Chapter 10

ACADEMIC SUMMARY
Over the next few decades the number of persons aged 65 years and above will increase rapidly (Demography Report, 2011). Because driving is probably going to be a more preferred mode of transportation, this change in demographics is alarming with regard to road traffic safety. The number of older persons holding a valid driver’s license and being active drivers will increase (OECD, 2001). At the same time, due to age-related visual, cognitive, and motor impairments, older drivers have a higher risk of being involved in a crash. Physical vulnerability increases with age as well. Consequently, more often, crashes lead to severe injuries which may prove fatal (Evans, 2004; Hewson, 2012).

Nonetheless, revoking driver’s licenses cannot be the solution to maintain road traffic safety. The importance of driving and mobility is well-understood and concerns persons with and without impairments likewise. Driving is important for a sense of independence; and therefore, contributes to quality of life (Carp, 1988; Kaplan, 1995), counters isolation and depression, and promotes subjective well-being and independence (Marottoli et al., 2000; Fonda et al., 2001). Often, however, older persons with and without impairments manage by restricting the situations in which they drive. For example, they tend to only drive under good weather conditions and avoid complex road and traffic situations (McGwin & Brown, 1999). Moreover, if drivers’ licenses are revoked, they may decide to cycle or walk, which, in many ways, might be more dangerous for themselves (Siren & Meng, 2012).

Older persons make up a unique group of drivers with a distinguishable crash profile and travel pattern. This needs to be considered when developing and implementing road traffic safety strategies. For example, older drivers are over-represented in at-fault crashes on intersections (McGwin & Brown, 1999; Evans, 2004; Davidse, 2007). Consistent with crash statistics, older drivers themselves report having difficulties identifying traffic signs, extracting the most relevant traffic sign, and also making decisions under time pressure, a reason why they, for example, travel at lower speeds (Musselwhite & Haddad, 2010). They experience problems estimating safe gaps between oneself and approaching cars (Oxley et al., 2006) which leads to an over-involvement of crashes when turning left (Griffin, 2004; Mayhew et al., 2006), but also makes passing straight through an intersection a problematic undertaking (Preusser et al., 1998). Approaching and crossing an intersection involves several processes resulting in a complex task. Crossing an intersection requires divided attention among several pieces of information, perceiving and processing changes in the traffic situation, perceiving and processing signals and
traffic signs, determining and executing a course of action (Braitman et al., 2007), and decision making under time pressure (Brouwer & Ponds, 1994).

In addition, chances of being affected by neurodegenerative diseases such as Parkinson’s disease (PD) increase. It is the second most common neurodegenerative disease after Alzheimer’s disease. Approximately 1 to 2 percent of the population aged 65+ is affected by PD (Alves et al., 2008). PD typically affects motor functions and cognition (Dubois & Pillon, 1992). Therefore, PD might affect driving safety (Heikkilä et al., 1998; Uc et al., 2009) as driving is a complex physical and cognitive task in a dynamic environment involving information perception and processing under time pressure, decision-making, motor programming and execution as well as fulfilling concurrent tasks (Heikkilä et al., 1998). Deficits in information processing in complex situations (e.g. addressing two driving tasks simultaneously or seeking out the most relevant traffic sign) have already been identified as a difficulty of the healthy older driver (Musselwhite & Haddad, 2010) leading to delayed judgments and decisions (Brouwer & Ponds, 1994; De Waard et al., 2009). These difficulties are even more evident in drivers with PD. As past research showed (Heikkilä et al., 1998; Wood et al., 2005; Cordell et al., 2008; Uc et al., 2009), drivers diagnosed with PD experienced more difficulties driving than healthy controls on the tactical and operational level of the driving task (i.e. maintaining lane position, controlling speed and time headway).

