2. **Physical and mental characteristics of the older driver**

This chapter discusses the age-related functional limitations, diseases and disorders that may affect the driving performance of older people. Only in the case of severe sensory, perceptual, and cognitive limitations does the relation between functional limitations and crash involvement become visible. Examples are eye disorders such as cataract, macular degeneration and glaucoma, and diseases like dementia, stroke, and diabetes. Less severe functional limitations can usually be compensated for by older drivers.

2.1. **Introduction**

Characteristics of older people that may be related to the difficulties older drivers encounter in traffic can be divided into three categories: age-related functional limitations, age-related disorders, and medication. This chapter briefly discusses each of these categories and describes their relevance to the driving task. No attempt is made to be complete. The aim is to present a general understanding rather than to give a comprehensive overview of all age-related functional limitations and disorders.

While reading this chapter, it should be kept in mind that individual differences in health, functions and activities are large in the older age group, probably even larger than in younger adults (Hardy, Satz, d’Elia & Uchiyama, 2007; Heron & Chown, 1967). This implies that there are large differences in the chronological age at which certain functional limitations manifest themselves, as well as in the pace at which the decline of functions continues. In addition, it should be kept in mind that the influence that functional limitations have on the mobility and safety of the driver is dependent on whether and how they are compensated. Are functional limitations taken into account in selecting and regulating activities, for example, by using assistive devices or by using compensation strategies such as avoiding peak hours? The latter topics will be discussed in the last section of this chapter.

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3 This chapter was based on chapter 4 of SWOV report D-2000-5 (Davidse, 2000) and on a text about Older drivers by Davidse which was written for the European Road Safety Observatory (ERSO, 2006).
2.2. Age-related functional limitations

The functional limitations which accompany ageing that are most relevant for driving are those that relate to vision and cognition. There are few indications that a decline in visual and cognitive functions as part of normal ageing has negative road safety consequences. Only in the case of moderate and severe visual and cognitive limitations resulting from age-related disorders does the relation between functional limitations and crash involvement become visible (Brouwer & Davidse, 2002; Brouwer, Rothengatter & Van Wolffelaar, 1988; Van Wolffelaar, Rothengatter & Brouwer, 1989). Examples are eye disorders such as cataract, macular degeneration and glaucoma, and diseases like dementia, stroke, and diabetes (see Section 2.3). The older the sample, of course, the more difficult it is to disentangle effects of ageing and pathology. With few exceptions, the probability of degenerative processes exponentially increases with age. Therefore, beyond a certain age, pathology is statistically normal. However, as Brouwer and Ponds (1994) conclude, “Whatever the nature of the impairments is, their final common effects are often quite similar: an increase in the time needed to prepare and execute a driving manoeuvre and a decreased ability to perform different actions in parallel” (p. 153).

2.2.1. Vision

Vision is the most important sense for the driving task. After all, most of the sensory input necessary to drive a car is visual. Visual functions generally taken into account in driver licensing are binocular visual acuity and visual field. Both functions decrease with ageing but the decrease is relatively small and scores generally remain well above the minimum licence requirements until high age unless there is ocular or neurological pathology. Declines in visual acuity, for example, typically occur in people with macular degeneration, whereas declines in visual field occur in people with glaucoma (increased eye pressure), diabetes and after stroke or other cerebral diseases (see Section 2.3). These diseases are found more often in the group of older drivers (Klein, 1991).

Functions that are more sensitive to ageing (i.e., deterioration begins earlier and accelerates faster with increasing age) are dynamic visual acuity, detection of movement, night-time visual acuity, sensitivity to glare, and contrast sensitivity (for a detailed description see Shinar & Schieber, 1991). Furthermore, higher order visual functions such as perceptual speed, field dependence, functional field of view and visual working memory are quite
sensitive to ageing. Tests in these domains have been repeatedly found to correlate with poor on-road driving performance and crash involvement (see e.g., Ball et al., 2006; Hoffman, McDowd, Atchley & Dubinsky, 2005; Wood, 2002).

**Dynamic visual acuity and detection of movement**
Dynamic visual acuity is the ability to resolve details of a moving target. Its deterioration is probably attributable to the required oculomotor control (Shinar & Schieber, 1991). The oculomotor system is also involved in detection of movement. However, the decline in detection of movement with increasing age appears to be mainly the result of age-related changes to neural mechanisms. Obviously, the ability to detect movement is very important for safe driving, not only for being able to detect vehicles driving on an intersecting road and to estimate their speed, but also for being able to detect changes in the speed of vehicles in front, i.e., stopping, slowing down, speeding up, and reversing (Holland, 2001; Shinar & Schieber, 1991).

