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Relation between Hazard Perception and Visual Behaviour

Emelie Eriksson Thörnell

UPPSALA
UNIVERSITET

Teknisk- naturvetenskaplig fakultet
UTH-enheten

Besöksadress:
Ångströmlaboratoriet
Lägerhyddsvägen 1
Hus 4, Plan 0

Postadress:
Box 536
751 21 Uppsala

Telefon:
018 – 471 30 03

Telefax:
018 – 471 30 00

Hemsida:
http://www.teknat.uu.se/student

Abstract

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The hazard perception test developed by Sagberg and Bjornskau (2006) measuring reaction times in relation to different hazardous situations in traffic, has been used in the present study to analyze older drivers' visual behaviour when passing/responding to the test.

The overall objective of this study has been to investigate the relation between hazard perception in traffic and visual behaviour among older drivers in comparison with a younger age group. The purpose of the study was to provide knowledge on what traffic situations that are more difficult for older drivers to interpret or perceive as hazardous. The elderly were expected to have more problems in situations that included objects classified as context hazards. Context hazards consist of objects that are slowly moving on the side of the road, which poses a situation where the driver should be prepared for the potential behaviour of that object.

The study was composed of two groups of drivers, one group of middle-aged drivers, 35-55 years old, and one group of older drivers, 65 years old and above, who performed the hazard perception test wearing an eye tracker. Hazard interpretation level within age group and situation was investigated, and eye movement data analyzed in terms of fixation duration time.

Overall results showed that the older participants had more problems in interpreting situations classified as context hazards as risky, especially context hazards consisting of pedestrians or cyclists. The differences were nevertheless significant. In addition, when investigating total fixation time on the hazard objects, the differences between age groups were shown to be significant for one of the situations consisting of pedestrians, classified as context/hidden hazard. No significant differences between age groups were found in either of the other situations.

The conclusions are that the elderly tentatively should be exposed to context hazards composed by pedestrians or cyclist in future training schemes. Since there were no significant differences between age groups, more research is, however, needed in the area. Also, since the class of context/hidden hazards, which showed significant differences in fixation time between age groups, was composed by only one situation, resembling situations should be investigated in order to verify these differences.

Handledare: Tania Dukic
Ämnesgranskare: Anders Jansson
Examinator: Elisabet Andresdottir
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Sammanfattning

I ett äldreprojekt i samarbete mellan Statens väg- och transportforskningsinstitut (VTI) i Sverige och Transportekonomiska institutet (TØI) i Norge genomfördes bland annat ett perceptionstest, skapat av Sagberg and Bjørnskau 2006, för att undersöka reaktionstider bland äldre förare i olika riskfyllda trafiksituationer. Försökspersonerna fick titta på videosekvenser av risksituationer och uppmanades trycka på en knapp när de upplevde att en situation kunde utvecklas till en riskfylld sådan. Äldre visade sig ha längre reaktionstider än den yngre referensgruppen i samtliga trafiksituationer, varav fem av situationerna visade på signifikanta skillnader mellan åldersgrupperna. Även ögonrörelser mättes i samband med testet, varvid följande studie har byggt vidare på de tidigare resultaten i reaktionstider med inriktning mot visuellt beteende hos äldre förare.

Syftet med studien var att undersöka relationen mellan perception av trafikfaror och visuellt beteende bland äldre förare i åldern 65 år och äldre jämfört med en yngre åldersgrupp. Resultaten ämnade bidra med information om vilka skillnader i visuellt beteende som eventuellt finns mellan åldersgrupperna, och för vilka klasser av kritiska situationer som skillnaderna var tydligast.

Riskobjekten i de kritiska situationerna delades upp i tre olika klasser; *uppenbara risker*, *kontextuella risker* och *dolda risker*. Skillnader mellan åldersgrupper förväntades existera och vara tydligast i situationer som bestod av kontextuella risker. Kontextuella risker kan beskrivas som potentiella risker placerade vid sidan av vägen där försökspersonen bör vara beredd på att riskobjektet kan göra en oväntad riskfylld manöver.

För att undersöka skillnader mellan äldre och yngre förare delades försökspersonerna huvudsakligen upp mellan de som antagits tolka den fördefinierade risken i varje situation som farlig gentemot de försökspersoner som *inte* tolkat situationen som farlig. Det visade sig att de äldre försökspersonerna i högre grad *inte* reagerade på risken i situationer som innehöll kontextuella faror, i synnerhet där den kontextuella faran bestod av fotgängare eller cyklister, trots att de fixerat risken. Skillnaderna mellan åldersgrupper var dock inte signifikanta. I de situationer där en majoritet av försökspersonerna reagerat i relation till risken undersöktes visuellt beteende vidare. Statiska analyser utfördes på den totala fixationstiden på *riskobjektet*, *andra väganvändare*, *vägrelaterade informationsobjekt* samt *övriga (irrelevanta) objekt*.

Skillnader i ögonrörelser mellan åldersgrupperna visade sig vara signifikant för en fara klassad som kontextuell/dold, vilken i det här fallet utgjordes av fotgängare, men inte för någon annan klass av faror. Båda åldersgrupperna fixerade andra väganvändare under ungefär lika lång tid i samtliga situationer, medan vägrelaterade informationsobjekt samt övriga irrelevanta objekt fick minst uppmärksamhet. Det här beror troligtvis på att försökspersonerna fått i uppgift att söka efter riskfyllda situationer, och därmed främst fixerar väganvändare som i högre grad än andra objekt kan förväntas orsaka en riskfylld trafiksituation.

Slutsatserna är att äldre i ett träningsprogram anpassat för äldre förare bör bli exponerade för situationer som består av kontextuella risker i form av fotgängare eller cyklister som befinner sig vid sidan av vägen då äldre verkar ha svårare för att uppfatta och tolka sådana typer av faror som riskfyllda. Fler och djupare studier behövs på kontextuella/dolda risker, för att ytterligare kunna verifiera resultaten i denna studie.

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Emelie Eriksson Thörnell

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1. Introduction

All over the world the human population is growing rapidly. Humans live longer, healthier, busier and more mobile lives than just a few generations ago. Hence, the quality of life has increased in the developed countries, also for the ageing population. The growth of the older population has never before taken such proportions. Different societal trends such as industrialization, urbanization, globalization and economic welfare have structured the way in which the elderly will approach their years of ageing; the activities in which they will engage, the places they want to see and the frequency of travels in comparison with their parents. The ageing population is likely to change even in the next generation, and thus, there is a great challenge to develop the society, not only to be adapted to the growing population, but also to the ageing populations' future needs (Rosenbloom, 2004).

The economic welfare, the globalization and the healthier and more mobile older population make it easier for the elderly to move between locations and go where they want independent of others. Thus, the elderly have become more dependent on the private car as their life quality, health and flexibility have improved, even as the rate of the elderly who holds a driver's licence has increased (Rosenbloom, 2004). Consequently, in the future there will be a growth of older drivers, why there is of importance to make deeper studies of the elderly in traffic in order to handle potential traffic conflicts in a proactive way.

The consequences for the elderly in traffic usually become worse than for younger drivers because of their increased fragility, something that have risen the accident rate for the elderly in a misleading way. In addition, the focus in traffic research in relation to the elderly was earlier mainly on the older drivers' functional deficiencies as a reason to reduce these from the driver population. The traffic research of the elderly has improved in recent years and the view of the elderly has changed by rather focusing on the possibility to change the traffic system so that the elderly still can be able to use it. By changing the perspectives in the traffic safety research area, handling the growing ageing population may somewhat facilitate. The ageing population will still be challenging enough in the future, thus it is easier to adapt the traffic system and training schemes to the ageing human than the other way around (Johansson, 2007).

1.1 Problem

Traditional responses to older drivers will not meet the needs of the ageing population. Only in Sweden, the amount of the elderly people with driver's licence will be about twice as high within two decades (Räddningsverket & IMS, 2007). As a consequence of the increasing participation by the elderly in traffic, older drivers' share of crash rates will grow in the next few decades. Hence, there is a need to further investigate the elderly in different traffic situations to increase the understanding of the elderly, and to facilitate for this age group in the future. It is of importance to approach the problem and investigate older drivers' behavioural driving pattern when being exposed to different types of hazardous traffic events. Since sight is the most important sense when it comes to driving, a way of examining older drivers' is to investigate their visual behaviour in different traffic situations.

1.2 Objective and Hypotheses

The overall objective of this study is to investigate whether visual behaviour differs between age groups, and if these differences depend on hazard class. The aim of the study is to contribute with further information on what type of visual behavioural differences that might exist between age groups, and for what classes of hazardous situations the differences might be evident. The study also contributes with information of the relation between hazard perception and visual behaviour.

In order to investigate potential differences between older and younger experienced drivers, two hypotheses will be presented and either supported or rejected depending on the results of the study:

Hypothesis 1: There are differences in visual behaviour among older and younger experienced drivers in different hazardous traffic situations.

Hypothesis 2: The differences between the age groups are assumed to be evident in traffic situations which include context hazards since these require high demands on drivers' perception ability, an ability that impairs with age.

The purpose of the study is to provide knowledge of what kind of hazardous traffic situations that is more difficult for older drivers to interpret or perceive as hazardous. Those situations can be used to determine scenarios for a training or refreshing course addressed to older drivers.

1.3 Limitations

It should be emphasised that there is *one* predefined hazard in each hazardous situation, and eye fixation data will solely be analyzed in relation to these predefined hazardous situations, even though other situations interpreted as hazardous might exist in the data. To be able to analyze the eye fixation data in relation to hazard perception, one also needs to know if the participants have interpreted the predefined hazard in each situation as hazardous. Once the participants have reacted to the predefined hazard, i.e. when the participants have been pressing a response button just *after* they have fixated the predefined hazard, they are assumed to have interpreted the predefined hazard as a risk. If the participants have not reacted, or have been pressing the response button in relation to another object than the predefined hazard, they are not assumed to have interpreted the predefined hazard as a risk. These cases will be registered and analyzed separately; however, no statistical analysis of the eye fixation data have been implemented based on the latter since their eye movements cannot be analyzed based on hazard perception.

1.4 Disposition

First, a synoptic theory will be presented in chapter 2, which aims at giving the reader the scientific background of previous knowledge and studies. Second, the observation and analysis method are outlined in chapter 3, followed by the results of the analysis in chapter 4. The report ends with a discussion of the results in chapter 5, followed by conclusions and suggestions for further research in chapter 6. A more detailed description of the contents of each chapter will be presented accordingly to every chapter respectively.

2. Visual Behaviour and Elderly in Traffic

Chapter 2 aims at giving the reader the background of previous research and theories in order to place the present study in its scientific context. The first section describes visual behaviour in general, accompanied by a section about earlier research of the elderly in traffic. Third, a project concerning elderly in traffic in collaboration between Norway and Sweden will be presented, since the present study is based on, and works as an add-on and extension of, that project. Finally, the chapter ends with a section about hazard classification theory that later will be applied to the hazardous situations in the current study.

2.1 Visual Behaviour

This section will describe four areas related to visual behaviour: eye movement structure, a historical overview of eye tracking techniques, and finally a brief description of video-based eye tracking systems since such a system has been used to collect the eye movement data in the present study.

2.1.1 Eye Movement Structure

There are basically two build up types of eye movements; *fixation*s and *saccades*. Fixations are defined as eye movements which stabilize the retina over a stationary object of interest while saccades are defined as the rapid eye movements occurring between fixations, used to reposition the fovea to a new location in the visual environment (Duchowski, 2003). There is not a clear definition of a fixation in terms of exact duration; however, during a fixation the eye position stabilizes within dispersion of typically ~2° and over a duration lasting from 66 to 416 milliseconds (218 ms on average). Thus, the brain has enough time to process essential information of the object during this time span. A saccade typically lasts for 20 to 35 milliseconds why no visual processing occurs in the brain, i.e. the fast motion cannot be perceived and no information obtained (Dong & Lee, 2008). Another type of eye movement behaviour is *smooth pursuits*. These movements remind about fixations since they remain stationary over an object of interest, with the difference that the eyes match the velocity of a moving target (Blake & Sekuler, 2006).

A moving object will capture visual attention simply because of its movements in relation to the environment, called bottom-up processes. In addition, eye movements are also affected of the visual search purpose, the intent of the viewer, and depend on what the subject are looking for, called top-down processes. The top-down processes was observed already in 1967 by Yarbus, a key researcher in the area (Duchowski, 2003). Hence, the eye movements are affected both by stimuli in terms of movement and also in terms of search task. It is also noteworthy to emphasize that the human can pay attention to objects in the periphery, i.e. objects that is not fixated, nevertheless, in most situations the fixated object is the one that is paid attention (Humphreys & Bruce, 1989).

