-free drivers (Andersson, Nielsson & Henriksson 1970).

Fell (1976) made a thought-provoking description of this human multifactorial pre-crash element of a collision:

A *"cause"* is the immediate, necessary reason for an *"effect"* which is the primary failure, non-performance or behaviour leading to the collision. Physical or physiological deficiencies, physical and mental conditions, experience, pre-occupation and risk taking behaviour are "causes", while perception (sensing, detection), comprehension (recognition, decision and action) are "effects".

Thus *visual factors* might be of importance as a causative factor (e.g. defective visual field, reduced visual acuity), leading to a lack of *perception,* (e.g. reduced recognition of a danger signal due to too blurred or too many inputs or due to a defective visual field). Such deficiencies might further lead to incorrect decisions and insufficient compensation for the danger and consequently incorrect actions.

It was not only drivers with organic visual defects who stated that they "did not see" a potentially dangerous situation. In the present study several such examples exist. Many other factors, mainly physiological and psychological ones, are of importance, such as mental state (alertness), degree of intoxication, preoccupation, and risk-taking behaviour. The "information failure" at the risk of precipitating collisions has been shown to increase with age from age 25 (Fell 1976).

Cross (1966) stated: "It appears that a majority of such traffic accidents as are due to visual causes result from the rather indefinable visual defects such as lack of visual concentration, defective visual judgement, defective perception and defective co-ordination of hand (or foot) and eye". One example of lack of visual concentration due to fatigue is a functional "tunnel vision". Visual judgement can be upset by driving at high speeds. This may cause errors in the estimation of own speed or in assessing the speed of approaching traffic, errors which are responsible for many accidents. The author found that "There is no evidence that these various types of visual judgement are associated with defective visual acuity, with defective muscle balance or with uniocularity".

In order to assess *the role of organic visual defects*, however, one important way is to perform epidemiological investigations. von Hebenstreit (1985) found a factor 6 relative increase of visual problems in the sub-group of drivers involved in accidents with a "visual" component. ($p < 10^{-6}$). In the present multivariate analyses of elderly drivers, a significant increase in accident risk was found in drivers with defective binocular visual acuity, reduced contrast sensitivity, unilaterally reduction of visual acuity, and low level of stereopsis.

These epidemiological observations indicate that organic visual defects can not be neglected as causative in spite of the drivers' compensating attitudes.

In a way, testing in "driving simulators" analogous to the testing and training of pilots is a further development in dynamic visual performance testing. Such tests might in another and more realistic way contribute to the evaluation of the behaviour of "risk drivers" in relation to the "driver-vehicle environment complex". Simple "mock cars" and simulators exist for testing special driving parameters (e.g. Lings 1987, Hedin & Lövsund 1986), but in an era of high technology, advanced simulators (e.g. Daimler-Benz, 1985; Szlyk et al., 1995) may perhaps be available in a not too distant future in many countries. The ideal simulator should test not only the driver's vision, but also his/her behaviour with respect to perception, comprehension, decision and action, thus offering a more integrated estimate of the risk drivers' traffic behaviour.

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The importance of vision in this connection could be illustrated with an example from real life: A famous race driver suddenly braked his car in a race before a left curve although he was not able to see a catastrophe happening after the curve. In that way he avoided being involved in the catastrophe. When asked how he had foreseen this situation he answered that he had noticed that all the spectators were looking in that direction. He took that as a sign of something being wrong. Experience and imagination, more than fast reaction time, saved him from the catastrophe. - But good vision, however, was the important precondition for the appropriate use of his imagination.

Conclusion: Imagination is important in connection with safe driving. However, it should be based on a realistic and adequate visual perception of the surroundings, - or in other words: good vision!

5.3. Economic, social and health aspects.

5.3.1. Nation estimates.

5.3.1.1. Background.

Assuming that the findings in this investigation from the district of Aarhus do not differ from the rest of the country, some general health aspects may be extracted from the study, since all consecutively collected accidents fulfilling the inclusion criteria in this region were included. To estimate national estimates on these conditions, some kind of converting factors will be needed.

5.3.1.2. Multiplication factors for the calculation of nation estimates.

Presuming that the proportion of police registration of the car accidents is constant throughout the year and the country, and assuming that visual problems do not systematically differ in the police and the non-police registered car drivers (cf. table 4.26), *the multiplication factor* describing an annual nation-wide incidence can be estimated. These estimates are of importance in an attempt to calculate the annual number of drivers with visual problems involved in accidents for the entire country (or per million inhabitants).

The *distribution of age* in the entire Danish population did not differ from the frequencies found in the police district of Aarhus (Danmarks Statistik, 1984, z' = 0.32, p= 0.75, Mann-Whitney test). A small, but significant surplus of females was found in Aarhus (51.3%), compared with the entire country (50.8%, chi square = 14, d.f. = 1, $p< 10^{-4}$). No systematic difference, however, was found between the visual parameters in female and male drivers (cf. table 4.2).

Seasonal variation: For practical reasons, the periods of investigation took place in the autumn and winter months, (cf. table 2.1 and 2.2.). Therefore, the estimates were weighted according to the average number of injured persons in each month of the years 1983-86 (Danmarks Statistik, 1984-87). Thus for data collection phase I, a "*season factor*" of 0.895 was calculated and for phase I and II combined: 0.982.

Estimation of multiplication factors:

A: the age group ≥ 50:

(Data collection group I and II combined):

a. *Number of days:*

365/252 = 1.45 (a)

b. *Demography:*

5,112,130/ 284,146 *) = 17.99 (b)

*) Inhabitants in Denmark/in Aarhus police district. (Politiets årsberetning, 1984)

c. *Registration factor*:

If all accidents fulfilling the basic inclusion criteria (cf. table 2.1) had been included in both phases (i.e. also the non-police registered accidents in phase II), the total number of drivers ≥ 50 (based on the phase I material ≥ 50: 82/61) would have been:

82 + 74 x (82/61) = 181 drivers,

and thus a so-called *"registration factor"* can be estimated as:

181/156 = 1.16 (c)

d. *Participation factor* (cf. table 2.8.):
156/122 = 1.27 (d)

e. *Season factor*:
1/ 0.982 = 1.018(e)

Multiplication factor (age >= 50):
a * b * c * d * e = *39.12 (Denmark)*
(or: 7.65 per mill. inh. per year)

B: The group of accident involved car drivers < 50 years:
In this group (and among unprotected road users) the multiplication factor is easier to estimate since in phase I both police registered and non-police registered accidents were included.
a. Number of days:
365/112 = 3.26 (a)
b. Demography:
5,112,130/ 284,146 = 17.99 (b)

d. Participation factor: (cf. table 2.8.):
249/187 = 1.33 (d)

e. Season factor:
1/ 0.895 = 1.117(e)

Multiplication factor (age < 50):
a * b * d * e = 87.12*(Denmark)*
(or : 17 per mill. inh. per year)

Thus, in Denmark the annual number of car drivers involved in accidents resulting in human injury and, with visual problems and, being below 50 years of age is estimated to be ***87*** x the numbers found in the participating drivers of the material.
For drivers ≥ 50 years, the corresponding multiplication factor is ***39***. (The estimates have been moderately truncated to provide integer values).
On this basis and on the presumptions given, corresponding national incidence rates might be roughly estimated through the results of the survey.

5.3.1.3. Nation estimates on visual factors and accidents.
In table 5.2 accident-involved drivers with different classifications of visual problems are registered. The annual number of drivers in Denmark involved in accidents with these kinds of visual problems may be estimated via the multiplication factors for the two age groups respectively.

Table 5.2. Estimated annual number of car accidents in Denmark resulting in personal injury with various visual problems in the drivers. Calculations based on investigated drivers (Alsbirk, 1999).

Age group:	**< 50:**		**≥ 50:**		**Total per year:**
Drivers investigated:	N=187		N=122		
Multiplication factor:	87		39		
	Study group:	Denmark:	Study group:	Denmark:	Denmark:
Accident visual acuity:		(95% limits*:)		(95% limits*:)	(95% limits: *)
at the limit :	0	-	2 (1.6%)	78 (9-282)	78 (9-282)
below the limit :	3 (1.6%)	261 (54-763)	12 (9.8%)	468 (242-818)	729 (386-1179)
Total :	3 (1.6%)	261 (54-763)	14 (11.5%)	546 (299-916)	807 (448-1271)
Binocular visual acuity:					
<0.5 :	1 (0.5%)	87 (2-217)	8 (6.5%)	312 (135-615)	399 (171-722)
Causal association:					
possible :	10 (5.3%)	870 (717-1600)	31(25%)	1209 (821-1716)	2079 (1449-2822)
probable :	0	-	11(9%)	429 (214-768)	429 (214-768)
subtotal :	10 (5.3%)	870	42 (34%)	1638 (1180-2214)	2508 (1829-3294)

*)Poisson distribution, cf. Documenta Geigy, p. 107-108 and appendix D 1.

Focussing on accident-involved drivers at or below the legally accepted level, in the age group <50, 1.6% had visual acuity at or below the limit at the time of the accident. In the age group ≥ 50, 11.5% had visual acuity at or below the legally accepted level. On average, every day 2 (95% limits 1 - 3) car drivers involved in traffic accidents resulting in human injury can be assumed to have visual acuity below the legally accepted limit.

Concerning accidents with a possible or probable visual factor/ accident association in Denmark, (cf. appendix C), it can be roughly estimated that in the case of drivers aged 50 or above, a total of 1638 (95% limits: 1180-2214) accidents per year (or 4 per day) a visual problem might be a contributory factor. Out of these accidents, a probable association is estimated in 429 cases (95% limits: 214-767), i.e. 1 per day.

5.3.2. Costs of traffic accidents:
The costs are mainly a) economic and b) health and socially related.

5.3.2.1. The economic costs of traffic accidents are difficult to estimate since they can be calculated in many ways. In Denmark the official method (Vejdirektoratet 1988) is to divide the costs into:
i: Recordable costs.
i.e. *a.* Loss of production, *b.* costs connected with hospitalisation etc. *c.* material costs etc.
ii: "Loss of welfare".
This indicates that society through road investments attaches importance (beyond what could be economically

Table 5.3. a. Costs of traffic accidents resulting in human injury, Denmark (in Danish kr. 1996) *) (Alsbirk, 1999):

Person related costs for each reported:		Recordable costs:	Loss of welfare:	Total:
Killed	:	1,930,000	3,859,000	5,789,000
Severely injured	:	183,000	60,000	243,000
Slightly injured	:	46,000	3,000	49,000

5.3. b. Costs of traffic accidents in Denmark, including loss of welfare (in D kr, 1996) *):

		Per reported traffic accident:	Per reported accident with human injury:	Per reported human injury:
a) Person related costs	:	248,000	578,000	462,000
b) Material costs	:	377,000	877,000	702,000
Total a) + b)	:	625,000	1,455,000	1,164,000

*) Ref. Vejdirektoratet, preliminary information, personal communication (1998).

motivated) the prevention of human suffering and deprivation (i.e. the costs, which society invests in the preventing of traffic accidents) (Vejdirektoratet 1993). In the annual reports, these costs have been estimated and calculated for police- reported accidents resulting in human injury (table 5.3, Vejdirektoratet, 1993+98).

Regarding the estimates, the costs of the accidents not registered by the police were also taken into account in the calculations of the average costs per police reported accident resulting in human injury (Vejdirektoratet 1998, personal communication). A total average loss of about 1,455,000 D kr. (1996) per police registered accident was reported.

In the present study, out of 287 road traffic accidents with human injury (phase I), 174 (60.6%) were reported by the police. These accidents were generally more serious, cf. chapter 2.3.1.1.

It is beyond the object of this study to make thorough economical analyses, however the amounts from table 5.3 provide impression of the economic costs of the accidents being focused upon in the present study. Furthermore, generalisations to the annual costs for Denmark might be applied through the calculated multiplication factors (cf. chapter 5.3.1.2) leading to crude estimates for the national annual costs of such accidents.

The total recordable costs of traffic accidents in Denmark are estimated to be approx. 10 milliard D. kr. (Vejdirektoratet 1998, personal communication). These estimates of the costs of road traffic accidents in Denmark are based on detailed analyses (LSSF, 1983).

In none out of 187 investigated accident involved drivers, aged < 50, a probable vision/accident association was estimated. Correspondingly, in 11 out of 122 (9%) examined drivers aged ≥ 50 a probable association was estimated (cf. appendix C.3, in which also accidents of non-responders have been evaluated). According to phase I, this age group of drivers constitutes 24.9% of the accident driver population. No difference in the estimated vision/accident association was found between police reported and non-police reported accidents (p= 0.74, Mann-Whitney test). Thus, when based on the present findings, the proportion of the entire accident driver population with a probable vision/accident co-association can be roughly estimated to: 11/122 x 24.9% = 2.2% (95% limits: 1.15% - 3.9%).

Presuming that this estimate is representative for Denmark, the recordable costs of traffic accidents in Denmark, with drivers' visual problems as a part of the cause, are estimated to be approximately 220 million D kr. (95% limits: 115-390 mill.).

For comparison, in a study from Pennsylvania in 1971, visual factors as prime causative identification were estimated to be present in 6-5% out of 81,696 crashes (Keeney 1975).

No attempt was made to prophesy which of the accidents were preventable since in most of the cases this is disputable and impossible to prove. Nevertheless, assuming that at least *some* of the accidents are preventable, the economic retrenchments can be roughly estimated according to such calculations. An estimate like that will depend on what system is applied to the early detection of drivers with bad vision.

5.3.2.2. Health related and socially related costs:

For injured persons the costs are of another nature. The health consequences of these accidents are comparable to all traffic accidents resulting in human injury (cf. table 4.32.). This also implies that tragic accidents occur due to drivers' visual problems. Accident I-VM-929 is such an example.

Acocella (1982) published a very serious case. Although one published accident case cannot be taken as evidence, such examples are rare in the literature. The following case history, furthermore, is of relevance in the new Europe, where legislation on this field vary and is under continuous development (e.g. the former East and West Germany).

"In October 1980, in Florida, a 78-year-old man accidentally drove his car into four young girls playing in a street. Three of the girls died; the fourth was critically injured. Although the driver had been living in the state for 13 years, he still carried only a driver's license from Ohio, his previous residence. His reason: Ohio licenses can be renewed by mail without any vision screening. The man's vision was sufficiently poor to prevent his passing a Florida licensing examination, so poor, in fact, that when he crushed the girls he thought he had hit a garbage can!"

In table 5.4 information is listed on the injury consequences of 11 accidents in which a probable vision/ accident association was estimated.

Ten out of these eleven accidents were reported by the police.

Assuming that the findings of the police district of Aarhus do not differ from the rest of the country, by multiplying with the factor 39 (cf. chapter 5.3.1.2) it can be roughly estimated that in Denmark (5.1 mill. inhabitants), in this kind of accidents with drivers aged ≥ 50, annually about

Table 5.4. The medical consequences of 11 traffic accidents with visual problems in investigated car drivers as a probable contributory etiological factor (Alsbirk, 1999).

Accident No.:	Drivers age:	Police-regist.:	Unhurt:	Slightly injured:	Severely injured:	Killed:	Total (Injured or killed):
I-V-001 :	80	+	1	1			1
I-V-64 :	58	+	1	1			1
I-V-141 :	73	-	1	1			1
I-V-517 :	75	+	1		2		2
I-V-906 :	66	+	1	2			2
I-V-922 :	53	+	1		1		1
I-V-924 :	75	+			1		1
I-V-929 :	76	+	1			1	1
I-V-950 :	57	+	1	1			1
I-V-987 :	59	+	1	1			1
I-V-991 :	81	+	1	1			1
Total :	(range: 53-81)	11	10	8	4	1	13
Police reg. :		10	9	7	4	1	12
Estimated annual total, Denmark *)		429	390	312	156	39	507
95% confidence limits** :		(214-768)		(135-615)	(43-399)	(1-217)	(270-867)

*) = Total number, found in the study * generalization factor for age ≥ 50: (=39)
**) Poisson distribution, cf. Documenta Geigy, p. 107-108 and appendix D 1.

- 500 persons are injured (95% confidence limits 270 -867) out of which:
- 40 persons are killed (95% limits: 1-217);
- 155 persons are severely injured (95% limits: 42-399) and
- 305 persons are slightly injured (95% limits: 135-615).

Obviously these estimates must be taken with caution since a great deal of uncertainty exists:
- Only accidents with a probable visual factor/ accident association are included in this calculation, making it a moderate estimate. None of the accidents with a possible relationship (N= 41) are included.
- The estimate of the number of persons killed should be taken with caution, since great uncertainty exists in the generalisation of one person (95% limits 1-217). In the Pennsylvania study from 1971, visual factors were estimated as "prime causative identification" in 72 out of 667 (10.8%) traffic deaths (Keeney 1975). Shober (1969) felt that 3-4% of all traffic victims killed in West Germany might have saved their lives if serious visual problems of the drivers had been corrected in time.
- Even in accidents with an estimated "probable" association, visual problems actually only constitute one of several factors leading to the traffic accidents.
-The estimates are based on the examination of participating drivers only. It is presumed (through the "participating factor", cf. chapter 5.3.1.2) that visual problems of non-responders are at least as serious as those of the investigated drivers.

- In this study, the definition of an accident in which a person is severely injured is not in total accordance with the official statistics. From table 5.5, based on the Danish Statistical Department (Danmarks Statistik 1985), it can be seen, that according to the official definition 65% of the injuries were classified "serious", whereas, by using the definition in this study (*i.e. hospitalised),* only 58% of identical injuries would have been defined as serious.
Thus also from this point of view, the estimates in the present study are moderate and may be underrated.

Table 5.6. Various possible procedures for health screening of car drivers applying for a renewal of driver's license (Alsbirk, 1999):

	Health parameters	***: Screening procedure:***
I.	*Relevant for traffic safety: (obligatory)*	
	1. <u>Today's practice</u>:	
	"General health"	: Clinical investigation
	Hearing	: Hearing test
	Vision	: Static visual acuity Visual field by hand
	2. <u>Others:</u>	
	Hypertension	: Blood pressure
	(Visual field defects	: Computerized perimetry *).
II.	*Other clinically "silent" diseases: (optional)*	
	1. <u>General diseases:</u>	
	Diabetes (early stage)	: Urine screening (stix)
	Kidney diseases	: Urine screening (stix)
	Hyper sedimentation	: Blood sedimentation reaction
	Blood diseases	: Blood hemoglobin and leukocytes
	Cerebral function	: Reaction time / driving simulator test *)
	2. <u>Eye diseases:</u>	
	Glaucoma and others	: Computerized perimetry *) Investigation by ophthalmologist

*) Could in selected cases be tested at special centers.

5.4. Future perspectives.

The present knowledge may contribute to give the society, including the lawgivers, a basis for discussing future perspectives:

This could either lead to an acceptance of the present status quo or provide some ideas for a change in the procedure of detecting car drivers with a reduced visual performance.

Thus, it is also possible to skip the obligatory procedures of re-testing as e.g. in Sweden, France and Germany or alternatively to intensify them, as in Finland.

In the end, the decision whether to re-test or not, and if so *when* and *how* to retest, is political. Therefore, no detailed conclusions will be drawn. Some premises, however, will be elucidated. The premises for the discussions of the question will be based on the authors literature review and the present findings with respect to the 3 main groups: a. the car drivers; b. the unprotected road users; and c. the community.

Table 5.5. Comparison of the criterion "serious injury" due to road traffic accidents in the study vs. in the official Danish statistics (Alsbirk, 1999):

	Danish Statistical Department:		
Present study:	Seriously injured*):	Slightly injured:	Total:
Hospitalized**)	7504	687	8191 (58.4%)
Treated in casualty wards	1627	4208	5835 (41.6%)
Total	9131 (65.1%)	4895 (34.9%)	14026 (100%)

*) i.e.:
1. Intra cranial injury, skull fracture, face or eye injury
2. Injury of trunk (chest and/or abdomen)
3. Injury of spine and/or pelvis
4. Fracture/dislocation or severe sprain of shoulder, arm or hand
5. Fracture/dislocation or severe sprain of hip, leg or foot
6. Serious injuries in more than one main region
7. Burn.

ref.: *(Danmarks Statistik* (1985, table 5.11.2))

**) The criterion for classifying an injury as "serious" in the present study.

5.4.1. Advantages and disadvantages of detecting car drivers with reduced visual capability:

5.4.1.1. The drivers:

i. advantages:

Theoretically, a medical "check-up" at certain intervals from a given age might lead to the detection of defective vision and diseases which offer few or no symptoms and which normally increase in frequency with age.

i.1. Detection of general diseases:

Such examples are seen in table 5.6.

The likelihood of detecting a disease dangerous to traffic or a clinically "silent" but grave life and health threatening general disease, as outlined in table 5.6, will depend on the medical screening procedure. Through the clinical investigation other important diseases could also be detected.

By offering the car drivers a screening programme, beyond what is strictly relevant for traffic safety, such an investigation and a health certificate might be more acceptable or yet attractive, even if the driver may have to pay himself.

i.2. Detection of eye diseases:

Complete detection of eye diseases is not possible by today's screening procedure, i.e. testing the static visual acuity and visual field by hand. It will require an examination by an eye specialist using modern equipment.

Some of the diseases leading to reduced visual acuity might be detected by a "traditional" visual acuity screening test (e.g. cataract, corneal diseases, certain retinal diseases and hazy vitreous body). By Donders visual field confrontation test only very severe visual field defects are detected.

The use of Donders' confronting method shows a great variation. In one accident-involved driver (II-VM-979), whose visual field was screened every 5th year, the defect was not detected by the general practitioner but it would probably have been found by an ophthalmologist.

Table 5.7. Prevalence of eye diseases in the elderly population, aged above 51 (the Framingham Eye Study). **)

	Age groups: 52-64:	65-74:	75-85:	Total:
Cataract:	4.6%	18.1%	46.1%	15.6%
DR.*) :	2.1%	2.9%	7.0%	3.1%
AMD*) :	1.6%	11.0%	27.9%	8.8%
OAG*) :	1.4%	5.1%	7.2%	3.3%

*): DR: diabetic retinopathy.
AMD: age related macular degeneration.
OAG: open-angle glaucoma.
**) Kini et al. (1978)

An important exception is open angle *glaucoma* which increases in frequency from age 50 with a prevalence of 1.4% from age 52-64 and 5-7% above 65 (Kini et al. 1978) (cf. table 5.7). Corresponding frequencies were found by Bengtsson (1981) in Southern Sweden.

In addition, table 5.7. shows the prevalence of the quantitatively most important eye diseases in the elderly population (the Framingham Eye Study).

Klein (1991) found the same four conditions primarily responsible for the decline in visual acuity and visual field in the elderly drivers and suggests them to be partly associated with an increase in vehicular accidents per mile driven by the elderly. Butler et al. (1997) stress the importance of keeping an eye on vision due to these four eye diseases.

MacKean and Elkington (1982) described car driving problems in the case of 214 glaucoma patients (cf. chapter 5.2.2.3.3) and Taglia et al. (1997) tested 26 glaucoma patients in a driving simulator. They found driving performance associated with reduced contrast sensitivity. In a case-control study among elderly drivers, Owsley et al. (1998) found increased injurious crash involvement for glaucoma patients (OR = 3.6, 95% CI, 1.0-12.6).

In the present study, the findings of 6 out of 222 car drivers aged ≥ 55 with undiagnosed glaucoma (cf. appendix C: 1 case and 5 controls = 2.7%, 95% limits: 16%), corresponded to the findings in several studies (e.g. Andersen 1958, Björnsson 1967, Nørskov 1971, and Bengtsson 1981). Undiagnosed this disease might lead to blindness, but since the visual field in the centre is preserved until at a late stage, it is detected neither by the patients nor by a vision test until late (cf. case V-C-800). Furthermore, for the detection of early or moderately advanced cases a screening by Donders' confronting test is not sufficient. A detailed visual field examination is necessary. Earlier this was an expensive and time consuming procedure. Nørskov (1971) generally did not find it worthwhile to perform glaucoma screening in large populations. Today, however, with the introduction of automated perimetry and personal computers, such a screening of car drivers (and other patients!) in relevant age groups might be easy and inexpensive to perform, if adequately organized (Bengtsson & Krakau, 1979; Crick & Crick, 1981; Hedin, Rumar & Verriest, 1981; Boberg-Ans & Vangsted, 1988). In the latest developments such a high quality test can be performed in a few minutes (Bengtsson, Heil and Olsson, 1998). However, a heavy load of borderline or false positive cases can be foreseen and may be taken into consideration. Seen in that perspective, the price may possibly be too high.

Besides glaucoma, important neurological diseases such as various brain tumors, cerebral infarcts etc. might be detected by such a screening.

Cataract: In this connection cataract is an important disease (cf. table 5.10). Bernth-Petersen (1981, 1985) and Ninn-Petersen (1996) presented epidemiological aspects concerning the change in indications for and outcome of cataract surgery. Today's surgical principles with intraocular lens implantation according to a re-calculation of the refractive power (based on ultrasound/ keratometry assessment, e.g. Sanders, Retzlaff and Kraff, 1988; Olsen, 1987) and with minimal induced astigmatism due to small incisions, have led to a revolution in the treatment of this disease. By the introduction of diffractive *multifocal intraocular lenses* in 1988 it was stated that possibly up to 80% of selected cataract patients with this type of lenses implanted might avoid glasses for near as well as distant vision (Lindstrom, 1988). This seems far too optimistic, since reduced contrast sensitivity, glare and haloes as well as reduced mesoptic vision have been demonstrated side effects to these new lenses, (Holladay et al.,1990; Percival and Setty, 1991; Hessemer et al. 1994; Winther-Nielsen et al. 1995). Side effects, which are important for driving safety in reduced illumination. This may explain, why these lenses have not lived up to the success expected. Corresponding problems have been demonstrated by using multifocal contact lenses (Hutnik and O'Hagen, 1997). New generations of such lenses may give rise to less of these problems due to foldable design with minimal induced astigmatism, especially when implanted in both eyes (Javitt et al., 1997).

Aspheric intraocular lenses which improve the contrastsensitivity seem to be a further step forward in relation to car driving.

The aphakic problems, known earlier, vividly self-reported in relation to car driving by McLemore (1963) with ring scotoma and diplopia after an operation in one eye, are nearly eliminated by the methods of modern cataract surgery. Applegate et al. (1987) found that among 293 patients operated for cataract with intraocular lenses, the self reported ability do drive a car increased from 21% before the operation to 34% one year after the operation. Monestam and Wachtmeister (1997) found a decline in visual problems in relation to driving from 82% before cataract surgery in 208 drivers to 5% after surgery. Thirty-seven per cent had problems with distance estimation before surgery and only 6% after the operation. Twenty-three per cent had visual acuity below legal level before surgery and only 4% after surgery. Alsbirk et al. (1988) found a corresponding decline in illegal visual acuity from 55% before surgery to 6% after surgery. On the other hand, due to glare and reduced contrast vision, 52 per cent of pseudophakic German patients did not fulfil the German requirements 10 months after cataract operation with implantation of monofokal intraocular lenses (Auffarth et al, 1994).

Corneal diseases: Today, by means of bank preserved donor grafts, also unclear or irregular corneas are effectively treated by corneal transplantation. The results depend on the primary diseases (Baun, Gregersen and Prause, 1987). Seventy-two percent of patients transplanted for keratoconus achieved visual acuity > 0.67 in a long term follow-up (Ehlers and Olsen, 1983).

Other eye diseases: The introduction of pars plana vitrectomy, YAG- laser capsulotomy of secondary cataract, and early laser treatment of sight threatening retinal diseases are further types of modern treatment of eye diseases which to some extent lead to the preservation of a visual capability. In a significant proportion of driving patients, these therapies will be sufficient for legally holding their driving license. The successful, blindness preventing effect of laser treatment of diabetic retinopathy is such an convincing example (Ferris, 1993).

Refractive surgery: In the last decade, the number of operations for myopia and astigmatism has increased (Waring, 1984, Maxwell and Nordan, 1986). The importance of this operation in relation to car driving is difficult to assess. Applegate et al. (1987) found an up to six time increase in glare at low background luminance. In the PERK study (Waring et al., 1985) some patients reduced driving at night and refused surgery on the fellow eye. Today, photo-refractive keratectomy (PRK) with Eximer lasers are increasingly used instead of radial keratotomy (RK). Even with this method, however, glare and night driving is a problem. Thus Piovella et al (1997) found night driving problems in 41% and perception of haloes in 36%. Schlote et al. (1997) investigated 32 myopic patients treated with PRK for mesoptic contrast sensitivity. Fifty-four percent did not fulfil the German night driving guidelines when tested without glare and 67% when tested with glare! Even one year after PRK the number of patients with reduced contrast sensitivity with and without glare was higher than before PRK (Katlun and Wiegand, 1998). The LASIK (laser in situ keratomileusis) and customised ablation modifications of this treatment might partly reduce such problems (Mulhern et al. 1997, Wang, Chen and Yang, 1997).

Thus, even when leaving out the aspects of legislation and accident prevention, a visual screening programme when applied on the relevant age groups, might lead to a better quality of life and a prevention of blindness in a significant proportion of the elderly population. As Keeney (1982) puts it: "The licensing procedure is the most extensive visual screening program in the world. It offers enormous opportunity to detect visual impairments and eye diseases".

i.3. Prevention of sufferings, deprivation and death by avoiding serious road traffic accidents.

In three per cent (11/309) of the drivers involved in accidents resulting in human injury, the casualty seemed to be partly due to the drivers' reduced visual capability (cf. chapter 5.3.2.2 and C.3). As shown, most of these conditions were treatable, thus leading one to assume that better visual records in the population of car drivers might result in a reduction of traffic accidents.

ii. Disadvantages:

For a small proportion of drivers, optical correction, operation for cataract or other modern treatments will not suffice in leading to a legally acceptable visual acuity in relation to car driving.

In this study, out of 17 accident involved car drivers with visual acuity at or below the legal level, only two (12%) could not be "legalised" solely by optical correction.

Of the two car drivers who could not be corrected, one (male, 79) had mature cataract and aphakia as well as severe age related macular degeneration (I-V-141). In spite of a cataract operation in his second eye, his vision could not be "legalised" due to the macular degenerations. Another driver (II-V-399) had visual acuity just below the limit and needed a corneal transplantation in order to fulfil the visual requirements.

Furthermore, chronic medical conditions, including reduced cerebral functions (causing a prolonged reaction time!) might lead to the withdrawal of some drivers' licenses.

In this part of the world, a driver's license is identified with individual freedom and personal integrity. The withdrawal of a driver's license may in some cases lead to deprivation, loss of job or loss of the possibility to reside in his/her present home, which further implicate impaired economy. For the sake of completeness the economic costs of a health certificate should also be mentioned, but compared to the costs of possessing a car and the obvious health advantages, this amount (assumed to be less than five hundred 1998 Danish kr.) seems to be moderate and acceptable.

Another economic problem to mention is the price of new optical correction, which in many cases is considerable.

5.4.1.2. The unprotected road users:

Advantages:

For the unprotected road users, the obvious advantage of a better visual capability of car drivers is the chance of being seen and detected earlier by the drivers. This may in some accidents be decisive for the con-sequences.

Provided that better visual capability of the drivers will lead to fewer accidents, this might lead to the avoidance of suffering, disablement or death. This convincing advantage seems probable. Especially the unprotected road users are often overlooked by drivers with a reduced visual acuity (cf. case I-V-929) and Acocella's (1982) case history (cf. chapter 5.3.2.2), while the more voluminous objects, e.g. roads, cars, buildings etc. as a rule are detected even at low levels of vision.

In this connection, no disadvantages for the unprotected road users are obvious.

5.4.1.3. The public health service:

Advantages:
Accepting the hypothesis that a better vision of the drivers leads to fewer accidents and fewer injured or killed persons, the advantages for the public health service are obvious. The economic and treatment resources are either saved or are available for treating diseases. The amount of money saved is arbitrary and beyond this study to assess.

Furthermore, by detecting life and health threatening diseases at an early stage in drivers with few symptoms (e.g.: 1. hypertension which, if not treated, may lead to stroke, acute myocardial infarction or death, and 2. glaucoma, which, if not treated, may lead to blindness), some resources for hospitalisation and social costs due to disablement might be used for other purposes.

Disadvantages:
Even if it is accepted that car drivers pay the primary costs in relation to the vision and health certificates, the consequences of detecting undiagnosed grave diseases are not without costs to the public health service. The medical costs of treating e.g. hypertension or glaucoma are considerable and should be compared economically, ethically and politically with the advantages of preventing disablement, hospitalisation etc.

Some increase in social costs may be expected for a small proportion of the drivers, since a limited number of those persons may be dependent on alternative transport as a substitute for private cars. Furthermore, some "social costs" for the community may be expected concerning the small number of drivers that may have to give op their jobs because of losing their driver's license.

5.4.1.4. Opinions on the question of re-testing drivers' vision:

Drivers, who had recently given up driving, reported more visual problems than their driving counterparts. To some extent they are sensitive to their own visual inadequacy (Kosnik et al., 1990). Looking at traffic legislation internationally, the questing on re-testing drivers' vision seems to be a rather controversial question (cf. table 1.1). This is of increasing relevance due to the growing population of elderly drivers. Kelsey et al. (1985) compared the two-year accident rate of 1,307,000 drivers <70 who received license renewal by mail with an ordinarily investigated control group. Although the "extension by mail" group had a 1% higher accident rate than the controls, this difference was not significant ($p<0,1$). On this basis they proposed to eliminate the re-testing of *accident-free* drivers below age 70, and Zaidel and Hocherman (1986) even found the testing of drivers from age 65 and above unnecessary. The conclusion of these investigations, however, has not been drawn on the basis of a long term follow-up investigation, concerning other health aspects. Hedin (1980) found that the beneficial effect of a re-testing had not been proved, but he supported the Swedish medical association, which recommended a health test of drivers at age 65 (Andreasson, 1984).

Hakamies - Blomquist et al. (1996) in a comparison of accident statistics between Finland and Sweden did not find evidence for any traffic safety effects on licence renewal procedure. On the contrary, by producing a modal shift toward a more risky mode of travelling, this screening may indirectly lead to higher fatality rates among older road users. Johansson et al. (1996) found that visual acuity and routine medical examination did not distinguish between convicted older drivers involved in crashes or other moving violations (n= 37) and controls (n= 37). An examination on cognitive status must also be involved in the assessment.

Various age levels have been proposed for a re-testing: The Danish Society of Traffic Medicine (1979) from age 55-60, Schober/West-Germany (1969) from age 50, Shinar-/USA-Israel (1977) from age 50, Lundt/West-Germany (1972) from age 60, Keltner and Johnsson/ USA(1992), Paetkau et al./Canada (1988) and Busse/ Germany (1993) from age 65. Harms/West-Germany (1985, 1987) recommend re-test even for young drivers and Lachenmayr (1998)/ Germany from age 40 (see chapter 5.4.2.1). Cross (1966) recommended a vision test of drivers involved in traffic accidents resulting in human injury.

Nelson et al. (1992) and Levy et al. (1995) showed significantly lower fatal accident risk in US-states, where older drivers legislatively have their vision re-tested at age 65 or 70 as compared to the 8 US-states, in which no such tests are required. On the other hand, Janke (1990) found no significant difference in conviction rates between California drivers, who had their licence renewed by mail, compared to normal office procedures. However, significant detrimental effect of this policy was noted for subgroups of drivers with recent experiences of traffic violations. The author took the results as an indication of ineffective policy more than as an argument for neglecting the problem.

As mentioned, Acocella (1982) published a very serious accident, which he found was a consequence of ignorance of the problem and legislative inhomogeneity in the USA (cf. p. 68). The same inhomogeneity has been actualised in the new Europe after 1989.

In *Germany* (where no requirements for a re-testing of private drivers exist), the discussion has been very intense. The German Ophthalmological Society has proposed a re-testing every 10th year until age 50, every 5th year until age 75, and after that every 2nd year. A statutory test of vision was proposed with respect to drivers involved in accidents in which visual problems might be suspected (Harms, 1985). This seems reasonable since in many countries accident repeaters and drivers involved in traffic accidents have been shown to have more visual problems than controls (Brody, 1941; Fletcher, 1949; ENO-foundation, 1948; von Hebenstreit, 1985; Keeney, 1968 and 1974. Gramberg-Danielsen (1986), who in his investigation from 1971 found no difference, supports a re-testing of elderly drivers: The purpose is not to exclude the drivers from the right to drive but to increase the mean visual acuity of the elderly driver population. One method proposed was the insurance companies' right of recourse against drivers in whom a visual defect was estimated to be sub-optimal and of importance for the accident. Schober (1969) wondered why young healthy drivers had to be tested, while the testing of elderly drivers with visual problems was met by a "laissez-faire" practice. Harms (1985) estimated the number of road traffic accidents due to visual problems of drivers to be at the same level as accidents due to the influence of alcohol! - In this study, the proportion between accidents, (probably) due to visual problems of the drivers vs. (probable) alcohol influence is about 1:5 (Table 5.8).

Table 5.8. Estimated proportion of car drivers influenced by 1) alcohol and 2) visual problems in relation to road traffic accidents (Alsbirk, 1999):

			Estimated number of drivers with:					
		Car drivers	illegal v. a.			probable association:		
Injury	Total (1985*):	influenced by alcohol*	age <50:	>=50:	Total:	age <50:	>=50:	Total:
Killed	772	180 (23.3%)	0	39	39 (5.1%)	0	39	39 (5.1%)
Severely inj.	8672	1315 (15.6%)	174	78	252 (2.9%)	0	156	156 (1.8%)
Slightly inj.	5183	802 (15.4%)	87	351	438 (8.5%)	0	312	312 (6.0%)
Sum (persons):	14627	2297 (16%)	261	468	729 (5.0%)	0	507	507 (3.5%)
Sum (accid.) :	11440	2297 (21%)			729 (6.4%)			507 (4.4%)

*) (ref: Danish Statistical Dept. 1985).
**) Estimated number of accidents with a probable association between visual factors in the drivers and the traffic accidents.

As seen, the car drivers were under the influence of alcohol in 21% of the officially recorded police-reported accidents. This estimate, however, is probably underscored. When car drivers involved in non-police-registered accidents are included, the proportion has been reported even higher, up to 37% (Christensen and Hem, 1974, Høeg et al. 1976). Both quantitatively and qualitatively speaking, the present investigation has indicated that the medical consequences of accidents due to alcohol influence are - not surprisingly- more serious than accidents due to visual impairments.

Harms' estimates are based on von Hebenstreit's investigations from 1974, re-published in 1985. The difference might partly be due to the differences between Denmark and Germany concerning the legislation on re-testing of drivers (cf. table 1.1.). A finding which suggests that ignoring elderly drivers' visual problems may be dangerous. Harms' hypothesis and v.Hebenstreits investigations have been questioned by Friedel (1988).

Seib (1990) documents that although elderly drivers partly compensate for their visual handicaps, it is relevant to perform periodical "eye certificate" as proposed by the German Ophthalmological Society. Lachenmayr (1998) recommended regular visual investigations in drivers from age 40, based on his recently published case/control study.
- In Germany private car drivers still have no re-testing of their vision (Lachenmayr, 1998).

In *France,* the opinion has changed from near ignorance of the problem to favoring examination of drivers' vision, including re-testings at a later date for formerly approved drivers (Perdriel, 1994; Sicard, 1994).

In *Denmark*, the Danish Society of Traffic Medicine (1979) recommended a re-testing from age 50-55 and successively every 5th year. Such a test is estimated to be of more importance than the medical examination of young, healthy drivers. The findings in the present study may lend support to this point of view. Furthermore, as demonstrated (fig. 5.1), the ability to compensate physiological changes in the eye without optic correction is significantly reduced from age 50.

It seems safe to *summarise* that evidence exists suggesting the benefit of re-testing drivers vision at a mature age, (Nelson et al, 1992; Levy et al, 1995), although some authors have their doubts about it (Kelsey et al., 1985; Zaidel and Hocherman, 1986). The opinions vary considerably. Age aspects of re-testings are discussed below.

On the basis of the present study, it can *not* be recommended to apply the Swedish, Austrian, German and French legislation in this field on Danish drivers. In those countries vehicles are routinely tested as they age, but the re-testing of private drivers' vision is not compulsory. On the contrary, several facts and arguments make the beneficial effect of testing the growing number of elderly drivers (with increasing visual problems) probable and even reasonable, when carried out properly.

As suggested, the question of regular, legislative re-testing is not only practical, but indeed disputatious and in the end rather political. Another question to consider is whether it is reasonable to perform visual tests on drivers involved in selected groups of road traffic accidents. A re-testing is not only a question of *when* to perform it but indeed also *how* to perform it, and *in which groups* of car drivers.

5.4.2. Future considerations on visual screening procedures.

5.4.2.1. Visual screening and age of the drivers:

Considering that very few young drivers, aged <50 have vision or other health problems relevant for traffic safety, the benefit of testing drivers' vision seems limited in the case of drivers aged below 50, seen also in relation to the efforts needed. In elderly drivers, however, it seems possible to identify a considerable number of drivers with significant, mostly adjustable, visual deficiencies and other diseases. An age limit is arbitrary and varies from country to country (cf. table 1.1.).

Various authors have recommended differing age limits. In Sweden age 65 has been proposed (Hedin, 1980; Andreasson, 1984); Davison (The United Kingdom, 1985) recommended age 50; and Harms and Dietz (West-Germany, 1987) recommended re-testing in younger drivers too. Some authors were sceptical concerning the benefit of a re-testing procedure (Hedin, 1980; Zaidel and Hochermann, 1986, Johansson, 1997) while others would like it intensified) (Keltner and Johnson, 1987 and 1992; Schieber ,1994; Lachenmayr 1998).

Shinar and Schieber (1991) recommend a two step screening approach with the possibility of more centralised and comprehensive testing of (elderly) drivers after the age 60 (or 50) who have failed the primary screening test.

The Danish Society of Traffic Medicine (1979) recommended a re-testing from age 50 - 55. The present investigation supports an intensification, or at least status quo, since the visual problems of the active drivers obviously tend to increase from age 40 (cf. table 4.1.). From the control group it is known that 3/103 (2.9%) of drivers aged ≥ 55, had visual acuity below the former legal level or binocular visual acuity below 0.5. Thus, among 635,000 car drivers in Denmark aged ≥ 55 (Christensen, Rådet for Trafiksikkerhedsforskning, personal communication 1988, Ministeriet for Offentlige Arbejder, TU-86, 1986), it can be estimated that approx. 18,500 of these (95% confidence limits: 2,860- 49,000) usually have a visual acuity below the legal level, whether according to previous or present legislation.

In a recent workshop in EU, it was recommended that group I licence holders must undergo a medical examination from the age of 60 and thereafter every 5 years. For group II drivers a medical examination was recommended at the year of 50 and thereafter every 5 years. For category C and D, it was further recommended that the drivers should undergo a medical examination every 10 years until the age of 50 (CIECA, 1999).

5.4.2.2. Optional screening.

Surprisingly, not in any of the 359 accidents in this study a follow-up investigation of the car drivers' vision has been initiated by the police.

Table 5.9. "The number plate test" applied to Danish number plates (Alsbirk, 1999):

Height of Danish number plate signs:	7.4 cm.
Height of the 6/60 sign on Snellens chart:	8.7 cm.