**Night-time visual acuity and sensitivity to glare**
Impaired night-time visual acuity is the result of two age-related changes that reduce the amount of light reaching the retina: reduced pupil size and yellowing of the lens (Olson, 1993). A consequence of reduced retinal illumination is that sources must be of higher intensity to be seen at night (e.g., Olson, 1993). Sensitivity to glare, which increases between the ages of 40 and 70, leads to a slower recovery from headlights and other reflecting sources (Fozard et al. (1977) cited in Aizenberg & McKenzie, 1997).

**Contrast sensitivity**
As far as contrast sensitivity is concerned, older adults have more difficulties detecting objects that are not outlined clearly or that do not stand out from their background. Its deterioration is probably attributable to changes in the eye itself as well as neural factors. Contrast sensitivity is – even more than visual acuity – necessary for the perception of (the information on) traffic signs. Besides this, contrast sensitivity is also believed to play a role in distance perception and the estimation of the speed of moving objects (Holland, 2001; Shinar & Schieber, 1991).

**2.2.2. Cognitive functions**
Age-related declines in sensory functions such as vision and hearing have an impact on the input the driver receives from other road users and from the road environment (e.g., traffic signs and signals, road markings). To select
the appropriate information, interpret it and make decisions which must then be translated into an appropriate driving action, and to compensate for sensory limitations, various perceptual and cognitive functions come into play. Some of these functions show effects of ageing. Cognitive functions for which appreciable effects of ageing are described, are fluid intelligence, speed of processing, working memory, and executive functions like inhibition, flexibility and selective and divided attention (Brouwer & Ponds, 1994; Salthouse, 1982).

The speed at which information is processed, is important to making safe decisions as a driver. Fundamental to this aspect of the driving task is the time taken by a driver to respond to the demand placed upon him or her by the traffic environment (often referred to as ‘perception-reaction’ time). Research studies have generally found that reaction times to simple stimuli do not deteriorate dramatically with age (Olson & Sivak, 1986). Reaction times of older drivers only slow down when drivers have to make decisions in complex situations (Quimby & Watts, 1981).

2.2.3. Motor functions

Motor functions that decline as people age are joint flexibility, muscular strength, and manual dexterity. These age-related changes can influence the ability to get in and out of a car, operate the vehicle, and can influence injury and recovery (Sivak et al., 1995). An example of the influence of reduced joint flexibility is that reduced neck rotation can hinder the driver while checking for approaching traffic at intersections or before merging. This is especially detrimental to older drivers, since they rely on neck rotation to compensate for their restricted visual field. Decline in joint flexibility is not the same for all body parts. In a study by Kuhlman (1993), older adults had approximately 12% less cervical flexion, 32% less neck extension, 22% less lateral flexion and 25% less rotation than the younger control group (Sivak et al., 1995). Joint flexibility can be greatly influenced by degenerative diseases such as arthritis, which is experienced to some degree by approximately half the population over 75 (Adams & Collins, 1987; cited in Sivak et al. 1995).

Muscle strength declines from the age of 50. The strength of muscles can play a role in limiting injuries from small impact collisions, such as whiplash. Other age-related physical factors that can influence injury severity are brittleness of the bones and reduced elasticity of soft tissues (Sivak et al., 1995).
2.3.  **Age-related disorders**

A number of age-related diseases and disorders are found to be related to crash proneness. These are: eye disorders, dementia, Parkinson’s disease, stroke, cardiovascular diseases and diabetes (Becker, 2000; Brouwer & Davidse, 2002; Marottoli et al., 1994; Vaa, 2003). These diseases and disorders can occur at every age, but they are more common among older adults.

2.3.1.  **Eye disorders**

The eye disorders cataract, macular degeneration, glaucoma and diabetic retinopathy are the leading causes of a significant decline in visual acuity and visual field while ageing (Klein, 1991). **Cataract** is characterized by a clouding of the eye lens and affects glare sensitivity, colour perception and night vision. Fortunately, it can be treated by replacing the lens with an artificial one. **Age-related macular degeneration** is a disorder of the central part of the retina and affects visual acuity and colour perception. This disorder, therefore, can lead to the inability to read road signs or to have a good view of distant road and traffic situations. **Glaucoma** affects the peripheral part of the retina as a result of damages caused by high intraocular pressure. This condition is painless and the patient is often unaware of the deficit in visual field, a deficit which interfere with the perception of cars or pedestrians approaching from the side (Klein, 1991). Persons with diabetes, a disease that affects between 10% and 20% of the older adults (Harris, Hadden, Knowler & Bennett, cited in Klein, 1991), are at higher risk of developing cataract, glaucoma and abnormalities that affect the retinal blood vessels (**diabetic retinopathy**). The latter often result in deficits in the peripheral visual field.

