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Multimodal Interaction Design of HMI for Electric Vehicles in China: A Study to Enhance User Experience

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ABSTRACT

Under the current severe challenges of global climate change and environmental pollution, the rapid development of electric vehicles (EVs) is seen as a key way to achieve sustainable development in the transport sector. EVs not only reduce dependence on fossil fuels and lower greenhouse gas emissions but also bring a new driving experience to users through their advanced technological features. In this transformation process, human-machine interaction (HMI) design plays a crucial role, which directly affects user acceptance and satisfaction with EVs. This study thoroughly analyses the application of multimodal interaction technology in HMI design for EVs, which greatly enriches the user interaction experience by integrating multi-sensory information such as visual, auditory, and tactile senses. We paid special attention to how the multimodal interaction design can enhance user convenience and driving safety, and how it can satisfy the needs of different users through personalized interaction. Through quantitative research methods, we used SPSS software to analyze the experimental data in detail to assess the effectiveness of multimodal interaction design in practical applications. The experimental results reveal the significant advantages of multimodal interaction design in enhancing user experience. Compared with traditional interaction methods, multimodal interaction design not only shortens the time for users to complete tasks and reduces the operation error rate, but also achieves a significant improvement in user satisfaction. These results suggest that multimodal interaction design can provide users with a more intuitive, natural, and enjoyable interaction experience, which is crucial for promoting the popularity of electric vehicles. In addition, the findings of this study provide valuable insights for the future development of HMI design for EVs. With the continuous advancement of technology and the increasing diversity of user needs, future HMI design needs to pay more attention to user-centered design principles and take full advantage of multimodal interaction technologies in order to create a smarter and more personalized driving experience.

Keywords: Electric Vehicles, HMI Design, Multimodal interaction Design, User Satisfaction, User Experience

INTRODUCTION

With the continuous progress of science and technology, Electric Vehicles(EVs) are gradually becoming an important part of the automotive industry (Mohammadi et al., 2023). NEVs not only have significant advantages in terms of energy efficiency and environmental protection, but also show great potential and innovation space in human-machine interaction (HMI) design, which, as a bridge between the driver and the vehicle, is crucial for enhancing the driving experience, guaranteeing driving safety, and improving the functionality of the vehicle (Yuan et al., 2015). In this context, multimodal interaction design has become an important research direction in the field of HMI for Electric Vehicles (Wei et al., 2023). Multimodal interaction design refers to the integration of multiple sensory channels, such as visual, auditory, tactile, etc., to achieve a more natural, intuitive, and efficient user interaction experience (Pramuanjaroenkij & Kakaç, 2023). In the context of Electric Vehicles, the application of multimodal interaction design can not only improve the user's operating convenience and driving comfort, but also reduce the driver's cognitive load to a certain extent, and improve driving safety (Jiang & Xu, 2023). With the rapid development of artificial intelligence, the Internet of Things, big data, and 5G, multimodal interaction design has shown a wide range of application prospects in many fields, such as smart homes, mobile devices, and automobiles (Xin et al., 2024). As the world's largest market for Electric Vehicles, China's market characteristics and consumer demands put forward unique requirements for HMI design. Chinese consumers are highly receptive to new technologies and have clear expectations for intelligent and personalized HMI design (Qin & Xiong, 2024). In addition, the rapid development of Chinese new energy vehicle manufacturers in intelligent internet technology provides rich application scenarios and data support for multimodal interaction design (Jiang & Xu, 2023). Therefore, researching and optimizing multimodal interaction design is of great significance to meet the needs of the Chinese market and enhance the global competitiveness of Chinese new energy vehicles.

