Accident Causation Factor Analysis of Traffic Accidents on the Example of Elderly Car Drivers using the Causation Analysis Tool ACAS

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ABSTRACT

The need of in-depth accident causation data in accident research is becoming more and more important. The German In-Depth Accident Study GIDAS is well qualified to deliver adequate data to conduct an investigation on this field, based also on identifying the causes of accidents. This led to the development and implementation of a special tool called ACAS (Accident Causation Analysis System) for the collection of such causation data adopting the GIDAS methodology. Using this system, for each accident participant one or more of five hypotheses of human cause factors are formed along the basic human functions active when managing a situation in traffic. These hypotheses are subsequently specified by appropriate verification criteria. To facilitate the analysis of accident causes, the information collected with ACAS is recorded in a structured code of digits. With the help of structured questionnaires for on-scene investigation used to interviews of accident participants it is possible to easily identify human failures and categorize these in the ACAS structure. Internal analysis of the herewith coded accident causation information has proven that with this system it is possible to find causes of traffic accidents with enough details to identify differences of psychological performances categorized by the basic human functions in the situation or the emergence of the accident.

Past studies on identifying typical accident scenarios of elderly traffic participants have shown that it is difficult to find typical circumstances and features of accidents caused by the elderly, based on classic accident research data. With the present study a first step in this direction is done by analyzing the causation coding of accidents with personal damages of n=817 non-elderly car drivers (aged 25-64) with failures of one of the five human causation categories and to n=169 elderly car drivers aged 65 and over (total of 986 for both age groups). The focus of this study lies on identifying the special causes of elderly traffic participants and analyzing the psychological effects which lead to failures in the situation of the accident event. The results of the causation analysis display that with elderly traffic participants the human failures are mostly about perception problems and difficulties with the execution of a desired action. The study also revealed that the causation category of an accident has an influence on the accident severity (injury-outcome) this is an important factor which has to be kept in mind when looking for countermeasures to decrease severe injuries or fatalities.

INTRODUCTION

In recent years methods and systems for the analysis and collection of causal factors in traffic accidents have been developed in Europe which are based on the principle of "real-life Investigation" with a data collection that is conducted at the scene of the accident and as soon as possible after the accident. Beside the method ACAS (Accident Causation Analysis System) presented in this study which was first presented by Otte in 2009 ESV Conference is used in the German In-Depth-investigation for example in the context of GIDAS [1], other European analysis systems such as DREAM (Driving Reliability and Error Analysis Method) in Sweden or HFF (Human Functional Failures) in France work according to the same principle in defining human failures with causation parameter. These analysis systems have in common that they consist of a method of analysis, an accident model and a classification system.
The present study presents the application of ACAS in a special survey on the comparison of young and older car drivers, i.e. how can the method of ACAS reflect differences between younger and older car drivers involved in accidents on one hand and which causation factors are related to younger versus older drivers on the other hand based on the five human functional levels of the model.

The collection of psychological data for the determination of relevant accident causation parameters from accident participants with ACAS is based on the following fundamental methodological requirements that affect the procedure, particularly when collecting human determined accident factors: The human factors analysis is done "on-scene" and "in-depth". The methodological core constitutes the approach in the form of a "real-life Investigation" which means an analysis of the accident causes as close as possible to the occurrence of the accident. The temporal and spatial immediacy of the data collection is regarded as an essential quality criterion for the relevance of accident causation data: The reliability and validity of the data is higher the more comprehensive the available information is, the less traces are "blurred" (this includes memory traces of the interviewed) and the shorter the experienced situation of the participants interviewed at the scene lies back to ensure the highest possible realism. While the technical and medical data collection is widely standardized and therefore holds little potential for economizing time, the temporal variability of the interviews with involved road users is fairly high. Extreme examples are the people that refuse to be interviewed on one hand and "emotionally overwhelmed" interviews with a high need to talk on the other hand. In experience however in most of the cases relevant human causation information can be determined sufficiently economical, if the interviewer proceeds hypothesis guided according to the basis of the classification scheme and the general accident model using a semi-standardized questionnaire.