As older drivers have a great amount of driving experience, observed difficulties on the tactical and operational level of the driving task might be the result of their deficits in selective/divided attention and decision making under time pressure (Brouwer & Ponds, 1994; De Waard et al., 2009). Therefore, difficulties with speed control, lane position, steering, and turning/crossing intersections (Heikkilä et al., 1998; Wood et al., 2005; Cordell et al., 2008; Uc et al., 2009) might not be the source of the problem, but rather the quantifiable outcome of the above mentioned deficits. Therefore, more tailored support, based on specific drivers’ characteristics (i.e. impairment of divided/selective attention and decision making under time pressure), might be a promising approach to keep drivers mobile and traffic safe. Older drivers might be helped by the provision of relevant traffic information in advance reducing the time pressure and divided attention requirements.

In this thesis, an Advanced Driver Assistant System (ADAS) providing information about traffic and speed limit signs, speeding, and following distance has been proposed and
tested in a longer-term driving simulator study with a group of healthy older drivers, drivers diagnosed with Parkinson’s disease (PD), and young drivers.

**9.1 Chapter 4: Intersection assistance: A safe solution for older drivers?**

Because older drivers experience problems in driving situations that require divided attention and decision making under time pressure (Brouwer & Ponds, 1994) as reflected by their overrepresentation in at-fault crashes on intersections (McGwin & Brown, 1999; Evans, 2004; Davidse, 2007), an Advanced Driver Assistance Systems (ADAS) especially designed to support older drivers crossing intersections was investigated. In a longer-term driving simulator study, the effects of an intersection assistant on driving performance were evaluated. Information about safe gaps to crossing traffic was presented to drivers in form of green, amber, and red flag on a head up display.

Eighteen older drivers between the ages of 65 and 82 years ($M = 71.44$ years) returned repeatedly completing a ride either with or without a support system in a driving simulator over a period of one month. Participants were randomly assigned to the control or treatment group. The control group completed twelve consecutive sessions without the ADAS. The treatment group drove two sessions without (sessions 1 and 7) and the remaining ten sessions with ADAS. In order to test the intersection assistance, eight intersections throughout the scenario and sessions 1, 6, 7, and 8 were depicted for further analyses. Results showed that ADAS affected driving. Equipped with ADAS, drivers allocated more attention to the road center rather than the left and right, crossed intersections in shorter times, engaged in higher speeds, and crossed more often with a critical time-to-collision (TTC) value.

**9.2 Chapter: Behavioral adaptation of young and older drivers to an intersection crossing advisory system**

Because it is often argued that what helps older drivers will also help young inexperienced drivers, in a second study, data of 18 young drivers between the ages of 20 and 25 years ($M = 22.3$ years) was collected. Drivers were randomly assigned to the control and treatment group. Unlike healthy older drivers, young drivers completed only the first eight sessions of the experiment over a period of three weeks. Driving
performance in terms of intersection time, maximum speed on intersections, time-to-collision to crossing traffic, frequency of critical crossing, and collisions of young drivers were compared to the performance of healthy older drivers (up until session 8). Gaze behavior of young drivers was also recorded and analyzed. Results indicate effects of ADAS on driving safety for young and older drivers as intersection time and percentage of stops decreased, speed and the number of critical intersection crossings increased. The number of crashes was lower for treatment groups than for control groups. This is true across age groups. As it was also observed for older drivers, with ADAS, young drivers allocated more attention to the road center compared to drivers of the control group, but also compared to sessions completed without ADAS.

9.3 Chapter 6: Longer-term exposure to an intersection assistant: Effects of ADAS use on intersection performance of older drivers diagnosed with Parkinson’s disease

As persons become older, the chance of being affected by a neurodegenerative disease such as Parkinson’s disease increases. Parkinson’s disease (PD) is the second most common neurodegenerative disease after Alzheimer’s disease. PD is typically characterized by motor and cognitive impairments (Dubois & Pillon, 1992), which may affect driving safety (Heikkilä et al., 1998; Wood et al., 2005; Cordell et al., 2008; Uc et al., 2009). Nonetheless, as a large survey study conducted in Germany revealed, 82% of persons diagnosed with PD still held a valid driver’s license and 60% of them were still active drivers (Meindorfner et al., 2005). Therefore, data of a group of active drivers diagnosed with PD (n = 9) between the ages of 68 and 82 years (M = 72.8 years) were also collected in the course of the experiment. Drivers completed twelve consecutive sessions (session 1 and 7 without ADAS, remaining ten sessions with ADAS) over a period of one month. Longer-term effects of the intersection assistant on driving performance were compared to the group of healthy older drivers of the treatment group. Results show, over the longer-term period, a decrease in time needed to pass the intersection and the number of stops before crossing an intersection, so they became less hesitant and more confident over time. It was also observed that healthy older drivers had a smaller minimum time-to-collision (TTC) value to crossing traffic and crossed more often with a critical TTC to crossing
traffic than drivers diagnosed with PD. At the same time, they caused less crashes than drivers diagnosed with PD. Nevertheless, ADAS use might have prevented crashes from occurring as it was found in previous studies.

