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# In-Car Gaming: A Scoping Review and Future Agenda

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While gaming increasingly permeates many facets of our daily lives, it is also gaining relevance as an in-car experience. However, despite the growing interest in in-car gaming within both research and practice, we lack a structured understanding of the phenomenon's main research fields and prevailing characteristics. Thus, this paper presents the findings of a scoping review of 42 relevant papers on gaming in cars. We identified five emerging research substreams: in-car game prototypes, gaming during automated driving, theoretical considerations for in-car gaming, effects of gaming while driving, and technology enabling in-car gaming. Furthermore, we provide an overview of the research's major characteristics about the game, gaming device, vehicle, and user. We reflect on trends recognized in our review, discuss contradictory results, for instance, regarding safety, and question whether a unique in-car gaming experience may exist. We propose research questions based on identified trends and gaps to guide future HCI research in this field.

CCS Concepts: • **Information systems** → **Multimedia information systems**; • **Human-centered computing** → *HCI theory, concepts and models*.

Additional Key Words and Phrases: In-car, gaming, entertainment, games, interaction, scoping review

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## 1 Introduction

Over the last decade, gaming has become a mainstream form of entertainment. It has shown a significant social and cultural impact [19] and has begun to transcend its traditional boundaries to influence areas such as work, art, education, or health [19, 46, 70]. Driven by technological trends such as ubiquitous computing, gaming has started to leave its traditional settings at home, on the PC, or console. The rise of mobile gaming, which currently accounts for around 50 % of all gaming [65], has made gaming easily accessible in many locations. As such, games are a commonly used medium to turn the daily commute into a more exciting activity [60] and also to bring mobile gaming into the car during all kinds of travel [15]. Therefore, it is no surprise that the automotive industry is increasingly turning to in-car gaming to address customers' entertainment needs and differentiate their products from competitors [49]. For instance, Tesla, Audi, and BMW - to name a few - have all recently announced or released in-car gaming services [1, 31, 77]. A development which researchers have long anticipated, with prototypes of in-car games going back to 2002 [13]. Recent research, such as Deng et al. [20], even suggests that in-car gaming could become a game

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format in its own right, offering unique gameplay experiences beyond what we know from existing games.

The technological capabilities of modern cars, including their multimodal interfaces, sensors, and significant onboard computing power, combined with the vehicle context's unique social and physical characteristics, present attractive opportunities for game design to create innovative gameful experiences [75]. In addition, emerging technologies like augmented reality (AR) and virtual reality (VR) expand the design space for creating novel gameful entertainment formats. For instance, Riegler et al. [66] reviewed the use of VR in the automotive context and found that passengers could benefit from VR applications in the field of gaming and entertainment. There are even gameful ideas that only work when VR or AR technology is used in vehicles [cf. 43]. For instance, by integrating vehicle motion data in AR and VR games, dynamic experiences that in real-time adapt to a car's speed [47, 62] or direction [31] can be created. Such contextual synchronization enables gaming experiences that transcend those typically encountered in home settings, offering higher levels of immersion while reducing motion-sickness [29]. Moreover, in-car gaming holds the potential to advance the field of location-based games. Location-based games use the player's physical location to influence the gameplay [42]. Utilizing vehicles and their geographical data opens new design avenues for location-based games, such as making games responsive to an actual journey by offering adaptive narratives and challenges that evolve based on the traveler's route and surroundings [12]. In-car gaming can also incorporate real-time traffic data [40] or weather conditions into the gameplay to make game experiences context-sensitive. By leveraging the distinctive characteristics of cars, in-car games can create novel, immersive, and context-sensitive experiences, ranging from individualized, location-based adventures to collaborative multiplayer interactions between vehicles [43, 91]. However, in-car gaming also presents new challenges for game design. Issues such as safety, distraction, or cognitive load are relevant factors to consider in the research and design of in-car games [cf. 61, 88]. Therefore, in-car gaming might require researchers to challenge and extend established theories of player experience, immersion, and game design, making it a valuable setting for exploring new directions in interactive entertainment.

The growing integration of game-like experiences in vehicles has been the subject of several existing reviews, most of which focus on automotive gamification and engaging behavior changes, for instance, to encourage ecological and safe driving [5, 21, 73, 82]. Only one of the previous reviews centered on gamification touches on the important area of in-car entertainment, mentioning that they rarely found gamification for leisure [5]. Despite the potential of in-car gaming as a new source of entertainment beyond gamification and the growing industry interest, existing research remains scattered and often isolates aspects of this multidimensional phenomenon. To date, no effort has been made to synthesize the emerging body of knowledge in this area. However, both research and practice would benefit from a structured overview of the current literature on in-car gaming to better understand how the fragmented results from individual studies complement or contradict each other, to highlight the overlap of disciplines like psychology, computer science, and Human-Computer-Interaction (HCI), and to identify underlying trends and gaps of this research field. To this end, this paper presents the results of a scoping review, as it allows for a broad exploration of diverse sources and types of evidence while providing a structured overview. This review aims to determine the most relevant research substreams emerging in the current body of literature, how to advance them, and identify potential research gaps based on prevailing trends. In this context, a research substream denotes an emerging stream of research within the overall field of in-car gaming that represents a focused area of investigation [cf. 3, 33]. Based on the results of an in-depth review of 42 relevant papers from HCI and related disciplines, this study contributes to a better understanding of the emerging phenomenon of in-car gaming by (1) summarizing the existing in-car gaming research and categorizing it into five predominant thematic research substreams,

(2) providing a structured overview of how in-car gaming manifests within the existing research and what characteristics regarding the game, gaming device, vehicle, and users can be found in different automotive-related use cases, and (3) highlighting trends and apparent contradictions within the research field to derive research gaps. This mapping allows us to draw conclusions about the entire research field as a sum of its predominant research substreams and trends. Because in-car gaming research frequently incorporates gaming formats like VR, AR, and pervasive games, our synthesis not only advances understanding within the automotive context but also generates insights for related games research. Ultimately, this synthesis reveals underexplored areas, such as the integration of vehicle-specific sensors into gameplay or recurring tensions between safety and engagement. By organizing the literature, our review enables researchers and practitioners to prioritize underexplored research areas and develop more cohesive, evidence-based approaches to in-car game design.