2.3.2.  **Dementia**

Dementia is characterized by severe limitations in multiple cognitive functions (as a result of (degenerative) brain pathology. As a rule of thumb, the prevalence of dementia doubles every five year starting from 1.0% for those aged 65 to 32% for those aged 90-94 (Hofman et al., 1991). The most common dementing illness is Alzheimer’s disease, accounting for approximately half of all dementia cases. Alzheimer’s disease is a steadily progressing degenerative disorder and is characterized by severe memory limitations and at least one other severe cognitive limitation such as apraxia, agnosia, aphasia or a dysexecutive syndrome.
Dementia often includes an impaired awareness of one’s own illness, as a result of which patients are often not capable of judging their own limitations and of adapting their behaviour accordingly (Kaszi, Keyl & Albert, 1991). Thus, drivers with dementia are less likely to limit their exposure to high risk situations than drivers who have diminished visual and physical abilities but intact cognitive abilities (Staplin, Lococo, Stewart, & Decina, 1999). The mere diagnosis of dementia is not always enough to advise older adults to stop driving. According to an international consensus group on dementia and driving, drivers should be advised to stop driving when they are diagnosed with moderate or severe dementia. When continued driving is considered permissible, it is of great importance to ensure regular follow-up examinations (Lundberg, Johansson and Consensus Group, 1997). With regard to patients with mild dementia, Veen and Bruyns (1999) – in their article in the Dutch journal *Tijdschrift voor Gerontologie en Geriatrie* – advise to request a driving test to determine the patient’s practical fitness to drive.

Vaa (2003) has calculated the relative risk of being involved in a crash due to dementia by means of a meta-analysis of 18 relevant studies. He found that drivers with dementia have a 45% higher crash rate than drivers without any medical condition.

### 2.3.3. Parkinson’s disease

Parkinson’s disease is a progressive, age-associated neurological syndrome that is primarily due to the insufficient formation and action of dopamine. Patients suffer from resting tremor, stiffness, the inability to initiate movements (akinesia), and impaired postural reflexes. In addition, Parkinson’s disease is associated with depression and dementia at rates much higher than age-related norms. Estimates of the prevalence of dementia in patients with Parkinson’s disease range from 30 to 80% (Kaszi, 1986, cited in Holland, Handley & Featam, 2003), whereas estimates of the frequency of dementia in the total group of people over 65 years of age vary from 5 to 15% (Hofman et al., 1991; Kaszi, Keyl & Albert, 1991).

Both the movement and cognitive effects of Parkinson’s disease have potentially important implications for the patient as a driver. In particular, laboratory and simulator studies have found impaired steering accuracy, reaction times and interpretation of traffic signals in patients who were in the early stages of Parkinson’s disease (Madeley, Hulley, Wildgust et al., 1990, cited in Poser, 1993). A meta-analysis of 11 studies that examined the relative
risk of being involved in a crash due to Parkinson’s disease or another disease that affects the central nervous system (such as stroke) showed that drivers that have one of these diseases have a 35% higher crash rate than drivers without any medical condition (Vaa, 2003).

One particular area of concern relating to driving and Parkinson’s disease is the occurrence of excessive sleepiness that is common in this disease. A study by Frucht (cited in Holland, Handley & Feetam, 2003) showed that excessive sleepiness was prevalent in 51% of the study participants. This sleepiness correlated with severity and duration of Parkinson’s disease and with risk of falling asleep at the wheel. The use of anti-Parkinson (dopaminergic) drugs also seems to contribute to the excessive sleepiness (Fabbrini et al., 2002; cited in Holland, Handley & Feetam, 2003).

2.3.4. Stroke

A stroke, also known as cerebrovascular accident (CVA), is a neurological injury whereby the blood supply to a part of the brain is interrupted, either by a clot in the artery or by a burst of the artery. Strokes can occur at every age, but are more prevalent among older than among younger adults. The incidence of stroke is five times higher among people aged 75 and above than it is for people between 55 and 64 years of age (Kappelle & De Haan, 1998). Many stroke patients recover well enough to resume driving. Those who stop driving are generally older and/or have other sources of impairment or disability in addition to the effects of their stroke (Fisk, Owsley & Pulley, 1997).