2.1.2 Eye Tracking Techniques – a historical overview

Early eye tracking techniques involved direct mechanical contact with the cornea, and in the beginning of the 20th century the first precise eye-tracking system based on light reflection of the cornea was developed. By then, the system recorded only horizontal eye position which required the head to be static. A few years later, motion picture photography was applied to record eye movements in two dimensions. In the first half of the 20th century the methods developed and corneal reflection and motion picture were combined in different ways (Jacob & Karn, 2003).

Basically two applications of eye tracking research developed during the 20th century: eye movements in reading and eye movements in usability engineering (the study of users interacting with products to improve design). Motion picture cameras to study eye movements in traffic started 1947, when a scientist named Fitts together with his team studied pilots' eyes as they used cockpit controls and instruments to land an airplane. A year later the first head-mounted eye tracker was invented. Thus, the usability approach of eye tracking paved the way for studying, not only eye movements in themselves, but also what the eyes were looking at, i.e. *the point of regard* (Jacob & Karn, 2003).

During the 1970s the eye movement research flourished. While engineers improved eye tracking technology, psychologists began to study the relationships between fixations and cognitive activity. Much of the relevant work in the 1970s focused on technical improvements to increase accuracy and precision and reduce the impact of the trackers on those whose eyes were tracked. The discovery that multiple reflections from the eye could be used to dissociate eye rotations from head movement increased tracking precision and also prepared the ground for developments resulting in greater freedom of participant movement. The advent of the minicomputer provided the necessary resources for high-speed data processing (Jacob & Karn, 2003).

During the 1980's, researchers began to investigate how the field of eye tracking could be applied to issues of human-computer interaction. Also, the start of eye tracking in real time as a means of human-computer interaction began in the 1980s. The combination of real-time eye movement data with other, more conventional modes of user-computer communication was also pioneered during the 1980s (Jacob & Karn, 2003).

2.1.3 Video-based Eye Tracking Instruments

The most commonly used eye tracking system today is the video-based corneal reflection eye tracker, and this type of system has also been used to measure the eye movements of the participants in the present study. Video-based trackers utilize image processing to compute the point of regard in real-time. The apparatus can be either table-mounted or head-mounted. Table-mounted apparatus requires the eyes to be fixed so that the eye's position relative to the head and point of regard coincide. Head-mounted apparatus requires measurements of multiple ocular features in order to disambiguate head movement from eye rotation (Duchowski, 2003).

2.2 The Elderly in Traffic

This section will describe three areas related to the elderly in traffic. First, an overview over the research history of the elderly in traffic will be outlined, followed by a brief description of typical crash types among the elderly that have been found so far. Finally, a section on how age related visual behaviour has been found to affect driving pattern through earlier studies, will be presented.

2.2.1 History

The studies of the elderly in traffic started from a viewpoint where it was questioned whether the elderly were more dangerous drivers than others. This discussion has been a topic in the traffic safety research area since the 1930s, and became of more interest during the 1970s when the discussion about traffic security increased. The elderly were supposed to have a higher accident risk compared to other drivers (Johansson, 2007). The traffic system was highly taken for granted and the focus was mainly put on the older drivers' functional deficiencies. The first proposed safety measures were oriented towards screening those drivers which were considered a high safety risk in traffic, and the solution was to reduce these from the driver population. At this time, the fact that the elderly generally drove less kilometres per year, were more fragile and, hence, were of most danger to themselves than to other drivers was not taken into account. During the 1980s research efforts were made to understand the accident epidemiology of older drivers in more detail. Soon, it was understood that the older drivers' overrepresentation in serious crashes was a combined product of the crash frequency and the probability of death or severe injury as a result of the crash. By now, the studies of the elderly in traffic took a more system-oriented approach (Hakamies-Blomqvist, 2004). In addition, the elderly were no longer generalized or considered as a homogenous group, why the elderly in the 1990's were divided into healthy and unhealthy (e.g. elderly suffering from dementia) in the continued traffic safety research (Green, 2007).

Nowadays, the studies of the elderly are differentiated between younger elderly (65-79 years) and older elderly (80 years and above), and there is a clear consensus that older people have no higher accident risk than other drivers. The studies of the elderly have continued from a mobility viewpoint, rather than through an approach where the elderly are considered a higher safety risk in traffic than others (Green, 2007). The life style, as affected by diet, exercise, stress, alcohol etc., plays a major role for the ageing process, which implies increased variability among the elderly, why it sometimes is more accurate to discuss biological rather than chronological age (Räddningsverket & IMS, 2007).

In Sweden, The Swedish Road and Transport Research Institute (VTI) represents the largest portion of road and traffic research in the country. There had been earlier studies of the elderly in traffic; nevertheless, it was in the mid 90s that the studies of the elderly in traffic at VTI became a stated area of research (Peters, 2009). At this time many scientists became active in the area at the same time which made possible research of the elderly over a cross-border research area. Nordic and European collaborations have been developed at the beginning of the 21st century since it is of importance to develop the traffic system similar in different countries in order to seek to adapt the traffic system to the ageing population and its growing mobility (Johansson, 2007).

2.2.2 Typical Crash Types

The risk of being killed when driving a car has been shown to increase with age (Strandroth & Persson, 2006; Li, Braver & Chen, 2003). This can partly be explained by the fact that the consequences for older drivers in accidents are greater compared to younger drivers in the same situation because of older drivers' increased fragility (Räddningsverket & IMS, 2007). Older drivers have also been shown to be involved in other types of car accidents compared to younger drivers. Typical crash types of older drivers often involve another vehicle, and earlier research have found that the typical older driver accident occurs at left-turns in intersections with heavy traffic, which requires high visual load and high demands on perceptive and cognitive skills (Hakamies-Blomqvist, 2004; Strandroth & Persson, 2006; McGwin Jr. & Brown, 1999).

2.2.3 Age Related Visual Behaviour in Traffic

Several studies have shown that vision impairs with age. The optical changes include age related sensitivity decrease to high frequencies and pupil size decrease. When the pupil size decreases the retina receives less light and older people are consequently not as sensitive to light as younger ones. The reduced pupil size also implies that visual acuity and contrast sensitivity impairs with age (Blake & Sekuler, 2006). Contrast sensitivity has been shown to have a significant impact on hazard perception performance, independent of other measures. *Hazard perception* is defined as the process of discovering, recognising and reacting to potentially dangerous situations (Vlakveld, 2008). M. S. Horswill et al. have, for example, found that hazard perception ability peaks at the age of 55 and then declines with increasing age, even in a sample of older adults who considered themselves relatively healthy. Thus, a significant proportion of individual differences in hazard perception can be attributed to cognitive and vision factors (Horswill, Marrington, McCullough, Wood, Pachana, McWilliam & Raikos, 2008).

In addition, several studies of the Useful Field Of View (UFOV) have shown that a reduction in the size of the field as a function of age. The UFOV is defined as the area from which a person can extract visual information within an eye fixation without head or eye movement (Ball, Beard, Miller & Griggs, 1988). Furthermore, UFOV have been shown to be important for the hazard perception ability. One consequence of the reduced UFOV for the driving task is that older drivers' distance perception is reduced and thus, they have less time to react than younger driver. This can explain the strong relationship between crash risk and UFOV, where a reduction in the UFOV makes it harder to detect traffic conflicts, which in turn impacts crash risk (Horswill, et al., 2008; Ball, Owsley, Sloane, Roenker, & Bruni, 1993).

In an intersection study made by Dukic and Broberg, the average fixation duration showed a tendency that older drivers need more time to process traffic information. Other results from the study showed that younger drivers spent more time looking at possible threats, such as other vehicles, that could cut their path in the intersection, whereas older drivers spent more time looking at road markings, position on the road, and information that permit to position their own vehicle (Dukic & Broberg, submitted). Also, in a laboratory test of Ranney and Pulling, the investigators found that older drivers scored lower on tasks requiring rapid switching of attention (Ranney & Pulling, 1990).

In an eye movement study in which the participants looked at traffic scenes images, the scientists Maltz and Shinar found that older participants had significantly longer search episodes than younger participants. In addition, they found that the visual search of older adults was characterized by more fixations and shorter saccades, although the average fixation durations remained the same (Maltz & Shinar, 1999). According to the scientists Poole and Ball, two other researchers in the traffic safety area, longer fixation duration indicates that the object is more engaging in some way or that the person has difficulty in extracting information, something more typically with increasing age (Poole & Ball, 2005).

These former studies show that there are differences between older and younger in visual behaviour in traffic, why this can be expected also in the present study as outlined in hypothesis 1: There are differences in visual behaviour among older and younger experienced drivers in different hazardous traffic situations.

2.3 The Elderly Project in Norway and Sweden

In 2007, a project called Older Car Drivers in Norway and Sweden – studies of accident involvement, visual search behaviour, attention and hazard perception (hereafter abbreviated the OCD study) was initiated by the Norwegian Public Roads Administration with a specification to perform research about older car drivers. The project on older car drivers was carried out in collaboration between The Swedish National Road and Transport Research Institute (VTI) in Sweden and The Institute of Transport Economics (TØI) in Norway. When the project started there was a generally expressed need for deeper analysis of accident data among older drivers (Levin, Dukic, Henriksson, Mårdh & Sagberg, 2009).

Three main methods were used to identify typical and atypical older driver accidents; an accident analysis of police reported accidents in Norway, a literature study on existing research on older drivers' behaviour (i.e. cognitive aspects on car driving) and experimental studies comprising visual and perception tests accomplished in Norway and Sweden. The experimental studies contained 50 participants from Sweden and 50 participants from Norway where, in addition, eye movements were recorded during the tests. These eye movements have been analysed in the Swedish field study, however no analysis of the recorded eye movements of the Norwegian participants during the hazard perception test were accomplished, why further studies of these are motivated and will be investigated in the present study (Levin et al., 2009).

2.3.1 The Hazard Perception Test

The hazard perception test, which the present study is based on, was developed by Sagberg & Bjørnskau in 2006 with the main purpose to investigate novice drivers' reactions in different hazardous traffic situations. In the OCD study the hazard perception test was reused, with the purpose to investigate potential differences between older and younger experienced drivers' traffic behaviour. In the test, a random sample of people of the age group 35-55 and 65 years and above, living in the larger Oslo area, were contacted and asked to participate if they complied with the following additional criteria:

- holding a category B driver's licence for at least 5 years
- driving a car at least once a week
- having driven at least 5 000 km the latest year
- not being a professional driver

The hazard perception test is composed by a video representation recorded from the driver's viewpoint and includes 13 different hazardous traffic situations with a predefined hazard in each situation. In order to gather the perception-reaction times, the participants were told to press a response button once they interpreted that a situation could develop into a hazardous situation. To record the eye movements of the participants in the hazard perception test, the eye tracking system SensoMotoric Instruments (SMI) was used. The SMI equipment is a head-mounted eye tracking system which measures the right eye's movements of the pupil centre with corneal reflection, together with recordings of the scene ahead, see **Fel! Hittar inte referenskälla.** (Levin et al., 2009):

Figure 1. The SMI Equipment.

