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Old, Diseased and Unfit to Drive a Motor Vehicle? An Evidence-Based View on Risk Factors among Senior Drivers in Germany

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Abstract: The present study aimed to identify risk factors among older adult drivers from realistic data in order to stimulate the development of appropriate safety measures in the future. For this purpose, N = 400 archived case files from the driving authority in Dresden (Germany), were systematically analysed. The risk criterion was the outcome of the fitness to drive (FTD) assessment required by the authority. The results show that there are several significant risk factors (aged over 80, dementia, multi-morbidity and involvement into complex accidents) that can serve as cues for being unfit to drive. The practical measures for enhancing traffic safety are discussed.

Key words: Older adult drivers, FTD, impaired drivers, driver assessment, risk factors, incapability.

1. Introduction

In the majority of OECD-countries[1], the ageing population is the fastest growing age group. In these countries, the proportion of people aged over 80 is predicted to rise from 4% of the population in 2010 to over 10% by 2050 [1]. A consequence of this is that the number of older adult drivers on the roads also increases [2], leading to an increase in traffic accidents [3]. This demographic development affects road safety and aggravates the dilemma between the implementation of state protection obligations and preserving the mobility of older adult drivers [4-6]. It is therefore a crucial task for the future (also compare Ref. [7]) to identify those 10% of older adult drivers suffering from capability impairment due to healthy problems in a valid and fair manner [8]). The ability to drive promotes social inclusion and is therefore associated with active participation in public life [5, 9]. Vice versa: the driver’s license revocation may lead to a risk of negative effects among older adult drivers, e.g., depressive symptoms [4, 6], feelings of loneliness and dependence [5] as well as a decline in physical and social health [4].

Aside from collision rates or epidemiological data from relevant diseases, one method to identify risk potentials in older adult drivers is to examine the results of the assessment of Fitness to Drive (FTD). Such examinations balance the share of impact from acute clinical diagnoses, age and reduced capability against coping and compensation strategies of the older driver. The final assessment result reflects the current fitness to drive condition. This evaluation, using a cohort of problematic older adult drivers from Germany, is examined in this paper.

1.1 Fitness to Drive and Road Safety Impairments

Driving ability relies on a complex combination of knowledge, behavioural and procedural capacities (e.g., Refs. [10, 11]), along with healthy facets (e.g.

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[1] The international “Organisation for Economic Co-operation and Development” (OECD) founded in 1961 with 36 member countries. Most of the countries are high-income economies with high Human Development Index.

absence of disorders and disease), capability features (e.g. minimum intelligence, reaction capacity, concentration), and factors of personality (e.g., emotional stability). Such key competences are summarized in a term called FTD [12]. FTD is defined as "the absence of any functional (sensory-perceptual, cognitive, or psychomotor) deficit, medical condition, or personality characteristic that significantly impairs an individual's ability to fully control the vehicle while conforming to the rules of the road and obeying traffic laws, or that significantly increases crash risk" [13]. Deficits of one or more FTD components are associated with a higher probability for road collisions or unsafe driving.

Official statistics show that the accident involvement of older adult drivers in Germany is comparatively high, relative to the short distances they typically travel [14]. This phenomenon is known as "Low Mileage Bias" [15, 16]. Research has shown that it is the more complex driving scenarios that older adult drivers find more challenging [17]. For example, older adult drivers are more likely to have a collision when determining traffic priority (17.6%) and when conducting manoeuvres like reversing (16.2%) [18]. However, violations such as speeding (4.6%) and driving under influence (0.8%) are not as frequently recorded for older adult drivers [18].

Among the multiple factors involved in such critical behaviours, the driver's health status with acute and chronic medical conditions (e.g., cardiovascular diseases, diabetes, sensory impairments; for quotes see Ref. [19]) and capability impairments caused by biological ageing processes are of particular importance [20-25]. Many of these widespread diseases are more common in older adult drivers [26]. These drivers also are more prone to a heterogeneous range of potential physical and/or mental handicaps, because of a higher fragility if they are involved in an accident [7, 27, 28]. Additionally, the chances of developing dementia increase with age, with a dementia rate of 40.95% among the cohort of people aged 90 years onwards [29].

