PRE-CRASH FACTORS INFLUENCING DRIVERS OF OLDER AGES IN INTERSECTION COLLISIONS

Thomas Broberg*º, Lotta Jakobsson*º, Irene Isaksson-Hellman*
***Volvo Car Corporation, Göteborg, Sweden**
º*Chalmers University of Technology, Division of Applied Mechanics, Göteborg, Sweden

ABSTRACT

The objective of this study is to understand the driver needs from a preventive and protective perspective focusing on cognitive pre-crash factors influencing the older driver in intersection collisions.

The study combines information from a statistical dataset and 33 in-depth cases. The statistical data confirms results from prior studies indicating that the 55+ drivers are relatively more involved in collisions occurring in intersections having an overall higher injury risk compared to the comparative group of drivers aged 25-35. The in-depth data indicates that missed observations were one major cause in the development of the collision scenarios studied. The major possible causes together with the contributing causes are analyzed and discussed.

Key words: collision, prevention, protection, aging, intersections,

ACCORDING TO DEMOGRAPHIC STUDIES by the UN (United Nations, Department of Economic and Social Affairs, Population Division, 2006) one out of every nine persons is expected to be 60 year or older in 2006. In 2050 it is predicted that one out three will be in this age group. It is essential that the safety needs for the older part of the population is considered when developing future automotive safety features.

Previous studies indicate that older drivers are more likely to be involved in collisions in complex traffic scenarios like intersections, although they in general are not more involved in collisions (Hakamies-Blomqvist et al. 2004). Of older drivers' collisions, a large portion occurs in intersections (Broughton 1988, Hauer 1988, Stamatiadis et al. 1991, Fontaine and Gourlet 1992, Hakamies-Blomqvist 1994, Villalba et al. 2001). A typical situation is one where the older driver turns left across the path of oncoming traffic on a main road and is struck by an oncoming vehicle with right-of-way.

Moreover, when involved in a traffic accident the older driver is generally at higher risk of sustaining an injury due to their vulnerability (Viano et al. 1990). Not only are older drivers more often injured and killed in road accidents than younger ones, there are also some differences in injury patterns. Injuries involving rib and sternum fractures and chest complications are more common among older car occupants (OECD, 2001, Zhou et al., 1996) whereas younger car occupants more often suffer from head injuries when involved in injurious collisions. To younger adults, rib fractures and other chest injuries are not usually life threatening but for older persons, they can pose serious risks. Due to the seriousness of the consequences of older driver accidents, protective as well as preventive vehicle design measures, focusing the older population, are important.

Especially for the preventive measures, knowledge of the underlying contributing factors which lead to intersection crash events is necessary. For vehicle based countermeasures, factors related to the human are of key importance, even though traffic environment factors may play a major role as well. In particular, one must understand the cognitive aspects of intersection driving and the challenges drivers face when negotiating this type of traffic environment.

The aim of this study is to investigate the influence of cognitive human related pre-crash factors for older drivers in intersection collisions using in-depth traffic accident data, as well as estimating the appropriateness and relevance of such data for this purpose. If contributing factors of this type can be identified and addressed for older drivers, this will presumably benefit all drivers.

METHODS

The study combines information from a statistical dataset and in-depth cases to frame the needs for drivers aged 55 and above in intersections, both from a preventive and protective perspective. This group is compared to a group of drivers aged 25-35 years. The in-depth cases form the basis for understanding the factors influencing the causation of intersection collisions comparing the group of 55+ and the comparative group. The statistical data is used to show the distribution of collision occurrence and injury risk and to put the results from the in-depth analysis of pre-crash factors into its context.

STATISTICAL ANALYSIS: Volvo Cars Statistical Accident Database with over 36 000 drivers is used as the statistical dataset. Crashes involving Volvo cars in Sweden in which the repair costs exceed a specified level, currently SEK 45 000, approx. 4900 EUR, are identified by the insurance company Volvia (If P&C Insurance). Photographs and technical details of the cars, e.g. damage, are sent to Volvo's Traffic accident research team. The owner of the car completes a questionnaire within a couple of months after the accident to provide detailed information about the crash and the occupants. With the consent of the occupant, injury data is gathered from medical records and analyzed by a physician within Volvo's Traffic accident research team. Injuries are coded according to the Abbreviated Injury Scale (AIS, AAAM 1985). This ongoing data collection process forms the basis of Volvo's statistical accident database (Isaksson-Hellman and Norin, 2005).

In this study a subset of drivers in Volvo's statistical accident database were analysed using collisions which have occurred between 1990 and 2007. Two age groups within this subset were selected; 5497 drivers aged 55 years and above and a comparative group of 4226 drivers aged 25-35 years.

IN-DEPTH STUDY: The 33 in-depth cases used in this study were collected in the Gothenburg area by Chalmers University and partners within a project called FICA ‘Factors Influencing the Causation of Accidents and incidents’ which is partly financed by governmental support within the Swedish Vehicle Research Programme (PFF). The subset used for this study was collected in year 2003 through 2005. The cases were collected mostly during daytime weekdays (Monday's through Friday's).

Each in-depth case contains extensive information of the collision scenario and the factors contributing to its development. The in-depth data was collected on-scene by a multi-disciplinary investigation team, with a focus on getting driver interviews as early as possible. After data collection, the contributing factors were systematically identified and coded using the method DREAM, Driving Reliability and Error Analysis Method (Ljung, 2002; Ljung et al., 2005). DREAM is an adaptation to the traffic safety domain of the more generic CREAM-methodology, Cognitive Reliability and Error Analysis Method (Hollnagel, 1998), which is mainly intended for industrial safety analysis.

