scientific reports

OPEN



The impact of LLM chatbots on learning outcomes in advanced driver assistance systems education

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Our study investigates the efficacy of ChatGPT-assisted learning in enhancing the understanding of Advanced Driver Assistance Systems (ADAS) functionalities, comparing it against conventional paperbased learning methods. By employing multiple-choice questionnaires and the NASA Task Load Index to evaluate comprehension and cognitive load, we aimed to assess the impact of interactive Large Language Model (LLM)-driven learning on knowledge acquisition and learner satisfaction. Our findings indicate that participants who engaged with ChatGPT-based training scored higher (on average 11% higher) in correctness and experienced lower cognitive and physical demands, suggesting a more effective and less stressful learning process. This study contributes by highlighting ChatGPT's potential to accommodate a wide range of learning preferences and improve the comprehension of complex systems or topics. This adaptability was evident across diverse educational backgrounds among young adult participants, showcasing the tool's ability to bridge knowledge gaps more efficiently than conventional methods. Our research advocates the integration of LLM-driven tools in educational and policy-making frameworks to improve the effectiveness of teaching complex systems. This suggests broader applicability and necessitates further investigation into the scalability and effectiveness of ChatGPT-based training across different demographics and learning domains, potentially informing future educational strategies.

Keywords ADAS, AI, ChatGPT, LLM, Mental workload, NASA TLX, Paper-based learning

In modern transportation systems, Advanced Driver Assistance Systems (ADAS) and Autonomous Vehicle (AV) technologies hold immense potential to revolutionise road safety, optimise traffic flow, and enhance accessibility^{1,2}. These systems, including functionalities such as Adaptive Cruise Control (ACC), Collision Avoidance (CA) and Blind Spot Assist (BSA), aim to assist drivers in managing the complexities of different driving tasks, thereby reducing the likelihood of accidents and improving overall road safety³. This potential is particularly critical given that human error accounts for 94% of traffic accidents⁴⁻⁶. The effectiveness of ADAS and AV technologies significantly depends on users' comprehension and proper use of these systems⁷. Current studies reveal a significant underutilisation of these features; only a few drivers consistently use systems like ACC, CA, and BSA⁸. This limited engagement can be attributed to various factors, including a lack of perceived benefits, trust issues, functional limitations⁹⁻¹¹, a lack of legal framework¹², and an absence of user knowledge and experience^{13,14}. This study focuses on ACC, CA, and BSA due to their demonstrated effectiveness in mitigating crash incidents and injuries, as highlighted by empirical evidence. These three functions represent a significant subset of commonly available ADAS features and are frequently the subject of studies having a substantial impact on safety. Specifically, the effective utilization of these three functions can decrease the number of car accidents by up to 89%^{14,15}. The table below demonstrates the manufacturer-specific and common names of these three ADAS functions.

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Educational needs for ADAS and AV

It is crucial to provide drivers with comprehensive education on the capabilities and limitations of ADAS to ensure they are used and monitored safely¹⁶. Current research on ADAS training methods has revealed limitations in conventional approaches, such as owner's manuals and dealership-based instruction^{14,17}. Instruction provided by dealerships faces challenges; for example, sales representatives may lack comprehensive knowledge of each ADAS function^{14,18}. Constraints on time or legal considerations may prevent them from fully explaining all the features¹⁹. Moreover, vehicle owner's manuals are often not designed as educational tools but as technical documents to inform about the system's functionalities²⁰. Furthermore, these manuals are usually extensive and employ technical language, making it difficult for the general public to comprehend their contents²¹. There is no platform for ADAS and AV drivers to safely learn and practice ADAS or autonomous functions, potentially accelerating the adoption rate of these technologies¹⁹. Given the importance of training, an inquiry arises regarding the most effective structure and format for learning these complex and advanced functions. The training of pilots involves a structured process that includes (I) theoretical lessons to understand the technology, (II) operating the technology within a simulation environment, and (III) practising the technology in real-world scenarios²².

Given these challenges, there is an immediate necessity for innovative training methodologies that can adapt to the different learning preferences of users and enable a more profound comprehension of ADAS and AV functionalities. Artificial Intelligence (AI) based training methods, especially those employing conversational agents, present a viable solution. Large Language Model (LLM)-based tools, such as ChatGPT, provide personalised, interactive learning experiences that can adapt to individual user requirements, offering customised explanations and immediate feedback. Recent studies have shown the significant positive impact of LLMs, such as ChatGPT, on education and training across various sectors, including automotive, transportation, aviation, maritime, medical, education, information systems, and construction^{23–33}, and all have evidenced that LLMs can significantly enhance learning outcomes. Recent studies focus on the performance of early-stage scholars, analysing how individual differences and task complexities affect their engagement and efficiency with LLMs. Additionally, they explore user strategies and perceptions, offering insights into the nuanced interactions between young scholars and LLMs. These findings align with broader research demonstrating the potential of LLMs to enhance learning outcomes across diverse fields.