RESEARCH SIGNIFICANCE

Enhance user experience: As the market for Electric Vehicles continues to expand, user demand for in-vehicle interaction is growing. By integrating multiple sensory channels, multimodal interaction design can provide a more intuitive and natural interaction, thus enhancing user satisfaction and driving experience. Promoting technological innovation: The rapid development of Chinese Electric Vehicles manufacturers in intelligent internet technology provides a technological foundation and application scenarios for multimodal interaction design. This study will promote the innovation and application of related technologies and accelerate the development of HMI design for Electric Vehicles. Satisfy market differentiation needs: Chinese consumers clearly expect intelligent and personalized HMI design. Multimodal interaction design can meet the specific needs of different user groups and provide differentiated competitive advantages for the Electric Vehicles market.

RESEARCH OBJECTIVES

Table 1 *The Research Objectives*

Research Objectives	Content
RO1:	Explore the application of multimodal interaction design and validate the effectiveness of multimodal interaction techniques such as gesture recognition, voice control and haptic feedback to achieve enhanced user experience.
RO2:	Understanding User Needs and Satisfaction: In-depth understanding of the needs of different user groups for multimodal interaction design for electric vehicles, including the acceptance of multimodal interaction technology and the experience of using it.
RO3:	Propose design principles and guidelines: Based on the results of the study, principles, and guidelines for HMI multimodal interaction design for EVs are proposed to provide practical design references for designers and developers.

RESEARCH QUESTION

Table 2 *The Experiment Specific Procedures*

Research Question	Content
RQ1:	How to validate the effectiveness of multimodal interaction techniques such as gesture recognition, voice control and haptic feedback for an enhanced user experience?
RQ2:	what are the differences in acceptance and preference of multimodal interaction technologies in EV HMIs among different user groups (e.g., different ages, genders, and driving experiences)?
RQ3	how to design a flexible multimodal interaction system to adapt to the individual needs of different users and different driving situations?

RESEARCH HYPOTHESIS

Table 3 *The Specific content of the Hypothesis*

Hypothesis	Content	Expected Validation Method
H1: Multimodal interaction design will improve task completion efficiency	In an electric vehicle HMI, users using a multimodal interaction design (including gesture recognition, voice control, and haptic feedback) will complete tasks faster than users using only traditional interaction methods (e.g., push buttons and touchscreens).	The volume reached the preset level and there were no missteps during the operation.
H2: Multimodal interaction design will reduce error rates.	Users will make fewer errors when using a multimodal interaction design than when using a traditional interaction.	Record the number of errors made by users when using the two different interaction modes in the experiment and analyze them statistically.
H3: Multimodal interaction design will increase user satisfaction.	User satisfaction ratings for HMIs with multimodal interaction design will be higher than those for traditional interaction methods.	Data will be collected and quantitatively analyze through a user satisfaction questionnaire.

LITERATURE REVIEW

With the rapid development of AI, IoT, big data, and 5G technologies, the intelligence and internet connectivity of electric vehicles have become an important development direction for the automotive industry (Zhou et al., 2022). The application of human-machine interaction (HMI) design in EVs, especially multimodal interaction design, is gradually becoming a key factor in improving user experience. Multimodal interaction design provides users with a richer and more natural interaction experience by integrating visual, auditory, tactile, and other sensory channels. The global electric vehicle market is experiencing rapid growth and innovation. According to a report by the International Energy Agency (IEA), global sales of Electric Vehicless reached 3 million units in 2020, a 41% increase from the previous year. This growth is due to government policy support, technological advances, and consumers' pursuit of environmental protection and new technologies. Especially in Europe and China, the promotion of electric vehicles has been driven by strict emission standards and government subsidies. Multimodal interaction design has become an international research hotspot in the field of human-computer interaction. This kind of design provides users with a richer and more natural interaction experience by integrating visual, auditory, tactile, and other multi-sensory channels. For example, German automakers have improved the ease of use and user satisfaction of vehicle HMIs by integrating advanced touchscreen, voice recognition, and gesture control technologies (Liu et al., 2023). In the US, technology companies have worked with automakers to develop AI-based multimodal interaction systems that enable more personalized and intelligent in-vehicle interactions. Existing research has shown that multimodal interaction can improve user cognitive efficiency and satisfaction. The application of gesture recognition and voice control in HMI has been shown to effectively reduce the cognitive load of drivers. HMI design in China, the world's largest market for electric vehicles, needs to incorporate international trends and the specific needs of local users. Chinese users are more receptive to in-vehicle technology and have a clear need for intelligent and personalized HMI design (Mou et al., 2023). In addition, the rapid development of Chinese EV manufacturers in smart internet technology provides rich application scenarios and data support for multimodal interaction design. In the research of multimodal interaction design, big data visualization interaction, interaction based on sound field perception, mixed reality physical interaction (Hu et al., 2024), wearable interaction and human-computer dialogue interaction are the current hot areas. Research in these areas involves not only the development of interaction technologies but also how to effectively integrate these technologies into EV HMI design to enhance user experience (Wang et al., 2023).