The focus of DREAM is identification of contributing factors or genotypes (Appendix A) and their observable effects or phenotypes (Appendix A) (Ljung 2002) using a set of interviews and contextual data (Ljung et al., 2007) together with a classification scheme of contributing factors. The contributing factors listed by DREAM cover a wide scope of driver, vehicle and traffic environment factors deemed relevant for vehicle based preventive safety systems. Driver factors include cognitive aspects of driver performance as well as temporary and permanent personal states and experience/education. Vehicle and traffic environment factors include both factors related to current status as well as the organisational factors leading to current status (design, maintenance, etc). The main categories of the genotypes and phenotypes in DREAM 2.1 are shown in Table 1.

Table 1. The main categories of genotypes and phenotypes in the classification scheme of DREAM version 2.1.

Genotypes (Contributing factors)			A: Phenotypes (Observable effects)
Organisation and Traffic environment	Vehicle	Driver	
J: Communication	G:Temporary HMI problems	B: Observation	Timing
K: Maintenance	H:Permanent HMI problems	C: Interpretation	Duration
L: Experience/knowledge	I:Equipment failure	D: Planning	Force
M: Organisation		E:Temporary Personal Factors	Distance
N: Road design		F:Permanent Personal Factors	Speed
O: Vehicle design			Direction
			Sequence
			Object
			Quantity/Volume

When analysing in-depth data with DREAM, the starting point is at the sharp end where driver actions result in error modes with error consequences (observable effects or phenotypes, see Figure 1). The phenotype which best fits the case is selected. From this phenotype, a DREAM-chart is then developed, covering all contributing factors judged present in the case under investigation. For the present study, the DREAM charts as developed and provided by the FICA-team 2003-2005 were used, using DREAM version 2.1. This version has been specifically developed with the aim of focusing the in car environment and assist in the analysis to help develop vehicle driver assistance features even though the Organisation and traffic environment is also considered. The structure of DREAM however is applicable also for versions adjusted for analysis concerning other aspects like road design and education of drivers (Ljung, 2007).

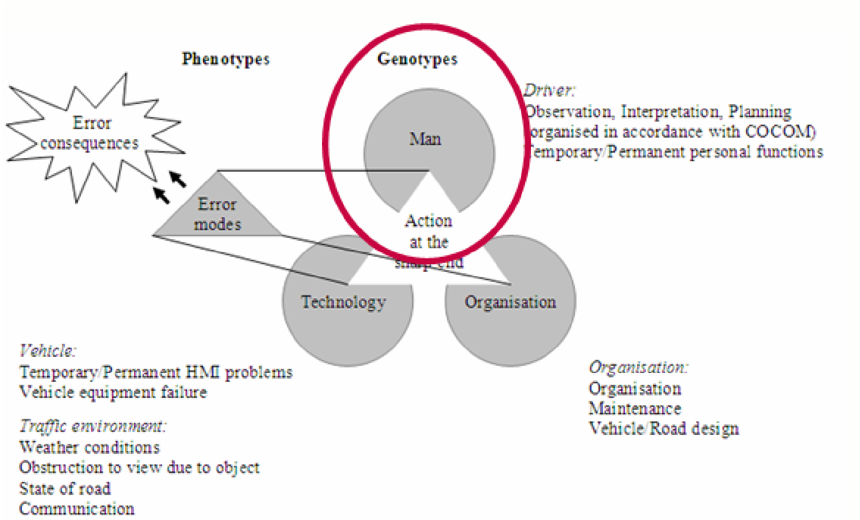


Fig. 1 - Schematic showing the focus area within the DREAM-analyses for this study which is focusing on the driver.

A particular feature of DREAM is its pre-defined links between contributing factors. Those pre-defined links means that the DREAM charts become highly structured representations of the contributing factors for each case, see figure 2. Also, they provide a way of discovering patterns in multiple cases through counting how many times factors and links are present in the cases chosen. This means that it is possible to build knowledge of the most common combinations and paths of contributing factors when DREAM-charts from a number of in-depth cases are aggregated into one analysis using for instance collisions with similar observable effects, same type of vehicle, same geographical point or similar type of driver. Figure 3 shows a schematic example of this.

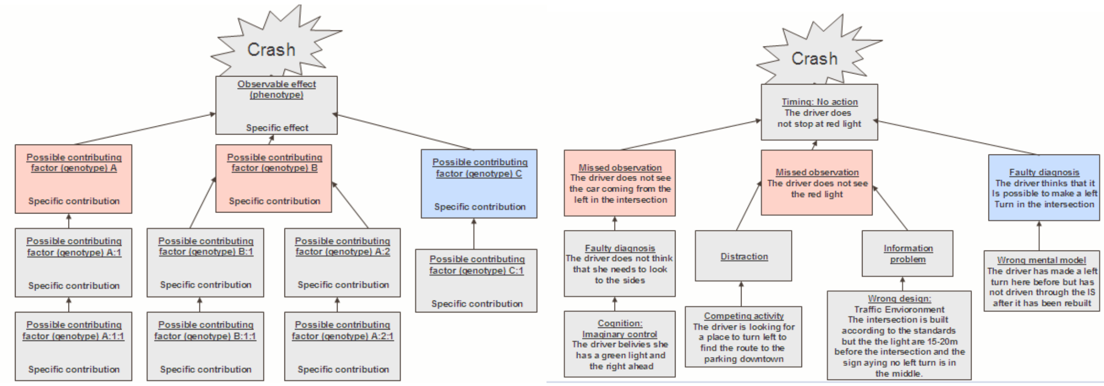


Fig. 2 - Examples of DREAM analysis.

