Developing an Artificial Intelligence Model to Enhance the Emotional Intelligence of Motor Vehicle Drivers for Safer Roads

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Abstract: Traffic accidents and risky driving behaviour are among the deadliest problems worldwide. This statement becomes an undeniable fact, thanks to the grim statistics of the World Health Organization, according to which more than 1 million people die on the roads every year. Road accidents are also among the leading causes of death among children and young people aged 5 to 29. Against this background, a number of studies look for a link between the emotional intelligence of motor vehicle drivers and the potential prevention of risky driving. Building on the scientific knowledge generated up to this point, the present study suggests a prototype of an AI-based model that aims, through ongoing assessment and subsequent training, to enhance the emotional intelligence of both future and current motor vehicle drivers who are prone to risky behaviour on the road. Through simulated scenarios in a virtual environment, the model aims to improve the ability of drivers to recognise and manage their own and other people's emotions and to react adequately to different situations on the road. The expectation is that the model will reduce the manifestations of aggression and intolerance on the road and ultimately lead to safer roads.

1 INTRODUCTION

Risky driving is a recognised factor in road traffic accidents. Driving behaviour significantly influences the occurrence of traffic accidents and fatalities. Intentional dangerous behaviours, such as exceeding speed limits or driving under the influence of substances, are among the predominant contributing reasons for traffic accidents. It is estimated that between 90% and 95% of traffic accidents worldwide are the result of human error (Aniah, 2021; Ahmed *et al.*, 2022). Given the serious and often fatal outcomes associated with risky driving practices, certain behaviours can seem confusing when viewed from a rational perspective. In this context, theories of risky decision-making emphasise the influence of emotions on an individual's actions in dangerous situations (Megías-Robles *et al.*, 2022).

Emotionally agitated drivers may approach hazards with impaired attention and thus – unintentionally or not – engage in reckless driving. Therefore, the tools by which drivers can exercise control over their own emotions and thus prevent risky driving are vital to getting drivers safely from point A to point B. Emotional control over oneself, as well as over others, is imperative in driving situations (Ahmed *et al.*, 2022).

According to Megías-Robles *et al.* (2022), the driver's emotional state is a critical factor in explaining risk-taking propensity. The authors also claim that an adequate ability to perceive, understand, and manage emotions would allow drivers to have better control over their emotional condition and their perception of other road traffic participants. As a result, it would help to reduce participation in risky behaviours and the number of road accidents.

The relationship between emotional intelligence (EI) and driving behaviour is the subject of increasing interest in the aspect of risky and aggressive driving behaviour, especially in the context of young drivers (Aniah, 2021). Drivers' emotions have been found to be among the main factors contributing to dangerous driving behaviour. Emotions can be measured, understood and regulated most effectively through EI.

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To varying degrees, large-scale studies have confirmed the link between EI and dangerous driving behaviour (Ahmed *et al.*, 2022). Emotion affects drivers due to its influence on the degree of self-control, thus also affecting the driving method (Aniah, 2021). A 2019 study also found that people who drive every day have poor EI, which hinders safe driving. The study suggests that training drivers in emotional regulation can contribute to safer roads (Parameswaran and Balasubramanian, 2020).

Taking into account the studies already carried out on the subject, the present study aims to develop an algorithm that will help develop the EI of vehicle drivers. The report is structured as follows: 1) Literature review of studies looking for a link between EI and driving; 2) Presentation of the research methodology; 3) Presentation of the developed model for evaluating and increasing EI; 4) Conclusion.

2 THEORETICAL BACKGROUND

At the end of 2023, the World Health Organization announced that around 1.19 million people die worldwide due to road traffic accidents annually. Road traffic accidents alone are the leading cause of death for children and young people between 5 and 29 years of age (WHO, 2023).

Similarly, in the United States, the National Highway Traffic Safety Administration states that in 2018, more than 2.7 million people were injured, and 36,096 people died in motor vehicle crashes. The data are frightening and show beyond doubt that it is imperative to identify the factors contributing to road accidents and to take measures to reduce them. Such factors may include vehicle defects and environmental obstructions, *i.e.* road and weather conditions, but dangerous driving behaviour also emerges as a significant factor. The latter is defined as any inappropriate driver activity that increases road hazards and the likelihood of a vehicle crash (Ahmed *et al.*, 2022).