RESEARCH METHODS

This study used experimental methods to verify the effect of multimodal interaction design on task completion efficiency. The experiment was divided into two groups: the experimental group used a multimodal interaction design (containing gesture recognition, voice control and haptic feedback), and the control group used a traditional interaction design (containing only touch screen operation). Task completion time and number of errors were used as the main dependent variables. This section will be from the experimental preparation and experimental content of the two aspects of the experimental design, in the experimental preparation of the experimental participants, experimental materials, and in order to carry out in the formal experiments carried out before the pre-experiment and other parts; experimental content part of the main description of the experiment and experimental content and process. The experimental design is the basis for the successful implementation of the experiment.

EXPERIMENTAL PREPARATION

Participants

A total of 34 subjects were recruited to complete the experiment, the age distribution of the subjects was between 23-30 years old, and the driving experience was between 0.5-10 years. Considering the difference between multimodal interaction and traditional car human-computer interaction, the subjects who were willing to understand and try multimodal human-computer interaction were selected to participate in the experiment. There were 17 undergraduate and graduate students from the design schools of higher education institutions and EV users, 9 male and 9 female subjects; 17 researchers and designers from scientific research institutes engaged in HCI research, 9 male and 9 female subjects respectively.34 The ratio of males to females in the experiment was 1:1, and two of them had software malfunctions during the experiment. Two of the subjects did not complete the experiment because the software they were operating had a malfunction and the data collected were incomplete. At the end of the experiment, a valid sample size of 37 was collected. At the end of the experiment, a valid sample size of 30 was collected, with 16 males and 14 females.

Description of the experiment

Participants were asked to watch the experimenter's interactions and fully understand the operating procedures during the experiment, and to familiarise themselves with the task icons and scene types in the upcoming experiment to avoid interfering with the completion of the main task during the experiment, and to complete the personal information and sign a data confidentiality agreement, so that all the data in the experiment would only be used for research purposes and would not be disclosed to the participants. Before the start of the experiment, the eye movements were calibrated and tested. The experimenter confirmed that the information was complete and answered all questions about the experiment. A ten-minute break was set between the two mini-experiments to allow participants time to relax and prepare for the next experiment. This break also helped to ensure that the participants' state and concentration was not compromised by excessive fatigue, which could affect the accuracy of the results. During each break participants were encouraged to stretch and relax their eyes to maintain their comfort and health.

Experimental Tasks

Experimental tasks are often designed to evaluate and compare the effectiveness, efficiency, and user experience of different interaction modalities. In this particular experiment, the goal was to test the performance of multimodal interaction designs versus traditional interaction designs in an electric vehicle environment. Multimodal interaction designs typically include multiple input modalities such as voice, haptic, visual, and gesture, whereas traditional interaction designs may rely primarily on physical buttons or touch screens. Standardized tasks were designed that required participants to complete the following actions using specified interactions: volume adjustment, navigation settings, climate control, and infotainment system control. Each task was predefined with clear steps and criteria for completion.