Distance for reading a Danish number plate sign with normal vision (6/6):

$$\frac{60m * 7.4}{8.7} = 51m$$

Distance for a person with visual acuity = 6/12 to recognize a number plate:

$$\frac{51m * 6}{12} = \mathbf{25.5\ m}$$

Normally this is only arranged in 1 or 2 instances a year in the Police District of Aarhus (E. Christensen, personal communication). As a consequence of the present findings it seems relevant to consider an optional vision screening procedure in selected groups of drivers.

5.4.2.2.1. The "number plate test".

The "number plate test" does exist. This principle has been used in The United Kingdom since 1935 (Plenty 1985, Taylor 1998). The method is easy to perform: A binocular visual acuity ≥ 0.5 in a Danish driver is assured (cf. table 5.9), if the driver is able to read a clean (if necessary illuminated) Danish number plate correctly at a distance of 26 m.

By testing the car drivers' binocular visual acuity this method is in accordance with the present procedure in the EU (such an examination could, if performed by the police, be used as a screening in relevant cases, analogous to the screening of the drivers' consumption of alcohol by means of the balloon method).

This simple method makes it possible to test drivers' binocular visual acuity in suspected cases (e.g. elderly drivers involved in traffic accidents or performing dangerous manoeuvres being suspected of overlooking important details). Performed as a police screening, it should only be taken as a rough guidance. In case of suspected visual problems, the drivers should be examined further. The proposal can be seen as a practical and inexpensive alternative to the prevailing ignorance of the problem.

As illustrated in fig. 5.1- 5.3 the "number plate test" is easy to perform and reflects important aspects of vision in traffic: Small, but sometimes important, details may not be seen if the driver is not able to read a number plate at a distance of 26 m.

Also, in the case of drivers involved in severe or multiple accidents or other drivers with dangerous traffic behaviour, it might be relevant to perform a vision and health examination (as proposed by Keltner and Johnson, 1987).

5.4.2.2.2. Alternative test procedures:

Public information, e.g TV showing "the number plate test" - or an analogous adjusted procedure on the TV-screen might give the drivers a regular opportunity to test their binocular visual acuity themselves.

More sophisticated methods for testing the drivers' vision, such as dynamic visual acuity (Hills and Burg, 1977, Tinning, 1979), contrast sensitivity testing (Evans and Ginsburg, 1985), computerised perimetry (Johnson and Keltner, 1983), glare testing (Sjöstrand et al. 1987), vision in reduced lighting (Aulhorn and Harms, 1970), and "Useful field of view" (Owsley et al.,1991 and 1998) should be mentioned. Such tests are obviously superior to the rather primitive screening procedures of today. However, if used consistently they will be expensive to perform, produce a heavy load of "false positives" and will be difficult to administer on a broad scale. Realistically, these methods will only be feasible in very highly developed countries. Up till today such procedures have not been widely used but they might be relevant in the future, if applied on *selected groups of drivers*

Fig.s 5.2.- 5.4. *Traffic situation as seen with a visual acuity = 0.16 (5.2.), 0.33 (5.3.) and 1.0 (5.4.). Notice the children playing around the car, the ball behind the car and the number plate on the car (cf. text). Photo: O. Jensen (K.E. Alsbirk, 1999).*

with a doubtful visual field in the "*grey zone area*". Further testing of drivers in advanced or PC based *driving simulators* seems more and more applicable (Hedin, Rumar & Verriest, l981; Løvsund et al., 1991; Szlyk et al., 1992, 1993 and 1995).

5.4.2.2.3.Perspectives on computerised visual field screening:

It is disputable, whether it is recommendable to perform visual field screening by *computerised perimetry* as a routine or only in selected cases. Johnson and Keltner (1983) screened 10,000 volunteer drivers and found visual field defects in 13% from age 65 and above (cf. chapter 1.3.3.2). Concerning the present study, in one accident (I-VM-929) the significant paracentral scotoma in the driver's best eye was neither found by the visual field screening by hand a.m. Donders, nor had it been detected by a vision test 8 months prior to the accident. In another case (II-VM-979), the visual field defect (an upper, homonymous quadrant anopsia in the right side) was not discovered by the general practitioner at several repeated 5-year examinations when renewing the driver's license for professional transport of persons. Probably this 50 year-old taxi driver had had the defect since childhood. According to the former medical guide for testing visual fields in relation to drivers' license in Denmark, the horizontal, the vertical and the two lower quadrants had to be tested. Examination of the upper two quadrants were not obligatory (Sundhedsstyrelsen, 1962). Looking at the illustrations incl. the visual field of the taxi driver (cf. appendix C 2., II-VM-979), this guide was indeed disputable. In the EU regulative of today, a visual field must be adequate in 120 degrees at the horizontal level (Færdselsstyrelsen 1997). It seems reasonable to revise this practice also. At least the 4 quadrants ought to be tested, e.g. as in Sweden, in which country 8 meridians (two horizontal, two vertical and four oblique) are all examined (Hedin, 1986).

The chance of detecting *glaucoma* in drivers at the relevant age is obviously bigger when using computerised perimetry as a routine screening, but the introduction of this procedure will demand more resources. In the EU a simple procedure for computerised visual field screening has been proposed for the future (Schneider 1986). Such programmes are available today, even for personal computers (e.g. Boberg-Ans & Vangsted 1988).

5.4.3. Conclusion:

Concerning a possible introduction of new test-procedures and intervals for re-testing drivers' vision many points have to be considered:

a. - A test procedure should be practical, quick, fair, cheap and easy to administer.

b. - The tests should ensure that i) only a few drivers with a vision dangerous to car driving continue to drive (i.e. offer a high *sensitivity*) and that ii) only a few drivers, who are not dangerous in traffic will lose their driver's license (i.e. have a high *specificity*).

c. - Besides, before discussing what kinds of tests are optimal for the given purpose, it is relevant to consider the overall problem: The indication of and relevant time interval for a re-testing the drivers' vision.

It seems futile to discuss detailed and sophisticated methods of testing 18 year-old healthy teenagers and at the same time, as in some countries (cf. table 1.1), almost ignore the significant and increasing visual problems of the middle-aged and elderly car drivers.

d. - Many kinds of solutions and models for vision and health screening of car drivers exist today and will continue to exist in the future in various countries. A simple test of the drivers' cognitive functions seems motivated, according to several studies.

In the end, the decision whether to introduce or intensify re-testing drivers' vision or not is a question of health politics.

As outlined earlier, the purpose of this study is to give an epidemiological basis of today for the discussion of future planning rather than to elaborate on tomorrow's detailed vision screening methods for car drivers.

Final remarks.

Good vision may imply a higher speed and thus, indirectly, may induce a risk of more serious traffic accidents. Conversely, a bad visual performance seems to be partly compensated for by a change in driving behaviour, including a reduction in speed (Rumar 1986a), -lower annual miles and greater avoidance of high-risk driving situations (Stutts, 1998). Older drivers with a history of at-fault crashes in the previous five years reported more avoidance than those who had crash-free records (Ball et al, 1998).

However, the logistic regression analyses in the present study indicate (after a correction for design variables and confounders) that *such a compensation is incomplete* and that, to some extent, increased accident risks in the elderly group of drivers appear to be associated with poor visual performances.

In countries, where authorities in the future decide to intensify or introduce the screening of drivers vision in accordance with the demographic and behavioural evolution, it seems that ophthalmologists will play an important contributing role.

Possible attempts to prevent some of the serious road traffic accidents may further depend on good co-operation with legislators, the police, general practitioners, and opticians.

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As Cross (1966) sums up: *" Road traffic accidents are one of the biggest causes of death in the highly motorized countries and they tend to affect the younger members of the population and particularly young males. It is of vital importance that we, as ophthalmologists, should keep this problem under close review so that we can play our part in reducing this form of mortality and of morbidity".*

6. MAIN CONCLUSIONS

6.1. The visual situation of accident-involved drivers in Denmark is characterized by an age related, significantly increasing proportion of drivers with visual problems. In the age group below 50 1.6% had visual acuity below the legal level when corrected as at the time of the accident, mainly due to inadequate optical correction. In the age group 50-69 the proportion was 8%, and from age 70 25% had illegal visual acuity at the time of the accidents. Eleven per cent of drivers aged ≥ 50 had not been visually tested within the last 10 years. No significant differences could be demonstrated on visual parameters between males and females, although a longer period since last visual test was found in males (p< 0.01).

In twelve out of 14 drivers (86%) with unilateral reduction of visual acuity, being involved in intersection accidents, the collision happened from the side with impaired vision (p< 0.02). Eleven of such bumpings (79%) took place from the left side (p< 0.06).

Presuming that the findings in this study is representative for Denmark, an estimated annual number of 730 car drivers involved in road traffic accidents resulting in human injury have *visual acuity below the former legal level* at the time of the accident (95% limits: 385-1180). Of these 260 (1.6% of the drivers) are below age 50 and 470 (9.8% of the drivers) above that age. Correspondingly, according to today's legislation, approx. 400 car drivers (171-722) involved in such accidents have illegal binocular visual acuity below 0.5, approx. 300 of them being ≥ 50 years of age.

6.2. Multiple logistic regression analyses with vision/accident risk estimates were carried out on 204 drivers aged ≥ 50 (the case/control study) with corrections for age, sex, annual driving, daily alcohol consumption, percentage of urban and professional driving, and visual reaction time. Generally, traffic accident risks were found to be significantly associated with the quality of vision. Contrast sensitivity (p= 0.003), and to a less degree unilaterally reduced visual acuity (p= 0.02), and binocular visual acuity (p= 0.03) seemed to be important test variables. Binocular visual acuity was identified as a stronger overall risk indicator (p=0.03) than monocularly tested visual acuity (p= 0.08). It can not be ruled out that stereopsis (p= 0.05) and the time interval since last visual test (p= 0.07) are critical factors. No significant association was found on central or paracentral visual field defects (p= 0.14), visual field defects, tested a.m. Donders (p= 0.43), colour vision defects (p= 0.89) or refraction (p= 0.89). Several visual variables tested were found mutually associated.

The conclusions of the multivariate analyses have been attempted illustrated by an individual assessment of the 359 traffic accidents.

Naturally, a one hundred percent evidence of an unambiguous causal *vision/accident co-association* can only be proved on rare occasions. However, a classification of the accidents has been attempted on the basis of the available knowledge, e.g. the testimonies, the results of the ophthalmological examination, and the information from the accident records. The assumption is that until age 50, an association is estimated as probable in none of the accidents and possible in 5%. In the intermediate group aged 50-59, an association is estimated as probable in 5% and possible in 25%. From age 70 and above, visual problems of the drivers were estimated to be probable associated factors in 37% of the accidents and possible factors in 25%.

In most of these accidents, vision seemed to be one of several contributory factors, thus confirming that traffic accidents are multi factorial events.

A vision/accident association is cautiously estimated as probable in 430 [216-761] traffic accidents with human injury in Denmark per year, or more than one per day.

6.3. A change of visual testing in private drivers towards a *binocular technique* with a cut-off point just below 0.5 has been introduced in the EU. This primarily means a reduction of the requirements. Out of 435 investigated drivers 4.6% had illegal visual acuity according to the former Danish requirements and 2.7 % by the present EU legislation, when using their usual optical correction. After optimized correction the corresponding proportions were reduced to 0.7% and 0.5%, respectively. Binocular testing is more simple to administer and to apply in optional screening procedures. Further, it seems to be a better overall risk indicator than monocularly tested visual acuity.

However, this technique does not identify drivers with unilateral reduction of visual acuity (who seems to have special problems in traffic) and the chance of detecting unilateral, unknown eye diseases is diminished.

6.4. A renewal of optical correction was sufficient to *legalize the driver's vision* in 15 (88%, 95% confidence limits: 64%-99%) of 17 accident drivers with visual acuity at (2) or below (15) the legal limit (at the time of the accident). Modern eye surgery might increase this proportion further.

6.5. The *health consequences* of accidents with driver's visual acuity at or below the lawful limit did not differ from the main group of accidents (p=0.7). This implies that if visual problems of drivers is accepted as a risk factor, serious, even fatal traffic accidents may from time to time be caused by drivers' reduced visual performance.

6.6. In the group of drivers aged 50 and above, acute or chronic *medical conditions,* including visual problems, were estimated to be of possible contributory importance in 16% of the accidents (95% limits: 10%-23%).

The overall proportion of accidents, in which an acute medical condition was estimated a contributory factor, was 3/359 (0.8%, 95% confidence limits 0.2% - 2.4%).

6.7. Whether to change administrative and practical procedures concerning visual screening of drivers' vision or not ultimately is *a question of health politics.* The results of the present descriptive and analytical study may give the authorities some arguments. Some premises pro et contra re-testing of elderly drivers are discussed, including health aspects. When applied to relevant age groups, a screening programme may to some extent function as valuable health prophylaxis, including the prevention of diseases and blindness. Further, a simple test of the drivers' cognitive functions is recommended.

On the present background, it can not be recommended to omit compulsory re-testing such as e.g. in Sweden, Germany and France.

Since vision as a contributory factor in traffic accidents is only very seldom investigated, it is proposed *in the future* optionally to focus on this problem in relevant age groups and suspected accident cases by means of a simple vision screening on the scene of the accident. E.g. a so-called "number plate test" (read at 26 m distance = test passed) would be cheap and easy to administer as a screening procedure. This could be analogous to the screening of car drivers under the influence of alcohol by means of a "balloon test".

6.8. The finding of *a significant, overall association* between the quality of drivers' vision and their traffic accident risk, indicate that the compensation for bad visual performance in the form of a change in their driving behaviour appears not fully adequate.

On this basis, supported by foreign studies, it seems safe to conclude that in the countries in which elderly car drivers' vision is not re-tested at all, the legislation is not in accordance with ophthalmological trends and the present demographic and behavioural development involving more and more elderly drivers in a more dense and complex traffic.

6.9. Since it is a fact that an increasing population of elderly drivers with visual problems will apply for a renewal of their licenses, it is relevant in selected cases to introduce more relevant and reliable methods for the evaluation of drivers' visual performance relevant for driving. Such methods include the useful field of view (UFOV) method and tests in interactive driving simulators. Especially for drivers with visual performance in the "gray zone" dubious to traffic safety, such methods should be investigated, developed and available.

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Regional epidemiological studies in this field are of importance from time to time. The purpose will be to establish practical applications and further research for the future in order to reduce to a minimal level the number of meaningless preventable traffic accidents.

7. Summary.

Chapter 1. Introduction.

A discussion of demography and traffic laws is followed by a literature survey emphasizing those epidemiological aspects which form the background for the present study. The main purpose of this study is to evaluate the importance of visual function as a factor in causing traffic accidents in Denmark.

With respect to demography, the aged population (over 65 years) constitute the group which is growing relatively most quickly in the Western world. In Scandinavia, the absolute number of those over 65 is expected to rise by 200-300% from 1960 to 2025, and the proportion of car owners in this age group is rapidly increasing. The proportion of 65 year old male Swedes who owned a car has risen from 7% in 1965 to 40% in 1983. In 1997 the corresponding proportion was 45%. These trends indicate a significant increase in the number of drivers over 65. This number is predicted to double between the years 1978 and 2000.

Numerous studies show that from the age of 50 and up, visual ability undergoes crucial changes. These changes can both be refractive changes or a result of eye disease.

Drivers' legislation is extremely varied from country to country and based partly on traditions. There is general agreement with respect to the minimal standards, but there is a considerable difference around the world, even, in fact, in the Scandinavian countries, about the required frequency of retesting.

In Denmark, the law was changed in 1966. Before this, private automobile drivers were required to have a health examination including a vision test every fifth year. After consideration of the requirements in Sweden, West Germany, and France, the Danish requirements were relaxed, and since then, drivers of private automobiles and trucks have been required to have their next vision test only when they reached the age of 70. The next test would normally occur at the age of 75 and after that, at 2-year intervals until the age of 80. Starting at the age of 80, an annual test is required. For drivers with so-called professional passenger transport licenses, the former requirement of a physical examination including vision test every fifth year has been retained. Since 1996, the requirements for lorry-drivers have been tightened up by introducing a retest of vision each 5th year from the age of 50.

The published literature dealing with the epidemiological aspects of this area is extensive. The reported conclusions span a wide spectrum, from the point of view that weak-sighted automobile drivers compensate completely for their visual handicap by changing their driving behaviour, to the viewpoint that drivers' visual problems constitute as great a danger factor as the misuse of alcohol. Many studies can be criticized because they contain important flaws: missing control groups, lack of control for the factor of age, lack of analysis of the relationship between visual problems and the individual traffic accidents. Nearly all of the studies have only small or no subgroups of drivers who fulfil the conditions of 1) being involved in a serious traffic accident, 2) having a vision problem, and 3) being a proband (participant) in an epidemiological investigation. Particularly important is the frequent failure to take account of dropouts from the studies (non- responders). Any comparison is made difficult by the great variations in traffic laws and demography from country to country, as well as from one time period to another. The validity of frequently cited studies and the extent to which they are representative must be cast in doubt when these are based on visual examinations of voluntary experimental subjects who are applying for renewal of their driving licenses. This group hardly reflects the overall population of drivers in actual traffic, including those involved in accidents.

Scandinavian epidemiological studies of the association between actual traffic accidents and vision problems have not been found. A Finnish study from 1973 concerning dangerous traffic behaviour has, however, pointed to the existence of such an association.

The present study seeks to elucidate this association through a descriptive analysis of the incidence of visual problems in automobile drivers who are involved in serious traffic accidents (e.g. those resulting in human injury requiring treatment or in death) as well as through an evaluation of the association between the accidents and visual problems, if any. Furthermore, it attempts to present Scandinavian epidemiological data as a basis for possible changes in practical and legal provisions for the detection and treatment of motor vehicle drivers with significant visual loss. General blindness- and health- prophylactic aspects of a possible intensified visual and health screening are also attempted examined.

The aim of this study is, if possible, to contribute to a reduction in serious traffic accidents by tackling one of the areas where there appears to be a realistic opportunity to do so.

Chapter 2. Material.

The study is based on a consecutive investigation with two main parts, conducted within the admission area for the two emergency rooms in , which was approximately the same area as that contained in the police district (284,000 inhabitants).In Phase I (the descriptive study), the inclusion criteria were as follows: active road users (i.e. passengers excluded) $\geq$ 10 years of age, who were involved in a traffic accident in which at least one driver was implicated and which resulted in human injury requiring treatment or examination at one of the city's two emergency rooms. For practical reasons, most foreigners and certain groups of criminals had to be excluded. The investigations in Phase I showed that the main visual problems among drivers were found in the group of those aged 50 years and older. There were certain problems with recording and contacting the uninjured drivers in accidents which were not reported to the police. Phase II of the study was therefore limited to automobile drivers aged 50 years or older who were implicated in accidents which were reported to the police. The basic requirements were unchanged. The age distribution of drivers 50 or over observed in Phase I was used as a basis for establishing a comparable control group of active automobile drivers, chosen at random from the Driver's License Registry of the Police.

Altogether the study included 405 automobile drivers and 157 unprotected road users, who were involved in 359 traffic accidents with human injury. The control group included 138 drivers aged 50 years or older. On the basis of the descriptive study (Phase I), the extent of police reports on this type of accident could be set at 61%, the reporting being greatest in the group of the most serious accidents.

The median age for implicated drivers in the descriptive study was 37, and 25% were older than 49. The median age of the unprotected road users was 23. Younger drivers (under 25 years) were significantly over-represented in the accident group (4-9 times) relative to their numbers in the daily traffic picture. A slight but significant over-representation was also found in drivers aged 75 and above. This agrees with reports from other countries.

The dropout rate (non-responders) was greatest in the group of accident-involved drivers under 50 (25%), while it was 22% among the older accident-involved drivers and only 8% in the control group of drivers. The dropout rate for unprotected road users was 17%. For drivers this rate was higher for those who lived farther away. Alternative information about non-responders was gathered confidentially, after the approval of the scientific ethics committee. The information was gathered from the driver's own doctors or ophthalmologists, or from ophthalmology departments in Aarhus and Randers. Information about visual acuity and known eye disease was obtained for 93% of these subjects. In only 2.3% of non-responders was no supplementary information obtained.

The final material of drivers in the descriptive study of visual parameters examined by the author consisted of 309 drivers involved in accidents (187 aged < 50 and 122 aged $\geq$ 50).

A restricted material of 204 drivers (91 probands and 113 controls) was used for logistic regression analyses (the case/ control study) with correction for the 3 design variables age, sex and annual driving. Further control was performed for the possible confounding factors: daily alcohol consumption, percentage of urban and professional driving, and visual reaction time.

Chapter 3. Methods.

This section contains descriptions of accident data collection, of how contact was established with the probands and control group, and of the examination of the road users.

Close cooperation with the city's two emergency rooms and the Police Department was effectively ensured by having a responsible secretary in each place who took responsibility for transmitting daily information about all road users/traffic accidents that fulfilled specified inclusion criteria.

According to prior agreement, confidentiality was maintained by transmitting no information from the study back to the police or other authorities. This is believed to have been a very important reason for the relatively low number of "non-responders" as well as for the reliability of information about the road users' vision and their use of visual aids at the time of the accident.

Two weeks after each accident, the road users involved received a written invitation to take part in the study. Confidentiality, the voluntary nature of participation, and the right to withdraw at any time were stressed, in accordance with the Helsinki declarations of 1975 and 1983. The road users were then contacted by telephone, at which time they had the opportunity to ask questions and obtain information before finally deciding whether to volunteer to take part in the study.

For a high proportion (88%) of the "non-responder" group information could be obtained from their own general practitioners or ophthalmologists about their general health, use of medication, etc., even though information about their vision was not always available.

Examination of the road users included 1) interviews, 2) collection of ophthalmological data and 3) collection of accident data from police reports. The interviews covered general information such as occupation and detailed driving information, general health information including medication and alcohol use as well as previous hospitalizations, information about eye disease and the use of visual aids, as well as the time and place of last vision test. Finally, the subject was asked about the subjective experience of the accident.

The examination was most often carried out 2-3 weeks after the accident at the Ophthalmology Department of Aarhus University Hospital. In a few cases it was performed at home or in another hospital department. The subjects static visual acuity, monocular as well as binocular, was tested without correction, with the correction used at the time of the accident, and also with optimal correction. The visual field was tested primarily with a confrontation test but in selected suspicious cases (about 14%) with the help of computer perimetry. All subjects underwent tests for depth perception (stereopsis), colour deficiencies (Ishihara test), contrast sensitivity (Arden grating) and visual reaction time. All were examined with an ophthalmoscopy (un-dilated pupil). If necessary, slit lamp examination, applanation tonometry, orthoptic tests, visual acuity test in the dark or under glare conditions, and computer-assisted perimetry was carried out. In a few cases, the patient (on a voluntary basis) was referred for further investigation with CT-scanning or neurological examination.

With permission of the Justice Ministry, the information about the accidents given by the road users themselves was supplemented, in 104 of 244 police- reported accidents, with an examination of the police reports. This was done with the aim of elucidating the association between the accidents and visual problems of the drivers.

The collected data was analyzed by computer, using primarily an SPSS-based data base. Further analysis was done on a PC with the help of the database analysis program "Reflex". The multiple logistic regression analyses was performed with professional statistical assistance by the program "Epicure".

Chapter 4. Results.

In this section the results of analyzing a series of medical and ophthalmological topics in relation to traffic accidents are presented.

4.1. In the descriptive study, visual problems were found to be prominently age dependent : among drivers under age 50 involved in accidents, fewer than 2% had acuity under the legal limit, defined as the former limit set by the National Board of Health for obtaining a driver's license. From 50 to 69 years, the corresponding proportion was 8%, and for age 70 and above, 25%. Binocular acuity testing revealed a similar tendency. Those drivers with increased reaction time and reduced contrast sensitivity, acquired colour vision defects, defects in the central visual field and age related macular degenerations (all visual parameters which are partly interrelated) tended to be the older ones.

The external conditions having to do with the 359 accidents were analyzed with special regard to the external visual milieu. Twenty five per cent of the accidents occurred in rain, fog or snow. Visibility was reduced in 11%. Four out of five accidents occurred in city areas, and 61% in one of several types of road crossing. Twenty five% of the accidents occurred in the dark, and 9% in twilight. An association was shown between accidents in the dark and 1) reduced visibility, rain, and fog, 2) accidents on straight roads or on curves, and 3) accidents in country areas with at most widely separated houses. In half of the 120 accidents which happened in the dark or twilight, the local lighting was either insufficient or nonexistent.

An analysis of the association between visual parameters and the external visual scene showed no association between any of the investigated values and accidents in dark or twilight. The same was true for visibility except that drivers involved in accidents with reduced visibility were significantly more myopic (on average 1 diopter) than the others. No obvious explanation for this association was found; in particular it was not apparent that these drivers more often failed to use their glasses. Five per cent the drivers had unilateral visual impairment (acuity <0.25). In crossroads accidents the proportion of drivers with unilateral impairment was 8% compared to 3% of those drivers involved in accidents in curves or straight roads (p = 0.17). Among 17 intersection accidents where the driver had unilateral visual impairment, the collision occurred in 65% of cases from the left, in 18% from the right, and 18% head on. Twelve of 14 (86%) side collisions happened on the same side as the visual impairment (p <0.05).

Visual examinations analyzed with respect to the motorists' driving parameters seemed to imply (though the results did not achieve statistical significance) that professional drivers had better visual performance than private drivers. In particular the vision of professional passenger transport drivers, who, according to Danish law, must have a vision test every five years, was found to be optimal.

Twenty seven per cent of drivers with "illegal vision" at the time of the accident did not use distance correction for driving even though most of them did use it for watching television. The corresponding fraction among drivers with legal vision at the time of the accident was 19 %. Uncorrected hyperopia and reduced accommodative power turned out to be an important problem in daily traffic among the drivers who were investigated. The widespread misunderstanding that, even in older people, hyperopia (long-sightedness) need only be corrected for reading is opposed.

Of 17 accident-involved drivers with legally inadequate vision, 15 (88%, 95% confidence limits: 64%-99%) could ob-tain legal vision simply through new optical correction. Correspondingly 8 out of 9 drivers (89%) with binocular visual acuity below 0.5 reached legal level of today by new glasses.

4.2. In the drivers aged 50 and above a multiple logistic regression analysis was performed (the case/control study). Drivers involved in non-police registered accidents and with incomplete information were omitted in order to minimize heterogeneous inclusion criteria. Two hundred and four drivers, (91 cases and 113 controls) fulfilled the criteria for the analyses. Age, sex and annual driving were taken as design variables, whereas daily alcohol consumption, percentage of urban and professional driving, and visual reaction time were corrected for as “confounding factors”.

The analysis showed that traffic accident risk was significantly associated with quality of vision. Contrast sensitivity (p=0.003) followed by unilaterally reduced visual acuity (p=0.02) and binocularly tested visual acuity (p= 0.03) seemed to be the most important variables. Reduced stereo-vision (p= 0.05) and the time interval since last visual test (p= 0.07) could not be ruled out as critical factors. No corresponding association was found in relation to central or paracentral visual field defects (p=0.14), visual field tested a.m. Donders (p=0.43), colour vision defects (p=0.8 9) or refraction (p= 0.89).

Several of the visual variables were found to be mutually associated. After control for design variables and con-founders, analyses of combinations confirmed that associations generally exist between the quality of vision and accident risk.

If non-police registered accidents were included, the analyses indicated that the following visual variables were associated with accident risk: uni-laterally reduced visual acuity (p= 0.068), binocular visual acuity (p= 0.013), contrast sensitivity (p= 0.15), and stereopsis (p= 0.017). Unilaterally tested visual acuity (p=0.04) and the years since last visual test (p=0.04) appeared to be weak although sig-nificant identificators of accident risk.

4.3. In Denmark changes in the vision test requirements for obtaining a driver's license in accordance with the European Union were effective on July 1st 1996. An important change was a tightening of visual standards for heavy truck drivers (weight > 3500 kg) or for drivers with permission to the commercial transport of persons, in that the requirement for the corrected acuity in the poorer eye was raised to 0.5. For private motorists a binocular acuity test with a limit of 0.5 replaced the former monocular tests.

Both the monocular and binocular tests are evaluated in the present study for 435 motorists. Among the 22 drivers not fulfilling the former Danish requirements for private drivers, only 12 (54%) did not fulfil the present EU demands. Thus in this group of drivers a slight decrease in visual requirements has been achieved with the present EU legislation.

4.4. With a view towards being able to evaluate the medical consequences of accidents in which the drivers had visual problems, a simple score was developed to rate the severity of an individual accident. This was based on primary information about any treatment, hospitalization (in cases with or without central nervous system damage), or death as a result of the accident. Thus this was more a qualitative than a quantitative evalu-ation. It is concluded that the medical consequences of accidents, including visually impaired drivers, were comparable with those of other accidents (p > 0.7). This implies that even very serious accidents involving fatalities occur as a probable result of visual problems of motorists. This finding is important for calculating the traffic medicine significance of visual impairment concerning traffic accidents in Denmark.

The use of seat belts is briefly discussed. No association was found between failure to use seat belts and failure to use the relevant visual correction (p = 1.0). The oldest accident involved motorists used seat belts significantly more frequently than did the younger ones (p < 0.02). Only 58% of 18-29 year-old drivers were wearing seat belts at the time of the accident, whereas 71% of the drivers over 49 years old used it.

Chapter 5. Discussion.

In this section the material, design, and results of the study are discussed with respect to results of other studies known from literature.

The need for recurrent regional epidemiological studies is underlined, first and most importantly because of the seriousness of the problem, but also because of the inconsistent conclusions of previous studies, the demographic development towards more older motorists and the variation in traffic customs and laws from country to country. Visual testing methods are being improved and the possibilities to remedy visual problems will become more and better.

The material and design of the present study are characterized as a well-defined (both in time and place) consecutive material of road users involved in serious traffic accidents with human injury and involving at least one car driver. A randomly chosen control group of active drivers provide the comparisons. The study is the first of its kind in Scandinavia. The ethical principles for the study (voluntary participation/ confidentiality) are seen to have been decisive in terms of the high participation rate (76%) and the validity of the data collected.

The investigation consists of both a descriptive and an analytic study. The descriptive study makes it possible to evaluate the relative occurrence of visual problems in a population of road users involved in accidents, in particular car drivers. In addition, the study provides the possibility of a careful generalization on a yearly national basis. The analytic (case/ control) study, in which a proband group was compared to a control group, makes it possible to estimate the relative risk for drivers with different types of visual problems. The calculated "odds ratio" in such a "case/ base" study is close to the true relative risk.

To the greatest possible extent methodological problems have been opposed by performing a logistic regression analysis on a restricted material with control for design variables and certain confounding factors.

On the basis of the literature and the results of this study, the meaning of the individual visual parameters is evaluated: Even though dynamic visual acuity appears to be more associated with accident risk than static visual acuity, the latter will for practical reasons continue to be the predominant vision test for many years in most countries. A good static visual acuity is deemed a necessary, although not sufficient, condition for a motorist to be able to react safely in an unforeseen traffic situation under difficult illumination or reduced visibility. In particular, the ongoing interpretation of small details in the traffic picture, for example the condition of the road surface, dark clothed road users, the attitude of children and other unprotected road users, and eye contact with other road users, is important. For such small details, the theoretical critical time interval available for an adequate reaction is reduced in direct proportion to the static acuity. Motorists' visual fields defects have been found to be associated with especially serious traffic accidents. However, in the analytical study, these motorists were not quantitatively over-represented in the group of accident--involved drivers. Unilateral visual impairment appears to be a limited but significant problem for the group of accident-involved drivers with a four to five fold increased accident risk ($p= 0.02$). In crossroads accidents these drivers were involved in significant more collisions from the impaired, often left side, (86%) than from the opposite side (14%).

Congenital colour blindness was not found significantly over-represented in the accident group nor associated to individual accidents. Acquired colour vision defects and central visual field defects, age related macular degenerations and reduced stereopsis, are visual parameters which were all found over-represented (stereopsis significantly) in the accident group, and mutually related. Reduced contrast sensitivity was found to be the visual variable most constantly and independently associated with increased accident risk. The road users' night vision was not systematically evaluated with a special night vision test. However, the motorists who were involved in dark or twilight accidents had, measured with the visual parameters investigated, no relative increased frequency of visual impairments. Drivers with subjective night vision problems should perhaps in future undergo a more exact examination with a night vision test and a test for glare sensitivity. Usable standardized equipment for this appears to be under development. Glare blinding constitutes - in this study also - an important visual problem in drivers with incipient cataract. Several accidents appear to have been caused partly by this condition. Here we can point to good treatment possibilities which modern ophthalmic surgery can provide with the implantation of pre-calculated intraocular lenses. Because of this, the indication for cataract surgery in the case of active drivers should be re-evaluated.

The need for visual re-testing is illustrated partly with reference to the discussion in a number of countries, partly on the basis of the association of visual problems with age. For each 5-year time interval since last visual test, a factor 1.4 - 2 significant increase in accident risk was found in drivers aged ≥ 50 in the logistic regression analyses.

Casuistic reports of the traffic accidents: To provide insight into the nature and extent of the traffic accidents and how they occurred, and to give the author's estimate of the possible association between individual accidents and visual problems, a list of cases is given as illustrative "soft" documentation in appendix C. 2. By combining the ob-served visual problems for the individual road user with the available accident data, including information from selected police reports, it has been possible to give a careful estimate of a visual problem/ accident association as probable/ possible/unlikely for each individual accident, but it is inherently extremely unlikely that 100 % evidence for an unambiguous association can be obtained. The study corroborates the multi-factorial nature of most traffic accidents.

On this basis the reported accidents were divided into the following categories: I. probable association between vision problem/ accident; II. possible association (drivers only); III. accidents where, although the driver had a visual problem, the association is judged unlikely. Discussed in addition to these are: IV. accidents where the driver's medical condition, medication intake or alcohol abuse is deemed important; V. drivers in the control group with noteworthy visual problems; VI and VII. accidents of special interest for other reasons.

A series of health parameters, based on the information gathered in the examination and an overall impression of the road users, are evaluated in relation to the individual accidents. A detailed clinical examination of the drivers was not carried out.

In 3 of the 359 accidents (0.8%) the accident occurred as part of an acute medical episode (2 transitory ischemic attacks, 1 "drop" attack). Besides, one motorist with severely impaired vision had hypoglycemia after the accident. A chronic medical condition of possible importance for the accident was seen chiefly in older motorists aged ≥ 50, namely in 11 of these. When the motorists with probable accident/visual problem co-association are added to those having an acute or a chronic medical condition, 16% (95% confidence limits: 10%-23%), or 1 out of 6 accidents among motorists ≥ 50 years of age are estimated to have a medical condition as a possible important contributing factor.

The influence of alcohol was found to be dominant among the drivers under 50. This was so even though no difference was found between the reported daily alcohol consumption of the older and younger drivers. The greatest use of medication was found among older drivers, but it was the younger ones (under 50) who regulated its use most poorly in relation to the accident behaviour. It is concluded that for younger drivers alcohol abuse was dominant and considerably more important than misuse of medication. Among drivers over 50 chronic medical conditions including visual problems were dominant causes or contributing causes to the accidents.

The importance of driver's mental state is briefly discussed. Imagination and alertness are important factors, but they should be based on a realistic perception of the surroundings - in other words: on good vision.

Economic, social and health aspects are discussed. An extrapolation from the observed incidence to the entire country with adjustments for age and sex distribution, season, police registration, and participation rate, leads to a rough estimate that the number of drivers with illegally low vision involved in the accidents on a nationwide basis constitute about 730 per year (386-1180). The variation with age is pronounced, in that 1.6% of drivers under 50 years lie at or under the visual limit, compared to 9.8 % of the drivers 50 years or above.

It is cautiously estimated that 1638 accidents per year (1180-2214) might have a visual problem as a contributory factor, out of which a probable association might exist in 430 accidents (214-767), or 1 per day.

Evaluated in proportion to the officially reported incidence of accident-involved drivers, who were under the influence of alcohol, (i.e. blood-alcohol concentration ≥ 0.5 ‰) on the basis of police reported accidents, the fraction of drivers with significant visual problems is estimated to be about 1/5.

Under the justified assumption that the consequences of accidents conditional on visual problems in drivers do not differ from other corresponding accidents, a cautious estimate of the yearly costs to the society of this type of accident is given. The proportion of traffic accidents with human injury in which a car driver's visual problem may be a probable co-factor is estimated to 2.2% (1.3-3.9%).

The overall annual recordable costs of traffic accidents in Denmark is approx. 10 billion D. kr (1996). Thus, the magnitude of the recordable annual economic costs of accidents involving human injury, in which a visual problem in a driver has played a probable role, is estimated at around 220 (115-390) million Danish kroner(1996)

The health consequences of this type of traffic accidents are pointed out. In Denmark it is estimated that due to significant visual problems of drivers, 39 (out of about 700) are killed annually (95% confidence limits: 1-217), 156 (42-399) are severely injured, and 312 (134- 614) are injured less severely. The estimates are cautious and must be taken with reservations.

Advantages and disadvantages of prospective future testing of drivers' binocular vision according to the European Union regulatory, is evaluated and compared with the current mon-ocular test. Seen from an administrative point of view, the binocular test has advantages. However, from an ophthalmological point of view particularly with the aim of preventing disease, blindness, or traffic accidents, the binocular test cannot be recommended. The accumulation of drivers with unilateral visual impairment in the accident group supports the tightening of visual standards for the worse eye in drivers of heavy transport (Group II driver's license) or commercial passenger transport. (More stringent standards have been followed up by requiring truck drivers also, in contrast to former requirements, to take a vision test every fifth year from age 50). The same results make somewhat of a case against introducing a binocular vision test. On the other hand, a modified binocular test in the form of the well-known number plate test from England could be recommended as a screening method, e.g. to be used by police in suspicious cases at the place of the accident, analogous to the possible use of the balloon test to screen motorists for being under the influence of alcohol. Being able to read a clean Danish number plate in good illumination at a distance of 25.5 metres is indicative of satisfying a minimum requirement of a binocular acuity of 0.5 (6/12). It should be emphasized that the method is recommended only as an advisory screening method. Furthermore, the method is suitable for drivers to test themselves.

The significance for traffic accidents of chronic medical conditions other than visual problems is difficult to evaluate. It is also difficult to evaluate the extent to which some of the accident-implicated drivers, who had such medical conditions would have been eliminated by means of more frequent medical examinations using today's procedures. Used in a limited group with questionable traffic competency, a reaction time test can be recommended. In specific accidents in this study a probable association between the accident and an observed significantly prolonged reaction time was found. Detection of such a prolonged reaction time (slower than 2 standard deviations from the mean, corresponding to 2.5%) will give a decisive contribution to the final, total evaluation of the driver. The standardization problem must, however, be solved before any general application.

A more integrated evaluation of the motorist's perception and ability to respond in traffic can only be partly achieved with an investigation of visual acuity, visual field, reaction time, and modern car simulators. The design of the ideal simulator of the future is a great challenge, and for now presumably a pipe-dream. It should be the aim that such an instrument will test the driver's vision, perception, and visualization ability, as well as decision making powers and ability to act.

Perspectives for the future:

The advantages and disadvantages of a more intensive screening for motorists with visual problems is discussed. For the drivers, earlier and more frequent health examinations generally involve the possibility of detecting "clinically silent" general illness, for example high blood pressure and neurological diseases with visual field defects, and eye diseases for example glaucoma, in relevant age groups. Other eye diseases, too, could be detected in earlier stages, and would therefore be easier to treat adequately. Last, but not least, the accident preventive aspects are underlined.

To the disadvantages belong the risk of losing a driving license and the accompanying social problems for the individual, who will not always be expected to see the accident-prevention perspective. For the individual the economic cost of the vision/health test is dependent on finance. This is estimated in any case to be modest compared to expenses of maintaining a car and compared to the visual and health advantages.

For the unprotected road user there can be only advantages to a generally improved visual status in the population of older active car drivers.

For the public health service, on the one side, reduced expenses can be calculated for treatment and care of severely injured road users as well as presumably reduced expenses as a result of detecting certain serious diseases in time. On the other side, increased expenses for follow up and treatment of any detected illness must be added, just as certain social expenses must be included for the limited number of motorists, who must give up driving.

It is concluded that the accident and health policy advantages of implementing intensified vision and health screening of drivers in the relevant age group will outweigh the disadvantages. This viewpoint is regarded as particularly relevant in those countries where there is absolutely no required re-testing of drivers' vision and health. The present study indicates that the benefits in relation to the efforts will be extremely limited for the group of drivers under 50 years, while in the age group above it will be possible to identify a considerable number of drivers with significant, often correctable, visual and other health defects.

Among the approx. 635,000 licensed drivers in Denmark 55 years or older, it is estimated that about 18,500 (95% confidence limits: 2,860-49,000) have a visual acuity under the legal limit using their normal correction.. Identifying drivers with traffic relevant visual problems can happen not only with an increase in the frequency of visual and health screening, but also with a qualitative improvement of the examination procedure. The epidemiological research should follow the technical development, which perhaps in the coming years will offer new, accessible procedures more relevant to traffic.

Losing the right to drive has important social consequences for the individual. Thus, there should be the possibility of supplemental special examinations in cases where a person's competence in traffic is doubted. Beyond the advisory driving license tests of today there are for example tests of night vision and glare sensitivity, contrast sensitivity, dynamic acuity, reaction times, and, if necessary, testing in an advanced car simulator. Such test possibilities could be available for drivers in an appeal situation and could be centralized in one or a few places in individual countries. The fraction of drivers, who will appeal after exhausting the possibilities of treatment, is judged to be very limited.

The primary test procedure should fulfil the demands of being practical, quick, cheap, fair, easy to administer, and that the results be reproducible. It should ensure that as few motorists as possible drive with vision that is dangerous in traffic (high sensitivity) and it should not exclude many drivers who in reality do not represent a hazard in traffic because of their vision (high specificity). Based on a number of investigations, it seems motivated to supply the examinations with simple cognitive test procedures of the elderly drivers.

In selected relevant traffic and accident situations an advisory screening of the drivers' vision, e.g. with the help of a simple, cheap and easily available "number plate test" mentioned earlier, is recommended.

Most of all one must take a position about the need for a re-test of the drivers' vision and health. It is useless to discuss sophisticated methods for testing vision in healthy 18 year-olds, while the law fails to recognize the increasing visual problems in middle-aged and elderly drivers.

In the end, the discussion of whether or not to introduce or intensify re-testing of driver’s vision is a question of health politics.

The purpose of the present study is to provide an up-to-date epidemiological foundation as a basis for the discussion of future planning rather than to work out details of tomorrow's methods of visual screening.

In conclusion it should be emphasized that the part played by visual problems in the causal pattern behind all traffic accidents is limited, roughly estimated to total 2-3%, although heavily correlated with age. Even if motorists with impaired vision do not appear to compensate completely for this by changing their driving behaviour, it should not be forgotten that the overwhelming and most serious share of traffic accidents involving human injury are caused by young drivers with impeccable vision and lightning fast reactions, but often under the influence of alcohol!

Chapter VI.
Main conclusions.
(See p. 77).

8. Summary in Danish.

Kapitel 1. Introduktion

Der redegøres for demografi og lovgivning og gives en litteraturgennemgang af epidemiologisk aspekter som danner baggrund for arbejdet, hvis *hovedformål* er en vurdering af synsfunktionens betydning som trafik-ulykkesfaktor i Danmark.