At the same time, drivers engage in dangerous driving for a variety of reasons, including fatigue, distraction, and driving under the influence of alcohol or drugs. A number of psychological factors, such as personality traits and emotions, have also been found to contribute to dangerous driving behaviour (Owsley *et al.*, 2003). Research has alerted to the fact that drivers' emotions can particularly strongly influence their destructive driving behaviour. Previous research has also emphasised the correlation between different emotions (e.g., feelings of frustration, anger, and sadness) and aggressive driving (Ahmed *et al.*, 2022). According to Aniah (2021), physiological and psychological variables such as gender, experience, age, and emotions inevitably influence the behaviour of drivers. The author defines driving as a psychomotor ability because it consists of body movement and a cognitive task. This ability can take many forms, but the technique a driver uses depends on their personality and behavioural profile.

In a broad sense, EI is a construct that encompasses all of a person's emotional abilities. In this regard, a number of studies have sought and found a relationship between EI and risky driving behaviour (Ahmed *et al.*, 2022). The results are of varying degrees of certainty due to the existence of different approaches to EI in the literature. The self-report ability model understands EI as a mental ability and focuses on the emotional skills included in a conceptualisation of EI. It uses self-report measures to assess these abilities. The performance-based ability model also views EI as a set of emotion-related abilities but assesses them using performance-based tests. Finally, the mixed model conceptualises EI as a broad construct combining both emotion-related skills and personality factors that are evaluated through self-report instruments (Megías-Robles *et al.*, 2022).

The primary motivation to look for a link between EI and driving is that it is the driving style of many drivers that is responsible for the significant number of accidents that occur (Aniah, 2021). The results of a study by Megías-Robles *et al.* (2022) found that higher self-reported EI, especially the ability to regulate emotions, was associated with a lower propensity for risky driving. According to the authors, emotion regulation and evaluation of the emotions of others are EI abilities that may predict the number of potential accidents. EI, which is explained as a person's ability to recognise, identify, use, express, as well as regulate their own and others' emotions, has been empirically proven to influence driving behaviour (Aniah, 2021).

Such a conclusion is hardly surprising to anyone. Emotions are a fundamental part of human behaviour – they guide an individual's attention, memory, motivation, and even decision-making process. In risky contexts, however, emotions are essential, given the time (momentary) pressure and substantial emotional consequences these situations often involve. The integration of emotional factors in the processing of risky behaviour has also been demonstrated at the neural level, including in the context of driving (Hernandez *et al.*, 2014). Driving is an activity in which emotions often arise – traffic jams, accidents, risky traffic participants, *etc.* – all these situations can cause fear, as well as retaliatory aggression, intolerance, and dangerous behaviour. In many cases, these emotions underlie human behaviour, but their consequences in risky driving are particularly significant (Megías-Robles *et al.*, 2022).

There is no doubt that emotion can arise at any particular moment while driving and can have a different emotional impact on the driver's behaviour. Therefore, various emotional states can affect driving differently because people differ in how they react to situations. This makes emotional control of self and others imperative in driving conditions (Owsley *et al.*, 2003).

Aniah (2021) opined that driving behaviour is usually a pattern chosen by the driver himself. Therefore, it is argued that the specific style and skills that a motor vehicle driver applies at a given place and time are strongly influenced by his emotions and the relationship between *stimulus and response*. The link between stimulus and response, or rather the *bridge* between them, represents the individual's EI.

The above gives reason to generalise that drivers with reported higher EI scores engage in less dangerous driving, which is reflected in fewer crashes and fatalities. Therefore, as reported by Ahmed *et al.* (2022), promoting and improving EI can be helpful in preventing risky driving among non-professional drivers. Incorporating EI training into driver training, on-the-job training, and licensing procedures can help develop safer drivers.

The problem with this type of evaluation of EI and training is the human factor, *i.e.* the private interest or the subjective opinion of the trainer, which can be a prerequisite for intentional or unintentional mistakes and corrupt practices in such an essential field as road safety. With the help of large language models and the incorporation of AI during the learning stage of driving for young adults, it can be very beneficial for them to be assessed and trained based on their EI. Their behaviour can be evaluated and then compared to "ideal" behaviour, which can help them nip the negative traits in the beginning stages before passing their driving test and becoming experienced drivers. Such negative behaviour is challenging to be subjected to change, if not impossible, after years and years of driving experience.

