Association of Expressed Driving Anger with Driving Performance Combining Simulator and Survey Data

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Abstract

The objective of the present study is to investigate the effect of anger on driver behaviour and safety focusing on certain characteristics of the driver and driving performance parameters. In order to achieve this objective, a driving simulator experiment was carried out, in which 125 participants from all age groups were asked to drive in different road and traffic conditions. Then, each participant filled in a questionnaire about his/her driving habits and behaviour, including a specific section about anger expression during driving and history of accidents. Anger expression was measured by identifying different aspects of emotions and behaviours of the drivers based on the Driving Anger Expression Inventory. First, a preliminary descriptive analysis was carried out in order to acquire insight into the structure of the data. In the next step, in order to reduce the number of independent variables related to anger, a factor analysis was performed, and 4 anger factors were identified namely: External Anger, Forgiveness, Internal Anger, Noble-Mindedness, introducing thus a new way of defining anger levels in an individual. Finally, 5 regression models (linear and logistic) were developed correlating several driving behaviour and performance measures (average speed, average time headway, accident probability, probability of exceeding the speed limit and probability of traffic violation or traffic penalty) with anger factors, other driving parameters as well as driver characteristics. Results indicate that drivers with higher level of driving anger drive faster, at smaller headways from the vehicle in front and are engaged in more accidents and road traffic violations. Notably, male drivers demonstrated higher levels of driving anger than females, while anger was found to decrease as age increases. The conclusions of the present research may enhance understanding of the characteristics and the importance of anger while driving on road safety and be exploited for drafting regulations against driving anger. .

Keywords

Driving Anger; Road Safety; Driving Anger Expression Inventory; Driving Simulator

1. Introduction

Driving anger is defined as the aggressive or angry behaviour of a driver. Such behaviour may include rude gestures, verbal insults and deliberately dangerous or threatening driving [1]. Driving anger can lead to quarrels, attacks and conflicts that cause injuries or even fatalities, while there is a direct link between driving anger, dangerous and aggressive driver behaviour [2]. [3], [4]. In addition, Driving Anger Expression (DAX) Inventory [5] is a widely used, valid and representative tool for measuring the expression of driving anger.

During the last decades, several researches have examined driving anger as evidenced by the number of studies published. Key factors that have been identified to increase driving anger are time pressure, masculinity, non-adaptability, anxiety [6], financial troubles [7], young age [8], traffic conditions that offer anonymity and/or easy escaping, male gender [9], the search for thrills or aggression, aggressive mood (possibly due to events irrespective of traffic conditions), traffic congestion only when not expected [10], cancelled driving goals, the development of technology (e.g. failure of satellite navigation devices), lack of forgiveness, overestimation of driving skills, competitiveness, hostility, aggression, lack of patience, insecurity, stress dependency, dependence on material rewards and appreciation of others [11].

Focusing on driving, anger has a serious impact on road safety causing loss of concentration and loss of vehicle control. It also increases the number of near-misses and accidents, the average speed, the probability of exceeding the speed limit and generally road traffic violations[12], [13]. Anger causes a decrease in productivity and a lower perception and assessment of traffic conditions and rules. The relationship between the appearance of the above unfavourable driving effects and the intensity of driving anger is proportional [14], [15].

Examining gender characteristics, aggression of both male and female drivers is higher against pedestrians who are men [16]. Only anger that comes as a reaction to other road users is associated with an increase in the probability of a road traffic infringement. On the other hand, anger due to conflict with someone on the phone or with a passenger is not associated with some sort of abnormal driver behaviour. Even when aggression includes behaviours that may not be visible to the intended driver, such as voices or blasphemy, reports of collision are greater among those drivers who were angry [17]. The adverse driving effects due to driving anger are similar to those resulting from driving under the influence [18]. Forgiveness has a significantly negative relationship with anger, the expression of driving anger and aggressive driving [19]. The fear of retaliation by a high-status person can prevent a low-status person from showing aggressive driving when in contact with a high-status person. A low-status vehicle is more likely to affect aggressive driving [20].