The widespread adoption of ChatGPT illustrates how LLM can quickly alter how we learn and communicate³⁶. These enhancements include providing customised responses, flexible output formats, and motivational benefits in training. The utilisation of AI in training for ADAS and AV is an emerging area of research. In our prior study³⁷, we assessed the effectiveness of ChatGPT as an instructional tool for simulating practical driving scenarios. Our findings indicated that participants trained using ChatGPT exhibited superior performance in activating and deactivating ADAS functions than those taught through conventional methods. Encouraged by these results, the current study pivots towards exploring theoretical learning aspects of ADAS. While these prior studies offer valuable contributions to understanding LLMs, our research diverges by providing a direct comparison between traditional paper-based methods and a ChatGPT-based learning platform, specifically within the context of ADAS education. Our approach is distinct in its empirical methodology that not only assesses cognitive load but also meticulously measures specific learning outcomes related to ADAS technologies. Moreover, our study uniquely explores the differential impacts of these learning methods across diverse demographic groups, with a focus on young drivers, thus adding a critical dimension to the discourse on educational methodologies and their practical implications in enhancing automotive safety.

Cognitive load theory and its implications

Cognitive Load Theory (CLT) provides a valuable framework for analysing the cognitive demands of learning to use complex systems like ADAS and AV. The theory distinguishes between three types of cognitive load: intrinsic, extraneous, and germane. CLT helps in designing training that effectively manages these loads to optimise learning^{38,39}. The NASA Task Load Index (NASA-TLX) has emerged as an established tool to assess the cognitive impact of different instructional methods and environments⁴⁰. The NASA-TLX is a multidimensional scale measuring perceived workload across six dimensions: mental demand, physical demand, temporal demand, performance, effort, and frustration level. This tool allows for a detailed examination of how learning activities influence cognitive load, thereby supporting the optimisation of educational approaches^{40,41}. By applying the NASA-TLX in evaluating ADAS training approaches within the CLT framework, educators and researchers can gain valuable insights into the efficacy of their instructional designs. This integration supports optimising training programs by effectively managing cognitive loads and contributes to a deeper understanding of the cognitive processes involved in learning complex systems. The application of the NASA-TLX across various educational contexts, as documented in studies by^{38,40,42,43}, emphasises its versatility and effectiveness in measuring cognitive load, making it an invaluable tool for enhancing the learning experience in ADAS training.

Our study's approach

In this investigation, we utilised ChatGPT to design an interactive training module to instruct drivers on operating ADAS functions and AV technologies. We tasked ChatGPT to study simulated ADAS and AV manual contents and then to translate them into conversational, interactive dialogues that adapt to user responses. This approach was intended to deliver personalised guidance, address user inquiries, and confirm understanding through targeted follow-up questions, enhancing the learning experience. To maintain the integrity and accuracy of the provided information, the experiment restricted ChatGPT to using only user manual data, excluding access to external knowledge sources. The methodological foundation for this strategy was rooted in instructional design

principles and learning science, aiming to optimise the effectiveness of the ChatGPT-led training sessions. In³⁷, we proposed a comprehensive framework for preparing ChatGPT prompts, designed to enhance instructional content across training domains by integrating general and application-specific principles, with a demonstrated effectiveness in ADAS and AV driver training scenarios. In³⁷, we trained the participants how to operate ADAS and AV functions in simulated AV, and we concluded that participants trained using ChatGPT performed better compared to conventional methods.

However, to our knowledge, no comprehensive study discusses how an LLM-augmented approach can be an effective training tool for teaching theoretical concepts about ADAS or AVs and measuring the user's mental workload. Therefore, In this study, we applied the same general and application-specific principles proposed in³⁷. We customised our instructions and guidelines to ChatGPT prompts to ensure that ChatGPT responds to participants based on the given user manual and in an easy-to-understand language, as training is intended for the general public. Our study aims to bridge these gaps by directly comparing an AI-based training tool against conventional owner's manuals, focusing on their effects on drivers' mental workload, task performance, and cognitive load. The outcomes of this research could significantly contribute to the development of evidence-based, user-centred ADAS training programs, promoting safe and responsible engagement with these increasingly essential vehicle technologies.