Figure 1. *A participant is testing*

Table 4 *The Specific content of the task*

Content	Procedure	Completion Criteria
Volume Adjustment	participants were required to increase or decrease the volume through a specified interaction (e.g., voice command, touchscreen swipe, or physical knob).	The volume reached the preset level and there were no missteps during the operation.
Navigation Setup	the participant must enter the destination, select the best route, and initiate navigation.	The system successfully recognizes the destination, provides route options, and starts navigation.
Climate control	The participant needs to adjust the temperature, wind speed, or direction in the vehicle.	The climate control system adjusts to the specified setting based on the participant's input.
Infotainment system control	the participant must select music, radio stations, or podcasts and adjust the playback settings (e.g. volume, playlist).	The infotainment system plays the selected content and the playback settings match the participant's input.

Experimental Setup

Taking the Aion EV as the experimental equipment, the multifunctional APP and the EV comes with some multimodal interaction functions are used to simulate the key operations of the multimodal interaction design of EVs. The control group uses the touch screen HMI system of the same vehicle. The experimental site is a part of the Guangzhou-Zhaoqing highway with a total length of 10 km.

Figure 2. *Some of the Aion EV on display*

Experimental Procedure

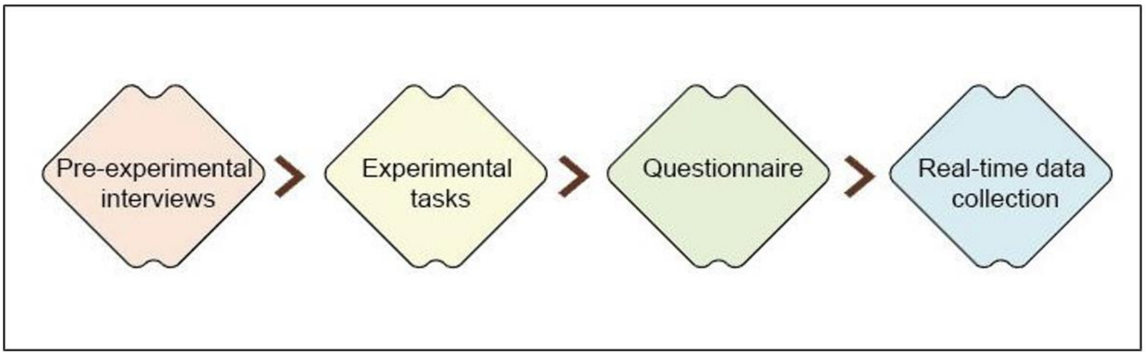

Figure 3. *The Experiment steps*

Table 5 *The Experiment Specific Procedures*

Procedure	Content
Pre-experimental interviews	To understand participants' expectations and prior experiences with EV HMI.
Experimental tasks	Participants were randomly assigned to either the experimental or control group to complete a standardized task using a specified interaction.
Real-time data collection	Participants' completion times and number of errors while performing the tasks were recorded.
Questionnaire	At the end of the experiment, participants were asked to fill out a satisfaction questionnaire to assess their preference and experience with the interaction style.

Pre-Experimental Results and Experimental Improvements

Five subjects with more than one year of driving experience were recruited to participate in the pre-test before the formal experiment. The pre-test involved only the completion of one task, which was required to be repeated three times by the participants, and the experimenters filmed and recorded the whole process of the pre-test through video equipment, and the participants gave their comments or questions about the pre-test after the completion of the experiment, and the experimenters recorded and answered them. The purpose of the pre-experiment was to provide valuable information on the feasibility of the formal study, clarification of precautions, and improvement of experimental methods.

Figure 4. *Some nighttime pre-testing*

Table 6 *The Pre-experimental problems and points for improvement*

Problem Type	Problem Description	Improvement Points
Data collection	Task performance (time to completion) data collection was not uniformly collected	Video equipment was used to record the entire experiment, and time data were collected in a uniformly punctuated manner at a later stage.
Icon perception problems	Unfamiliarity with interface icons	Participants were familiarized with the task content and interface icons before the experiment.
Equipment debugging problems	Software flashback occurs, affecting the overall progress of the experiment.	Reserve time for equipment problems and save experimental data in time.
Seat Height Problems	Uncomfortable for small or tall participants.	Adjust the position of the equipment and seat height to the height of the participant before the experiment.