To negate the decline in key driving skills, many older adult drivers develop strategies to compensate. For example, they may avoid certain driving situations (e.g., darkness, bad weather condition, rush hour) [30-32], reduce speed, rely on driver assistance systems [22, 33], or drive very cautiously and carefully due to critical self-monitoring [34]. In addition to such internal compensation strategies, there are also legally defined obligations or restrictions of a medical or technical nature that are directed at the driver or the vehicle. For example, obligations are regarding functional support pertaining to the driver (e.g. limb prosthesis), the vehicle (e.g. hand operated brake), or car use (e.g., daytime journeys only), and restrictions are regarding the exclusion of higher-level-vehicles from use (according the German Driving Licence Ordinance).

1.2 Fitness to Drive Assessment—Legislation and Procedure

The Fitness to Drive (FTD) examination in Germany is ordered by the driving license authority upon being notified of a driver's defect or illness. However, age alone is not a reason for demanding an examination. Every FTD inspection follows a standardized procedure whereby all European drivers must meet the minimum standards of physical and mental fitness as defined in Annex III of the European directive (European Directive 2006/126). All EU countries must comply with the EU Directive related to FTD, which are implemented into national legislation. However, Item 5 in Annex III of the EU Directive mentioned before allows exceeding and more differentiated requirements. The diagnostic procedure of the FTD examination usually includes a medical check, an anamnesis and the review and inclusion of external findings, e.g. from the attending family doctor. Sometimes psychological expertise is also implemented, e.g., capability tests. The framework for the assessment is based on type, severity, course, and treatment of the disease as well as compensation options, and additional risk factors such as comorbidity. This is done by specialized doctors with particular qualification according to requirements defined by German Driving Licence Ordinance in order to ascertain the adequate functional status and the person's ability to drive safely (e.g., Refs. [10, 15, 35]). The examinations are carried out according to the applicable appraisal guidelines and the relevant assessment criteria (for details see Ref. [10]). Three possible outcomes can be considered: (1) fit to drive, the person is considered to be free of contra-indication; (2) conditionally fit to drive with restrictions and obligations; (3) unfit to drive, in cases of clear contra-indications for safe traffic participation.

2. Design and Methods

In this study, we used archived case files from the driving license authority of Dresden. Please note that every assessment has to be carried out following an objective incident. In most cases, there was a traffic safety relevant incident (e.g., cognitive confusion during a traffic control, speed selection not appropriate to the situation, confusion of accelerator and brake pedal when parking). The police must report such an incident to the driving licence authority (cf. § 2 Para. 12 of the Road Traffic Act). Courts and public prosecutors (cf. § 474 Para. 2 of the Code of Criminal Procedure) and private individuals, including a family doctor, may also pass on FTD relevant information.

The data in the present study are therefore a realistic representation of a group of so-called "problem" drivers who have been identified and assessed by experts who subsequently assigned traffic-safety-relevant diagnoses following examination. The systematic data collection, including the analysis of the reports, was conducted from October to December 2017. Only reports from older adult drivers, who were at least 65 years old when the assessment started, were included, covering a period between 2007 and 2017. During this timeframe, all cases, regardless of the outcome (positive, negative, positive with restrictions or obligations) were included in the study (N = 400). The drivers fell between 65 and 95 years (mean = 77.7; SD = 6.08), of these only 13% were female [36]. The variables used included the type of the reporting body (e.g., police, court, and family doctor), diseases relevant for FTD (according to German legislation) and type of traffic incident. In the case of collision involvement, the more detailed circumstances (e.g., reason for the accident, type of unsafe behaviour) were also coded.

The aim of this study was to identify whether risk factors due to age, diseases, comorbidity and traffic conspicuousness (e.g., driving errors, see Ref. [37]), or accident involvement were associated with the FTD prognosis. Based on previous literature, we expect that age and single diseases will not serve as a risk factor for road safety (or the estimation of being unfit to drive), whereas the risk should be higher for persons with multiple diseases.