2.3.2 Hazardous Situations

The different hazardous traffic situations in the hazard perception test were of such kind that the driver needed to be prepared to steer or brake because of the potential danger if the driver did not react (Sagberg & Bjørnskau, 2003). A hazardous traffic situation is defined as any motion by some of the road users, which can possibly develop into a hazard, and for which the driver has to be especially prepared for braking or steering (Sagberg & Bjørnskau, 2003; Underwood, Phelps, Wright, van Loon & Galpin, 2005; Horswill, et al., 2008). Every hazardous situation was defined within a critical time interval where a reaction could be assumed to be relevant in relation to the current situation. During this time interval the participants' reaction times were registered. The length of each critical interval differs and lasts between 5 and 25 seconds, depending on each hazardous situation. According to Sagberg and Bjørnskau, the critical interval in the current 13 hazardous situations starts as soon as it is possible to observe that a hazardous situation may occur, i.e. the time when the driver need to be prepared to brake or steer, and stops at the point where the driver would need to react in order to have avoided a collision, given that the defendant continued its journey (Sagberg & Bjørnskau, 2003), see *Figure 2*:

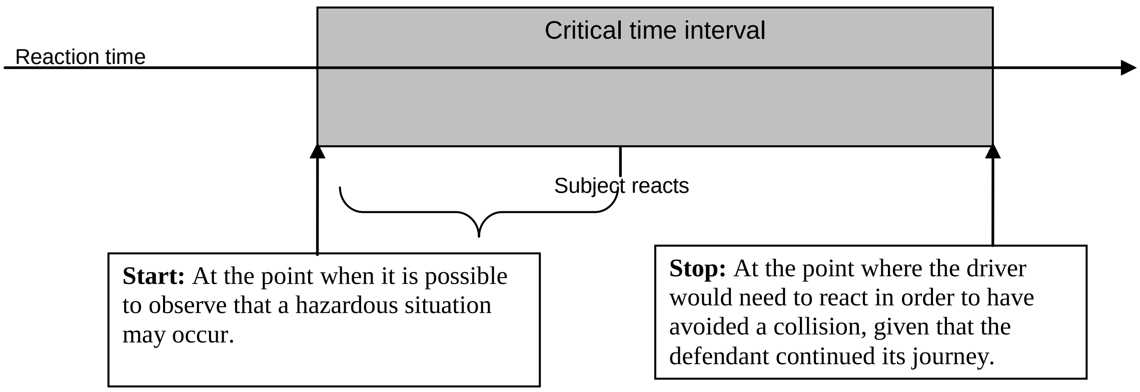

Figure 2. Illustration of critical time interval.

The hazard perception test implied that the reaction times were longer for the elderly than for the younger participants and significantly so for five of the situations (see **Table 1**). However, the tendency was the same for all 13 situations; the elderly exhibited longer reaction times for the predefined hazards than the younger participants. There were, nevertheless, situations where some of the elderly seemed to be as good as, or even better, to handle the hazardous situations in comparison with the younger participants, which implies that the variations in reaction times were higher among the older participants than among the younger ones. The overall conclusion from the hazard perception reaction times was that the older drivers as a group cannot be generalized and that further investigations are needed in the area (Levin et al., 2009). The present study of eye movements is one such study.

Table 1. Reaction times (in seconds) and p-levels among the age groups within each situation

Situation	Older	Younger	p
1	2.68	2.03	0.012
2	2.80	2.31	
3	6.41	3.63	<0.001
4	7.25	7.12	
5	8.79	3.87	<0.001
6	3.10	3.41	
7	3.83	3.76	
8	2.86	2.42	
9	2.63	2.09	<0.001
10	2.87	2.24	0.013
11	2.40	2.11	
12	3.60	3.02	
13	1.91	1.86	

2.4 Traffic Hazard Classification

Studies based on a systematic classification of hazards are necessary in order to improve our understanding of these matters, and will be of use when investigating if the eye movements differ particularly between age groups in certain classes of hazards. Four classifications that have been outlined by three different research groups will be introduced in the following section.

A first class of hazards, *context hazards* (Vlakveld & Twisk, 2008), is defined as standing, slowly moving road users on the side of the street (e.g. pedestrians or slowly moving vehicles on the left or right side of an intersection) which can be dangerous according to their potential unexpected behaviour onward. Drivers should anticipate the hazards following behaviour in order to avoid potential collision with them (Vlakveld & Twisk, 2008; Renge, Ishibashi, Oiri, Ota, Tsunenari & Mukai, 2005; Crundall, Chapman, Trawley & Underwood, 2008). Crundall et al., (2008) use the title *predicting behaviour*, while Renge et al. (2005) define the hazards as *hazards relating to prediction of other road user(s) behaviour*. This class of hazards will, however, be named context hazards in the following.

A second class of hazards; *hidden hazards* (Vlakveld & Twisk, 2008), is defined as obstacles that obstruct the vision, like a parked vehicle or an intersection. The hazards can be anticipated to appear from a blind corner (Vlakveld & Twisk, 2008; Renge et al., 2005; Crundall et al., 2008). Crundall et al. define the hazards as *predicting from the environment*, while Renge et al. define the hazards as *potential hazards*. This class of hazards will, however, be named hidden hazards in the following. Crundall et al. (2008) define a third class of hazards as *multiple source monitoring* as multiple sources of potential hazards of both context and hidden hazards.

Finally, a fourth class of hazards is outlined by Renge et al. (2005) and is titled *obvious hazards*, which is composed by moving objects usually in front of the car, e.g. a pedestrian walking across the street. If the driver does not take any evasive action, an accident or a traffic conflict can be expected to happen, since an obvious hazard usually uses the roadway in front of the car, and the driver needs to be prepared for breaking or steering (Renge et al., 2005).

As the title explains, an obvious hazard is probably a hazard that is the easiest to perceive, with low demands on cognitive and perceptive skills. Hidden hazards can, on the other hand, be assumed to be difficult to be prepared for since the hazard object(s) is (are) not visible from the beginning. Context hazards can also be assumed to be more difficult to predict in comparison with an obvious hazard, since the demands on the drivers' perception ability increases and does also put demands on wider search behaviour. Since drivers' perception ability have been shown to decline with older age (see section 2.1.2), situations that include context hazards can be assumed to be more complicated for older drivers. Hence, it can be expected that the eye movements will differ between age groups for this class of hazards as outlined in hypothesis 2: The differences between the age groups are assumed to be evident in traffic situations which include context hazards since these require high demands on drivers' perception ability, an ability that impairs with age.

3. Method

To investigate if there are differences in visual behaviour among age groups the analyzed situations were divided into two different areas. One area was composed by those situations where a majority of the participants (in at least one of the age groups) were assumed to have interpreted the predefined hazard in each situation as hazardous. In contrast, the second area was composed by those situations where a majority of the participants were assumed to *not* have interpreted the predefined hazard as hazardous. This area division was made based on Sagberg's and Bjørnskau's hazard perception test, and the purpose was to investigate what situations which were possible to further analyze in relation to hazard perception.

The analysis of the eye movement data was performed in two different steps. These two steps handle the divided areas of situations, in relation to hazard interpretation. The purpose with step 1 was to analyze if there were differences in hazard interpretation level between age groups in each situation. The situations where a majority of the participants in both age groups interpreted the situation as hazardous were further analyzed in step 2. The two analysis steps are described in more detail in the following sections.

First, however, the observation method of the eye movement data will be described. The observation method outlines the systematic collection of raw data and describes the observations of the eye movements in relation to the critical time interval within each situation, and also from a fixation viewpoint in more detail.

3.1 Observation Method

Ten out of 13 situations have been analyzed in the present study. The three unstudied situations have not been processed because: 1) The situation included more than one predefined hazard object in different places of the driving view that together made the situation hazardous. Since the analysis was based on the amount of time that the participants were fixating different objects, especially the hazard object, involved in each situation, there turned out to be a somewhat more complex task to take two or more hazard object(s) into account if they were scattered throughout the viewing scene. 2) The situation did not include a predefined hazard object and it was not possible to gather the fixation durations in relation to a hazard object. 3) The situation was time consuming because of its length and was eliminated in order to minimize the time of data processing for the benefit of video analysis.

3.1.1 Participants

Table 2 shows the main characteristics of the two driver groups after correction of missing data (for handling of missing data, see section 3.3.3 and 4.3.6):

Table 2. Characteristics of Norwegian driver samples after reduction of missing values

	Younger	**Older**
Age (years)	44.6 (35-55)	70.1 (65-81)
Gender	8 females 6 males	8 females 9 males
Annual driving distance (km)	16 857 (7 000- 40 000)	11 294 (2 000-20 000)
Years with license	26 (7-36)	45.8 (19-60)

3.1.2 Measure Interval

The eye movement analysis began at the moment before the road user(s), i.e. the hazard object(s), involved in the hazardous situation were first visible in the video, during a fixed time interval, in order to analyze the eye movements related to the hazardous situations. Situation 2, which involves the predefined hazardous object of a woman on a pavement, will work as an example (see *Figure 3*):

Figure 3. Woman on right pavement walks against pedestrian crossing.

The woman was first visible in the video a moment earlier than the latter figure shows, why the eye movement analysis began just the moment before she shows up, as shown in *Figure 4*:

Figure 4. The moment when the hazard object is first visible (woman marked with a red box).

The eye movement analysis ended as soon as the road user(s), i.e. the hazard object(s), involved in the hazardous situations were no longer visible in the video and hence, did not pose a risk anymore. For situation 2 this happened when the driver just have passed the woman, at the moment as shown in *Figure 5*:

Figure 5. The moment when the hazardous situation can be considered to be over (i.e. woman not visible anymore).

However, there were exceptions in some of the situations (see situation 1, 3 and 10 in Appendix 1) because the hazard object(s) involved in the hazardous situation continued being visible through the rest of the video even when the hazardous situation could be considered to be over. In these situations the analysis of the eye movements ended as soon as the road user(s), i.e. the hazard object(s), involved in the hazardous situation had reached the lane or walkway that it was moving towards. An example of this is situation 1, where a white car pulled out from the left without yield. The hazardous situation was over at the time when the car had reached the right lane that it was moving towards, which happened at the moment as shown in *Figure 6*:

Figure 6. The moment when the hazardous situation can be considered to be over (i.e. car has reach the lane that it is moving towards).

3.1.3 Collection of Raw Data

The eye movement analysis was made through a frame-by-frame method in a video program called VirutalDub which allows for identification of *what* object that the participant fixated and the amount of frames that elapsed while the participant fixated these objects. To evaluate the observation method of raw data, an inter-reliability rate method was performed to ensure the reliability of the method. Some of the fixation data were therefore measured by two investigators. The inter-reliability rate was implemented by comparing common and uncommon amount of frames interpreted as start and end of fixation. The inter reliability rate reached over 96 %, and the observation reliability can therefore be considered to be satisfying.

In *Figure 7*, a picture from situation 2 is represented where the participant at the actual point was fixating the predefined hazard object (the elderly woman). The red fixation marker indicates what object the participant is fixating, while the red line at the bottom of the video window indicates that the participant presses a response button in relation to the hazardous situation. At the bottom of the window there is a magnification of the current time in terms of number of frames and the number of seconds that have elapsed since the video started (40ms/frame):

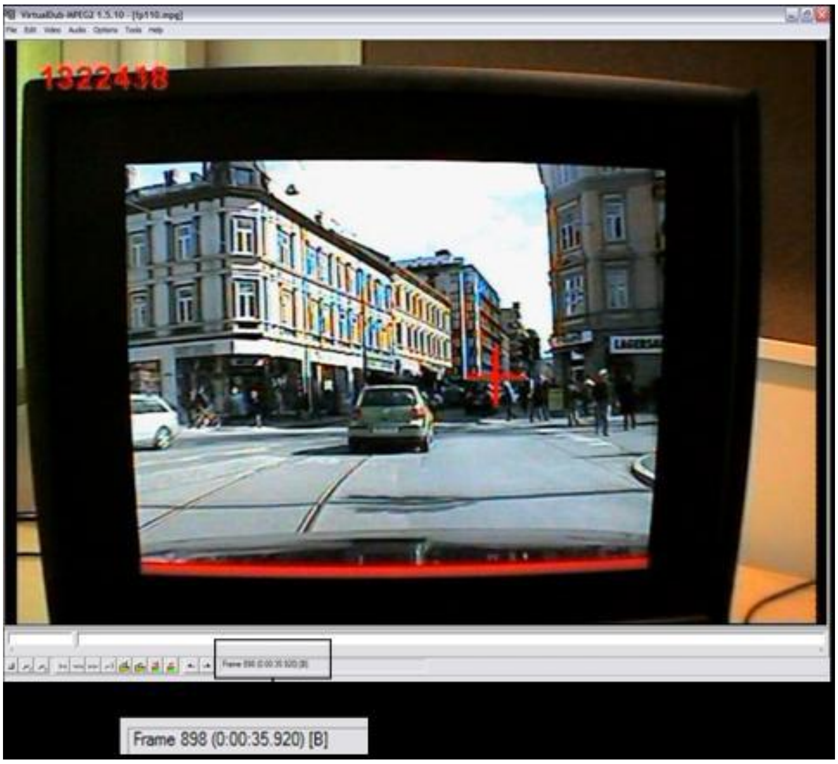

Figure 7. Video data from one of the participants in situation 2.