This means that it is profoundly analyzed which assessments, expectations or intentions played a role and for which reasons. Within ACAS the theoretical framework for this purpose is the classification scheme of five categories of basic human functions that were effective when coping with the driving task. Except for the first step (the objective access to information), the next steps describe in a sequential manner human functional qualities that individually or in combinations were active in the accident development and contributed to the causation: information admission, information evaluation, goal setting/planning and executing the operation/action. With this hypotheses guided methodology an economic interview of accident participants or witnesses is assured, without running the risk that relevant data are not considered.

An accident-explanatory relevance of the human causation data is ultimately achieved by comparing these with the technical, medical and infrastructural data of the accident sampled from the field of accident analysis and the accident reconstruction. Herewith other influencing factors i.e. those related to injury severity can be identified. The accident reconstruction thus represents an important complementary part of an accident causation analysis.

**Elderly car drivers in traffic**

Before discussing the results of an analysis on causation factors the general situation of elderly car drivers in traffic accidents is displayed.

The demographic change in Germany and in many other countries is a well-known phenomenon which leads to a distribution of population, where the share of older people in society is continuously increasing (according to the official publication of the German statistic office [2]). On the other hand human while life expectancy is continuously increasing, the appearance of age related diseases such as dementia or defects in eye sight is not delayed in the same manner. This situation will expectably have a significant impact on the accident situation in many countries and will be among the future challenges of road safety measures. In publications on the accident rates by road users of different age groups uniformly a typical profile was found: The highest accident rates are found in the age group of the 18-21-year olds, which is due to lack of driving experience, youth typical driving motives and higher risk tolerance. The rate decreases in the other age groups and stays at a low level until the age of about 65. In the age groups 65 years and older the accident rate begins to rise again and reaches the magnitude of novice drivers.

This characteristic of age related causation responsibility is also found in the GIDAS data as so-called “bathtub-curve” when analyzing the ratio of participants causing an accident to participants that were involved in an accident without having caused it for the different years of age (figure 1).
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Figure 1: Ratio of causers to non-causers of accidents for different years of age in the GIDAS database (2000-2011).

Here the novice road users are 2 times more likely to cause an accident than to be “innocently” involved in an accident. This ratio quickly falls to less than one for road users in their late twenties and thirties and subsequently begins to rise again. With ages of about 65 years and older the curve begins to rises at a higher rate and reaches a ratio of over 1.5 for road users aged 75 and older. Overall however seniors are not more likely to be involved in accidents than the average car driver [3], [4].

The situation of elderly car drivers and their specific circumstances in the scope of traffic accidents is displayed in this study by comparing the elderly car drivers to the non-elderly car drivers. Thus two age groups were chosen:

- The elderly car drivers can be defined as the group of drivers aged 65 and older. This is consistent with a common age classification found in literature and statistics.
- The age group for comparison consists of drivers aged 25 to 64 years. The young and novice drivers (aged 18-24) were excluded in this survey to leave out their specific features e.g. due to inexperience or a high risk acceptance.

To illustrate the current situation of elderly car drivers in the context of traffic accidents in Germany in a first step the data of the German Federal Statistical Office, DESTATIS was analyzed [5]. Here the most common failures which led to traffic accidents with injuries reported by the police are displayed, comparing the elderly drivers with the non-elderly drivers (Figure 2). It has to be kept in mind that these failures are collected in the context of law enforcement and do not represent the actual causes which led to the accidents. They are rather used in the official national statistics and represent the driving trajectories before the impact.

Figure 2: Common failures of car drivers at injury accidents in Germany according to the police, comparing elderly drivers with non-elderly drivers.

The kinds of accidents that are more frequent in the group of elderly car drivers compared to the non-elderly car drivers (turning accidents, right of way accidents etc.) are accidents which occurred in more complex traffic situations like at intersections. These situations require a high capability for orientation in traffic with is more difficult for the elderly road users than for non-elderly road users. On the other hand among the most common failures leading to traffic accidents are failures which are less frequently found with elderly drivers such as not maintaining the distance to other road users, inappropriate speed or driving under the influence of alcohol. These failures often are a result of a higher risk acceptance which is more dominant in the group of the non-elderly car drivers (even though the young and novice drivers are not included in this group). Senior citizens in general have a more pronounced desire for safety in any aspect.