The dataset was analysed using SPSS Statistics software from IBM Corp. (Version 22, 2013), starting with prevalence rates from potentially risk factors and FTD result. Then, a two-stage analysis based on correlational and logistic regression analysis was implemented to predict the FTD result and clarify the influence of relevant predictors.

3. Results

The prevalence of diseases in the drivers was first examined using descriptive statistical methods. It is important to note that a person can have multiple diseases or impairments (multimorbidity). The highest prevalence was found for cardiovascular diseases (e.g. high blood pressure, coronary heart disease; 48.1%) followed by mobility restrictions (34.8%) and dementia (32.5%). In a medium percentage range, we observed vision deficits (27.1%), diabetes mellitus (24.3%), hearing impairment (21.7%) and diseases of the nervous system (19.9%). Less frequently were driving under influence of medications (12.8%) or alcohol and narcotics (4.6%) and kidney diseases (6.9%). Other forms of disease were represented with 17.1% of cases.

On average, each driver had 2.5 diseases (SD = 1.675). While the number of diseases a driver had did not correlate with age ($r = 0.059$; $p = 0.244$), the rank order of prevalence rates was significant associated with the statistics from Robert-Koch-Institute (RKI) (2015) for 65-74 years old drivers ($r = 0.786$, $p = 0.036$) along with a smaller effect for persons above 75 years ($r = 0.679$, $p = 0.094$).

In terms of collisions, the most common cause was driving errors (86.7%). Minor collisions were the result of errors in manoeuvring (turning, reversing, driving in/out). Collisions that were caused in moving traffic were mostly due to non-compliance to minimum distance from the vehicle in front. Figs. 1 and 3 illustrate the main driving errors and violations that resulted in a collision across the whole traffic situation, whereas, Figs. 2 and 4 demonstrate the errors and violations that resulted in a collision during moving traffic.

In 79.7% of the cases, the primary reason for a police report was a collision. Of these, 66.2% (N = 139) occurred in moving and therefore complex traffic. The more minor collisions (N = 68; 32.4%) occurred in parking spaces. Collisions in moving traffic were significantly more frequent [χ^2 (1, 206) = 24.35, $p < 0.001$]. In each case of accident-involvement the older driver was mainly responsible for it [83.8% of the cases, compared to partly responsible and not responsible; χ^2 (1, 209) = 96.02, $p < 0.001$]. Information about accident characteristics, diseases or to violations against traffic regulations was taken from the police reports and coded according to official statistics and literature [14, 38].

The FTD outcomes categorised the drivers into four groups: those with positive outcome, negative outcome, positive outcome with restrictions/obligations and persons who have died before the official decision had been made. There were no significant differences regarding gender. In most of the cases (67%), the driver had to submit his or her driving license back to the authority. Only 16.75% of the drivers were able to prove that they were fit to drive and 15.25% were given obligations or restrictions on their licence (e.g., exclusion of higher-level vehicles from group 2; no balance vehicles, driving within a small radius around the place of residence; no night driving). The number of negative assessments was significantly higher relative to the number of positive ones, or those with restrictions and obligations [χ^2 (1, 399) = 53.29, $p < 0.001$]. Cases where the driver had died during the assessment process were excluded from further analysis, as well as those who had voluntarily gave up their driving licence and returned it to the authority without facing an FTD examination. We therefore do not have a reliable diagnosis of this subgroup's states of health.

For the diagnostic categories of positive, negative and restricted positive outcome, there was a significant difference in terms of the overall number of diseases the driver had [F (2, 384) = 2.594, unilateral: $p = 0.038$], with the negative cases having the most diseases (mean = 2.59 vs. mean = 2.09 in cases of a positive outcome).