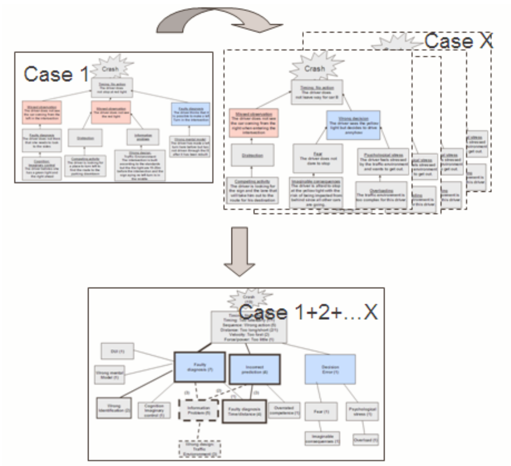


Fig. 3 - Schematic principle of how a number of DREAM-analyses are aggregated.

The focus of this study is to investigate the cognitive contributing factors which influence older drivers in intersections, thus leaving analysis of technology and organization to future studies. Of specific interest are factors related to the general cognitive functions *observation*, *interpretation* and *planning* (Table 1) as defined in DREAM 2.1. Table 2 lists the sub factors for these three categories. In complement to the cognitive factors, temporary personal states such as psychological stress, drowsiness/fatigue and driving under the influence of drugs like alcohol (DUI), will also be considered. Analysis of Permanent personal states, i.e. functional disorders or medical states, are not included in the study.

Table 2. The subgroups related to the main category cognitive genotypes according to DREAM 2.1.

Main category	Sub groups
Observation	Missed observation
	False observation
	Wrong identification
Interpretation	Faulty diagnosis
	Wrong reasoning
	Decision error
	Delayed interpretation
	Incorrect prediction
Planning	Planning
	Inadequate plan
	Priority error

For this study collisions categorized as related to intersections by the FICA-team were chosen. The collisions include the following types of scenarios (Appendix B); Straight Crossing Path (SCP), Left Turn Across Path – Opposite Direction Conflict (LTAP-OD), Left Turn Across Path – Lateral Direction Conflict (LTAP-LD), Right Turn Into Path (RTIP) and other which include front/rear end at turns and traffic lights etc. Figure 4 shows the number of cases for each scenario type for the 55+ group and the comparative group. A total of 19 cases of drivers aged 55 years and above are selected and compared to a set of 14 cases with drivers aged 25-35 with the average age of 70.9 years and 30.2 years, respectively.

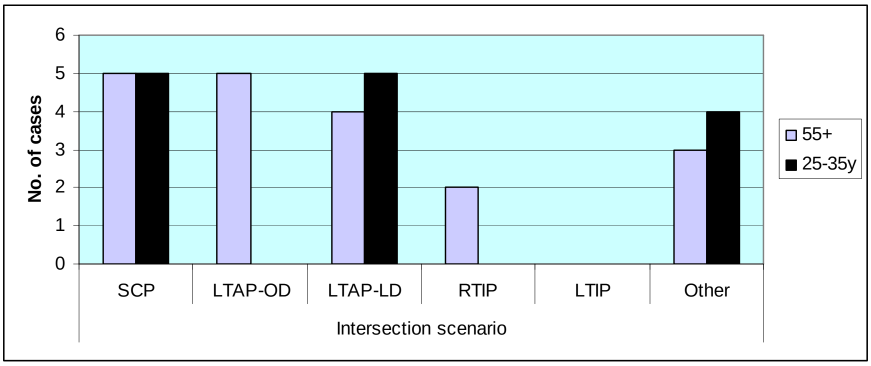


Fig. 4 - Number of cases for intersection collision scenario per group.

In 4 of the collisions a 55+ driver and driver from the comparative group were involved in the same collision. The DREAM charts for the 55+ drivers and the comparative group have been aggregated to identify and compare trends as to possible causal factors focusing on the general cognitive functions *observation, interpretation* and *planning*, table 2. The in-depth studies cover a large number of information and conditions surrounding the collision scenario. This is all taken into account in the DREAM analysis (Ljung 2002, Ljung et al., 2005). In figure 5 some of the extensive information covered in the in-depth cases is shown comparing the age group of 55+ with the group of drivers aged 25-35 years.