Furthermore, the average trip from home to work is filled with many events that cause feelings of hostility and thoughts of mental violence. The use of private cars is a mean of expressing anger and aggression, depending on the personality of the driver [21]. The tendency for aggressive driving in a person may be inherent as a characteristic of its personality or temporary and dependent on the mood and the circumstances. There is a significant difference between occasional irritation and lack of tolerance. Therefore, anger creates a risk due to deliberate behaviours [22]. Aggressive driving is increasing every year and it's associated with more than half of traffic-related deaths in the United States. It was also found that the relationship of anger-aggression varies between countries [24]. To the extent that driving anger remains significantly associated with the risk of an accident, it is a serious threat to public safety. Therefore, treatment programs and intervention strategies are needed for this phenomenon to be reduced.

Based on the above literature review on the scientific fields of driving behaviour and anger some basic limitations can be identified. The first concerns the fact that anger is a multidimensional phenomenon which means that a single question of a questionnaire cannot capture all aspects of the anger behaviour. For this purpose, it will be much more accurate to identify unobserved (latent) anger behaviours and then correlate them with specific driving performance parameters. A second limitation identified, concerns the fact that experimental processes including both driving performance data as well as questionnaire surveys are missing. Especially through driving simulators which allow the examination of a range of driving performance measures in a controlled, relatively realistic, and safe driving environment, the effect of anger on simulated driving performance has not been investigated. These are the gaps in the literature that the present research is dealing with and will be further analysed in the following chapters.

The objective of the present study is to investigate the effect of anger on driver behaviour and safety combining a driving simulator experiment and a questionnaire survey. In particular, the research focuses on what extent driving anger, depending on certain characteristics of the driver (e.g. driving experience, age, gender, etc.) contributes to certain driving patterns as well as on accident probability. In order to achieve this objective, an extensive literature review was conducted and presented above in order to better identify the gaps in the literature and the correlation between anger and driving. Then a driving simulator experiment took place and a questionnaire was filled through the Driving Anger Expression (DAX) Inventory for a sample of 125 drivers. All methodological steps are included in the following chapter. In the results chapter, the statistical analyses methodologies are presented including the implementation of descriptive statistics, factor analysis as well as the development of 5 regression models. Finally, the conclusions of the research are analysed and discussed in the final section of the paper.

2. Methodology

2.1 Overview of Experiment

Within the present research, a driving simulator experiment was carried out, in which 125 participants were asked to drive under different types of distraction (no distraction, conversation with passenger, cell phone use) in different road (urban/rural) and traffic conditions (high/low). Each participant aimed to complete 12 driving trials, while in each trial, 2 unexpected incidents were scheduled to occur at fixed points along the drive.

The driving simulator experiment took place at the Department of Transportation Planning and Engineering of the National Technical University of Athens, where the FOERST Driving Simulator is located. The NTUA driving

simulator is a motion base quarter-cab and consists of 3 LCD wide screens 40" (full HD: 1920x1080pixels), driving position and supportive moving base. The dimensions at a full development are 230x180cm, while the base width is 78cm and the total field of view is 170 degrees (Figure 1).

Figure 1. Driving simulator

For the purpose of the present study, the driving task referred to one rural driving session (Figure 2), under typical conditions, without any external distraction sources. The rural route was 2.1 km long, single carriageway and the lane width was 3m, with zero gradient and mild horizontal curves. Ambient vehicles' arrivals were drawn from a Gamma distribution with mean m=12sec, and variance $\sigma 2$=6 sec, corresponding to an average traffic volume Q=300 vehicles/hour (moderate traffic conditions). These traffic arrivals distributions are appropriate for describing vehicle arrivals for the given traffic flow, whereas Gamma distributions are typical for describing vehicle arrivals for moderate to high traffic flows.

Figure 2. Driving simulator scenario in rural area

2.2 Questionnaire Design

Each participant was requested to fill in a questionnaire about his/her driving habits and behaviour. The sections of the questionnaire included:

- driving experience - car use
- emotions and behaviour of the driver
- anger expression inventory during driving (DAX)
- history of accidents, near misses, and traffic violations

For the purpose of the present research, the sections that are further analyzed were the anger and the history of accidents. The anger section section measured different aspects of emotions and behaviours of the drivers modified by the research team from the Driving Anger Expression Inventory [5], rated on a 4-point scale (almost never-almost

always). The results of this section were related to performance in those conditions of the driving simulator more likely to result in impatience or anger. Consequently, the history of accidents, near-misses and traffic violations section aimed to elicit specific information on the above, measured in terms of frequency of occurrence (0-9+ times in total, or in the past 2 years, depending on the section).