In order to examine which of the variables were able to predict the FTD outcomes, the variables, starting with age, types of diseases, and traffic incident were introduced initially as single predictors and were then combined in a second step into a logistic regression model with FTD as the criterion (values "positive" vs. "negative" outcome). Drivers who had been allowed to keep their driving license with restrictions or obligations were categorized as "positive". The bivariate associations with coefficients [Odd's ratios (OR) or Spearman's Rho (r_s)] are displayed in Table 1. OR expresses the probability of a person with a certain feature to get a negative outcome compared to people without that feature.

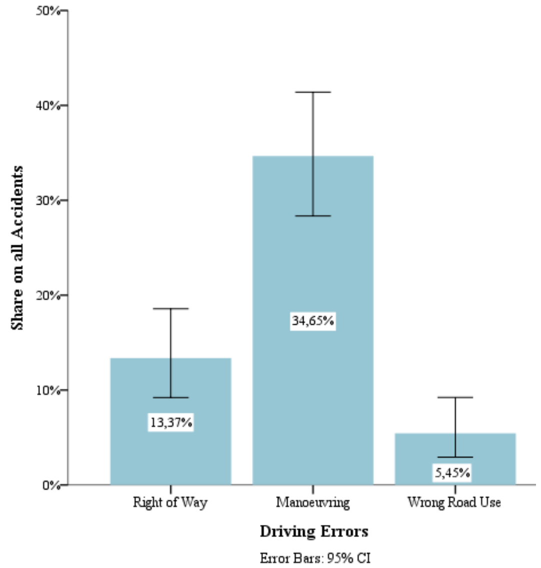

Fig. 1 Share of driving errors on all accidents.

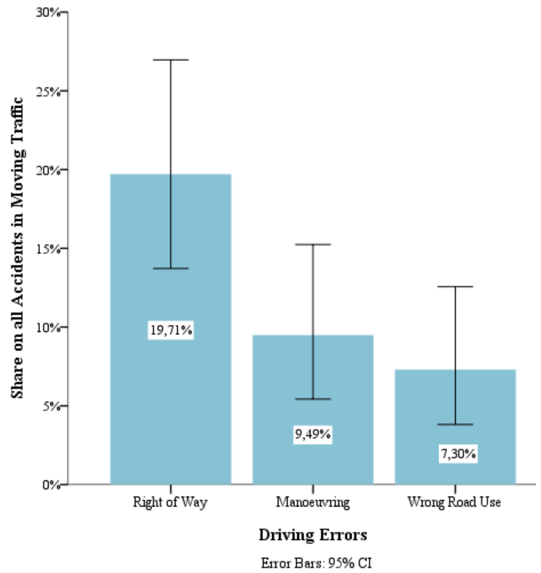

Fig. 2 Share of driving errors on accidents in moving traffic.

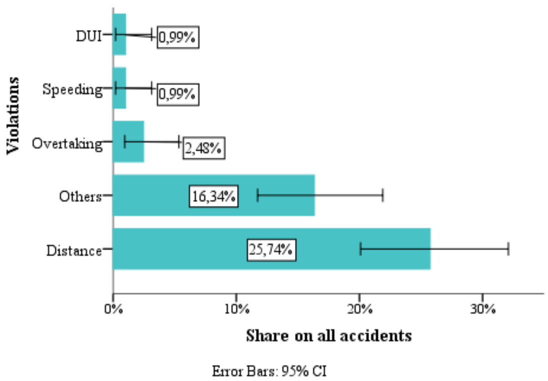

Fig. 3 Share of violations on all accidents.

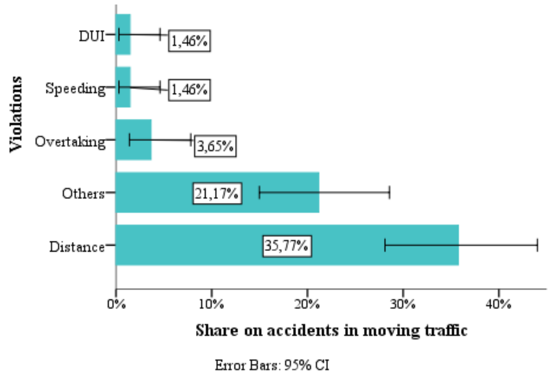

Fig. 4 Share of violations on accidents in moving traffic.