The remainder of this paper is organised as follows: Section "Materials and methods" details the methodology, including the study design, participant recruitment strategies, and data collection techniques. Section "Results" offers a comparative analysis of the learning outcomes and cognitive loads experienced by participants in conventional versus ChatGPT-assisted training groups. In section "Discussion", the discussion synthesises the study's findings, exploring the educational implications for ADAS technologies, identifying limitations of the current research, and proposing directions for future inquiries. Building on the insights and analyses presented, section "Conclusions" delivers recommendations for stakeholders involved in developing and implementing ADAS training alongside concluding remarks that encapsulate the study's contributions to the field.

Materials and methods

This study compares the relative efficacy of conventional paper-based learning methods versus a ChatGPT-based learning platform in educating participants about three ADAS functions: ACC, CA, and BSA. As mentioned in the previous section, the selection of these specific ADAS functionalities was motivated by their demonstrated potential to significantly reduce vehicular accidents, with correct usage potentially preventing up to 89% of human-caused traffic incidents^{14,15}. This research focused on young drivers aged 18 to 24, a group selected based on their increased likelihood of involvement in road accidents⁴⁴ and their presumed fluency with digital technologies. This group is highly receptive to educational programs designed to improve their driving skills and increase their awareness of safety practices¹⁹.

The methodology and participant engagement strategies are detailed across several subsections of the manuscript. Section "Participants recruitment" outlines the participant recruitment process, followed by an explanation of the experimental design rationale in section "Experiment design rational". Section "Participant's registration and briefing session" describes the registration and briefing sessions for participants, while section "Analysis of user interaction with Chatgpt" presents an analysis of user interaction with the ChatGPT learning platform. These sections collectively emphasise our systematic approach to examining the impact of different learning mediums on driver safety education.

Participants recruitment

In terms of participant recruitment, a two-fold strategy was implemented, leveraging both traditional and digital channels to ensure a comprehensive and representative sample from the target demographic. Traditional methods included distributing flyers and placing advertisements in local community centres and university campuses. On the digital front, strategies encompassed the use of online platforms, including web pages, emails, announcements on student portals, and online forms. This hybrid approach enabled the recruitment of a diverse group of 54 participants, balancing gender and background to enhance the study's relevance. Participants were randomly divided into two groups, each comprising 27 individuals: one receiving paper-based instructions and the other engaging with the ChatGPT-based learning platform. Gender distribution was carefully monitored: the paper-based group consisted of 14 males and 13 females, while the ChatGPT group included 15 males and 12 females. The mean age was 21.29 years (SD=2.44) for the paper-based group and 20.11 years (SD=2.45) for the ChatGPT group. This careful composition of participants was designed to ensure a balanced comparison between the two instructional methods.

We performed Pearson Chi-Square tests to confirm that the two groups were similar. These tests are designed to check if there is a statistical difference between groups in terms of categorical data, such as gender, as this is the suitable test for such data⁴⁵. The results showed no significant link between the type of training group (paper-based vs. ChatGPT-based) and the gender of participants (p=0.785), with all p-values exceeding the standard threshold for significance (p<0.05). This outcome indicates that how the participants were distributed between the groups did not favour one gender over another. Consequently, this balanced distribution supports the reliability of our comparison between the two groups' learning outcomes, suggesting that any observed differences in outcomes can be attributed to the training method rather than imbalances in participant demographics or experiences.

The ethical considerations of this study were meticulously addressed, and protocols were approved by the RMIT University Human Research Ethics Committee (Approval Number: EC 25022). All experiments were performed in accordance with relevant guidelines and regulations. This approval demonstrates the adherence to high ethical standards, ensuring the protection and welfare of participants. Each participant received

detailed information about the study's purpose and methods, and informed consent was obtained before their involvement.