According to Dong & Lee (see section 2.1.1), fixations are defined as durations between 66-416 ms, for which the brain has enough time to process the information of the fixated object. Since the elapsed time between two frames in the videos is 40 ms, a fixation was counted as when the fixation marker remained stable over at least three frames, i.e. 80 ms. Hence, the fixation marker in the current situation needed to be stable at least between the current frame 898 and 900 to be counted as a fixation (see *Figure 7*). With *stable* means that the fixation marker does not move noteworthy from its location. Even during fixations the eyes move slightly, but the movement was counted as a saccade first when the fixation marker clearly jumped from one point to another. When the fixation marker stabilized once again this was counted as the beginning of a new fixation (as long as the fixation marker remained stable in the same location for at least 80 ms). Since information processing occurs also during smooth pursuits, these were treated the same way as fixations. To facilitate, the word fixation/fixations is used through the rest of the report even in the cases where the information processing were performed through smooth pursuits. The important thing is to be aware of the fact that it is about information processing of objects, rather than whether the information process consisted of fixations or smooth pursuits.

During the observation process the data were continuously registered and summarized in a scheme for all the 10 different traffic situations. The reaction to the predefined hazard (or the lack of it) was also registered by noting whether the participant presses the button in relation to the predefined hazard object or not. The collected raw data described above have been handled in step 1 and 2 and will be described in more detail in the following.

3.2 Step 1: Hazard Interpretation Analysis

The first analysis step was performed through a hazard interpretation viewpoint by identifying those participants who interpreted the predefined hazard as a hazardous situation and those who did not. The purpose with step 1 was to analyze whether there were differences in interpretation level between age groups in each situation.

In the cases where the participants fixated the hazard object and reacted in relation to it, i.e. were pressing the response button just *after* they had fixated the predefined hazard object, were assumed to have interpreted the hazard as a risk. Those who did *not* react in relation to the predefined hazard even though they fixated it, or in the case when a participant reacted to another object than the predefined hazard, were assumed to *not* have interpreted the predefined hazard as a risk. The amounts of participants who were assumed to interpret/not interpret the predefined hazard as a risk were investigated in all of the different situations and compared within age group. The potential differences among older and younger participants were analyzed by a χ^2-test in order to investigate if these differences were more evident and perhaps significant for certain classes of hazardous situations.

3.3 Step 2: Fixation Duration Analysis

Participants who reacted in relation to the predefined hazard (examined in step 1) were assumed to have interpreted the predefined hazard as a risk. Consequently, only the eye movements within the situations where a majority of the participants reacted in such a way could be further analyzed based on hazard perception. Thus, in step 2 the total fixation duration time and the mean fixation duration time on each class of hazards were investigated and analyzed with a repeated measures ANOVA method. The total fixation duration time on other objects than the hazard object were also investigated in order to examine what other objects that may have attracted the participants' interest when they did not focus on the hazard object. Potential differences between age groups and for each situation were examined. These other objects were divided into three categories:

- Road users
- Roadway and road informative objects
- Environmental objects

The three object categories are further described in the following (a similar categorization is also used by Underwood et al., 2005):

1. *Road users*

Road users are characterized by mobile objects such as pedestrians, cyclists, cars and buses. In the analysis the total fixation duration on objects belonging to this category were examined both with and without including the hazard object (since the hazard object also is a road user).

2. *Roadway and road informative objects*

This category of objects is characterized by the roadway itself, road markings, pedestrian crossings, road signs and traffic light; i.e. static information which facilitate for the driver to function in the driving environment.

3. *Environmental objects*

The last category of objects is characterized by other surrounding objects, considered irrelevant, such as buildings, hedges, parked cars, lampposts, petrol stations and off screen.

3.3.1 Statistical Method

The statistical analysis of the fixation duration time were performed by a general linear model; repeated measures ANOVA. The repeated measures ANOVA method is used when the same variable for the same subjects is measured under different conditions or at different points in time. In the present study, the different conditions was composed by the different traffic situations, also called within-subject factor, while age, on the other hand, is called the between-subject factor (Hill & Lewicki, 2006). The following null hypothesis was tested:

H_0 *= no differences between population means*

The repeated measures ANOVA analysis was performed in the statistical tool SPSS statistics and the significance level through the report was $\alpha = 5$ %. The α –level is the probability to reject the null hypothesis even though it is true, also called a type I error. A type II error, β, means that the null hypothesis cannot be rejected even though it is false. When a type II error occurs the study gives a false negative correlation ($p > 0.05$) although a true difference exists. A type I error can be considered more serious since a rejection of the null hypothesis, even though it is true, can lead to false significant results and misleading conclusions. It is of importance to be aware of that these types of error exist, since there is always a risk that the interpretation of results may be jeopardized (Rogers, 1996). Hence, if significant differences are shown between age groups in the present study this is statistically significant at a 95% safety level. **Table 3** summarizes the type I and type II error:

Table 3. Type I and Type II error

	Null hypothesis true	Null hypothesis false
Reject null hypothesis	**Type I Error**	**Correct**
Fail to reject null hypothesis	**Correct**	**Type II Error**

When investigated the total fixation duration and mean fixation duration time on the hazard object, the two factors were composed by *age group* and *class of hazards*, while the total fixation duration on other categories of objects were composed by *age group* and *situation*. Between-subject factor (age group) and within-subject factor (class of hazards or situation) per se can be expected to affect eye movements; nevertheless, the analysis method used in the present study takes into account that the two factors are expected to affect eye movements due to interaction effects. The interaction effect will be in focus for this study. The following linear model shows how the dependent variable is affected both by single effects of the two factors, together with the interaction effect:

$$Y_i = b_1 + b_2 \times bs + b_3 \times ws + b_4 \times bs \times ws + \varepsilon$$

where

Y_i = dependent variable
b_i = intercepts
bs = first order effects of the between-subject factor (age group)
ws = first order effects of the within-subject factor (either class of hazards or situation)
$bs \times ws$ = interaction effect of the two factors
ε = residual

Table 4 and **Table 5** will work as a representation of the independent versus the dependent variables in the statistical model that were used:

Table 4. Independent variables (age group and class of hazards) versus dependent variables (Est. mean)

Class of hazards		*Obvious*	*Context/Hidden*	*Context*
Age group	*Young*	Est. mean	"	"
	Old	"	"	"

Dependent variables (Est. mean) which were measured:

- Total fixation duration on the hazard object
- Mean fixation duration on the hazard object

Table 5. Independent variables (age group and situation) versus dependent variables (Est. mean)

Situation		*1*	*3*	*6*	*8*	*9*	*10*
Age group	*Young*	Est. mean	"	"	"	"	"
	Old	"	"	"	"	"	"

Dependent variables (Est. mean) which were measured:

- Total fixation duration on roadway users
- Total fixation duration on roadway related informatics
- Total fixation duration on environmental objects

3.3.2 Assumptions when using repeated measures ANOVA

There are some assumptions that should be met when using the repeated measures ANOVA; *multivariate normality*, *homogeneity of variances* and *sphericity and independence* (Hill & Lewicki, 2006). These assumption requirements were tested in SPSS, and whether these were met or not will be outlined briefly in the results section. In the following, the three repeated measures ANOVA assumptions will be outline in brief. For a fuller description of these assumptions, the reader is referred to Statistic literature (see References).

The dependent variable shall be normally distributed within groups; however, skewness of the distribution usually does not have a large effect on the F statistics. Also, the variances in the different groups of the design should be identical; i.e. homogeneity of variances is assumed in the statistical model that is used. The F statistics are nevertheless quite robust also against violations of these assumptions.

The sphericity assumption is necessary for the F-test to be valid since it states that the within-subject model is composed by independent components. Violations of this assumption can cause severe problems. A spherical matrix has equal variances and covariances equal to zero. Comparisons between means generate a set of contrasts that specify the main effect and interaction hypotheses. If these contrasts are not independent of each other the partitioning of variances poses problems. Thus, if changes across levels are correlated across subjects the compound symmetry and sphericity assumptions have been violated and independent contrast cannot be computed (Hill & Lewicki, 2006). A multivariate approach to the analysis is recommended if the sphericity assumptions are violated, however, this approach require sufficient degrees of freedom. An alternative to the multivariate approach is to adjust the univariate test degrees of freedom with a correction factor. SPSS automatically uses the Greenhouse-Geisser Epsilon (G-G) and the Huynh-Feldt Epsilon (H-F) as these correction factors. Generally, the H-F correction factor is more reliable since the G-G correction factor has been shown to be conservative, i.e. it sometimes fails to detect a true difference between group means (Austin, 1997), why the p-values generated by the H-F correction factor were used when investigating differences between age groups in different classes of situations or situaions.

3.3.3 Handling Missing Data

Compensation for potential missing values is necessary to be able to perform the repeated measures ANOVA method that is wanted during the present study. There are several different substitution methods to handle missing data. The newer substitution methods require extensions of substitution methods in SPSS, often to an additional price premium. In the standard set, there are mainly three ways in which to handle missing data. These are:

- Case-wise deletion
- Pair-wise deletion
- Mean substitution

Case-wise deletion means that data which contains missing data for at least one of the selected variables is list wise excluded from the analysis, i.e. the substitution method removes cases (subjects) if there is a missing value on any of the variables. Since *pair-wise deletion* is not possible to use when performing general linear models this substitution method will not further be described in the present report. *Mean substitution* is the replacement of all missing values by the means of that variable. Mean substitution was a very common way to replace missing values in the past, but the substitution method implies some problems why it is no longer recommended (Hill & Lewicki, 2006). How the missing data are handled in the present study will be outlined in the results section.

4. Results

The following chapter will outline the results from the study. At first, the reasons to why there has arisen missing data during the data process will be outlined. Second, the hazard classification theory described in section 2.4 will be applied to the current situations in the present study. In the lasts sections, the results from the analysis steps; step 1 and step 2 respectively, are outlined in detail.

4.1 Missing Data

From the main participant data there have been missing data due to different reasons. The missing data led to that whole participant data, or parts of participant data within some of the situations were lost, due to the following reasons:

- error at start up of the computer program
- eyebrow shading for the camera
- monocular vision: eye prosthesis
- reflex in the lenses
- calibration problems
- response light invisible
- video chin up

Because of the above described reasons the total amount of participants lowered from 50 to 31 participants (see **Table 2**). The higher the amount of missing data, the lower the variance turns out in the dependent variable. To minimize this problem the situations which consisted of missing data ≥ 50 % from participants within at least one of the age groups, were excluded from the statistical analysis (see Step 2).

Figure 8 visualizes the percentages of missing data within each age group in every situation that was analyzed statistically. Situations which consisted of missing data ≥ 50 % within each age group were excluded. Within each situation, there turned out to be a higher amount of missing data among the elderly than among the younger participants. This can probably be explained by the fact that there were some problems with the calibration settings to a higher extent among the elderly compared to the younger participants:

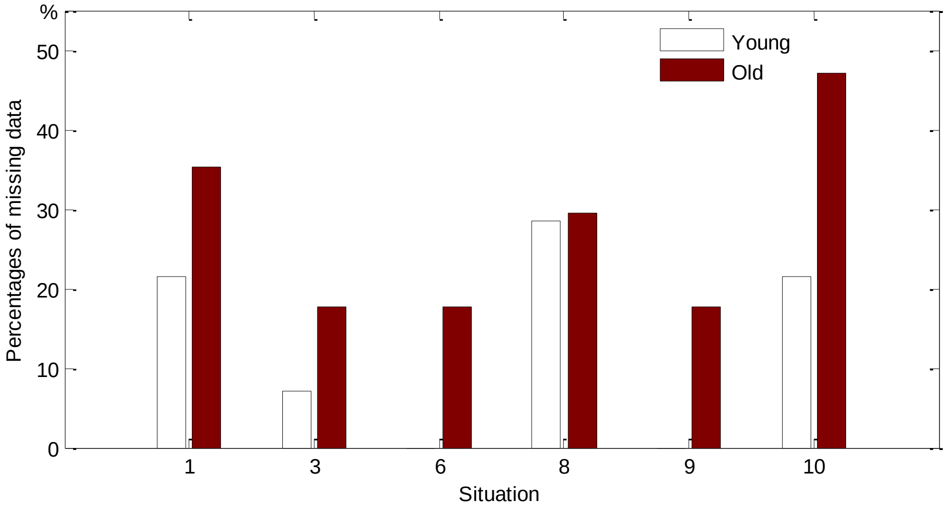

Figure 8. Percentages of missing data per age group within each of the analyzed situations.