DATA AND FINDINGS

In the course of conducting the experiment, data are collected in two areas: the time taken to complete the task, and the number of errors made in the course of completing the task. These data will not be used for analysis directly after the experiment, but will first be collated and pre-processed, e.g. removing invalid data, formatting, categorizing, etc. to ensure the accuracy and usability of the data. Once the collation and pre-processing are complete, these data are ready to be used for subsequent analysis. In short, this statement describes what is involved in the collection of experimental data and the process of collating and pre-processing the data at the end of the experiment.

Table 7 *The task completion time*

Groups	**Type of task**	**N**	**Mean(s)**	**SD(s)**	**SE**	***P***
Experimental group (multimodal)	Volume Adjustment	30	45.00	10.23	1.50	0.001
Experimental group (multimodal)	Navigation Setup	30	40.15	8.45	1.24	***
Experimental group (multimodal)	Climate control	30	50.20	12.34	1.83	***
Experimental group (multimodal)	Infotainment system control	30	35.08	9.12	1.35	***
Control group (traditional)	Volume Adjustment	30	60.45	15.21	2.45	***
Control group (traditional)	Navigation Setup	30	65.10	14.11	2.11	***
Control group (traditional)	Climate control	30	70.30	18.23	2.70	***
Control group (traditional)	Infotainment system control	30	55.20	16.34	2.45	***

Table 8 *The normality test*

Groups	**N**	**Shapiro-Wilk test W-value**	**Shapiro-Wilk test P-value**
Experimental group (multimodal)	30	0.96	0.20
Control group (traditional)	30	0.94	0.15

Note: W values close to 1 in the table indicate that the data are closer to a normal distribution, and p-values greater than 0.05 usually indicate that the distribution of the data does not significantly deviate from a normal distribution and that the assumption of a normal distribution can be accepted.

Based on the data analyzed above, the mean task completion time and standard deviation for each group on each task were first calculated. The mean task completion time of the experimental group on all tasks was lower than that of the control group. An independent samples t-test was conducted on the task completion times of the experimental and control groups, Table 8 Secondly, a normality test was conducted on the task completion times of the two groups to confirm that the data distribution conformed to a normal distribution, Table 7 The results showed that the experimental group's completion times on all tasks were significantly lower than those of the control group, with a p-value of less than 0.001, which suggests that the multimodal interaction design significantly improves the efficiency of task completion. Therefore, hypothesis H1 is valid.

Table 9 *The Error rate in completing tasks*

Type of task	Number of errors(times)	Experimental group (multimodal)	Control group (traditional)
Volume Adjustment	0	28/30 (93.3%)	24/30 (80.0%)
	1	2/30 (6.7%)	6/30 (20.0%)
	0	27/30 (90.0%)	3/30 (10.0%)
Navigation Setup	1	3/30 (10.0%)	8/30 (26.7%)
Climate control	0	25/30 (83.3%)	18/30 (60.0%)
	1	5/30 (16.7%)	12/30 (40.0%)
Infotainment system control	0	28/30 (93.3%)	26/30 (86.7%)
	1	2/30 (6.7%)	4/30 (13.3%)

Note: Values in the table indicate the frequency of each error count category, i.e., the number of participants; in parentheses is the frequency or percentage of that error count category, calculated by dividing the frequency by the total sample size (30 participants).

The table shows the number and percentage of participants in the experimental and control groups who made 0 and 1 errors on different tasks. As can be seen from the table, the proportion of participants with 0 errors was higher in the experimental group than in the control group in all tasks, while the proportion of participants with 1 error was lower than in the control group, which suggests that the multimodal interaction design helped to reduce operational errors. Therefore, hypothesis H2 is valid.