## 2 Scoping Review

This paper applies a scoping review, which is particularly suitable for exploring and mapping existing research on broad topics, such as in-car gaming, rather than focusing on empirical data or effect sizes [59]. This exploratory approach allows us to synthesize the content of a wide range of studies, including non-empirical studies, to provide a holistic overview of the entire research field. Like other reviews, the method proceeds from formulating research questions to creating a search string and inclusion/exclusion criteria, prioritizing breadth of coverage over strict quality assessment as seen in other methods. From this, relevant articles are identified, selected, data extracted, and summarized [59]. The review followed the methodology developed by the Joanna Briggs Institute [59], which matches the PRISMA-Statements for Scoping Reviews [79].

### 2.1 Research Questions

The aim of this research is to explore and structure the emerging field of in-car gaming as a whole. The following research questions guide the scoping review to provide both an overview of the research field (RQ1) and an in-depth understanding of its key characteristics (RQ2):

- **RQ1:** What are the main research substreams pursued in the research field of in-car gaming?
- **RQ2:** What key characteristics of the research field emerge from current research on in-car gaming?

### 2.2 Search Strategy

The search was conducted with Scopus<sup>1</sup> and Web of Science<sup>2</sup>. These databases were chosen for their quality in terms of article coverage and interdisciplinarity [16, 23, 71]. They include content from over 7,000 reviewed publishers and index publications from other relevant databases such as IEEE, Elsevier, Springer Nature, Taylor & Francis, ACM, or SAGE [23].

The search string consisted of two parts. The first part consisted of the words relevant to gaming. This part was deliberately simple and broad, using the keywords 'gaming' and 'game\*' linked by an OR operator. When scanning the first articles, game theory was excluded as it was irrelevant to our topic but made up a significant proportion of the results. "Game" is a term used in many different contexts, not necessarily related to entertainment. It was not possible to refine the terms without losing relevant literature, so only "game theory" was directly filtered out. In contrast, other non-relevant papers, such as those on the Olympic games, were deleted after scanning the title. Our search did not include gamification, as reviews already cover this research topic [5, 21, 73, 82]. These

<sup>1</sup>Scopus: <https://www.scopus.com/>

<sup>2</sup>Web of Science: <https://webofknowledge.com/>

reviews do not focus on using games for entertainment in cars but, for instance, find eco-driving and safety behavior as the main objectives of in-car gamification.

For the second part of the search string, car-related keywords were collected and linked using an OR operator. By scanning and assessing various papers and keywords, we decided on the following selection of terms as they gave the best results: "in-vehicle", "in-car", "automotive", "automobile", "passenger", and "rear seat". The keywords "road", "driver/driving", and "mobility" were not used as they did not provide any additional relevant work that was not already covered by the other keywords. For the terms "road" and "driver/driving", this was mainly due to their frequent metaphorical use. "Mobility" was often used in research on older and disabled people and was therefore dismissed. We limited the search to titles, abstracts, and keywords, as a full-text search was expected to result in many false positives due to the frequent use of automotive and gaming as examples. The specific search string for each database can be found in Appendix A. The search was not limited to a specific time period. The search was performed in February 2025 and returned 2,292 hits for Scopus after excluding conference reviews and 549 hits for Web of Science.

### 2.3 Selection

All identified citations were exported after the search, and duplicates ( $n = 461$ ) were removed. The following exclusion (EC) and inclusion (IC) criteria were defined based on the research objective. The criteria were developed and revised after discussion among the author team.

- **EC1: *False positive*:** Words are used in a different context and sense (e.g., games is used for Olympic Games)
- **EC2: *System*:** The paper is about a system that could also enable gaming (e.g., vehicle-to-vehicle communication) rather than a system specifically for gaming or games.
- **EC3: *Example mention*:** The paper mentions gaming and automotive as an example use case in the title, keywords, or abstract, but the paper is not about in-car gaming.
- **EC4: *Gamification*:** The paper is about gamification.
- **EC5: *Content instead of context*:** The paper is about automotive content in a game (e.g., racing games).
- **EC6: *Testing system*:** The paper uses a driving simulation or game to test something unrelated to gaming in a car.
- **EC7: *Quality control*:** The record is a call for a workshop without any results or a magazine article.
- **EC8: *Language*:** The paper is not in English.
- **IC1: *Digital game*:** Game or gaming refers to a digital game.
- **IC2: *In-car*:** The game is specifically used in a car.

Titles and abstracts were screened by the first two authors against the inclusion and exclusion criteria for the review, and potentially relevant sources were retrieved in full. A Cohen's kappa [17] of 0.89 was calculated for the agreement between the reviewers for the title and abstract screening, which can be interpreted as near-perfect agreement [44].

Disagreements were resolved through discussion. Most papers excluded in this first screening process were excluded because of EC1. Examples of phrases using the word game without reference to our research were Olympic games, game changer, game mode, game analysis, game engine, hawk-dove games, evolutionary games, Stackelberg game method, game algorithm, or using the term "game" as a synonym for venison. The full text of the selected results ( $n = 106$ ) was then carefully evaluated using the same inclusion and exclusion criteria. The first two authors each reviewed half of the papers and briefly summarized their arguments for an article's potential inclusion or exclusion. The final inclusion/exclusion decision was made jointly based on an extensive discussion