Experiment design rational

A 15-min learning session was set for both instructional groups to mirror practical learning scenarios while avoiding excessive mental workload. This timeframe was chosen based on empirical studies regarding how well information is retained and how engagement levels fluctuate, specifically aligning with our intended audience's reading and comprehension skills⁴⁶. The educational content, comprised of user manuals that explain the ADAS functions, was around 1050 words. The length of the user manual was selected carefully, ensuring the material was detailed and manageable within the given period, especially considering that non-native English speakers have an average reading speed of 139 words per minute⁴⁶. The rationale behind the user manual's length and design approach encompassed two primary objectives. The first was to ensure that the manual was sufficiently comprehensive to cover the necessary details of the ADAS functions without overwhelming the participants. Secondly, the manual was designed to emulate the typical experience of consulting a vehicle's manual, providing users with a realistic and familiar reference. This strategy was designed to promote a comprehensive, streamlined learning process, especially beneficial for younger drivers. This approach is fundamental as the target demographic, younger drivers, is statistically more likely to be involved in traffic accidents⁴⁴. The design strategy also accounted for cognitive load theory, which suggests that the volume of information and the method of its presentation can significantly influence learning outcomes³⁹. By maintaining a balance between conciseness and comprehensiveness, the manual was designed to prevent cognitive overload, thereby enhancing the participants' learning efficiency within the given time constraints. Enhancing their understanding of ADAS technologies could significantly improve their driving safety¹⁶. Figure 1 illustrates the sequence of steps followed in the experiment, including participant registration, training (either paper-based or ChatGPT/LLM-based), ADAS functions assessment, and the NASA-TLX questionnaire.

Participant's registration and briefing session

All participants were guided through a standardised registration process. They were provided with a comprehensive explanation of the experiment's setup, objectives, and potential implications. Each participant was presented with a "Participant Information and Consent Form," which had received prior approval from the RMIT University Human Research Ethics Committee. After reviewing the details mentioned in the form, participants signed the form to give informed consent to participate in the study.

Subsequently, all participants were introduced to the introductory document detailing the purpose of the experiment and describing what they were expected to learn about each ADAS function. Below are the four key points participants were asked to focus on while learning about each ADAS function.

Training participants with a paper-based user manual

The paper-based training group participants commenced their learning phase, followed by a brief orientation session following registration. They were provided with a comprehensive user manual in printed form, intentionally designed to simulate the look and function of a typical vehicle owner's manual, customised for the experimental setup. The manual, approximately 1050 words in length, was thoughtfully structured to promote easy navigation and understanding.





ADAS function manufacture specific name	ADAS function common name		
Dynamic Radar Cruise Control ⁴⁷	Adaptive Cruise Control ⁷		
Side Collision Mitigation ⁴⁸	Blind Spot Assist ⁷		
Collision Avoidance Assist ⁴⁹	Collision Avoidance ⁷		

Table 1. ADS functions names: manufactures specific vs common names.

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Key learning points	Description
Common names of ADAS functions	Participants should identify the commonly used names of the ADAS features to ensure accurate communication and understanding
Purpose of each function	An explanation of what each ADAS function is designed to do, helping participants understand the functions' benefits and applications
The operational speed of each function	Details on the speed range within which each ADAS function operates effectively are crucial for understanding each feature's limitations and optimal use
Purpose of buttons in ADAS functions	A comprehensive overview of the function of each button associated with ADAS features, ensuring participants can utilise these functions correctly and efficiently

Table 2. Key learning points.

The design and formulation of the user manual considered both logistical considerations and the necessity to provide equal learning opportunities to participants in both the paper-based and the ChatGPT-trained groups. Consequently, participants were allocated 15 min to comprehend the nuances of three ADAS functions outlined in the manual.

During the 15-min period, participants were encouraged to engage with the manual actively, highlighting the importance of self-paced learning in conventional instructional settings. This experiment phase was critical in assessing the efficacy of paper-based materials in facilitating the comprehension of complex technical concepts compared to interactive, LLM-based tools like ChatGPT.

The paper-based training component of the study was designed with attention to detail, from the manual's length to its physical presentation. The aim was to provide a learning experience aligned with the logistical and experimental parameters and adhere to pedagogical best practices. Through this careful and deliberate design, the study effectively pursued its objectives of comparing the effectiveness of paper-based versus ChatGPT-based learning modalities with thorough precision.

Training participants with an interactive ChatGPT user manual

The group that trained using the ChatGPT interactive user manual experienced a distinct approach compared to their counterparts. The training content was the same for both groups, and the approach used in the ChatGPTbased manual was aimed to provide an engaging, interactive, and personalised learning experience. Participants focused on learning about three ADAS functions, detailed in Tables 1 and 2. Like conventional training groups, ChatGPT group participants were also allocated 15 min for their training. However, they had the flexibility to ask ChatGPT an unlimited number of questions, enabling them to explore the material as thoroughly as needed within the allocated timeframe. Participants engaged with ChatGPT following a framework proposed by³⁷, which outlines both general LLM prompting principles and application-specific guidelines. This interaction framework ensured that ChatGPT provided accurate responses that were aligned with the user manual's content.