2.3 Sample Characteristics

Participants in the experiment met certain inclusion criteria. They had a valid driving license, drove for at least 3 years, have driven more than 2500 km during the last year, drove at least once a week during the last year, drove at least 10 km/week during the last year, didn't have important psychiatric history, didn't have any important kinetic disorder that prevent them from performing basic driving moves, didn't have dizziness or nausea while driving or as a passenger, weren't pregnant, weren't alcoholics or had any other drug addiction.

In table 1, distribution of participants per age group and gender is presented. The mean age is 50.17 years, with a standard deviation of 15.57 years and a range of 58 years. The average driving experience is 25.6 years, with a standard deviation of 13.84 years and a range of 47 years. The average education is 15.56 years with a standard deviation of 3.05 years and a range of 18 years. In the total of 125 drivers 44.8% were men and 55.2% were women. Young, middle-aged and elderly groups were 24%, 30.4% and 45.6% respectively. It should be noted that an oversampling of older drivers was chosen due to lack of relevant research in the literature.

Table 1: Distribution of Participants per Age Group and Gender

Age Group	Female		Male		Total	
18-34	9	7%	21	17%	30	24%
35-55	26	21%	12	10%	38	30%
55+	34	27%	23	18%	57	46%
Total	69	55%	56	45%	125	100%

2.4 Analysis Background

In the present study different statistical methods and tools were used including correlation coefficients, factor analysis, probability distributions, regressions analysis, statistical significance of models, theory of elasticity.

Factor analysis is a statistical method used to describe variability among observed, correlated variables in terms of a potentially lower number of unobserved variables called factors. Factor analysis searches for joint variations in response to unobserved latent variables. The observed variables are modelled as linear combinations of the potential factors. Factor analysis aims to find independent latent variables. The theory behind factor analytic methods is that the information gained about the interdependencies between observed variables can be used later to reduce the set of variables in a dataset. Factor analysis is related to principal component analysis (PCA). Principal component analysis is a statistical procedure that uses an orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of linearly uncorrelated variables called principal components [23].

Model development was held by using regression analysis. A set of statistical processes estimated the relationships among variables focusing on the relationship between a dependent variable and one or more independent variables or predictors. The type of regression models used were multiple linear regression for continuous dependent variables and generalized ordinal logistic regression for discrete variables. Once regression models have been constructed, it was important to confirm the goodness of fit of the models and the statistical significance of the estimated parameters. Used checks of goodness of fit included the R-squared, analyses of the pattern of residuals and hypothesis testing. Statistical significance was checked by an F-test of the overall fit, followed by t-tests of individual parameters [24].

3. Analysis and Results

Following the data collection from the driving simulator experiment a preliminary statistical analysis was performed. Descriptive statistics have been implemented to examine the database such as mean values, standard deviation, range values etc. In table 2 the key variables are described, and their key values are presented.

Table 2: Key variables' characteristics

Driver characteristics	Description	Min	Max	Average
Age	Age of the participant	22.00	80.00	50.17
Education	Years of education	0.00	16.00	12.00
Experience	Years of driving experience	3.00	50.00	23.06
Gender	Male/Female			
Driving performance parameters	**Description**	**Min**	**Max**	**Average**
Time run	duration (msec) since start of the drive	19.00	374.00	129.20
Distance car	distance of the vehicle from the beginning of the drive (m)	99.67	3.104.35	1.176.48
Average speed	actual speed (km/h)	19.63	69.83	39.24
Reaction time	reaction time at unexpected incident (sec)	500.00	5.484.00	1.493.00
Lateral position	track of the vehicle from the middle of the road (m)	1.16	4.49	2.20
Average direction	direction of the vehicle compared to the road direction (degrees)	0.01	4.03	1.93
Average brake	brake pedal position (%)	0.00	7.07	1.87
Average gear	chosen gear (0 (idle), 6 (reverse))	1.31	4.27	2.75
Average motor revolvation	motor revolvation (1/min).	1.209. 00	5.622.00	2.476.00
Average space headway	distance to the ahead driving vehicle (m)	18.76	927.52	206.03
Average timeheadway	time to the ahead driving vehicle (sec)	3.54	256.84	37.10
Average time to line crossing	time until the road border line is exceeded (sec)	17.69	552.93	130.72
Average time to collision	time to collision (all obstacles) (sec)	5.20	22.08	10.10