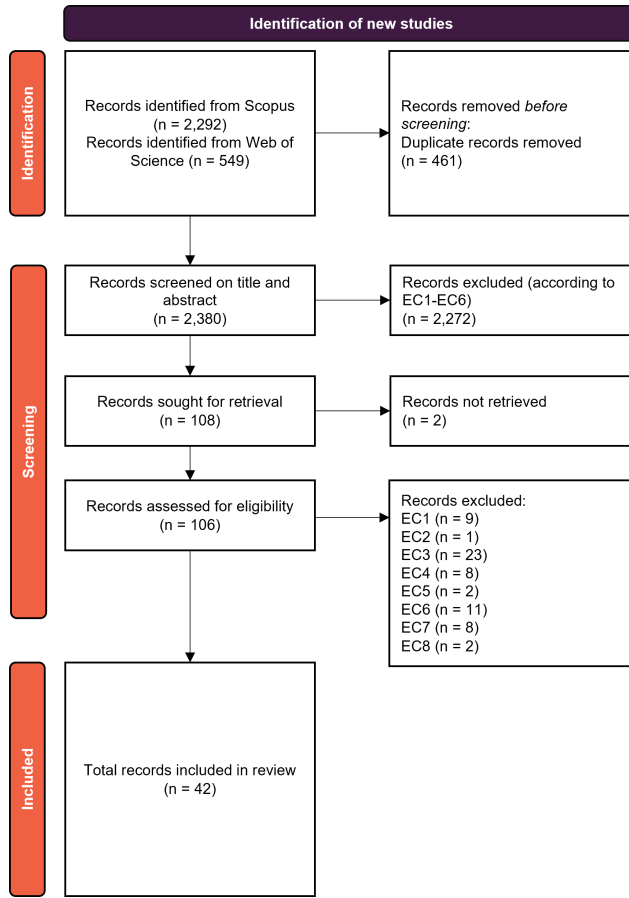


Fig. 1. Scoping review process for paper identification and inclusion [56]

of each paper in the team. The results of the search and the study inclusion process are shown in Figure 1.

### 2.4 Data Extraction and Analysis

We employed a structured approach for data extraction, using a data charting form, as described in the methodology for scoping reviews by Peters et al. [59], which builds on Arksey and O’Malley [4] and Levac et al. [45]. After reading half of the 106 papers to decide on inclusion, Author A developed a preliminary data charting form with the two research questions in mind. This preliminary data charting form included the categories: general information, research objectives and contributions, user evaluations/empirical studies, game-related information, and vehicle-related information. Next, to coordinate the data extraction procedure, the authors selected three studies [20, 43, 78] from the total sample that sounded promising based on their titles and independently extracted data from these studies using the data charting form. Subsequently, the team compared their results and discussed their procedure to ensure consistency in their data extraction approach. Next, the first two authors divided the remaining papers in the review set and extracted the data. During this process, two meetings were held to discuss the suitability of the data charting form. The data charting

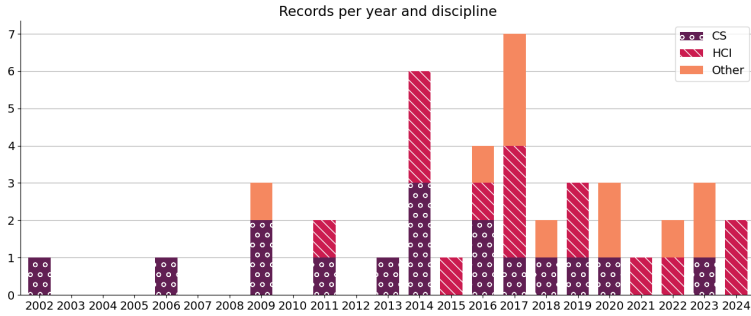


Fig. 2. Papers per year and discipline

form was refined and updated as the project progressed. As new categories and attributes were added, the entire set of papers was reviewed against the added criteria. The final chart, including subcategories and attributes, is available in Appendix B.

To gain insights into RQ1, the first two authors independently clustered the papers according to the data collected in the categories *research question*, *main findings*, and *contribution type*. Following this bottom-up approach, Author A identified five research substreams, while Author B identified seven. After discussing overlaps and differences, the authors agreed upon five final substreams. Three substreams overlapped perfectly between the authors, while the other substreams were consolidated. Two pairs of substreams from Author B were each merged into one substream from Author A. A consensus of 79 % reflects the proportion of papers that both authors placed in the same final substream out of the 42 papers included in the review. The remaining papers were categorized after further discussion.

To address RQ2, the reviewer team conducted an inductive analysis to identify patterns in the existing research, primarily examining the categories *user evaluation/empirical study*, *game-related information*, and *vehicle-related information* in the data charting form [59]. During this process, the authors closely examined aspects that showed significant variance and heterogeneity across multiple studies. For example, it was observed that while many studies highlighted the user’s role, the role itself varied between driver and passenger. The authors then aggregated and structured these characteristics identified across the research field. Throughout this iterative process, it became clear that the existing research centers around four main objects of interest: the game, the gaming device, the vehicle, and the user. Regardless of the research substream, these objects are central to the existing in-car gaming research. However, the role of these objects differs between the different research substreams. The results of this analysis are presented in the following section.

### 3 Results

#### 3.1 Overview of Papers

The final subset of records included 42 papers, of which 27 were conference papers, 14 were articles, and one was a letter. The papers were primarily published in Computer Science venues (31), of which 15 were in HCI venues. Other disciplines include Security Research (4), Engineering (2), Health Sciences (2), Transportation (2), and Social Sciences (1). The location of the first author was mostly in Europe (22), followed by Asia (9), North America (7), and Australia (4). The number of publications peaked in the mid-2010s with up to seven papers per year and has since decreased to one to three papers per year. An overview can be seen in Figure 2.

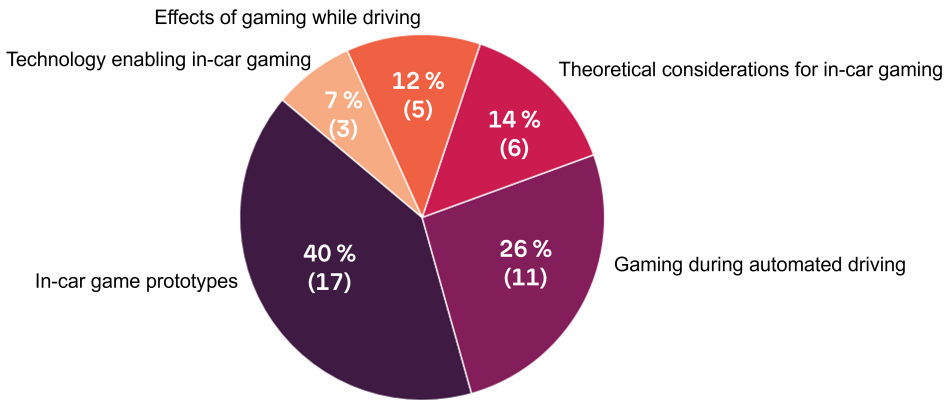


Fig. 3. Papers per substream

### 3.2 Research Substreams of State of the Art Research on In-Car Gaming

Answering the first research question, we found five research substreams based on the papers' extracted main findings and contributions (see Figure 3).