According to^{26,50}, if the instructions given to ChatGPT are vague, this may result in ChatGPT producing irrelevant or incorrect responses. To address this issue, detailed context and thorough information were supplied to ChatGPT, following the recommendations suggested by³⁷. This approach ensured that ChatGPT's responses were precise and tailored to the learning objectives, which is essential for accurately conveying the manual's information to the general public. Since user manuals often present information in a technical format that may not be readily accessible to all users, it was crucial to instruct ChatGPT to simplify the content. This strategy aimed to make the information comprehensible to a lay audience, acknowledging that user manuals typically demand significant knowledge and time for effective utilisation²⁰.

Furthermore, conventional user manuals often lack an interactive learning component, which can influence their educational effectiveness⁵¹. By leveraging ChatGPT's interactive capabilities, we sought to overcome this limitation, offering a more dynamic and engaging learning experience. This approach enhanced the comprehension of the ADAS functions and served diverse learning preferences among participants, thereby improving the effectiveness of the training. Training through the ChatGPT interactive user manual showed the capability of LLM tools to enhance learning experiences. By employing a structured interaction framework and adhering to clear instructional guidelines, we ensured the delivery of accurate and accessible content, thereby addressing the limitations associated with traditional user manuals.

Analysis of user interaction with ChatGPT

ChatGPT group learned about the ADAS function through the interactive ChatGPT-based user manual. Therefore, to facilitate a thorough understanding among participants interacting with the ChatGPT group and ensure that participants engaged with ChatGPT in an informed manner, instructions were given to the participants to initiate their conversation with the following questions. The goal was to ensure that each participant understood the functions they needed to learn: "Can you please list all the functions discussed in this user manual?".

Participants were instructed to familiarise themselves with the ADAS functions commonly known names in the industry, including the purpose of each function, the activation and deactivation speeds, and the buttons associated with each function, as detailed in Table 2. On average, each participant asked ChatGPT six questions, with the average response being 80 words in length. Therefore, the interactions were concise enough without reaching the maximum token capacity of 8,192 tokens offered by ChatGPT version 4.0 (last updated in December 2023.), potentially leading to inaccurate or irrelevant responses^{52,53}. Throughout the experiment, we did not observe any inaccurate responses generated by ChatGPT while responding to the participants.

However, we acknowledge that this study's limitation lies in the relatively short user manual, which does not reflect how ChatGPT would respond to larger documents that could challenge ChatGPT's token capacity. A further challenge arises from the token limitations of large language models. When these limits are reached, portions of the conversation may be truncated, potentially leading to a loss of context or a forgetting of previously given instructions. Therefore, consistent reiteration of key instructions is essential to maintain adherence to specific guidelines or the use of particular terminology, such as the ADAS function names and symbols required in this study³⁷. Another limitation of ChatGPT is its inability to access or provide very recent or real-time information³⁷. However, in our experiment, we did not encounter any of these limitations, as the user manual was concise, and we instructed ChatGPT to rely solely on the information provided in the user manual. To provide a comprehensive overview of ChatGPT's performance, we present four examples, one illustrating each ADAS function about which participants inquired. Figure 2 shows ChatGPT's response regarding the ACC function, in which a participant asked about the buttons, and ChatGPT's response was accurate as per the provided user manual. Figures 3 and 4 demonstrate the responses about the CA and BSA functions, respectively, and again, the responses are accurate. Figure 5 relates to a function not discussed in the user manual. ChatGPT's responses to participants.

Results

This study explored the effectiveness and impact of different training methods, specifically contrasting ChatGPTassisted learning versus conventional paper-based learning approaches. Participants were given a user manual that detailed three ADAS functions, as presented in Table 1. Following this educational segment, individuals from both groups were subjected to a Multiple-Choice Questionnaire (MCQ) test to evaluate their understanding, with their answers analysed for accuracy and correctness. Additionally, after the learning activity, all participants were required to complete the (NASA TLX) survey. This was used to assess and compare the cognitive load associated with each training method.

vo You

what are the buttons available in ACC

ChatGPT

For the Adaptive Cruise Control (ACC), which is referred to as Dynamic Radar Cruise Control (DRCC) in the manual, the following buttons are available:

- A (Vehicle-to-vehicle distance switch): Adjusts the following distance between your vehicle and the one ahead.
- B ("+RES" switch): Used to increase the set speed.
- * C (Cruise control main switch): Activates or deactivates the cruise control system.
- D (Cancel switch): Cancels the current speed setting.
- E ("-SET" switch): Sets the speed or decreases the set speed.

Do you understand how to use these buttons, or would you like me to explain it to you again?

Fig. 2. Screenshot of a learner inquiring about the ACC function.