In the next step, a factor analysis was performed in order to reduce the number of independent variables related to anger. As a result, 4 anger factors were defined are presented in table 3. The drivers' responses to the driving anger expression inventory were imported as variables and were analysed using the factor analysis method. Their responses had a frequency ranging from 1 (almost never) to 4 (almost always) of some form of anger expression. The chosen analysis method was Principal Component Analysis and the rotation method was Varimax. Communalities, scree plot, rotated and unrotated component matrix, eigenvalues were taken into consideration for the final model. The 4 factors identified as the optimal solution are the following:

- external anger
- forgiveness
- internal anger
- noble-mindedness

Table 3 demonstrates correlations and coefficients between factors and initial variables.

Table 3: Factors Analysis Results

Factor 1: External Anger	Loadings	Coefficients
I try to cut in front of the other driver	0.753	0.174
I make negative comments about the other driver	0.747	0.138
I glare at the other driver	0.747	0.170
I think things like "Where did you get your license?"	0.734	0.140
I give the other driver the finger	0.676	0.100
I swear at the other driver aloud	0.674	0.128
I shake my head at the other driver	0.663	0.145
I make hostile gestures other than giving the finger	0.639	0.102
Factor 2: Forgiveness	Loadings	Coefficients
I pay even closer attention to being a safe driver	0.724	0.197
I think about things that distract me from thinking about the other driver	0.644	0.172
I do things like take deep breaths to calm down	0.638	0.175

I try to think of positive solutions to deal with the situation	0.625	0.161
I turn on the radio or music to calm down	0.584	0.190
I just try to accept that there are bad drivers on the road	0.576	0.149
I decide not to stoop to their level	0.504	0.082
Factor 3: Internal Anger	Loadings	Coefficients
I don't accept that there are frustrating situations while driving	0.674	0.223
I break out to others later	0.667	0.245
I drive a little faster than I was	0.643	0.192
I go crazy behind the wheel	0.554	0.191
I break out to fellow passengers	0.534	0.165
Factor 4: Noble-Mindedness	Correlations	Coefficients
I don't try to scare the other driver	0.911	0.350
I don't drive right up on the other driver's bumper	0.911	0.350
I tell myself it's not worth getting involved in	0.651	0.202
I decide not to stoop to their level	0.596	0.179

The first factor (external anger) illustrates 16.66% of variance and includes anger positive variables such as expressions of aggressive mood gestures, disapproval etc. towards other drivers. The second factor (forgiveness) illustrates 11.49% of variance and includes anger negative variables including practices related to forgiveness towards other drivers such as trying to remain calm, accepting the situations, avoiding fighting and anger. The third factor (internal anger) illustrates the 10.12% of variance and includes anger positive variables related to anger expressions other than the ones intended for other drivers. The fourth factor (noble-mindedness) explains 8.71% of variance and includes anger negative variables related to nobleness displayed by the driver on various occasions.

The new factors that have been extracted through the analysis are defined as follows. External anger is defined as the attempt to interfere with the course of others, the expression of critical thoughts and insults, the exchange of threatening wars, the manifestation of obscene, insulting and repugnant gestures. Forgiveness is defined by practices of increasing attention, changing thoughts, applying sedative breaths, trying to find positive solutions to avoid conflict or accident, playing music to avoid anger episodes, accepting the driving deficiency of some unconscious drivers, refusing to engage in inappropriate conflict incidents that will degrade the level of the situation. Internal anger is defined as conflict with someone on the phone or with a passenger, anger that's not being expressed or expressed later in time. Noble-mindedness in this research is defined and characterized by the avoidance of aggressive practices such as causing terror to the other driver, accident, engaging in conflict, self-identification as superior to other unconscious drivers.