There were mainly two ways in which missing data could be handled in SPSS when using the repeated measures ANOVA: case-wise deletion and mean substitution (see section 3.3.3). Since the missing data were randomly distributed across cases, case-wise deletion would have resulted in that the data material ended up with very few cases left for each age group. The remaining method was mean substitution. The missing values were replaced both with the mean for a variable within each age group and with the series mean (the mean for a variable without taking into account the age division) to investigate if the differences between age groups differed from case to case with changing substitution method. The anticipation was that results would not change, and that something still could be said about the material even though not the optimal substitution method was used. For a fuller method discussion, see section 5.2.

4.2 Traffic Hazard Classification Results

The hazard objects in the situations were shown to be either obvious hazards or context hazards. One exception did, however, exist in situation 3 (see Appendix 1). The hazard objects, i.e. a woman and her child, were most of the time slowly moving on the side of the street, classified as a context hazard, but were completely hidden by an oncoming car part time during the time interval, classified as a hidden hazard. The hazards in situation 3 were therefore classified as something in between these two classifications; a context/hidden hazard. As a result, this implied three classes of hazards: *obvious hazards*, *context hazards* and *context/hidden hazards*. To summarize the three classifications of hazardous situations the hazard classes are shown together with an example in the following.

4.2.1 Obvious Hazards

The obvious hazards were to be found in situation 6, 8 and 10. *Figure 9* shows situation 6 that includes an obvious hazard (see also situation 8 and 10 in Appendix 1):

Figure 9. An obvious hazard: Car ahead has to stop to back into parking space.

4.2.2 Context Hazards

The context hazards were to be found in situation 1, 2, 4, 7, 9 and 13. *Figure 10* shows situation 2 that includes a context hazard (see also situation 1, 4 7, 9 and 13 in Appendix 1):

Figure 10. A context hazard: Woman on right pavement walks against pedestrian crossing.

4.2.3 Context/Hidden Hazards

Context/hidden hazards were included only in situation 3, shown in *Figure 11*:

Figure 11. Context/hidden hazard: Pedestrians to the left hidden by oncoming van.

4.3 Step 1: Hazard Interpretation Results

The following section will show the hazard interpretation level in both age groups and for each situation. It turned out to be six different ways in which the participant reacted (or not reacted) in relation to their fixations (or lack of fixations) on the hazard object. The different ways in which the participants reacted are summarized in **Table 6** (the analysis steps will be based on area 1 and 2):

Table 6. Different ways of reactions in relation to fixation of the hazard object

1) The participant fixate the hazard				**2) The participant *does not* fixate the hazard**	
I) The participant press the button in relation to another object than the hazard object	II) The participant does not press the button at all	III) The participant press the button in relation to the predefined hazard	IV) The participant press the button *both* in relation to the predefined hazard and in relation to another object	I) The participant press the button in relation to another object	II) The participant does not press the button at all
Area 1: The participants have *not* interpreted the predefined hazard as a risk		**Area 2:** The participants have interpreted the predefined hazard as a risk		Not analyzed	

Analysis step 1 and 2

The participants that did not fixate the hazard object at all were so few why no further analyses of these scenarios were made. Hence, most of the participants fixated the hazard object at some point in each situation. In addition, a majority of the participants in both age groups pressed the button in relation to the predefined hazard, i.e. they pressed the button just *after* they have fixated it, see III) and IV) in **Table 6**. This indicates that a majority of the participants overall interpreted the predefined hazard in the 10 different situations as hazardous. Consequently, the eye movements in these situations could be compared and analyzed based on hazard perception.

Before turning to the analysis based on hazard perception in step 2, *Figure 12* will clarify the percentages of the participants within each age group which have interpreted versus *not* interpreted each situation as hazardous. The differences between age groups were analyzed with a χ^2-test. *Figure 12* is based on area 1 and 2 shown in **Table 6**.

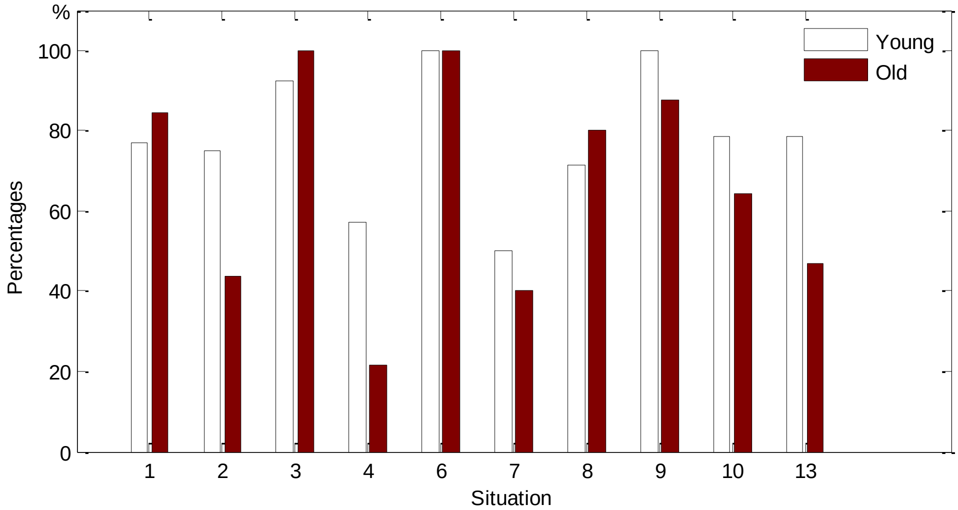

Figure 12. Percentages of participants in each age group that have reacted on hazard in each situation.

In situations 1, 3, 6, 8, 9 and 10 a majority of the participants in both age groups reacted in relation to the predefined hazard (> 50 %) and were further analyzed in Step 2. In the remaining situations; 2, 4, 7 and 13, a majority of the elderly participants did *not* react in relation to the predefined hazard, while the younger still did. The elderly reacted in relation to another object or not at all, even though they fixated the hazard object. As visualized in *Figure 12*, the differences between age groups were most striking in situations 2, 4 and 13, however not significant. The four situations where a majority of the elderly did not react in relation to the predefined hazard are shown in *Figure 13-16:*

Figure 13. Situation 2, context hazard

Figure 14. Situation 4, context hazard

Figure 15. Situation 7, context hazard

Figure 16. Situation 13, context hazard.

The results indicate that a majority of the elderly tended to interpret the predefined hazards in these situations as non-hazardous while a majority of the younger participants interpreted them as hazardous. All four of these situations include context hazards which are composed by pedestrians or cyclist, and none of them of slowly moving cars. The differences between age groups were, however, not significant.

There should be mentioned that though all reaction times were registered in the OCD study, only the time that passed until the very first reaction within each critical interval was compared within age groups. Since there have been shown that reactions could occur in relation to another object than the hazard object, the reactions in relation to the hazard object were not always measured. There were quite few participants that reacted in relation to another object than the hazard object; nevertheless, if reaction times were re-measured only in relation to the hazard object, this could in fact affect the results from the OCD study shown in **Table 1**.

4.4 Step 2: Fixation Duration Results

Step 2 will move further with the situations where a majority of the participants interpreted the predefined hazard as a risk since only these situations can be analyzed based on hazard perception. These situations, as shown in *Figure 12*, were 1, 3, 6, 8, 9 and 10. The total fixation duration time on the hazard object, road users, road informative objects and environmental objects were analyzed and compared within age group. The results will be outlined visually in graphs to show the total fixation duration time for both age groups.

4.4.1 Time on the Different Objects

The results of the total fixation duration distribution on objects in each category are summarized in the cumulative bar chart in *Figure 17*. The age groups are clustered and the different categories of objects are stacked to visualize the amount of time that the participants in each age group fixate the different categories of objects. The road users' category does *not* include the hazard object, which is separated and visualized on its own:

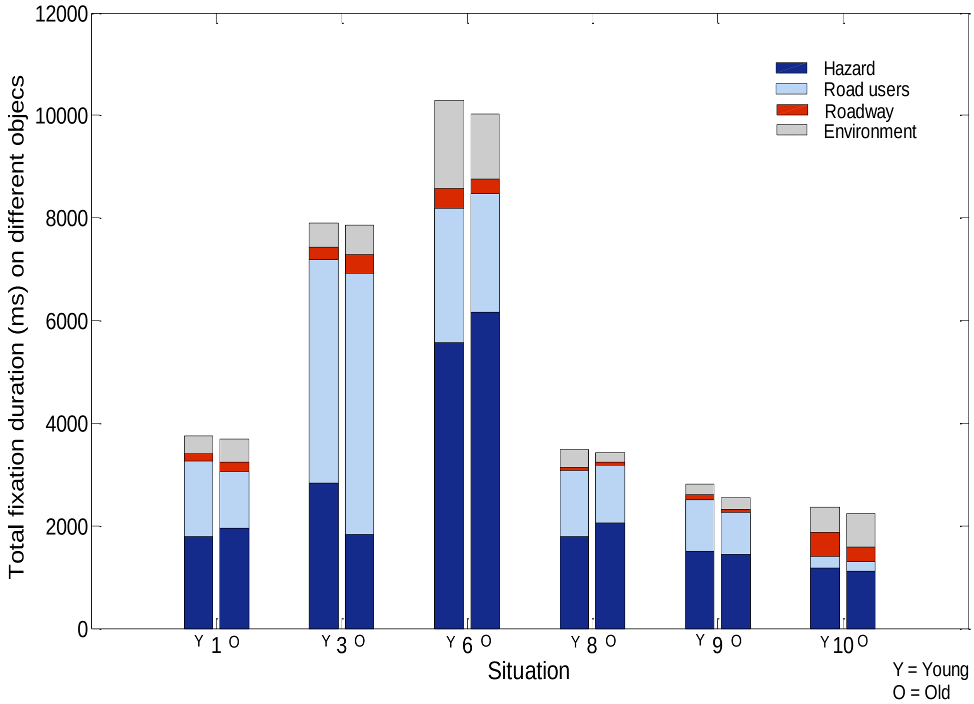

Figure 17. Total fixation duration time on each category of objects (in ms) per age group and situation.

As visualized in *Figure 17*, the road informative objects and the environmental objects (indicated with red and gray colours) were not fixated to the same extent as the hazard object and the other road users (indicated with dark and light blue colours). When summarizing the hazard object in combination with the other road users in each situation, the total fixation duration time was quite similar for both age groups. The younger age group fixated the hazard objects to a higher extent than the elderly in situation 3, 9 and 10, while the results were reversed for situation 1, 6 and 8. The relative differences, when watching the hazard object, were greatest in situation 3.

The total fixation duration time on each category of objects will be outlined in more detail in sections 4.4.2 – 4.4.5 (for the hazard object, the mean fixation duration time will be visualized as well). The figures and the data (i.e. F- and p-values) in these sections visualize the results from when the missing values have been replaced by the mean for the variable within each age group; however the figures do not change much in appearance when replacing the missing values with the series mean, except for situation 8 and 10 when investigating the total fixation duration on environmental objects (see section 4.4.5).

4.4.2 Fixation Duration on the Hazard Object

In the following section the results of the total fixation duration time and the mean fixation duration time on the hazard object will be outlined and the results within each age group for every class of situations shown visually.