Demografisk er ældrepopulationen over 65 år den relativt hurtigst voksende på den vestlige halvkugle. Det absolutte antal over 65-årige i de skandinaviske lande forventes at stige med 200-300% fra 1960 til 2025 og andelen af bilejere i denne aldersgruppe er stærkt stigende: I 1965 ejede ca. 7% af 65-årige svenskere en bil, i 1983 40%. I 1997 var den tilsvarende andel 45%. Disse tendenser indebærer en betydelig stigning i antallet af bilister over 65 år. Fra 1978 til år 2000 er anslået en fordobling.

Talrige undersøgelser viser, at der fra 50-års alderen og fremad indtræffer afgørende ændringer i befolkningens synsevne i form af ændret refraktion og egentlige øjensygdomme.

Lovgivningen vedrørende bilister er globalt set meget varieret og til dels baseret på traditioner. Med hensyn til synsgrænser er der i det væsentlige enighed, men omkring intervallerne for genundersøgelse af synet er der betydelige forskelle verden over, selv i de skandinaviske lande.

I *Danmark* blev loven ændret i 1966. Tidligere krævedes helbredsundersøgelser med synsprøve af privatbilisterne hvert 5. år. Under henvisning til forholdene i Sverige, Vesttyskland og Frankrig blev kravene lempede og sidenhen skulle privatbilister og lastvognschauffører således først til ny synsprøve ved 70-års alderen og herefter med alder/ gyldighedsperioderne: 70/4 år, 71/3 år, 72-79/2 år, ≥ 80/1 år. For chauffører med såkaldt "erhvervsmæssig personbefordring" har man fastholdt kravene om helbredsundersøgelse inkl. synsprøve hvert 5. år. Siden 1996 er reglerne for lastvognschauffører skærpet, idet synet i denne gruppe nu skal genundersøges hvert 5 år fra 50 års alderen.

Den publicerede litteratur om epidemiologiske aspekter på området er omfattende. Konklusionerne spænder vidt, lige fra det synspunkt, at den svagtseende bilist ved ændret trafikal adfærd kompenserer fuldt ud for sit synshandicap til synspunktet, at bilisternes synsproblemer udgør et lige så stort faremoment som misbrug af alkohol. En række arbejder kan kritiseres for væsentlige mangler: manglende kontrolgrupper, manglende hensyntagen til aldersfaktoren, manglende analyse af relationen mellem synsproblemerne og de enkelte trafikulykker. Alle studier har kun små - eller ingen - delgrupper af bilister, som opfylder kravene om 1) at være impliceret i en alvorlig trafikulykke og 2) at have et synsproblem samt 3) at blive involveret som proband i en epidemiologisk undersøgelse. Væsentligt er en ofte manglende redegørelse for frafald ("non-responders"). Sammenligning vanskeliggøres af store variationer i lovgivning og i den trafikale demografi fra land til land, samt fra tidsperiode til tidsperiode. Validiteten og repræsenterbarheden af hyppigt citerede undersøgelser må drages i tvivl, når disse er baserede på synsundersøgelse af frivillige forsøgspersoner blandt aspiranter til kørekortfornyelse, hvilket næppe afspejler realiteterne blandt bilisterne i den aktuelle trafik, herunder i forbindelse med trafikulykkerne.

Der er ikke fundet skandinaviske epidemiologiske studier om associationen mellem egentlige trafikulykker og synsproblemer. Et finsk arbejde fra 1973 om farlig trafikal adfærd har dog peget på en sådan sammenhæng.

Undersøgelsens *hovedspørgsmål* er søgt belyst gennem en deskriptiv analyse af synsproblemers forekomst hos bilister involverede i alvorlige trafikulykker (dvs. med behandlingskrævende personskade eller drab) samt ved en vurdering af forbindelsen mellem et eventuelt synsproblem og ulykkerne. Yderligere er det tilstræbt at præsentere skandinaviske epidemiologiske data som grundlag for eventuelle ændrede praktiske og lovgivningsmæssige foranstaltninger for opsporing og behandling af motorførere med betydende synsnedsættelse. Generelle blindheds- og helbredsprofylaktiske aspekter af en eventuel intensiveret syns- og helbredsscreening er yderligere søgt belyst. Det *overordnede formål* med undersøgelsen er, om muligt, at bidrage til en reduktion af alvorlige trafikulykker på et af de områder, hvor dette synes realistisk muligt.

Kapitel 2. Materiale

Undersøgelsen er baseret på en konsekutiv undersøgelse i to hovedfaser indenfor optageområdet for de to skadestuer i Århus, som var tæt sammenfaldende med Århus politikreds (284.000 indbyggere). I *fase I (det deskriptive studie)* var indgangskriterierne: aktive trafikanter (passagerer undtaget) ≥ 10 år, som var involveret i en trafikulykke med mindst 1 bilist impliceret og med behandlingskrævende personskade, behandlet på eller visiteret af en af byens to skadestuer. De fleste udlændinge og visse grupper af kriminelle måtte af praktiske grunde udgå. Undersøgelserne i fase I viste, at de synsmæssige hovedproblemer blandt bilisterne fandtes i aldersgruppen fra 50 år og opefter. Der var visse problemer med registreringen af og kontakten til de uskadte bilister i ikke-politiregistrerede ulykker. Undersøgelsens *fase II* blev derfor begrænset til bilister ≥ 50 år implicerede i politiregistrerede ulykker med uændrede basiskriterier. Aldersfordelingen af bilisterne over 50 år i fase I blev benyttet som grundlag for etableringen af en sammenlignelig *kontrolgruppe* af aktive bilister, tilfældigt udvalgt via kørekortregistret ved Århus Politi.

Sammenfattende indgik 405 bilister og 157 ubeskyttede trafikanter, involveret i 359 trafikulykker med personskade, i undersøgelsen. Kontrolgruppen omfattede 138 bilister i alderen ≥ 50 år. På basis af det deskriptive studie (fase I) kunne graden af politiregistrering af denne type ulykker fastsættes til 61%, idet politiregistreringen var størst i gruppen af de mest alvorlige ulykker.

Medianalderen for implicerede bilister i det deskriptive studium var 37 år og 25 % var ældre end 49 år. Medianalderen hos de ubeskyttede trafikanter var 23 år. Yngre bilister (under 25 år) var signifikant overrepræsenteret i ulykkesgruppen (4-9 x) i forhold til deres repræsentation i det daglige trafikbillede, hvilket er i overensstemmelse med internationale erfaringer. En lille, men signifikant overrepræsentation var også fundet blandt ulykkesbilister over 75 år.

Frafaldsprocenten (non-responders) var størst i gruppen af ulykkesinvolverede bilister under 50 år (25%), mens den var 22% blandt de ældre ulykkes-involverede bilister og kun 8% i kontrolgruppen af bilister. Blandt de ubeskyttede trafikanter var frafaldsprocenten 17%. I bilistgruppen tiltog frafaldsprocenten med bopælsafstanden. Alternativ information blev indhentet fortroligt, efter accept af den videnskabsetiske komite, via egen læge eller regionens øjenlæger, inklusive øjenafdelingerne i Århus og Randers. Der opnåedes information om visus og kendte øjensygdomme hos i alt 93%. Kun hos 2,3% opnåedes ingen supplerende information.

Det endelige materiale til *beskrivelse af synsparametre hos en population af ulykkesinvolverede bilister*, som alle er undersøgt af forfatteren, består af 309 bilister (187 < 50 år og 122 ≥ 50 år).

Et begrænset materiale bestående af 204 bilister (91 probander og 113 kontrolbilister) opfyldte kriterierne for at indgå i en logistisk regressionsanalyse (case/kontrol studiet) med korrektion for de 3 designvariabler: alder, køn og årlig bilkørsel. Yderligere blev der kontrolleret for mulige confounders, nemlig dagligt alkoholforbrug, procentvis bykørsel og erhvervskørsel samt endelig visuel reaktionstid.

Kapitel 3. Metoder

Her beskrives indsamlingen af ulykkesdata, opnåelse af kontakt med probander og kontrolgruppen samt undersøgelsen af trafikanterne.

Nært samarbejde med byens to skadestuer samt Århus Politigård blev effektiv sikret via en ansvarlig sekretær hvert sted, som efter fastlagte kriterier dagligt sørgede for at videregive informationer om alle trafikanter/ trafikulykker, som opfyldte indgangskriterierne.

Efter aftale gik ingen oplysninger tilbage til politiet eller andre myndigheder, idet tavshedspligten respekteredes. Dette skønnes at have været en meget væsentlig forudsætning for det relativt lave antal af "non-responders" samt pålideligheden af informationerne om trafikanternes syn respektive brug af synshjælpemidler på ulykkestidspunktet.

Primært fik trafikanterne 2 uger efter trafikulykken en skriftlig opfordring til at indgå i undersøgelsen. Fortrolighed, frivillighed og fortrydelsesret blev understreget jvf. Helsinki deklarationerne af 1975 og 1983. Sekundært kontaktedes trafikanterne pr. telefon og fik hermed lejlighed til uddybende spørgsmål inden endelig stillingtagen til frivillig deltagelse i undersøgelsen.

For en stor del (88%) af "non-responder" -gruppen kunne der via egen læge eller øjenlæge opnås værdifuld, relevant information om generel helbredsstatus, medicinforbrug m.m., selvom oplysninger om synsfunktionen ikke altid forelå.

Undersøgelse af trafikanterne omfattede 1) interview, 2) indsamling af oftalmologiske data og 3) indsamling af ulykkesdata via politirapporter. Interviewene omfattede generelle data, inklusive erhverv samt detaljerede kørselsoplysninger, almen helbredstilstand, herunder medicin- og alkoholindtagelse samt tidligere indlæggelser, og oplysninger om øjensygdomme, brug af synshjælpemidler samt tid og sted for sidste synskontrol. Endelig blev der spurgt om den subjektive oplevelse af den aktuelle ulykke.

Undersøgelsen blev oftest foretaget på øjenafdelingen, Århus Universitetshospital, om muligt 2-3 uger efter ulykken, i enkelte tilfælde i hjemmet eller på hospitalsafdeling. Der undersøgtes for statisk synsstyrke, såvel uden som med den aktuelle korrektion ved ulykken og med optimal korrektion, testet såvel monokulært som binokulært. Synsfeltet undersøgtes primært med konfrontations-test for hånd a.m. Donders og i udvalgte suspekte tilfælde (ca 14%) ved hjælp af computerperimetri. Alle fik foretaget undersøgelse af den rumlige dybdeopfattelse (såkaldt stereosyn), farvesyn (Ishihara test), kontrast-sensitivitet (Arden grating) samt visuel reaktionstid. Der blev hos alle undersøgte foretaget oftalmoskopi på udilateret pupil og efter behov suppleret med spaltelampeundersøgelse, applanationstonometri, ortoptisk test, undersøgelse af synsstyrke i mørke eller modlys samt computerperimetri. I enkelte tilfælde blev patienten (på frivillig basis) henvist til yderligere udredning med CT-scanning eller neurologisk undersøgelse.

Trafikanternes oplysninger om ulykkerne blev, med Justitsministeriets tilladelse, i 104 af 244 politiregistrerede ulykker suppleret med gennemgang af politirapporter, specielt med henblik på at belyse associationen mellem synsproblemer hos bilisterne og ulykkerne.

De indsamlede data blev bearbejdet ved hjælp af EDB, primært via en SPSS-baseret database, sekundært på PC ved hjælp af database- analyseprogrammet "Reflex". Den logistiske regressionsanalyse blev med professionel statistisk bistand udført ved hjælp af programmet "Epicure".

Kapitel 4. Resultater.

Her præsenteres analyseresultaterne af en række relevante trafikmedicinske og oftalmologiske problemstillinger fra forskellige indgangsvinkler.

4.1. I den *deskriptive undersøgelse* fandtes en udtalt *aldersvariation* af synsproblemerne: Blandt ulykkesinvolverede bilister under 50 år lå mindre end 2% under den "lovlige synsgrænse", defineret som den af Sundhedsstyrelsen fastsatte grænse for opfyldelse af de daværende synskrav til kørekort. Fra 50-69 år var den tilsvarende proportion 8% og fra 70-års alderen 25%. En lignende tendens fandtes ved undersøgelse for binokulær synsstyrke. Høj alder var også den hyppigst associerede fællesnævner for bilister med forlænget reaktionstid og reduceret kontrast-sensitivitet, erhvervede farvesyns-defekter, defekter i det centrale synsfelt og makuladegeneration (AMD), - alle synsparametre, som er delvist interrelaterede.

De *ydre ulykkesomstændigheder* omkring de 359 ulykker er analyseret med særligt henblik på det eksterne synsmiljø. 25% af ulykkerne indtraf under regn, tåge eller sne. Sigtbarheden var reduceret i 11%. 4 ud af 5 ulykkestilfælde indtraf i byområder, og 61% i en af flere typer vejkryds. 25% af ulykkestilfældene skete i mørke og 9% i tusmørke. Der påvistes association mellem ulykker i mørke og 1) nedsat sigt, regn og tåge, 2) ulykker på lige vej eller i kurver og 3) ulykker i landområder med ingen eller spredt bebyggelse. I halvdelen af de 120 ulykker, som foregik i mørke eller tusmørke, var den lokale belysning utilstrækkelig eller ikke etableret.

En analyse af sammenhængen mellem synsparametre og det eksterne synsmiljø viste for ingen af de undersøgte værdier association til ulykker i mørke eller tusmørke. Det samme gjaldt med hensyn til sigtbarhed, bortset fra, at bilister involveret i ulykker med reduceret sigtbarhed var signifikant mere myope (nærsynede), (gennemsnitligt 1 dioptri) end de øvrige. Der fandtes ingen umiddelbar forklaring herpå, specielt var disse bilister tilsyneladende ikke mere efterladende med brug af brillekorrektion. 5% af bilisterne havde ensidig synsreduktion (synsstyrke < 0.25). I vejkrydsulykker var proportionen heraf 8% mod 3% ved ulykker på lige vej eller i kurve (p=0.17). Blandt 17 krydsulykker hos bilister med ensidig synsnedsættelse skete kollisionen hos 65% fra venstre, hos 18% fra højre side og 18% forfra. 12 af 14 (86%) sidekollisioner skete i samme side som synsnedsættelsen (p <0.05).

Synsundersøgelser, analyseret i forhold til *bilisternes kørselsparametre,* antydede (trods manglende signifikans) at bilister i professionel transport havde bedre synspræstationer end privatbilister. Specielt var synet optimalt blandt erhvervschauffører med personbefordring, som ifølge dansk lov synsundersøges hvert 5. år.

27% af bilisterne med "ulovligt syn" på ulykkestidspunktet anvendte ikke afstandskorrektion ved bilkørsel, selvom de oftest benyttede den til TV. Den tilsvarende fraktion blandt bilister med lovlig synsstyrke ved ulykken var 19%. Ukorrigeret hypermetropi (langsynethed) og nedsat akkommodationsevne viste sig blandt de undersøgte bilister at udgøre et vigtigt problem i dagligdagens trafik. Den udbredte misforståelse, at hypermetrope, "langsynede", også i moden alder kun behøver læseglas, imødegås.

Af 17 ulykkesbilister med ulovligt syn, kunne 15 (88%, 95% sikkerhedsgrænser: 64-99%) bibringes lovligt syn alene gennem ny optisk korrektion. Tilsvarende opnåede 8 ud af 9 bilister (89%) med binokulær synsstyrke under 0.5 på ulykkestidspunktet lovligt syn i henhold til nutidige regler med ny brillekorrektion.

4.2. Gruppen af bilister ≥ 50 år analyseredes med multivariat logistisk regression, (*case/kontrol studiet).* Bilister involverede i ikke-politiregistrerede ulykker eller hos hvem oplysningerne var inkomplette blev udelukket fra analysen for at minimere heterogene inklusionskriterier. 204 bilister (91 cases og 113 kontrolbilister) opfyldte analysens indgangskriterier. Alder, køn og årlig kørsel blev inkluderet som "design variabler", hvorimod dagligt alkoholforbrug, procentandelen af bykørsel og erhvervskørsel samt visuel reaktionstid i analysen var inkluderet som "confounding faktorer".

Analysen viste, at traffikulykkesrisiko var associeret med synskvalitet. Kontrastfølsomhed (p=0.003) fulgt af ensidig synsnedsættelse (p= 0.02) og binokulær synsstyrke (p= 0.03) syntes at være de vigtigste synsvariabler. Reduceret stereosyn (p= 0.05) og tidsforløbet siden sidste synstest (p= 0.07) kunne ikke udelukkes som kritiske synsfaktorer. Der fandtes ingen association vedrørende centrale og paracentrale synsfeltsdefekter (p=0.14), perifere synsfeltsdefekter testet a.m. Donders (p= 0.43), farvesynsdefekter (p= 0.89) eller refraktion (p = 0.89).

Flere af de beskrevne synsvariabler viste sig at være indbyrdes afhængige. Efter kontrol for designvariabler og confoundere bekræftede kombinationsanalyser, at der overordnet er association mellem synskvalitet og ulykkesrisiko.

Hvis *ikke-politiregistrerede* ulykker inkluderes i analysen, fandtes følgende synsparametre sandsynligt associeret med øget ulykkesrisiko: ensidig synsnedsættelse (p=0.008), binokulær synsstyrke (p= 0.013), kontrastfølsomhed (p=0.015), og stereosyn (p= 0.017). Ensidigt testet synsstyrke (p=0.04) og tidsforløbet siden sidste synstest (p=0.04) viste sig at være svagere, omend signifikante indikatorer for ulykkesrisiko.

4.3. I Danmark er *ændringer af kørekortcirkulæret m.h.t. synstest* blevet indført 1. juli 1996 i overensstemmelse med et EU-regulativforslag af 1981. Væsentlige ændringer er en skærpelse af synsstyrken hos chauffører med tung transport (vægt ≥ 3500 kg) eller med professionel persontransport, idet kravet til korrigeret synsstyrke på dårligste øje skærpes til 0,5. Vedrørende privatbilister er der indført binokulær synstest med minimumsgrænse = 0.5 til erstatning for den tidligere monokulære test.

Både den monokulære og den binokulære test er søgt appliceret på nærværende materiale, idet begge metoder er testet hos 435 bilister. Blandt 22 bilister, som ikke opfyldte de tidligere danske synskrav for privatbilister, levede kun 12 (54%) ikke op til de nuværende EU krav. Der er således i denne gruppe af bilister tale om en marginal lempelse af synskravene i forbindelse med den nye EU-lovgivning.

4.4. Med det sigte at kunne vurdere de *helbredsmæssige konsekvenser* af ulykkerne med synsproblemer hos bilisterne, er der udarbejdet en simpel "score" for alvorlighedsgraden i den enkelte ulykke. Denne er baseret på primære oplysninger om evt. behandling, visitation til indlæggelse (uden eller med beskadigelse af centralnervesystemet) og dødsfald i den enkelte ulykke, og er således mere en kvalitativ end en kvantitativ evaluering. Det konkluderes, at de helbredsmæssige konsekvenser af ulykkestilfælde med synsproblemer hos bilisterne var sammenlignelige med de øvrige ulykker (p> 0.7). Dette indebærer, at også meget alvorlige ulykker med trafikdrab indtræffer som sandsynlig følge af synsproblemer hos bilisterne. Fundet har betydning for de kalkulerede estimater over synsproblemernes trafikmedicinske betydning for samtlige trafikulykker i Danmark.

Anvendelse af *sikkerhedssele* er kort belyst. Der fandtes ingen association mellem manglende anvendelse af sikkerhedssele og manglende anvendelse af relevant synskorrektion (p = 1.0). De ældste ulykkesinvolverede bilister anvendte sikkerhedsselen signifikant hyppigere end de yngre (p < 0.02). Kun 58% af 18 - 29-årige bilister benyttede sikkerhedssele i forbindelse med ulykkestilfældet. I gruppen af bilister over 49 år, benyttede til sammenligning 71% sikkerhedssele på ulykkestidspunktet.

Kapitel 5. Diskussion.

På baggrund af de fra litteraturen kendte undersøgelsesresultater diskuteres materiale, design og resultater af nærværende undersøgelse.

Behovet for tilbagevendende regionale epidemiologiske undersøgelser understreges, først og fremmest på grund af problemets alvor, men også på baggrund af de forskelligartede konklusioner af tidligere studier, den demografiske udvikling hen imod flere ældre bilister i trafikken og variationen i trafikkultur og lovgivning fra land til land. Synstestmetoderne udvikles teknisk, og mulighederne for afhjælpning af synsproblemer bliver stedse flere og bedre.

Materialet og designet af nærværende undersøgelse karakteriseres som et i tid og sted veldefineret, konsekutivt materiale af trafikanter involverede i alvorlige trafikuheld med personskade og med mindst 1 involveret bilist. I tilgift er medtaget en tilfældigt udvalgt kontrolgruppe af aktive bilister. Undersøgelsen er den første af sin art i Skandinavien. De etiske principper for undersøgelsen (frivillighed/ fortrolighed) anses for at have været afgørende for en høj deltagerfrekvens (76%) og for validiteten af de indsamlede data.

Undersøgelsen består af et deskriptivt og et analytisk studie. *Det deskriptive studie* muliggør en vurdering af den relative forekomst af synsproblemer i en population af ulykkesinvolverede trafikanter, i særdeleshed bilister. Desuden giver det mulighed for en forsigtig generalisering på årlig, national basis. *Det analytiske case/-kontrol studie,* hvor en probandgruppe blev sammenlignet med en kontrolgruppe, giver mulighed for et estimat af den relative risiko hos bilister med forskellige typer kendte synsproblemer. De beregnede "odds ratio" ligger i et sådant "case/base" studie tæt på den relative risiko.

Metodologiske problemer er videst muligt søgt imødegået ved en såkaldt logistisk regressionsanalyse på et begrænset materiale af bilister med kontrol for designvariabler og confoundere.

På baggrund af litteraturen og de fundne resultater er *betydningen af de enkelte synsparametre* vurderet: Selvom dynamisk synsstyrke har vist sig at være bedre associeret med ulykkesrisiko end *statisk synsstyrke* vil sidstnævnte af praktiske grunde i en årrække stadig være den dominerende synstest i de fleste lande. En god statisk synsstyrke bedømmes at være en nødvendig, omend ikke tilstrækkelig betingelse for at bilisten sikkert kan klare en uforudset trafiksituation under vanskelig belysning eller nedsat sigtbarhed. Herunder har den løbende tolkning af små detaljer i trafikbilledet, f. eks. vejoverfladens beskaffenhed, mørkklædte trafikanter, børns og andre ubeskyttede trafikanters attituder og øjenkontakten med medtrafikanter betydning. For sådanne små detaljer gælder, at det teoretiske, kritiske tidsinterval, som er til rådighed for en adækvat reaktion, nedsættes direkte proportionalt med den statiske synsstyrke. *Synsfeltsdefekter* hos bilisterne er i flere enkelttilfælde fundet associerede med alvorlige trafikulykker. De var imidlertid i det analytiske studie ikke kvantitativt overrepræsenterede hos de ulykkesinvolverede bilister. *Ensidig synsnedsættelse* synes at være et begrænset, men signifikant problem hos ulykkesbilisterne med en 4-5 x øget ulykkesrisiko (p= 0.02). I vejkrydsulykker var disse bilister implicerede i signifikant flere kollisioner fra samme (oftest venstre) side som synsnedsættelsen (86%) end fra den modsatte side (14%).

Medfødt farveblindhed er ikke fundet signifikant overrepræsenteret i ulykkesgruppen eller associeret til enkelte ulykker. Erhvervede *farvesynsdefekter* var indbyrdes relaterede med *centrale synsfeltdefekter, aldersrelateret makuladegeneration (AMD) og nedsat stereosyn,* synsparametre, som alle fandtes overrepræsenterede (stereosyn signifikant) i ulykkesgruppen. Nedsat kontrastsyn var den synsparameter, som mest konstant og uafhængigt var associeret med øget ulykkesrisiko. Trafikanternes mørkesyn er ikke systematisk vurderet ved hjælp af specielle mørkesynstest. Bilister, involverede i *mørke eller tusmørkeulykker*, havde, vurderet med de undersøgte synsparametre, ingen relativ øget hyppighed af synsfejl. Bilister med subjektive mørkesynsproblemer bør måske i fremtiden underkastes en nøjere analyse med mørkesynstest og test for blænding. Brugbart standardiseret udstyr synes at være under udvikling. *Blænding* indebærer - også i nærværende undersøgelse - et væsentligt synsproblem hos bilister med begyndende katarakt. Flere ulykkestilfælde syntes således at være delvist betingede heraf. Der kan her peges på de gode behandlings-muligheder, som moderne øjenkirurgi med indoperering af prækalkulerede intraokulære linser indebærer. Netop hos aktive bilister anbefales indikationen for kataraktoperation på denne baggrund revurderet.

Behovet for en genundersøgelse af synet belyses dels på baggrund af diskussionen i en række lande, dels på baggrund af synsproblemernes aldersassociation. Hos bilister $\geq$ 50 år fandtes for hvert 5 års længere tidsforløb siden sidste synstest en faktor 1,4-2, signifikant øget ulykkesrisiko ved den logistiske regressionsanalyse.

Kasuistiske rapporter om trafikulykkerne: For at belyse trafikulykkernes karakter, omfang og opståelsesmåde og forfatterens estimering af evt. association mellem de enkelte ulykker og synsproblemer, er der som illustrativ, "blød" dokumentation gengivet en række kasuistikker i appendix C.2. Ved at sammenholde de fundne synsproblemer hos den enkelte trafikant med de tilgængelige ulykkesdata, inklusive oplysninger fra udvalgte politirapporter, har man i hvert ulykkestilfælde kunnet give et forsigtigt estimat af en *synsproblem/ ulykkesassociation* som sandsynlig/ mulig/ usandsynlig, men man kan ifølge sagens natur kun yderst sjældent opnå 100% evidens for en entydig sammenhæng. Undersøgelsen bekræfter, at trafikulykker oftest er *multifaktorielle.*

På denne baggrund blev de rapporterede ulykker grupperet i: I: *sandsynlig* association mellem synsproblemer/ulykke; II: *mulig* association (kun bilister); III: ulykker, hvor en association trods synsproblemer hos bilisten er vurderet som *usandsynlig.* Derudover er omtalt: IV: ulykker, hvor medicinske tilstande, medicin- eller alkoholmisbrug hos bilisten vurderedes som væsentlige; V: bilister i kontrolgruppen med bemærkelsesværdige synsproblemer; samt VI og VII: ulykker af anden speciel interesse.

En række *helbredsparametre* er vurderet i forhold til den enkelte ulykke, baseret på de ved undersøgelsen indsamlede oplysninger samt helhedsindtrykket af trafikanterne. En detaljeret klinisk undersøgelse af bilisterne er ikke gennemført.

I 3 ud af de 359 ulykkestilfælde (0.8 %) indtraf en ulykke som led i en *akut medicinsk episode* (2 transitorisk iskæmiske attakker, 1 "drop" attak). Derudover havde en bilist med svær synsnedsættelse, hypoglykæmi efter ulykken. *Kroniske medicinske tilstande* af mulig betydning for ulykkestilfældet sås overvejende hos bilister $\geq$ 50, nemlig hos 11. Hvis gruppen af bilister med sandsynlig ulykke/synsproblem association medregnes til kategorien af bilister med en akut eller kronisk medicinsk tilstand, skønnedes i alt 16% (95% sikkerhedsgrænser 10%-23%) - eller 1 ud af 6 ulykker blandt bilister $\geq$ 50 år at have en medicinsk tilstand som mulig medvirkende, betydende årsag til ulykken.

Alkoholpåvirkning fandtes helt dominerende blandt de yngste bilister (under 50 år). Dette på trods af, at der ikke fandtes forskel på de ældre og de yngre bilister m.h.t. det angivne daglige alkoholforbrug. Der fandtes større *brug af medicin* blandt de ældre bilister, men det var de yngste (under 50 år), som i relation til ulykkesadfærd dårligst administrerede brugen af denne. Det konkluderes, at hos yngre bilister var alkoholmisbruget dominerende og væsentligt vigtigere end misbrug af medicin. Blandt bilister over 50 år var kroniske medicinske tilstande, inklusive synsproblemer, dominerende som årsag eller medvirkende årsag til ulykkerne.

Betydningen af *bilisternes mentale tilstand* diskuteres kort. Forestillingsevne og opmærksomhed er vigtige faktorer, men de må baseres på realistisk perception af omgivelserne - med andre ord på et godt syn.

Økonomiske, sociale og sundhedsmæssige aspekter omtales. Ud fra en ekstrapolering fra de fundne incidenser til hele landet, justeret for alder, køn, årstid, politiregistrering og deltagelsesfrekvens, kan det groft estimeres at andelen af bilister med ulovligt syn involveret i ulykkerne udgør 730 per år (386-1180). Aldersvariationen er udtalt, idet 1.6% af bilisterne under 50 år ligger på eller under synsgrænsen mod 9.8% i gruppen af bilister over eller lig 50 år.

Det estimeres forsigtigt, at i forbindelse med 1638 trafikulykker pr. år (1180-2214) kan bilisten have et synsproblem som medvirkende faktor. Heraf skønnes en årsagsmæssig sammenhæng at være sandsynlig ved ca. 430 ulykker (214-767) - eller godt 1 om dagen.

Vurderet i forhold til officielt angivne incidenser af alkoholpåvirkede ulykkesbilister på basis af politirapporterede ulykker (d.v.s. blod-alkohol koncentration $\geq$ 0,5‰), er fraktionen af bilister med signifikante synsproblemer estimeret til at udgøre ca. 1/5.

Under den sandsynliggjorte forudsætning, at konsekvenserne af ulykkestilfældene betingede af synsproblemer hos bilisterne ikke adskiller sig fra de øvrige tilsvarende ulykker, er der givet et forsigtigt estimat over de årlige samfundsmæssige omkostninger af denne type ulykker. Andelen af person-skadeulykker, hvor en bilists synsproblem kan have spillet en medvirkende rolle estimeres til 2.2 % (1,3-3,9%).

De samlede årlige registrerbare udgifter i forbindelse med trafikulykker i Danmark anslås til ca. 10 milliarder D. kr. (1996). Størrelsesordenen af de samlede årlige *registrerbare økonomiske omkostninger* af trafikulykker, hvor et synsproblem hos en bilist synes at have spillet en sandsynlig rolle, kan således estimeres til ca. 220 millioner danske (1996) kroner (115-390 mill.).

Også de *helbredsmæssige* følger af denne type trafikulykker påpeges. Det er estimeret, at 39 (ud af ca. 700) årligt bliver dræbt i Danmark (95% sikkerhedsgrænser 1-217), 156 (42-399) kommer alvorligt til skade, og at 312 (134 - 614) kommer lettere til skade, p.g.a. af væsentlige synsproblemer hos bilisterne. Estimaterne er forsigtige og må tages med forbehold.

Fordele og ulemper ved undersøgelse af bilisternes syn med binokulær test i henhold til EU-regulativet vurderes og sammenlignes med den tidligere anvendte monokulære test. Set fra et administrativt synspunkt indebærer den binokulære test fordele. Fra et oftalmologisk, sygdoms-/ blindhedsprofylaktisk og delvist fra et ulykkesprofylaktisk synspunkt kan den binokulære test imidlertid ikke umiddelbart anbefales. Ophobningen af bilister med ensidig synsreduktion i ulykkesmaterialet understøtter skærpelsen af synskravene til det dårligste øje hos chauffører med tung transport (gruppe II kørekort) eller med erhvervsmæssig persontransport. (En sådan skærpelse er, som konsekvens heraf, fulgt op af, at også lastvogns-chauffører i modsætning til tidligere synsundersøges hvert 5. år (fra 50 års alderen). De samme resultater taler i nogen grad imod at indføre binokulær synstest. Derimod anbefales en modificeret binokulær test som screeningsmetode, f.eks. anvendt af politiet i suspekte tilfælde på ulykkesstedet i form af den fra England kendte *"nummerplade-test",* analogt med muligheden for at screene bilisternes grad af alkoholpåvirkning med "ballon- test metoden". Det er beregnet, at man ved at læse en dansk, ren nummerplade i god belysning i 25,5 meters afstand tilfreds-stiller et basalt krav om en binokulær synstyrke på 0,5 (6/12). Det skal understreges, at metoden kun anbefales som en vejledende screeningsmetode. Metoden egner sig endvidere som en selvtest af bilisternes syn.

Betydningen for trafikulykkerne af *kroniske medicinske tilstande* udover synsproblemer er vanskelig at vurdere. Det er også vanskeligt at vurdere, hvorvidt nogle af de ulykkesimplicerede bilister med sådanne medicinske tilstande ved nutidens procedurer ville have været sorteret fra ved en eventuel hyppigere helbredskontrol. Anvendt på en begrænset gruppe med tvivlsom trafikhabilitet kan anbefales en test for *reaktionstid.* I enkelte ulykker i nærværende studium fandtes en sandsynlig association mellem ulykken og fundet af en signifikant forlænget reaktionstid. Påvisningen af en sådan forlænget reaktionstid (langsommere end 2 standarddeviationer fra middelværdien, svarende til 2.5%) vil kunne give et afgørende bidrag til den endelige, samlede vurdering af bilisten. Standardiseringsproblemer må dog løses forud for en sådan generel applikation.

En mere integreret vurdering af bilisternes perception og handleevne i trafikbilledet kan kun delvis belyses med undersøgelse af synsstyrke, synsfelt, reaktionstidsmåling og nutidens bilsimulatorer. Designet af fremtidens ideelle simulator er en stor udfordring og indtil videre formentlig en utopi. Det bør tilstræbes, at en sådan tester bilistens syn, perception, forestillingsevne såvel som beslutnings- og handleevne.

Fremtidsperspektiver.
Fordele og ulemper ved en mere intensiveret opsporing af bilister med synsproblemer diskuteres. For *bilisterne* indebærer tidligere og hyppigere helbredsundersøgelser generelt en mulighed for opdagelse af "klinisk tavse" almensygdomme, som f.eks. blodtrykssygdom og neurologiske sygdomme med synsfeltsdefekter samt øjensygdomme, eksempelvis grøn stær, i relevante aldersgrupper. Også andre øjensygdomme ville kunne opdages på et tidligere stadium, og dermed give bedre betingelser for sufficient behandling. Sidst, men ikke mindst, understreges de ulykkespræventive aspekter.

Til ulemperne hører risikoen for tab af kørekort og dermed sammenhængende sociale problemer for den enkelte, som ikke altid vil forventes at kunne indse det ulykkesforebyggende perspektiv. De økonomiske udgifter til selve syns/helbredsattesten er for den enkelte afhængig af finansieringen. Den skønnes under alle omstændigheder at være beskeden, sammenlignet med udgifter til vedligeholdelse af bil og sammenholdt med de syns- og sundhedsmæssige fordele.

For de *ubeskyttede trafikanter* kan kun opregnes fordele ved en generel forbedret synsstatus hos populationen af ældre, aktive bilister.

For det *offentlige sundhedsvæsen* kan på den ene side påregnes nedsatte udgifter til behandling og pleje af alvorligt tilskadekomne trafikanter samt formentlig reducerede udgifter som følge af at visse alvorlige sygdomme opdages i tide. På den anden side må der også påregnes øgede udgifter til opfølgning og behandling af eventuelle påviste sygdomme, ligesom der må påregnes visse sociale udgifter til den begrænsede del af bilisterne, som må ophøre med at køre selv.

Det *konkluderes*, at de ulykkesmæssige og sundhedspolitiske fordele ved gennemførelse af intensiveret syns- og helbredsscreening af bilisterne i en relevant aldersgruppe vil opveje ulemperne. Dette synspunkt anses for særligt vedkommende i de lande, hvor man helt afstår fra genundersøgelse af syn og helbred hos bilisterne. Nærværende undersøgelse tyder på, at udbyttet i forhold til indsatsen vil være yderst begrænset for gruppen af bilister under 50 år, mens det i aldersgruppen herover vil være muligt at identificere et betydeligt antal bilister med væsentlige, ofte korrigerbare syns- og andre helbredsdefekter.

Blandt ca. 635.000 kørekortindehavere i Danmark $\geq$ 55 år skønnes ca. 18.500 (95% sikkerhedsgrænser: 2.860-49.000) at have en synsstyrrke under "lovlig" grænse med sædvanlig brugt korrektion. En identificering af bilister med trafikrelevante synsproblemer kan ikke alene ske ved en forøgelse af syns- og helbredsscreeningernes hyppighed, men også ved en kvalitativ forbedring af undersøgelsesproceduren. Den epidemiologiske forskning bør følge den teknologiske udvikling, som i de kommende år måske vil frembyde nye, tilgængelige og mere trafikrelevante procedurer.

På grund af de store sociale konsekvenser en evt. fratagelse af kørekortet kan have for den enkelte bilist, bør der i enkelte tilfælde være mulighed for at supplere med særlige undersøgelser, hvor vedkommendes trafikhabilitet drages i tvivl. Udover de i dag kendte vejledende køreprøver kan eksempelvis nævnes afprøvning af blændings- og mørkesyn, kontrastsyn, dynamisk synsstyrke, reaktionsevne og, om nødvendigt, afprøvning i avancerede bilsimulatorer. Sådanne testmuligheder kunne være til rådighed for bilister i en ankesituation og ville kunne centraliseres til et eller få steder i det enkelte land. Fraktionen af bilister, som efter udtømmelse af behandlingsmulighederne vil anke, bedømmes som ret begrænset.

Den primære testprocedure bør opfylde kravet om at være praktisk, hurtig, billig, reproducerbar, retfærdig og let at administrere. Den bør sikre, at så få bilister som muligt kører med et trafikfarligt syn (høj sensitivitet) samt at ikke for mange bilister, som i virkeligheden ikke er visuelt trafikfarlige, frasorteres (høj specificitet). På baggrund af flere overbevisende studier, synes det velmotiveret at supplere undersøgelserne med en simpel test af bilisternes cognitive færdigheder.

I udvalgte, relevante trafik- og ulykkessituationer anbefales en vejledende screening af bilisternes syn, f.eks. ved hjælp af en enkel, billig og let tilgængelig "nummerplade-test", som tidligere er omtalt.

Overordnet må man tage stilling til behovet for en genundersøgelse af bilisternes syn og helbred. Det er nytteløst at diskutere sofistikerede metoder til undersøgelse af synet hos raske 18-årige, mens man lovgivningsmæssigt ser gennem fingre med de stigende synsproblemer hos midaldrende og ældre bilister.

I den sidste ende er diskussionen om, hvorvidt man skal introducere eller intensivere genundersøgelse af bilisters synsfunktion eller ej et spørgsmål om sundhedspolitik.

Formålet med nærværende undersøgelse er mere at give et opdateret epidemiologisk fundament, som grundlag for diskussionen af den fremtidige planlægning, end at udarbejde detaljer for morgendagens metoder til synsscreening.

Det skal afslutningsvis understreges, at synsproblemernes andel i årsagsmønstret bag de samlede trafikulykker er af begrænset størrelse, skønsvis samlet 2-3%, omend stærkt korreleret til alder. Selv om bilisterne med et nedsat syn ikke til fulde synes at kompensere for dette med ændret trafikal adfærd, skal det ikke glemmes, at den altovervejende og alvorligste del af trafikulykkerne med personskade forårsages af unge, ofte alkoholpåvirkede bilister med et fejlfrit syn og en lynhurtig reaktionsevne!

Kapitel 6. Konklusion.

6.1. Den *synsmæssige situation* blandt ulykkesinvolverede bilister i Danmark karakteriseres ved en med alderen tiltagende hyppighed af synsproblemer. Blandt bilister under 50 år havde 1,6 % syn under den lovlige grænse, i reglen på grund af utilstrækkelig brillekorrektion. Hos 50-69 årige var denne andel 8 % og fra 70 års alderen 25%. 11% af bilisterne $\geq$ 50 havde ikke været synstestet de sidste 10 år.

Hos 12 ud af 14 bilister med ensidig synsnedsættelse, som var impliceret i vejkrydsuheld, skete kollisionen fra samme side som synsnedsættelsen ($p< 0.02$), heraf 11 (79%) fra venstre side ($p<0.06$).

Forudsat at fundene i nærværende studie er repræsentative for Danmark, kan antallet af bilister med ulovligt syn (i henhold til tidligere lovgivning) impliceret i personskadeuheld estimeres til ca. 730 om året (95% sikkerhedsgrænser: 385-1180). Heraf skønnes 260 (1.6% af bilisterne) at være under 50 år og 470 (9.8% af bilisterne) at være over denne alder. Tilsvarende skønnes 400 bilister, (171- 722) involverede i sådanne ulykker efter nutidige kriterier (binokulær synsstyrke < 0,5) at have ulovligt syn, hvoraf ca. 300 vil være $\geq$ 50 år.

6.2. Multivariat logistisk regressionsanalyse med syns-/ulykkes risikoestimater blev udført på et be-grænset materiale af 204 bilister $\geq$ 50 (case/ control studiet) med korrektion for alder, køn, årlig kørsel, alkoholindtagelse, procentvis by- og landkørsel samt visuel reaktionstid. Sammenfattende fandtes trafikulykkesrisikoen overordnet at være associeret med bilisternes synskvalitet. Kontrastsensitivitet (p= 0.003) og i mindre grad ensidig synsnedsættelse (p= 0.02) og binokulær synsstyrke (p=0.04) syntes at være betydende variabler. Den binokulære synsstyrke identificeredes som en stærkere risikoindikator (p= 0.03) sammenlignet med den tidligere anvendte monokulære synsstyrkeudmåling (p= 0.08). Det kan ikke udelukkes, at stereosyn (p=0.05) og tidsforløbet siden sidste synstest (p= 0.07) er kritiske parametre. Der fandtes ikke signifikant association mellem ulykkesrisiko og centrale og paracentrale synsfeltsdefekter (p=0.14), synsfeltsdefekter testet med Donders' konfrontationstest (p= 0.43), farveblindhed (0.89), eller refraktion (p= 0.89).

- Flere af de testede variabler fandtes indbyrdes afhængige.

Konklusionerne af multivariatanalyserne er forsøgt illustreret via en individuel subjektiv vurdering af hver enkel af de 359 trafikulykker.

Ved et forsigtigt skøn estimeres ingen af ulykkerne med < 50 årige bilister at være sandsynligt associerede med et synsproblem, men muligt associeret blandt 5%. Blandt de 50-69 årige estimeredes en sandsynlig association hos 5% af bilisterne og en mulig association hos 25%. Fra 70- års alderen skønnes et synsproblem at være en sandsynlig medvirkende faktor hos 37% og en mulig faktor hos 25%.
Ved de fleste af ulykkerne var synet hos bilisterne en af flere medvirkende faktorer, hvilket bekræfter, at en trafikulykke er en multifaktoriel hændelse.

6.3. Siden juli 1996 er undersøgelse af privatbilisters synsstyrke blevet forenklet med indførelse af binokulær teknik (begge øjne samtidigt). I henhold til EU- reglerne er en synsstyrke på 0.5 nu grænsen for lovligt syn i denne bilistgruppe.

Blandt 435 undersøgte bilister havde 4.6% ulovligt syn i henhold til de gamle regler mod 2.7% efter nugældende regler. Efter optimering af synsstyrken med ny brillekorrektion reduceredes de tilsvarende proportioner til henholdsvis 0.7% og 0.5%.

Den binokulære synsstyrkeudmåling er enklere at administrere, og synes at være en bedre risikoindikator, men den identificerer ikke bilister med ensidige, hidtil ukendte øjenlidelser.

6.4. Ny optisk korrektion var tilstrækkelig til at give 15 ud af i alt 17 bilister (88%, 95% sikkerhedsgrænser 64-99%), som på ulykkestidspunktet havde en synsstyrke på eller under den lovlige grænse, et fuldt legalt syn. Moderne øjenkirurgi vil sandsynligvis have kunnet øge denne andel.