- In-car game prototypes (n = 17): Papers about prototypes of games that are explicitly designed for cars.
- Gaming during automated driving (n = 11): Papers about gaming while in a vehicle with conditional automation.
- Theoretical considerations for in-car gaming (n = 6): Papers suggesting ideas, considerations, and models relevant to in-car gaming.
- Effects of gaming while driving (n = 5): Papers about the effects of gaming as a driver while driving.
- Technology enabling in-car gaming (n = 3): Papers about technologies that enable in-car gaming.

In the following, the findings per identified research substream are summarized. An overview of the substreams and their papers can be found in Table 1.

**3.2.1 In-Car Game Prototypes.** The largest substream aims to present in-car game prototypes that enhance the passenger experience. These focus on improving social interaction and well-being, or using mixed reality.

Five papers focus on promoting **social interaction** among passengers. Broy et al. [10] developed collaborative tablet games for car rides that encourage communication and cooperation through interactive mini-games such as music quizzes and observation challenges. Two studies aim to improve safe driving through their prototypes. Hoffman et al. [30] and Zuckerman et al. [91] introduced a location-based game in which children use a phone to locate characters and must keep them steady to ensure their "survival." This approach encourages interaction between children and parents while using the dynamics of the game to promote safe driving practices. Similarly, Maurer et al. [47] adapted Tetris to drop tiles according to the car's speed to improve communication between passengers and drivers while discouraging speeding behavior. Finally, Meschtscherjakov et al. [48] demonstrated how the unique spatial arrangement in the car can be used for social interaction through a prototype card game where players push cards on a tablet, with each corner corresponding to a different car seat.

Table 1. Overview of all articles included within this review

Substream	Papers
In-car game prototypes	[10], [11], [12], [13], [29], [30], [36], [40], [38], [43], [47], [48], [62], [75], [78], [83], [91]
Gaming during automated driving	[28], [50], [52], [51], [54], [76], [35], [81], [85], [86], [87]
Theoretical considerations for in-car gaming	[20], [37], [39], [58], [72], [84]
Effects of gaming while driving	[6], [32], [63], [68], [80]
Technology enabling in-car gaming	[9], [57], [67]

Focusing on improving **well-being**, Sundström et al. [75] developed games that use children's driving postures as input to encourage better posture during gameplay. Similarly, Krome et al. [38] created a game that promotes physical activity based on movements in the car to reduce stress during traffic jams. In addition, Sven Krome and his colleagues designed two games to positively influence how people perceive frustrating traffic situations: an interactive music experience that can be played on the inactive steering wheel of an autonomous car [36] and an engaging exertion game that adapts to the vehicle's speed [40]. Together, these works highlight the potential social and health benefits of integrating gaming experiences into cars.

The other eight papers in this substream focus on the use of **mixed reality** in in-car games. Liselott Brunberg and her colleagues have been pioneers in this area, with studies focusing on mixed-reality gaming, player attention, and dynamic scenery integration. An initial study improved gameplay by incorporating real-world factors, such as the car's speed, direction, and timing, into the game by triggering location-based events [13]. The following study balanced player attention between traffic and gameplay by designing games where players must detect and interact with opponents in other cars, promoting both safety and fun [11]. A third study integrated dynamically changing scenery into games for passengers, exemplified by interactive audio crime stories influenced by players pointing a custom handset in different directions and hearing different sounds [12]. These studies first demonstrated the feasibility and benefits of integrating games into vehicles, using the reality outside the car as part of the gameplay. Later studies provide essential design knowledge for the in-car use case of mixed reality, such as Togwell et al. [78], who explored how existing game genres can be adapted for AR in autonomous cars. This includes incorporating real-world elements, such as other vehicles, into the gameplay and changing the appearance of reality, such as augmented cracks in car windows, based on game events. Pöhlmann et al. [62] demonstrated how manipulating the perception of linear in-car VR motion through vehicular translational gain and attenuation can enhance user comfort and experience. Lakier et al. [43] designed in-car games for automated driving, focusing on the potential for multiplayer games between vehicles. Wang et al. [83] designed head-up display interfaces for enjoyable in-car gaming experiences and explored their implications for game design by creating two games augmented by the real-world view. Finally, Hock et al. [29] explored the design of games for players fully immersed in VR, where the visuals in VR match the movement of the vehicle to mitigate simulator sickness.

and increase enjoyment. These papers demonstrate that mixed reality is a preferred method for leveraging the vehicle environment to create unique gaming experiences.

**3.2.2 Gaming During Automated Driving.** This substream focuses on the potential influence of gaming on driving behavior in an automated car. An overview of studies in this substream can be found in Table 2. Studies in this field mostly use casual games from the market and collect quantitative data in a driving simulator. Two studies used a self-made game-like task [51, 52] and one a self-made game [87]. Studies such as Muguro et al. [51] suggest that AR games may enhance takeover scenarios, leading to increased vigilance but with a one-second increase in reaction time [51, 52]. Similarly, Wu et al. [87] demonstrated that games can be designed to increase situational awareness and improve takeover time by transforming other vehicles into game elements. More mixed results were found by Wu et al. [86], who found that playing Tetris can reduce drowsiness and increase takeover performance in younger drivers. However, a decrease in takeover performance was found in older drivers. Vogelpohl et al. [81] observed longer reaction times to return attention to the road after playing Tetris, compared to no task or reading. Findings for transition times for takeover during gaming range from five to eight seconds [50] to 16 to 18 seconds [76]. Reasons for these differences could be different playing times and game types. Nair et al. [54] found that longer game immersion correlates with slower responses, and Jiang et al. [35] found that situational games can improve situation awareness and takeover performance compared to non-situational games or no game, suggesting that certain types of games can positively influence driving performance. So, while vigilance increases consistently when gaming in automated cars, reaction time depends on the game. To compensate for this, investigations into the voice command showing a more assertive voice leading to a faster reaction during gaming [85] might be helpful. Somewhat separate in this substream stands Hecht et al. [28], who explored how conditional automation in vehicles impacts non-driving activities like gaming. Their results showed that frequent switching between automated and manual driving negatively affected the gaming experience. This suggests that games should be designed to be interruptible.