9.4 Chapter 7: Longer-term effects of ADAS use on speed and headway control in drivers diagnosed with Parkinson’s disease

In addition to the intersection assistant function, the ADAS investigated also provided information about speed limits, speed, speeding, and following distance. Effects of the information on speed and headway control were also studied in drivers diagnosed with PD and healthy older drivers of the treatment group over the same period. Results indicate an effect of ADAS use on performance. Removing ADAS (session 7) after short-term exposure led to deterioration of performance in all speed measures in the group of drivers diagnosed with PD. These results suggest that provision of traffic information was utilized by drivers diagnosed with PD in order to control their speed.

9.5 Chapter 8: Discussion and Conclusion

Specifically for groups with impairments, in our case persons diagnosed with PD, a system that works solely on the level of information provision might not be enough. Persons diagnosed with PD experience not only motor impairments, but often also cognitive impairments, which make safe driving a manifold challenge. Information needs to be perceived, processed and acted upon in a timely manner. Because of the symptoms of PD, any scenario is possible and plausible. Because of difficulties with dividing/selective attention, drivers might fail to perceive the most relevant information in a particular traffic situation. In this case, drivers might be helped with a system that provides that information. Because of slower reaction times, driver might not be able to process information fast enough, especially in situations that require a quick response. Here, having information available in advance might counter the problem with reaction times. Taking into account motor impairments, this type of support might not be sufficient. An additional intervening system such as emergency braking or forward collision avoidance might be suitable for drivers diagnosed with PD. For example, akinesia, hypokinesia, and bradykinesia make it difficult for drivers to stop or adjust an action/movement quickly. Even if a driver is able to seek out the most relevant traffic
information and process that information quickly, motor impairments might hinder him/her to put a new plan in action: an intervening actions. The relation between TTC values and collisions support this idea. Drivers diagnosed with PD had the greatest TTC to crossing traffic, being the most conservative in the study. Nonetheless, they caused four crashes in intersections. Moreover, these drivers also chose for the longest time headway, but one driver caused a rear-end collision because he dozed off. The occurrence of paroxysmal symptoms, such as sudden onset of sleep, is unpredictable, but also well documented (Hobson et al., 2002; Meindorfner et al., 2005). An alertness monitoring system might be helpful to detect drowsiness and sudden onset of sleep and prevent its consequences. In general, crashes are rare events, but it seems that in critical situations drivers diagnosed with PD have a greater risk of being involved or causing a crash. Intervening systems might be utilized to avoid those crashes.

That action should not be limited to collision avoidance functions, but might also include an intervening speed monitoring system. Drivers diagnosed with PD do not speed intentionally. Exceeding the speed limit might be due to difficulties of fine-tuning or because inhibiting a movement such as releasing the accelerator. When the posted speed limit is reached, pressure should be applied to the gas pedal making acceleration more difficult. Even though more research is needed to clarify the added safety benefits, it is technically possible. Most systems and interventions mentioned here have already been implemented or are investigated at the moment. It seems that in the end, tailored support is possible. But to support drivers, support should be custom-made for each individual. As drivers diagnosed with PD might need an intervening system due to their motor impairments. Healthy older drivers might only need advance information. Young drivers, on the other hand, might need an intervening system or a system that provides feedback on their performance, tutoring them to be safer drivers. As all this is possible, it might just be the question of finding the right mix for the individual.