In table 4 the correlations coefficients are presented (Pearson correlations for continuous and spearman correlations for discrete variables) between several other driving characteristics and the anger factors. The purpose is to identify high correlation between variables and factors which means they cannot be included in a statistical model. Independent variables that showed a high correlation between them were not taken into account in the final models.

Table 4: Correlations Coefficients between Independent Variables

Variables	External Anger	Forgiveness	Internal Anger	Noble-Mindedness
Age	-0.352**	-0.019	-0.091	0.244
AgeGroups	-0.352**	-0.055	-0.073	0.269*
Gender	-0.283*	0.377**	0.197	-0.070
Education	0.155	0.103	-0.007	0.020
Driving Experience	-0.203	-0.025	-0.185	0.243
External Anger	1	0	0	0
Forgiveness	0	1	0	0
Internal Anger	0	0	1	0
Noble-Mindedness	0	0	0	1

***. Correlation is significant at the 0.01 level.*

**. Correlation is significant at the 0.05 level*

Based on table 4, relatively high correlations appeared between the anger factors and several independent variables such as Age, Gender, Education and Driving experience. For this reason and in order to preserve the validity of the models, the anger components were mainly used in the statistical analysis to avoid multicollinearity. Correlation coefficients were also calculated between anger factors and driving behaviour variables, a process that was a preliminary step towards the development of the models. The corresponding results appear in table 5.

Table 5: Correlations Coefficients between Dependent Variables and Anger Factors

Variables	External Anger	Forgiveness	Internal Anger	Noble-Mindedness
Average Speed	0.262	-0.266	0.003	-0.17
Average Time Headway	-0.275	0.313	0.103	0.178
Number of Speed Limit Violations	0.238	-0.457	0.005	-0.109
Number of Accidents	-0.111	-0.407	0.012	-0.016
Number of Tickets	0.399	-0.149	0.071	-0.244

In the next step, the development of statistical models is presented aiming to determine the relationship between anger and driver behaviour. The multiple linear regression method was chosen for continuous variables. The method used for the discrete variables was generalized ordinal logistic regression correspondingly. At this point it should be noted that the exported models were the result of a series of tests in which several relations were developed that included combinations of all variables recorded. These models were evaluated with statistical tests and logical interpretation of their results. It is also reported that each time a model was tested, all independent variables were initially used, and then rejected those that had t-test/Wald less than 1.64 (a 95% confidence level).

In Table 6 parameters estimates for the following dependant variables are presented

- average speed
- average time headway
- probability of accident (based on history accident involvement)
- probability of exceeding the speed limit
- probability of traffic violation or penalty (based on history traffic violations and penalties)

Table 6: Parameter Estimates of Models

Variables	Constant	External Anger	Forgiveness	Internal Anger	Noble-Mindedness	Sig.
Avg. Speed	48.933	2.003	-2.138	-	-	0.019
t-test	49.583	2.064	-2.091			
Sig.	0.000	0.044	0.041			
Avg. T.Head	43.823	-5.082	6.084	-	-	0.006
t-test	18.786	-2.215	2.517			
Sig.	0.000	0.031	0.015			
logit P(Speed>limit)	1.295	0.501	-0.938	-	-	0.019
Wald	13.308	3.155	6.862			
Sig.	0.000	0.078	0.009			
logit P(Accident>0)	-1.681	-	-0.836	-	-	0.001
Wald	22.259		10.762			
Sig.	0.000		0.001			
logit P(Ticket>0)	0.592	0.742	-	0	-0.487	0.006
Wald	4.133	7.529			3.778	
Sig.	0.042	0.006			0.052	

The predominant multiple linear models are presented below.