6.5. De helbredsmæssige konsekvenser af ulykkerne, som delvist skyldes synsproblemer hos bilisterne, adskilte sig ikke signifikant fra de øvrige ulykker (p=0.7).

6.6. Akutte og kroniske medicinske tilstande, inkl. synsproblemer, bedømtes som mulig medvirkende ulykkesårsag hos 16% af bilisterne $\geq$ 50 år (95% sikkerhedsgrænser 10-23%).

Proportionen af ulykker, hvor en akut medicinsk sygdom var medvirkende ulykkesfaktor estimeredes til 3/359 = 0.8%, (95% sikkerhedsgrænser = 0.2%-2.4%).

6.7. I den sidste ende er afgørelsen af, hvorvidt man skal indføre eller intensivere genundersøgelse af bilisternes synsfunktion et *spørgsmål om sundhedspolitik.* Nærværende resultater og analyser kan bidrage til diskussionen pro et contra. I relevante aldersgrupper vil et eventuelt screeningsprogram som sidegevinst kunne indebære værdifuld helbredsprofylakse, herunder forebyggelse af alvorlige sygdomme og blindhed. Endvidere anbefales en simpel test af bilisternes cognitive færdigheder. På baggrund af de ob-serverede fund kan det ikke anbefales at udelade obligatorisk genundersøgelse af bilisterne som det er tilfældet i blandt andet Sverige, Tyskland og Frankrig.

Da synsfunktionen hidtil kun meget sjældent er blevet undersøgt i forbindelse med trafikuheld, anbefales det i relevante aldersgrupper og ved suspekte ulykker, at udføre en simpel synsscreening i form af "nummerpladetesten". Herved skal en ren dansk nummerplade i god belysning kunne læses i 26 meters afstand. Juridisk kunne en sådan screening på ulykkesstedet sammenlignes med en "ballontest" for alkoholindtagelse.

6.8. Fundet af en signifikant association mellem bilisternes synskvalitet og trafikulykkesrisiko indebærer, at bilisterne ikke kompenserer fuldt ud for et utilstrækkeligt syn.

- På basis heraf samt på udenlandske studier konkluderes det, at i lande, hvor bilisters syn overhovedet ikke genundersøges, er lovgivningen ikke i overensstemmelse med trafikoftalmologiske erfaringer. Den anses heller ikke for at være i trit med nuværende demografiske og adfærdsmæssige udviklinger med tilstedeværelsen af flere og flere ældre bilister i en tiltagende tæt og kompleks trafik.

6.9. Da en stigende population af bilister med synsproblemer således må forventes at ville ansøge om kørekortfornyelse er det relevant, at introducere mere relevante og pålidelige metoder til at evaluerer bilisternes synsevne. Sådanne metoder kunne i udvalgte tilfælde blandt andet indbefatte "useful field of view" (UFOV) - metoden og afprøvning af bilisterne i interaktive bilsimulatorer.

Navnlig ved afprøvning af bilister med synspræstationer i "gråzone området", hvor trafikhabiliteten må betvivles, bør sådanne metoder undersøges, videreudvikles og være til rådighed.

- - -

Regionale epidemiologiske studier er af betydning fra tid til anden. Det overordnede formål må være at evaluere nuværende - og etablere fremtidige, praktiske procedurer for undersøgelse af bilisternes trafikhabilitet i den hensigt at reducere antallet af meningsløse trafikulykker, som *kan* forebygges, til et minimum.

9. Appendix A. Letter to the road users.

Århus Kommunehospital **8000 Århus d.**
Øjenafdelingen

Til

Vi tilbyder Dem hermed en grundig, gratis øjenundersøgelse. Det har vist sig, at enkelte trafikuheld skyldes synssvækkelse, undertiden uden at de implicerede parter har været vidende herom.
- Jeg er - med Justitsministeriets godkendelse - fortroligt blevet gjort bekendt med, at De i denne forbindelse vil deltage i en øjenundersøgelse som led i et forskningsprojekt. Projektet skal belyse sammenhængen mellem trafikulykker og evt. kendte eller skjulte øjensygdomme.

Det vil være af stor samfundsmæssig betydning, hvis De i denne forbindelse vil deltage i en øjenundersøgelse som led i et forskningsprojekt. Projektet skal belyse sammenhængen mellem trafikulykker og evt. kendte eller skjulte øjensygdomme.

Det skal understreges, at undersøgelsen vil foregå i fortrolighed; - resultaterne vil være underkastet min lægelige tavshedspligt! Hverken politi eller forsikringsselskaber vil modtage oplysninger om undersøgelsesresultaterne vedrørende Deres synsevne.

De vil få tilbudt en fuldstændig øjenundersøgelse, inkl. rådgivning og evt. brillerecept. Selvom De for nylig har fået synet undersøgt og ikke mener at lide af synsnedsættelse, er det af største betydning, at De deltager.

Undersøgelsen tager ca. 3/4 time, er fuldstændig smertefri og omfatter: synsprøve med evt. brillebestemmelse, undersøgelse af det perifere og centrale synsfelt, stereosynet (øjnenes evne til at arbejde sammen), farvesynet og kontrastsynet. Desuden vil deres nethinde blive efterset.

Jeg vil bede Dem om, inden for de kommende uger uforbindende at kontakte mig telefonisk på telefon ** ****** lokal **** (i dagtiden) eller om aftenen på telefon ** ****** (privat). Inden De endelig tager stilling til, om De vil deltage, har De således mulighed for at få besvaret eventuelle tvivlsspørgsmål. Såfremt De herefter ønsker at deltage i undersøgelsen, kan vi aftale en tid, som passer Dem - evt. udenfor arbejdstiden.

De bedes venligst medbringe dette brev samt Deres eventuelle øjenmedicin og briller ved undersøgelsen. Eventuelle rejseudgifter vil kunne dækkes.

Deres deltagelse er naturligvis frivillig, ligesom De kan fortryde et evt. givet tilsagn om undersøgelse.

Idet jeg håber De vil deltage

med venlig hilsen

Knud Erik Alsbirk
1. Reservelæge.

- - - - - - - - - - - - - - - - - - - -

9. Appendix B

Department of Ophthalmology **8000 Aarhus C**
Aarhus Municipal Hospital

Mr./Mrs.....

Herewith we offer you a thorough eye examination free of charge.
Some accidents are due to visual problems which now and then are unnoticed by the persons involved.

With the sanctions of the Ministry of Justice I have received information on your involvement in a traffic accident in this year.
In this connection it will, from a social point of view , be of importance if you will take part in a scientific investigation. The purpose of the project is to elucidate the connection between traffic accidents and known or unknown eye diseases.

I would like to emphasize that the investigation is highly confidential. The results will be protected by my medical professional secrecy. Neither the police nor the insurance companies will receive information about your visual ability.

I should like to offer you a complete eye examination, including advice and, if necessary , glass prescription. Even if you have had your vision examined recently and if you do not believe you have visual problems, it is of uttermost importance that you participate.

The investigation will take 3/4 hour. It is without any pains and includes: test of visual acuity, possibly with test of glasses, investigation of the peripheral and central parts of the visual fields, the depth perception (the cooperative ability of the two eyes), the colour and contrast perceptions. Furthermore your retina will be examined.

I kindly ask you within the coming week, non-committally to contact me on phone ** ******, extension **** (in the daytime) or in the evenings on ** ****** (private). In that way you have the opportunity to get answers to possible questions of doubt before you finally decide whether you will participate. Provided you after this want to participate in the examinations, we can make an appointment according to your plans, if necessary outside your working hours, or at home.

You are kindly asked to bring this letter together with your possible eye medicine and glasses for the examination. Traveling expenses will be paid.

Naturally, your participation is voluntary, as well as you can withdraw a given commitment to the examination.

Hoping that you will participate,

with kind regards
Yours sincerely,

Knud Erik Alsbirk, M.D.

Appendix C:

Case reports, including an analysis of possible or probable association between traffic accidents and a) visual problems of car drivers and b) various medical conditions.

C.1. Introduction and methods used:

In order to give a realistic impression of the problem, i.e. traffic accidents with human injury, a considerable number of case histories of relevance for traffic medicine has been sampled.

As outlined in the method chapter (3), an attempt was made to evaluate every accident concerning the possible importance of visual factors in relation to the event. Again it must be emphasized that these observations are not given as scientific results, but more as a kind of illustration and as a contribution to the discussion.

It has been intended to approach the problem by giving an estimation based on the accident records and the ophthalmological findings in the involved partners.

In 174 (60.6%) of the 287 accidents in phase I. a police report was at hand (cf. table 2.5), whereas in phase IIa., due to the selection method, all 72 accidents were police reported cases. Thus, in summary, 246 (174 + 72), out of 359 investigated accidents (68.5%) had a report in the police files.

In case of a visual problem or other health problems in a car driver or an unprotected road user, the police report (when available) was studied in the Police Office of Aarhus with permission.

Thus, in total 104 police reports out of 246 (42%) were studied in detail.

Although many road-users were reported to have overlooked a partner involved in the accident, a follow-up investigation of the drivers' vision had not been initiated on the demand of the police in *any* of the reports studied, including the most clear cases.

In non-police registered accidents an evaluation was based on testimonies from the involved participants and on information on local geography.

Documentation and classification of the accidents:

Ninety-nine accident cases, out of which 43 are illustrated by a drawing, and 7 control drivers with visual problems are described.

The accidents in which a visual problem was a co-factor and classified as I) *probable* or II) *possible* are reported casuistically (for phase 2, only car drivers are reported).

This was done to provide a background for the evaluation of the possible association mentioned above. A more detailed analysis on this relationship is performed in Appendix C.3.

Furthermore, III) a few accidents involving car drivers with visual problems in which a connection was estimated to be *unlikely* were casuistically described, as well as IV) accidents in which *medication, drug or alcohol abuse* problems of the road users might be of some importance.

Not only accident involved drivers (cases) had visual problems. Also the drivers in the *control group* with significant visual problems are briefly mentioned (V).

Finally, two cases in which visual factors might play a role VI) and VII) of special interest for traffic-medicine, are included in the case reports, although the drivers had no important visual problems.

9. C.2. - Case reports.

Contents:
I: Accidents in which an association between visual problems and the accident seems *probable* (16 cases: 12 car-drivers and 4 unprotected road users).

II: Accidents in which an association with a driver's visual problem was estimated to be *possible*, as one out of several contributory factors (46 cases, drivers only).

III: Accidents with some visual problems in the car drivers, in which an association is classified as *unlikely* (11 cases).

IV: Accidents in which *drug/ alcohol abuse or a medical disorder* of the road user were estimated to be of some importance (43 cases).

V: Drivers in the *control group* with noticeable visual problems (7 cases).

VI: One example of an accident in which solely *external visibility factors* are of importance.

VII: One example of an accident in which good visual performance in a difficult and dangerous situation probably *prevented* a more serious outcome.

Some accidents are overlapping group I and II and III, due to more than one driver with visual problems. Ninety-nine reports are given on probands (43 illustrated) and 7 on controls.

When available, information on visual acuity will be as follows: visual acuity in the right/ left eye, - binocular visual acuity.

Indications on the accident numbers:
When referring to the case histories, the subgroup and type of problems will be indicated, (e.g. **I-V-924** indicates an accident in subgroup **I** with a visual problem (**V**) of the road user).

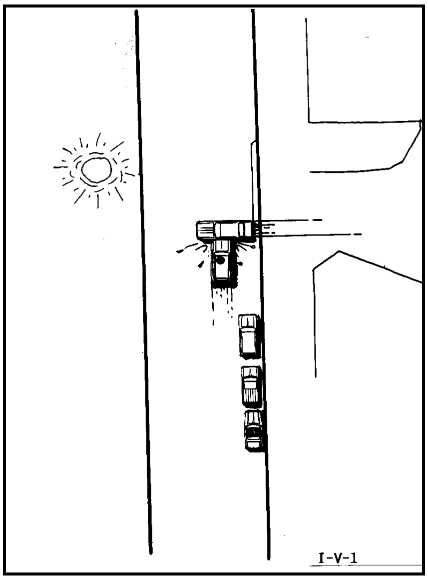
List of indications:
V: influence of Visual factors;
M: influence of Medical factors;
A: influence of Alcohol;
D: influence of Drugs or medication;
E: External factors of primary importance;
C: Controls.

e.g. **VMD**: several relevant factors (*v*isual, *m*edical, *d*rugs) combined.

I: Accidents in which visual factors of the drivers are estimated as *probable* contributory factors.

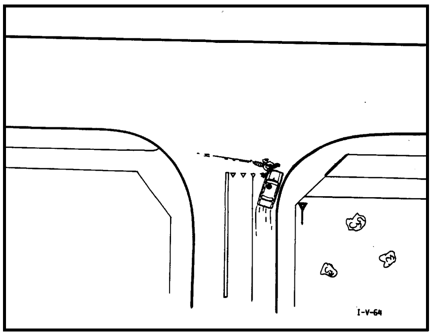
A: Car drivers (N=12):

I-V-1. Part 1: Male, 80, healthy. On a sunny morning, (Jan., 9.15 a.m.) while driving 40 km/h he drove into a car coming from a small side-road on his

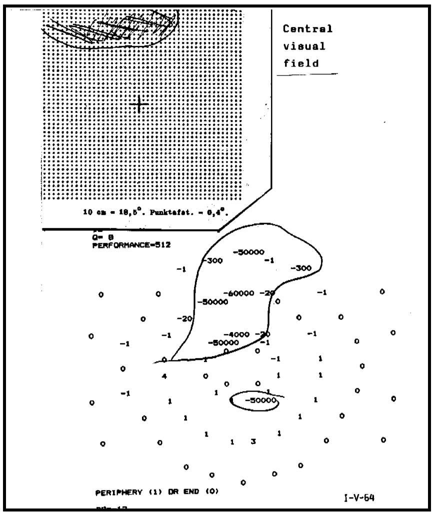


right side partly hidden behind 3 parked cars. Accident visual acuity, (tested in sun-glare) 0.15/0.15; binocularly: 0.25 (with correction). Correctable (in darkroom) to 0.33/0.5. Slit lamp investigation revealed cortical posterior cataract in both eyes, senile macular degeneration with reduced colour perception, and in the right eye, paracentral scotoma (Amsler chart). Contrast sensitivity was reduced (109), and visual reaction time averaged 1.04. *Part 2,* female, 40, did not see part 1 because of the parked cars. She had no visual problems. *Comment:* Although part two was to blame, the visual problems of part 1 combined with external factors (the parked cars) were estimated as a probable contributory factor in his not having noticed the dangerous situation.

I-V-64. Male, 58, with arthritis. Two months earlier he suffered an inferior branch vein thrombosis in the left eye with reduced visual acuity (illegal). In the situation in question he overlooked a

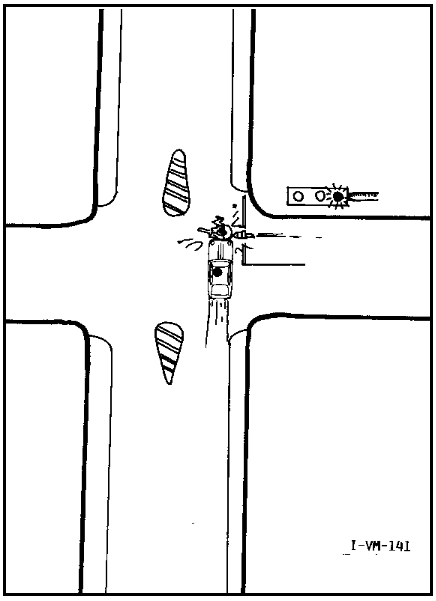


bicyclist coming from the left. Accident visual acuity: 0.4/0.05, binocularly 0.5 (without correction). Correctable to 1.25/0.10. Visual field: big scotoma on left eye upward from centre to 30 degrees (see figure).

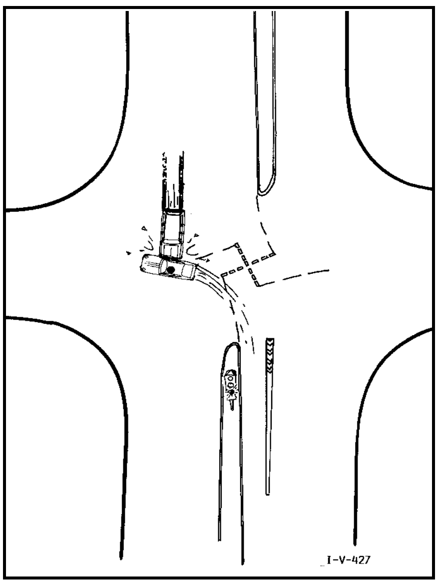


He died of cancer one year later. *Comment*: because of 1) the short period following the branch vein thrombosis, 2) the subjective testimony, and 3) the objective findings, an association between the driver's visual problems and the accident is estimated as probable.

I-VM-141. Male, 73, in healthy condition. Six years earlier cataract operated in the right eye. He overlooked a red light and drove directly into a 17-year-old moped rider coming from the right in a crossroads. Accident visual acuity: 0.3/light perception; binocularly



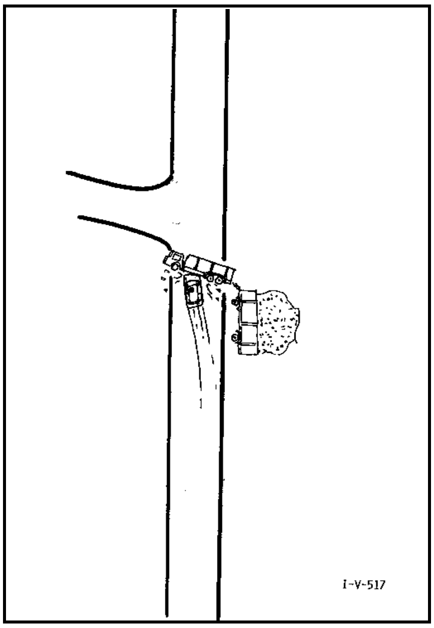
0.3 with own correction (+9). No improvement with other glasses. Visual field tested by hand reduced in the left eye. Contrast sensitivity: 89, colour perception severely reduced. Slit lamp investigation: aphakia in the right eye, mature cataract in the left eye. Ophthalmoscopy: right eye: age related macular degeneration (AMD). VRT: significantly prolonged (1.78). *Comment:* visual factors estimated as probable contributory factors. The increased reaction time might be of importance too (cf. table 10.2).



I-V-427. Female, 80, in healthy condition. In a crossroads she turned to the left in front of a car coming from the opposite direction (see figure in previous column). For cosmetic reasons she did not wear her glasses.

Visual acuity (tested 1/2 year before) 0.33/ 0.33 (without correction). Correctable to 0.67/0.5 (+1.75 sph. o.u.). She was severely injured. (Information from ophthalmologist, general prac-titioner and family). *Comment:* use of optimal correction would probably have warned her in time against the approaching car, which she overlooked.

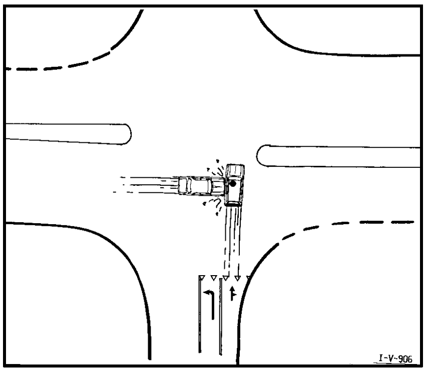
I-V-517. Male, 75, healthy. October, at 5 o'clock a.m., in twilight and rain he drove directly into the dark underside of a lorry with trailer, which had overturned a few



minutes before. Accident visual acuity: 0.3/0.5 binocularly: 0.5 (without correction). Correctable at 1.0/1.0 (-1 cyl 100° +1.5 sph.() -0.75 cyl.100°). Red-green colour blind. Contrast sensitivity slightly reduced (95). VRT: 0.58 (normal). Slit lamp: slight cataract in the left eye. Visual field and ophthalmoscopy normal.

Comment: in the extremely difficult sight situation, the patient's uncorrected, reduced visual acuity and reduced contrast sensitivity were estimated as important contributory factors in the accident. The case illustrates that a driver's vision may fulfil the demands in normal conditions, but in difficult and surprising traffic situations the vision is insufficient and ought to be optimized.

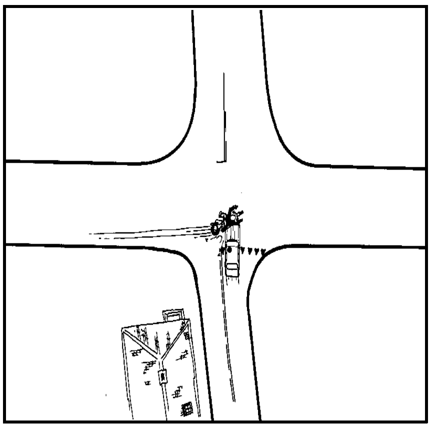
I-V-906. Male, 68, treated for duodenal ulcer. Overlooked part 2 from the left side. Accident visual acuity 0.2/0.25, binocularly 0.33 (without correction). Correctable to 0.67 bilaterally (+2/ +1.75). VRT: 0.64 (normal). Visual



field, contrast sensitivity and slit lamp investigation: normal. Ophthalmoscopy revealed slight macular degeneration. *Comment:* The visual acuity, which was far below the lawful limit, is estimated to have been of significance for the driver overlooking part 2. No external factors were contributory.

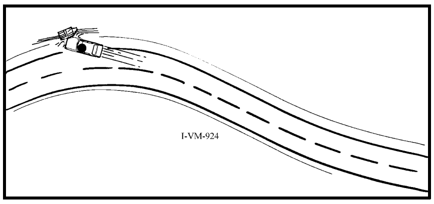
I-V-922. Male, 53, with reduced hearing in the left ear. Traumatic cataract in the left eye for 20 years. Suffered from a tendency to dazzling. In the dark he overlooked a moped rider with lights on coming from the left side.

Accident visual acuity: 1.25/0.5,



binocularly: 1.25 (without correction), correctable to 1.25/0.8. Visual field: tested by hand: normal. Computerized perimetry: bad performance and cooperation in the left eye. Contrast sensitivity: 74. VRT: 0.78 (both normal). Slit lamp investigation showed dense, nasally localized traumatic cataract in the left eye. Ophthalmoscopy: no retinal damage. Stereopsis: (5) reduced. *Comment:* the localized dense cataract in the left eye is estimated to be a probable co-factor. The hearing defect in the left ear might also be of importance for the driver's unawareness of the moped.

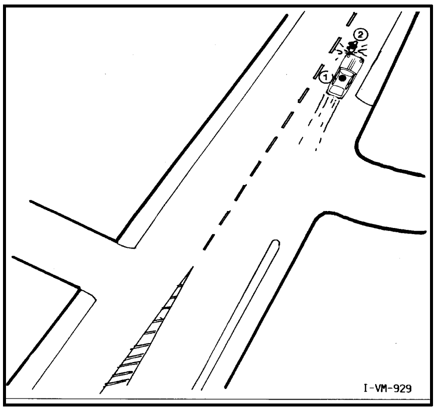
I-VM-924. Male, 75, suffering from (insulin treated) diabetes mellitus for 11 years, who was to have cataract surgery the following day. At 10 o'clock p.m. in



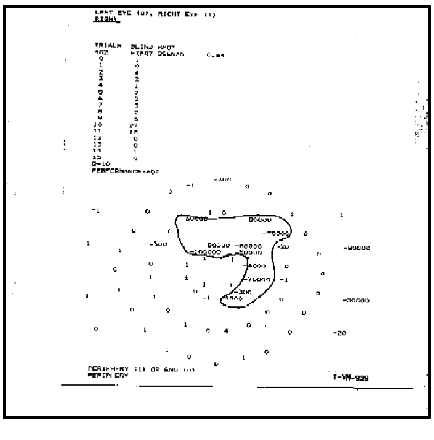
fog and darkness, the driver, who was hungry following a meeting, drove directly into a transformer station and was injured. The road in the village was unlit. He did not notice the reverse S-curve of the road.

At the casualty ward his blood glucose level was measured at 1.6 mmol/l. Accident visual acuity: 0.01/0.2 (with bad correction). Correctable at 0.3/0.8. Visual field: concentrically reduced in the right eye. Contrast sensitivity 85. VRT: 1.68 (increased). Slit lamp: advanced cataract in the right eye and slight cataract in the left eye. Ophthalmoscopy (left): slight simplex diabetic retinopathy without maculopathy. *Comment*: 1) the patient's reduced (and illegal) visual acuity due to several problems was estimated as an important contributory cause. The case further illustrates the *multi-factorial genesis* of most accidents: 2) reduced blood glucose level, 3) increased visual reaction time, 4) fog and darkness.

I-VM-929. Part 1, male, 76. Seven years earlier he had had a cerebral haemorrhage with left side hemiparesis. In



clear weather without any external obstructing factors he overlooked and hit a 68-year-old pedestrian waiting in the middle of the road to cross the street. She was severely injured and died within one day. Several witnesses had foreseen the accident without being able to stop the car driver, who apparently did not even reduce his speed until he was a few metres in front of the waiting pedestrian. Eight months before he had been examined by an ophthalmologist.
Examination: Accident visual acuity (part 1): 0.4/0.2, binocularly 0.4 (with correction). Correctable at 0.5/0.4 (astigmatism). Visual field by hand normal. Computerized perimetry revealed a paracentral scotoma in the right eye (see below), severely reduced

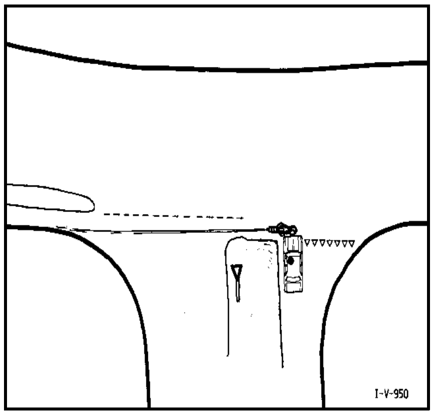


performance in the left eye and reduced cooperation (fixation control score: 64%).

Colour vision test indicated acquired central defects. Contrast sensitivity 100 (reduced). VRT: 1.19 (prolonged). Amsler chart: paracentral scotoma in the better (right) eye. Slit lamp: on both eyes incipient cataract. Ophthalmoscopy: pronounced AMD in both eyes. *Part 2:* female, 68, had two years earlier as a pedestrian been involved in a traffic accident suffering concussion and skull fracture. No visual information available. Autopsy revealed a fatal lesion to the upper part of the cervical spine. Furthermore, in the basal part of the cerebrum an old, superficial cystic scar, probably causing the first trauma, was found.

Comment: According to the police report, part 1 was sentenced due to lack of alertness, while the traffic behaviour of part two was not estimated as blamable. The multiple visual problems in part one (especially a big paracentral scotoma in his best (right) eye), combined with prolonged visual reaction time (VRT) were estimated to have been of probable importance for him not noticing the pedestrian in time.

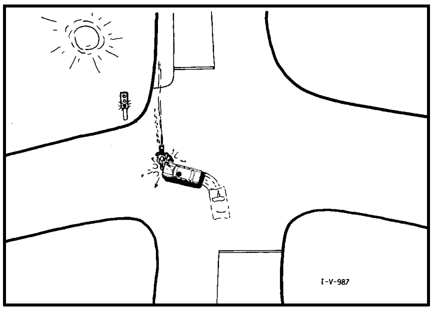
I-V-950. Female, 57, with myopia (-5/-9), treated for hypertension. Three years earlier she had been hospitalized for cerebral circular insufficiency. Coming from a side road she totally overlooked a bicyclist approaching from the left. In her own opinion she was



distracted by a turning car.

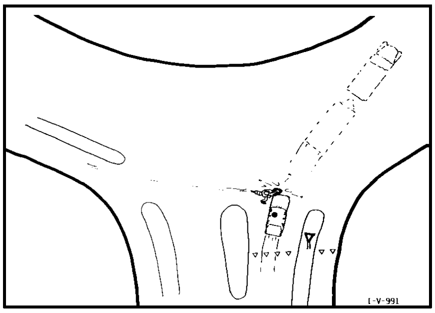
Accident visual acuity: 1.0/0.3 - binocularly 1.0. Correctable at 1.0 bilaterally. Visual field and slit lamp investigation: normal. Ophthalmoscopy: myopia and fundus hypertonicus III. *Comment:* as soon as the patient was adequately corrected for her left-sided myopia she said, "Now I know why I overlooked the bicyclist!". Although the case is debatable, on the basis of this it is estimated that her uncorrected myopia in the left eye was a probable contributory factor for her overlooking the unprotected road user.

I-V-987. Female, 59. Twelve years earlier suspected of epilepsy. Since then healthy. When turning to the left at a crossroads she was blinded by the sun at 12 a.m. and therefore failed to see an on-coming moped rider.
Accident visual acuity: 0.6/0.4 with 2 year old corrections. Correctable to



1.0/0.9 (+2.75/+2.25). Visual field, stereopsis, colour perception and VRT normal. Contrast sensitivity 84 (normal). Slit lamp investigation revealed subcapsular, incipient cataract in both eyes. *Comment*: the combination of subcapsular cataract and insufficient correction for her hyperopia was estimated to have been of importance for the degree of dazzling and for her overlooking the moped rider.

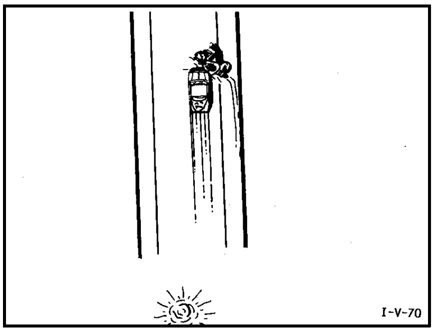
I-V-991. Male, 81, healthy. In misty darkness, entering a roundabout, he overlooked a dark clothed bicyclist (with lights on) coming from the left .
Accident visual acuity: 0.5/0.2



binocularly 0.6 (without correction). Correctable at 0.9/0.6 (hyperopia and astigmatism). Visual field, stereopsis and colour perception: normal. Contrast sensitivity: 102 (reduced). VRT: 1.03. Slit lamp investigation: incipient cataract in both eyes. *Comment:* the insufficient correction of the driver with a vision "at the limit" and reduced contrast sensitivity were estimated as probable contributory factors for him not noticing the bicyclist coming from the left side (with the lowest visual acuity). The misty darkness and the dark dressing of a bicyclist might be significant external contributing factors too. The importance of optimal correction in difficult lighting and visual situations is illustrated in this case and must be emphasized.

B. Unprotected road users: (N=4)

I-V-70. Female, 12 years old, bicyclist. In clear, sunny weather at 9 a.m. she turned to the left leaving a bicycle path without noticing a white car approaching from behind.

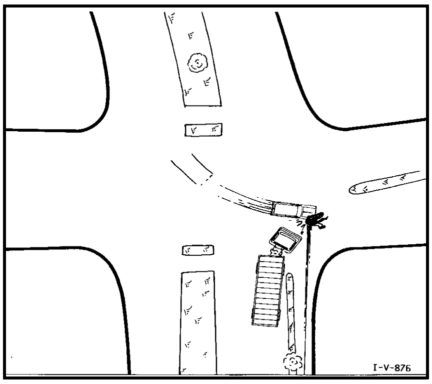


Accident visual acuity: 0.05/0.10 - binocularly 0.10 (without correction). Correctable at 1.0 bilaterally (-2.5 () -0.75 cyl./-2.75). VRT: 0.44. Visual field normal. The driver's vision was normal. The girl had glasses for distance but she did not use them consistently. She was blinded by the sun from the east when looking backwards. The uncorrected myopia is estimated to be of significant importance in the dazzling problems and overlooking the white car. - Also unprotected road users ought to use adequate optical corrections in traffic.

I-V-458. Male, 31, pedestrian, who had had 3 beers prior to the accident. In a T-crossroads and in the dark he misinterpreted an approaching light and thought it to come from a moped. In fact it was a bus with one light damaged. Accident visual acuity: 0.2/0.3, binocularly 0.3 (without correction), correctable to 1.0 bilaterally (-1.0 sph.). *Comment*: the uncorrected myopia in this difficult traffic situation is estimated as a probable co-factor. The darkness, the defect lights of the bus and the alcohol consumption might be contributory factors too.

I-V-595. *Part 1,* male, 84, (bicyclist), who entered a crossroads during yellow light which then turned red. Only one metre away did he see a car coming from the right. Accident visual acuity: unknown. One year later he was checked by an ophthalmologist. Visual acuity: hand movement/0.1 (without improvement with glasses). Slit lamp investigation revealed double side cataract and ophthalmoscopy central macular degenerations, primarily in the right eye. *Part 2:* male, 29, with insulin treated diabetes for the last 19 years. He entered the T-cross with 50 km/h. Too late he realized that part 1. continued his course. Visual acuity: 0.9/0.6. Ophthalmoscopy showed bilateral simplex retinopathy. No cataract or visual field defect was found. *Comment:* the severe visual problems of the bicyclist were estimated to have been the probable primary contributory factor.

I-V-876. Female, 20, with myopia. In medical treatment for asthma. She did not wear glasses because of rain. On a bicycle, in daylight at speed 30 km/h she drove through a green light at the crossroads, but too late she saw a car turning left, coming from the opposite direction, partly hidden behind a lorry.



Accident visual acuity: 0.1/0.05, binocularly 0.1 (without correction). Correctable at 1.25. *Comment:* with correction, e.g. contact lenses, the bicyclist would probably have seen important details of this traffic situation. Other factors such as: 2) a misunderstanding between the two car drivers (see figure above) and 3) the obstructed view due to the lorry might be contributory too. *Bicycling in rain with glasses* is a well known problem, therefore the use of contact lenses may be indicated.

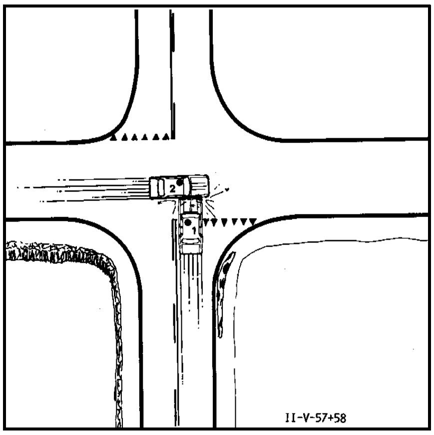
(In a very similar accident with the same position of cars, a myopic bicyclist had v.a. 0.1/0.3 (uncorrected). A causal relationship was estimated possible).

II: Accidents in which visual factors of the drivers are estimated as *possible* contributory factors (N= 46).

Introduction: These cases are all debatable. Sometimes a causal association is almost unlikely, sometimes almost probable. They illustrate, however, how difficult it is to classify a causal relationship. They are mentioned because of some kind of visual problems which (theoretically) could not be excluded as one out of several contributory, etiological factors.

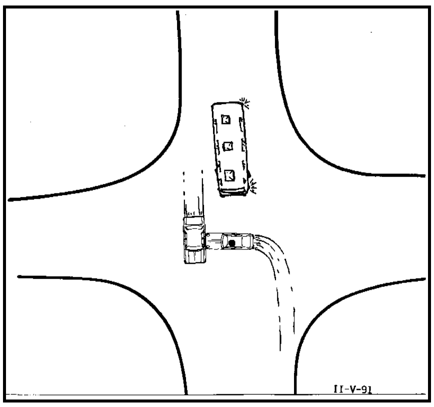
II-V-54. Male, 27, lorry driver. After an operation for a left side traumatic cataract he was prescribed a contact lens. In a crossroads with high speed he drove through yellow and red light. When braking at high speed he could not avoid hitting a moped rider, coming into green light from his right side. He refused to participate in the investigation. One year earlier an eye practitioner had found visual acuity 1.0/0.5 with left contact lens. *Comment:* a causal relationship in this case is rather unclear. Possibly he might not have been using his contact lens and had been compensating by looking at the left side of the road (i.e. the side in which he had visual problems), thus overlooking the moped rider coming from the right?

II-V-57 and II-V-58. *Part 1.* Female, 43, myopic and treated for duodenal ulcer. In a crossroads, coming from a side road, she broke the "rule to give way" , overlooking part 2, who came from her left side. Snow and a high hedge obstructed the view. *Part 2,* male, 26, with psychomotoric retardation and right side amblyopia. Examination: *Part*



1: accident visual acuity: 0.5/0.5 - binocularly 0.67 (with -3.75/-2.5), correctable to 1.0/0.67. Myopic fundus was seen by ophthalmoscopy. Further visual parameters including VRT (=0.67 sec.) were normal. *Part 2:* accident visual acuity: 0.25/1.25 binocularly 1.25 without correction, unimprovable. Visual fields normal. Depth perception: 0. Ishihara test revealed red/green colour blindness. Contrast sensitivity: 71. VRT: 0.65. Amsler chart showed a right side scotoma. A 10° right side convergent squint was found. *Comment:* the poor view, the insufficiently corrected myopia and blamable traffic behaviour of part 1 are the most probable reasons for this accident. The coincidence of a right-sided amblyopia in part 2 and a surprising traffic situation in the same side is probably a contingency but it might be a contributory factor.

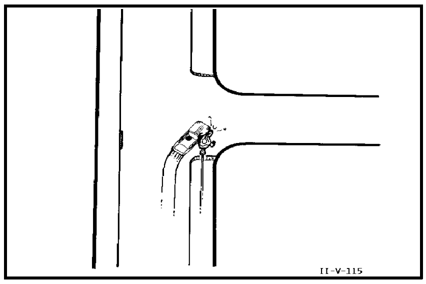
II-V-91. Female, 56, healthy, with left side amblyopia and squint. Turning to the left at a crossroads, she mis-interpreted the traffic situation because of a car approaching from the opposite direction and being partly hidden behind a bus.



Accident visual acuity: 0.5/0.02 binocularly 0.5 (without correction). Correctable at 0.67/0.02 (hyperopia). Visual field, slit lamp investigation, contrast sensitivity and colour perception normal. Depth perception severely reduced (2). Ophthalmoscopy showed extrafoveal fixation in the left eye. Amsler grid: left side central scotoma. *Comment*: the driver's visual acuity being below the lawful limit and the severe left-sided amblyopia might possibly have been contributory factors in the driver miscalculating the traffic situation in the left side of the visual field.

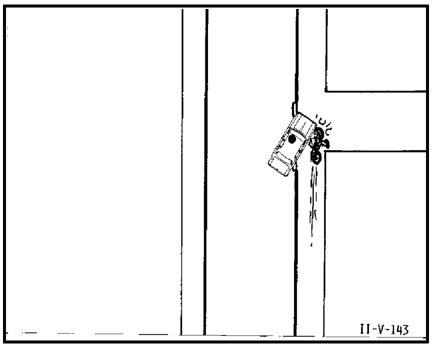
II-V-115. Female, 41, with right side excessive myopia and amblyopia. Turning to the right from a main road, she overlooked a bicyclist on the bicycle path on her right side.

Examination: Accident visual acuity: 0.1/0.67, binocularly 0.67 (with-18/-3), correctable at 0.1/ 1.0. Depth perception reduced (Titmus score=2). Visual field



for hand movements concentrically reduced in the right eye due to the powerful glass. Contrast sensitivity =75. VRT= 1.71, (severely prolonged). Ophthalmoscopy revealed excessive myopic fundus. *Comment:* The right side amblyopia and reduced visual field might be contributory factors in overlooking the bicyclist coming from behind at the right side. The significantly prolonged visual reaction time should be kept in mind too.

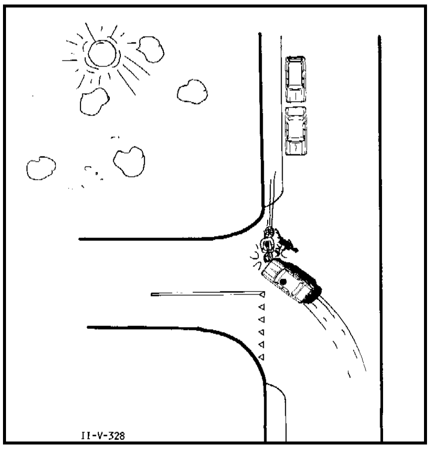
II-V-143. Male, 67, healthy. On a clear day, when turning to the right, he overlooked a bicyclist approaching from behind on a bicyclist path.



Accident visual acuity: 0.25 bilaterally (without correction). Correctable to 1.0/0.67 (hyperopia +2). VRT = 0.53, other visual parameters: normal. The bicyclist had normal vision. *Comment:* the missing correction for hyperopia leading to illegal visual acuity might have contributed to him overlooking the bicyclist in the mirror or the rear window, although a "dead angle" might be contributory too.

VM-160. See IV.

II-V-328. Male, 66, with severe bronchitis, operated for a hip fracture (a.m. Charnley). Turning to the left he

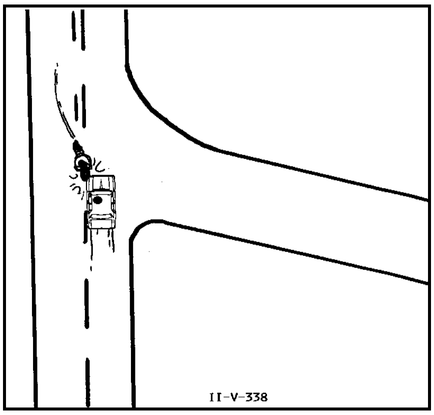


overlooked a bicyclist because he was dazzled by the sun shining through the

trees.

Accident visual acuity 0.4/0.5 - binocularly: 0.5 (with 15-year-old glasses). Correctable to 0.9/1.0 (+0.75/+1.0). Slit lamp investigation revealed immature cataract in right eye. *Comment:* the tendency to dazzling due to cataract might be increased because of unsufficient correction.

II-V-338. Male, 63. Treated for duodenal ulcer. With the left front of his car he collided with a bicyclist, who from the opposite side was turning to the left.

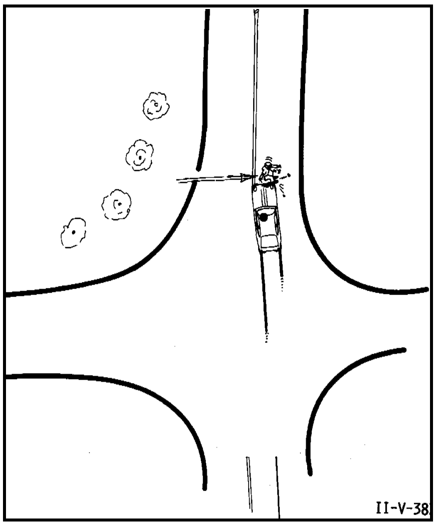


Accident visual acuity 0.5/0.2, binocular visual acuity 0.5 (without correction). Correctable to 1.25/0.9 (+1.25 sph. o.u.). VRT= 0.66. Visual field, slit lamp investigation and ophthalmoscopy normal. *Comment*: Visual acuity at the limit. With optimal visual acuity he might possibly have braked in time.

VMD-384. See IV.

II-V-387. Male, 40, healthy. In darkness with clear visibility, on a slightly curved road he had just passed a crossroads. At a spot with insufficient lighting a female pedestrian, 72, walked in front of the car from the left. The pedestrian was instantaneously killed.