The between-subject factor age did not show any significant differences when investigating the total fixation duration on the hazard object, while the within-subject factor hazard class did ($F = 236.7$, $p < 0.001$). The interaction effect between these factors showed significant differences between age groups ($F = 3.9$, $p = 0.035$). A closer look at the interaction effect showed that it was the class of context/hidden hazards which differed significantly between age groups ($p = 0.002$). The context/hidden hazards were composed only by situation 3. The results from the OCD study showed that the reaction times also differed significantly in situation 3 and the time difference between age groups was largest in this situation compared to the other situations with significant differences (see **Table 1**). The interaction effects are visualized in *Figure 18*, i.e. the figure shows the differences between age groups when comparing total fixation duration time on the hazard object in each class of hazards:

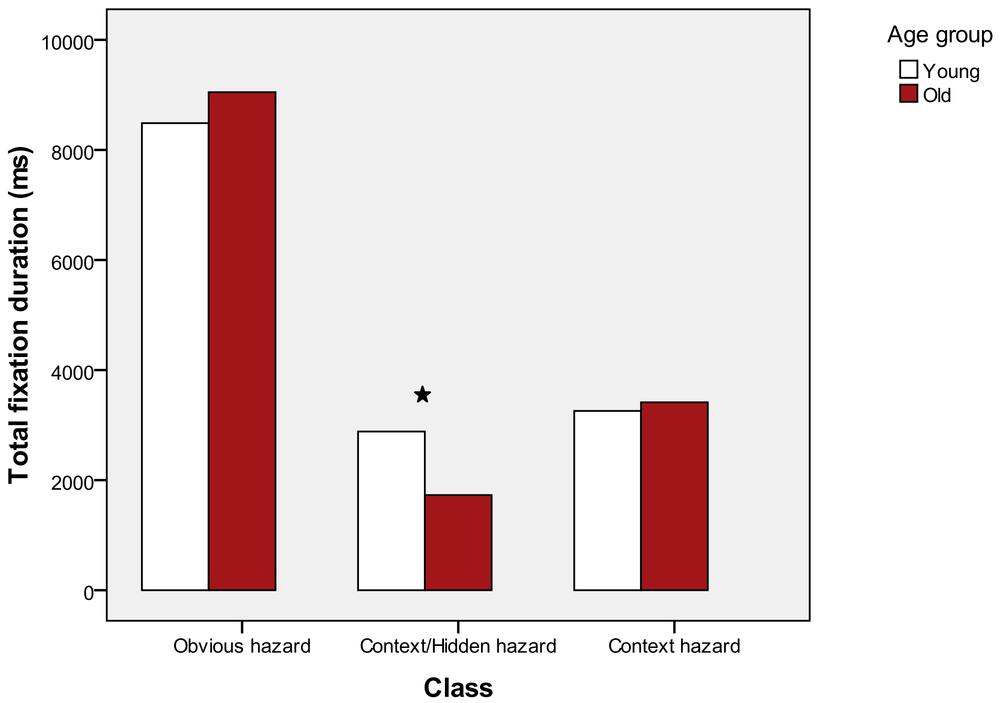

*Figure 18.*Total fixation duration time in ms on hazards per age group and class of hazards (* = Sig. 0.05)

The difference between age groups was most evident in the class of context/hidden hazards which only included situation 3, where a woman and a child moved along the road, were hidden by a van and then crossed the street (see Appendix 1 or *Figure 11*). The younger age group fixated the hazard object for a longer time than the older participants in this situation. A closer look at situation 3 showed that the elderly to a higher extent did not perceive the hazard until it became visible behind a van, even though the hazard were visible earlier. In the class including solely context hazards, the differences between age groups were small. Situations that belong to this class of hazards were composed by slowly moving cars on the side of the street, while situation 3 was composed by pedestrians. In addition, there were some differences in total fixation duration time between age groups in the class of obvious hazards, where the elderly fixated obvious hazards to a somewhat higher extent than the younger participants (see *Figure 18*).

The between-subject factor age did not show any significant differences either when investigating the mean fixation duration on the hazard object, while the within-subject factor hazard class did ($F = 44.0$, $p < 0.001$). The interaction effect between the factors did not show significant differences between age groups. The interaction effects are visualized in *Figure 19*, i.e. the figure shows the differences between age groups when comparing mean fixation duration time on the hazard object in each class of hazards:

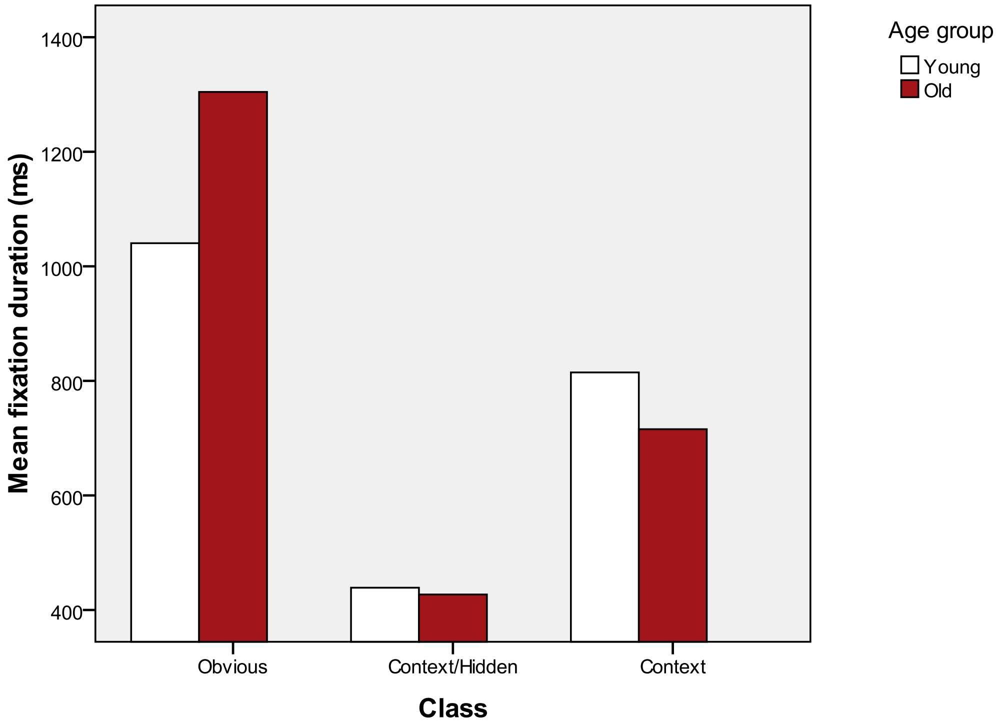

Figure 19. Mean fixation duration time (in ms) on hazards per age group and class of hazards.

As visualized in *Figure 19*, the mean fixation duration for the elderly was higher in the class of obvious hazards, while the results were reversed for context and context/hidden hazards. The differences between age groups were, however, not significant.

4.4.3 Fixation Duration on the Road Users

In the following section the results of the total fixation duration time on the road users will be outlined and the results within each age group for every situation will be shown visually.

The between-subject factor age did not show any significant differences when investigating the total fixation duration on the road users including the hazard object, while the within-subject factor situation, on the other hand, did ($F = 265$, $p < 0.001$). When investigating the total fixation duration on the road users without including the hazard object, the between-subject factor age did not show any significant differences, while the within-subject factor situation did ($F = 112.8$, $p < 0.001$). The interaction effect between age and situation did not show any significant differences, either when including the hazard object or when not including the hazard object.

Figure 20 visualizes the interaction effect between the factors age and situation of the total fixation duration time on objects belonging to the road users' category. The right figure shows the total fixation duration time on road users including the hazard objects, while the left figure shows total fixation duration time on road users *not* including the hazard objects:

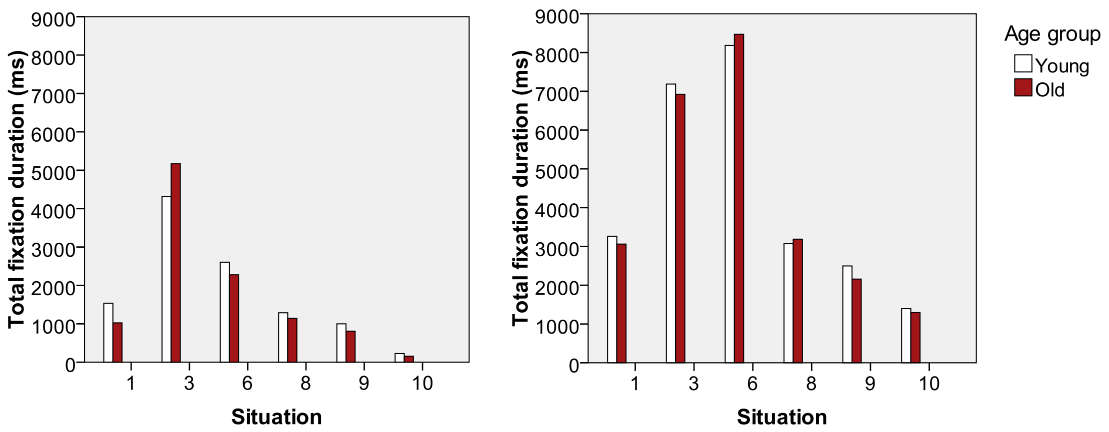

Figure 20. Total fixation duration time on road users (in ms) per age group and situation.

When looking at the total fixation duration times that the participants in both age groups fixated road users including the hazard object (right figure) the differences between older and younger participants were very small. When the hazard object is *not* included (left figure) the younger participants fixated the road users for longer durations than the elderly in all of the situations except situation 3.

4.4.4 Fixation Duration on Road Informative Objects

In the following section the results of the total fixation duration time on road informative objects will be outlined and the results within each age group for every situation will be shown visually.

The between-subject factor age did not show any significant differences when investigating the total fixation duration on the roadway and road informative objects, while the within-subject factor situation did ($F = 2.38$, $p < 0.001$). The interaction-effect between age and situation did not show any significant differences. *Figure 21* visualizes the interaction effect of the total fixation duration on the roadway and road informative objects between age and situation:

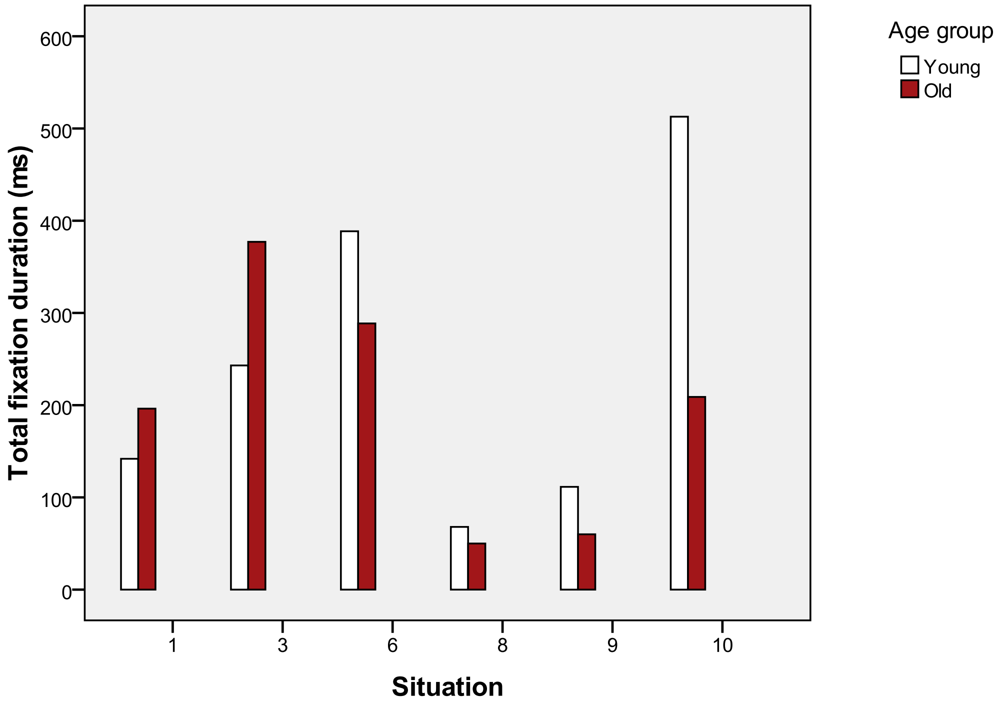

Figure 21. Total fixation duration time on road informative objects (in ms) per age group and situation.

Compared to the hazard objects and the objects belonging to the road users' category, the total fixation duration time on roadway and roadway related informatics is low for both age groups. The differences between age groups are similar for situation 6, 8, 9 and 10 where the younger age group fixated the roadway and road informative objects for longer total durations than the elderly. The results are opposite against Dukic's and Broberg's results as described in section 2.2.3 where the elderly were shown to fixate the roadway and road informative objects to a higher extent than the younger participants. In situation 1 and 3 the results however coincides with Dukic's and Broberg's results, since the elderly fixated road informative objects for longer durations in comparison with the younger participants in theses situations.

4.4.5 Fixation Duration on Environmental Objects

In the following section the results of the total fixation duration time on environmental objects will be outlined and the results within each age group for every situation will be shown visually.