Table 10 The Satisfaction in multimodal interactions

Groups	N	Mean	SD	SE	95% (CI)	Shapiro-Wilk test W-value	Shapiro -Wilk test P-value	Levene's test P-value
Experimental group (multimodal)	15	4.20	0.45	0.07	(4.06, 4.34)	0.96	0.20	0.65
Control group (traditional)	15	3.45	0.51	0.08	(3.30, 3.60)	0.94	0.15	

The 95% confidence intervals in the above table indicate that we are 95% confident that the true mean satisfaction falls within this interval. Shapiro-Wilk test is used to assess the normality of the data, a W-value close to 1 indicates that the data are closer to normal distribution, and a P-value greater than 0.05 usually indicates that the data distribution does not significantly deviate from normal distribution. Levene's Test is used to assess the chi-squaredness of the two data sets, a P-value greater than 0.05 indicates that the variances of the two groups are not significantly different, and a t-test can be performed. Variance Alignment, a p-value greater than 0.05 indicates that the variances of the two groups are not significantly different and a t-test can be performed. Based on the experimental data and statistical analyses in Table 10, we can conclude that the multimodal interaction design significantly increased user satisfaction. The average satisfaction of the experimental group is higher than that of the control group, and the p-value of the independent samples t-test is less than 0.001, indicating that the difference is statistically significant. In addition, the results of the normality test and the variance chi-square test support the rationality of using the t-test. Therefore hypothesis H3 is valid, i.e. multimodal interaction design can significantly increase user satisfaction. This finding suggests that the application of multimodal interaction design in EV HMI has significant practical implications for enhancing user experience.

SUMMARY AND GUIDING PRINCIPLES

Based on the findings and data analysis of this study, the following are several strategies to optimize the design of multimodal interactions to further enhance the user experience of EV HMIs:

Table 11 *The Guiding Principle*

Guiding Principles	Content
Personalisation features:	Allows users to customize multimodal interaction settings such as voice commands, gestures, and sensitivity of haptic feedback according to their personal preferences. Feedback is collected through user research to optimize personalization options to meet different user needs.
Optimize interaction feedback mechanisms	Enhance the feedback mechanism of the system to ensure that users receive timely and clear feedback when using multimodal interactions. For example, provide audio and visual feedback in voice recognition and gesture control to enhance user confidence.
Integrate multiple interaction modalities	Integrate multiple interaction modes in the design to ensure that users can flexibly choose the most suitable interaction mode in different situations. For example, while driving, users can choose voice control over touchscreen operation to minimize distractions.

In this study, we systematically explored the application of multimodal interaction design in human-machine interfaces (HMIs) for electric vehicles and empirically tested it against three core hypotheses. Through a series of scientific experimental designs and data analyses, we verified the significant advantages of multimodal interaction design in enhancing the user experience by improving the task completion efficiency, reducing the error rate, and improving the user satisfaction. The following is a summary of the research achievements and contributions:

The first is the improvement in task completion efficiency: the experimental results show that participants with multimodal interaction design completed the given task in a shorter time on average compared to traditional interaction methods. This finding confirms the potential of multimodal interaction design in enhancing the efficiency of user operations. Secondly, the reduction of error rate: by comparing the number of errors in the experimental and control groups, we found that the multimodal interaction design significantly reduced the number of errors made by the users during the operation process and improved the accuracy of task completion. Finally the increase in user satisfaction: the results of the user satisfaction questionnaire show that the user satisfaction scores of the multimodal interaction design are significantly higher than those of the traditional interaction design, suggesting that the multimodal interaction design is able to provide a more pleasurable user experience. This study not only explores the advantages of multimodal interaction design theoretically but also verifies its effectiveness in practical applications through empirical studies, providing a scientific basis for the application of multimodal interaction design. By improving the task completion efficiency, reducing the error rate, and enhancing user satisfaction, this study provides an effective optimization solution for electric vehicle HMI design, which helps to improve the overall user experience. Secondly, this study involves a number of disciplinary fields, such as human-computer interaction, cognitive psychology, industrial design, etc., which pushes forward the in-depth development of cross-disciplinary research and provides new research perspectives and methods for researchers in the related fields.