That motivated the authors of the present study to develop a prototype model based on AI that would balance, without removing, the human factor and minimise the associated risks. In addition, a central place in the developing AI model is precisely the emotions and, more specifically, the ability of the individual to recognise (empathy) and regulate (self/control) both his own and others' emotions. The key thing about these two elements is that, although worded differently, they are involved in the different models of EI, which makes them generalisable to the EI personality.

3 METHODOLOGY

The methodology of the study includes three main stages: *1) Literature review* (introduced in the section "Theoretical background"), *2) Determination of assessing variables* (described in the section "Methodology", and *3) Explanation of the construction of the developing AI model* (described and analysed in "Results" and "Discussion" sections): elements selection, model structure, action algorithm, process analysis.

Based on the theoretical analysis, the research methodology introduces three *basic variables*, which, with the help of information and communication technologies (ICT) and human control, will be prioritised for research, analysis and improvement: emotion regulation or *self-control (x)*, emotion recognition (in others and self) or *empathy (y)*, and evaluation of the *EI as a construct (z)*.

The measurement and evaluation of *variable z* will follow one of the three schools of EI: cognitive ability, personality trait, or mixed model. The choice is yet to be refined and validated. Based on the selected overall construct, *additional variables* will be introduced, such as self-knowledge or social skills (elements of the mixed EI model).

The need to introduce baseline variables in the first place is justified by existing research on the subject of the relationship between the baseline variables specified and the driving pattern applied by the individual. Implementation of additional variables will look for underestimated or so far neglected correlations between EI components and driving behaviour. At this stage, these variables are not built into the model and its algorithm.

The developed AI model is tied to risky driving, which is why the algorithm will look for correlations between the basic and potential additional variables introduced so far and the characteristics of the motor vehicle driver identified in the background literature, influencing the genetic driving style. These *key variables* are: *aggression (a)*, *intolerance (b)*, and *risk-taking (c)*.

An interdisciplinary team of Bulgarian university scientists with expertise in management, risk management, entrepreneurship, social sciences, and ICT participated in developing the methodology and AI model. The goal is to specify as much as possible the main elements of the model, the algorithm, and the overall process from development to implementation and validation of the AI model.

4 RESULTS

From the perspective of the ICT that build the model's algorithm, the research introduces a toolkit of three technologies: artificial intelligence (AI), virtual reality (VR), and blockchain technology (BT). Table 1 describes the need for their applicability.

Table 1: Type and applicability of implemented ICT. Source*:* own development.

Technology	Applicability
Artificial Intelligence (AI)	Definition: It focuses on the creation of intelligent agents, *i.e.*, systems capable of perceiving their environment, reasoning, and acting to achieve specific goals. AI models strive to mimic and sometimes even surpass human cognitive abilities such as learning, problem-solving, pattern recognition, and natural language understanding (Antonova *et al.*, 2021; Gignac & Szodorai, 2024). Applicability: AI models can analyse large amounts of data faster and more accurately than human raters. At the same time, in big data sets, AI models can detect complex patterns that are difficult or even impossible for humans to spot. In addition, while there is still debate about their accuracy, AI models also offer greater objectivity. They are less susceptible to subjective bias, which reflects in more objective results. These two advantages, along with automating the evaluation process and saving time and resources, make AI models an adequate substitute for human resources.
Virtual reality (VR)	Definition: VR is a technology that creates immersive and interactive environments that simulate real or imagined scenarios. VR users wear headsets that display 3D images and sounds and sometimes use controllers or gloves to interact with the virtual world. VR can create realistic and engaging experiences that can stimulate emotions, thoughts, and behaviours (Susindar *et al.*, 2019). Applicability: Well-developed EI is largely believed to result from an individual's experience, which is why parallels between EI and wisdom are often sought and found. Through VR technology, the participant will be placed in situations that mimic real life and are known to help develop EI competencies.
Blockchain Technology (BT)	Definition: A distributed database that records transactions in a way that is secure, transparent, and resistant to change. Information in the blockchain is organised into blocks that are linked together by cryptographic hashes. Once added, information on a blockchain is virtually impossible to change, making it highly reliable. This technology is decentralised, meaning there is no one central authority to control the network. Instead, blockchain networks are managed by multiple computers, making them resistant to censorship and manipulation (Tripathi *et al.*, 2023). Applicability: Implementing the BT on the AI model is necessary to preserve the confidentiality of each training participant's data. Personality test results do not constitute medical information by themselves. However, the fact that they provide personal and sensitive information for the individual requires a more serious commitment to their preservation.