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What is the main purpose of CA and what is it's operational speed

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ChatGPT

The main purpose of the **Collision Avoidance (CA)**, referred to as **Collision Avoidance Assist** in the manual, is to **detect obstacles in front of the vehicle and warn of potential collisions**. If necessary, it can **automatically apply the brakes** to avoid or mitigate a collision.

The **operational speed** for Collision Avoidance Assist is between **approximately 7 mph (10 km/h)** and 90 mph (150 km/h).

Do you understand the purpose and operational speed of CA, or is there anything else you'd like to know about it?

Fig. 3. Screenshot of a learner inquiring about the CA function.

You

How many radar sensor BSA uses to monitor and what is the activation speed of this function?



The **Blind Spot Assist (BSA)** function uses **four radar sensors** located in the bumpers to monitor the space next to the vehicle. This system becomes active at a **minimum speed of about 3.1 mph (5 km/h)** and can function up to approximately **130 mph (210 km/h)**.

Do you understand how the radar sensors work and the activation speed of BSA, or would you like me to go over it again?

Fig. 4. Screenshot of a learner inquiring about the BSA function.

Effectiveness of ChatGPT versus paper training on ADAS learning

In this study, participants were categorised into two groups based on the training method they received: ChatGPT-based training and paper-based training. Each group comprised 27 individuals, making a total of 54 participants. The evaluation of performance outcomes, presented in Table 3, reveals notable differences in the comprehension of ADAS functionalities across the two training modalities.

The group trained with ChatGPT achieved an overall average correctness score of 85.12%, higher than the 74.02% scored by the paper-based training group. Given the non-normal distribution of our data, the Mann–Whitney U test was selected instead of the t-test or ANOVA, as it is more appropriate for our analysis⁴⁵ to compare overall comprehension scores between the groups. This test, specifically chosen for its suitability with data not adhering to a normal distribution, recorded a p-value of 0.002. The statistically significant difference this result indicates supports the superior effectiveness of the ChatGPT-based training method.

When considering participants' prior experience with ADAS, we categorised them as regular users who frequently use ADAS functions while driving in real life and 'never/occasionally users'. Among regular users, the ChatGPT group scored an average correctness of 91.12%, higher than the paper-based group's 80.47%, with a p-value of 0.014. This result indicates a significant advantage for the ChatGPT method among participants familiar with ADAS. For participants who had never or only occasionally used ADAS functions, those who received ChatGPT-based training had an average correctness score of 79.12%, compared to 67.58% for the paper-based training group. With a p-value of 0.011, this difference is also statistically significant, suggesting that ChatGPT-based training enhances learning outcomes even for individuals without ADAS experience. However, the impact is less pronounced than it is for regular users.

To further examine the independent contributions of the learning method and prior ADAS usage, a multiple regression analysis was conducted. The results showed that Learning Method and ADAS Usage are



What is the function of LKA and at what speed we can activate this function

ChatGPT

0

The user manual you provided doesn't specifically mention a function called Lane Keeping Assist (LKA). The functions detailed in the manual are Dynamic Radar Cruise Control (DRCC), Side Collision Mitigation (SCM), and Collision Avoidance Assist (CAA). If you're interested in any of these functions or have another aspect of the vehicle's ADAS you'd like to learn about, please let me know!

Would you like more details on any of the functions we've discussed, or is there something else you'd like to know?

Fig. 5. Screenshot of a learner inquiring about a non-existing function in the user manual.

Groups-division w.r.t training method	Total participants average correct score in % (27 participants/ per group)	Regular users of ADAS functions average correct score in % (13 participants / per group)	Never/Occasionally used ADAS function average correct score in % (14 participants / per group)
ChatGPT-based training group	85.12	91.12	79.12
Paper-based training group	74.02	80.47	67.58

Table 3. Participants' average score after being educated using different methods.

both significant predictors of participant scores. The model accounted for 53.91% of the variance in scores (R^2 =0.5391), highlighting the influence of these factors in determining performance. The analysis revealed that transitioning from paper-based to ChatGPT-based training was associated with an average increase of 11.40 percentage points (β =11.3954, *p*=0.000193), while regular ADAS usage was associated with an average increase of 12.89 percentage points (β =12.8910, *p*=3.42E-05). These findings reinforce the statistical significance of both factors, aligning with the Mann–Whitney U test results.