References

Hu, C., Gu, S., Yang, M., Han, G., Lai, C. S., Gao, M., Yang, Z., & Ma, G. (2024). MDEmoNet: A multimodal driver emotion recognition network for smart cockpit. *2024 IEEE International Conference on Consumer Electronics (ICCE)*, 1–6. https://doi.org/10.1109/ICCE59016.2024.10444365

Jiang, Z., & Xu, C. (2023). Policy incentives, government subsidies, and technological innovation in new energy vehicle enterprises: Evidence from China. *Energy Policy, 177*, 113527. https://doi.org/10.1016/j.enpol.2023.113527

Liu, W., Zhu, Y., Huang, R., Ohashi, T., Auernhammer, J., Zhang, X., Shi, C., & Wang, L. (2023). Designing interactive glazing through an engineering psychology approach: Six augmented reality scenarios that envision future car human-machine interface. *Virtual Reality and Intelligent Hardware, 5*(2), 157–170. https://doi.org/10.1016/j.vrih.2022.07.004

Mohammadi, M., Thornburg, J., & Mohammadi, J. (2023). Towards an energy future with ubiquitous electric vehicles: Barriers and opportunities. *Energies, 16*(17), 6379. https://doi.org/10.3390/en16176379

Mou, L., Zhao, Y., Zhou, C., Nakisa, B., Rastgoo, M. N., Ma, L., Huang, T., Yin, B., Jain, R., & Gao, W. (2023). Driver emotion recognition with a hybrid attentional multimodal fusion framework. *IEEE Transactions on Affective Computing, 14*(4), 2970–2981. https://doi.org/10.1109/TAFFC.2023.3250460

Pramuanjaroenkij, A., & Kakaç, S. (2023). The fuel cell electric vehicles: The highlight review. *International Journal of Hydrogen Energy, 48*(25), 9401–9425. https://doi.org/10.1016/j.ijhydene.2022.11.103

Qin, S., & Xiong, Y. (2024). Differences in the innovation effectiveness of China's new energy vehicle industry policies: A comparison of subsidized and non-subsidized policies. *Energy*, *304*, 132151. https://doi.org/10.1016/j.energy.2024.132151

Wang, Y., Wijenayake, S., Hoggenmüller, M., Hespanhol, L., Worrall, S., & Tomitsch, M. (2023). My eyes speak: Improving perceived sociability of autonomous vehicles in shared spaces through emotional robotic eyes. *Proceedings of the ACM on Human-Computer Interaction, 7*(MHCI), 1–30. https://doi.org/10.1145/3604261

Wei, F., Walls, W. D., Zheng, X., & Li, G. (2023). Evaluating environmental benefits from driving electric vehicles: The case of Shanghai, China. *Transportation Research Part D: Transport and Environment, 119*, 103749. https://doi.org/10.1016/j.trd.2023.103749

Xin, F., Zhang, G., & Huang, Y. (2024). Research on intelligent vehicle cockpit design based on multimodal human-computer interaction technology. *Proceedings of the 2024 International Conference on Digital Society and Artificial Intelligence*, 130–134. https://doi.org/10.1145/3677892.3677914

Yuan, X., Liu, X., & Zuo, J. (2015). The development of new energy vehicles for a sustainable future: A review. *Renewable and Sustainable Energy Reviews, 42*, 298–305. https://doi.org/10.1016/j.rser.2014.10.016

Zhou, X., Williams, A. S., & Ortega, F. R. (2022). Eliciting multimodal gesture+speech interactions in a multi-object augmented reality environment. *Proceedings of the 28th ACM Symposium on Virtual Reality Software and Technology*, 1–10. https://doi.org/10.1145/3562939.3565637