The developed model for increasing the EI of drivers is based on three AI models: machine learning, deep learning and natural language processing, and more specifically:

1) *Machine Learning: Classification, Regression, Clustering*

The classification will serve to classify participants' responses into different personality types or traits, such as "extroverted" or "introverted." Regression will be applied to predict the values of the entered (baseline, additional, and key) variables related to the learner's personality. Clustering will be applicable when grouping participants with similar personality profiles.

2) *Deep Learning: Neural Networks, Recurrent Neural Networks*

Neural networks will simulate the workings of the human brain and can detect complex patterns in data. They are used for natural language analysis, pattern recognition and processing large amounts of unstructured data. Recurrent neural networks, on the other hand, are suitable for analysing sequential data, such as text responses to questions in personality tests. They can pick up on contextual information and extract deeper meanings.

3) *Natural Language Analysis: Sentiment Analysis, Keyword Extraction, Semantic Content Analysis, Personalised Recommendations*

AI models will be used to analyse large amounts of text responses to personality test questions to identify keywords, phrases and emotional responses that are characteristic of certain personality traits. In some cases, AI models will operate to analyse facial expressions, gestures and other non-verbal signals to gain additional information about an individual's personality. As a result, AI will create personalised recommendations for an individual's EI development based on test results, as well as for the virtual experiences that will be most relevant to the object, subject and purpose of the learning.

Figure 1 presents the algorithm of the developed AI model. The whole process is divided into *four main Stages*: *I)* Measurement and evaluation of the introduced *basic (x, y, z)*, *key (a, b, c)* and *additional variables*; *II)* Verification of the results obtained by a person*; III)* and *IV)* Depending on the results of *Stage II* – respectively unsatisfactory or satisfactory from the point of view of human evaluation, in the next stage either a human specialist makes a new measurement and evaluation of the variables, or the AI determines the virtual experience that the object to be subjected to.

The model introduces *four working agents*: *(A)* – learner, *(B)* – training/evaluating AI, *(C)* – training/assessing/supervising specialist persons, and *(D)* – AI-defined the virtual experience. In *Stages I* and *III*, blockchain encryption of the data generated from the tests to measure the sought variables was introduced. This, as stated at an earlier stage, is imperative from the point of view of the object's confidentiality and to protect its data. The results of such tests, if publicly available, may have an adverse impact on an individual's personal and professional development in the future. Also, blockchain technology will neutralise the possibility that the records of the results can be tampered with and manipulated.

The role of virtual reality, on the other hand, is to act as an imaginary learning environment, where learning does not mean learning phrases or behavioural responses (Han & Lorenzo Najord, 2024). On the contrary, the goal is a rapid accumulation of life experience, but in a protected (virtual) environment, with this experience directly related to developing the basic variables – self-regulation and empathy, and reducing the key variables – aggression, intolerance, propensity to risk. In fact, in virtual reality, the individual will be trained to respond most effectively to the *stimulus-response* interdependence that Aniah (2021) also talks about. This effective response is due to a developed EI capability.