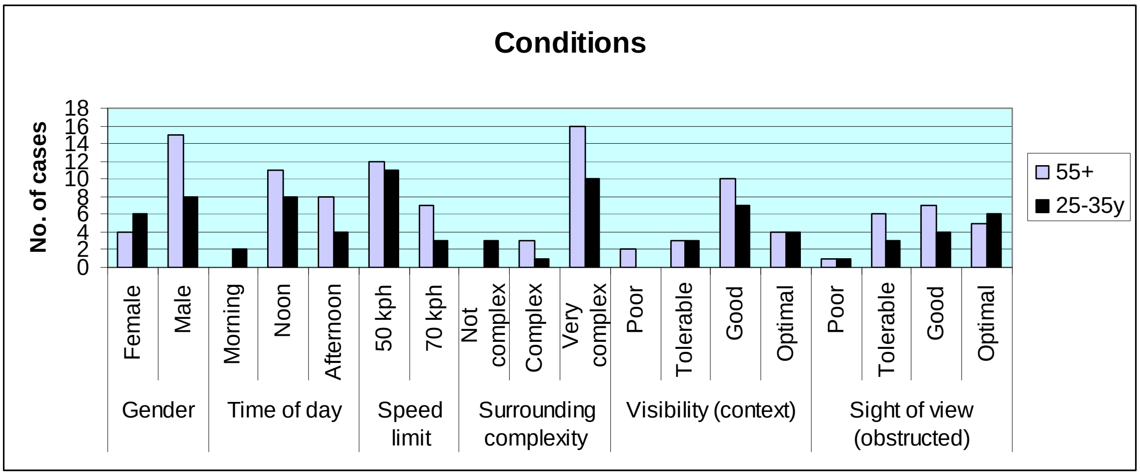


Fig. 5 - Number of cases related to gender, time of day, speed limit, surrounding complexity, visibility and sight of view per age group.

RESULTS

STATISTICAL ANALYSIS: The relative frequencies (including 95%-ile confidence intervals) of involvement in intersection crashes were calculated for the two age groups, respectively (Figure 6). The relative frequency is calculated as the number of drivers in the age group involved in the intersection / no intersection crash, divided by the total number of drivers in the age group. A significant higher involvement in crashes in intersections for the drivers aged 55 years and above is found as compared to the group of drivers aged 25-35 years.

Figure 7 shows the injury risks for drivers involved in a crash in an intersection, comparing the two age groups. Both for MAIS2 and MAIS3+ injuries there is a higher risk for the age group of 55+ as compared to the 25-35y group, although not statistically significant.

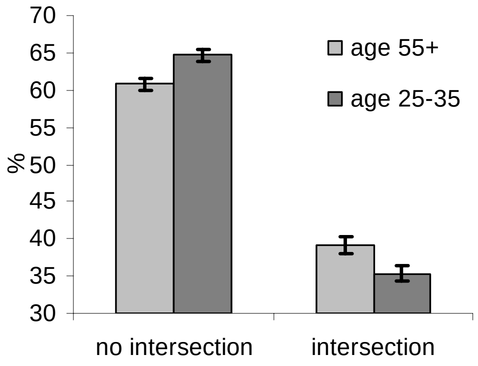


Fig. 6 - Relative frequencies (including 95% confidence intervals) of being involved in a crash in intersection / no intersection for the two age groups.

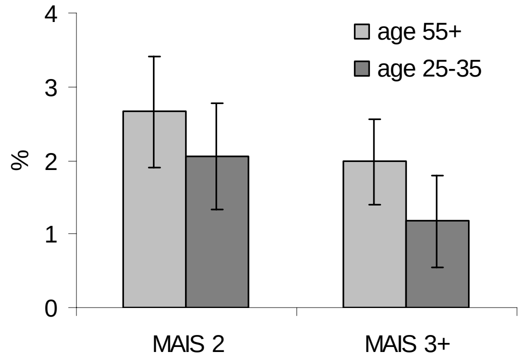


Fig. 7 - Risk of MAIS2 and MAIS3+ injuries for drivers involved in a crash in an intersection for the two age groups.

IN-DEPTH STUDY: For the 33 cases studied, the number of main category cognitive genotypes (contributing factors) appearing in the DREAM analyses are listed in Table 3, comparing the drivers of age 55 and above with the group of drivers age 25-35. Among the three main cognitive contributing categories (genotypes), the *observation* and *interpretation* categories are the most common for both age groups. The third main category, *planning* appeared to a less degree in the DREAM charts for these cases.

Table 3. Number of main category cognitive genotypes (contributing factor) appearing in the DREAM analysis studied.

Main category genotype (contributing factor)	Drivers aged 55+ 19 cases total	Reference: Drivers aged 25-35 14 cases total
Observation	12	9
Interpretation	12	10
Planning	4	3

Looking at the factors within these groups, the contributing factor (genotype) *missed observation* is the most common among all cases. All the 12 drivers in the older age group and all the 9 in the comparative group, who had factors from the main genotype category *observation* were coded as *missed observation*. The factor *faulty diagnosis* which is related to the main genotype category *interpretation* was found to be the second most common factor among all the cases. Other subgroups related to *interpretation* are *interpretation error* and *decision error*. Cases sorting under the genotype category *planning*, all did so by having the factor *inadequate plan* present. The results of the aggregated DREAM analyses for each of the three main categories of genotypes are shown below. The number of cases for each observable effect (phenotype) and contributing factor (genotype) is shown within brackets and the most common paths of contributing factors are highlighted with thicker lines.

<u>Observation category:</u> Figures 8a and 8b show the aggregated DREAM-analysis charts for the 19 cases of 55+ drivers comparing the 14 cases within the 25-35y group, respectively. The paths of contributing factors (genotypes) which relate to the main genotype category *observation* can be

followed. The different observable effects (phenotypes) that resulted in the crash are listed with the number of cases in brackets.