The between-subject factor age did not show any significant differences, while the within-subject factor situation did ($F = 33.2$, $p < 0.001$). The interaction-effect between age and situation showed significant differences when investigating total fixation duration on environmental objects ($F = 3.39$, $p = 0.016$). A closer look at the interaction effect showed that it was both situation 8 ($p = 0.001$) and situation 10 ($p = 0.026$) which differed significantly between age groups. In the results from the OCD study the reaction times for the age groups did not differ significantly in none of these situations (see **Table 1**). Both situations are obvious hazards, however, in situation 8 the younger age group fixate the hazard object for longer total time, while the results were shown to be reversed for situation 10, see *Figure 22*:

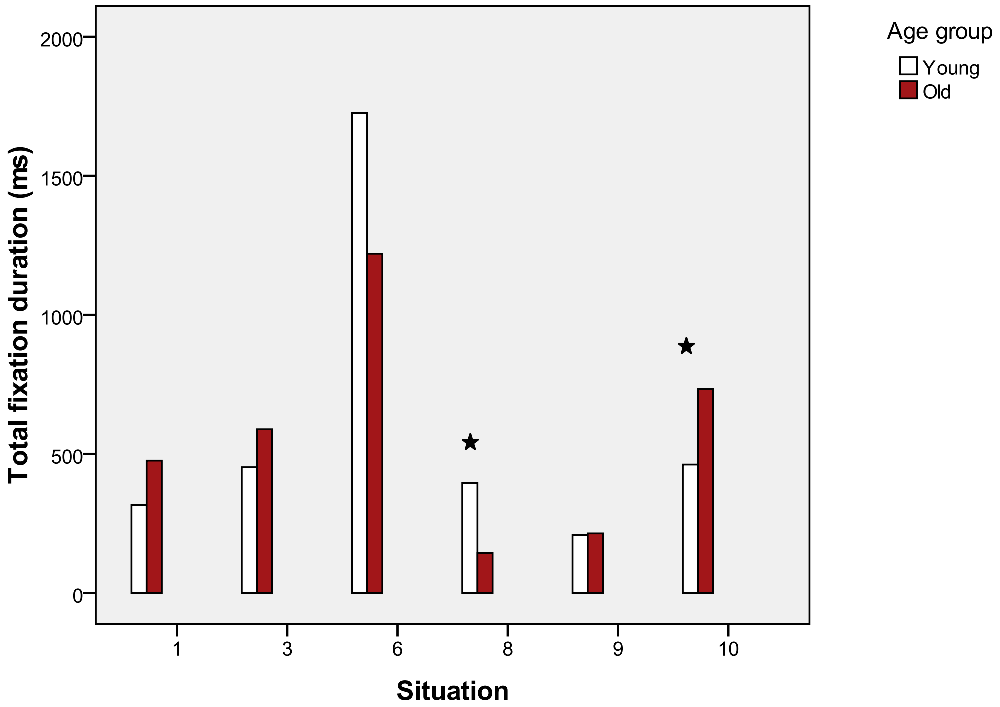

Figure 22. Total fixation duration time on environmental objects (in ms) per age group and situation (* = Sig. 0.05)

The amount of time that both age groups fixated road environment is somewhat higher compared to road informative objects, but smaller in comparison with the amount of time that the participants fixated the hazard object and objects belonging to the road users' category. As visualized in *Figure 22*, the younger age group fixated environmental objects to a higher extent than the older participants in situation 6 and 8, while the results are reversed for situation 1, 3 and 10. In situation 9 the differences between age groups are negligible. Situation 1 and 3 is classified as context and context/hidden hazards while situation 10 is an obvious hazard.

The within group substitution mean method showed that the differences between age groups were significant for situation 8 and 10. Since the results did not show any significant differences of the interaction effect when replacing the missing values with the series mean, and since the missing values replaced by means are as high as 29 %, the significant results in these situations should be interpreted with caution. Situations 3, 6 and 9 had missing data to a lower degree (around 10 %), why mean substitution should do less harm to these cases.

4.4.6 Violations of Assumptions

The assumptions of the repeated measures ANOVA outlined in section 3.3.2; multivariate normality, homogeneity of variances and sphericity and independence were violated for all dependent variables described in the latest four sections. The repeated measures ANOVA method is, nevertheless, robust against violations of multivariate normality and homogeneity of variances, while the violations of sphericity was handled with G-G and H-F correction factors in SPSS Statistics.

5. Discussion

Initially, this chapter summarizes and discusses the results from analysis step 1 and 2 followed by a method and validity discussion.

5.1 Result Discussion

The elderly have been shown to have more problems in interpreting four of the analyzed situations as hazardous since a majority of the elderly did not react in relation to the predefined hazard even though they fixated it. All of these four situations were composed by context hazards including pedestrians or cyclists. The differences between age groups were most striking in three of these situations, although not significant. Probably, the elderly have more experience of context hazards composed by pedestrians and cyclists, why they did not interpret these situations as hazardous to the same extent as the younger participants.

There were shown to be significant differences in total fixation duration time between age groups for the context/hidden hazard including only situation 3 (see section 4.4.2), where the elderly did not discover the hazard object as early as the younger participants. The hazard was discovered by a majority of the elderly at a later time in comparison with the younger age group, something that probably can be explained by the older participants reduced UFOV (see section 2.1.2). Among those situations that were analyzed in this study, the differences in reaction time between age groups were also shown to be greatest in situation 3 (see **Table 1**). There were no significant differences between age groups in any of the other hazard classes, why context/hidden hazards rather than pure context hazards should be of more focus in future studies. Interestingly, the context/hidden class was composed by pedestrians and the pure context class by cars.

As shown in the OCD study, the older age group did significantly react slower to the predefined hazard in situation 1, 3, 9 and 10 (see **Table 1**). Probably, the slower reaction time among the elderly was primary caused due to cognitive factors in situations 1, 9 and 10, rather than differences in visual behaviour between age groups. Only in situation 3 where the total fixation duration time significantly differed between age groups, the reaction time can be assumed to have depended on differences in visual behaviour since the elderly were shown to discover the hazard at a later time. An important thing to take into account is that since the participants sometimes reacted to other objects than the predefined hazard, and though only the time that passed until the very first reaction within each critical interval was compared within age groups in the OCD study, this might not have given satisfactory results of reaction time differences between age groups.

Both age groups spent most amount time to fixate objects within the road users' category (including the hazard object) and least amount of time on road informative objects and environmental objects. The results imply that when one of the age groups did not fixate the hazard object to the same extent as the other group, they still fixated other road users during the situations. The elderly probably fixated road users in a narrower field of their UFOV. The amount of time on road users is probably a result of the instructions given to the participants, to search for potential threats, also called top-down processes (see section 2.1.1), which naturally can be assumed to appear among the road users rather than among road informative or environmental objects.

The hypotheses outlined in the beginning of this report are repeated:

Hypothesis 1: There are differences in visual behaviour among older and younger experienced drivers in different hazardous traffic situations.

Hypothesis 2: The differences between age groups are assumed to be evident in traffic situations which include context hazards since these require high demands on drivers' perception ability, an ability that impairs with age.

The differences were seldom significant, why hypothesis 1 must be rejected for all of the investigated areas except when examining the total fixation duration time on the hazard object in the context/hidden class. Even though some situations classified as context hazards showed interesting results, especially context hazards which were composed by pedestrians or cyclist, with a tendency that the elderly did not react to these situations to the same extent as the younger participants, there were no significant differences between age groups, why also hypothesis 2 must be rejected.

The mean fixation duration time on the hazard object was shown to be similar for both age groups in each class of hazards (see *Figure 19*). In their intersection study, Dukic and Broberg found that the elderly spent longer average time on different objects, while Maltz and Shinar, on the other hand, did not (see section 2.2.3). Thus, the present study support Maltz' and Shinar's results, nevertheless, one should be aware of the instructions that the participants did receive before measuring mean fixation duration time on the hazard classes. The participant instructions may have affected their visual behaviour and, hence, their mean fixation duration time.

In a majority of the situations, younger seemed to fixate the roadway and road informative objects to a higher extent than the elderly, which opposes the results from Dukic's and Broberg's intersection study (see section 2.2.3). The results can possibly be explained by the fact that younger to some extent fixated a larger amount of objects than the older participants in each situation. The younger participants still reacted faster to the predefined hazard why there seem not to constitute a risk in that they fixated the roadway and road informative objects to a higher extent than the elderly. In situation 1 and 3, however, the results coincided with Dukic's and Broberg's results. Hence, there did not seem to be any clear pattern neither between age groups nor among class of hazards when examining the total fixation duration on road informative objects. This is probably due to the fact that the amount of time that the participants fixated this category of objects was low to be able to see any clear trends in the data.

Obvious hazards were assumed to be easier to perceive and be prepared for. In this class of hazards, the elderly fixated the hazard objects for somewhat longer durations than the younger participants. As mentioned in section 2.2.3, Poole and Ball (2005) assumes that longer fixation duration indicates that the object is more engaging in some way or that the person has difficulties in extracting information. Probably both alternatives are true for the elderly in these situations. Once the elderly discovered the hazard object they nevertheless seemed to keep their eyes on the hazard object, while the younger age group could move their eyes to other objects as well without loosing control over the hazardous situation. Also, when studying the amount of time on environmental objects, the younger participants spent more time on these in situation 6 and 8, which implies that the younger fixated other objects than the hazard object (such as environmental objects) to a higher extent compared to the elderly. The reason to this is probably the fact that younger needed less time to process the information about the hazard object, and that it was easier for younger to switch attention between objects shown by Ranney & Pulling (1990) in section 2.2.3.

5.2 Method Discussion

What is most critical in this study is that the analysis matrix consisted of missing data which needed to be handled in the statistical analysis. Mean substitution is not a recommended method, however, since the substituting of means were performed in three different ways without the results changing particularly with substitution method, the degree of uncertainty about the method is likely to, to some extent, have been reduced.

There are other ways in which visual behaviour can be measured, e.g. the total amount of fixations on different objects. Since the purpose was to investigate what situations the elderly might have more problems in interpreting as hazardous, the total fixation duration probably was the most appropriate dependent variable. In addition, fixations differ in their length from 80 ms to a few seconds why the amount of fixations would not give a satisfactory level of information processing of the different objects in hazardous traffic situations.

5.3 Validity

One might oppose against the lack of real-world exposure to the participants in the hazard perception test that has been used in this study. To be able to compare different drivers' visual behaviour, the participants need, however, to be exposed to the same situation. In the real and constantly changing world, it is not possible to expose the drivers to the same situation why the video based situations in the present study are strongly motivated. In addition, there is nothing that can distract the participants from their main task which is the case in authentic driving. Hence, the participants can solely concentrate on the visual scene in the different scenarios.

As mentioned in section 2.1.1, a person can process information in the periphery even though a particular object is not fixated, why one cannot be sure of what the participants actually have perceived. The fixated object is, nevertheless, usually the object that is paid attention. It could be assumed that this is even more likely in hazardous situations since the hazard objects caused a potential threat, and it becomes more important to fixate it, than to handle the information from the periphery.

6. Conclusions

Since there was a tendency that a majority of the older participants had more trouble in interpreting context hazards consisting of pedestrians or cyclist as hazardous, the elderly should tentatively be exposed to such hazards in future potential training schemes. The training scheme could advantageously consist of context hazards which take an unexpected action that turns into a hazardous situation. More research is, however, needed in the area since the differences between age groups were not significant. In addition, the older participants had significant shorter total fixation duration time on the hazard object in the context/hidden class of hazards, and did not discover the hazard as early as the younger age group, why the elderly advantageously also should be exposed to these types of hazards in training. The class of context/hidden hazards did consist only of one situation, which would make it interesting to study more situations resembling to the current context/hidden hazardous situation (situation 3) in order to verify the results in this class of hazards.

6.1 Future Work

During the collection of eye movement data, not all raw data were analyzed. Additional analysis could advantageously be done to investigate the eye movement pattern, scan paths, the total amount of fixations et cetera, to further analyze visual behaviour among the elderly. Such studies could provide with deeper knowledge about search pattern and whether the elderly differs in search strategy in comparison with younger drivers. Also, comparison of the results with other substitution methods than the one used in the present study could be performed, to either strengthen or question the substitution method used in the present study.

The eye movements could advantageously be further analyzed even within other events than the predefined hazardous situations. This would enable more situations in each hazard class, which would be of use in order to investigate whether the classification made in the present study can be verified. Also, further studies should be made based on context hazards, especially context hazards in terms of pedestrians and cyclists on the side of the street. The classification could therefore tentatively take into account whether the context hazardous situations are composed by pedestrians/cyclists or cars.

Since only the time to the very first reaction within each critical interval was compared within age groups in the OCD study, further studies should investigate which reactions that actually were related to the hazard object, and re-compare these reaction times between age groups to ensure that the significance levels shown in **Table 1** do not change.