Little research has been done into the effects of stroke on fitness to drive. In general, it is assumed that effects of a stroke on motor performance, such as paralysis, can be compensated for by vehicle adaptations and retraining. Other effects, such as apraxia (lack of ability to imagine, initiate or perform an intended action) and lateral neglect, have more severe consequences. In the case of lateral neglect, which means that the patient does not react to or look at things that are located on one side of the visual field (the side opposite to the affected hemisphere), people should be advised to stop driving (Brouwer & Davidse, 2002). A study in which driving of left and right-sided stroke victims and controls were compared, showed that the performance of those with right-sided brain-damage was consistently poorer than that of those with left-sided damage. The former more frequently failed the driving test, and particularly performed more poorly at intersections (Simms, 1992).
2.3.5. Cardiovascular diseases

Cardiovascular diseases include diseases such as angina pectoris (chest pain), cardiac arrhythmias, heart failure and hypertension (abnormally high blood pressure). Studies that have separated out these different conditions have indicated that only cardiac arrhythmias and angina pectoris increase crash risk (see e.g., Foley, Wallace & Eberhard, 1995; Gresset & Meyer, 1994). Meta-analyses of 14 and 3 studies that examined the relative risk of being involved in a crash due to arrhythmia and angina respectively showed that drivers that have the respective diseases have a 27% and 52% higher crash rate than drivers without any medical condition (Vaa, 2003).

2.3.6. Diabetes Mellitus

Diabetes is a disorder that is characterized by high blood sugar levels, especially after eating. The incidence of diabetes becomes much more common with increasing age, with 17-20% of 70 year olds having difficulty regulating glucose as compared with 1.5% of 20 year olds (Holland, Handley & Feetam, 2003). There are two types of diabetes: insulin dependent (type I) and non-insulin dependent (type II). The former are dependent on insulin injections, the latter can control blood sugar levels by diet, weight reduction, exercise and oral medication.

Estimates of the crash risk associated with diabetes used to be as high as twice the rate of average drivers. However, improved medications, better monitoring by diabetic patients of their own blood glucose levels, and improved understanding of diabetic control seem to have reduced the crash risk (Hansotia, 1993, cited in Holland, Handley & Feetam, 2003). An important drawback of tighter control of blood glucose levels is that hypoglycaemic episodes are now much more common. During these episodes with low blood sugar levels, cognitive functions are degraded. Even with only modest levels of hypoglycaemia at times when individuals may be totally unaware that they are hypoglycaemic (Waller, 1992). All in all, serious diabetes (treated with oral drugs or with insulin) is still one of the strongest predictors of crashes, showing a stronger relationship than other illnesses examined (Holland, Handley & Feetam, 2003). Persons with diabetes are also at higher risk of developing the eye disorders cataract, glaucoma and abnormalities that affect the retinal blood vessels (diabetic retinopathy), all affecting visual acuity and visual field (see Section 2.3.1).
2.3.7. Comorbidity

Many older adults suffer from more than one disease. In a study by Holte & Albrecht (2004) it was found that two out of three persons aged 60 years and above suffer from at least one illness. Nearly every second person suffers from more than one illness. Suffering from more than one disorder can reduce the driver’s possibility to compensate for the effects of these disorders. In addition, suffering from more than one disease often means that multiple medication has to be prescribed (polypharmacy), which increases the likelihood of pharmacokinetic or pharmacological interactions (see Section 2.4).

2.4. Medication

Several studies have indicated that certain prescribed drugs increase the crash rate of drivers. These are, among others, benzodiazepines, tricyclic and ‘second generation’ antidepressants, painkillers (analgesics), and first generation antihistamines (Holland, Handley & Feetam, 2003). Older adults, however, are likely to exhibit altered sensitivity to medication. This altered sensitivity is most often in the direction of an increased effect, including side effects and adverse reactions, and the duration of action of a drug may be significantly prolonged due to a reduced clearance of the drug and its active metabolites (Holland, Handley & Feetam, 2003). Since many older adults suffer from more than one disease, they are also more likely to be prescribed multiple medication. The more different medicines that are being taken, the greater the likelihood of pharmacokinetic or pharmacological interactions. Medicines which are not prescribed but that can be obtained over-the-counter can add to this effect (Becker, 2000; Holland, Handley & Feetam, 2003).