The results demonstrate that age (above 80 years only; $r_s = 0.10$, $p = 0.046$), hearing impairment (OR = 2.71), dementia ($r_s = 0.64$, $p < 0.01$), and multiple diseases (sum of all diseases with $r_s = 0.37$, $p < 0.001$; weighted sum of diseases with $r_s = 0.39$; $p < 0.001$; and high-risk-diseases with $r_s = 0.35$, $p < 0.001$; see Ref. [39]), along with accident-complexity (OR = 1.84), significantly increase the risk of a negative FTD outcome. Hearing impairment was significantly associated with age ($r_s = 0.23$, $p < 0.01$), the sum of diseases ($r_s = 0.30$, $p < 0.01$), and involvement into a high complex accident ($r_s = 0.20$, $p < 0.01$), indicating a reduced general efficiency in driving skills. Although, cardio-vascular diseases and accident responsibility were not significant in the 95% interval, there was a trend in the direction of a negative outcome.

The results of the bivariate analyses were used to see the prediction share of a single risk factor on FTD outcome. In addition to this, multivariate logistic analyses were used to compare different prediction models under simultaneous consideration of several risk factors and their interdependencies. Table 2 displays the different models from the regression analysis, including regression coefficient with significance test and explained variance in the FTD outcome (coefficients are Nagelkerke-R^2 and percentage of correctly assigned subjects in the last column). Model I considers only age and suggests age only explains 6% of the variance in the criterion variable. The number of diseases as both a sum index and as a weighted sum of the risk diseases explains 26% of the variance, which is 20% more than age (Model II). However, if all three predictors are considered simultaneously, there is no additional explanation of variance (Model III), suggesting that age and multimorbidity are interrelated, which can be seen from significant intercorrelations ($r_s = 0.16$, $p < 0.05$).

The complexity of the accident explains an additional 4% of the variance in the FTD result, adding an independent contribution to the regression model ($p = 0.051$) without improving the correct assignments. Model IV suggests that 72.8% of FTD results can be correctly predicted by the predictors and the remaining 27.2% can be attributed to individual examination findings. Model V demonstrates that a combination of multimorbidity, expressed in terms of higher risk diseases and the number of diseases, along with involvement in highly complex accidents provides the best prognoses of a negative FTD assessment, with an outcome of 73.5% correctly assigned cases.

Table 1 Predictors and their influence on the assessment outcome (negative vs. positive).

Predictor	Coefficient	*p*-value	Confidence interval	
Age 68 and above	$r_s = 0.08$	0.101	-	-
Age 75 and above	$r_s = 0.063$	0.219	-	-
Age 80 and above	$r_s = 0.102$*	0.046	-	-
Seeing	OR = 1.436	0.312	0.712	2.894
Hearing	OR = 2.710*	0.015	1.210	6.068
Restriction of motion	OR = 0.976	0.947	0.482	1.978
Cardio-vascular diseases	OR = 1.944	0.090	0.902	4.191
Diabetes	OR = 0.807	0.563	0.391	1.667
Diseases of the nervous system	OR = 1.875	0.117	0.855	4.111
Alcohol and narcotics	OR = 3.341	0.195	0.539	20.706
Medications	OR = 1.075	0.885	0.403	2.869
Kidney diseases	OR = 0.360	0.196	0.076	1.692
Dementia	$r_s = 0.644$**	0.000	-	-
Multimorbidity	OR = 3.431*	0.018	1.234	9.542
Sum of all diseases	$r_s = 0.336$**	0.000	-	-
Weighted sum of diseases	$r_s = 0.391$**	0.000	-	-
High-risk diseases	$r_s = 0.345$**	0.000	-	-
Traffic conspicuousness	OR = 0.668	0.071	0.432	1.035
Accident	OR = 0.673	0.074	0.436	1.039
Complexity	OR = 1.837*	0.045	1.014	3.329
Police	OR = 1.090	0.694	0.710	1.671
Fault of accident	OR = 0.668	0.065	0.436	1.026

OR = odds ratios, r_s = Spearman's rank correlation; * $p < 0.05$; ** $p < 0.01$.