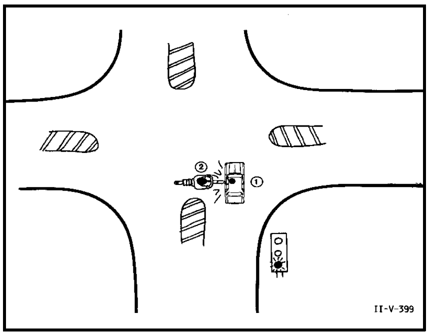
Accident visual acuity: 0.9/0.6 binocularly 1.0 (with correction). Tested in darkness binocularly: 0.7. Correctable at 1.25 bilaterally (-3.25 () -1.5 cyl./-3.75 () -1.75 cyl.) The visual field was slightly reduced because of a heavy spectacle frame. The other visual parameters including VRT were normal. Blood alcohol concentration: 0. *Comment*: darkness significantly impaired the



driver's astigmatic (night-)myopia, which might be contributory to detecting the pedestrian too late. The pedestrian's dark dress with no reflective tags and the behaviour was probably contributory.

II-V-397. Female, 50, healthy, with left side amblyopia due to astigmatism. In daylight she did not notice a bicyclist coming from the left in a "dead angle". Accident visual acuity: 1.0/0.03. Visual reaction time: contrast sensitivity, colour perception and visual field tested by hand: normal. A left sided 10° convergent strabismus and extrafoveal fixation, as well as severely reduced depth perception were seen. *Comment*: the deep left side amblyopia might have contributed to the driver not having noticed the bicyclist coming from the left.

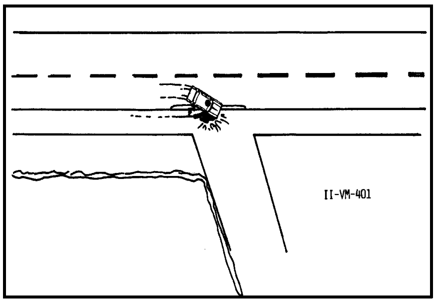
II-V-399. *Part 1:* male, 55, with right side amblyopia and earlier treated for keratitis of both eyes. In daylight on a



rainy day he drove through a green light at a crossroads and was hit by a bicyclist coming (part 2) from the left.

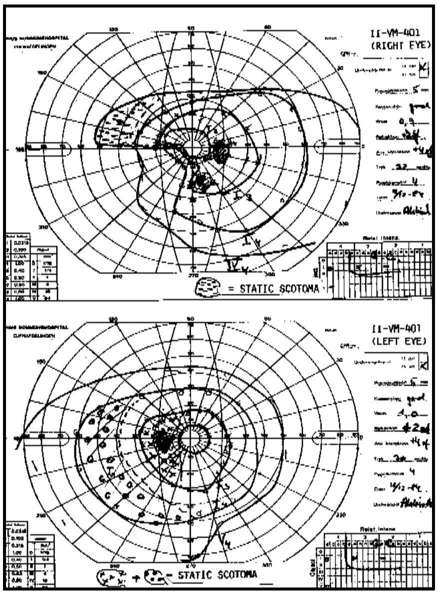
Accident visual acuity: 0.1/0.4 binocularly: 0.4 (with correction). Correctable at 0.1/0.5 (hyperopia). Slitlamp investigation revealed minor scars after keratitis. Visual field, colour perception and contrast sensitivity normal. VRT: 1.01. Depth perception: 0. *Part 2,* male, 82, with Menier's disease. Accident visual acuity 0.25/0.33, binocularly 0.5 (without correction). Correctable at 0.67 bilaterally. Ophthalmoscopy and slit lamp investigation showed incipient cataract. Visual field normal. VRT: 0.66. intraocular tension: 18/23. A slight excavation of the optic nerve was found in the left eye. No macular degeneration. *Comment:* the behaviour and visual problems of part 2 are estimated to be a primary cause, but secondarily, in part 1 a visual acuity below the legal level with right sided amblyopia and double-sided scars of the corneas might, on that rainy day, have contributed to him not being aware of the bicyclist coming from the left. Part 1 was advised to have a corneal transplantation in a not too distant future.

II-VM-401. Male, 63, taxi driver. 5 years earlier hospitalized for vascular infarction in the right hemisphere due to



hypertension. When driving he sometimes observed a "hole" in his visual field. On a clear day, when turning to the right into a service station, he did not notice a moped rider coming from behind on the bicyclist path. Examination: accident visual acuity: 0.6/0.9 - binocularly: 1.0, correctable at 0.9/0.9. Visual field: normal for hand movements. Computerized and kinetic perimetry (Goldmann) showed scotomas in the left part of the visual field, the static scotomas exceeding the dynamic scotomas (Riddoch phenomenon, dotted on the figure).

Depth perception, Amsler chart and colour perception normal. Contrast sensitivity 90. VRT: 1.02. Ophthalmoscopy showed glaucomatous excavation of the optic nerve on both

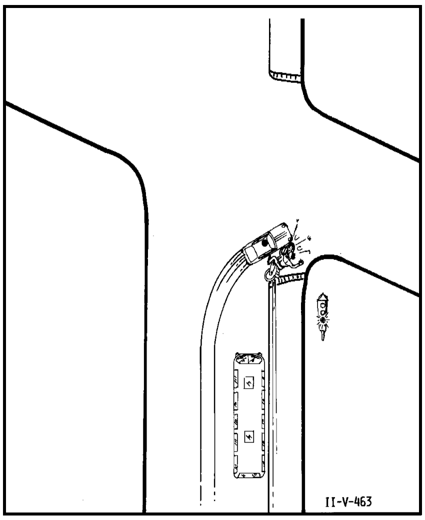


eyes, with a notch on the right eye. Applanation tonometry: 30/28. Anti-glaucoma therapy with Timolol was instituted. A CT-scan showed central and cortical cerebral atrophy and an old infarction in the right hemisphere. EEG: focal, abnormal, low frequency activities over the same hemisphere. *Comment*: possibly, the car driver has scanned the visual field when looking backwards to the right. In this visual scanning the moped rider might have been placed in the scotoma, positioned to the left of the centre. A "dead angle" in the car, however, is probably the most important cause.

II-V-414. Male, 26, healthy. In darkness and rain he overlooked an approaching bicyclist (with dim lights) from the opposite side in a left-hand curve. The bicyclist (female, 20) was severely injured. Examination: accident visual acuity: 0.6/0.7 - binocularly: 0.9 (in darkness without correction). Correctable at 1.0 bilaterally (-1.0 sph. () -0.75 cyl. o.u.). Further investigations normal. *Comment:* the bad weather conditions, the darkness combined with the bicyclist's dim lights were of primary importance, but the night myopia of the driver might also have contributed to his overlooking the bicyclist.

II-V-454. Female, 50, earlier treated for right sided keratitis. Suffered from night vision problems (dazzling and hemeralopia (dark blindness)). In daylight she overlooked a car (cf. III-V-453) coming from the right side in a crowded traffic situation. A passenger was injured. Examination: accident visual acuity: 1.0/1.0 - binocularly: 1.25 (emmetropia). Other visual parameters were normal apart from slightly elevated contrast threshold for low frequencies (15+13+12+11+ 10+8). No abnormal pigmentation of the retina was found. *Comment:* the contrast threshold for the lower frequencies was found to be in the upper end of the scale for her age group. In a complex, crowded situation this might be a contributory factor, but in this case rather debatable. See also **III-V-453**.

II-V-463. Female, 54, with rheumatic fever as a child, now treated for hypertension. Right side amblyopia with strabismus. Turning to the right from a

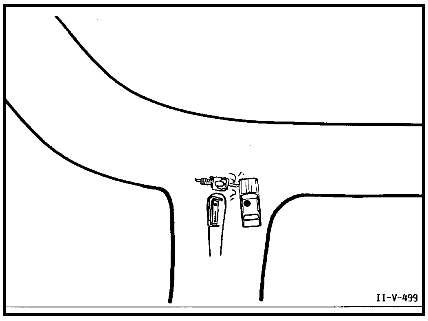


main road into a side road, she did not notice a bicyclist coming from behind, partly hidden behind a bus.

Examination: accident visual acuity: 0.3/1.0 - 1.0 with correction (+4 () -1.5 cyl. 90º/+3,5 () -0.5 cyl. 175º). Apart from hypertensive retinopathy (I), the driver had a slight divergent strabismus.

Comment: overlooking a bicyclist ("the bicyclist merged with a pedestrian") on the amblyopic side might be associated, although the fact that the bicyclist was hidden behind the bus probably was of importance too. The bicyclist (male, 27) had a unilateral, uncorrected myopia (v.a. 0.4/1,25) which, however, in this connection is estimated to be of no importance.

II-V-499. Male, 62, healthy. Since childhood he has had a left side amblyopia. Now increasing problems with

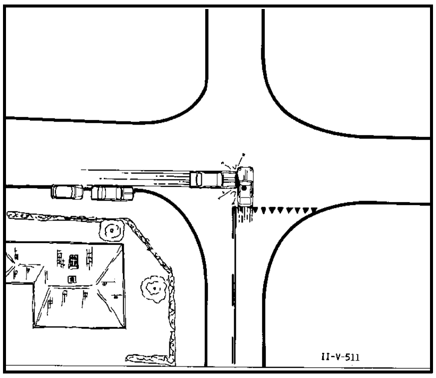


dazzling. Turning to the left from a side road he overlooked a bicyclist coming from the left behind a low road sign.

Examination: accident visual acuity: 0.5/0.05 with correction, correctable at 1.0/0.05. (Astigmatic hyperopia). VRT: 1.15. Ophthalmoscopy showed slight macular degeneration. Depth perception: 0. Amsler chart with big central scotoma on the left side. Further visual parameters were normal. *Comment:* the severe left sided amblyopia might be of importance for overlooking the bicyclist from the left, although the road sign as an external factor obstructed the view.

II-V-511. Female, 57, healthy with a slight left sided amblyopia. In clear daylight on a wet road she totally overlooked a car coming from her left side, statably because of cars parked in front of a small shop on the corner.

Accident visual acuity: 0.8/0.4 - 0.8. Correctable at 0.9 bilaterally. Other visual parameters: slit lamp investigation revealed incipient posterior cataract on both sides. *Comment:* the uncorrected left side hyperopia in combination with the developing cataract might be a contributory factor for her having overlooked the car from the amblyopic

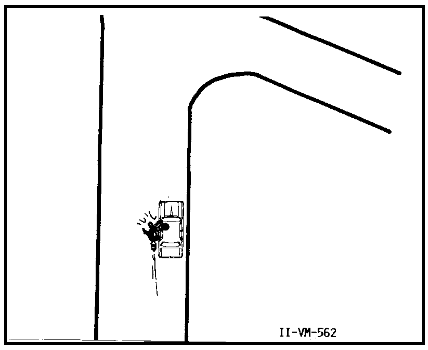


side. The visual obstruction, due to the small shop and the parked cars, is estimated to be of importance too.

II-VMA-534. Male, 22, with slight right side amblyopia. For headaches and hypertension he would normally take Diazepam 5 mg x 3. On the day of the accident he had taken 5 mg 10 hours before, 5 mg 2 hours before and 1 beer 1 hour before the accident. When turning to the left in a T-crossroads he miscalculated a car coming from his right side. In order to avoid a collision he drove into a lamp post. Examination: accident visual acuity: 0.4/0.7 (without correction), correctable at 0.9/1.0 (-1.75 cyl./-0.5 () -1.5 cyl. 170°). Visual field, colour perception and contrast sensitivity: normal. Depth perception reduced (2). Five degrees right side intermittent exotropia was found. *Comment:* the uncorrected astigmatism and the slight right side amblyopia as well as the reduced depth perception might have contributed to the miscalculation of the car from the right side. Intake of Diazepam and alcohol might have been contributory too.

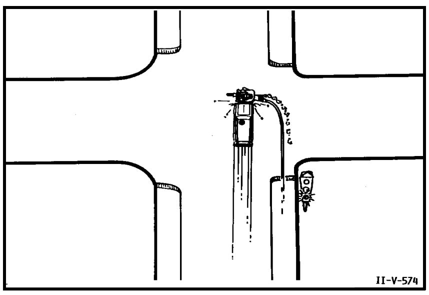
II-V-535. Female, 41, healthy with myopia. She claimed having not seen a dark car stopping in front of her in misty daylight in a T-crossroads giving signal to the left. A child passenger was injured. Examination: accident visual acuity: 0.3/0.4 binocularly 0.5. VRT: 0.95. Correctable at 1.0/1.0 (myopia -1/-0.75). VRT: 0.95. Further visual parameters including contrast sensitivity normal. *Comment:* no external factors obstructed the survey. Although the driver was very stressed, due to her profession, uncorrected myopia, with visual acuity below the lawful limit, is estimated to have been of possible importance for this accident too.

II-VM-562. Male, 74. with diabetes mellitus (NIDDM) for the last 10 years. Five years earlier he suffered from acute myocardial infarction. Since then 14 hospitalizations for transitory ischemic attacks (TIA). Opening the left door of his car he overlooked a bicyclist



overtaking from behind who drove directly into the door and was injured. Examination: accident visual acuity: 0.5/0.5 binocularly 0.5 (with correction). Correctable at 0.9 binocularly. Visual parameters were normal, including normal ophthalmoscopy. The visual reaction time (VRT) was significantly prolonged (1.97 seconds). Furthermore, a severe osteochondrosis in the cervical columna with reduced rotation mobility was found. *Comment:* a reduced mobility in the cervical spine, a "dead angle" and a visual acuity that had not been optimally corrected might all have been contributory factors.

II-V-574. Male, 41. Since early childhood right side amaurosis due to a retinal detachment. In a crossroads a



moped rider on the right side of the car turned to the left in front of the driver.

Examination: (information from eye specialist): accident visual acuity: -

LP/1.25. Left eye with normal visual parameters. *Comment:* The traffic behaviour of the moped rider was highly blamable. However, the car driver's unawareness of the moped rider's behaviour, might to some extent be due to his right side amaurosis.

II-V-577. Female, 45, healthy apart from adiposity. In rainy daylight, coming from a side road into a T-crossroads, she broke the rule to give way to approaching traffic. She miscalculated or overlooked a car from the left side on the main road. She refused to participate in the investigation. No information on the use of glasses was available from the police report. Statably she used them. Information from general practitioner and optometrist. Visual acuity: 1.0/1.0 with correction (-1.25 () -0.5/-0.75). *Comment:* the fact that she overlooked or miscalculated the velocity of the car while overtaking is difficult to account for. The rain on the window, no use or use of dewy glasses for myopia might be of importance.

II-VA-598. Male, 64, in treatment for hypertension. Left side amblyopia since childhood. In clear daylight he overlooked a car coming from his left side with no external obstructions. Examination: accident visual acuity: 0.8/0.01 - binocularly 0.9 (with correction), correctable at 1.25/0.01. Visual field by hand: normal. Contrast sensitivity: 86. Depth perception: 0. VRT: 0.54. Ophthalmoscopy showed a left side extrafoveal fixation and hypertensive retinopathy. *Comment:* a causal association can not be excluded in this case, in which he overlooked a driver coming from behind in the amblyopic side.

II-V-599. Part 1. Male, 65. Disabled because of severe bronchitis and asthma. When turning to the left from a side road he overlooked a car approaching from the right from behind a small hill. He misinterpreted the lights in the darkness, thinking it was a small farm. Part 2, male, 26, healthy. Two hours before the accident he had taken 3 drinks. Examination: Part 1: accident visual acuity: 0.6/1.0, binocularly 1.0 (without correction, correctable to 1.0 on both eyes, hyperopic astigmatism). Further investigation confirmed a known red/green colour blindness. Apart from that, the findings were normal including normal contrast sensitivity. Part 2 had normal visual parameters apart from deuteranopia. VRT=0.68. Blood alcohol was 1.2 ‰. *Comment:* the uncorrected vision in the right eye of part 1 might have contributed to the confused perception of the approaching lights, although obstruction in view due to the small hill is probably of great importance. Furthermore, the alcohol consumption of part 2 was a probable contributory factor.

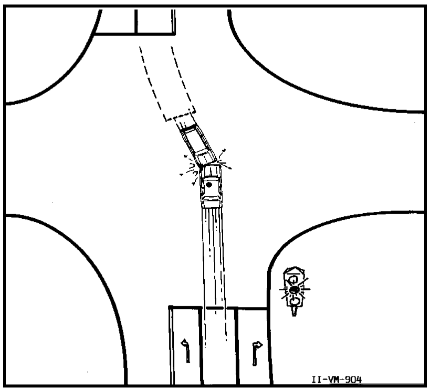
II-V-606. Male, 64. Operated for duodenal ulcer. In clear twilight, on a wet road, in a left curve he suddenly drove into a bicyclist (a mother with a small child) on his right side while overtaking. Statably the bicyclist was without rear light. Accident visual acuity: 0.6/0.7, - binocularly 0.7 (without correction). Correctable at 1.0 o.u. (+1/+1.25). Visual field, depth and colour perception as well as central visual field normal. Also the contrast sensitivity (= 68) and VRT (0.8 sec.) were normal. Ophthalmoscopy and slit lamp investigation normal. *Comment*: too late he recognized the unlit bicyclist in the twilight. Possibly optical correction for hyperopia, leading to perfect vision might have helped him react in time.

II-V-612. Female, 44. Healthy. Disinclined to use her glasses because of problems with the spectacle frames. While overtaking a tractor she overlooked the blinking lights indicating that the tractor intended to turn to the left. Examination: accident visual acuity: 0.5/0.4 binocularly 0.6 (without correction). Correctable at 1.0/0.9 (+1/+1.25). Further visual parameters including VRT normal. *Comment:* the slightly reduced visual acuity might have contributed to her not having noticed the sign from the tractor (which apparently was slightly soiled too).

II-V-620. Female, 51, since childhood in treatment with Phenobarbital for epilepsy. In misty darkness and rain with apparently bad lighting conditions she overlooked a dark dressed pedestrian, coming from her left side outside the zebra crossing. Examination: accident visual acuity: 1.0/1.0 - 1,0 (without correction). Correctable at 1.25 (+0.5 sph.) bilaterally. VRT: 1.0. Contrast sensitivity: slightly reduced for the lowest frequencies (16+10+11+10+9+8). *Comment:* the primary cause of this accident was the behaviour of the dark dressed pedestrian, crossing the road outside the zebra crossing. Although debatable, the reduced contrast sensitivity in the bad weather and light conditions cannot be excluded as a contributory factor.

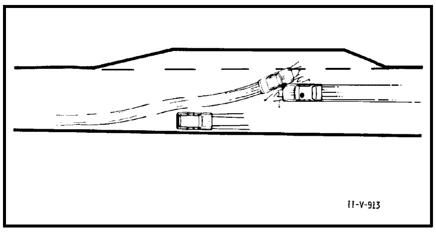
II-V-879. Male, 69. Six years earlier cerebral infarction with a left side hemiparesis. In treatment with Dicumarol and Digoxin. In the situation in question, with reduced visibility, he overlooked a bicyclist coming at 20 km/h down the road from behind as he was turning to the right. Examination: accident visual acuity: 0.6/0.8-1.0 (with correction). Visual field for hand normal. By computerized perimetry a small scotoma in the left periphery was found (after the infarction). Further visual parameters including contrast sensitivity were normal including VRT (0.72). Depth perception slightly reduced (4). The spectacle frames had heavy side bars. *Comment:* the reduced visibility due to the rain in combination with the side bars of the spectacles are estimated to be of some significance for overlooking the bicyclist, although a "dead angle" in the car and the relatively high speed of the bicyclist might be contributory factors too.

II-VM-904. Male, 60. Six and four years ago hospitalized because of TIA. In treatment with anti-coagulation. Slight hypertension. In clear twilight, partly because of slippery roads, he went onto a crossroads at yellow/red light, having overlooked a car coming from the opposite side, waiting to turn to the left. Accident visual acuity: 1.0/0.67, binocularly 1.0 (with correction). Visual fields for hand: normal. Computerized perimetry: In spite of severely reduced cooperation, small scotomas were found, primarily in the right eye. Depth perception slightly reduced. Contrast



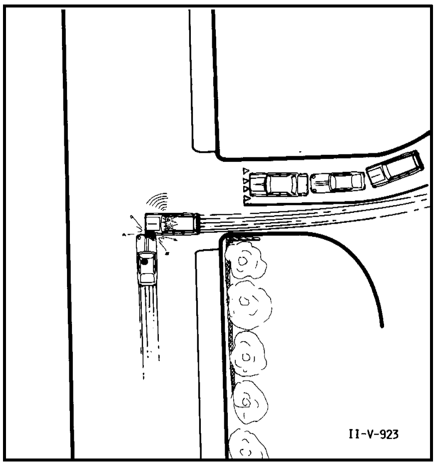
sensitivity normal, VRT normal (0.58). No scotomas on Amsler charts. Ophthalmoscopy revealed severe vascular retinopathy with a branch vein thrombosis in the right eye. *Comment:* although the visual reaction time was good, a testing with the computerized perimeter revealed significantly reduced attention, estimated by reduced fixation control. The slippery road is estimated to be of importance too, but small scotomas, due to the infarctions in the retina, might have been contributory in him not having noticed the turning car.

II-V-913. Male, 44, healthy. In clear darkness (with no road lights) he was blinded by an oncoming car. Too late he noticed that another oncoming car was skidding on the road.



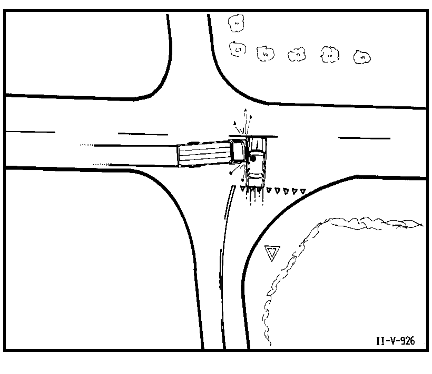
Examination: accident visual acuity, tested in darkness: 0.4/0.4 - 0.5. Correctable at 0.67 bilaterally (-0.5 sph. () -2.0 cyl.). Contrast sensitivity 86, VRT: 0.66. Depth perception was normal. *Comment*: defective brakes on the skidding car were the primary cause but dazzling and the driver's uncorrected night myopia combined with astigmatism might have contributed to him not having noticed the critical accident situation in time. The driver was prescribed glasses for use especially for night driving.

II-V-923. Male, 58. 9 years earlier



operated for a pituitary adenoma. Statably he overlooked an ambulance coming from the right with the blue emergency lights on, partly hidden behind trees and parked taxis. Examination: accident visual acuity: 0.9/0.5 - 0.90 (with correction). Correctable at 1.0/1.25 (astigmatic hyperopia). Visual field for hand: normal. Computerized perimetry showed upper bitemporal quadrant-anopsia. Depth perception severely reduced. VRT: 0.77. Contrast sensitivity: 0.86. Ophthalmoscopy: normal. *Comment*: under the complex circumstances he might have overlooked the blue emergency lights of the ambulance, which at the critical moment might have been placed in the scotoma in the periphery of the right eye.

II-V-926. Female, 51, healthy, apart from left side amblyopia after a trauma when she was 3 years old. In a crossroads she concentrated on two cars coming from her right side and overlooked a lorry from her left side. The accident happened in clear daylight. Examination: accident visual acuity: 0.8/0.1 binocularly 0.8 (without correction). Correctable at 1.0/0.1. Depth perception: 0. VRT: 0.79, contrast sensitivity: 85. Amsler chart showed



paracentral scotoma on the left eye. Slit lamp investigation revealed a minor posterior cortical cataract in the left eye. (Probably due to trauma in childhood). Visual fields: for hand normal. *Comment:* an association between the left side cataract and amblyopia and overlooking the lorry from the left is estimated as possible. Furthermore, she was distracted by two cars coming from her right side.

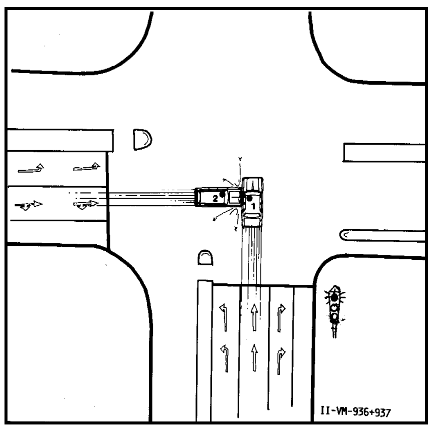
VMD-931, see IV

II-V-932. Male, 50, healthy. In clear daylight he overlooked a car driver (who broke the stop and give way rule) from his left side, partly because of buildings near to the corner.

Accident visual acuity 0.7/0.9 binocularly 1.0. Correctable at 1.25 (+1 sph.) binocularly. Visual fields, stereopsis, contrast sensitivity and colour perception normal. *Comment:* primarily the blamable behaviour of part 2 in combination with the buildings situated near the corner were estimated to be of importance for this accident. The role of the slightly reduced visual acuity of the right eye due to uncorrected hyperopia is debatable in this case.

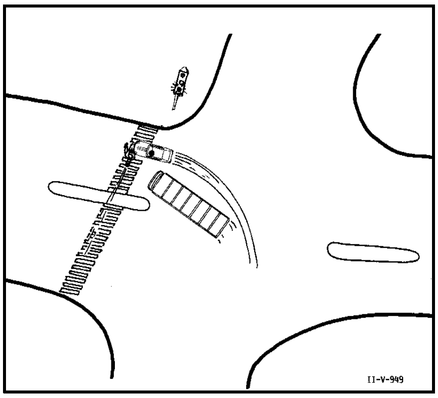
II-VM-936 and 937. *Part 1,* male, 63. Earlier treated for nervous breakdown. Now healthy. In clear daylight on a wet road he drove through a red light and into a car coming from his left side (part 2). This car was partially hidden behind another car.

Accident visual acuity 0.5/0.7 without correction, binocularly 0.8. Correctable at 1.0 bilaterally. VRT: 0.72. Other visual parameters normal. *Part 2:* male



56, with right side amblyopia. Accident visual acuity (information by general ophthalmologist): 0.01/0.7 with correction, correctable at 0.01/0.8. Further visual parameters unregistered. *Comment:* part 1 apparently had a "black out", causing him to drive through the red light. The visual problems of both parts might have contributed to them not taking care in time.

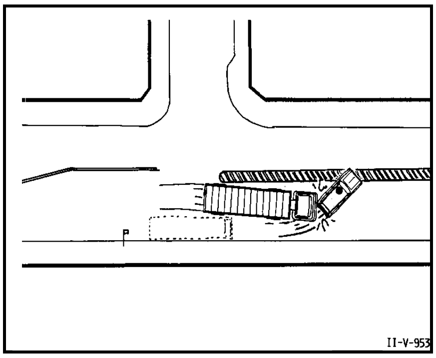
II-V-949. Female, 56, healthy, with a left side amblyopia. When turning to the left at a crossroads with traffic lights, she was in on the zebra crossing passed by a bicyclist coming from her left side and being partly hidden behind a bus. The pedestrian signal for the bicyclist had



changed to red. Examination: accident visual acuity 0.7/0.2 bin-ocularly 0.9 (without correction), correctable at 1.0/0.4. Depth perception 0. Visual field: normal. VRT: 0.77. Slit lamp investigation and ophthalmoscopy: normal. *Comment*: the behaviour of the bicyclist was indeed to blame. The role of the driver's left side amblyopia in not having noticed an unexpected road user from the left is debatable.

II-V-951. Male, 65, healthy, with hyperopia and convergent strabismus. At a crossroads he totally overlooked a moped rider from his left side partly hidden behind a car. Examination: accident visual acuity: 0.9/0.6 - binocularly 0.9 (with correction), correctable at 0.9/1.0 (hyperopia with 4 PD basis out for esophoria). Depth perception, visual fields and contrast sensitivity: normal. VRT: 0.75. A few degrees of esophoria was found. *Comment:* this patient suffered from diplopia without correction but denied having diplopia with correction. Although debatable, the combination of the obstruction of view and the non optimally corrected hyperopia in his left eye might have contributed to him overlooking the moped rider from this side.

II-V-953. Male, 73, 2 years earlier acute myocardial infarction, now in healthy condition. From a parking position he wanted to turn his car around but overlooked a truck from behind, partly hidden by a bus. Examination: accident visual acuity: 0.3 / scarcely 0.5 binocularly 0.5 (without correction). Correctable at 1.25 o.u. (+1.25/+1.75). Visual



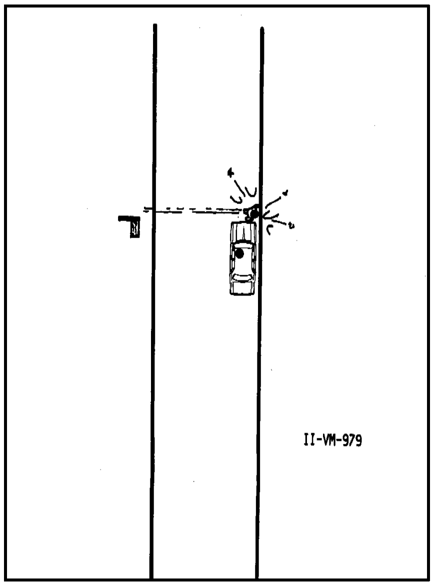
field, depth, colour and contrast perception as well as slit lamp investigation and ophthalmoscopy were all normal. VRT: 0.65. *Comment:* the driver's visual acuity being "at the limit" due to uncorrected hyperopia might have been of significance for him overlooking the lorry from behind in the mirror, although the poor view due to the bus behind, was probably of primary importance.

II-VM-973. Male, 61, with three earlier hospitalizations for AMI and one for right sided hemiparesis. When turning to the right from a main road he overlooked a bicyclist on the bicycle path coming from behind at high speed. Accident visual acuity: 0.4/0.6 - 0.6 (without correction) or with used correction: 1.0/0.9. The car driver was unsure whether he had used or not used his spectacles;- he often removed them when turning due to heavy side bars. Visual field including compu-terized perimetry: normal. Stereopsis, colour and contrast perception as well as Amsler chart: normal. VRT: 0.8. *Comment:* whether using his glasses or not he had visual problems on the right side, since visual acuity was 0.4 without correction. With correction he had a scotoma from the side bars. New spectacle frames were recommended.

II-VM-974. See IV.

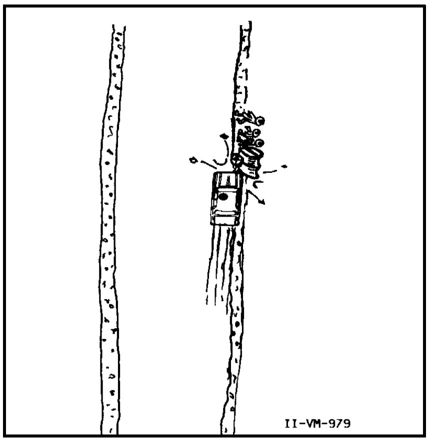
II-VM-979. Male, 51, taxi driver. When he was 14, he suffered a severe skull lesion (from a spade). Now in healthy condition. In the situation in question he hit a pedestrian, crossing the road from the left side, with the right side of the car (illustration above).

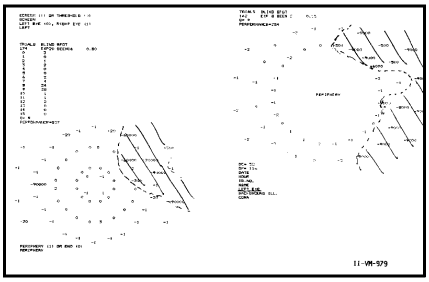
The weather was misty, and statably he therefore noticed the pedestrian, dressed

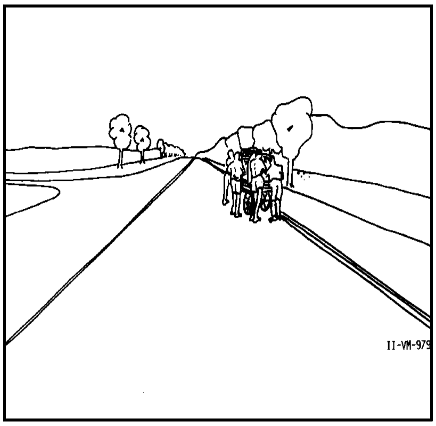


in grey, too late and did not brake in time (the road was slippery).

Twenty-five years earlier he had been involved in a very serious accident, having overlooked 3 scouts pulling a cart on the right side of the road. (Ill.).
Examination: accident visual acuity: 0.8/0.7-0.8. Correctable at 0.9 bilaterally.

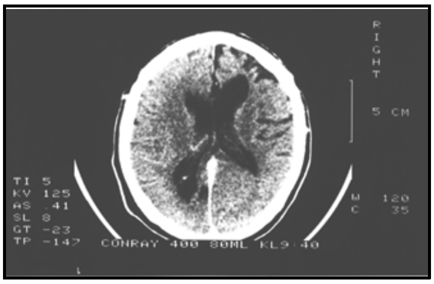






Visual field by hand: partial right side, homonymous hemianopsia, confirmed by *computerized perimetry*.

Depth perception was moderately

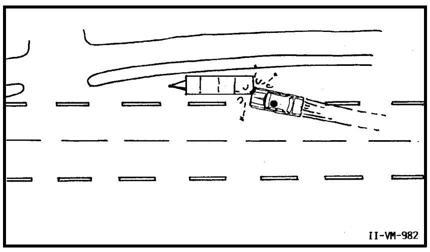


reduced (3). Colour perception: protanopia. Contrast sensitivity: 82. VRT: 0.77. Amsler grid: normal. Neuro-ophthalmological investigation revealed reduced optokinetic nystagmus from the right and slight fixation nystagmus. Neurological examination revealed a right side ataxia. *Comment:* under the misty weather condition he miscalculated the pedestrian's position. Since the collision happened in the right side of the visual field, a coincidence with the visual field defect in that side might have been a contributory factor. The accident which happened 25 years earlier is of special interest. A comparison between the visual fields (ill.) and the reconstructed picture (ill. from photography) made a causal relationship of this earlier severe accident highly probable.

In order to exclude a cerebral tumour a *CT-scan* was performed. This revealed a central and cortical atrophy including a localized infarction in the left occipital lobe (contra-coup lesion?) and at the right frontal pole due to the lesion of the skull trauma. No tumour was found (ill.).

II-VM-982. Male, 50, suffering from alcohol abuse and depressions for many years. Earlier pseudo-suicidal attempt. In a depressive state of mind, without using his glasses and in rainy darkness he drove into a parked non-illuminated trailer. Statably he wanted to turn to the right passing the trailer.

Examination: accident visual acuity: 0.2/0.3, binocularly 0.4. Correctable at 1.0/1.25 (+3.5/+1.5). Other visual parameters were all normal. VRT: 0.58. (Blood alcohol: 0,3 ‰). *Comment:* further examinations including contact to a psychiatrist gave no safe evidence for



pseudo-suicidal attempt, but this possibility could not be excluded. The combination of an non-illuminated parked trailer in an unlit dark place, the rain and driving with vision far below the legal level without correction might be of importance too. (Ill.).

II-V-988. Male, 73, earlier hospitalized for gastrointestinal complaints. He had increasing problems with glare. On a winter afternoon in January with low sun he was blinded, partly because of steam and ice on the windscreen, partly by the sun. He misjudged the icy road and skidded into a lamp post. Examination: visual acuity: 0.9/0.8, binocularly 1.0 (with correction) without further improvements. Ishihara test: protanopia. Contrast sensitivity 86. VRT: 0.63. Slit lamp investigation showed incipient cortical cataract. *Comment:* although the visual acuity fulfilled the demands, the slight cataract in combination with poor view may have been of importance in him being blinded and thus misjudging the icy road.

III. Accident-involved car drivers with visual problems in which an association to the traffic accident was classified as unlikely.

a) Drivers with illegal visual acuity.
b) Drivers with severe reduction of vision in one eye.
c) Drivers with other known visual problems.

a) Drivers with illegal visual acuity (N=2):

III-V-60. Male, 48. Healthy apart from migraine. In clear daylight, while stopping and waiting for the traffic, he was hit by a bicyclist from the left side (illegal direction in one-way traffic). Examination: accident visual acuity: 0.4/0.4, - binocularly 0.6 (without correction). Correctable at 1.0 o.u. (+2 o.u.). Further eye examinations were all normal including the visual fields.

III-V-163. Female, 58, healthy. In daylight she met a bicyclist, who on the right side of the car suddenly lost control of the bicycle and made a curve into the car. Examination: accident visual acuity: 0.4/0.4, binocularly 0.5 without correction, correctable at 1.0 o.u. All other visual parameters normal. VRT: 0.74. *Comment:* the behaviour of the bicyclist is estimated to be the probable cause of this accident.

b) Drivers with unilateral visual reduction (N= 6), cf. table 4.12:

III-V-182. Male, 23, since childhood suffering from right sided amblyopia, operated for strabismus. In an overtaking manoeuvre he hit a pedestrian walking on the opposite (left) side of the road. The accident happened in clear darkness with no illuminations. The pedestrian was wearing a very small reflective tag. Examination: accident visual acuity: 0.1/ 1.0, binocularly 0.67 with correction (+7.5/+8). Visual field and colour perception: normal. Depth perception: (0). Amsler chart revealed scotoma on the right eye. Contrast sensitivity: 74. VRT: 0.46. The patient had a severe, 40 degrees divergent strabismus in his right eye. *Comment*: In spite of a severe right side amblyopia and strabismus, no causal relationship between the visual problems and the dark accident can be directly argued for. The severely reduced depth perception might (however) be of some importance. The patient was referred to strabismus operation.

VMA-301 see IV-VMA-301.

III-V-453. (See also **II-V-454**). Female, 20. Since childhood right sided amblyopia. In heavy traffic, she was overlooked by a car (II-V-454) driver coming from a side road on her left side. Examination: Accident visual acuity: 0.1/0.9- 1.0 (without correction), correctable at 0.1/1.25). Depth perception = 0. Amsler chart revealed a right sided central scotoma. Extrafoveal fixation was found at ophthalmoscopy. *Comments:* The pathological findings in this road user is not estimated to be of any significant importance to the accident.

III-V-540. Male, 44, healthy. Involved in a pile-up caused by a police motor bike passing transversely. Accident visual acuity: 1.0/0.1 binocularly 1.0 (without correction), correctable at 1.0/0.9 (left side hyperopic astigmatism). VRT: 0.67, depth perception, visual field, colour perception and contrast sensitivity all normal.

III-V-608. Male, 22, with convergent strabismus (as a child). Involved in a pile-up at too high speed. Examination: accident visual acuity: 0.1/1.0, binocularly 1.0. Correctable at 0.9/1.0 (right side 3 D myopia). Depth perception 0. Red/green colour blindness. VRT: 0.73. Ophthalmoscopy showed myopic fundus in the right eye.

III-V-997. Male, 70, treated for bronchitis. Passing a crossroads he drove into a parked car which he had overlooked. The wind screen was dewy and covered with ice. Examination: accident visual acuity: 0.8/0.2 binocularly 0.8. Correctable at 1.0/0.5 (astigmatic hyperopia). Contrast sensitivity 95. Visual field normal. Depth perception reduced (2), colour perception slightly reduced. Ophthalmoscopy revealed left side macular degeneration, Amsler chart showed slight paracentral scotoma in the left eye. No cataract was found by slit lamp investigation. *Comment:* although the patient had some visual problems, the primary cause for this accident is estimated to be the unclear wind screen.

c) Drivers with other known visual problems (N=3).

III-V-72. Male, 38, with known glaucoma for the last 2 years. Treated with Timolol. A car driver (male 63) from the opposite side made a curve to the left directly in front of part 1. Examination: accident visual acuity: 1.0/1.25 - binocularly 1.25 with correction. Computerized perimetry showed small arcuate glaucoma scotomas downward, nasally located in both eyes. Applanation tonometry: 20/24. Ophthalmoscopy: the optic discs on both sides had slightly glaucomatous excavations and on his left side sequels following a branch vein thrombosis. Stereopsis, colour perception and contrast sensitivity (67) all normal. VRT: 0.40. *Comment:* although this driver had juvenile glaucoma in both eyes and a branch vein thrombosis in his left eye, the behaviour of the counterpart (with no visual problems) was estimated to be the probable cause of this accident.

III-V-941. Female, 73, with myopia. Twice operated for breast cancer and twice on both hips a.m. Charnley. Treated for Hashimoto's myxedema. In dense traffic an 11-year-old bicyclist drove into the right side of her car coming from behind. The bicyclist's hand was injured. Examination: accident visual acuity: 0.4/0.5,- binocularly 0.5 (with -4.5 sph. () -3 cyl/ -1.5 sph. () -5 cyl), improvable to 0.5/0.5 binocularly 0.5. Visual fields, depth perception, and colour perception as well as contrast sensitivity normal. VRT = 0.94. Amsler chart with small scotomas in the right eye. Slit lamp investigation and ophthalmoscopy revealed slight cataract in both eyes and slight myopic degenerations in the posterior poles. *Comment:* neither the history of general diseases nor the visual problems of the driver were estimated to be of any importance in this accident.

III-V-955. Male, 50, with trauma to the right eye 12 years earlier. At a crossroads he was suddenly met from the right side by a bicyclist who went through the red light. Examination: accident visual acuity: 0.8/1.25 binocularly 1.25 (without correction or improvement). Computerized perimetry showed a small horizontal scotoma in the centre of the right side. Ishihara test: protanopia. Contrast sensitivity: 69. VRT: 0.75. Amsler chart confirmed the scotoma below the centre. Depth perception close to normal (7). Ophthalmoscopy revealed right side optic atrophy. No cataract was found. *Comment:* the visual field problem in the lower central part of the right eye is not estimated to have been of any importance in this case.

IV. Medical cases

Cases in which medical problems, alcohol and drug abuse might be important etiological co-factors in relation to the traffic accidents: (N=43)

1.) Drivers.

A. Drugs or alcohol involved (N=22):

IV-MA-005. Male, 32, healthy. At 2.25 a.m. having consumed 6 drinks, he lost control of his car on an icy road, on which he was alone, and drove into a tree. Examination: Accident visual acuity: 0.67/0.5 - binocularly 0.67, correctable at 1.0/0.67 (slightly myopic). Further visual parameters normal. VRT: 0.77. Blood alcohol: 2.11‰. *Comment:*

His lack of control of the car was primarily seen as due to the influence of alcohol.

IV-MA-061. Male, 29, healthy. Under the influence of alcohol he lost control of his car and drove into the ditch. He did not use his seat belt and had a severe concussion. Examination: Accident visual acuity: 1.0 o.u. (without correction). Further visual parameters normal. VRT: 0.77. *Comment:* The influence of alcohol seemed to be an important co-factor in this accident.

IV-MA-104. Male, 37, with severe social problems, partly due to alcohol intake. With no driver's license, he drove through red light and on a wet road in clear twilight, severely injured a pedestrian in a zebra-crossing. Examination: He refused to participate. No information of visual parameters available. Blood alcohol: 2.38‰. *Comment:* The case emphasizes the well-known and tragic role of alcoholism in relation to car driving.

IV-MA-106. Female, 41, who was treated for vein thrombosis in her right leg with Dicumarol and Diazepam 5-10 mg per day. After having had some drinks she lost control of her car. At a wet crossroads in clear daylight she drove directly into a lorry. She was severely injured. Examination: all visual parameters normal. *Comment:* her loss of control is estimated to be primarily due to her alcohol intoxication, blood alcohol concentration: 0.86‰.