Our findings highlight the efficacy of ChatGPT-based training in enhancing the understanding of ADAS functionalities for all participants, outperforming paper-based methods. This effectiveness is statistically significant across different levels of prior ADAS experience, with notable benefits for both 'regular users' and those with little to no previous experience. The multiple regression analysis reinforces these findings, demonstrating that both the learning method and prior experience are significant predictors of performance. The results affirm the value of employing interactive, AI-based learning approaches like ChatGPT to improve educational outcomes in technical domains.

Comparison of NASATLX between two learning groups

In our comparative study, we analysed the impact of two distinct training methods, ChatGPT-based and paperbased, on participants perceived mental workload using the NASA-TLX. This comprehensive tool assesses six key workload dimensions: mental demand, temporal demand, physical demand, performance, effort, and frustration, alongside an overall workload score, with the result presented in Table 4. Our participant pool was divided equally into two groups, each undergoing one of the two training methods, to explore differences in the learning experience, particularly in the context of ADAS functionalities.

Mental demand

The ChatGPT-based training group reported a mental demand score of 61.85, notably lower than the 75.18 reported by the paper-based group. This suggests that participants found the ChatGPT-based training cognitively less demanding. The significant difference between the groups (p=0.001) indicates a clear advantage of ChatGPT in reducing the cognitive load on learners. The interactive nature of ChatGPT simplifies complex ADAS functionalities, making them more accessible and easier to understand. At the same time, it customises the information to meet the learner's specific needs, effectively reducing mental stress.

The groups-division w.r.t training method	Average mental demand score/100	Average temporal demand score/100	Average physical demand score/100	Average performance score/100	Average effort score/100	Average frustration score/100	Average NASA mental workload score/100
ChatGPT based group	61.85	59.62	15.74	88.70	60.55	35.55	40.77
Paper-based group	75.18	65.92	19.44	80.18	73.88	44.81	49.87

Table 4. Participants' average NASA TLX scores by educational method.

Temporal demand

The temporal demand metric, indicating perceived time pressure, showed the ChatGPT group scored 59.62, compared to the higher score of 65.92 for the paper-based group. While the difference, with a p-value of 0.069, indicates a trend, ChatGPT training may allow for a learning environment with less time pressure. ChatGPT's responsive dialogue format streamlines the learning process, ensuring efficient use of participants' time. Additionally, its ability to provide direct answers to specific queries greatly reduces the time needed to locate information within a manual.

Physical demand

For physical demand, the ChatGPT group reported lower scores (15.74) than the paper-based group (19.44), suggesting that the AI-driven approach results in a learning experience that is less physically demanding. The p-value of 0.054 indicates a slight difference close to but does not achieve, statistical significance.

Performance scores

Reflecting participants' self-evaluated success in completing tasks were notably higher in the ChatGPT group (88.70) compared to the paper-based group (80.18). This significant difference (p < 0.001) highlights the learners' confidence in their outcomes with ChatGPT-based training. It implies that this method could be more successful in enhancing understanding of the material, likely due to the personalised and interactive feedback provided by ChatGPT.

Effort and frustration

Effort and frustration scores further explain the training methods' impact, with the ChatGPT group reporting lower effort (60.55) and frustration (35.55) compared to the paper-based group (73.88 and 44.81, respectively). These significant differences (p < 0.001 for effort and p = 0.001 for frustration) highlight the ChatGPT method's efficiency and role in creating a more positive learning environment by minimising stress and exertion. The direct, conversational interaction with ChatGPT, paired with its ability to distil information according to the learner's needs, potentially makes learning more engaging and less overwhelming, leading to a smoother and more enjoyable educational experience.

Overall NASA mental workload

The aggregate NASA mental workload score, which integrates the six dimensions into a comprehensive measure of workload, was significantly lower for the ChatGPT-based group (40.77) compared to the paper-based group (49.87), with a *p*-value of < 0.001. This significant difference reinforces the findings of the individual dimension and conclusively supports the superior efficiency and reduced demand for ChatGPT-based training across multiple facets of the learning experience.

These findings collectively indicate that ChatGPT-based training reduces participants' overall learning load and enhances their performance and satisfaction with the learning process. The statistical analyses offer strong evidence that the observed differences in workload and performance between the training methods are significant, suggesting the potential advantages of integrating LLM-based tools into educational practices.

Discussion

The findings from our study provide evidence for the effectiveness of ChatGPT-based training in enhancing the understanding of ADAS functionalities among participants. The data in Table 3 shows that individuals exposed to ChatGPT-based training achieved higher average correctness scores across both subgroups. This indicates that interactive, LLM-based or AI-powered learning methods may facilitate a more profound comprehension of complex systems than conventional learning approaches. This highlights the potential of integrating interactive technologies in educational settings to accommodate diverse learning styles, provide immediate feedback, and foster a more engaging learning environment⁵⁴.