Operationalisations: Multimorbidity—dichotomous 1 vs. 2 or more diseases; number of all diseases—sum of all relevant diseases of a person; weighted sum of diseases—relevance of diseases was determined according to Charlton (2010) and weighted with numbers (1—low impairment to 4—high impairment), sum of the weighted values per person was calculated; high risk diseases—dichotomous according to Charlton (2010) high risk diseases are dementia, cardiovascular diseases, alcohol & drug addiction; traffic conspicuousness—dichotomous: people who had an incident in traffic vs. people who were not conspicuous in a traffic accident (but e.g. reported by their GP); accident—people with an accident vs. people without an accident; complexity—dichotomous: people with a high complex accident (in moving traffic) vs. others; police—people who were reported by the police vs. people who were reported by other sources (e.g. family, GP, etc.); fault of accident—people who were given the full fault of the accident vs. others.

Table 2 Logistic regression model for the negative outcome of the assessment.

Model	*N*	Predictors	Regression-coefficient	Sig.	Nagelkerke's R^2	Explained variance in criterion	Correct assignment
I	147	Age	0.024	0.427	0.006	6%	68%
II	147	Weighted multimorbidity	0.230	0.003	0.262	26%	72.8%
		High-risk diseases	1.253	0.079			
III	147	Age	0.001	0.974	0.262	26%	72.8%
		Weighted multimorbidity	0.230	0.003			
		High-risk diseases	1.253	0.079			
IV	147	Age	0.018	0.612	0.301	30%	72.8%
		Weighted multimorbidity	0.215	0.007			
		High-risk diseases	1.271	0.078			
		Complexity	-1.404 -0.601	0.051 0.167			
V	147	Weighted multimorbidity	0.221	0.005	0.299	29.9%	73.5%
		High-risk diseases	1.278	0.076			
		Complexity	-1.338 -0.573	0.059 0.184			

Sig. = significance.

4. Discussion

In order to suggest safety measures for the future, the aim of this paper was to identify risk indicators among older adult drivers that can increase the likelihood of receiving a negative FTD prognosis. The burden of capability losses to drive safely is accompanied by impairments in cognitive functions through decreases in the volume of grey and white matter and reduced connectivity of frontostriatal pathways and impairments in the neurotransmission [40, 41] as well as with health-related impairments like diseases.

For several individual diseases such as vision, motion restrictions, kidney diseases, diabetes or coronary diseases, the risk potential for a negative FTD result does not appear to be particularly high, according to similar findings from accident analyses due to medical conditions and diseases (see also Refs. [25, 31]). This might be partly due to the fact that adequate coping skills are available and positive personality traits are likely to be supportive for the doctor-patient-compliance at higher age: risk accelerators like hostility, aggressiveness or sensation seeking decline, conscientiousness and agreeableness increase and the person perceives herself as vulnerable [42, 43]. It is, therefore, not the diagnosis that characterises a driver, but the way in which it is dealt with.

On the other hand, the benefits of compensation strategies are limited. In addition to overestimating one's own driving skills, the severity of a disease can be too severe to be sufficiently compensated (e.g. in the case of dementia). The simultaneous presence of several illnesses, i.e. co-morbidity, can exhaust the possibilities of compensation. This is because the interactions between illnesses and age-related functional limitations, as well as the interactions between medication taken, can have a significant influence on the FTD prognosis. In the present study, the simultaneous presence of several documented diseases, operationalized by three different parameters (multimorbidity as a category, as a sum-index or as a weighted index with different significance of individual diseases), was shown to increase the risk of a negative FTD result. The stepwise logistic regression demonstrates that age and multiple diseases are likely to be two aspects of the same situation given that the number of diseases increases with age [44]. Only the addition of the accident complexity variable slightly increases the predictive power of the FTD result. The interaction between health complaints and deficits in cognitive action control, including self-monitoring, self-criticality, and disease awareness, appears to be a dangerous combination of "functional incapacity". In the present study, we narrowly interpreted the term "comorbidity" as the documented presence of one or more additional diseases co-occurring with a primary disease. This definition does not include further components of the total burden of dysfunction from socioeconomic, cultural, environmental, and patient behavior characteristics.