Taking *no action* or performing the *wrong action* is the most common observable effects (phenotypes) among the 55+ group. For the comparative group of drivers taking *no action* is the most common observable effect. The aggregated charts also show that the patterns among contributing factors (genotypes) are quite similar between the 55+ group and the comparative group. Figure 8a shows that *distraction* and *lack of attention* (5 cases each) are the most common contributing factors to *missed observation* for the 55+ group (highlighted in Figure 8a). Going further down the path, a *competing activity* causing the *distraction* or *lack of attention* is the most common contributing factor, showing 6 appearances in the charts. This pattern is repeated when aggregating the DREAM-analysis for the comparative group cases (Figure 8b). Of 9 *missed observations*, 7 have *distraction* or *lack of attention* as contributing factor with 4 and 3 appearances respectively. In 3 of the 4 cases where *distraction* plays a role, *competing activity* is listed as a contributing factor. In 3 cases a *faulty diagnosis* is a possible cause of the *missed observation* in the 55+ group (Figure 8a). No such case appeared in the charts of the reference set (Figure 8b).

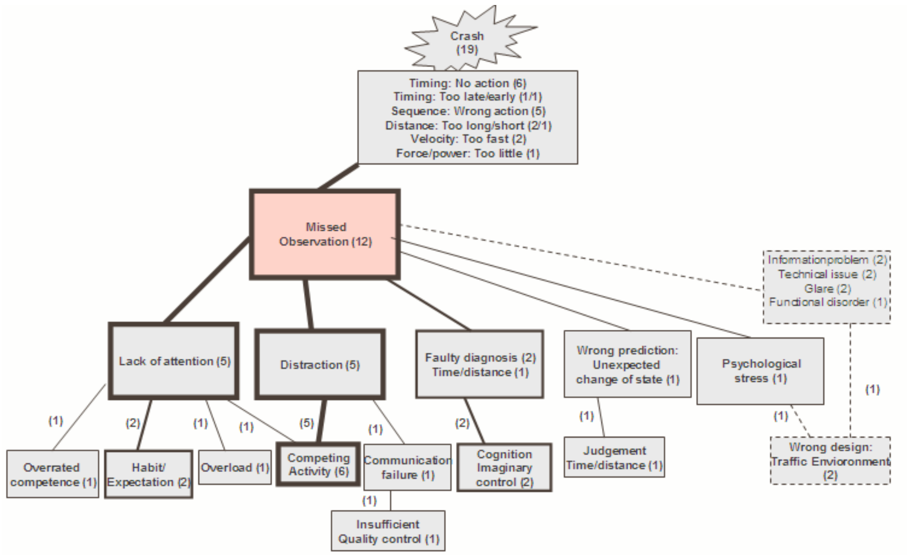


Fig. 8a - Aggregated DREAM-analysis focusing the main category genotype observation for the 19 cases in age group 55+.

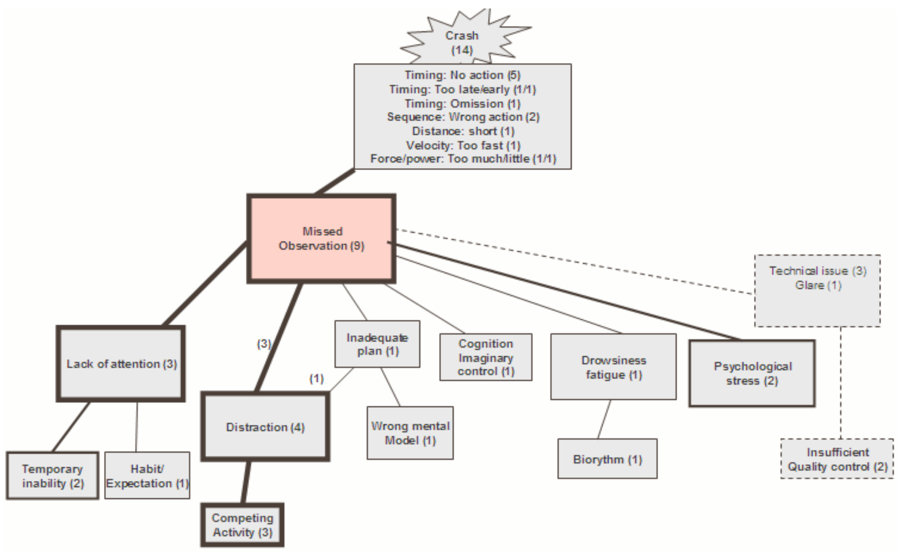


Fig. 4b - Aggregated DREAM-analysis focusing the main category genotype observation for the 14 cases in the reference age group.

Interpretation category: The aggregated DREAM charts in Figures 9a and 9b show the paths of the contributing factors related to the same observable effects (phenotypes) as used in Figures 8a and 8b. Here the factors *faulty diagnosis*, *incorrect prediction* and *decision error* are the first order of contributing factors (genotypes). These factors relate to the main category *interpretation* as defined by DREAM (Table 2).

Again, trends among contributing factors are similar for the 55+ drivers (Figure 9a) and the comparative group (Figure 9b). Here *faulty diagnosis of time/distance* is the most frequent contributing factor to the *faulty diagnosis* or *incorrect predictions* for the 55+ group. An *information problem* with *hidden* or *complex information* is another major possible source of the *faulty diagnosis* or *incorrect predictions* as highlighted in Figure 9a. Also for the comparative group as shown in Figure 9b, *faulty diagnosis of time/distance* is a common possible cause. The general contributing factor *Information problem* with the specific contributing factor *hidden information* is also a highlighted path with 6 cases. In 3 cases *imaginary control* is a possible cause of the *faulty diagnosis* for the comparative group of drivers. Only one case of this causal factor is found among the 55+group (Figure 9a) while there are 2 cases of *wrong identification* as possible cause to the *faulty diagnosis* here.