Figure 3: Distribution of responsibility of car drivers for an accident comparing elderly drivers to non-elderly drivers.
An analysis of the GIDAS (German In-Depth-Accident-Study) data from the years 2008 – 2012 shows the share of responsibility for an accident (in the judicial sense) for elderly and non-elderly car drivers (figure 3). GIDAS is based on a in-depth statistical random selection of accidents with injured persons and is representative for the accident distribution [6]. When involved in an accident elderly car drivers are more often solely (49%) or mainly (19%) responsible for the accident occurrence than non-elderly car drivers (solely responsible 38%; mainly responsible 12%). This characteristic can be explained by the fact that senior citizens tend to fail more clearly in critical situations.

The initial speed of car drivers at the time of the accident emergence is analyzed in figure 4.

Figure 4: Cumulative frequencies of initial speeds of car drivers for different age groups.

The cumulative frequency for non-elderly and elderly car drivers is about equal for speeds up to 50 kilometers per hour which account for about 75% of the cases of the non-elderly car drivers and about 85% of the cases for the elderly car drivers. For the 25% respectively 15% of cases with higher initial speeds than 50 km/h the non-elderly car drivers were travelling with higher speeds than the elderly car drivers which tend to take fewer risks.

Although the analysis of the Federal German statistical data (DESTATIS) and the common GIDAS data serve to highlight the accident situation of the two different age groups, the exact causes of the accidents are not identifiable. For this reason a causation analysis with the ACAS method was conducted.

Accident causes of elderly car drivers according to ACAS

To identify specific causes of accidents for different age groups the focus clearly lies on the human causation factors as they are influenced by psychological and physiological effects in different age groups and human related causes are with over 90% the most common causes by car drivers. As initially mentioned, the analysis of the human factors with the ACAS methodology is achieved by describing the human participation factors - and failures of these - in a chronological sequence from the perception to a specific action/operation [7]. This is done by considering the logical sequence of basic human functions when reacting to a request for reaction: Information access – Information admission – Information evaluation – Planning – Operation. These functions provide the 5 categories of human factors where failures may lead to an accident.

- **Category 1 (Information access)**: If the participant did not have access to relevant information at the emergence of the accident. An available piece of information cannot be perceived if it was covered / hidden by objects inside or outside the vehicle or if it could not be registered due to physical conditions or disease.

- **Category 2 (Information admission)**: When the relevant information could have been acquired by the participant, however it was not acquired in time or at all. The participant could have been able to gather the information by reason of adequate perception conditions, however failed to do so.

- **Category 3 (Information evaluation)**: The participant has recorded all relevant information but has misjudged or misinterpreted it.

- **Category 4 (Planning)**: The information was recorded and evaluated correctly however the participant drew wrong conclusions concerning the action to manage the situation. This concerns no reflex actions - the participant must have had enough time for planning. A further form is the conscious/planned action against well-known traffic rules.

- **Category 5 (Operation)**: Errors or difficulties arose during the execution of the planned action. This can cover too late, wrong, omitted or reflex actions. Only usable if the incorrect action was causal for the accident.

A combination of multiple factors can be used if more than one “causation factor” can be assigned to each road user. The causation factors from each of the five categories of the basic human functions can be further specified by subdividing each “category” into specific influence criteria and from there further into specific so-called “indicators” of these characteristics (Figure 5). Due to the
hierarchical structure of the accident causation factors they can therefore be recorded in a 4-digit-number, the so-called ACAS-code. These factors are independent from the question of guilt or responsibility of an accident. This means that an accident participant that is not guilty of causing an accident in the judicial sense may well have contributed to the emergence of the accident (e.g. by a late evasive reaction) and thus he may have been assigned with a causation code. For each traffic participant such a code can be given.

**Composition of 4-digit-code on accident-causation-factors.** In road traffic accidents causes for all fields of interaction can be expected: (1) Human causes, (2) causes from the range of the technology of the vehicle and (3) causes from the range of the infrastructure and/or the environment. The first number of the causation code is describing which field of interaction is addressed with the code. Accordingly with all human causation factors (group 1) the first number of the code is „1“.