In addition to the finding regarding comorbidity and age, the observation that dementia was significantly likely to predict a negative FTD must also be discussed. In approximately one-third of the current sample, the drivers demonstrated evidence of dementia, highlighting the fact that this kind of disease seems to be over representative among the problem group of older adult drivers. In German population, the dementia prevalence rate among 80-year-old is estimated at about 10% [45]. However, dementia rate in Europe for the age group of between 65 to 69 years old is around 1.6% and is 25 times this in those over 90 years [29]. Toepper and Falkenstein [46] conducted a literature review observing a 10-fold increased risk in drivers with dementia failing an on-road driving assessment along with an accident risk that is 1.77-fold 3 years before diagnosis. These results suggest that people with severe or moderate dementia are no longer fit to drive, irrespective of the type of dementia. Importantly, in all forms of dementia it appears common that the ability to drive is impaired at some point during the course of the disease. It should therefore be a priority in road safety work to have a measure of detecting dementia as early as possible.

The present results appear to suggest that hearing impairment increases the likelihood of a negative FTD result. This finding can be explained by the confounding influence from age and multimorbidity on FTD outcome among the subjects in the study sample. In Germany, FTD shall be questioned only, if hearing is lost for more than 60% in the better ear and if further deficits like impaired vision or disturbance of balance are effective at the same time (Driving Licence Ordinance, Annex 4 No. 2) [47, 48].

5. Practical Implications

The extent to which older adult drivers can estimate their deficits and compensate consciously still remains relatively unknown [2, 49]. Given that screening procedures based solely on chronological age do not increase road safety, since there is no clear valid and reliable assessment battery for general FTD assessments when considering older adult drivers (see Refs. [50, 51]). When relying on empirical studies there are several biasing factors. For instance, in academic studies, FTD evaluations are run by researchers who are often not FTD experts. They also use self-selecting participants who are generally not representative of the sample they are examining, reducing the validity of findings and assumptions [21, 52].

This raises the question of what can be done to improve the assessment of older adult drivers. It seems reasonable to suggest a combination of an on-road assessment, with the presentation of a health certificate for drivers at an age of minimum 75 years (submitted at the beginning of the assessment) may be a suitable option. This self-declaration of health status would ideally be completed together with the family doctor and include a statement on cognitive function and multimorbidity, as well as an indication of individual risk factors.

Taking into consideration the finding that comorbidity was a predictive factor for a negative FTD result, this factor should be considered more when developing driver safety policies. The Annex III of the European directive (European Directive 2006/126) includes 13 chapters, with the final one concerning "miscellaneous conditions". It includes organ transplants and artificial implants, as well as the category "not mentioned above". At this point, comorbidity at higher age should be mentioned as a new category.

Finally, we still must consider some methodological limitations. Given that the study used retrospective data, it does not have an experimental manipulation. This aside, the sample uses real world data and is not affected by self-selection. There was no control group available, as it is not possible for ethical, legal and organisational reasons to assign subjects to an FTD assessment from the cohort of all older adult drivers who have so far remained safe drivers. Therefore, the effects reported here rather capture a "bottom effect" and thus the minimum expression of the risk potential for an unfavourable FTD result. However, we must note that FTD assessments ensure that the prerequisites for safe driving are always present for every driver and that other road users can rely on the driver's existing ability and capability to drive safely. Under the umbrella of general road safety, both individual mobility needs, and protective purposes are to be considered.

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Declarations of Interest

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