One critical factor contributing to these outcomes is the interactive nature of ChatGPT-based training, which likely engages users more effectively than conventional methods²⁶. The improved scores among both regular and non-regular ADAS users in the ChatGPT groups highlight its efficiency in addressing knowledge gaps compared to paper-based methods. Additionally, despite their detail, user manuals often require substantial prior knowledge and considerable time to be used effectively²⁰. The effectiveness of these manuals is further limited by the absence of an interactive learning experience⁵¹.

The efficacy of ChatGPT-based training in improving comprehension among learners points towards the necessity of rethinking educational strategies, particularly in the technical and automotive industries. Further investigation should examine the long-term retention of knowledge gained through such interactive methods

and the expansion of ChatGPT-based training to more varied and more extensive groups, including individuals from different demographics, as this study focused solely on younger participants.

Moreover, our analysis indicates that ChatGPT-based training significantly reduces the overall NASA mental workload for learners, suggesting a more intuitive, less stressful, and efficient learning process than conventional methods. The pronounced reduction in mental demand, performance, effort, and frustration aspects, supported by statistically significant differences, implies that the ChatGPT-based approach makes learning complex topics like ADAS functionalities more accessible and enhances learners' confidence in their understanding of the material. Such cognitive and physical strain reductions emphasise the crucial role of interactive, adaptive training methods in improving learning efficiency and effectiveness.

The significant p-values obtained for mental demand, performance, effort, frustration, and the overall NASA mental workload further substantiate the efficacy of ChatGPT-based training in reducing participants' perceived workload. This reduction is not merely coincidental but directly attributable to the training method's engaging and interactive nature. Although temporal and physical demands did not achieve statistical significance, the observed trends suggest that ChatGPT-based training might also lessen time pressure and physical effort, contributing to a more favourable learning experience.

The utilisation of LLM-based tools like ChatGPT in educational contexts, particularly for subjects requiring an in-depth understanding of complex systems, offers a promising avenue for enhancing learning experiences. ChatGPT-based training can improve educational outcomes, increase learner satisfaction, and promote long-term knowledge retention by mitigating the mental, physical, and emotional challenges associated with conventional learning methods. Future studies should explore the generalisability and effectiveness of these training methods across various domains and learning environments, aiming to validate and extend the applicability of our findings.

Conclusions

This study shows that ChatGPT-assisted learning significantly improves understanding of ADAS functionalities over conventional paper-based methods. Higher correctness scores among ChatGPT group participants underscore the effectiveness of interactive, AI-driven learning approaches in enhancing comprehension. These results confirm ChatGPT's role in lowering cognitive loads, evidenced by the NASA TLX, and indicate superior performance outcomes and lower physical demands, all of which contribute to a more fulfilling learning experience. The notable differences in mental, temporal, and physical demands, alongside improvements in performance, effort, and frustration levels between ChatGPT and paper-based training, underscore ChatGPT's training efficiency. This method enhances comprehension of complex subjects while reducing associated stress and effort, making it an attractive option for educational programs, especially in technical and automotive fields.

This paper reveals that ChatGPT-based training is highly adaptable, effectively meeting the diverse learning needs of individuals from various educational backgrounds and skill levels. These interactive methods outperform conventional teaching approaches in bridging knowledge gaps, irrespective of the learners' prior experience with ADAS functionalities. Moreover, the evidence points to a significant advantage in adopting AI-driven tools like ChatGPT within educational frameworks. Such technologies enhance immediate learning outcomes and learner satisfaction. The outcomes of this work recommend a critical reassessment of existing educational models to embrace interactive and adaptive technologies. Future investigations should aim to extend the scope of ChatGPT-based training to examine its scalability, effectiveness across different learning areas, and impact on a broader array of learner demographics.

Data availability

The datasets generated and/or analysed during the current study are not publicly available due to privacy and confidentiality requirements set by RMIT University's human research ethics committee. However, the corresponding author can make the data available upon a reasonable request, subject to the Ethics Committee's approval and after the data have been de-identified.

Received: 27 May 2024; Accepted: 19 February 2025 Published online: 01 March 2025

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Author contributions

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Funding

This work was supported and funded by the Deanship of Scientific Research at Imam Mohammad Ibn Saud Islamic University (IMSIU) (Grant number IMSIU-RP23017).

Declarations

Competing interests

The authors declare no competing interests. The authors have no relevant financial or non-financial interests to disclose.

Informed consent

Informed consent was obtained from all subjects involved in this study.

Additional information

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