IV-VMA-160. Male, 28, mentally retarded. Having consumed three drinks, he skidded into a tree in darkness on a wet, straight road. Examination: accident visual acuity 0.5/0.5, binocularly 0.67 (without correction). Correctable at 1.0 binocularly (myopia). VRT: 1.13, other visual parameters: normal. Blood alcohol concentration was 0.92 ‰. *Comment:* the alcohol consumption was probably the primary cause, but the road surface has possibly been misjudged, due to the uncorrected night myopia (-0.75/-0.5).

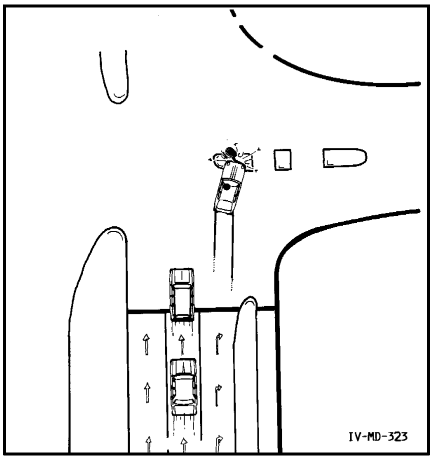
IV-VMA-301.Male, 43, with left side amblyopia since childhood, having difficulties in driving at night. He had consumed 3 drinks prior to the accident and had not slept the night before. In clear daylight, on a wet road, he drove into a queue of cars, possibly because he fell asleep. Examination: blood alcohol concentration: 1.31 ‰. Accident visual acuity: 1.0/0.2 - binocularly 0.9 (without correction). Correctable at 1.0/1.0 (left side - myopia). VRT: 0.58. Contrast sensitivity 78. Visual field and colour perception normal. Depth perception reduced (3). *Comment:* tiredness and alcohol intake seemed to be the dominating causes for this accident. The reduced visual acuity in the left eye is estimated not to have been contributory in this accident.

IV-MA-303. Male, 32 with chronic abuse of alcohol. Several times investigated for right sided sensory disturbances (paresthesias). CT-scan and cerebral X-ray arteriograms have been normal. Since the day before the accident he had consumed 19 drinks. He lost control of his car and drove into the ditch. No counterparts. Visual parameters revealed red/green colour blindness (unknown) and a small bitemporal upper quadrant anopsia. A repeated CT-scan was normal. VRT: 0.75. *Comment*: alcohol consumption and tiredness are estimated to be the important causal factors in this non-police-reported case.

IV-MDA-319. Male, 39. Treated in a psychiatric department for periodic alcoholism and reactive psychosis. His driver's license was withdrawn because of drunken driving. After having drunk 7 beers and taken 5 tablets of Diazepam, each 5 mg, he was involved in two accidents while driving a former girlfriend's car, which he had stolen. First he hit the rear end of one car, which he overtook, however. A few minutes later he continued and then drove into the rear end of another car which was stopping at a crossroads. A passenger in this car suffered a neck lesion. The driver refused to participate in the investigation. No information was available on visual parameters. Blood alcohol: 1.29 ‰. *Comment:* chronic alcoholism and drug abuse seem to be important problems in traffic medicine.

IV-MD-323. Male, 46, with a psychiatric history and use of psycho-pharmacological drugs. Before the accident, moderate alcohol consumption. In clear darkness he drove straight into a signal at a crossroads at high speed. In the hours before he had taken Lexotan (Bromazepam) 6 mg x 2 and Halcion (Triazolam) 0.5 mg x 2. He reported to be influenced by the drugs at the time of the accident, which to some extent was confirmed at a clinical examination.

Accident visual acuity: 1.0 with correction in both eyes. Other visual parameters were all normal. Blood



Triazolam: 0.02 mmol/kg and Bromazepam 0.3 mmol/kg. Blood alcohol 0.05 ‰. *Comment:* lethargy due to drug influence and to a lesser extent intake of alcohol are seen as primary causes of the accident in this case. No suicidal attempt was suspected.

IV-MD-492. Male 63, controlled for cataract over 8 years. He had moderate osteochondrosis in his cervical spine. He was treated with Nordotol (Carbamazepin) 500 mg a day, Temesta (Lorazepam) 2.5 mg x 3, Truxal (Chlorprotixen) 15 mg x 4, Rohypnol (Flunitrazepam) 1 mg at night and Panodil (Paracetamol) 500 mg x 4. At a crossroads, he was overlooked by a car driver turning to the left in the opposite direction. Examination: Accident visual acuity: 1.0/0.7 (with correction for hyperopia). Slit lamp investigation revealed slight cataract in both eyes, mostly on the left side. Contrast sensitivity= 58. Amsler chart revealed a central scotoma on the left side. VRT:

1.04 (prolonged). The mobility in the cervical spine was estimated sufficient. *Comment:* Although this patient had a high level of medicine intake, no correlation to the accident seemed likely, neither with respect to the visual problems nor the intake of medication.

IV-MD-495. Female, 17. Five years of drug abuse (Heroin). At a crossroads she drove through a red light and straight into a car turning left. She refused to participate. Information from her general practitioner revealed normal visual acuity in both eyes (at the 5 year examination!). Alcohol consumption was not suspected. No blood test for drugs was taken. The information on the drug consumption prior to the accident was rather unreliable. *Comment:* information insufficient. Drug abuse cannot be eliminated as a contributory factor. Also the lack of a driver's license and driving lessons should be mentioned as important factors.

VMA-534 (see II).

IV-MD-560. Male, 27. During the last 12 years treated for epilepsy. In the year before the accident he had had two epileptic attacks related to strain, but statably never in relation to car driving. He was treated with Phenytoin (phenobarbital) 100 mg x 3. On a main road he overlooked an overtaking motorcyclist as he was turning the car to the left. Examination: Accident visual acuity: 1.25 in both eyes; all visual parameters normal. VRT: 1.05 (prolonged). *Comment:* An epileptic attack in relation to the accident was not suspected. The influence of Phenytoin is unlikely as an important factor. However, the visual reaction time was in the upper end of the normal scale (cf. table 10.2).

IV-MA-600. See II-V-599.

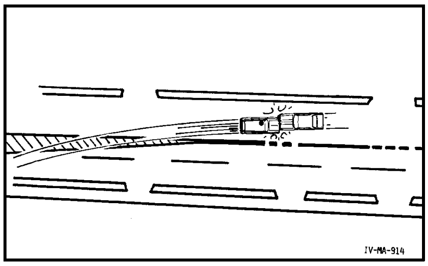
IV-MA-626. Male, 35, healthy. In the course of 9 hours he had at least 14 drinks and then at 2 a.m., on a wet road in rainy darkness, he lost control of his car and drove into a parked lorry. A passenger's cervical spine was injured. Examination: Accident visual acuity: 1.0 without correction in both eyes. Apart from a small pterygium, not affecting the corneas, the eye examination was normal. Blood alcohol: 1.91‰. *Comment*: The role of the alcohol influence is obvious.

IV-MD-63l. *Part 1*: Male 38, disabled due to morbus Crohn, treated with Imodium (Loperamid) 2-3 capsules per day and Questran (Colestyramin) l dose a day. In rain and clear twilight, on a wet road, he was inattentive while adjusting the radio and talking to a passenger. Too late he noticed the stop lights of a car waiting for a lorry which was approaching from the opposite direction to turn to the left. The waiting car was pushed into the opposite side of the road in front of the lorry. The female driver was severely injured. Six hours before the accident part I had taken 30-40 drops of opium (50-70 mg opium) for his disease. Examination: accident visual acuity: 1.0 o.u. (without correction). Further visual parameters all normal. VRT = 0.76. *Comment:* The non-awareness in part 1 might to some extent be correlated to his intake of fatiguing medicine (opium), although a direct relationship with this low level is unlikely. Furthermore, the brakes of the lorry turned out to be partly defective.

IV-MA-875. Male, 33, healthy. Prior to the accident he had taken 8 drinks. In a curve, at 4.48 a.m., he skidded with his car on a dark dry road in clear weather. The car rolled over several times. The driver's and the front passenger's seat belts had been fastened. Two passengers on the rear seat was not wearing seat belts. All passengers and the driver were able to leave the car before it burned out. Examination: the visual parameters of the driver were all normal including visual field and visual acuity. Blood alcohol: 1.37 ‰. *Comment:* alcohol consumption is estimated to be the primary cause. This case proves that even in case of burning cars it is of important to be fastened by a seat belt, as it increases the chances of performing safe escape manoeuvres.

IV-MA-901. *Part 1.* Male, 60, adipose, with unknown alcohol consumption. He was killed in an accident on a dry road in clear darkness. *Part 2*, a lorry-driver, approaching downhill from the opposite direction braked for a car and drove directly onto the opposite side of the road due to defective brakes. Examination: the lorry driver had normal health and visual parameters. The blood alcohol concentration of the dead driver was 1.39 ‰, the liver biopsy revealed liver steathosis. *Comment:* although part 1 was intoxicated, this accident was primarily due to defective brakes on the lorry.

IV-MA-914 *Part 1.* Female, 38, with known alcohol abuse. One week before the accident she consulted a neurologist for an isolated epileptic attack. A divorce case was running. On the day of the accident she had been drinking heavily. In clear darkness she was seen driving at 100 km/h with a wavering course. After a transient reduction of speed she suddenly accelerated to 130 km/h and turned onto the opposite side of the road and collided with a confronting school bus, which was pushed for 20 metres. Part 1 was killed on spot. *Part 2*, a 21

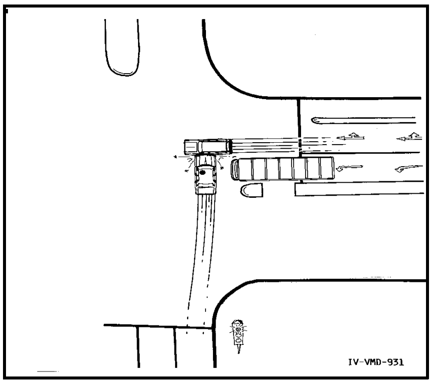


year-old female was seriously injured with fractures to the cervical spine. In the car of part 1 an empty whisky bottle was found. Blood alcohol concentration: 2.43‰! *Comment*: the severe alcohol consumption, possibly aggravated by the marriage problems, is estimated to be the primary cause of this accident. It is unclear whether an epileptic attack had been released at the moment of the accident. Her general practitioner found suicide unlikely. Autopsy revealed no pathological findings in the cerebrum. Fracture of dens epistrophei with lesion of the medulla oblongata was found to be the direct cause of death. The serious consequences of permitting car drivers with a known chronic alcohol abuse to continue driving is emphasized.

IV-VMD-931. Male, 57. Treated with Frisium (Clobazam) 5+5+10 mg and Fenemal (Phenobarbital) 150+150+100 mg for epilepsy. CT-scan performed 1 year prior to the accident was normal.

EEG showed sharp waves in the left fronto-temporal region. On a clear day on a wet road he drove through the red lights and overlooked a car coming from his right side partly hidden behind a lorry.

Examination: accident visual acuity: 0.5/0.4, binocularly 0.6 (without correction), correctable at 1.0 o.u. (+1 sph. o.u.). VRT: 0.87. Visual field including



computerized perimetry: normal. Contrastsensitivity: 79. Ophthalmoscopy revealed severe retinal arteriosclerosis. Prior to the accident he had had one drink. *Comment:* the uncorrected hyperopia might have been contributed to him overlooking the traffic lights, although a TIA or a small epileptic attack were the most probable factors. The high intake of antiepileptic drugs with a hypnotic effect should be kept in mind.

IV-MA-967. Male, 52, disabled because of excessive intake of alcohol. Five years earlier operated for lumbar disc herniation. In clear daylight on a wet road, after having had some drinks he lost control of his car and drove into a road sign. Severely injured he died 7 months later. (Blood alcohol: 1.38‰).

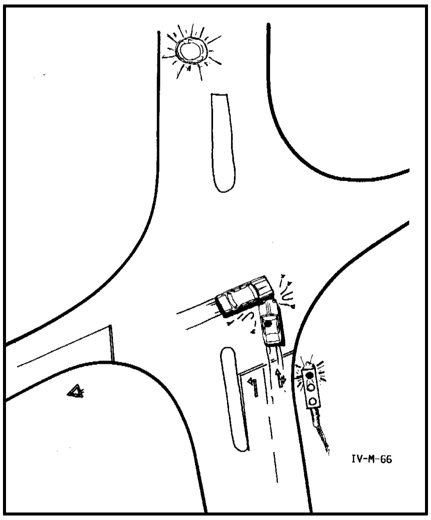
IV-MAV-996. Male, 54, healthy. In 3 1/2 hours he had had 5 drinks. On an icy road, in clear darkness, at 4 a.m. he lost control of his car and drove into a house. He was alone in the car. Examination: Accident visual acuity: 0.90/1.0, correctable at 1.0/1.25 with correction for hyperopic astigmatism. Ishihara colour-test revealed deuteranopia, and ophthalmoscopy revealed a chorioretinal scar in the right posterior pole as well as a slight cataract, due to an earlier uveitis. Blood alcohol: 1.26 ‰. *Comment:* Although this driver said that he had overlooked the icy road conditions and had small visual disturbances due to an earlier uveitis, the influence of alcohol is estimated as the primary cause in this accident.

B) Medical disorders (N=18):

IV-M-55. Male, 77. Twenty-five years and two years ago he had acute myocardial infarction. For one year type II diabetes. Coming from a side-road he overlooked a car from the left at a crossroads and drove out in front of it. Examination: accident visual acuity 1.0/0.67, binocularly 1.0 (with correction)- without improvement. Visual fields normal. VRT: 0.87. Contrastsensitivity: 84. Colour and depth perception normal. Ophthalmoscopy showed no diabetic retinopathy. No cataract was found. By medical examination a severely reduced mobility of the cervical columna was found. *Comment:* the reason for overlooking the car coming from the left is rather unclear. A cerebral TIA cannot be excluded. The reduced mobility of the cervical columna might be an important contributory factor too.

IV-M-66. Male, 69. Eighteen years earlier he had a right side lobectomy for pulmonary cancer, since then in healthy condition. On a sunny afternoon he drove through the red lights at a crossroads, possibly blinded by the sun. He drove directly into a car coming from the left. Examination: accident visual acuity: 0.6/0.6 - binocularly 0.6 with correction, correctable at 0.67 o.u. (hyperopia). VRT: 0.63. Ishihara test revealed red/green blindness. Visual field tested by hand: normal. By computerized perimetry a small scotoma in the temporal periphery of the right eye was found. No cataract was found by slit lamp examination. The ocular fundi were normal on both sides. *Comment:* a mild transitoric ischaemic (TIA) attack might possibly explain this accident. The driver had amnesia with respect to the accident. The following four years he showed no signs of cerebral or other metastasis. Insufficiency of his vertebral arteries was diagnosed after 5 years.

IV-M-117. Female, 64. Five years earlier



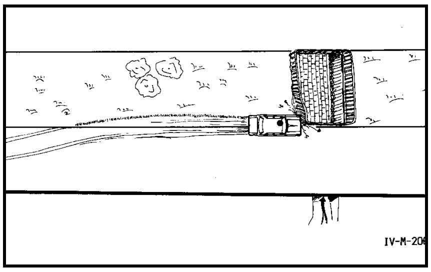
treated at home for "cerebral haemorrhage". Since then she had vascular problems in the right leg. On the day of accident she overlooked a bicyclist coming from the opposite side when turning to the left at a T-cross. Examination: accident visual acuity: 0.67 (with correction) in both eyes. Visual field by hand and tangent screen: normal. Contrast sensitivity 69. VRT: 0.94. Ophthalmoscopy revealed severe retinal arteriosclerosis. *Comment*: no external or visual factors could explain her overlooking the bicyclist. The use of glasses at the time of accident was assured by the driver. She felt her attention was diverted by another car. The general arteriosclerosis might be of some importance, although the VRT was close to the mean value.

VM-141. See I.

VMA-160. See IV-A.

IV-M-206. Male, 67. The last 4 months several TIA's with left side ataxia, dysphasia, diplopia and paresthesias. At the department of neurology a CT-scan showed a suspected infarct in the right parietal hemisphere. He was treated with Acetyl salicyl acid (ASA), Dicumarol, Isoprenalin and Nitroglycerine. In clear daylight he suddenly changed direction into the centre strip of the main road and hit a grill net. He was alone in the car and he had amnesia concerning the accident.

The traffic behaviour was interpreted as an epileptic grand mal or a TIA. Due to



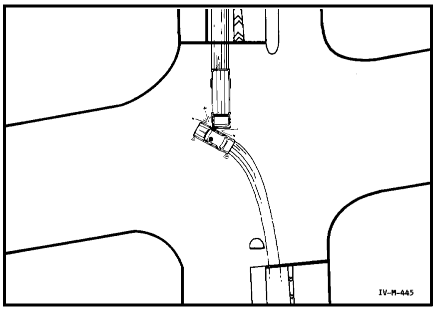
increasing left side paresis and tendency to falling, he was hospitalized a few days later, and CT-scan revealed that the "infarction" was really a tumour. Examination: (information from ophthalmological department). Accident visual acuity: 0.8 o.u. (probably with corrections). Ophthalmoscopy showed small retinal drusen. Visual field for hand: normal, but he had a left side simultaneous visual agnosia. The patient was operated for a malignant glioblastoma in his right hemisphere, but died half a year later. *Comment:* This individual accident was due to an epileptic attack or TIA secondary to a growing tumour in his right hemisphere.

IV-VM-384. Male, 71. Eleven-year-old skull fracture due to a horse accident. Five years earlier acute myocardial infarction. At a crossroads he broke the rule to give way to on-coming traffic, overlooking a car from the left, which was partly hidden behind a house near the road. Examination: accident visual acuity: 0.6/0.6 binocularly 0.6 without correction. Correctable at 0.8/0.9 (hyperopia). Contrast sensitivity: 97. Colour perception: normal. VRT: severely prolonged (1.67). Ophthalmoscopy showed moderate retinal arteriosclerosis. Intraocular tension and slit lamp investigation normal. *Comment*: the driver overlooking the car coming from the left was probably due to 1) general arteriosclerosis (with prolonged VRT), 2) obstructed view due to a house and possibly 3) uncorrected hyperopia with reduced visual acuity (above legal limit).

VM-401. See II.

IV-M-445. Male, 77, treated with ASA for general arteriosclerosis. At a crossroads, waiting to turn to the left, he moved the car too late to prevent a collision with an approaching lorry, which was driving too fast (70 km/h).

Examination: accident visual acuity: 0.9/0.8 binocularly 0.9 (without correction, not improvable). Visual fields: normal. Contrast sensitivity: 90. Depth perception reduced (2). Colour perception slightly reduced. VRT: 2.34 (sic!), estimated as a mean of 10 tests. No scotomas were found on the Amsler chart. Ophthalmoscopy revealed a slight macular degeneration on both eyes. No cataract



or glaucoma was found. *Comment:* in this aged driver the extremely slow reaction time (2.34 sec., cf. table 10.2) was estimated as an important reason for a false evaluation and dangerous behaviour in the traffic situation. Also the reduced depth perception should be mentioned.

IV-M-455. Female, 29. Six years earlier hospitalized for cephalalgia vasomotorica, treated with Dihydroergotamin. Four years ago involved in a traffic accident, in which she suffered a concussion. Since then recurrent faintings and drop attacks in various situations, including car driving. Her husband had once, as a passenger, prevented a serious accident by intervening. In the situation in question, in a curve on a clear day with a dry road surface, she swerved into the ditch. Just before, statably, she had suffered an attack of unconsciousness. Examination: accident visual acuity and all visual parameters were normal. The patient was referred to neurological department. EEG, X-ray of the skull and electrolytes in the blood as well as blood glucose level were found to be normal. She was treated with Dihydroergotamine and apparently she was without any symptoms for a long period. *Comment:* the case was interpreted as migrainoid cephalalgia basilaris. Probably a psycho infantile constitution was of significance too.

VM-562. See II.

VM-904. See II.

VM-924. See I.

VM-929. See I.

VM-936. See II.

IV-VM-974. Male, 69, receiving treatment for Parkinson's disease with Madopar (Levodopa) 250 mg x 4, Alival (Nomifensin) 25 mg and Amantadin 50 micrograms per day. In a crossroads, when turning to the left, he overlooked a car approaching from the opposite side. He refused to participate in the investigation. Information obtained from neurologist and eye practitioner. Visual acuity 3 years earlier (with correction: 0.67 in both eyes (+5.5 () -1.25 cyl./ +3.5 (-0.5 cyl). Visual field by hand: examined 3 years before the accident: normal. Further information unavailable. His driver's license was withdrawn by the police. *Comment:* both the neurological disorder and visual problems (his use of glasses was unknown) might have contributed to him having overlooked the confronting car in this case. Lings (1987) has showed that patients with Parkinson's disease have reduced traffic ability when tested in a mock car.

VM-979. See II.

VM-982. See II.

2.) Unprotected road users (N=3):

a. General diseases:

IV-M-575. Male, 27. Diabetes for 20 years diabetes treated with insulin and for 14 years treated for epilepsy. In clear daylight, standing at the side of the road, he suddenly got a grand mal attack during which he fell onto the road in front of a bus and was run over. Examination: at the casualty ward a low blood glucose level was found (5.4 mmol/l). *Comment:* the epileptic attack was probably provoked by hypoglycemia.

b. Drug and alcohol abuse:

IV-MD-421 Male, 29, with known schizophrenia, treated with Zuclopenthixol (Cisordinol) 300 mg intramuscularly once a week and Lysantin (Orphenadin) 5 mg x 2. Driving a motorbike without a driver's license he changed direction before a T-cross and drove into a car. He refused to participate. Information obtained from ophthalmologist. Examination: accident visual acuity: 1.0 in both eyes (without correction). Visual field by hand: normal. *Comment*: the road user might to some extent have been influenced by his illness or drugs, a direct relationship is unlikely, however. Severe alcohol consumption was not suspected. He was treated in the casualty ward and not hospitalized.

IV-M-476. Male, 21, pedestrian. No known information on earlier diseases. At 3 a.m. on a dark, unlit road he was lying transversely in a curve on the right side of the road. During the hours before he had consumed at least 8 drinks. He was hit by a road user, who had no chance of avoiding a serious accident. The pedestrian was killed on the spot. Examination: blood alcohol: 2.13‰. (The patient had known myopia (-1.75 / -1,25 sph.)). *Comment:* a peculiar psychiatric behaviour in combination with alcohol consumption was estimated to be the primary cause. - Suicide seems probable. The driver's visual parameters were all normal.

V: Drivers in the control group with noticeable visual problems (N=7).

V-C-743. Male, 52, healthy. Used glasses for watching TV but not for driving. Visual acuity: 0.4/0.3 - binocularly 0.5. Correctable at 1.5 in both eyes (+1.25/ +2()-0.5). Other visual parameters all normal. Contrast sensitivity 72. VRT: 0.73. *Comment:* typical case of hyperopic driver with "illegal" visual acuity without corrections.

V-C-751. Male, 54. 16 years earlier trauma to the right eye. Disabled due to rheumatism, treated with Dextroproproxifen 165 mg 4 and Ketobemidone (Ketogan) 10 tablets per month. He used glasses only when watching TV, not for driving. Examination: visual acuity: 0.05/0.4 (without correction). Correctable at 1.0/1.25 (myopia -2.5/-1.5). Further visual parameters all normal. *Comment:* myopic driver, with vision below the legal limit without correction and perfectly normal with correction. In danger in darkness and in difficult, unexpected situations.

V-C-788. Male, 65, car dealer, healthy. Normally he would drive without correction (which he used when watching TV). Visual acuity: 0.2 in both eyes, binocularly 0.2. Correctable at 1.0 o.u. (hyperopia +1.75 sph.). Further visual parameters normal. *Comment:* moderate hyperopia with uncorrected visual acuity far below the legal limit.

V-C-828. Male, 76, treated for asthma with Prednisolon. Three years ago he had suffered a left side central vein thrombosis. Information from ophthalmologist: visual acuity: 0.6/0.1 (with correction: +10.5 sph. () -3 cyl./+10 sph. () -3.75 cyl.). Ophthalmoscopy revealed sequels after the central vein thrombosis. Visual fields by hand: normal in both eyes. *Comment:* severe hyperopia with visual acuity at the limit, primarily due to the central vein thrombosis.

V-C-831. Male, 79. Three years earlier he had AMI without sequels and one year earlier right side peroneus paresis. For the last 7 years decreasing visual acuity. Normally he did not use glasses for driving. Visual acuity: 0.05/0.2, binocularly 0.2 (without correction). Correctable at 0.2/0.4 (+2.25 sph.() -1 cyl./ +3 sph.() -0.75 sph.). Central field tested by Amsler chart revealed paracentral scotoma in both eyes. Contrast sensitivity: 58. Colour perception reduced, especially in the right eye. Ophthalmoscopy revealed bilateral macular degeneration with a macular hole in the right eye. *Comment:* This man drove 5,000 km per year. He denied having had any accidents. Visual acuity far below the legal limit. He was warned against driving.

V-C-833. Male, 79, earlier treated for an ulnar paresis. He often drove without correction. Examination: visual acuity: 0.3/0.4, binocularly 0.4 (without correction). Correctable at 0.9 o.u. (+2.25 sph. () -1.5 cyl./+2 sph. () -0.75 sph.). Further visual parameters were all normal. No cataract or macular degeneration. *Comment*: hyperopia with uncorrected visual acuity below the lawful limit. Nearly fully correctable.

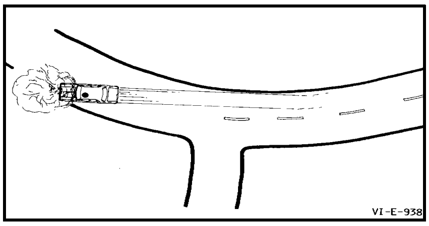
V-C-800. Male, 67, prostatectomy 3 years ago. For the last 2 years he had observed decreasing vision in his left eye but had not yet consulted an ophthalmologist. Normally he drove without glasses. Examination: visual acuity 0.8/0.2 - binocularly 0.9 without correction. Correctable at 1.25/0.2 (+1 sph.). Visual field, even when tested a.m. Donders, was severely reduced in the left eye and to a lesser extent in the right eye (computerized perimetry). Contrast sensitivity: 78. VRT: 0.8. Ophthalmoscopy revealed a slight excavation of the right optic nerve and a nearly complete excavation in the left eye. Applanation tonometry: 22/23 mm Hg. A left side amblyopic pupillary reaction was found. *Comment:* undiagnosed, nearly complete glaucoma in the left eye, and beginning visual defect (nasal step) in the right eye too. Visual field in the right eye was compatible with driving in the future, provided it was continuously controlled by an ophthalmologist.

* * *

In the control group another 4 drivers (789, 790, 778, 825) had *undiagnosed glaucoma*. 1. male, 65, secondary to anterior chamber lens implantation after cataract surgery. 2. male, 65, glaucoma simplex. 3. male, 62, glaucoma simplex and 4. male, 77, glaucoma simplex. In the accident group at least one driver had undiagnosed glaucoma (cf. II-VM-401). *Comment:* an earlier and more thorough examination of drivers (including computerized visual field screening) might probably result in the detection of a number of undiagnosed glaucoma patients!

VI. Accidents with external visual factors:

VI-E-938 As an example, one case will be described: Male, 58, healthy. In a "wall of fog", in a right curve, he slowly followed the white stripes in the middle of the road which suddenly ceased. He lost his bearings and drove straight into a



tree on the other side of the road.

A moderate contusion to the thorax was the result (he used the seat belt). Accident visual acuity: 0.4/0.9 binocularly 0.9 without correction, improvable at 0.9 in both eyes (+0.75/+0.5). Further visual parameters all normal. *Comment:* the sudden discontinuation of the stripes in the middle of a curve, in a difficult visibility situation, is an important cause of this accident and a typical external visual factor.

(See also **II-V-499**)

VII. An accident in which good visual performance in a difficult and dangerous situation probably prevented a more serious outcome.

VII-V-416. Male, 47, healthy. In clear weather, in a curve, he saw a pedestrian behind a parked car in the right side of the road on his way to the opposite side. After having noticed that the pedestrian behind the car absent-mindedly failed to see him, he braked resulting in "only" one of the pedestrian's legs being injured. Examination: accident visual acuity: 1.0/0.7 binocularly: 1.25 without improvement. All other investigations normal. VRT: 0.85. The visual parameters of the pedestrian were normal. *Comment:* in the statistical evaluation this accident was classified: vision/accident association: unlikely. In this connection, however, it is mentioned as a "positive case", because the good vision and imagination of the driver made him brake in time to prevent a more serious, if not fatal, outcome of the accident.

C.3. Individual analysis of a possible or probable association between the traffic accidents and visual problems of the car drivers.

In the case-control study (cf. chapter 4.2) the question of an association between drivers' vision and the traffic accidents has been elucidated by logistic regression analysis of drivers aged ≥ 50.

Table C.1. Estimated association between the traffic accidents and visual factors in all 562 road users involved in accidents (phase I and II) (Alsbirk, 1999).

Visual factors in the road users as co-etiology:	Drivers <50 yrs. N=249	Drivers ≥ 50 yrs. N=156	Unprotected road users N=157	Total N= 562
Unlikely :	202 (81)	97 (62)	121 (77)	420 (75)
Possible :	13 (5)	33 (21)	18 (11)	64 (11)
Probable :	0 (-)	12 (8)	4 (3)	16 (3)
Unknown :	34 (14)	14 (9)	14 (9)	62 (11)
All :	249(100)	156(100)	157 (100)	562 (100)

In each individual accident it was primarily estimated whether visual problems in the road user and/or external visibility problems might have been contributory co-factors to the crashes. Since the *human factor* of vision is in focus, the accident information has been condensed into more relevant parameters which converge at estimating any association between the individual probands' visual problems and the accidents.

Table C.1. shows the classification of the 562 accident involved road users. Such evaluations were also attempted on some of the non-responders on the basis of data collected in police reports, records of ophthalmologists, general practitioners, hospital departments and the Institute of Forensic Medicine. In 62 cases (11%) the information was too incomplete to permit an estimation.

Accordingly, the road users hereafter were roughly classified into 4 groups:

Classification:
Estimated co-association:

- **unlikely;** (i.e. an association can be almost excluded).
- **possible;** (i.e. an association can not be excluded but, on the other hand, can not be classified as probable).
- **probable;** (i.e. vision as a contributing co-factor seems likely).
- **unknown ;** (i.e. the information is too incomplete to make a proper classification).

The methods of classification were given in method chapter 3. and in appendix C.1 .

The estimated association will be analyzed in relation to:
1. Various types of road users,
2. the drivers' age,
3. visual parameters of the drivers,
4. place of accidents, and
5. car driving parameters.

1. Type of road users:
As can be seen from table C.1, an association has been esti-mated as probable in 3% (12/405) of the car drivers aged ≥ 50 and 2.5% (4/157) of the unpro-tected road users (p=1.0, Fisher's exact test). Eliminating the unknown cases these rates increases to 12/357 =3.4% in car drivers and to 4/143 = 2.8% in unprotected road users.

The estimates in the individual types of road users can be seen in table C.2, which is based on the phase I material. This phase constitutes an unrestricted sample of accidents with injury (cf. chapter 2.3.1.).
The results indicate that the importance of visual problems in various types of road users in relation to traffic accidents seem to be most important in the case of bicyclists, pedes-trians and car drivers.

In accordance with the arguments in chapter 4, the visual factors of the *drivers* have been most relevant to study in this connection. In the following analyses, this group is in focus:

2. Age:
In table C.3., the estimated association between the accidents and the visual parameters has been analyzed in relation to the drivers' age, showing that the relationship seems more pronounced with increasing age. A *probable association* was estimated to exist in none of the drivers aged < 50, in at least 4% (5/123) of the accidents with driver's aged 50-69, and in 37% (7/19) in accident-involved drivers aged 70 and above. Furthermore, a *possible association* was found in 6 % (13/215) of accidents with driver's aged < 50, in 24% (29/123) of accidents with driver's aged 50-69, and in 21% (4/19) of accidents with drivers aged 70 and above. The trends in these estimates are highly significant ($p = 10^{-6}$). When analyzing the investigated drivers of phase I only, the same tendency was found ($p < 10^{-5}$, Mann-Whitney test).

The findings somehow support the results of the descriptive study (chapter 4.1.) in which visual problems in the drivers increase significantly with age.

3. Visual parameters:
Most of the visual test parameters have been analyzed in relation to a possible vision/ accident association. In all parameters examined, (except refraction, (p> 0.8)), a highly significant surplus of drivers with low vision scores were found in the group of drivers with a probable vision/accident association compared to drivers in whom such as association was estimated unlikely.

The same trend was found concerning

Table C.2. Estimated association between the traffic accidents and visual factors in various types of road users. (Phase I: 287 accidents with 488 road users) (Alsbirk, 1999).

Associa-tion:	*Type of road users:* Car-drivers	Bicyc-lists	Pedestri-ans	Mo-peds	MC	Trac-tors	Total
Unlikely:	249 (76)	66 (79)	21 (60)	21 (84)	13(100)	2 (100)	372 (76)
Possible:	32 (10)	7 (8)	9 (26)	2 (8)	0(-)	0 (-)	50 (10)
Probable:	6 (2)	3 (4)	1 (3)	0 (-)	0(-)	0 (-)	10 (2)
Unknown:	42 (13)	8 (10)	4 (1)	2 (8)	0 (-)	0 (-)	56 (11)
Total(pct)	329(100)	84(100)	35(100)	25(100)	13(100)	2 (100)	488(100)

Table C.3. Visual problems as co-factors in 405 accident-involved drivers in relation to age (Alsbirk, 1999):

Association:	*Age groups:* 10-39	40-49	50-59	60-69	70 +	All	Mean (Range)
Unlikely	:154 (68)	48 (76)	58 (69)	31 (60)	8 (40)	299 (74)	40.3 (14-79)
Possible	: 5 (27)	8 (13)	15 (18)	14 (27)	4 (20)	46 (11)	53.6 (22-74)
Probable	: 0 (-)	0 (0)	4 (5)	1 (2)	7 (35)	12 (3)	69.4 (53-81)
Unknown	: 27 (15)	7 (11)	7 (8)	6 (12)	1 (5)	48 (12)	40.2 (18-72)
Total	:186(100)	63(100)	84(100)	52(100)	20(100)	405(100)	42.7 (14-81)

(Unlikely/ probable: $z' = 4.94$, $p \sim 10^{-6}$, Mann-Whitney test) visual reaction time (VRT) (co-association unlikely: mean = 0.73, - possible, mean = 0.85, - probable: mean = 1.0, $p< 10^{-3}$).

One must bear in mind the *risk for a systematic bias,* including elements of self fulfilling prophecies. High age is a common factor in these drivers with mutually interrelated impaired visual parameters. The

Table C.5. Types of roads on the scene of the accident in relation to the estimated association between the driver's visual problems and the accidents (N= 405 accident-involved drivers) (Alsbirk, 1999).

Association:	*Type of roads:* Crossroads	Straight roads	Curved roads	Misc.	Total
Unlikely:	184 (72)	85 (80)	20 (87)	10	299
Possible:	35 (14)	9 (8)	2 (9)	0	46
Probable:	10 (4)	1 (1)	1 (4)	0	12
Unknown:	27 (11)	11 (10)	0 (-)	10	48
Total:	256(100)	106(100)	23(100)	20	405

(crossroads vs. straight/curved roads). (z'=2.07, p< 0.05, Mann-Whitney test)

Table C. 4. Association between visual factors and the accidents in drivers in relation to static visual acuity (Alsbirk, 1999).

Visual acuity:		*Association*: Unlikely	Possible	Probable	Total
a)Monocular testing:	Illegal	2 (1)	7 (17)	6 (55)	15 (5)
	Limit	0 (-)	1 (2)	1 (9)	2 (1)
	Legal	255 (99)	33 (81)	4 (36)	292 (94)
	Total	257(100)	41(100)	11(100)	309(100)

(Illegal versus legal: z'= 7.9, p <10^{-6}, (Mann-Whitney test).

Visual acuity:		Unlikely	Possible	Probable	Total
b)Binocular testing:	<0.5	0 (-)	4 (10)	5 (45)	9 (3)
	0.5-0.59	2 (1)	7 (17)	2 (18)	11 (4)
	0.6-0.9	36 (14)	20 (49)	2 (18)	58 (19)
	1.0	116 (45)	8 (20)	1 (9)	125 (40)
	1.2+	103 (40)	2 (5)	1 (9)	106 (34)
	Total	257(100)	41(100)	11(100)	309(100)

(Unlikely versus probable: z'= 4.6, p <10^{-5}, (Mann-Whitney test).

		Unlikely	Possible	Probable	Total
c) Contrast-sensitivity (thresholds):	median :	67	72	76	68
	(range) :	(43-95)	(49-97)	(71-109)	(43-109)

(Unlikely versus probable: z'= 4.66, p <10^{-5}, (Mann-Whitney test).

calculations must be taken with precaution; they are descriptive and illustrative more than to be taken as proof of a vision/ accident association.

As illustration static visual acuity and contrast sensitivity are shown in the three classifications of drivers investigated (table C.4).

As demonstrated, a probable association was estimated in the case of drivers with illegal visual acuity in 6 out of 15 (33%), in 5 out of 9 (56%) drivers with binocular visual acuity <0.5, and in 7 out of 20 (35%) with a binocular visual acuity <0.6. On the other hand, out of 11 drivers in which a probable vision/accident association was estimated, 4 (36%) had legal visual acuity and 6 (55%) had binocular visual acuity ≥ 0.5. All accidents in this group are described in appendix C.2. (I). Contrast thresholds were significantly higher (lower sensitivity) in drivers with vision/accident association estimated as probable).

4. Place of accidents, lighting and visibility: No significant relation to the estimated causal association between visual parameters and the accidents was found in different lighting conditions (p> 0.8, Mann-Whitney test) and visibility conditions (p > 0.3, Mann-Whitney test). However, a probable association was estimated more often in crossroads accidents (p< 0.05) compared to accidents happening on straight or curved roads (table C.5). This might be related to the fact that a slight surplus of drivers with unilateral reduction of visual acuity was found in intersection accidents, (cf. chapter 4.1.4). Furthermore, in these more complex traffic situations, visual perception is probably of more decisive importance than in driving on straight and curved roads.

Several authors (e.g. Wiktorsson 1985) have shown increasing problems with road- intersections in drivers aged ≥ 65.

5. Driving para-meters: Accident-involved elderly drivers in which a probable vision/ accident association was estimated, had a significantly lower annual driving distance (p= 0.04) compared with the remaining group (table C.6). Furthermore, their extent of urban driving was significantly larger (p=0.009).

Accidents in which a probable association was estimated, seemed slightly over-represented (although insignificantly) in case of private drivers as compared with professional drivers (cf. table C.7).

These results (table C 6 and C 7) are partly explained by a higher proportion of elderly, private - and urban living drivers in this group.

Discussion:

As can be seen from the results of the analyses in this chapter, the association suggested in the logistic regression analyses (chapter 4.2.) between certain visual parameters and the occurrence of traffic accidents, is supported. Again high age is a common denominator. However, although the analyses are rather illustrative, no conclusive evidence can separately be drawn from them.

Table C.6. Driving parameters in relation to the estimated association between the accidents and the drivers' visual problems (accident drivers aged ≥ 50 with known annual driving, N= 134) (Alsbirk, 1999).

Association:	*Annual driving:* 0-9.999	10.000-19.999	20.000+	Total	Median (range)	Pct. urban driving:
Unlikely :	24 (57)	28 (58)	32 (73)	84	15000 (800-100000)	55%
Possible :	10 (24)	12 (24)	10 (23)	32	15000 (2500-80000)	53%
Probable :	6 (14)	5 (10)	1 (2)	12	10000 (500- 20000)	73%
Unknown :	2 (5)	3 (6)	1 (2)	6		
Total :	42 (100)	48(100)	44(100)	134		

Annual driving : unlikely vs. probable: (z'=2.05, p=0.04, Mann-Whitney test)
Pct. urban driving: unlikely vs. probable: (z'=2.6, p=0.009, Mann Whitney test).

Table C.7. Type of driving in relation to the estimated association between the accidents and the drivers' visual problems (accident-involved drivers) (Alsbirk, 1999).

	Private	Professional drivers: transport of persons +	-	Miscel-laneous	Total
Association:					
Unlikely:	225 (72)	37 (76)	22 (85)	15	299
Possible:	39 (13)	5 (10)	2 (8)	0	46
Probable:	12 (4)	0 (-)	0 (-)	0	12
Unknown:	35 (11)	7 (14)	2 (8)	4	48
Sum:	311(100)	49(100)	26(100)	19	405

(Private vs professional: z'=1.17, p=0.24, Mann-Whitney test)

C. 4. General health parameters found in the study

As seen in the literature review, the role of various medical conditions as co-factors in traffic accidents seems rather low. In the present study, visual factors in road users are the main object, which has been studied systematically.

In this connection it has also been obvious to register acute and chronic medical conditions of the road users in relation to the traffic accidents. It has not been possible to perform a thorough medical examination. In addition, a regular study of the health records has not been feasible, as it is only a secondary aspect of this investigation. Therefore, this part of the examination has been rather superficial. However, medical conditions which have been mentioned in the accident or casualty ward records have been filed. On the other hand, the intake of medication and alcohol has been registered systematically in the interviews. In the non- responders information was obtained from the general practitioners' records.

Since the data from the study population have been collected consecutively within a defined region, the findings may, however, to some extent *illustrate* the role of medical conditions in traffic accidents, resulting in personal injury in Denmark.

Four kinds of conditions have been considered.

1. Acute medical conditions,
2. chronic medical conditions,
3. drivers under the influence of alcohol, and
4. drivers under the influence of medication or drugs.

The methods used for the individual evaluations are mentioned in appendix C.1.

Table C. 8. Health factors in car drivers in relation to 359 traffic accidents with human injury (relevant accident case histories indicated) (Alsbirk, 1999).

	Car drivers:			*(Unprotected road users):*
Age group:	<50 *N=249*	>=50 *N=156*	Total: *N=405*	*(N=157)*
1.Acute medical conditions:	**1** (IV-M-455)	**2** (IV-M-206 IV-V-M-66(?))	**3**	(IV-M-575)
2.Chronic medical conditions:	**0**	**11** (II-VM-562*, II-VM-904*, II-VM-936, II-VM-979*, II-VM-982*, IV-M-55, IV-M-117(?), IV-VM-384*, IV-M-445, IV-VMD-931*, IV-VM-974*)	**11**	
3.Alcohol abuse:	**11** (IV-MA-005, IV-MA-61, IV-MA-104, IV-MA-106, IV-MA-160*, IV-VMA-301, IV-VMD-303*, IV-MDA-319*,IV-MA-626, IV-MA 875, IV-MA 914*)	**2** (IV-MA-967, IV-MAV-996)	**13**	(IV-MD-476)
4. Influenced by drugs or medication :	**5** (II-VMA-534*, IV-MD-323*,IV-MD-495(?), IV-MD-560(?),IV-VMA-631(?))	**0**	**5**	(IV-MD-421)
Subtotal :	**17**	**15**	**32**	
5.Visual problems as a probable co-factor :		**12** (I-V-1, I-V-64 I-VM-141*,I-V-427, I-V-517, I-V-906, I-V-922, I-VM-924*, I-VM-929*,I-V-950, I-V-987, I-V-991)	**12**	**4** (I-V-70, I-V-458, I-V-595, I -V-876)
Total :	**17**	**27**	**44**	

*) Indicate overlapping other health factors (see casuistic reports for details).