$$Avg.Speed = 48.9 + 2 * (Ext.Anger) - 2.1 * (Forgiveness) \quad (1)$$

$$Avg.Time\ Headway = 43.8 - 5.1 * (Ext.Anger) + 6.1 * (Forgiveness) \quad (2)$$

$$P(Speed > Limit) = \frac{1}{1 + e^{1.3 - \{0.5 * (Ext.Anger) - 0.94 * (Forgiveness)\}}} \quad (3)$$

$$P(Accidents > 0) = \frac{1}{1 + e^{-1.68 - \{-0.84 * (Forgiveness)\}}} \quad (4)$$

$$P(Ticket > 0) = \frac{1}{1 + e^{0.59 - \{0.74 * (Ext.Anger) - 0.49 * (Noble - Mindedness)\}}} \quad (5)$$

The above equations show that external anger has a positive relationship with the average speed, the probability of exceeding the speed limit, the probability of traffic penalty and a negative relationship with average time headway. Forgiveness has a negative relationship with the variables average speed, the probability of exceeding the speed limit and the probability of engaging into an accident or a road traffic infringement. It also has a positive relationship with the average time headway. Forgiveness has greater elasticity than anger, therefore, affects every dependent variable more than external anger for the same percentage change. Noble-mindedness has a negative relationship with the probability of getting a penalty fare, and again its percentage change affects way more the dependent variable than external anger.

4. Discussion

The aim of this study was to investigate the effect of anger on driver behaviour and safety using a driving simulator and questionnaires. In particular, the research focused on to what extent driving anger, depending on certain characteristics of the driver (e.g. driving experience, age, sex, etc.), contributes to certain driving patterns and the probability of an accident.

The added value of the present research relies on one methodological and two key result findings. The methodological findings concern the implementation of a large sample driving simulator experiment. More specifically, although the sample of the experiment was slightly oversampled with middle aged older drivers, results confirm the literature findings that were focused on younger drivers or participants from equal age groups [25]. The first key result of this research concerns the development of four factors in order to represent driving anger. Based on the factor analysis that was implemented the factors that represent driving anger are external anger, forgiveness, internal anger and noble mindedness. The second key finding of the study concerns the quantification of the above driving anger factors on specific driving simulator and questionnaire parameters. The findings are in line with those of the international literature. The influence of driving anger on the average speed, the probability of violating the speed limit and the number of road traffic violations were confirmed by the current study [26].

The association of anger with age and gender was also confirmed. Age and anger are inversely related and have a high correlation. Gender and anger are high correlated as men show higher levels of anger than women. Anger that comes as a reaction to other road users is associated with an increase to the probability of traffic violation and the odds of a crash. Conversely, anger that is not being expressed by any mean or due to conflict with someone on the phone or with a passenger is not associated with some sort of abnormal road behaviour. Every dimension of forgiveness has a significantly negative relationship with anger, the expression of driving anger and aggressive driving. It was also found that forgiveness affected dependent variables more than anger for the same percentage change. Even when aggression includes behaviours that may not be visible to the intended driver, such as voices or blasphemy, reports of collision are greater compared to drivers who remain calm.

The examined variables, average speed, probability of exceeding the speed limit, probability of an accident, probability of traffic penalty, are all increased by anger. On the other hand, forgiveness and noble-mindedness have the opposite effect. Average headway measured in time is also dependent from driving anger. Drivers with higher levers of anger seemed to decrease the distance between vehicles. One significant remark is that the correlation between the number of accidents and forgiveness found to be greater than the one with driving experience. In conclusion drivers with higher level of driving anger drive faster, decrease the distance between vehicles and engage in more accidents and road traffic infringements.

To conclude, there is an increasing research focusing on driving anger as evidenced by the number of studies published over the last decade. However, additional research is needed in several sub-areas to better understand driving anger and for support the development of intervention strategies to eliminate its adverse effects. Future studies should consider a different driving assessment of the effects of anger with the use of more objective sources (e.g. police/insurance reports, in car driver monitoring in realistic conditions) for driver behaviour data. Anger experts have described the difference between what's known as state and trait anger. Trait anger refers to a chronic, long-standing personality characteristic that shows up as an almost constant tendency to become angry at the slightest provocation. State anger refers to temporary, short-lasting outbursts of anger. The impact of those two different types of anger on road safety should be further examined. Finally, future research focusing on examining drivers' reactions the moment they appear to be in anger state are essential for a deeper understanding of the mechanism of anger in driving.

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