As described in section 2.2, the older age, the greater the individual differences, why it could be more accurate to discuss biological rather than chronological age. The prerequisite requirements to participate in the study (see section 2.3.1) may, to some extent, have reduced the individual differences. Still, it would be of interest to perform deeper studies on the elderly by adding a questionnaire to the research to qualitatively investigate their lifestyles in order to enable division of the elderly into potential subgroups.

An issue that should be borne in mind in future studies is that your behaviour depends on what is perceived, and what is perceived depends on your behaviour (Blake & Sekuler, 2006).

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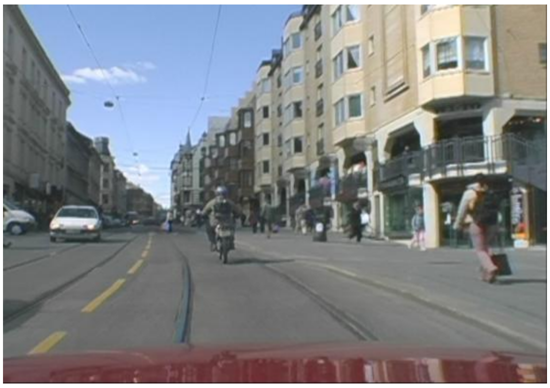
Appendix

Appendix 1

The 10 analyzed situations:



1. Van from left does not yield

2. Woman on right pavement approaches crossing without looking to the side.

3. Pedestrians to the left hidden by oncoming van.

4. Two oncoming bicyclists (children) on wrong side of the road (rural highway).

6. Car ahead stops to back into parking space.

7. Oncoming cyclists on wrong side of street, without hands on handlebar.

8. Man on rollerblades appearing in front of stopped bus.

9. Car pulling out from petrol station.

10. Car from the right pulling out at narrowing after passing toll gate.

13. Two men standing in the middle of the street, hidden by car ahead.

Appendix 2

Data from analysis of total fixation duration on hazard object:

Table 7. Multivariate normality and homogeneity of variances tested.

Report

Age_group		tot_time_obvious	tot_time context/hidden	tot_time_context
Young	N	14	14	14
	Median	8172,50	2881,50	3080,00
	Mean	8486,50	2883,07	3257,14
	Std. Deviation	1261,805	1192,434	1042,449
	Skewness	1,327	-,545	,521
Old	N	17	17	17
	Median	9320,00	1729,00	3414,00
	Mean	9048,76	1728,65	3413,94
	Std. Deviation	2426,916	692,702	1004,551
	Skewness	-,524	1,194	,357
Total	N	31	31	31
	Median	8480,00	1920,00	3400,00
	Mean	8794,84	2250,00	3343,13
	Std. Deviation	1977,910	1101,419	1007,667
	Skewness	-,108	,521	,399

If perfectly symmetrical, i.e. normally distributed, the skewness value would be 0

Table 8. Sphericity tested.

Mauchly's Test of Sphericity[b]

Measure:MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
class	,637	12,636	2	,002	,734	,790	,500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b. Design: Intercept + age_group
Within Subjects Design: class

Table 9. Corrected tests of non-sphericity.

Tests of Within-Subjects Effects

Measure:MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
class	Sphericity Assumed	7,403E8	2	3,702E8	236,719	,000
	Greenhouse-Geisser	7,403E8	1,467	5,046E8	236,719	,000
	Huynh-Feldt	7,403E8	1,579	4,688E8	236,719	,000
	Lower-bound	7,403E8	1,000	7,403E8	236,719	,000
class * Age group	Sphericity Assumed	1,236E7	2	6181255,788	3,953	,025
	Greenhouse-Geisser	1,236E7	1,467	8426174,653	3,953	,038
	Huynh-Feldt	1,236E7	1,579	7827984,464	3,953	,035
	Lower-bound	1,236E7	1,000	1,236E7	3,953	,056
Error(class)	Sphericity Assumed	9,070E7	58	1563739,513		
	Greenhouse-Geisser	9,070E7	42,548	2131661,058		
	Huynh-Feldt	9,070E7	45,799	1980330,379		
	Lower-bound	9,070E7	29,000	3127479,027		

Table 10. Significant levels (Sig.) within class of hazards

Pairwise Comparisons

Measure:MEASURE_1

Class	(I) Age group	(J) Age group	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
						Lower Bound	Upper Bound
Obvious	0	1	-562,265	718,493	,440	-2031,749	907,219
	1	0	562,265	718,493	,440	-907,219	2031,749
Context/Hidden	0	1	1154,424*	342,791	,002	453,338	1855,510
	1	0	-1154,424*	342,791	,002	-1855,510	-453,338
Context	0	1	-156,798	368,741	,674	-910,958	597,362
	1	0	156,798	368,741	,674	-597,362	910,958

Based on estimated marginal means

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

*. The mean difference is significant at the ,05 level.

Appendix 3

Data from analysis of total fixation duration on road users:

Table 11. Multivariate normality and homogeneity of variances tested.

Report

Age group		totdurusers_urisk 1	totdurusers_urisk 3	totdurusers_urisk 6	totdurusers_urisk 8	totdurusers_urisk 9	totdurusers_urisk 10
Young	N	14	14	14	14	14	14
	Median	1300,00	3940,00	2900,00	1184,00	940,00	194,00
	Mean	1480,00	4345,50	2605,71	1288,00	1000,00	218,71
	Std. Deviation	500,092	1318,538	1085,157	702,383	500,584	318,072
	Skewness	,803	1,070	-,200	1,800	,471	2,487
Old	N	17	17	17	17	17	17
	Median	1280,00	5080,00	2440,00	1200,00	880,00	194,00
	Mean	1115,29	5095,94	2306,06	1141,18	825,41	173,65
	Std. Deviation	326,154	1790,975	1258,348	371,407	618,095	177,989
	Skewness	-1,549	-,729	,469	,575	1,019	2,212
Total	N	31	31	31	31	31	31
	Median	1280,00	4757,00	2441,00	1200,00	880,00	194,00
	Mean	1280,00	4757,03	2441,39	1207,48	904,26	194,00
	Std. Deviation	446,259	1614,994	1173,779	541,173	565,812	247,499
	Skewness	,604	-,067	,168	1,907	,698	2,667

Table 12. Sphericity tested.

Mauchly's Test of Sphericity[b]

Measure:MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
situation	,026	98,952	14	,000	,473	,535	,200

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b. Design: Intercept + A.g

Within Subjects Design: situation

Table 13. Corrected tests of non-sphericity.

Tests of Within-Subjects Effects

Measure:MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
situation	Sphericity Assumed	3,966E8	5	7,933E7	111,260	,000
	Greenhouse-Geisser	3,966E8	2,364	1,678E8	111,260	,000
	Huynh-Feldt	3,966E8	2,676	1,482E8	111,260	,000
	Lower-bound	3,966E8	1,000	3,966E8	111,260	,000
situation * Age group	Sphericity Assumed	6348696,398	5	1269739,280	1,781	,120
	Greenhouse-Geisser	6348696,398	2,364	2685756,208	1,781	,170
	Huynh-Feldt	6348696,398	2,676	2372435,703	1,781	,163
	Lower-bound	6348696,398	1,000	6348696,398	1,781	,192
Error(situation)	Sphericity Assumed	1,034E8	145	712974,512		
	Greenhouse-Geisser	1,034E8	68,551	1508085,756		
	Huynh-Feldt	1,034E8	77,605	1332152,368		
	Lower-bound	1,034E8	29,000	3564872,560		

Appendix 4

Data from analysis of total fixation duration on road way and road informative objects:

Table 14. Multivariate normality and homogeneity of variances tested.

Report

Age group		tot_dur_rway_w1	tot_dur_rway_w3	tot_dur_rway_w6	tot_dur_rway_w8	tot_dur_rway_w9	tot_dur_rway_w10
Young	N	14	14	14	14	14	14
	Median	40,00	180,00	320,00	,00	,00	376,00
	Mean	147,64	248,07	388,57	65,14	111,43	483,43
	Std. Deviation	265,287	215,052	513,313	121,670	298,583	343,946
	Skewness	2,892	,995	2,208	2,255	3,419	,947
Old	N	17	17	17	17	17	17
	Median	169,00	280,00	240,00	58,00	,00	376,00
	Mean	186,71	365,82	297,47	52,35	64,59	287,53
	Std. Deviation	179,088	547,703	228,972	70,987	81,574	142,646
	Skewness	1,765	3,005	1,204	1,727	,943	-1,194
Total	N	31	31	31	31	31	31
	Median	160,00	200,00	240,00	,00	,00	376,00
	Mean	169,06	312,65	338,61	58,13	85,74	376,00
	Std. Deviation	219,072	428,459	379,822	95,626	206,743	268,209
	Skewness	2,416	3,501	2,564	2,308	4,452	1,469

Table 15. Sphericity tested.

Mauchly's Test of Sphericity[b]

Measure:MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
situation	,131	55,044	14	,000	,618	,724	,200

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b. Design: Intercept + Agegroup
Within Subjects Design: situation

Table 16. Corrected tests of non-sphericity.

Tests of Within-Subjects Effects

Measure:MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
situation	Sphericity Assumed	2952675,665	5	590535,133	8,068	,000
	Greenhouse-Geisser	2952675,665	3,090	955559,448	8,068	,000
	Huynh-Feldt	2952675,665	3,620	815693,741	8,068	,000
	Lower-bound	2952675,665	1,000	2952675,665	8,068	,008
situation * Age group	Sphericity Assumed	448514,504	5	89702,901	1,226	,300
	Greenhouse-Geisser	448514,504	3,090	145150,474	1,226	,305
	Huynh-Feldt	448514,504	3,620	123904,728	1,226	,305
	Lower-bound	448514,504	1,000	448514,504	1,226	,277
Error(situation)	Sphericity Assumed	1,061E7	145	73191,424		
	Greenhouse-Geisser	1,061E7	89,610	118432,846		
	Huynh-Feldt	1,061E7	104,975	101097,772		
	Lower-bound	1,061E7	29,000	365957,118		

Appendix 5

Data from analysis of total fixation duration on environmental objects:

Table 17. Multivariate normality and homogeneity of variances tested.

Report

Age group		tot_dur_environ_w1	tot_dur_environ_w3	tot_dur_environ_w6	tot_dur_environ_w8	tot_dur_environ_w9	tot_dur_environ_w10
Young	N	14	14	14	14	14	14
	Median	376,00	400,00	1500,00	289,00	140,00	560,00
	Mean	332,57	457,36	1725,71	356,57	208,57	488,00
	Std. Deviation	300,837	486,326	886,946	234,004	269,554	362,338
	Skewness	,661	2,080	1,396	1,190	1,658	,462
Old	N	17	17	17	17	17	17
	Median	392,00	360,00	1280,00	240,00	200,00	584,00
	Mean	441,41	577,00	1264,65	177,06	213,71	663,06
	Std. Deviation	345,696	856,709	423,124	151,631	246,014	297,158
	Skewness	,865	2,385	-,010	,641	2,479	,747
Total	N	31	31	31	31	31	31
	Median	392,00	360,00	1320,00	258,00	200,00	584,00
	Mean	392,26	522,97	1472,87	258,13	211,39	584,00
	Std. Deviation	325,555	705,402	700,556	210,327	252,530	334,409
	Skewness	,801	2,551	1,750	1,251	1,951	,344

Table 18. Sphericity tested.

Mauchly's Test of Sphericity[b]

Measure:MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
situation	,147	52,029	14	,000	,604	,706	,200

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b. Design: Intercept + Agegroup
 Within Subjects Design: situation

Table 19. Corrected tests of non-sphericity.

Tests of Within-Subjects Effects

Measure:MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
situation	Sphericity Assumed	3,417E7	5	6834714,379	34,499	,000
	Greenhouse-Geisser	3,417E7	3,021	1,131E7	34,499	,000
	Huynh-Feldt	3,417E7	3,528	9686431,913	34,499	,000
	Lower-bound	3,417E7	1,000	3,417E7	34,499	,000
situation * Age group	Sphericity Assumed	2247005,251	5	449401,050	2,268	,051
	Greenhouse-Geisser	2247005,251	3,021	743777,478	2,268	,086
	Huynh-Feldt	2247005,251	3,528	636909,230	2,268	,075
	Lower-bound	2247005,251	1,000	2247005,251	2,268	,143
Error(situation)	Sphericity Assumed	2,873E7	145	198111,217		
	Greenhouse-Geisser	2,873E7	87,611	327882,325		
	Huynh-Feldt	2,873E7	102,312	280771,179		
	Lower-bound	2,873E7	29,000	990556,083		