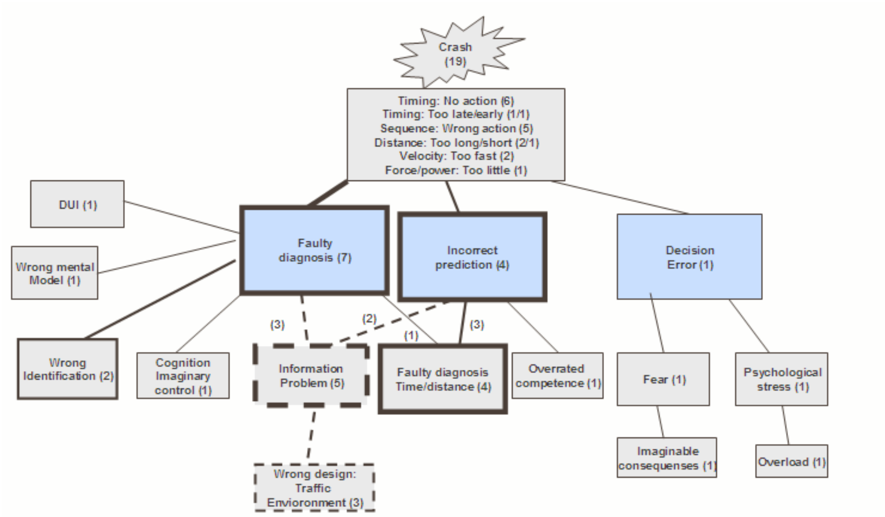


Fig. 9a - Aggregated DREAM-analysis focusing the main category genotype interpretation for the 19 cases in age group 55.

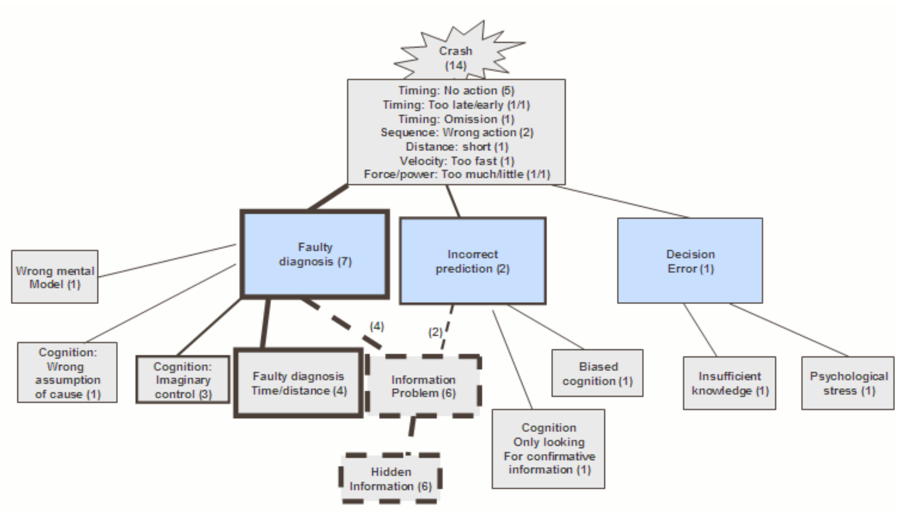


Fig. 9b - Aggregated DREAM-analysis focusing the main category genotype interpretation for the 14 cases in the reference age group.

Planning category: Looking at the aggregated DREAM-analysis charts where *planning* was a possible main category cause (genotype) of the collision some differences between the two age groups are seen (Figures 10a and 10b). The only factor found in both groups is *inadequate planning*, but it can be noted that for the 55+ drivers in two of the cases, *distraction* due to a *competing activity* could have caused the *inadequate planning*. This cause was not found in any of the comparative group charts (Figure 10b). For the comparative group there are 2 cases showing *overlook of side effects* as a possible cause of the *inadequate planning* (Figure 10b).

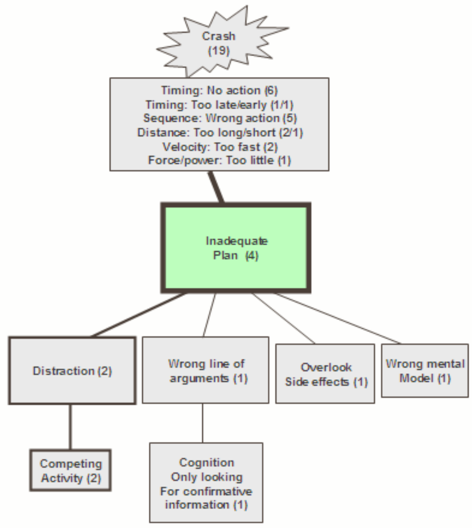


Fig. 10a - Aggregated DREAM-analysis focusing the main category genotype planning for the 19 cases in age group 55.

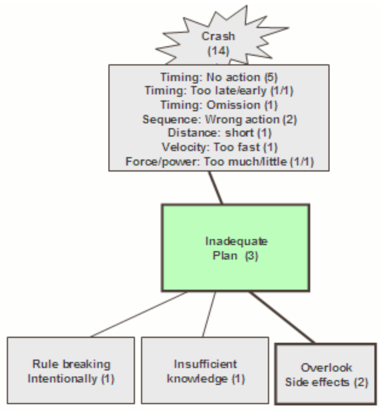


Fig. 10b - Aggregated DREAM-analysis focusing the main category genotype planning for the 14 cases in the reference age group.