**3.2.3 Theoretical Considerations for In-Car Gaming.** This subset of papers aims at conceptual and theoretical contributions, mainly presenting early ideas for in-car games without implementation or empirical investigation. One study focused on defining the design space of enjoyable interactions during partially automated driving, identifying constraints and research gaps, and linking it to theoretical considerations of stress reduction, paving the way for a stress-free driving experience [37]. An ideation workshop explored game designs that promote stresslessness and well-being in the automotive context and presented a catalog of design features and game ideas for further research in this area [39]. Another study examined the rear seat area for entertainment, exploring different activities and providing important implications for interaction design in this space. Using these implications, they proposed an exemplary multiplayer trivia game for children and adults [84]. In addition, one study addressed the lack of literature on specifications and user needs for automotive games by surveying potential users to identify preferences between driver and passenger games and outlining considerations for both [58]. Another paper applied game design to in-car games, presenting preliminary game concepts that iteratively evolve to balance safety and engagement [72]. Finally, one paper built a model that uses perceived habits, interaction quality, fit, user experience, and play value to explain the continued usage intention of in-car gaming [20]. These papers contribute to our conceptual and theoretical understanding of in-car gaming, providing insights into design considerations, user preferences, and integrating gaming experiences within the automotive context.

Table 2. Papers on gaming during automated driving; Abbreviations: RT = Reaction Time, SA = Situation Awareness, TOP = Takeover performance.

Paper	Year	Game used	Data type	Participants	Variable
[51]	2021	Self-made	Quantitative	13	RT
[52]	2023	Self-made	Quantitative	15	RT, Vigilance
[86]	2020	Tetris	Quantitative	36	Drowsiness, TOP
[87]	2023	Self-made	Quantitative	34	SA, TOP
[28]	2020	Any	Quantitative	33	Acceptance, Usability
[85]	2019	Fruit Ninja Smart Shapes	Quantitative	20	RT
[50]	2017	Temple Run	Quantitative	30	Transition time
[54]	2020	Turtle Survival	Mixed	15	RT
[81]	2018	Tetris	Quantitative	60	RT
[76]	2022	2048	Quantitative	31	TOP, SA
[35]	2023	Subway Parkours Tetris	Quantitative	45	TOP, SA

**3.2.4 Effects of Gaming While Driving.** Another subset of papers deals with the effects of driving while gaming. One study found that Pokémon GO is used while driving and is often a distraction while doing so [6]. Sawano et al. [68] even presented a traffic accident involving Pokémon Go and discussed how to deal with the game on the road. In general, smartphone gaming while driving has raised alarming concerns due to increased accident risks associated with reduced driving performance [63]. A deficit has also been found for a non-visual audio guessing game [32]. These studies clearly show the dangers of playing games while driving in non-automated cars. While these risks certainly need to be considered, there are also positive aspects. Trumbo et al. [80] found increased driving performance associated with decreased fatigue when drivers played a musical trivia game on monotonous road segments.

**3.2.5 Technology Enabling In-Car Gaming.** The smallest subset of papers that emerged from the data extraction were studies that explored technologies to enable in-car gaming. Saldana et al. [67] explored predicting connectivity times when traveling on roads with Wi-Fi access points. This can help players decide whether or not to start a game. To extend the connection time, they suggest using vehicle-to-vehicle connections. To ensure reliable online gaming, Palazzi et al. [57] suggested smart access points in vehicular networks. Looking at the consequences of online gaming over vehicular ad hoc networks, Ben Jaballah et al. [9] emphasizes the importance of network performance and addressing cheating threats, where players cheat about their position. Together, these papers focus on technological innovations to improve connectivity for in-car gaming and show that we need to provide seamless and enjoyable state-of-the-art in-car gaming experiences.

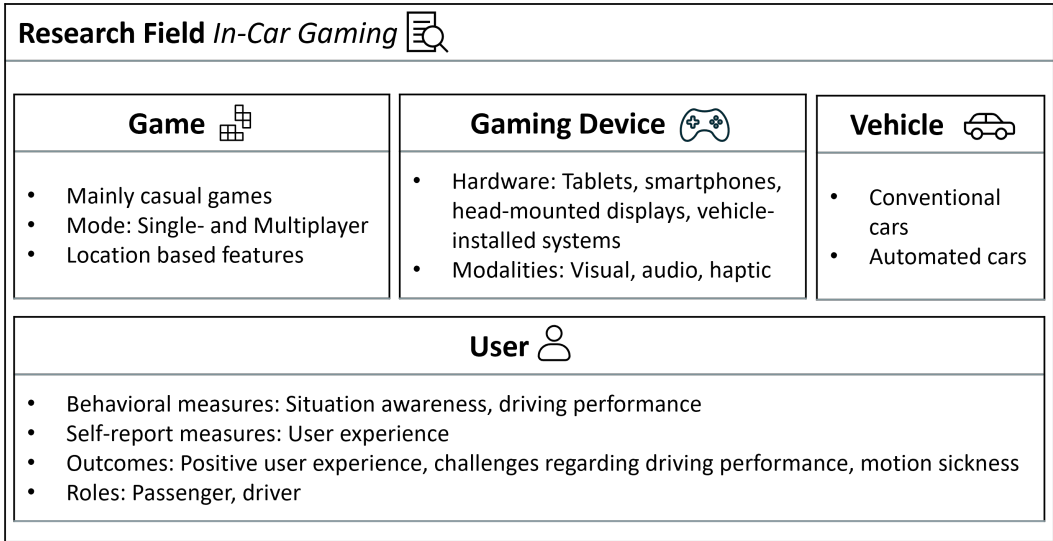


Fig. 4. Overview of the key characteristics of in-car gaming research.

### 3.3 Key Characteristics of In-Car Gaming Research

To address the second research question (RQ2), we inductively aggregated the research field’s key characteristics by analyzing the collected data. The analysis revealed that prior research is quite diverse but predominantly revolves around four research objects: the game, the gaming device, the vehicle, and the user. Figure 4 provides an overview of the identified central research objects used in the following to synthesize and discuss the key characteristics of current research on in-car gaming.