The road users focused upon have been casuistically registered in appendix C.2 (IV), some of which overlap mutually as well as with some of the visual cases (in the groups I, II, and III). In order to anticipate such overlapping in the calculations, the cases in table C. 8 have been classified according to the kind of condition, which was estimated to be of primary importance. Thus a given road user is registered only once in the table.

For the sake of completeness, the accidents in which a visual problem was estimated as a probably contributory causal factor were included in the table (C.8-5).

As regards the unprotected road users, only a few obvious cases are casuistically mentioned.

Further, more detailed information from each case can be studied in appendix C. 2-IV (and appendix C. 2-I as far as visual problems are concerned).

Discussion

Taken as minimal values, these findings give some indications:

1. Acute medical conditions of relevance for the traffic accidents are rather rare, but in this study they were found in 3 drivers out of 359 accidents with injuries in which a car driver was involved (0.8%, 95% confidence limits: 0.2% - 2.4%). These cases are: IV-M-455, IV-M-206 and IV-V-M-66, cf. Appendix C.2. Besides, in one case (I-VM-924), classified in the group with vision as a probable factor, an attack of hypoglycemia can not be excluded as one of more causal factors.

Elderly drivers apparently dominate in the case of acute medical conditions, but in one case (IV-M-455), however, a young woman apparently had a fainting in relation to the accident.

2. Chronic medical conditions in this study were primarily seen in the case of drivers $\geq$ 50 years of age. The eleven individual cases focused upon can all be further studied in Appendix C. 2. -IV. Two had earlier fractures to the skull, two earlier TIA (transitoric ischaemic attack), one had earlier cerebral vascular insult, two had earlier myocardial infarction and general atherosclerosis, one was in treatment for Parkinson's disease and one for epilepsy. Two drivers suffered from mental diseases.

The test parameter *"visual reaction time (VRT)"* is primarily seen as a rough indicator of the state of the central nervous system. Five out of the 11 car drivers had a significantly prolonged visual reaction time (≥ 1.21 sec., cf. table 10.2).

In the logistic regression analyses of the case/control study (cf. appendix D 2) it is suggested that if visual reaction time should be used as an optional supplement to the investigation of elderly car drivers, a rather high cut-off score has to be used.

Most of the cases in which this parameter was significantly prolonged, (>97.5% limit, 1.21 sec.: II-V-115, I-VM-141, IV-VM-384, IV-M-445, II-VM-562, I-VM-924) illustrate that the reaction time (in this end of the scale) seems to be a useful indicator of impaired function of the central nervous system, as seen in relation to traffic ability.

3. Obviously, *the role of alcohol intake* in relation to the traffic accidents contrarily was a greater problem among young drivers (table C 8).

The daily alcohol consumption has been registered in the young as well as the elderly accident-involved drivers investigated (table C 9. a).

No significant difference between these two groups was found. Providing the information is valid, this findings suggest that the young drivers compared to the elderly group handle their alcohol consumption in relation to traffic behavior in an immature and dangerous way. When comparing cases and controls, the daily alcohol consumption seems equal in these two groups (p= 0.23, cf. table C.9. b).

The validity of data concerning daily alcohol consumption may be taken with caution. Such information is nearly impossible to verify. Contrary to that, information on daily use of medication could partly be checked via information from general practitioners.

4. *The daily use of medication* has been systematically registered through the interviews, or via the general practitioners as mentioned above. The registered intake of medication was roughly and qualitatively classified in the following groups: I: no use, II: medication not affecting the nervous system, and III: drugs affecting the nervous system. In table C. 10, these data have been analyzed.

Not surprisingly, the daily use of medication was significantly higher in the elderly group of drivers (42%) as compared with the younger (14%), p ≥ 10^{-6}). When focusing on drugs, affecting the central nervous system, the same trend was found, although the difference was not statistically significant, p= 0.15, Fisher's exact).

A comparison of cases and controls (drivers ≥ 50) reveals no significant difference (p=0.53).

On the other hand, in the case of being under the influence of *medication in relation to driving*, this problem seems to dominate in the younger drivers (cf. table C. 8), parallel to the problems concerning managing alcohol in relation to driving. However, in a few cases, elderly drivers with a chronic medical problem might have been under the influence of anti-epileptic medication too (e.g. IV-VMD-931).

Tiredness was often mentioned in the interviews. A systematic scoring or evaluation, however, has not been attempted but it is mentioned in the case reports. Corfitsen (1982) found that the reaction time was significantly prolonged in the case of young, tired and drunk drivers.

Conclusion:
Concentrating on the accident-involved car drivers, it seems safe to conclude that in the case of young drivers < 50, abuse of alcohol was the predominant factor of those registered, followed by the influence of drugs or medication. On the other hand, in case of the elderly drivers (age ≥ 50), chronic medical conditions and visual problems seem to be the predominant health factors.

To sum up concerning the group of drivers under age 50, in one out of 249 accident-involved car drivers (0.4%) a medical problem seemed to contribute to the accident. In at least 16 cases (6.4%), the influence of alcohol or drugs seemed to be of importance. Possibly this estimate is underscored.

In the case of elderly drivers ≥ age 50, acute and chronic medical conditions (apart from significant visual problems) seemed to be of some importance for the accidents in 13 out of 156 drivers (=8.3%, 95% limits: 4.5% - 13.9%). Adding the 12 drivers with significant visual problems in which a probable vision/accident association was estimated, the proportion of drivers ≥ 50 with a chronic or acute medical condition of possible relevance for the actual accident totals 16% (95% confidence limits: 10-23%) or one in six.

Table C.9. a. Alcohol consumption (drinks per day) in accident-involved car drivers (Alsbirk, 1999):

Age group:	*Number of drinks per day:* 0:	1-3:	4-8:	Unknown:	Total:	Mean:
<50 :	81(43)	97(52)	5 (3)	4 (2)	187(100)	0.8
>=50 :	63(52)	52(43)	3 (2)	4 (3)	122(100)	0.7
Total :	144(47)	149(48)	8 (3)	8 (3)	309(100)	0.8

(< 50 vs. ≥ 50: z'= 1.47, p= 0.14, Mann-Whitney test)

b. Alcohol consumption (drinks per day) in accident-involved drivers and a control group, aged ≥ 50 (Alsbirk, 1999):.

Drivers:	*Number of drinks per day:* 0:	1-3:	4-8:	Unknown:	Total:	Mean:
Cases :	63(52)	52(43)	3 (2)	4 (3)	122(100)	0.68
Controls :	55(43)	54(43)	5 (4)	12(10)	126(100)	0.91
Total	118(48)	106(43)	8 (3)	16 (6)	248(100)	0.80

(cases vs. controls: z'= 1.19, p= 0.23, Mann-Whitney test).

Table C.10. a. Use of medication or drugs in accident-involved car drivers: (Alsbirk, 1999).

Age group:	*Daily use of medication:* No use:	-NM:*	+NM:*	Total:
<50 :	161 (86)	19 (10)	7 (4)	187(100)
>=50 :	71 (58)	41 (34)	10 (8)	122(100)
Total :	232 (75)	60 (19)	17 (6)	309(100)

(< 50 vs. > 50: z'= 5.41, p< 10^{-6}), Mann-Whitney test)

b. Use of medication or drugs in accident-involved car drivers and a control group, aged ≥ 50 (Alsbirk, 1999).

Drivers:	*Daily use of medication:* No use:	-NM:	+NM:	Total:
Cases :	71(58)	41(34)	10 (8)	122(100)
Controls :	69(54)	44(35)	13(10)	126(100)
Total :	140(56)	85(34)	23 (9)	248(100)

(cases vs. controls: z'= 0.62, p= 0.53, Mann-Whitney test).

*)- NM: medication not affecting the nervous system,
+NM: medication affecting the nervous system.

Appendix D 1.
Statistical methods:

By M. Sc. Anders Holst Andersen and K.E. Alsbirk (1999).

I. Confidence intervals on estimates in Denmark, calculated from the *multiplication factors*: (cf. table 5.4)

a. *For single values:*
the 95% confidence limits for the population in Aarhus in the investigated periods are found according to the Poisson distribution, cf. Documenta Geigy, p. 107-108:

E.g.: for age ≥ 50 with 11 probands, the 95% confidence limits are (5.5-19.7). The estimated number in Denmark per year (with multiplication factor 39) is 39 * 11= 429 with the 95% confidence limits (39 * 5.5 - 39 * 19.7) = (214-768), cf. table 5.2 and 5.4.

b. *For combined values*:
For age < 50, the multiplication factor is 87, and for age ≥ 50, the multiplication factor is 39.
With X1 probands in the first group and X2 probands in the second, the estimated number in Denmark per year is 87 * X1 + 39 * X2, and the confidence interval is:

$$\left(\sqrt{87*X1+39*X2}+/-1.96*\sqrt{(87^2*X1+39^2*X2)/4*(87*X1+39*X2)}\right)^2$$

e.g. with X1= 3 , X2 = 12, the estimated number in Denmark per year is (87 * 3 + 39 * 12) = 729.

The 95% confidence interval is:

$$\left(\sqrt{729}+/-1.96*\sqrt{14.05}\right)^2$$

i.e. (386 - 1179), cf. table 5.2.

II. Confidence intervals for proportions.

These intervals have been calculated according to the Binomial distribution, (cf. Documenta Geigy, p. 85-103).

III. Mann-Whitney (rank sum) test.

The Mann-Whitney test (Andersen, 1987; Therkelsen, 1972) has been applied for the comparison of two unpaired samples. When applied on non-grouped samples, the test statistic is in the legends and figures named Mann Whitney test and for grouped samples correspondingly M.W.R. (Mann-Whitney Rank Sum test).

IV. Exact test in binomial distributions.

The significance of the surplus of drivers in specific age groups in figure 2.6 to 2.7 are found from the tail probabilities in the binomial distribution. E.g.: In figure 2.7, the study group consist of 269 private drivers (phase I), out of which 21 (7.8%) were aged ≥ 20, compared to 2% in the background population of private drivers in Denmark (Danmarks Statistik, 1982).

The one sided p - value is the probability that a value for a binomial distribution (U), with the numbering parameters 269 and the probability parameter 2%, exceeds 21. This quantity can be approximated by the probability that a standard normal distribution exceeds:

$$U=((21-0.5)-269*0.02)/(\sqrt{269*0.02*0.98})=6.6$$

(Thus the young private drivers are highly significant over-represented in relation to the traffic accidents).

Appendix D.2.

Methodological aspects of the choice of statistical analysis and the selection of variables to be adjusted for when assessing the impact of the visual parameters on the accident risk

By Professor Lic. Scient Michael Væth and K.E. Alsbirk.

1. Design variables.

The purpose of the case-control study was to identify and evaluate risk factors related to the vision of the driver. To obtain valid estimates of the risk associated with the visual parameters from such a study it is important to adjust for the confounding effects of other risk factors that may be associated with the risk factors of interest. Moreover, the analysis should reflect the design of the study implying that variables used in the selection of controls should also be included in the analysis.

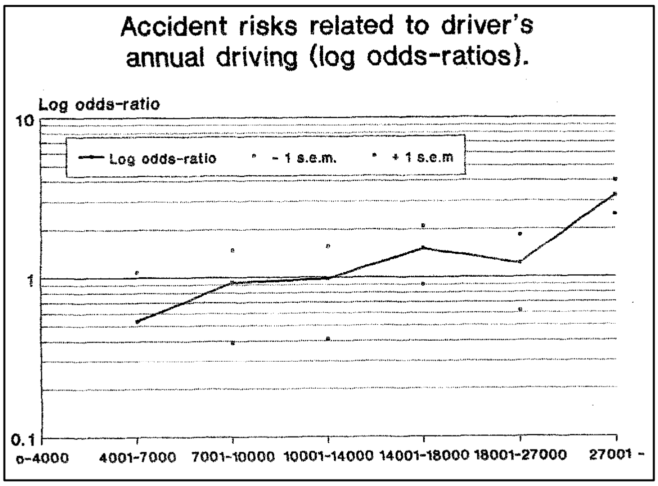
In the present study the control group was age and sex-matched (in distribution) to a subset of the cases. For given sex and age the controls were obtained as a random sample of holders of a driver's licence. The sampling was therefore done independently of the annual driving distance, which is obviously an important risk factor (see figure D.2.1).

Consequently, the sampling procedure used to select the control group implies that the effects of *age, sex and annual driving distance* should be controlled when assessing the impact of the remaining factors on the accident risk. These three variables are denoted *design variables* and are included in all analyses presented in section 4.2 and below. Due to the matching the effects of age and sex on the accident risk could not be estimated in the present study. The dependence of the accident risk on the annual driving distance could, however, be assessed, since one may show that the odds ratio for a given annual driving distance *x* relative to a reference distance *y* is an estimate of the ratio of the accident risks for these two annual driving distances.

Statistical methods useful for analysing data from a case-control study include:
- Stratified analysis using Mantel-
- Haenszel procedure.
- Logistic regression.
- Conditional logistic regression.

All three methodologies allow for control of the effects of confounding factors. In the present study the number of confounding factors are relatively large compared to the sample size, and stratified analyses were therefore not considered feasible. Of the two regression methods the conditional logistic regression may be preferable from a theoretical point of view, since the analysis is based on comparisons within subsets of cases and controls which are identical with respect to all three design variables. A tight, simultaneous control of these variables will, however, result in a reduction of the effective sample size, since many of the subsets will contain only cases or only controls and therefore not contribute useful information to the analysis.

On these grounds it was decided primarily to use logistic regression for the analyses, but some of the analyses were also performed as conditional logistic regression to see if the results were sensitive to the choice of analytic approach.



2. Confounders, non-visual variables.

The next step in the analysis included identification of confounding factors among the non-visual variables. Systematically performed analyses of each of these variables with simultaneous control of the design variables showed that the following non-visual variables were related to the accident risk and that adjustment for these factors was necessary when evaluating the effect of the visual variables.

Table D 2-1. Odds-ratios on accident risk in relation to daily alcohol consumption, controlled for design variables, (N=207):

Drinks per day:	*Odds ratio:*	*95% confidence limits:*	*n=*
< 1	: 1	- -	107
1 - <2	: 0.77	(0.4 - 1.6)	67
2 - <3	: 0.54	(0.1 - 1.9)	16
≥ 3	: 0.68	(0.5 - 0.97)	17
			207

*) Odds-ratios estimate the increase in risk, compared to the first category.

a. Daily alcohol consumption:

Surprisingly it appears that a higher daily consumption of alcohol - (to a certain limit) - seems related to lower accident risk (cf. table D 2.1). This should not be interpreted as drinking having a protective effect before driving, but it may suggest that car drivers, who can afford a certain, controlled, daily consumption of alcohol (about 2 drinks per day) constitute a population with lower accident risk. The data is based on interviews. The information on alcohol consumption is probably not very reliable. Moreover, after a serious accident, a question on daily drinking habits probably affects probands more than control persons. A systematic and higher degree of under-reporting in the proband group compared to the controls might explain the results observed.

b. Percentage of urban driving:
A significant increase in risk was found with increasing urban driving, (Odds-ratio = 1.17 for a 10% increase (c. l.: 1.04 - 1.32, p=0.008).

c. Percentage of professional driving:
A significant association was found when the proportion was 50% and a-bove, compared to below that limit: (Odds-ratio = 3.18 (1.32-7.63), p = 0.01). Note that this effect is corrected for the effect of annual driving dist-ance.

d. Visual reaction time:
(cf. chapter 3.3.6.3.d.): Although rela-ted to the vision this variable reflects mainly the function of the central nervous system. The dependence of the accident risk in visual reaction time appears rather complex (cf. table D 2-2).

The highest accident risk in this analysis is found among drivers with low test scores (<0.6), the lowest risk is seen in the range 0.8 - 1.0 sec. Above this limit the risk increases again.

In 14 drivers, a double estimation was performed according to the me-thod described by Therkelsen (1972). A standard deviation of 0.1 second was found.

Table D 2-2. Odds-ratios on accident risk in relation to visual reaction time, controlled for design variables, (N=221):

Visual reaction time (seconds):		*Odds ratio:*	*95% confidence limits:*	*n=*
≤ 0.6	:	1	-	15
0.6 - 0.65	:	0.16	(0.02 - 1.1)	17
0.66 - 0.7	:	0.31	(0.05 - 2.0)	19
0.71 - 0.75	:	0.21	(0.04 - 1.17)	34
0.76 - 0.8	:	0.11	(0.02 - 0.61)	23
0.81 - 0.85	:	0.07	(0.01 - 0.42)	33
0.86 - 0.9	:	0.08	(0.01 - 0.57)	19
0.91 - 1.0	:	0.07	(0.01 - 0.43)	28
> 1.0	:	0.28	(0.05 - 1.69)	33
				221

*) Odds ratios estimates the increase in risk, when the test scores increases one step value.

Conclusion:
An evaluation of non-visual variables (corrected for design variables) identified the following to be of significant importance: *Daily alcohol consumption, percentage of urban driving, percentage of professional dri-ving, and visual reaction time*. This was further confirmed, when the four parameters were fitted simultaneously. Therefore, these variables were intro-duced as *confounding factors* in the logistic regression analyses.

Appendix E.

Computer formulas used in the data-base program "REFLEX-The Analyst" for some calculated secondary variables.

A. Visual parameters:

PRIMARY PARAMETERS:

UTVOD (= accident visual acuity, right eye)
UTVOS (= accident visual acuity, left eye)
UTBINVIS (= binocular visual acuity at the time of the accident)
BINOPT (= binocular visual acuity after optimum correction)
(Unknown values are given the value=9.99)

DERIVED CALCULATED VARIABLES:

UTVISMAX (= accident visual acuity in the better eye); *UTVISMIN* (= accident visual acuity in the worse eye):

FORMULA: *UTVISMAX* =@IF (UTVOD >=UTVOS,UTVOD,UTVOS) (if, then, else)

UTVISMIN =@IF (UTVOD <=UTVOS,UTVOD,UTVOS) (if, then, else)

UTVISLOV: (= accident visual acuity, classified according to the stipulated former (before 1996) level of visual requirements for a driver's license.

FORMULA: *UTVISLOV* = @CASE ((UTVISMAX <0.6 AND UTVISMIN < 0.2) OR (UTVISMAX < 0.5), "ILLEGAL", UTVISMAX >2, "UNKNOWN", (UTVISMAX THRU(0.5,0.6) AND UTVISMIN = 0.2) OR (UTVISMIN < 0.2 AND UTVISMAX = 0.6), "LIMIT", @TRUE, "LEGAL")

The formula will classify all with known UTVOD and UTVOS in:

1: illegal

2: limit

3: legal

4: unknown

BINGEV: (= binocular gain, e. g. the difference between visual acuity in the better eye and binocular visual acuity)

FORMULA: *BINGEV* = UTBINVIS - UTVISMAX

DELTA: (= the difference between the binocular visual acuity at the time of accident and after optimum correction.

FORMULA: *DELTA* = BINOPT- UTBINVIS

B: qualitative accident injury score (QAISUM) (cf. chapter 4.4, p. 49)

PRIMARY DATA:

INJ.PROB (=PROBANDS)

INJ.SEC (="SECOND PARTICIPANTS" INVOLVED)

INJ.THR (="THIRD PARTICIPANTS" INVOLVED)

(0=killed , 1= CNS affected, 2= hospitalized and no injury of CNS, 3= slightly injury with not hospitalization).

DERIVED DATA:

FORMULAS:

KILLED= @CASE (INJ.PROB=0 OR INJ.SEC=0 ORINJ.THR=0,8,@TRUE,0)

CNS = @CASE (INJ.PROB=1 OR INJ.SEC=1 OR INJ.THR=1,4,@TRUE,0)

NOTCNS = @CASE (INJ.PROB=2 OR INJ.SEC=2 OR INJ.THR=2,2,@TRUE,0)

SLIGHT = @CASE (INJ.PROB=3 OR INJ.SEC=3 OR INJ.THR=3,1,@TRUE,0)

QAISUM = (KILLED + CNS +NOTCNS + SLIGHT)

Appendix F: Age tables

TABLE. 10. 1. CONTRAST-SENSITIVITY IN DIFFERENT AGE GROUPS, DRIVERS N=429 (Alsbirk 1998)

	AGE GROUPS:									*AGE-*
	10-19	*20-29*	*30-39*	*40-49*	*50-59*	*60-69*	*70-79*	*80-90*	*TOTAL:*	*MEAN:*
Arden-scores:										
0-19:	0	0	0	0	0	0	0	0	0	
20-39:	1	0	0	0	0	1	0	0	2	43.5
40-59:	4	13	13	9	9	7	1	0	56	40.70
60-79:	6	55	36	38	89	74	14	2	314	48.25
80-99:	1	2	4	1	19	10	13	3	53	59.40
100 +:	0	0	0	0	0	1	1	2	4	74.25
TOTAL:	12	70	53	48	117	93	29	7	429	48.86
MEAN :	58.17	66.03	64.53	66.04	71.22	71.06	78.24	87.43	69.31	
S.D. :	14.01	7.051	8.893	8.426	7.672	10.04	10.65	12.80	10.06	
95% limits:										
upper:	85.6	79	81.9	82.4	86.3	90.7	99	112.5	89.0	
lower:	30.8	52	47	49.5	56	51.5	57.3	62.3	49.5	

(Age 10 +: T= 8.67, slope = 0.23, $p < 10^{-4}$, linear regression)

TABLE 10. 2. VISUAL REACTION TIME (VRT) IN DIFFERENT AGE GROUPS, DRIVERS N=427 (Alsbirk 1998).

	AGE GROUPS:									*AGE-*
	10-19	*20-29*	*30-39*	*40-49*	*50-59*	*60-69*	*70-79*	*80-90*	*TOTAL:*	*MEAN:*
VRT:										
0- 0.24:	0	1	0	0	0	0	0	0	1	22
0.25-0.49:	1	5	8	3	0	0	0	0	17	31.47
0.5-0.74 :	7	37	28	30	50	34	4	1	191	45.05
0.75-0.99:	3	18	14	14	54	53	13	0	169	52.69
1.0-1.24 :	1	8	1	1	12	6	5	5	39	55.15
1.25-1.49:	0	0	0	0	0	1	2	1	4	74.5
1.5-1.74 :	0	0	0	1	0	0	2	0	3	62.33
1.75-1.99:	0	0	0	0	0	0	2	0	2	73.5
2.0-2.24 :	0	0	0	0	0	0	0	0	0	
2.25-2.49:	0	0	0	0	0	0	1	0	1	77
2.5+:	0	0	0	0	0	0	0	0	0	
TOTAL:	12	69	51	49	116	94	29	7	427	49.01
MEAN :	0.728	0.716	0.664	0.724	0.787	0.797	1.1	1.056	0.780	
S.D. :	0.179	0.203	0.154	0.200	0.139	0.142	0.419	0.169	0.219	
95% limits:										
upper:	1.08	1.10	0.97	1.1	1.06	1.08	1.9	1.38	1.21	
lower:	0.36	0.31	0.35	0.34	0.5	0.5	0.27	0.72	0.34	

(Age 40 +: T= 6.84, slope = 0.01, $p<10^{-4}$, linear regression)

Appendix G. Abbreviations.

AIS: Abbreviated Injury Scale

AMD: Age related macular degeneration

Bin. v. a.: Binocular visual acuity.

CVI: Cerebro - vascular insult.

DVA: Dynamic visual acuity.

DRP: Diabetic retinopathy.

EDP: electronic data processing.

M.W.R.: Mann Whitney rank sum test, (for comparing classed samples, cf. appendix D-1.

O. dxt.: Right eye

O. sin.: Left eye

OR: Odds ratio.

PCT: Per cent

V. a.: Visual acuity

VRT: Visual reaction time

TIA: transitoric ischemic (cerebral) attack *UFOV*: useful field of view (cf. p 21, 22)

For abbreviations in relation to the *case history numbers*: cf. appendix C-2.

10. References

AAAM V A (1980): The abbreviated injury scaling. American association for automotive medicine AIS-80.
Acocella N (1982): How drivers with poor vision stay behind the wheel. Sightsaving 51: 12-14.
Ahlmann-Olsen O (1942): Motor Jan (in Danish). 24: 18-20.
Aldman B (1982): Onödiga skillnader i synskrav avslöjade vid nordisk kongres i trafikmedicin (in Swedish). Läkartidningen 79: 3537-38.
Alsbirk K E & Pedersen B (1983): Perforating lesions of the eye in motor accidents 1971-1980 (in Danish with summary and legends in English). Ugeskr. Læg. 145: 3115-20.
Alsbirk K E (1987): EDB-programmel The-Analyst (in Danish). Ugeskr. Læg 149: 2990-91.
Alsbirk K E, Bargum R, Kobayashi C & Otland N (1988): Visual outcome of modern cataract surgery in 100 active car drivers. Legal and social aspects (European Congress of Cataract and Refractive Surgery, Copenhagen 1988).
Andersen B (1987): Statistiske metoder. In: Andersen D, Havsteen B, Juhl E & Riis P: Lægevidenskabelig forskning, en introduktion 4. ed. (in Danish): 141-150.
Andersen K E (1985): Persontrafikken forventes at stige på grund af befolkningens alderssammensætning (in Danish). Dansk vejtidsskrift 2:28-29.
Andersen O Corydon (1958): Die Häufigkeit des glaucoms (in German). Acta Ophthalmol 36: 672- 80.
Anderson SJ, Holliday IE (1995: Night driving: effects of glare from vehicle headlights on motion perception. Ophthalmic Physiol Opt; 15(6):545-551.
Andersson A L, Nilsson A & Henriksson N-G (1970): Personality differences between accident-loaded and accident-free young car drivers. Br. J. Psychol 61: 409-421.
Andreasson R (1984): Läkarnes roll i den medicinska körkortsbedömningen (in Swedish). Läkartidningen 81, nr. 38: 3366-70.
Andreasson R(1994): Människan och trafiken. Et bidrag til trafikmedicinens historia (in Swedish). T. Fisher Co, Stockholm; 143-145.
Applegate R A, Trick L R, Meade D L & Hartstein J (1987): Radial Keratotomy Increases the Effects of Disability Glare: Initial Results. Ann. Ophthalmol 19: 293-97.
Applegate W B, Miller S T, Elam J T, Freeman J M, Wood, T O and Gettlefinger T C (1987): Impact of Cataract Surgery With Lens Implantation on Vision and Physical Function in Elderly Patients. JAMA; 257 (8); 1064-66.
Auffarth-GU; Hunold-W; Hurtgen-P; Wesendahl-TA; Mehdorn-E (1994): Nachtfahrtauglichkeit pseudophaker Pa-tienten [Night driving capacity of pseudophakic - in German]; Ophthalmo-loge; 91(4): 454-9.
Aulhorn E & Harms H (1970): Über die Untersuchung der Nachfahreignung von Kraftfahrern mit dem Mesoptometer (in German). Klin. Monatsbl. Augenh 157: 843-73.
Backman AL (1983): Health survey of professional drivers. Scand J Work Environ Health 9: 30-35.
Bailey I L (1985): Bioptic telescopes. Arch. Ophthalmol 103: 13.
Ball K, Beard B L, Roenker D L, Miller R L and Grieggs D S (1988): Age and visual search: expanding the useful field of view. J. Opt. Soc. Am. 5A. (12) 2210-19.
Ball K, Owsley C and Beard B (1990): Clinical visual perimetry underestimates peripheral field problems in older adults. Clin. Vision Sci. 5(2): 113-25.
Ball-K, Owsley-C, Sloane-ME, Roenker-DL, Bruni-JR (1993): Visual attention problems as a predictor of vehicle crashes in older drivers. Invest- Ophthalmol-Vis-Sci.; 34(11): 3110-23.
Ball-K, Owsley-C (1993): The useful field of view test: a new technique for evaluating age-related declines in visual function. J-Am-Optom-Assoc; 64(1): 71-9.
Ball K, Owsley C, Stalvey B, Roenker DL, Sloane ME, Graves M (1998): Driving avoidance and functional impairment in older drivers. Accid Anal Prev; 30(3):313-22
Barron-C(1991): Bioptic telescopic spectacles for motor vehicle driving. J-Am-Optom-Assoc. 62(1): 37-41
Baun O, Gregersen E & Prause J U (1987): Irreversible immune reactions following keratoplasty. Acta Ophthalmologica 65: 641-47.
Bengtsson B & Krakau C E T (1979): Automatic perimetry in a population survey. Acta Ophthalmologica 57: 929-37.
Bengtsson B (1981): The prevalence of glaucoma. Br.J.Ophthalmol 65: 46-49.
Bengtsson B, Heil A & Olsson J (1998): Evaluation of a new threshold visual field strategy, SITA, in normal subjects. Acta Ophthalmol. 76: 165-69.
Bentzen C F & Høgsbro (1909): Auto-mobilføreres syn (in Danish). Ugeskr. Læg 71: 359-60.
Berggren L (1970): Coloured glasses and colour vision with reference to car driving. Acta Ophthalmol 48: 537-45.
Bernth-Petersen P (1981): A change in the indications for cataract surgery? A 10 year comparative epidemiologic study. Acta Ophthalmol 59: 206-10.
Bernth-Petersen P (1985): Cataract surgery. Outcome Assessment and Epidemiologic Aspects. Acta Ophthalmol. suppl 63
Björnsson G (1967): The primary glaucoma in Iceland (Thesis). Acta Ophthalmol suppl. 91: 65-83.
Boberg-Ans L J & Vangsted P (1988): An Automated Screening Perimeter for the Personal Computer. Glaucoma 10: 77-79.
Brainin P.A (1980): Safety and Mobility Issues in Licensing and Education of Older Drivers. U.S.Dept. of Transportation, National Highway Traffic Safety Admini-stration, DOT-HS-805 492: Washington D.C.
Brody L (1941): Research contribution of safety education. Center for safety education, New York University: 1-77.
Brühning E & Harms H(1983): Unfallbeteiligung und Sehfähig-keitsminderung älterer Pkw-Fahrer (in German). Zeitschrift für Verkehrssicherheit 29: 19-28.
Buchholtz U (1998): Freude am Fahren im Alter oft getrübt (in German). Fortschritte der Medizin; 116 (4): 41-42.
Buckley S A, Wheatcroft S M, Benjamin L and Jenkins L (1996): Comment on laser photocuagulation for diabetic retinopathy. Eye; 10; 404-05.
Bülow(1913): Bekendtgørelse Nr. 160. Om Førerprøve og Førerbevis (in Danish). Lovtidende: 821-23.
Burg A (1968): Vision and Driving: A Summary of Research Findings. Highway Research Rec no 216: 1-12.
Busse-H (1993): Sehvermögen und Verkehrstauglichkeit im Alter (in German). Fortschr- Med. 10; 111(16): 274-78
Butler RN, Faye EE, Guazzo E, Kupfer C (1997): Keeping an eye on vision: primary care of age-related ocular disease. Part 1.Geriatrics;52(8):30-41.
Byrnes V A (1962): Visual factors in automobile driving. Tr. Am. Ophth. Soc; 60: 60-84.
Byrnes V A (1967): Vision and its importance in driving. Sight-Sav. Rev 37: 87-91.
Campbell E O & Ellis K G (1969): Chronic medical conditions and traffic violation and accident experience of diabetic drivers. Modern med.of Canada 24: 29-31.
Cashell G T W (1966): Visual functions in relation to road accidents. Transactions Ophthalm. Soc. U.K 8: 617-627.
Castanera-Molina J & Castanera-Molina F (1988): Radial Keratotomy with excimer laser. Clinical results. Proceedings from the Sixth Congress of the European Intraocular Implantlens Council.
Charman WN (1985): Visual standards for driving. Ophthal. Physiol. Opt 5: 211-220.
Charman WN (1996): Night myopia and driving. Ophthalmic Physiol Opt; 16(6): 474-85.
Chevaleraud J P (1981): The driver's visual informations. 2nd international congress on vision and road safety, Paris. La Prevention Routiere International: 11-12.
Chmielarz M & et al(1987): Vision impairing wear of windshields. Forschungs-gemeinshaft auto-sicht-sicherheit, ESV--konferenz, Köln: 1-8.
Christiansen M (1966): Førerbevis og tavshedspligt (in Danish). Ugeskr. Læg 128: 308.
Christensen S & Hem J (1974): (in Danish) Ugeskr. Læger 136: 1699-1702.
CIECA (1998): Guide on driver licensing, (CD-rom), Brussels. ISBN: 90-76408-05-X
CIECA (1999): Procedure and periodicity of the medical examination, Brussels
Clayton A B (1976): Perceptual and visual factors in the causation of road accidents. 1. Int. Congr. on Vision and Road Safety, Linas: 57-63.
Colenbrander A (Consilium Ophthalmo-

logicum Universale/ Visual function comittee) (1988): Visual Acuity Measurement Standard. Ital J Ophthalmol. p 5-18.
Colenbrander-A; Fletcher-DC (1992): Low vision rehabilitation: vision requirements for driving. Ophthalmic-Nurs-Technol.; 11(3): 111-15.
Cole M D, Clearkin L, Dabbs T & Smerdon D (1987): The seat belt law and after. Br.J.Ophthalm 71: 436-40.
Corfitsen M T (1982): Increased viso-motoric reaction time of young tired drunk drivers. Forensic Science International: 121-125.
Corfitsen M T (1993): Tiredness and visual reaction time among nighttime cab drivers: a roadside survey. Accid- Anal-Prev. 25 (6): 667-73.
Corfitsen-MT (1994):Tiredness and visual reaction time among young male nighttime drivers: a roadside survey. Accid-Anal-Prev. 26(5): 617-24.
Council F M & Allen J A (1974): A study of the visual fields of North Carolina drivers and their relationship to accidents. Highway safety research center: 1-36.
Crancer A & McMurray L (1968): Accident and Violation Rates of Washington's Medically Restricted Drivers. JAMA 205, no 5: 74-77.
Crick R P & Crick J C P (1981): The sine -bell screener. Doc.Ophthal.Proc.Series 26: 233-237.
Cross A G (1966): Visual acuity and driving. Transactions of the Ophthalmological Society of UK 86: 627-637.
Daimler-Benz A G (1985): The Daimler-Benz driving simulator. OWV 6705 Stuttgart-Untertuerkheim
Dalgaard J B (1977): Dræbt i bil (in Danish). Retsmedicinsk Institut Århus & Rådet for trafiksikkerhedsforskning rapport 21.
Dalgaard J B & Arnold D R (1985): Diabetikerdødsfald retsmedicinske aspekter (in Danish). Ugeskr. L: 1955-1960.
Damgaard-Jensen E (1948): Serieundersøgelser over synsstyrken hos motorførere. (in Danish). Dansk Ophthalmologisk Selskabs møde, København, Febr. 1948.
Danielson R W (1957): The relationship of fields of vision to safety in driving. Am.J.Ophthalmol 44: 657- 680.
Danish Ophthalmological Society (1909): Synsprøve for automobilførere. Meddelelse (in Danish). Ugeskr Læg 71: 27-28.
Danish Society of Traffic Medicine(1979): Beslutningsreferat og rekommendationer fra stående udvalg (in Danish). seminar, 24.-25. oktober: 4-8.
Danmarks Statistik (1982): Persontransportundersøgelsen oktober 1981 (in Danish). Statistiske Efterretninger A-1982-31: 1073-1087.
Danmarks Statistik (1984-87): Road traffic accidents (in Danish). Danmarks Statistik.
Davey J B (1956-57): The effect of visual acuity on driving ability. Br.J.phys 13-14: 62-78.
Davison P A (1978): The role of drivers' vision in road safety. Lighting Res 10: 125-139.
Davison P A & Irving A (1980): Survey of visual acuity of drivers. TRRL Laboratory, report 945: 1-22.
Davison P A (1985): Inter-relationships between British Drivers' visual Abilities, Age and Road Accident Histories. Ophthal Physiol Opt 5: 195-204.
De Europæiske Fællesskabers Tidende (1991): Rådets direktiv af 29.juli 1991 om kørekort (in Danish); 24 august 1991; L 237/20-21 991.
de Boer N-G (1981): Signalling and public lighting. 2nd International Congress on Vision and Road Safety, Paris 1: 18.
De Klerk N H & Armstrong B K (1983): Admission to hospital for road trauma in patients with diabetes mellitus. J Epidemiology and Community Health 37: 232-237.
Derefeldt G, Lennerstrand G & Lundh B (1979): Age variations in normal human contrast sensitivity. Acta Ophthalmol 57: 679-692.
Decina-LE; Staplin-L (1993): Retrospective evaluation of alternative vision screening criteria for older and younger drivers. Accid-anal-Prev. ; 25(3): 267-75.
Diaper CJ(1997): Pulfrich revisited. Surv Ophthalmol; 41(6):493-499.
Dionne-G; Desjardins-D; Laberge-Nadeau-C; Maag-U (1995): Medical conditions, risk exposure, and truck drivers' accidents: an analysis with count data regression models. Accid-Anal-Prev. ; 27(3): 295-305.
Directorate-General for Transport(1986): Minimum standards of physical and mental fitness for driving a motor vehicle.: 1-10.
Documenta Geigy K A: Matematik und statistik (in German). Wissenshaftliche Tabellen 6. Aufl.: 107-108.
Domey RG, Mc Farland RA (1961): Dark adaptation as a function of age and individual prediction. Am.J. Ophthalmol. 51, 1262-68.
Dreyer V (1961): Studier over kontrast-tærskler. Eksperimentelle undersøgelser over klarhedsskelneevnen under små synsvinkler ved fotoptisk fovealt syn. (In Danish with English summary). Thesis, København
Dubois-Poulsen C J (1981): VISION, synthesis at the 2nd international congress on vision and road safety, Paris. La prevention routiere internationale 1: 21-24.
Edwards-MG; Schachat-AP (1991):Impact of enucleation for choroidal melanoma on the performance of vision-dependent activities. Arch-Ophthalmol. Apr; 109(4): 519-21.
Ehlers N & Olsen T (1983): Long term results of corneal grafting in keratoconus. Acta Ophthalmologica 61: 918-926.
Ehlers N et al. (1990): Clinical experiences from grafting 1000 eyes (in preparation).
Eisenmann D, Jacobi FK, Dick B, Jacobi KW, Pabst W (1996): Glare sensitivity of phakic and pseudophakic eyes. [Article in German]. Klin Monatsbl Augenheilkd; 208(2):87-92.
Elkington, A R (1995): Visual field required for safe driving wrongly defined. (BMJ ; 310; 56-57.
Elliott DB, Sanderson K, Conkey A(1990): The reliability of the Pelli-Robson contrast sensitivity chart. Ophthalmic Physiol Opt; 10(1):21-24.
Elliott DB, Bullimore MA, Patla AE, Whitaker D (1996): Effect of a cataract simulation on clinical and real world vision. Br J Ophthalmol;80(9):799-804.
ENO-Foundation (1948): Personal Characteristics of Traffic-Accident Repeaters. The ENO-Foundation for Highway Traffic control Connecticut.
Evans D W & Ginsburg A P (1985): Contrast sensitivity predicts age-related differences in highway-sign discrimination. Human Factors 27(6): 637-42.
Fell J C (1976): A motor vehicle accident causal system: The human element. Human Factors 18 (1): 85-94.
Fejer TP (1995): Correction of night myopia and glare for night driving. Can J Ophthalmol. 30: 25-7.
Ferris LF III (1993): How effective are treatments for diabetic retinopathy? JAMA; 10: 1290-91.
Fishbaugh J (1995): Look who's driving now-visual standards for driver licensing in the United States. Insight;20 (4): 11-20.
Fishman G A, Anderson R J, Stinson L & Haque A (1981): Driving performance of retinitis pigmentosa patients. British J of Ophthalmol 65: 122-26.
Fleck R, Kolling GH (1996): Two new stereotests for long distance: examination of stereopsis with regard to permission of driving. Ger J Ophthalmol; 5(1):53-59.
Fledelius H C (1988): Refraction and size in the elderly. A review based on literature, including own results. Acta Ophthalmol. 66, 3; p.241-48.
Fletcher E D (1947): Visual problems in motor vehicle operation. One-eyed drivers. Optometric Extension Program, Notes, Duncan, Oklahoma 1 No 11: 49-52.
Fletcher E D (1949): Visual acuity and safe driving. J. Am. Optom. Associat 20: 439-442.
Foldspang A, Juul S, Olsen J & Sabroe S (1986): Epidemiologi, Sygdom og befolkning (in Danish). Munksgaard: 97-109.
Folketingsdebat (1966 a): Første behandling af forslag til lov om ændringer i færdselsloven (in Danish). Folketingstidende: 3756-3786.
Folketingsdebat (1966 b): Anden behandling af forslag til lov om ændringer i færdselsloven (in Danish). Folketingstidende: 6024-6028.
Fonda G (1983): Bioptic telescopic spectacle is a hazard for operating a motor vehicle. Arch.Ophthalmol 101: 1907-08.
Fonda G (1986): Suggested vision standards for drivers in the United States with vision ranging from 20*175 (6*52) to 20*50 (6*15). Ann. Ophthalmol 18: 76-79.
Fonda-G (1989): Legal blindness can be compatible with safe driving. Comment in: Ophthalmology 1989 (10): 1455-6.
Fonda G (1991): Special Correspondence: Vision Standards. New Jersey Med. 88