DISCUSSION

The findings in this study contribute to knowledge about the needs of older drivers in intersections both from a preventive and protective perspective. The statistical data confirms prior studies identifying the older drivers as more vulnerable and more involved in intersection collisions. Since the group of older drivers is growing, knowledge helping to prevent these collisions will have a great impact and is necessary for a future vision of no injuries.

Data and case descriptions from the in-depth studies reveal that collisions generally are the result of a combination of contributing factors which together put drivers in positions where time and/or resources are no longer sufficient to resolve the situation. Moreover, the dependencies and interactions between contributing factors make it near impossible to single out any one single factor as a main or root cause. A great strength of the DREAM-analysis is that this complexity is reflected in the coding of contributing factors and therefore can be studied at the aggregated level.

Even though the interaction with the traffic environment is important, the driver aspect is of highest interest when trying to find collision countermeasures in a vehicle perspective, which is what this study is focusing on (though humbly recognizing the equal importance of all other factors related to the man, technology and organization).

As pointed out in the introduction, the emphasis in the study has been on evaluating whether retrospective in-depth data analyzed using the DREAM methodology could be of use to understand pre-crash factors for older drivers in comparison to a younger group of drivers. Of course, due to the limited number of available cases, there is no statistical verification of the contributing factor trends found in the analysis. However, the analysis gives an indication of which pre-crash factors influence the older driver in intersections as well as showing the feasibility of the DREAM method.

Although in-depth cases have a very high level of detail and provide a powerful tool, there are limitations. For one, since interviews and analysis are carried out by different team members, some subjectivity is unavoidable. The number of cases also constitutes a limitation. A sample of 33 cases is way too small considering the large span of situations and possible causes. For a larger number of cases, an aggregated DREAM-analysis would have greater possibility to identify clear trends. Moreover, the team collecting the data has not specifically focused the age-related aspects of the drivers in their analysis. Even if the visual performance of the driver is taken into account in the DREAM-analysis, no actual tests have been performed to get an objective measure. The visual performance is one physical aspect that decreases with age (Sekular et al., 1982, Fozard, 1990) that could have an effect of the cause of a traffic accident. Other sensory functions and physiological aspects like motion capacity may contribute as well both independently and in interaction with the cognitive factors.

Some trends can be identified in this study. A major contributing factor path for the 55+ drivers seems to be *missed observations* caused by *distraction* or *lack of attention* possibly due to a *competing activity*. However, the same trend is also the most common within the comparative group when looking at the aggregated DREAM-charts. Similar trends are seen looking at the most common genotypes within the main category *interpretation* as well, so similar trends of causation are seen when comparing the aggregated DREAM-charts for both the 55+ drivers and the comparative group. For this set of cases it is therefore not possible to identify any particular distinctions in causation between the two groups.

Another way of interpreting this result is that the causal factors actually are the same for older driver as compared to the younger drivers, only more accentuated. This would support the hypothesis that by addressing pre-crash factors for older drivers all drivers will benefit. This of course needs to be further studied.

Even though the in-depth data analyzed reflects a subset of the whole area of concern and the relatively small number of in-depth cases available for this study (making statistically significant conclusions unlikely to be drawn), the study identifies several relevant causes involving older drivers. More cases would enhance knowledge further but it is also essential to complement this data using different theories and studies to further explore contributing factors. These factors could relate also to other driver aspects, like age related physiological aspects (i.e. the decline of visual performance, night vision, motion capacity) as well as compensatory aspects of how and when older drivers use their vehicles. Typical complementary methods could be experiments using driving simulators and on–road tests, such as Naturalistic Driving Studies where also different aspects of the vehicle and infrastructure could be considered. Combining these different methods will add to more in-depth understanding. Based on these possible further activities, and knowledge gained in this study, relevant preventive measures for enhanced protection especially focusing the older part of the population may be defined both from a vehicle and infrastructure design point of view as well as from societal aspects like training and enforcement.

CONCLUSIONS

Although drivers aged 55+ are more involved in intersection crashes as compared to drivers aged 25-35 as shown in previous studies as well as in the statistical analysis in this study, the reasons for this are not easy to disclose. The present study explores the possibilities of using retrospective in-depth accident data using a specific method of describing contributing pre-crash factors. Indications were found that the older age group may have specific capabilities and this study adds to the understanding of potential cognitive mechanisms behind the occurrence of intersection crashes with older drivers. Complemented with further studies, such as Naturalistic Driving Studies in complex traffic environments or/and using a driving simulator, this study can have implications on future development needs for preventive and protective safety system in cars as well as the infrastructure.

ACKNOWLEDGEMENT

Many thanks to Mikael Ljung Aust, Chalmers University of Technology and Volvo Car Corporation, and Jesper Sandin, Chalmers University of Technology, for their counsel and support in understanding how to use DREAM in this study.

Also the Traffic Accident Research team at Chalmers University of Technology that have collected and made the analysis of the in-depth cases deserves a special warm and hearty salute for their hard and dedicated work.

The in depth cases used have been developed in the Swedish national project ‘Factors Influencing the Causation of Accidents and incidents’ (FICA), financed by the Swedish Vehicle Research Program (PFF) administered by VINNOVA, Sweden, Autoliv Research, Swedish Road Administration, Saab Automobile, Volvo Car Corporation, Volvo AB and in collaboration with The Department of Computer and Information Science at Linköping University.

REFERENCES

AAAM (Association for the Advancement of Automotive Medicine). The Abbreviated Injury Scale, 1985 Revision; AAAM, Des Plaines, OL, USA, 1985.

Broughton, B. The Variation of Car Drivers' Accident Risk with Age. Research Report 135, Transport and Road Research Laboratory, Crowthorne, UK, 1988.

Fountaine, H., Goulet, Y., Elderly People, Mobility and Safety. In Paper presented at the European Road Safety Conference organized by FERSI and VTI, Berlin, 1992.

Fozard, J. L., Vision and hearing in aging. In Handbook of the Psychology of aging, Birren, J. E. and Schiare, K. W. (Eds), New York, Academic press, INC. 1990.

Hakamies-Blomqvist, L. Older Drivers in Finland: Traffic Safety and Behavior. Reports from Liikenneturva, Helsinki, No. 40, 1994.

Hakamies-Blomqvist, L., Sireén A., Davidse, R. Older Drivers – A Review. Swedish National Road and Transport Research Institute (VTI), VTI Report 497A, 2004.

Hauer, E. The Safety of Older Persons in Intersections. In: Transportation in an ageing society: Improving mobility and safety for older persons. Special Report 218, vol 2, Washington D.C.: Transportation Research Board, National Research Council, 1988.

Hollnagel, E., Cognitive Reliability and Error Analysis Method: CREAM. Elsevier Science, Ltd, Oxford, 1998.

Isaksson-Hellman I, Norin H. How Thirty Years of Focused Safety Development has Influenced Injury Outcome in Volvo Cars. AAAM Int. Conf. 2005.

Ljung, M., DREAM - Driving Reliability and Error Analysis Method. ISRN: LIU-KOGVET-D--02/16--SE (Master Thesis). Department of Computer and Information Science (IDA), Linköping University, Linköping, 2002.

Ljung, M., Furberg, B., Hollnagel, E., Handbook of DREAM. Version: 2.1. Applied Mechanics, Chalmers University of Technology, Göteborg, 2005.

Ljung, M., Manual for SNACS SafetyNet Accident Causation System. Version 1.1, Chalmers University of Technology, Göteborg, 2007.

Ljung, M., Fagerlind, H., Lövsund, P. and Sandin, J., Accident investigations for active safety at CHALMERS – new demands require new methodologies. Vehicle System Dynamics 45(10): 881 – 894, 2007.

OECD. Ageing and Transport: Mobility Needs and Safety Issues. Paris, OECD, 2001.

Sandin, J., Ljung, M., Understanding the causation of single-vehicle crashes: a methodology for in-depth on-scene multidisciplinary case studies, Int. J. Vehicle Safety, Vol. 2, No. 3, pp.316–333, 2007.

Sekular, R., Kline, D. and Dismukes, K., Aging and human visual function New Work: Alan R., Liss, Inc., 1982.

Stamatiadis, C.T., Taylor, W.C., Mc Kelvey, F.X. Elderly Drivers and Intersection Accidents. Transportation Quarterly, 45, 1991: 377-390

United Nations, Department of Economics and Social Affairs, Population Division. Population Aging 2006, 05-55245, January 2006, 16,335

Viano, D.C.,Culver, C.C., Evans, L., Frick, M., Scott, R. Involvement of Older Drivers in Multivehicle Side-impact Crashes. Accident Analysis & Preventition. Vol. 22, No.2, pp. 177-188, 1990.

Villalba, J., Kirk A., Stamatiadis N. Effects of Age and Cohort on Older Drivers, SAE 2001-013349, 2001.

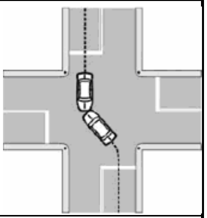
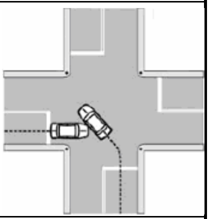
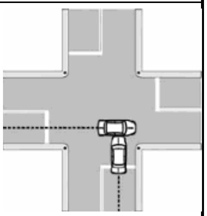
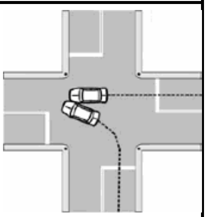
Zhou, Q., Rouhana, S., Melvin, J. Age effects on thoracic injury tolerance. SAE962421, 40th Stapp Car Crash Conference, 1996.

APPENDIX A:

Excerpt from the SNACS manual vers 1.1 (Ljung M. 2006).
"The terms *phenotype* and *genotype* are deliberately chosen to reflect their counterparts in biology. Two humans (two phenotypes) never look exactly the same, but the underlying genotypes that generate their different looks are identical for both. The same goes for accidents and near-misses; the looks are different, but the set of possible underlying causes is the same. What differs between looks is which subset of genes or causes that is dominant or active for the particular situation (critical event/phenotype)."

Appendix B:

Intersection collision scenarios:

CROSSING	
Left Turn Across Path/Opposite Direction **LTAP/OD**	
Left Turn Across Path/Lateral Direction **LTAP/LD**	
Straight Crossing Paths **SCP**	
MERGING	
Left Turn In Path **LTIP**	
Right Turn In Path **RTIP**