Each of the three fields of interaction is subdivided into specific categories of causation factors (As seen exemplarily for group 1 in Figure 3). These categories are described by the 2nd number of the causation code. Each category is further subdivided into characteristic influence criteria (3rd number of the code), which represent the most frequent factors, which led to an accident. Only in the human causation factors (group 1) each influence criteria can be further specified by specific indicators (4th number of the code).

**Example:** If someone were distracted by a conversation with a passenger, and thus did not recognize important traffic information, the code of this cause would be:

1 – 2 – 01 – 3 Code

**Explanation:** The accident cause is from the group of human causation factors (first number = 1); Not recognizing something is a failure in the category of the information admission (second number = 2); The influence criterion here is a distraction from inside the vehicle (third number of the code = 1); The distraction in the vehicle occurred due to a passenger (fourth number of the code = 3)

The analysis of the accident data from the GIDAS database was conducted for car drivers taking cases from the years 2011 and 2012 from the Hannover Region. An inter rater reliability check for the quality of the ACAS coding resulted in the best accordance for this sampling unit (about 75%).

According to the sample frame (figure 6) the GIDAS dataset provided 1,844 injury accidents with 3,604 participants. The causation coding of these accidents lead to n=817 non-elderly car drivers (aged 25-64) involved in an accident with failures of one of the five human causation categories and to n=169 elderly car drivers aged 65 and over (total of 986 for both age groups). The distribution of car drivers in an accident according to their causation factors (Figure 7) shows different frequencies for elderly car drivers and for non-elderly car drivers.
Figure 7: Distribution of car drivers in an accident according to the causation factors.

Even though the amount of cases makes it difficult to conduct a thorough in-depth statistical analysis, tendencies can well be identified: 17% of the elderly car drivers which have contributed to the emergence of an accident were identified to have had a failure from the category of “Information access”. The frequency in this category is fairly the same as with the experienced drivers with 16%. Elderly car drivers however seem to have more problems with the information admission (59% were assigned with a code of this category while only 48% of the younger drivers were coded with a failure from this category). The following three categories of human failures (Information evaluation, Planning, Operation) in general are less frequent for car drivers. Here the elderly car drivers had fewer failures in the categories “Information evaluation” and “Planning” than the experienced car drivers while “Operation”-failures were more frequently found among the elderly car drivers than among the experienced car drivers.

To explain the different frequencies of the human failure categories between the two age groups the causation information was analyzed on the more detailed level of the subcategories (criteria). Figure 8 shows the distribution of the criteria in category 1 (Information access).

Figure 8: Frequencies of specific failures (criteria) in the human failure category 1 (Information access) comparing the two groups of elderly and non-elderly car drivers.

Category 1 consists of 4 different criteria which are subcategories of “information access”-failures and thus allow analyzing failures from this category in more detail. Even though both age groups (elderly and non-elderly but experienced car drivers) nearly equally often had failures in the “Information access” the specific criteria of this category shows that “information masking” (6,5%) and “Information not accessible due to disease” (e.g. poor eye sight) with 1,2% are more frequent with elderly car drivers than with the experienced car drivers (4,9% respectively 0,2%).

The fact that elderly car drivers more often have failures in the category of information admission becomes clear when looking at the criteria in this category (see Figure 9). Except for the “distraction from inside the vehicle” all other criteria are more frequent in the group of elderly car drivers. This is especially visible in the criteria of “Activation too low”. Here symptoms of illnesses or blackouts which lead to perception problems in combination with a higher fatigability show their effect as they are more common with older people. This finding is congruent with studies found in literature (e.g.[8]) where the symptoms of age related diseases and their impact on the ability to drive a vehicle in traffic are well described. In this scope it has to be kept in mind that the use of alcohol which is also found in this criterion is not a factor which is more commonly found with elderly car drivers (see also Figure 2).

Figure 9: Frequencies of specific failures (criteria) in the human failure category 2 (Information admission) comparing the two groups of elderly and non-elderly car drivers.