(7); 497-8.
Forrest KY, Bunker CH, Songer TJ, Coben JH, Cauley (1997): Driving patterns and medical conditions in older women. J Am Geriatr Soc.;45 (10):1214-18.
Freeman J T (1972): Elderly drivers: Growing numbers and growing problems. Geriatrics 27: 46-56.
Friedel B (1988): Sehvermögen und Kraftverkehr (in German). Zschr. für Verkehrssicherheit 34: 60-65.
Frier-BM(1992): Driving and diabetes [editorial]. BMJ. 21; 305: 1238-9
Færdselsstyrelsens cirkulære nr 26. af 11, marts 1997: Cirkulære om kørekort (in Danish). Færdselsstyrelsen j.nr. 1995-400-12.
Glad A (1977): Krav til førere, Syn (in Norwegian). Transportøkonomisk Institut, projektrapport Oslo
Golding A P (1984): Eyesight on the roads: A demographic investigation of the relationship between visual acuity and accident risk in drivers. NIPR, Pretoria.
Goldstein L G (1964): Human variables in traffic accidents: A digest of research. Traffic Safety 8: 26-31.
Graca J L (1986): Driving and aging. Clin.Geriatr.Med 2: 577-589.
Gramberg-Danielsen B (1963): Ursachen des Pulfrich-Phänomens und seine Bedeutung im Strassenverkehr (in German). Klin Monatsbl. Augenheilk 142: 738-742.
Gramberg-Danielsen B (1966): Visusminderung und Verkehrsunfall unter dem Gesichtspunkt des Personalmangels (in German). Klin Mbl Augenheilk 148: 579-589.
Gramberg-Danielsen B (1967): Sehen und Verkehr (in German). Springer-Verlag Berlin, Heidel-berg, New York
Gramberg-Danielsen B (1968): Medikament, Auge und Verkehr (in German). Klin. Monats-blt.f.Augenheilk 153(1): 280-290.
Gramberg-Danielsen B (1970): Statistische Erhebungen Über die Sehshärfe der Fahrerlaubnisinhaber Klasse 3 (in German). Klin. Monatsbl. Augenheilk 157: 273-280.
Gramberg-Danielsen B (1970a): Die Sehschärfeverteilung der deutschen Kraftfahrer (in German). Z.f.Verkehrssicherheit 16: 207- 12.
Gramberg-Danielsen B (1971): Tagessehschärfe und Unfallhäufigkeit im Strassenverkehr (in German). Z f.Verkehrssicherheit 17, no 2: 105-15.
Gramberg-Danielsen B (1971): Häufigkeit und Bedeutung herabgesetzter Sehschärfe im Strassenverkehr (in German). Bundesgesund-heits-blatt no 18: 253-56.
Gramberg-Danielsen B (1972): Die verkehrsmedizinische Bedeutung der Farbentüchtigkeit (in German). In: Lundt P V: Sehvermögen und Kraftverkehr, Schriftreihe des Bun-desm. für Verkehr 38: 117-119.
Gramberg-Danielsen B & Repkewitz D (1976): Zur Unfallhäufigkeit einäugiger Lastkraftwagenfahrer (in German). Bundesgesundhbl 15-16: 252-256.
Gramberg-Danielsen B (1984): Das Sehen in der Dämmerung (in German). Unfall und Sicherheits-forschung Strassenverkehr 47: 91-93.
Gramberg-Danielsen B (1986): Altersehtest und Haftpflichtversicherung (in German). Zeitschrift für Verkehrssicherheit 32: 47-48.
Gregory D R (1982): The physicians' role in highway safety reporting requirements. Legal Medicine: 259-266.
Gresset-JA; Meyer-FM (1994): Risk of accidents among elderly car drivers with visual acuity equal to 6/12 or 6/15 and lack of binocular vision. Ophthalmic- Physiol-Opt. ; 14(1): 33-7.
Grosskopf U, Wagner R, Jacobi FK, Krzizok T (1998): Twilight vision and glare sensitivity in monofocal and multifocal pseudophakia (in German). Ophthalmologe; 95(6):432-7.
Holladay J T et al. (1990): Optical performance of multifocal intraocular lenses. J. Cat. Refr. Surg. 16 (6): 775-7.
Hager G (1963): Das Sehorgan und das Unfallgeschehen im Strassenverkehr (in German). Klin Mbl Augenheilkunde 142: 427-433.
Hakemies-Blomquist L (1990): Körkort på livstid. Et symposium om äldre som bilförare. Äldre föreres självförvållade olycker (in Swedish). NTF Stockholm 901002.
Hakemies-Blomquist L et al (1996): Medical screening of older drivers as a traffic safety measure - a comparative Finnish- Swedish evaluation study. J. Am Geriatr Soc;44: 650-653.
Hales R H (1982): Functional ability profiles for driver licensing. Arch. Ophthalmol 100: 1780-82.
Hames L N (1976): Is it safe to wear telescopic devices when driving? Traffic Safety Nov: 24-34.
Harms H, Kröner B & Dannheim R (1984): Augenärztliche Erfahrungen bei Kraftfahrern mit unzureichender Sehschärfe (in German). Klin. Mbl. Augenheilk 1985: 77-85.
Harms H (1985): Aktuelle Probleme des Sehens im Strassenverkehr (in German). Zeitschrift für Verkehrssicherheit 31: 50-58.
Harms H & Dietz K (1987): Über die Ursachen unzureichenden Sehens bei Kraftfahrern und ihre Bedeutung im Strassenverkehr (in German). Klin Mbl Augenheilk 190: 3-7.
Harms H (1986): Sehmängel als Unfallursache (in German). Zeitschrift für Verkehrssicherheit 32: 36-39.
Hartmann H (1964): Diabetes und Fahrtauglichkeit (in German). Helvetica Medica Acta 31: 257-279.
Hedin A (1980): Retesting of Vehicle Driver's Visual Capacity. J Traffic Medicine 8: 18-20.
Hedin A, Rumar K & Verriest G (1981): Visual field testing of driving license applicants. Third Int. Congr. Ergophthalmol. Istanbul.
Hedin A (1986): Trafiksynen. In: Andreasson R: Körkortsmedicin, Trafikmedicin (in Swedish) Raben & Sjögren: 120-138.
Heinsius von E (1969): Sehschärfe und Unfallhäufigkeit bei Kraftfahrern (in German). Zbl. Verkehrs-Med 15: 164-68.
Henderson R L & Burg A (1973): The role of vision and audition. Santa Monica, California System Development Cooporation.
Henderson R L & Burg A (1974): Vision and audition in driving. System Development corporation, Santa Monica, California
Herner B, Smedby B & Ysander L (1966): Sudden illness as a cause of motor-vehicle accidents. Brit. J. industr. Med 23: 37-41.
Hessemer-V; Frohloff-H; Eisenmann-D; Jacobi-KW (1994): Mesopisches Sehen bei multi-und, monofokaler Pseudophakie und phaken Kontrollaugen (in German). Ophthalmologe; 91(4): 465-8.
Higgins KE, Wood J, Tait A (1998):Vision and driving: selective effect of optical blur on different driving tasks. Hum Factors; 40(2):224-32
Hills B L (1975): Some studies of movement perception, age and accidents. Transport and road research laboratory, Crowthorne, Berkeshire suppl rep. 137UC
Hills B L & Burg A (1977): "A reanalysis of California driver vision data: General findings". Department of the Environment Department of Transport, TRRL Report. LR 768, Crowthorne, England
Hills B L (1980): Vision, visibility, and perception in driving. Perception 9: 183-216.
Hirschberger H G & Miedel H (1980): Sicht und Sehprobleme in der Fahrausbildung (in German). Zeitschrift fur Verkehrssicherheit 26: 65-70.
Hjorth B, Tvedt A, Dahl K and Holmstrøm A (1991): Ulykkestrafikanter og syn (in Norwegian). Kongsberg Ingeniørhøgskole, Optikkavdelingen, Hovedopgave 1991.
Hofstetter H W (1976): Visual acuity and highway accidents. J Amer Optom Assoc 47: 887-893.
Hogan R E & Linfield P B (1983): The effect of moderate doses of ethanol on heterophoria and other aspects of binocular vision. Ophthal. Physiol. Opt 3-1: 21-31.
Hole G (1981): Night driving training. 2nf International Congress on Vision and Road Safety, Paris 1: 13-14.
Holmberg B(1986): Äldres förflytningsmönster (In Swedish). In "Trafiksäkerhet och åldrande. Nordiska trafiksäkerhetsdagar" NORD, Stockholm 1986: 53-60.
Hulbert-MF; Vernon-SA(1992): Passing the DVLC field regulations following bilateral pan-retinal photocoagulation in diabetics: Eye; 6: 456-60.
Humphriss D (1983): A survey of research projects into the relation of drivers vision to road accidents in overseas countries and South Africa. The South African Optometrist March: 11-19.
Humphriss D (1987): Three South African studies on the relationship between road accidents and drivers' vision. Ophthal Physiol. Opt 7, No1: 73-79.
Hutnik CM, O'Hagan D (1997): Multifocal

contact lenses--look again! Can J Ophthalmol; 32(3):201-205.

Hvoslef H (1986): Trafikmiljöåtgärder (in Sweedish). In "Trafiksäkerhet och åldrande. Nordiska trafiksäkerhetsdagar", NORD, Stockholm 1986: 85-98.

Häkkinen L (1984): Vision in the Elderly and Its Use in the Social Environment. Scand. J.Soc.Med suppl.35: 5-60.

Høeg J, Guldholt I, Dalgaard J B, Kæmpe B & Hansen F (1976): Alkohol hos trafikkvæstede (in Danish). Ugeskr. Læger 138: 3211-3216.

Isler RB, Parsonson BS and Hansson GJ (1997): Age related effects of restricted head movements on the useful field of view of drivers. Accid Anal Prev; 29 (6): 793-801.

Ivers RQ, Mitchell P, Cumming RG (1999): Sensory impairment and driving: The Blue Mountains Eye Study. Am J Public Health;89(1):85-7.

Janke M K (1990): Safety effect of relaxing California's clean-record requirements for driver license renewal by mail. Accid. Anal. & Prev; 22(4); 335-49.

Jahn E (1963): Sehvermögen und Kraftverkehr (in German). Bundesgesundheitsblatt 6: 393-403.

Javitt JC, Wang F, Trentacost DJ, Rowe M, Tarantino N (1997): Outcomes of cataract extraction with multifocal intraocular lens implantation: functional status and quality of life. Ophthalmology; 104(4):589-99.

Jensen P B & Lings S (1987): Trafikhabilitet efter hjerneblødning. En neuropsykologisk undersøgelse (in Danish). Nordisk Psykologi 39(4): 302-06.

Johansson G & Rumar K (1968): Visibility distances and safe approach speeds for night driving. Ergonomics 11: 275-82.

Johansson K et al. (1996): Can a Physician Recognize an Older Driver with Increased Crash Risk Potential? Am. Geriatr Soc 44:1198-1204

Johansson K (1997) Older automobile drivers: medical aspects. Thesis., Karolinska Institute, Stockholm, Sweden.

Johnson CA & Keltner J (1983): Incidence of Visual Field Loss in 20,000 Eyes and Its Relationship to Driving Performance. Arch Ophthalmol 101: 371-75.

Johnston P B & Armstrong M F J (1986): Eye injuries in Northern Ireland two years after seat belt legislation. Br.J.Ophthalm 70: 460-62.

Jude E B et al. (1998): Pupillary dilatation and driving in diabetic patients. Diabet Med ; 15(2): 143-47.

Juhl M (1984): Trafikproblemer og lægers indberetningspligt (in Danish with English summary).Retsmedicinsk Institut, Århus Universitet: 67 and 96.

Justitsministeriet (1932): Bekendtgørelse om Motorkøretøjer, nr.192 af 30. juni 1932 §44 (in Danish). Lovtidende: 1141-47.

Justitsministeriet (1950): Ændringsbekendtgørelse af 4.september 1950, §44 stk.2 (in Danish). Lovtidende 376: 935.

Juul-Jensen P (1965): Epilepsy. A Clinical and Social Analysis of 1020 Adult Patients with Epileptic Seizure. Munksgaard, Copenhagen thesis: 122-26.

Katlun T, Wiegand W (1998): Change in twilight vision and glare sensitivity after PRK (in German) Ophthalmologe; 95(6): 420-6

Kalberer M (1971): Zur Bedeutung von Farbensinnstöhrungen im Strassenverkehr. Ophthalmologica 163: 171-177.

Keeney A H (1968): Relationship of ocular pathology and driving impairment. Trans. Pennsylv.Academy of Ophthalm.& Otolaryngol 21: 22-26.

Keeney A H (1968): Ophthalmic pathology in driver limitation. Tr. Am. Acad. Ophth. & Otol 72: 739-40.

Keeney A H (1974): Significance of visual problems in Pennsylvania drivers. Pennsylvania Medicine August: 49-51.

Keeney A H (1974 a): Field loss vs Central Magnification. Arch.Ophthal 92: 273.

Keeney A H (1975): The automobile as a weapon. Trans. Stud Coll. Physicians Phila 42 (3): 233-33.

Keeney A H & Garway J (1981): The dilemma of the monocular driver. Am.J.Ophthalm 91: 801-803.

Keeney A H (1982): Qouted in: Acocella N: How Drivers with poor vision stay behind the wheel. Sightsaving 51: 12-14.

Kelleher D K (1979): Driving with low vision. Visual impairment and blindness Nov: 345-350.

Kelsey S L, Janke M, Peck R C & Ratz M (1985): License extension for clean-record drivers: A 4-year follow-up. Journal of Safety Research 16: 149-167.

Keltner J L & Johnson C A (1987): Visual function, driving, safety, and the elderly. Ophthalmology 94: 1180-88.

Keltner-J L; Johnson-CA(1992): Visual function and driving safety (editorial): Arch-Ophthalmol. 1992 Dec; 110(12): 1697-8.

Kini M M, Leibowitz H M, Colton T & Nickerson R J (1978): Prevalence of senile cataract, diabetic retinopathy, senile macular degeneration, and open-angle glaucoma in the Framingham eye study. Am.J.Ophthalmol 85: 28-34.

Klein R. (1991): Age-related eye disease, visual impairment, and driving in the elderly. Hum-Factors. 33(5): 521-5

Kline D W, Schrieber F, Abusamra L S & Coyne A C (1983): Age, the eye, and the visual channels: contrast-sensitivity and response to speed. J. Gerantology 38: 211-216.

Kline-D W; Kline-TJ; Fozard-JL; Kosnik-W; Schieber-F; Sekuler-R.(1992): Vision, aging, and driving: the problems of older drivers. J-Gerontol; 47(1): 27-34.

Klit-Hansen, L (1993): Kørelys i Danmark-effektvurdering af påbudt kørelys i dagtimerne (in Danish). Rådet for Trafiksikkerhedsforskning Notat 2/1993.

Kommissionen for de Europæiske Fællesskaber (in Danish) (1982): Vejledning vedrørende EF-kørekort.

Kosnik WD; Sekuler R; Kline DW (1990): Self reported visual problems of older drivers. Hum Factors 32: 597-608.

Kristensen P (1988): Synskrav og kørekort (in Danish). Ugeskr læger 150: 1488-89.

Krogh E. (1995): Syn og trafiksikkerhed, Kor-respondancer (in Danish). Ugeskr Læger 157/3; p. 305 and 157/10; p. 1360-61.

Laberge-Nadeau C, Bourbeu R & Maag U (1983): L'accès universel aux cours de conduite dans les écoles secondaires ne réduit pas la morbidité et la mortalité des jeunes Canadiens (in French). L'union Médicale du Canada 112: 759-66.

Lachenmayr B. (1989): 13. Sehanforderungen an den Verkehrsteilnehmer (in German). In: Auge und Allgemeinleiden. Der Augenartz als Konsiliarius, Enke, Stuttgart, 13; p 166-185.

Lachenmayr-B; Buser-A; Muller-S (1994): [What visual information does the automobile driver need for safe driving in street traffic?]: Welche visuelle Information benotigt der Kraftfahrer fur die sichere Teilnahme am Strassenverkehr? (In German). Ophthalmologe; 91(3): 383-94.

Lachenmayr-B; Buser-A (1994): [Limitation of lens power in automobile drivers]. Brillenglasstarkenbegrenzung beim Kraftfahrer (in German). Klin-Monatsbl-Augenheilkd. 1994 Jan; 204(1): 37-43.

Lachenmayr B (1995): Driving with light during the day? (in German). Ophthalmologe 92: 93-9.

Lachenmayr B (1998): Reduziertes Sehvermögen führt zu erhöhtem Unfallrisiko im Strassenverkehr [Reduced visual function causes higher risk of traffic accidents] (in German). Der Ophthalmologe 1-98 - 95; 44-50.

Lauer A R, de Silva H R & Forbes T W (1939): Report to Highway Research Board, Washington.

Lewandowski, I (1995): Syn hos Trafikanter, en litteraturstudie (in Norwegian). Inger Consult, Postbox 269, 3051 Mjøndalen, Norge.

Levy DT; Vernick JS; Howard KA (1995): Relationship between driver's license renewal policies and fatal crashes involving drivers aged 70 years or older. JAMA 274: 1026-30.

Levitt J G (1975): Vision and Driving. The Ophthalmic Optician Dec: 1109-16.

Liesmaa M (1973): The influence of a driver's vision in relation to his driving. The Optician 166: 10-13.

Linberg-JV; Tillman-WT; Allara-RD (1988): Recovery after loss of an eye. Ophthal-

Plast-Reconstr-Surg.; 4(3): 135-8.

Lindstrom R L (1988): Clinical results of a new multifocal lens. Proceedings From the Sixth Congress of the European Intraocular Implantlens Council, Copenhagen: 85.

Lings S (1987): Nogle neurologiske lidelsers betydning for trafikhabiliteten (in Danish with English summary). Aarhus Universitetsforlag

Lovie-Kitchin J E & Brown B (1986): Reaction time in age-related maculopathy. Am. J.Ophtom.Physiol.Opt 63(5): 366-371.

LSSF Odense Universitet, Rådet for Trafiksikkerhedsforskning Odense Universitet & ØSA Vejdirektoratet (1983): Trafikuheldsomkostninger (in Danish). Vejdirektoratet

Luff K, Gramberg-Danielsen B & Lutz F U (1976): Experimentelle Untersuchungen über die Blendwirkung von Halogenfernlicht (in German). Bundesgesundheitsblatt 15-16: 237-251.

Lundt P V (1972): Sehvermögen und Kraftverkehr (in German). Schriftenreihe des Bundes-ministers für Verkehr 38: 1-77.

Luoma J (1984): Perception and eye movements in simulated traffic situations. Acta Ophthalmol suppl.161: 128-134.

Løvsund P; Hedin A; Törnros J (1991): Effects of driving performance of visual field defects: a driving simulator study. Accid-Anal-Prev. 23: 331-42.

Maag F & Bullet R P (1983): The Functionally One-eyed Professional Driver. Schweiz.Rundschau Med. (PRAXIS) 72 (42): 1333-1337.

MacKean J M & Elkington A R (1982): Glaucoma and driving. Br.Med.J 285: 777- 778.

Mannan M S and Ernvall, T (1996): Older drivers in Finnish accident data. Road &transport Research, vol 5 (3): 104-18.

Mars-S; Keightley-S (1990): Visual standards for driving and occupations. Practitioner; 234(1481): 34-35.

McConnell-RA; Spall-AD; Hirst-LW; Williams-G (1991): A survey of the visual acuity of Brisbane drivers. Med-J-Aust. 1991 15; 155(2): 107-11.

McGwin G Jr, Owsley C, Ball K (1998):Identifying crash involvement among older drivers: agreement between self-report and state records. Accid Anal Prev; 30(6):781-91

McKnight-AJ; Shinar-D; Hilburn-B (1991): The visual and driving performance of monocular and binocular heavy-duty truck drivers. Accid-Anal-Prev. Aug; 23(4): 7.

McCloskey LW; Koepsell TD; Wolf ME; Buchner DM (1994): Motor vehicle collision injuries and sensory impairments of older drivers. Age- Ageing; 23(4): 267-73.

McCrimmon RJ, Deary IJ, Huntly BJ, MacLeod KJ, Frier BM (1996): Visual information processing during controlled hypoglycaemia in humans. Brain; 119(Pt 4):1277-1287.

Macdonald W A (1985): Human Factors and Road Crashes- a Review of their Relationship. Report CR39. Dep. of Mechanical Engineering, Melbourne ISBN 0 642 51226 3.

McLemore C S (1963): Cadillacs, Volkswagens, and aphakic corrections. Arch. of Ophthalmol 70: 734-735.

McGwin G, Sims R V, Pulley L V & Rosemann J M (1999): Diabetes and Automobile Crashes in the Elderly. Diabetes Care; 22:220-27.

Maxwell W A & Nordan L T (1986): Trapezoidal Relaxing Incision for Post Keratoplasty Astigmatism. Ophthalmic Surgery 17: 88-90.

Merry B J (1987): Biological mechanisms of ageing. Eye 1: 163-170.

Miles P W (1956): Can modern visual research reduce traffic accidents?. Canad. Serv.Med.J 12: 227-236.

Miller J W & Ludvigh E (1962): The effect of relative motion on visual acuity. Surv. Ophthalmol 7(2)

Ministeriet for Offentlige Arbejder (1987): TU-86, trafikundersøgelse, (Report in Danish).

Monestam E, Wachtmeister L (1997): Impact of cataract surgery on car driving: a population based study in Sweden. Br J Ophthalmol; 81(1):16-22

Mortimer R G and Fell J C (1989): Older drivers: Their fatal crash involvement and risk. Accid. Anal. & Prev. 21(3), p 273-82.

Mourant R & Mourant, R (1979): Driving performance of the elderly. Acid. Anal. & Pres 11: 242-253.

Mulhern MG, Foley-Nolan A, O'Keefe M, Condon P I (1997): Topographical analyses of ablation centration after eximer laser keratectomy and laser in situ keratomileusis for high myopia. J Cataract Refract Surg 1997; 23 (4): 488-494.

Nadler D J et al. (1984): Glare disability in eyes with intraocular lenses. Am. J. Ophthal mol 97: 43-47.

Naughton T, Pepler R D & Waller J A (1985): Investigative risk levels for heart attacks (myocardial infarct victims). Quoted in OECD-report: Traffic safety of elderly road users OECD, PAris: 60-84.

Nelson-DE; Sacks-JJ; Chorba-TL (1992): Required vision testing for older drivers [letter]: N-Engl-J-Med.; 326(26): 1784-5.

Neumann A C, McCarty G R, Steedle T O, Sanders D R & Raanan M (1988): The relationship between cataract type and glare disability as measured by the Miller-Nadler glare tester. J.Cataract refract.Surg 14: 40-45.

Neumann A C et al. (1988b): The relationship between indoor and outdoor Snellen visual acuity in cataract patients. J.Cataract Refract.Surg 14: 35-39.

Nielsen K Axel (1966): Lov om ændringer i færdselsloven af 8.juni 1966 (in Danish). Lovtidende A: 324-326.

Ninn-Pedersen K (1996): Cataract patients in a defined Swedish population 1986-1990. Thesis. Dep. of Ophthalmology, Lund University Hospital Sweden.

Nordisk Trafiksikkerheds Råd (1990): Äldre bilförares olycker i korsninger (in Swedish). Rapport 53: (Nord 1009:66).

Norman L G (1960): Medical aspects of road safety. The Lancet: 1039-44.

Norman L G (1960a): Medical aspects of road safety. The Lancet: 989 994.

Norman L G (1962): Road traffic accidents, Epidemiology, Control, and Prevention. World Health Organization, Public health papers No. 12 Geneva: 74-75.

North R V (1985): The relationship between the extent of visual field and driving performance - a review. Opthal. Physiol. Opt 5: 205-210.

North, R V (1987): The influence of age upon visual functions and driving performance. A review. Vision and Vehicles II. Elsvier Science Publishers.

North R V (1993): Work and the Eye. Oxford Medical Publications, Oxford University Press.

Nørskov K (1971): Anvendelse af rutinetonometri til opsporing af glaucoma simplex. En undersøgelse på Falster med 5 års follow-up (thesis, in Danish with English summary). Acta Ophthalmol.

OECD-report (1978): New research on the role of alcohol and drugs in road accidents. OECD, Paris.

OECD-report (1985): Traffic safety of elderly road users. In: Report prepared for OECD and WHO. OECD, Paris: 21-38.

Offret G (1982): Du Role des troubles de la vue dans les accidents de la route (in French). Bull.Acad.Nat.Med 166: 757-761.

Olsen J (1988): Case-kontrolundersøgelser (in Danish). Nordisk Medicin 103: 205-207.

Olsen T (1988): Theoretical approach to intraocular lens calculation using Gaussian optics. J Cataract Refract Surg 13: 141-145.

Olson P L & Sivak M (1986): Perception-response time to unexpected roadway hazards. Human Factors 28(1): 91-96.

Optometry Today, (1996): Survey shows 16% of All UK Drivers Fail Number Plate Test. October 21, 1996, p. 10.

Owsley-C; Ball-K; Sloane-ME; Roenker-DL; Bruni-JR (1991): Visual/cognitive correlates of vehicle accidents in older drivers. Psychol-Aging. 1991 Sep; 6(3): 403-15.

Owsley C, et al. (1998): Visual processing impairment and risk of motor vehicle crash among older adults. JAMA. 1998 Apr 8; 279 (14): 1083-1088.

Owsley C, McGwin G Jr, Ball K (1998): Vision impairment, eye disease, and injurious motor vehicle crashes in the elderly Ophthalmic Epidemiol; 5(2):101-13.

Owens D A & Leibowitz H W (1976): Night myopia: Cause and a possible basis for amelioration..J.Optometry & physiological optics 53(11): 709-717.

Paetkau M E, Taerum T and Hiebert T (1988): Prevalence of illegal motor vehicle driving among visually impaired elderly patients in Alberta. Can J Ophthalmol 23; 7, 301-4.

Parisi-JL; Bell-RA; Yassein-H (1991): Homonymous hemianopic field defects and driving in Canada. Can-J-Ophthalmol. 26(5): 252-6.

Pearson A R, Tanner V, Keightley S J, Casswell A G (1998): What effect does laser photocoagulation have on driving visual fields in diabetics? Eye; 12: 64-68.

Perdriel-G (1994): [Visual information and road safety]: Information visuelle et securite routiere (in French). Bull-Acad-Natl-Med.; 178(6): 1075-82; discussion 1082-6

Perdriel G (1998): Le role des commissions médicales du permis de conduire. La Prevention Routier, janvier-fevrier ; (in French), 42; 8.

Perryman KM, Fitten LJ (1996): Effects of normal aging on the performance of motor-vehicle operational skills. J Geriatr Psychiatry Neurol; 9(3):136-41.

Phillips AJ, Ruthstein A (1965): Glare - a study into glare recovery time with night driving spectacles. Br. J. Physiol. Optics. 22, 153-64.

Piovella M, Camesasca FI, Fattori C (1997): Excimer laser photorefractive keratectomy for high myopia: four-year experience with a multiple zone tech-nique. Ophthalmology; 104 (10): 1554-65.

Pfoff-DS; Werner-JS (1994): Effect of cataract surgery on contrast sensitivity and glare in patients with 20/50 or better Snellen acuity. J-Cataract-Refract-Surg.; 20(6): 620-5

Plenty J V (1985): Visual requirements for motorists. Brit. orthopt. J 42: 69-71.

Politiets Årsberetning (1984): (in Danish).: 140, 150,and 160.

Preston D L, Lubin J H & Pierce D A (1991): Epicure. HiroSoft International Corp, 1463 E. Republican Ave. Suite 103. Seattle. USA.

Quimby A, Maycock G, Carter ID, Dixon R & Wall JG (1986): Perceptual abilities of accident involved drivers. Transport and Road Research Laboratory Report no 27: 1-29.

Raffle A (1985): Medical aspects of fitness to drive. A guide for medical practitioners. The medical commission on accident prevention London

Renwick M Y, Olsen G G & Tyrell M S (1982): Road fatalities in rural New South Wales. Weighing the causes. Medical J of Australia: 291-295.

Richards O W (1963): Vision at Levels of Night Road Illumination. Highway research Record 25: 76-82.

Richmond P & Ebert E C (1933): Speed of visual perception. US naval medical Bulletin 31: 150-152.

Rizzo M, Robin DA (1996): Bilateral effects of unilateral visual cortex lesions in human. Brain; 119(Pt 3):951-963.

Rogers P N, Ratz M and Janke M K (1987): Accident and conviction rates of visually impaired heavy-vehicle operators. Report No. CAL-DMV-RSS-87-11. Sacremen-to, Calif. Dep. Motor Vehicles, Jan 1987.

Romer C J (1981): Speech at the 2nd international congress on vision and road safety, Paris. La prevention routiere international 1

Rosenberg Th & Goldschmidt E: Socialhåndbog for øjenlæger (in Danish). Stubtoft & Co: 1976.

Rothmann K J (1986): Modern epidemiology. Little, Brown and Company, Boston Toronto.

Rubin-GS; Roche-KB; Prasada-Rao-P; Fried-LP (1994): Visual impairment and disability in older adults. Optom- Vis-Sci. ; 71(12): 750-60.

Rumar K (1971): Bilbelysningen i går, i dag, i morgon (In Swedish). Läkartidningen 68 1906-1916: 1906-1916.

Rumar K (1981): The visual environment in road traffic. Statens väg och trafikinstitut (VTI), Linköping 59

Rumar K (1986): Människa-fordon-miljö. Ett system (in Swedish). In: Andreasson R: Körkortsmedicin, Trafikmedicin (in Swedish) Raben & Sjögren: 222-227.

Rumar K (1986a): Age and road user behaviour. Trafikduglighed och ålder. (in Swedish). 4th Nordic Congress of Traffic Medicine Esbo, Finland, congresspaper.

Ruth J E (1986): Effect of aging on some physiological functions relevant in Traffic (in Swedish). Paper at the Nordic symposium Road Safety and Aging, Åland October 1985. Gotab, Stockholm (NORD): 75-78.

Rådet for de Europæiske Fællesskaber(1980): Rådets første direktiv af 4. december 1980 om indførelse af et EF- kørekort (in Danish). De Europæiske Fællesskabers Tidende L 375: 1-15.

Sachsenweger von R & Nothaass E (1961): Eine Analyse von 4011 Verkehrsunfällen aus augenärztlicher Sicht (in German). Deutsch Gesundh 16: 868-72.

Sachsenweger-M; Sachsenweger-U(1987): Quality of space perception of moving objects in the aged (in German) ZFA.; 42(3): 139-42

Sanders D R, Retzlaff J & Kraff M C (1988): Comparison of the SRK II formula and other second generation formulas. J. Cataract refract surg 14: 136-141.

Schlote T, Kriegerowski M, Bende T, Derse M, Thiel HJ, Jean B (1997): Mesopic vision in myopia corrected by photorefractive keratectomy, soft contactlenses, and spectacles. J Cataract Refract Surg; 23(5):718-725.

Schneider W (1986): Visual Functions and Accident Risks in Traffic Operations. Report on the second CEC supported international workshop held at Cologne.

Schober H (1969): Forderung nach periodischer Überprüfung des Sehvermögens von Führerschein-inhabern. Klin. Mbl. Augenheilk 155: 299-301.

Schou S (1917): Fordringerne til Chaufførers Synsevne (in Danish). Forhandlinger i Det Oftalmologiske Selskab i København 14: 434-438.

Schwartz F (1939): Der Einäigige als Motorfahrzeugsführer (in German). Schweitz. med. Wschr 44: 1145.

Schieber-F. (1994): High-priority research and development needs for maintaining the safety and mobility of older drivers. Exp-Aging-Res. ; 20(1): 35-43.

Seedorff H H (1956): The effect of alcohol on the motor fusion reserves and stereopsis as well as the tendency of nystagmus. Acta Ophthalmol 34: 273-280.

Seib-H (1990): [Knowledge of accident causation research in relation to age-induced decrease in the performance of elderly motorists, their accident risk and legal consequences] (in German) Z-Gerontol; 23(2): 86-96.

Shinar D (1977): Driving Visual Limitations: Diagnosis and Treatment. Dept. of Transportation, report DOT-HS-803-260, National Highway Traffic Safety Administration Washington, DC

Shinar D & Drory A (1983): Sign registration in daytime and nighttime driving. Human Factors 25(1): 117-122.

Shinar D (1984): Actual versus estimated night-time pedestrian visibility. Ergonomics 27(8): 863-871.

Shinar D, Gilhead E. (1987): Contrast sensitivity as a predictor of complex target detection. Proceedings at the 31st Meeting of the Human Factor Society. Santa Monica, CA: Human Factor Society; 1194-97.

Shinar-D; Schieber-F (1991). Visual requirements for safety and mobility of older drivers. Hum-Factors. 33(5): 507-19.

Shipp M D and Penchansky M I L R (1995): Vision Testing and the Elderly Driver: Is There a Problem Meriting Policy Change? J Am Opt Assoc; 66 (6): 343-51.

Sicard-A (1994): [The road accident is not inevitable] L'accident de la route n'est pas une fatalite (in French).

Bull-Acad-Natl-Med.; 178(6): 1069-73.

Sivak M (1996): The information that drivers use: is it indeed 90% visual? Perception; 25(9):1081-1089.

Sjølie A K (1985): Ocular Complications in Insulin Treated Diabetes Mellitus. An epidemiological study. Acta Ophthalmologica Suppl. 172.

Sjöstrand J, Abrahamsson M & Hård A-L (1987): Glare disability as a cause of deterioration of vision in cataract patients. Acta Ophthalmol 65(suppl.182): 103-106.

Skalka H W (1980): Effect of age on Arden grating acuity. Br. J. Ophthalmol 64: 21-23.

Skjærbæk Olesen O (1949): Om synsfeltsdefekter ved hypofyseadenomer (og visse øjen-problemer i trafikken) med spec. henblik paa trafiksikkerheden (in Danish). Ugeskr. Læger 13: 36-39.

Smeed R J (1953): Some factors affecting visibility from a driver's seat and their effect on road safety. Brit. J Physiol.Optics 10: 63-84.

Soper J W H (1986): Autobiographical pictorial study of a cataract in progress. J.Cataract. Refract. Surg 12: 303-307.

Stadfeldt A (1906): Om synsprøver for sømænd (in Danish). Bibl Læg SR VII: 305-334.

Steel SE, Mackie SW, Walsh G(1996):Visual field defects due to spectacle frames: their prediction and relationship to UK driving standards. Ophthalmic Physiol Opt;16(2):95-100.

Strengell G (1986): Trafiksäkerhet och åldrande, Befolkningsutveckling (In Swedish). In "Trafiksäkerhet och åldrande. Nordiska trafiksäkerhetsdagar" (NORD), Stockholm 1986: 41-45.

Sturgis S P & Osgood D J (1982): Effects of glare and background luminance on visual acuity and contrast sensitivity: Implications for driver night vision testing. Human Factors 24(3): 347-360.

Stutts JC,1998:Do older drivers with visual and cognitive impairments drive less?.J Am Geriatr Soc;46(7):854-61.

Sundhedsstyrelsen (1910): Cirkulære til landets læger af 27. dec. 1910 (in Danish). Ugeskr Læg 73: l03.

Sundhedsstyrelsen (1919): Cirkulære til landets læger af 1.jan.1919 (in Danish).

Sundhedsstyrelsen(1923):Spørgsmål angående Udfærdigelsen af Førerbevis til Personer, der lider af en eller anden legemlig Defekt (in Danish). Sundhedsstyrelsens Aars-skrift: 262-65.

Sundhedsstyrelsen(1962): Blanket til helbredsmæssige oplysninger ved udstedelse af førerbevis til motorkøretøj, P.L. 42: Afsnit B, pkt.1.2. (In Danish).

Sundhedsstyrelsen (1981): Lægelovens § 12 særligt med henblik på indberetning af motorførere med sygdomme eller mangler i legemlig eller sjælelig henseende, der må betragtes som uforenelige med motor-kørsel (in Danish). Ugeskr. Læger 143: 720.

Szlyk JP, Alexander, KR, Severing K and Fishman GA (1992): Assesment of driving Performance in Patients with Retinitis Pigmentosa. Arch Ophthalmol. 110: 1709-13.

Szlyk JP, Brigell M, Seiple W(1993):Effects of age and hemianopic visual field loss on driving.Optom Vis Sci; 70(12): 1031-1037.

Szlyk-JP; Fishman-GA; Severing-K; Alexander-KR; Viana-M (1993): Evaluation of driving performance in patients with juvenile macular dys-trophies. Arch- Ophthalmol.111(2): 207-12.

Szlyk-JP; Seiple-W; Viana-M (1995): Relative effects of age and compromised vision on driving performance. Hum-Factors; 37(2): 430-6.

Szlyk JP; Pizzimenti CE, Fishman GA; Kelsch R; Wetzel LC; Kagan S; Ho K. (1995): A comparison of drivers in older subjects with and without age-related macular degenerations. Arch Ophthalmol. 113: 1033-40.

Szlyk JP, Seiple W, Laderman DJ, Kelsch R, Ho K, McMahon T, 1998: Use of bioptic amorphic lenses to expand the visual ield in patients with peripheral loss. Optom Vis Sci; 75(7):518-24.

Szymankiewiczowa-S; Parfiniewiczowa-E (1989): [Evaluation of the efficiency of the visual system in automobile drivers] (in Polish) Klin-Oczna; 91(2-3): 35-6.

Taglia D P, Szlyk J P, Deepak P E, Kong H, Wilensky J T (1997): Dri-ving Performance in Patients with Glaucoma. Abstract, AAO meeting, San Francisco, October 1997.

Taylor J F (1982): Vision and driving. The Practitioner 226: 885-889.

Taylor J F (1983): Epilepsy and driving. Research progress in Epilepsy: 533-37.

Taylor J F (1987): Vision and driving. Ophthal. Physiol. Opt. 7: 187-189.

Taylor SP, 1997: Accuracy of recall of the legal number plate testing distance by U.K. drivers. Ophthalmic Physiol Opt;17(6):473-77

Tennenhouse D J (1984): The Physician's Duty to Warn: A New Twist. Survey of Ophthalmology 28: 339-341.

Thalmann H (1971): Der Einäugige im Strassenverkehr (in German). Schweizerische Medizinische Wochenschrift 101: 981-987.

Therkelsen A J (1972): Rangsum test til sammenligning af en serie hyppigheder (in Danish). In: Medicinsk Statistik, Akademisk Boghandel, Århus: 141-144.

Timmermann A (1985): Direct measurement of windscreen surface wear and the consequences for road safety. Forschungsgemeinshaft Auto, Sicht, Sicherheit, Köln congresspaper: 1-13.

Tinning S (1979): Bevægelsens betydning for synsstyrken (in Danish). Nordisk Trafikmedicinsk Information 1: 1.

Tinning S (1995): Syn og trafiksikkerhed, korrespondance (in Danish). Ugeskr Læger 157/10. 1360-61.

Todorovic P (1984): Review of manuals in European countries and advice to doctors on health factors affecting drivers. Yogoslav institute of physical culture and sports medicine.

Trafikministeriets bekendtgørelse om kørekort (in Danish), Bekendtgørelse nr 196 af 11. marts 1997, j.nr. 1995-4402-47.

Transportforskningsberedningen (TFB) (1984): Den lokala och regionala kollektivtrafiken om 10-20 år. Förändringer av äldres resvanor fram til sekelskiftet (in Swedish). Rapport 1984: 28 Stockholm.

Töllner E (1984): Dämmerungssehen und Blendempfindlichkeit (in German). Deutschen Gesellshaft für Verkehrsmedizin Kongress-bericht: 94-99.

van Rijn L J and Völker-Dieben H J (1999): Assessment of vision impairment in relation to driving safety. A literature study. CIECA report. University Hospital Vrije Universiteit, Dep. of Ophthalmology, Amsterdam.

Vägverket (1998): Âdre bilförares problem i trafiken. (In Swedish). Borljänge, Publikation: 63, 1998.

Valverius M R (1986): Alcohol and traffic safety. Current status. 4th Nordic congress on traffic medicine, Esbo, Finland congresspaper: 1-27.

Vejdirektoratet (1988-93): Trafikøkonomiske enhedspriser (in Danish). Vejdirektoratet, Økonomisk-statistisk afdeling.

Vejdirektoratet 1998: Personal communication.

Verriest G, Neubauer O, Marre M & Uvijls A (1980): New investigations concerning the relationship between congenital colour vision defects and road traffic security. Int. Ophthal 22: 87-99.

Verriest G et al (1985): The occupational visual field: II Practical aspects; the functional visual field in abnormal conditions and its relationship to visual. Proceedings of the 6th Int.Visual Field Symposium: 281-326.

v. Hebenstreit B (1984): Sehvermögen und Verkehrsunfälle (in German). Klin Mbl Augenheilk 185: 86-90.

v. Hebenstreit B (1985): Sehstörungen und Unfallhäufigkeit in Strassenverkehr (in German). Der Augenartz 19: 45-48.

Vinding T, Appleyard M, Nyboe J and Jensen G (1992): Risk factor analyses for atrophic and exudative age-related macular degeneration. An epidemiological study of 1000 aged individuals. Acta Ophthalmol 70; 66-72.

Vingrys A J & Cole B L (1986): Origins of colour vision standards within the transport industry. Ophthal.Physiol.Opt 6: 369-375.

von Bahr G (1971): Ar halvljusregeln verkligen motiverad? (In Swedish). Läkartidningen 68: 2205-2206.

Waller J A (1965): Chronic medical conditions and traffic safety. The New England Journal of Medicine 273, no 26: 1413-1420.
Walraven N-G (1981): Retro-flection, signalling. 2nd International Congress on Vision and Road Safety, Paris 1: 19-20.
Wanscher J H (1982): Sidesynsvirkningen (in Danish). Medicinsk Forum 35: 127-128.
Wang Z, Chen J, Yang B (1997): Comparison of laser in situ keratomileusis and photorefractive keratectomy to correct myopia from -1.25 to 6.00 diopters. J Refract Surg 1997; 13 (6): 528-534.
Waring G O (1984): Evolution of Radial Keratotomy for Myopia. Trans ophthalmol. Soc. U.K. 104: 28-42.
Waring G O et al. (1983): Results of the Prospective Evaluation of Radial Keratotomy (PERK) study One Year After Surgery. Ophthalmology 92: 177-198.
Wasmund C (1982): Über die beeinflussung optisher funktionen durch diagnostische pupillenarweiterung (eine verkehrs-ophthalmologische Studie). Aus der Augenklinik und Poliklinik der freien Universität, Berlin.
Weber O (1966): "Evighedskørekort" - trods klar advarsel fra lægeforeningens hovedbestyrelse (in Danish). Ugeskr. Læg 128: 308-310.
Westerlund E (1966): Førerbevis til motorkøretøj fra 18. til 70.år. (in Danish). Ugeskr. Læg 128: 310.
Whillans M G and Allens M J (1991): Color Defective Drivers and Safety. Optometry and visual science 69; (6): 463-66.
Wiktorsson J (1984:1): Äldres säkerhet i trafiken. Olycksanalys (in Swedish). Litteraturstudie. In: Transport- forskningsdelegationen, Stockholm, TFD S: 55-81.
Wiktorsson J (1985): Äldre bilförares säkerhet i tätort olycksanalys (in Swedish). Department of Highway Engineering, Chalmers University of Technology, Sweden.
Wilkinson ME (1998):Driving with a visual impairment *Insight;* 23(2):48-52
Williams AF, Carsten O (1989): Driver age and crash involvement. Am J Public Health; 79: 326-7.
Wingaard P (1974): Lovsamling for Medicinalpersonale (in Danish). F.A.D.L.s forlag 2: 348-349.
Winther-Nielsen-A; Gyldenkerne-G; Corydon-L (1995): Contrast sensitivity, glare, and visual function: diffractive multifocal versus bilateral monofocal intraocular lenses. J-Cataract- Refract- Surg.; 21(2): 202-7.
Wiseman EJ, Souder E (1996): The older driver: a handy tool to assess competence behind the wheel. Geriatrics ;51(7):36-38
Wood-JM; Troutbeck-R(1992): Effect of restriction of the binocular visual field on driving performance. Ophthalmic-Physi-ol- Opt. 1992 Jul; 12: 291-8.
Wood-JM; Troutbeck-R (1994): Effect of visual impairment on driving. Hum-Factors. 36 (3): 476-87.
Wood-JM; Troutbeck-R (1995): Elderly drivers and simulated visual impairment. Optom-Vis-Sci.; 72(2): 115-24.
Wulf H R, Schlichtling P (1988), Medstat (2. udgave). Statistikprogram (in Danish) Astra, Roskilde, Denmark.
Ysander L (1966): The safety of physically disabled drivers. Brit.J.Industr.Med 23: 173-180.
Ysander L (1970): Sick and Handicapped Drivers. Acta Chirurgica Scandinavica. Supplementum 409.
Ysander L & Herner B (1976): The traffic behaviour of elderly male automobile drivers in Gothenburg, Sweden. Accid. Anal. & Prev 8: 81-6.
Zahle C Th (1910): Bekendtgørelse nr. 137, Justitsministeriet (in Danish). Lovtidende: 779-780.
Zaidel D M & Hocherman I (1986): License Renewal for Older Drivers: The Effects of Medical and Vision Tests. J of Safety Research 17: 111-116.
Åberg L & Rumar K (1975): Headmovements of drivers. Equipment and exploratory study. Department of Psychology, University of Uppsala, Sweeden Report 182.
Åberg L (1977): Headmovements of driver's compensatory head movements due to restrictions in the visual field. Dept.of Psychology, Univ. of Uppsala, Sweden 205.

11. Subject index: