


VR Virtual Driving Game: Reinventing the Traffic Rules Learning Panorama

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Abstract: In recent years, road traffic accidents have occurred frequently in China, and the traditional driving safety education model has been difficult to meet the actual demand due to the problems of single form and poor training effect. To cope with these challenges, this study builds an innovative driving simulation safety education system with the help of virtual reality (VR) technology, combined with the theory of man - made traffic accident factors. Based on the Unity3D engine, the system builds a virtual scene based on real road data and realizes traffic flow simulation by using SUMO, which highly reproduces the driving environment and behavior with VR technology. Through the collision detection mechanism, the system sets up violation triggering conditions, adopts customized screen space rendering method to simulate the driver's vision, builds image - based 3D panorama of the accident scene, and cultivates safe driving habits from the cognitive and perceptual perspectives. After actual testing, the system can conduct driving simulation and safety training under different roads, weather and traffic conditions, effectively stimulating the user's enthusiasm for learning and enhancing the awareness of driving safety, which is of high practical value and in line with the conclusion that VR immersive training is more effective in enhancing the user's participation and knowledge memory. In the future, with the continuous innovation of technology, this kind of system is expected to play a more critical role in the field of traffic rules learning.

1 INTRODUCTION

In modern society, the number of automobile ownership continues to grow rapidly, and road traffic safety problems are becoming more and more prominent. In China, the high incidence of traffic accidents has become one of the social concerns. These accidents not only cause a large number of casualties and property losses, but also have a serious negative impact on social harmony and stability. According to relevant statistics, the number of casualties caused by traffic accidents remains high every year, and the economic losses are huge. Traditional ways of learning traffic rules, such as classroom theory teaching and static graphic publicity, have obvious limitations. These methods lack interactivity and interest, and it is difficult for learners to transform the knowledge of traffic rules into safe behavior in actual driving, resulting in unsatisfactory training results.

With the rapid development of science and technology, virtual reality (VR) technology has emerged. “Song et al. state in ‘Application and Prospect of VR Technology in Automotive Industry’ that VR technology has achieved significant results in automotive design and production training (Song, 2023). Its application experience and development trend in the automotive industry provides a reference for the development of VR virtual driving game in the field of learning traffic rules, which helps to promote the innovation of this game in technology and application mode .” With its unique immersive and interactive features, VR technology opens up a new way to learn traffic rules. VR technology can create highly realistic virtual environments, allowing learners to experience various traffic scenarios as if they were there, so that they can understand and apply traffic rules more intuitively. Taheri et al. pointed out that VR driving simulation can effectively measure driver behavior and characteristics (Taheri et al,

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2017), which provides strong support for the application of VR technology to traffic rule learning.

People can see, in previous studies, there has been literature pointing out that traditional driver education methods have difficulties in transforming knowledge into actual driving skills, which makes it difficult to meet the needs of realistic traffic scenarios. At the same time, some studies have emphasized the potential of VR technology in the field of education, arguing that it can provide a more vivid and interactive learning experience. There is also literature that analyzes existing VR driving simulation games and finds that although these games have made some progress in scene simulation, they still need to be improved in terms of the depth of traffic rule education and the evaluation of their effects.

Therefore, this study aims to explore how VR virtual driving games can reshape the learning mode of traffic rules, and ultimately achieve the goal of reducing traffic accidents by strengthening learners' understanding of and compliance with traffic rules.

Specifically, this study focuses on the following key elements: exploring the unique advantages of VR virtual driving games in traffic rule learning compared with traditional learning methods; exploring the methods of designing efficient VR virtual driving games to achieve efficient traffic rule learning; and analyzing the challenges and limitations of this new learning method in the process of actual promotion and application.

Based on the Unity3D engine, the system builds a virtual scene based on real road data and realizes traffic flow simulation by using SUMO (Hu et al, 2022). Jin et al. (2024) pointed out in 'Research on automobile virtual simulation training platform based on VR technology' that when constructing virtual scenes based on VR technology, Unity3D engine can effectively integrate multiple resources and optimize scene details. This provides technical support for this paper to utilize this engine to build virtual driving scenes, further verifying the feasibility of this method. Which highly reproduces the driving environment and behavior with VR technology. Through the collision detection mechanism, the system sets up violation triggering conditions, adopts customized screen space rendering method to simulate the driver's vision, builds image - based 3D panorama of the accident scene, and cultivates safe driving habits from the cognitive and perceptual perspectives. "The virtual reality-based simulation training method and system for power plant safety driving proposed by Southern Power Grid FM Power Generation Company (2021) in A virtual reality-based simulation

training method and system that employs similar collision detection and scenario simulation techniques for power plant safety driving training. The application of this patented technology provides a practical reference for the functional design of the VR virtual driving game in traffic safety education in this paper, and verifies the effectiveness of these technologies in training scenarios." After actual testing, the system can conduct driving simulation and safety training under different roads, weather and traffic conditions, effectively stimulating the user's enthusiasm for learning and enhancing the awareness of driving safety, which is of high practical value and in line with the conclusion that VR immersive training is more effective in enhancing the user's participation and knowledge memory. In the future, with the continuous innovation of technology, this kind of system is expected to play a more critical role in the field of traffic rules learning. "Kiran et al. (2024) in 'Accelerating autonomous vehicle safety through Real-Time Immersive virtual reality gaming simulations'. immersive virtual reality gaming simulations to enhance autonomous vehicle safety. The simulation techniques and ideas in this study provide a reference direction for VR virtual driving games to achieve more realistic and efficient simulation in traffic rule learning, which helps to further explore the potential of VR technology in this field.

To explore these issues in a comprehensive and in - depth manner, this paper first conducts a systematic review of related literature. By sorting out the current status and research results of VR technology in education, especially in the learning of traffic rules, the hotspots and shortcomings of the current research are clarified. Then, the research methods used in this study are elaborated in detail, including case analysis of existing VR virtual driving games, user experience research, and data collection and analysis methods. After completing the data collection and analysis, specific research results will be presented and an in - depth discussion will be conducted with these results. The discussion will include the conclusions, innovations, shortcomings of the study, and the outlook on the future research direction.

2 THE IMPACT OF VR DRIVING GAMES ON TRANSPORTATION

VR virtual driving games are revolutionizing the way traffic rules are learned. Traditional methods of

learning the rules of the road, such as classroom lectures and static pamphlets, have long been plagued by a lack of interactivity and limited engagement. In contrast, VR virtual driving games offer a dynamic and immersive experience.

These games create highly realistic virtual driving environments that approximate real-world scenarios. For example, they can accurately reproduce the layout of city streets, including traffic lights, crosswalks, and other vehicles. Highways and mountain roads can also be faithfully reproduced, including the unique challenges each road condition presents, such as high-speed traffic on freeways and sharp turns on mountain roads. This allows learners to experience different driving conditions first-hand, far more effectively than simply reading about them.

In addition, VR virtual driving games incorporate elements such as weather changes and day/night cycles. Rain, snow, fog, and glare all affect real-life driving conditions, and these games can simulate these effects. The day/night cycle further adds to the realism, as driving at night requires different skills and awareness of traffic rules. By experiencing these variations, participants can better understand how traffic rules apply in different situations.

The interactivity of VR games also plays a crucial role. Learners are not passive recipients of information; instead, they actively participate in the virtual environment. When they violate traffic rules, the game can provide instant feedback, such as warning sounds or pop-up messages. This real-time feedback can help learners correct their behavior and reinforce their understanding of the rules. In addition, the ability to freely navigate the virtual world and make driving decisions gives learners a sense of agency, making the learning process more engaging and memorable.

VR - based learning models for traffic rules learning are still in the early stages of development. Currently, most VR virtual driving games integrate traffic rules into the gameplay in a rather basic way. They typically present traffic rules as simple instructions or tasks, such as "stop at the red light" or "yield to pedestrians." However, this approach lacks depth and fails to fully utilize the potential of VR technology.

A more effective VR - based learning model should be grounded in educational psychology and cognitive science theories. For example, the constructivist theory emphasizes that learners construct knowledge through their experiences. In the context of VR - based traffic rules learning, this means creating scenarios where learners can actively experiment with different driving behaviors within

the boundaries of safety and observe the consequences. For instance, in a virtual intersection, learners could be given the opportunity to test different ways of yielding to other vehicles and pedestrians, and then reflect on how their actions comply with traffic rules.

Another important aspect is the use of gamification elements. Incorporating rewards, levels, and challenges can make the learning process more motivating. For example, learners could earn points for correctly following traffic rules, and these points could be used to unlock new driving scenarios or vehicles. Levels could be based on the complexity of the traffic situations, starting from simple scenarios and gradually progressing to more challenging ones.

Furthermore, the VR - based learning model should consider the individual differences of learners. Piaseczna et al. in *Driving Reality vs. Simulator: Data Distinctions*, provide an in-depth analysis of the data differences between driving reality and simulators (Piaseczna et al., 2024). It was found that simulators fall short of reality in terms of physical simulation and driver physiological feedback for certain complex driving scenarios. This reveals that we need to pay attention to these differences when utilizing VR virtual driving games for traffic rule learning in order to better translate game learning into real-world driving. "Some learners may be more visual, while others may prefer auditory or kinesthetic learning. VR technology allows for the customization of the learning experience to meet these different needs. For example, visual learners could benefit from more detailed visual cues in the virtual environment, while auditory learners could have additional voice - overs explaining the traffic rules.

3 RESEARCH APPROACHES AND LITERATURE INSIGHTS

Research Methodology and Literature Review: This study synthesizes a variety of research methods to comprehensively analyze the application of VR virtual driving games in the learning of traffic rules. In the case study section, several representative VR virtual driving games on the market are carefully selected, and analyzed in depth from multiple dimensions, such as the architectural design of the game, the ingenious integration of traffic rules, and the feedback of users' actual experience during the game. Through the detailed study of these cases, we not only summarize the advantages of the current VR virtual driving games in enhancing user participation

and simulating real driving scenes, but also excavate the problems in the depth of rule education and interactivity design, etc. We corroborate the results of these analyses with the subsequent analysis of the literature in order to have a more comprehensive understanding of the current situation in this field.

In terms of user experience research, a combination of questionnaires and field interviews was used. The questionnaire survey covered user groups of different ages, genders, driving experiences and other backgrounds, and extensively collected information on their overall satisfaction with the game, their actual gains in terms of the learning effect of traffic rules, and their specific suggestions for the improvement of the game. At the same time, field interviews were conducted with some representative users to gain a deeper understanding of their emotional experience during the game, the operational difficulties they encountered, and the dynamic process of changing their understanding of traffic rules. These findings will provide strong user feedback support for the subsequent analysis of the effects of VR virtual driving games in practical applications, and complement each other with the literature analysis and technical level research to jointly build up a comprehensive understanding of the application of VR virtual driving games in the learning of traffic rules.

In the literature review section, the development history and application status of VR technology in the field of education are sorted out. It is found that VR technology has achieved remarkable results in medical education, engineering training and other fields, but its application in the field of traffic rules learning is still in its infancy. Existing research mainly focuses on the technical realization of VR driving simulation, scene construction and preliminary exploration of educational applications. However, no systematic theories and methods have been developed on how to deeply integrate traffic rule education with VR game design and how to assess the learning effect of learners in the game.

From the technical level, VR virtual driving games involve a variety of key technologies. Ma et al., in 'Design and realization of virtual driving system based on VR technology' (Ma et al., 2023), also used the Unity3D engine to build a virtual driving system, detailing the use of the engine to implement the scene interaction and physical simulation, and their research results provide practical experience and technical details reference for the technical realization of the system in this paper." For example, the Unity3D engine is utilized for the construction of virtual scenes, which provides a

wealth of features and tools to quickly create realistic road, vehicle, and environment models. As Hu Shengming et al. point out, utilizing Unity 3D for electricThe design of electrical fault simulation of a moving vehicle, the technical principle of which is similar to the construction of a VR virtual driving scene (Hu et al, 2022). Meanwhile, the traffic flow simulation is combined with SUMO to make the traffic situation in the virtual scene more realistic and dynamic. In terms of simulating the driver's vision, the screen space rendering method with custom coding can accurately simulate the driver's field of vision and visual experience in different driving scenarios. In addition, the violation triggering mechanism established based on the collision detection principle can monitor the driving behavior of players in real time and give corresponding hints and feedback when violating traffic rules.

In terms of educational models, there is a lack of educational models of traffic rules specifically for VR virtual driving games. Most games simply incorporate traffic rules into the game tasks, lacking systematic and targeted educational design. Future research needs to combine the theories of educational psychology and cognitive science to build a more scientific and effective educational model to enhance the effect of learning traffic rules.

Literature Analysis: The in - depth analysis of the existing related literature helps to comprehensively understand the development trend of VR virtual driving games in the field of traffic rules learning, clarify its potential and limitations, and provide a solid foundation for subsequent research. In this part, we will discuss the application advantages, existing problems, effect evaluation and other aspects.

4 EXPLORING THE PROMISING ASPECTS OF VR - DRIVEN TRAFFIC RULE LEARNING

4.1 Application Advantages

VR virtual driving games show certain application potential in the field of traffic rules learning. From the application cases, some VR virtual driving games have successfully attracted the attention of learners and significantly increased their interest in learning. For example, a certain game has carefully set up a rich variety of driving scenarios, covering city streets, highways, mountain roads, etc. This enables learners to drive in different environments. This enables

learners to practically experience and apply traffic rules in different environments. At the same time, the weather changes, alternating day and night and other elements incorporated in the game further enhance the realism and interest of the learning process, creating an immersive learning atmosphere for learners, which helps them to understand more deeply the application of traffic rules in different contexts. Moreover, the intuitive feedback in these games about rule - following or breaking helps learners quickly correct misunderstandings.

4.2 Existing Problems

Despite the many advantages of VR virtual driving games, there are also obvious shortcomings. In terms of traffic rule explanation, many games are deficient. Learners often just passively follow the rules during the game, and lack in-depth understanding of the principles and importance behind the rules. Taking traffic signals as an example, most games simply prompt players to stop or pass without explaining in depth the origin and significance of the signal rules. This shallow presentation of rules is not conducive to learners building a complete knowledge system of traffic rules, and it is difficult to transfer the application of rules in the game to actual driving scenarios. For instance, learners may not understand why a particular lane - changing rule exists, leaving them confused when faced with real - world driving situations.

4.3 Lack of Interactivity and Interestingness

The interactivity and interestingness of the game also need to be further improved. The operation interface design of some games is complicated, which increases the operation difficulty of learners and affects the game experience. At the same time, the tasks lack challenge and attraction, which cannot fully stimulate learners' enthusiasm for participation. For example, some game tasks are monotonous and repetitive, lacking changes and novelty, leading to learners' easy boredom and low participation. This situation restricts the effect of VR virtual driving games in the learning of traffic rules, and fails to make full use of its technical advantages to enhance the learning effect. Additionally, the lack of social interaction elements in these games means learners miss out on the opportunity to discuss and learn from others' experiences.

4.4 Effect evaluation status and improvement direction

In terms of the effect assessment of VR virtual driving games, the existing literature exposes obvious deficiencies. Currently, most studies only assess learners' mastery of traffic rules through simple questionnaires or tests, which is too single - minded and lacks an in - depth analysis and evaluation of the learning process. Almallah et al. (2021) mentioned the relevant influencing factors in their study of driving simulation motion sickness and sense of presence, which provides a new perspective for us to assess the effect of VR virtual driving games. Future research needs to establish a more scientific and comprehensive assessment system that integrates the knowledge acquisition, skill enhancement, attitude change, and other aspects of learners (Zhao, Huang, 2025). Through the all - round evaluation of the learning process and results, we can more accurately judge the actual effect of VR virtual driving game in traffic rules learning, and provide a strong basis for the optimization and improvement of the game. This comprehensive assessment should also consider real - world driving transferability for more practical insights.

5 CONCLUSIONS

This study conducted a systematic research on the status quo, challenges and innovative solutions of VR virtual driving games in the field of traffic rules learning. Through case analysis of existing games and user experience research, it is found that VR virtual driving games have great potential in traffic rules learning, and can provide learners with a more immersive and interactive learning experience. However, the development of this field still faces many challenges, including bottlenecks at the technical level, lack of educational theories, and high costs.

To address these challenges, this study proposes a series of innovative solutions, including deep rule - based educational integration, personalized learning experience, and enhanced social interaction functions. These innovative solutions are expected to enhance the effectiveness and application scope of VR virtual driving games in traffic rules learning. The innovation of this study is that it is the first time to systematically analyze the current situation and challenges of VR virtual driving games in traffic rules learning, and propose targeted innovative solutions. In particular, the innovations of integrating in - depth rule education into game design, using artificial

intelligence to achieve personalized learning experience, and enhancing social interaction functions provide new ideas and directions for further development in this field.

However, this study also has certain shortcomings. The main one is the lack of large - scale empirical studies to verify the effectiveness of the innovative programs. Future research can carry out actual user tests to collect more data to evaluate the effectiveness of the innovative solutions, and optimize and improve them based on the test results. Meanwhile, with the continuous development of VR technology, such as the application of 5G technology and the upgrading of hardware equipment, the application of VR virtual driving game in the learning of traffic rules will be more promising. The subsequent research can further explore how to better utilize the new technology to improve the performance and learning effect of the game, and how to combine the VR virtual driving game with the actual driving training to form a more perfect learning system of traffic rules. Additionally, exploring cross - cultural applications of these VR driving games could expand their reach.

REFERENCES

- Almallah, M., Hussain, Q., Reinolsmann, N., & Alhajyasee, W.K.M. 2021. Driving simulation sickness and the sense of presence: Correlation and contributing factors. *Transportation Research Part F: Traffic Psychology and Behaviour*, 78, 180 - 193. <https://doi.org/10.1016/j.trf.2021.02.005>
- Jin, H., Wang, J., Pan, Y., et al. 2024. Research on automobile virtual simulation training platform based on VR technology. *Technology and Innovation*, (22), 54-56+60. DOI:10.15913/j.cnki.kjycx.2024.22.015
- Hu, S., Zeng, Y., Wang, X., et al. 2022. Electric car electrical fault simulation based on the Unity 3d game design. *Computer knowledge and technology*, 19(6), 92 - 93 + 99. DOI:10.14004/j.carol carroll nki CKT. 2022.0296
- Kiran, A., Salunkhe, S.S., Srinivas, B., Vanitha, M., Altaf Ahmed, M., & Venkata Naga Ramesh, J. 2024. Accelerating autonomous vehicle safety through Real - Time Immersive virtual reality gaming simulations. *Entertainment Computing*, 50, 100674. <https://doi.org/10.1016/j.entcom.2024.100674>
- Ma, K., He, Z., & Li, C. 2023. Design and realization of virtual driving system based on VR technology. *Technology and Innovation*, (09), 63-65. DOI:10.15913/j.cnki.kjycx.2023.09.018
- Piaseczna, N., Doniec, R., Siciński, S., Barańska, K., Jędrychowski, M., & Grzegorzec, M. 2024. Driving Reality vs. Simulator: Data Distinctions. *Electronics*, 13(14), 2708. <https://doi.org/10.3390/electronics13142708>
- Song, R., Xue, N., & Wang, B. 2023. Application and Prospect of VR Technology in Automotive Industry. *Automotive Digest*, (12), 4
- Southern Power Grid FM Power Generation Co. 2021. A virtual reality - based simulation training method and system for power plant safety driving: CN202110988191.7[P]. 2021 - 11 - 23
- Taheri, S.M., Matsushita, K., & Sasaki, M. 2017. Virtual Reality Driving Simulation for Measuring Driver Behavior and Characteristics. *Journal of Transportation Technologies*, 7, 123 - 132. <https://doi.org/10.4236/jtts.2017.72009>
- Zhao, L., & Huang, J. 2025. Design of virtual interactive educational games based on human perception. *Entertainment Computing*, 52, 100891. <https://doi.org/10.1016/j.entcom.2024.100891>