**3.3.1 Characteristics of the Games.** When examining the design of the games in the identified literature, it becomes apparent that almost all of them, except Brunenberg and Ollila [13] and Brunenberg et al. [12], are casual games. With relatively simple controls, easy-to-learn gameplay, and, most importantly, designed for short gaming sessions, they qualify as casual games compared to "regular" core or hardcore games [41]. While the early works of Brunenberg and Juhlin [11] and Brunenberg et al. [12] feature storytelling to foster long-term engagement, the other approaches lack narrative design elements. From a genre perspective, shooter games [78, 83, 87] or shooting games [11, 43] are most common, as well as quiz games [10, 32, 80, 84]. The rest of the games have a wide variety of game elements and little overlap. The distribution of game modes shows a preference for single-player games, with 23 papers dealing with single-player games and 15 with multiplayer games. As noted by Lakier et al. [43], within the in-car multiplayer games, there is an overrepresentation of cooperation with only two competitive approaches [11, 43]. Interestingly, all between-car multiplayer games rely on players being in the same location at the same time. In addition, all identified papers investigate games in a moving vehicle, ignoring situations of parked or waiting vehicles. As expected, the majority of games incorporate location-based features as a central gameplay mechanic [12, 30, 36, 47, 91], or mixed reality elements [11, 12, 29, 43, 78, 83].

**3.3.2 Characteristics of the Gaming Devices.** In terms of input and output devices, the early works of Brunenberg and Juhlin [11], Brunenberg and Ollila [13] and Brunenberg et al. [12] rely on Pocket PCs as input and output devices. While these may be relics of their time, handheld devices are represented

throughout, either with tablets [10, 28, 48, 54, 75, 81] or phones [6, 30, 35, 50, 57, 63, 67, 76, 84, 85, 91]. Including works using head-mounted displays (HMD) [29, 62, 78], more than half of all papers rely on players bringing their own devices for gaming. Another group of studies use hardware installed in vehicles [20, 32, 36, 38–40, 43, 51, 52, 83, 86, 87], such as integrated visual interfaces [20, 43], screens combined with motion tracking sensors as inputs [38, 83], or special steering wheels [36, 51].

While the early works with Pocket PCs by Liselott Brunnberg designed mixed reality games [11–13], later studies using handheld devices such as tablets and phones typically focus on games from the market [6, 28, 35, 50, 54, 63, 67, 76, 81, 85] or propose games without mixed reality elements [10, 48, 84]. Studies that use HMDs or in-vehicle hardware often propose game designs that include mixed reality elements [29, 36, 43, 51, 52, 62, 78, 83, 87]. This includes AR [43, 51, 52, 78, 83] and VR with motion or objects mapped from reality [29, 62, 87]. In terms of modalities, most papers focus on video output and haptic input. At the same time, only a few rely on auditory [12, 32, 80] and haptic output [75] or speech input [32, 80] for their games.

**3.3.3 Characteristics of the Vehicles.** In terms of the vehicle, the main distinction is between automated and conventional vehicles and the role of the driver. Most studies on automated vehicles do not specify the exact level of automation [34]. However, many mention scenarios involving takeovers or limited periods of driver inactivity, which can be classified as conditional automation. Fully autonomous cars are infrequently mentioned and are never the sole focus of these studies [52, 78]. In automated vehicles, periods of driver inactivity and the takeover process are key factors, while in conventional cars, the driver must remain engaged at all times. These differences are reflected in research on in-car gaming. Studies on automated cars focus primarily on gaming during periods of driver inactivity [36–38, 40, 43, 87] or during a takeover scenario [28, 35, 50–52, 54, 76, 81, 85, 86]. In contrast, research on conventional cars tends to explore passenger games [10–13, 30, 47, 78, 83, 91] or play while maintaining control of the vehicle as the driver [6, 32, 63, 80].

**3.3.4 Characteristics of the Users.** Finally, the user is central to in-car gaming. One way the research reflects this is through the analysis of user behavior in relation to in-car gaming. Behavioral **measures** were primarily used to assess the impact of gaming on driving performance and safety [32, 35, 63, 76, 80, 81, 86, 87]. These measures included reaction time [43, 51, 52, 54, 81, 85], and situation awareness [35, 76, 87]. These studies collected quantitative data and presented a mixed picture: In-car gaming can improve driving performance and situation awareness [35, 51, 80, 86, 87], but can also lead to reduced driving performance [32, 63] and prolonged reaction times [52, 76, 81].

Another way to include the user is by evaluating user feedback on in-car games. Various metrics have been used in laboratory settings, focusing on engagement and enjoyment [18, 29, 36, 38, 52, 75, 78, 83], and usability and user experience [10, 20, 28, 30, 36, 40, 43, 48, 54, 62, 91]. These evaluations generally painted a positive picture, but **motion sickness** among passengers was a recurring concern. Several studies have investigated or discussed this issue [10, 29, 30, 48, 52, 62, 83, 91]. Hoffman et al. [30] reported several children having problems with motion sickness, while Meschtscherjakov et al. [48] found motion sickness to be a problem for some people in real traffic but not on a test track. Pöhlmann et al. [62] reported low motion sickness for increased visual motion of the vehicle in VR. Wang et al. [83] found that games that require the user to move in a three-dimensional space are perceived as more likely to cause motion sickness than platform games that follow the vehicle's direction. Possible solutions, such as minimizing reading in game design [10], adapting games to driving conditions [30, 91], incorporating screen breaks [30, 91], placing engagement tasks in a virtual environment outside the car [52], or developing non-screen-based games [91], have been suggested but remain untested.

Beyond looking at specific measures, categorizing users into target groups provides a clearer understanding of their experiences. Most studies did not explicitly specify a target audience, except seven papers that addressed families and children [12, 30, 48, 75, 83, 84, 91]. However, research on in-car gaming delineates different **roles** for passengers and drivers. Of the 42 papers, 19 focus on the driver gaming in a car, 15 focus on the passenger, and eight focus on both the driver and the passenger. Research on drivers that game has primarily focused on automated vehicles, but has also included conventional vehicles, with the goal of ensuring safety while maintaining engagement [32, 35, 50, 51, 54, 68, 72, 76, 80, 81, 85–87]. These studies often use the behavioral measures mentioned above. Passengers have been the primary focus of studies on gaming in conventional cars. Research aimed at passengers seeks to enhance the travel experience by designing engaging in-car games [11–13, 29, 30, 47, 75, 78, 83, 91] or propose technologies that enable gaming on the road [9, 57, 67]. Papers that focus on both the driver and passengers typically aim to promote social interaction between them in conventional cars [10, 47, 48, 84, 91] in order to involve all individuals in the gaming experience.