In evaluating the possible impact of medication on driving, it should be taken into account that medication is prescribed for an illness, and that the illness may itself affect driving-related abilities. A particular medication could affect driving independently, it could worsen any deterioration in driving ability caused by the illness, but it could also act to reduce the risk to the patient caused by the illness. The vital point is not whether the specific drug has an effect on driving performance, but rather, whether the individual is capable of functioning safely having used it (Holland, Handley & Feetam, 2003).
2.5. Compensatory behaviour

The age-related functional limitations, disorders and medication described in the previous sections do not automatically lead to unsafe traffic behaviour. Other characteristics of older road users can prevent safety problems. They include the awareness of one's own limitations, driving experience, and compensatory behaviour such as driving when the roads are less busy or when it is daytime and dry. One can think of various reasons for older people having the possibility to compensate (Brouwer & Davidse, 2002; Brouwer, Rothengatter & Van Wolffelaar, 1988). In the first place, they often have more freedom in choosing when to travel. Various studies have shown that older adults more often choose to drive during daytime and dry weather (Aizenberg & McKenzie, 1997; Hakamies-Blomqvist, 1994c; McGwin & Brown, 1999; Smiley, 2004; Zhang et al., 1998). In the second place older people on average have a great deal of driving experience. The traffic insight they have acquired may give them the ability to anticipate on possible problematic situations. In the third place, the diminishing desire for excitement and sensation when getting older possibly plays a role. Older people, on average, less often drink-drive than younger adults and are generally more inclined to obey the traffic rules (Brouwer, Rothengatter & Van Wolffelaar, 1988; Hakamies-Blomqvist, 1994c).

When referring to the hierarchic structure of the driving task described by Michon (1971, 1985; see Section 4.4.1), possibilities for compensatory behaviour are offered especially on the higher task levels (Brouwer & Davidse, 2002). On these higher levels (strategic and tactic), there is hardly any pressure of time, which gives the driver enough time to make the right decisions. On the strategical level (i.e., when and where am I going to drive), the driver can decide to drive during daytime, thereby avoiding difficulties as a result of night-time visual acuity and sensitivity to glare. On the tactical level (i.e., how fast do I want to go?), the driver can decide to keep more distance to the vehicle in front in order to have more time to react. Another decision than can be made on the tactical level is to reduce speed well before approaching an (unfamiliar) intersection in order to have more time to perceive all aspects of the traffic situation, to interpret them and to decide on how to act. On the operational level (i.e., how and when to steer, which pedals to press), there is hardly any possibility to compensate. The driver has only tenths of seconds to decide on steering and braking. If he needs more time, he will have to take the proper decisions on the higher task levels, by
keeping more distance to the vehicle in front (tactical level), or by travelling at less busy times of the day (strategical level).

There is, however, one important precondition for compensatory behaviour to be effective. The traffic environment has to enable the (older) driver to compensate (Brouwer, 1996, 2000). Buildings or curves close to an intersection, for example, take away the opportunity to take more time to perceive, interpret and operate. Similarly, drivers that tailgate the older driver will deprive him of the opportunity to take the time that he needs to drive safely.

Lastly, experience can only compensate for functional limitations to a certain degree. The possibility one has to compensate for one or more functional limitations is dependent on the extent to which functions concerned are affected, and on the quality of the functions or experiences that have to compensate for the deficit. For example, people can compensate for a restricted visual field by turning their head. However, if neck rotation is also restricted, compensation might not be good enough to fully compensate. With regard to the role that experience can play in compensating for functional limitations, Holland (2001, p. 38) argues that “experience contributes significantly to the ability to compensate for deficits at the manoeuvring [i.e., tactical] level, but only up to a certain point at which information processing related deficits begin to outweigh the experience advantage.” She concluded this after having noted that declines in hearing, vision and reaction times start at the ages of 30 or 40 year, whereas people in their 40s and 50s still have the lowest crash rates. So it seems that their longer driving experience, greater caution and tolerance of other road users and lower competitiveness and lower aggression bring advantages that outweigh any slight decrement in abilities. However, by the late 60s and 70s, older drivers impairments seem to begin to outweigh any advantages they have accumulated with their years of experience and more cautious behaviour, and, combined with their increase in physical frailty, they are beginning to experience more risk on the roads (Holland, 2001).