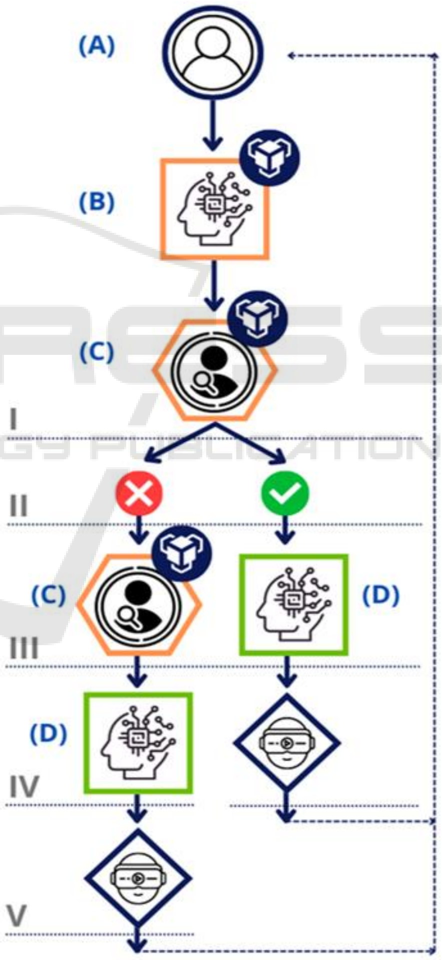

Figure 1: Working algorithm of the developed AI model for evaluating and improving the EI of motor vehicle drivers for safer roads. Source*:* own development.

In their study, Susindar *et al.* (2019) demonstrate that the use of VR can be an effective emotion-inducing method when investigating emotion-influenced decision-making. As stated in the theoretical background, this is highly inherent to drivers of motor vehicles who are daily exposed to emotionally arousing situations and have to make immediate decisions and respond to the stimulus-response relationship according to their momentary mood. Susindar and his co-authors' research focused on extracting and generating situations that evoke fear and anger – emotions that drivers also face on the road. At the same time, the authors of the cited study add that it is not entirely clear how the virtual environment affects performance (or learning) and the degree to which emotions are evoked. This means, on the one hand, that it is not categorically clear whether an individual would react in the same way in a real and virtual environment and, on the other hand, that more in-depth research is needed in this direction. However, the latter in no way belittles VR technology capabilities, as evidenced by similar studies on the topic (Marques *et al.*, 2022; Mancuso *et al.*, 2023; Hariyady *et al.*, 2024).

Considering the rapid growth of technology in every aspect, people are more and more concerned about how to improve user experience rather than the construction of the experience itself. Giving people the opportunity to experience this in virtual reality would allow them to see their mistakes and correct them in their free time in a safe environment, making them better on the road without the risks of actually being there. This would help them improve their EI time and time again, improving the quality of their driving skills, thus improving the overall quality of driving for the other drivers on the road around them.

As the graph (Figure 1) shows, the process does not stop after the learner's experience in virtual reality. New measurements and evaluation of the basic variables, as well as the additional and key variables adopted in the Methodology, are needed. Therefore, the algorithm starts again from *Stage I*. The subsequent steps, *i.e.* whether to stop or continue training, depend on the evaluation of agents B and C and the decision of agent B. Realistically, the process of increasing EI may never stop and even apply to refresher driving courses (similar to the periodically conducted psychological tests) of experienced drivers of motor vehicles.

Although still unproven categorically, some EI researchers believe that this ability and its inherent competencies have the potential to develop positively over time, one of the reasons being precisely the accumulated life experience. The AI model developed and presented in the present study is based precisely on the statement that EI can be developed and that it undergoes evolution with age (Gilar-Corbi *et al.*, 2019).

5 DISCUSSION

When analysing the algorithm, the logical question arises: What necessitates human monitoring and control of the evaluation of the AI model? Conversely, if this activity is entirely within a human's capabilities, why is it necessary to introduce the use of AI?

First of all, the potential of AI to process vast amounts of data at a speed beyond the reach of a human being has already been repeatedly tested and proven. However, not only is speed essential, but so is the refinement of the results. Subjectivity and unintentional omissions in data analysis are human. But the same goes for imperfect (yet) AI, which, like its creator, is also not immune to biases and errors in its algorithm. In fact, the AI model being developed to increase the EI of drivers shows precisely how natural and artificial intelligence should collaborate – in a balanced synergy, but also with a good-natured mistrust of the abilities of one or the other.

On the other hand, it is essential to note that AI models cannot and are not expected to replace human raters. In the overall model, the human factor is equal to the involvement of AI. This further justifies the intervention of blockchain technology in the algorithm. The encryption of the data from the conducted tests and training will guarantee the confidentiality and objectivity of the process. Therefore, AI models should be used as an additional tool to justify and support decision-making. To ensure the validity and reliability of AI-based test results, careful validation studies need to be conducted.