#### 4 Discussion

This scoping review provides a structured overview of the current literature on in-car gaming, highlighting the diversity of the research field underlying this emerging phenomenon. Our review identifies five interconnected research substreams: in-car game prototypes, gaming during automated driving, effects of gaming while driving, theoretical considerations for in-car gaming, and technology enabling in-car gaming, and aggregates key characteristics of the research field along four central research objects: the game, the gaming device, the vehicle, and the user.

The research substreams collectively define the research priorities and illustrate their evolution over time. The largest substream, comprising a third of the papers, focuses on *in-car game prototypes*. Closely related is the research substream *theoretical considerations for in-car gaming*, which primarily deals with theoretical discussions of specific design concepts. The substreams *gaming during automated driving* and *effects of gaming while driving* both examine the consequences of integrating gaming into the driving context, emphasizing implications on safety and driver behavior. However, while research on *effects of gaming while driving* includes studies investigating drivers playing games in conventional cars, recent research on *gaming during automated driving* exclusively focuses on drivers in automated vehicles. Additionally, a few papers address *technology enabling in-car gaming*, dealing with existing connectivity challenges.

The overview generated by this scoping review further revealed that, regardless of the research streams, all research in this emerging field focuses repeatedly on the same four research objects. At the heart of in-car gaming research is the *game*. A major focus of existing research is on games that are tailored to the unique conditions of the in-car environment; for example, many games incorporate location-based features. Current research uses a variety of *gaming devices*, such as smartphones, tablets, HMDs, and in-vehicle hardware, to deliver the gaming experience to users. While the focus is often on touch input and visual output, some prototypes demonstrate that audio and haptic feedback can also be integrated to create a multi-sensory experience. In most of the papers reviewed, the choice of gaming device seems to correlate with the game design. For example, when using HMDs for in-car gaming, the game design can incorporate AR environments that exploit the HMD's capabilities. Next, characteristics of the *vehicle*, such as whether it is a conventional or automated car, significantly influence the design of the game and the role of the user. For example, in an automated car, visual games for the driver become feasible, unlike in conventional cars. Ultimately, the *user* is the central figure in in-car gaming research. Research focuses on behavioral measures such as driving performance and situational awareness, as well as self-reported measures that assess user experience. These measures vary with the level of vehicle

automation: while takeover performance is a valid measure in automated vehicles, in conventional cars driving performance in general is considered. In essence, the field of in-car gaming research can be understood as an interplay between these four research objects, each influencing the others. A game without a suitable device would be ineffective, just as a user cannot engage in in-car gaming without the other elements.

Furthermore, the four central research objects and the research streams are closely linked. The research objects are studied consistently across the substreams, and their characteristics influence the focus of the substreams. For example, the substream *effects of gaming while driving* considers conventional vehicles, whereas the substream *gaming during automated driving* focuses on automated vehicles. Similarly, the substream *in-car gaming prototypes* focuses on games that are self-designed and tailored to the in-car context. In contrast, other substreams often utilize off-the-shelf games, emphasizing the user's experience of one game as a substitute for in-car gaming in a broader sense. This illustrates that while the research objects are consistently explored across the substreams, the focus and characteristics differ, reflecting the diverse priorities within in-car gaming research.

Based on this overview and the data, an emphasis on active exploration of practical applications and designs characterizes this field. This is evident in the prevalence of *in-car game prototypes*, which focus on the development and evaluation of design approaches and user experience measures, and in the research objects *games* and *gaming devices*, where innovative concepts are often explored. The focus of current research on practical applications rather than theoretical developments can also be seen in the comparatively small number of *theoretical considerations for in-car gaming*, which themselves mainly propose game ideas [37, 39, 72, 84].

Furthermore, examining the development of the research substreams shows that new technological advancements in adjacent fields, such as gaming and automotive, also influence research at this intersection. Notable changes can be seen in the substreams *in-car game prototypes* and *gaming during automated driving*, as well as in the research objects *gaming device* and *vehicle*. The gaming device and the vehicle, being technological products themselves, rely heavily on advances in their field. Examples include the increased use of AR and VR in in-car gaming and the consideration of *in-car gaming during automated driving*. This coincides with the growing application of AR in the automotive sector [64] and the increase in studies related to automated vehicles in the field of automotive user interface [7]. This suggests that new developments, such as connected cars through the expansion of broadband internet to 5G or procedurally generated games through new AI technologies, are also likely to influence research at this intersection in the future.

While research has identifiable focal points, as shown by the substreams, many foundational aspects of in-car gaming remain unexplored. Research peaked in 2017, but the number of publications has since stabilized at a lower level. This trend raises questions about the current state and future direction of in-car gaming research. It appears that much of the innovation and development is shifting from academia to industry as technology matures, with companies increasingly focusing on practical applications and commercial products [49]. However, there are several thematic gaps that need to be explored to enable practitioners to leverage their potential further and provide users with novel entertainment experiences. Therefore, we provide a research agenda based on trends and gaps we recognized across the analyzed pool of papers.

#### 4.1 Identified Trends and Corresponding Research Avenues

In the following section, we highlight emergent trends in the research field. Building upon these, we articulate a set of research questions and delineate existing gaps that invite further scholarly exploration within the HCI research community.

**4.1.1 In-Car Gaming: Context Shift or Unique Experience.** Our review reveals a fundamental tension in in-car gaming research regarding the consideration and use of the vehicle context, including the specific technologies, environment, and social situations in games for in-car gaming. Most commercial implementations and some reviewed research studies simply put off-the-shelf games in cars. These studies focus primarily on the feasibility of in-car gaming rather than integrating the context and thereby ignore the vehicle context's unique opportunities and challenges in gameplay [1, 35, 50, 54, 77, 86]. Other research uses games that acknowledge the context but do not fundamentally depend on it for gameplay [10, 12, 75, 83]. These custom in-car games incorporate basic context characteristics (e.g., speed, seat configuration), but the car's context is not central to the gameplay or narrative and, thus, the user experience. On the other hand, a growing body of research presents prototypes that fully embrace the car's unique environment by integrating real-time environmental and vehicle data and leveraging sensors and in-car technologies. These native in-car game prototypes often employ AR/VR and context-aware design to create dynamic, context-sensitive experiences that are difficult to replicate outside of cars [29, 43, 78, 91].