The three specific criteria of the category „Information evaluation“ which are based on failures due to a misjudgement or a wrong expectation are less frequently found in the group of elderly car drivers. This explains why elderly car drivers in general have fewer problems with the information evaluation than the group of experienced car drivers where none the less a portion of young drivers with less experience can still be found. Especially failures relating to the misjudgement of the behaviour of the own vehicle are well underrepresented in the group of the elderly (2,4% of drivers that contributed to an accident) when comparing to the
If the elderly traffic participants have recorded all the necessary information for accomplishing the driving task they are able to use this information better in the sense of the information evaluation (judgement/interpretation) because the elderly often have more driving-experience and driving-routine and are often more cautious than younger people.

While 13% of the experienced car drivers had failures from the category of making an adequate plan in a traffic situation (category 4) - based on the recorded and subsequently evaluated information – only 6% of the elderly car drivers were found to have had failures in this category. The criteria of this category are “intentional breach of rules” and “decision errors” based on a correct interpretation/evaluation of the situation. Figure 11 displays that elderly car drivers have noticeably less often intentionally breached the traffic rules (e.g. by speeding, too little distance to vehicle ahead, irregular use of roadway etc.) than the non-elderly car drivers: while 8.6% of the experienced car drivers were attributed with a causation code from this criteria only 3% of the elderly car drivers: while 8.6% of the experienced car drivers were attributed with a causation code from this criteria only 3% of the elderly car drivers had failures based on this aspect. The reason why the elderly car drivers obey traffic rules more than younger drivers is that in general older citizens have a higher need for security, and thus have a risk-reduced driving style with less deliberate violations. Furthermore due to the distinct routine and experience of the elderly car drivers in traffic the ability to appropriately plan action steps increases which has the effect that elderly car drivers commit slightly fewer decision errors (3.6% of the drivers) than the non-elderly drivers (4.7% of the drivers) such as an inappropriate maneuver.

Figure 10: Frequencies of specific failures (criteria) in the human failure category 3 (Information evaluation) comparing the two groups of elderly and non-elderly car drivers.

When it comes to executing the planned action again a higher percentage of elderly car drivers had failures in both of the criteria of the “operation”- category than the younger car drivers (Figure 12). On the one hand the decision time during the planning phase for older traffic participants is extended, which leads to the fact that with increased time pressure a false reaction or no reaction at all is conducted (Reaction error: 4.7% of the elderly; 3.7% of the non-elderly).

On the other hand difficulties with the execution of an operation due to restricted mobility can also be seen as a result of age related diseases. Particular diseases (dementia, degenerative diseases) [9] likewise have a disruptive impact on human action programs, which could be the explanation why “mix-up” and operation errors such as confusing the brake pedal with the accelerator pedal are more frequently found among non-elderly (4.9% of drivers).
the elderly car drivers (3.6%) than among the non-elderly (0.9%).

To benefit from the analysis of the causation information especially in the sense of accident prevention the knowledge of the accident severity as a function of the human causation category is of significant importance.

Figure 13: Distribution of human causation categories for different accident severities (maximum injury severity), comparing non-elderly car drivers with elderly car drivers.

The distribution of slight-injury-accidents on the human causation categories compared to the distribution of severe-injury-accidents (including fatal accidents) shows an evident variation for both age groups (figure 13). For the non-elderly car drivers 51% of the slight-injury accidents were caused by an “Information admission” problem while only 41% of the severe/fatal accidents came from this category. Also more slight-injury accidents than severe-injury accidents were caused by “Information evaluation” problems. This ratio however reverses for the causation categories “Planning” of an action and executing the planned action (“Operation”). Accidents caused by these categories provide considerably higher shares to the severe injury accidents than to the slight injury accidents. Thus even though accidents caused by failures from the category of “Planning” and “Operation” occur less often, than accidents caused by “information admission” failures, their injury outcome is more severe. For the group of the elderly car drivers the balance between slight-injury accidents and severe-injury-accidents are equally distributed as with the non-elderly. However the deviation between the two distributions is not as big as with the younger control group.