Attention to detail throughout the process is significant as irreparable damage can be done to the learner's psyche, which is not the purpose of the AI model. It is extremely crucial to create and apply the "training" in virtual reality according to the test results of the entered variables. A hypersensitive person would accept such experiences in one way, and a more selective individual in his feelings would have a radically different perception of what is happening. Therefore, every AI-proposed and human-approved virtual learning environment in EI must be perfect and maximally adapted to the personal qualities of the respective learner.

It is equally important to explain why the basic variables, such as empathy and self-regulation, are set in the algorithm rather than examining only the EI construct as a whole. Or why the general construct EI is asked at all, and not only the connections between empathy and self-regulation of motor vehicle drivers and their aggressive and angry behaviour that puts them in risky situations are investigated. As stated earlier, self-regulation and empathy are part of the general EI construct. Although in the pilot presented AI model, as well as numerous other studies, they are studied as independent competencies, in reality, it is not possible to fully develop these two abilities without the other EI competencies, regardless of which of the three EI models will be followed. For example, the mixed model includes self-regulation and empathy, as well as self-knowledge, motivation, and social relationships. Goleman himself, one of the creators of the model, points out that it is not possible to achieve self-regulation without self-awareness since each of the sub-competencies of self-management steps on self-awareness (Goleman and Chernish, 2023). This necessitates the study, evaluation and improvement of the general EI construct by examining the construct's constituent components separately, *i.e.*, it is crucial to approach the problem deductively.

Limitations of the Study

A significant limitation of the study and the introduced model is the lack of definitive data on the effectiveness of some of the applied ICT. The analyses and tests carried out so far are scarce, and the results are contradictory. Therefore, the application of the described technologies does not guarantee the desired result.

Another limitation of the study is the lack of data from the practical application of the developed model. The presented model is purely theoretical and has not been validated empirically, which limits the ability to conclude its reliability and predictive validity. To overcome this limitation, it is necessary to conduct an empirical study in which the model is tested on a large and heterogeneous sample of participants. The formed interdisciplinary team needs to conduct considerable research and testing in this direction, but the model aims to make a start.

On the other hand, implementing such an algorithm in a seemingly state-controlled but apparently private-interest-dominated environment, such as driving schools, requires considerable will and agreement from multiple (dis)interested parties. In this sense, just creating the AI model is not enough. Therefore, the author collective's future efforts will be directed to the experimental introduction of the model and the search for validation of the algorithm and the expected results.

Applicability

The goal of the research team is to apply the algorithm as a priority in the courses for acquiring driving skills. It is an environment in which the individual most actively reveals himself – as more aggressive, more intolerant, more selfish or vice versa. Bulgaria is first in the EU in terms of road deaths in 2023. The European Commission published preliminary data for last year – the EU average is 46 deaths per million inhabitants. In Bulgaria, the ratio is 82 victims per one million inhabitants (Apostolova, 2024). In this sense, the developed AI model is expected to lead to significantly greater self-awareness and self-regulation of their own emotions in both inexperienced and seasoned drivers on the roads.

At the same time, the developed AI model can also be used in a number of other areas where weak self-regulation of emotions leads to conflict situations or where reducing the levels of aggression is necessary. The results of the implementation will validate the results and allow the model to be embedded in educational programs and its application in the fight against hate speech, intolerance of differences, selfishness, cruelty to the weaker, *etc.* This will be the subject of future research by the authors.

6 CONCLUSION

Death on the roads as a result of serious road traffic accidents is one of the saddest facts of our time, which we must either accept or overcome. Over 1 million people die on the road, not a small number of them children and young people. The purpose of the developed AI model to increase the EI of drivers is precisely this – fighting statistics, risky driving, but above all, saving lives before they are even in danger.

It is essential to clarify that in this "battle", neither EI nor AI is a panacea. The human factor remains a significant unknown, along with the cultural and social characteristics of one or another country. However, suppose it is almost impossible to change the cultural and social conditions. In that case, only the way in which the individual responds to the *stimulus-response* relationship is within his capabilities.

In conclusion, the developed AI model is a small step towards achieving high EI drivers of motor vehicles and reducing risky behaviour on the road. Although further research and efforts are needed to implement this technology, it is essential to find a way to save human lives and reduce the socio-economic costs directly related to traffic accidents.

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