Analyzing the GDV-accident-type is an appropriate method to describe differences in the accident events of certain age groups. The accident type is classified by the initial conflict situation which led to the crash. There are 7 main categories of accident types (driving accidents, Turning-off accidents, Crossing accidents, Pedestrian accidents, accidents with parked vehicles, accidents in lateral traffic and “other” accidents) which are further specified by nearly 300 subtypes in those categories.

Figure 14: Accident types of accidents with non-elderly and elderly car drivers crossed with the categories of human causation factors.

The 5 most frequent accident types of non-elderly and elderly car drivers are displayed in figure 14.
Accidents with elderly car drivers are often based on a conflict between a vehicle turning to the left and oncoming traffic (Type 211: 8.25%) or traffic from the left (Type 302: 7.22%). Both types of accidents are mainly caused by information admission errors (73% respectively 60%) and also have a fair amount of errors from the “information admission”. In contrast the causes of accidents with vehicles in front which are braking (Type 611) or driving (Type 601) also seem to have a high emphasis on the failure categories “Planning” (67% respectively 0%) and “Operation” (33% respectively 25%). The non-elderly car drivers have a slightly different distribution of accident types than the elderly: The most frequent type is the conflict with a vehicle driving in front (Type 601: 72.6%) followed by crossing accidents (Types 342, 321, 301). With the exception of the accidents with bicyclists coming from the right (Type 342) a fairly high amount of causes from the categories “Evaluation” and “Planning” can be observed here.

CONCLUSIONS

The analysis and evaluation of accident causation data is a necessary step to prevent more accidents from happening. The knowledge about the human failures is an essential part e.g. for the development of driver assistance systems. One of the European methodologies to collect accident causation data is the accident causation analysis System ACAS which is used in Germany in the framework of the GIDAS accident data collection. This study gives an example of the causation analysis with ACAS in the context of reflecting differences of causation factors comparing younger and older car drivers involved in accidents. This is done by focusing on the human factors (human failures) and analyzing these along the ACAS-classification scheme of five categories of basic human functions that were effective when coping with the driving task.

An overview over the situation of elderly car drivers in accidents using the typically available accident data from the national statistics and also from the GIDAS in-depth data is well suitable to identify the responsibility for the accident and breach of rules in the judicial sense. The German national statistics data for example shows that the elderly have higher frequencies of certain violations of traffic rules than non-elderly car drivers and the analysis of the GIDAS data additionally shows that elderly car drivers are more often solely or mainly responsible for the accident occurrence than non-elderly car drivers. However distinct human failures in the phase of the accident emergence which led to the violation of rules (why did the violation occur?) cannot be identified with these data.

For the assessment of the human accident causes with ACAS some 817 non-elderly car drivers (age 25-64) and 169 elderly car drivers (age 65+) from the GIDAS database which had contributed to the emergence of an injury accident were used. The causation factors collected for these two age groups were analyzed concerning the main failure categories of human failures and for more detail concerning the subcategories (criteria) of these main categories. The non-elderly car drivers had more failures from the categories of the information evaluation (Misjudgment of a situation) and the planning of an appropriate action (e.g. intentional breach of rules). In contrast to this the elderly car drivers more frequently had problems with the admission of the necessary information (perception) in a traffic situation and with the operation of the vehicle. Relevant information often was not perceived by elderly car drivers due to the symptoms of age relate diseases and difficulties with the execution of an operation due to restricted mobility was found to be more frequent with elderly car drivers.

The results of the causation analysis display that with elderly traffic participants the human failures are mostly about perception problems and difficulties with the execution of a desired action. To cope with these constraints the conditions of perception must be simplified (e.g. at the level of transport planning) and the complexity of infrastructure and vehicle technology must be reduced. The study also revealed that the causation category of an accident has an influence on the accident severity (injury-outcome) this is an important factor which has to be kept in mind when looking for countermeasures to decrease severe injuries or fatalities.

This study has shown that ACAS is an appropriate tool to collect and to deliver relevant accident causation data. The findings from real world accidents are consistent with statements found in literature on the constraints of elderly traffic participants and the background of their typical causes of accidents. With larger case numbers in the future research questions concerning the causes of accidents can be answered in more detail and with more statistical certainty.
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Further information on GIDAS can be found at http://www.gidas.org

REFERENCES