This variance raises a critical question for HCI research: *Can the automotive context enable gameful experiences fundamentally distinct from other mobile or location-based gaming, or do vehicles merely represent a new application field for existing games?* In particular, whether in-car gaming can sustainably produce novel, unique gameplay experiences that encourage players to explicitly seek out games for this unique environment remains unclear. To advance the research field in this area, we propose a set of research questions to fill gaps identified in our review:

(1) Utilizing Car-Specific Sensors and Data in In-Car Gaming

Our review found that in-car game prototypes studied in the existing body of literature tend to incorporate rather basic vehicle sensors and data (speed, GPS, camera) [12, 47], often mirroring smartphone capabilities. However, vehicles' sensory capabilities and data that go beyond the features of smartphones (e.g., lidar, radar, 360° cameras, suspension system, seat actuators) remain largely unexplored, although they could enable more immersive and more interactive gameplay experiences. Therefore, we ask researchers to explore:

- **Q1:** Can advanced sensor data (e.g., lidar, cabin biometrics, suspension system) be mapped to and leveraged within established game design frameworks to create novel mechanics?
- **Q2:** What are the effects of incorporating advanced vehicle sensor data on player immersion, engagement, and overall user experience in in-car gaming?

(2) Leveraging and Understanding the Variety of Modalities in In-Car Gaming

Our review found that most in-car games rely on visual output and haptic touch input, mirroring traditional gaming [14]. Further, a handful of studies have explored audio-based games in the car [12, 32, 80] or gesture recognition for other use cases in the car besides gaming [66]. Nevertheless, the full range of modalities available in modern cars, such as vibrations, lighting, scent, or air conditioning, remains largely untapped in both research and practice [27]. Furthermore, the impact of different modalities on in-car gaming experiences is not well understood. Leveraging the modalities found in modern vehicles could enable in-car gaming to further differentiate from home or mobile gaming and enhance the relevance of in-car gaming. We therefore ask:

- **Q3:** How can game design and game solutions include modalities of in-car interfaces and their effects?
- **Q4:** How do different modalities influence user experience, and what differences exist between various approaches?

- **Q5:** Do games using multi-sensory integration (e.g., scent, audio, proprioceptive feedback) in vehicle-native gaming systems elicit different experiences compared to traditional home or mobile gaming setups?
- (3) Exploring the Social and Spatial Context of In-Car Gaming Experiences
- Initial research on the specific seating arrangement in cars found that social interactions differ based on seating positions [25]. However, we have not found any research that has analyzed in-depth the social dynamics of cooperative and competitive games in cars. Further, given that passengers cannot easily leave the situation, designers of in-car gaming experiences should pay particular attention to designing games that are comfortable and enjoyable within the confined space of cars [75]. Based on our review, previous research has not sufficiently addressed these specifics and their implications on psychological and behavioral outcomes. Therefore, we propose the following research question:
- **Q6:** How do spatial constraints and fixed seating arrangements of vehicles shape social dynamics and interaction in in-car gaming?
  - **Q7:** How do the specific spatial characteristics influence gaming experiences, and to what extent can these characteristics be used as an opportunity in game design?
- (4) Off-the-Shelf vs. Native Design: Quantifying Contextual Value
- Current research lacks comprehensive comparisons between native in-car games (designed for and deeply integrated with vehicle contexts) and conventional off-the-shelf games when played in a car. While studies like Engl and Nacke [24] demonstrate that context significantly affects gameplay experiences, finding a different experience for the same conventional game played in stationary versus mobile settings, these differences have not been systematically explored within the unique automotive environment. This gap is particularly salient given the HCI paradigm of situated design, which emphasizes how interaction and experience are profoundly shaped by their specific physical, social, and temporal contexts [74]. Therefore, applying this situated lens can be helpful for understanding the potential value of games specifically designed for the car. We therefore ask HCI researchers to address the following questions in future research:
- **Q8:** How does game experience differ between native in-car games and off-the-shelf games, both within the vehicle and in at-home settings?
  - **Q9:** What unique experiential value, if any, do native in-car game designs offer over off-the-shelf games when played in the car?

Varying perspectives characterize the field of in-car gaming: viewing the car as a new gaming environment or embracing gaming in the car as a fundamentally new play experience. While early implementations suggest both paths are technically viable, the unique value of automotive play remains unproven. Our proposed research questions aim to empirically test whether native automotive games elicit distinct experiential and sensory value. Additionally, more knowledge about user needs and interests is essential to understand what kind of experiences players seek in this novel entertainment space, guiding the design of engaging in-car gaming experiences.

**4.1.2 Divergent Safety Outcomes in In-Car Gaming: Risks and Benefits.** Our scoping review reveals another critical tension in in-car gaming research: the same technology that poses well-documented safety risks also contains untapped potential for safety enhancement. This paradox emerges from three key findings in the literature:

*Risk-Benefit Dichotomy by Design.* Studies demonstrate that conventional mobile games degrade driving performance [35, 50, 81, 85]. Conversely, context-aware designs using AR or audio games show promise for maintaining or even improving situational awareness [51, 52, 80, 86, 87]. This

divergence shows that safety outcomes depend less on gaming per se than on specific design choices and integration strategies.

*Disciplinary Silos.* Our review also revealed that psychological studies of driver distraction rarely engage with game design literature on engagement patterns, while game prototypes often lack rigorous safety validation. This fragmentation leads to safety research testing conventional games without safety-optimized designs and studies researching game designs prioritizing engagement metrics over safety outcomes.

*Mixed Ethical Considerations.* Lastly, our review reveals a fragmented approach to ethical considerations in in-car gaming research. While approximately half of the reviewed papers mention ethical concerns, they mostly focus on safety risks and mitigation strategies. A common theme is a call for developers to proactively address these risks, such as by adherence to general guidelines for safe in-vehicle information systems or disabling game features during critical driving situations [6, 10, 43, 87]. Furthermore, comprehensive safety validation before public release is frequently acknowledged as essential [10, 32]. However, many papers overlook ethical considerations entirely.

To transform this tension into actionable guidelines for safe, engaging in-car gaming experiences, we propose the following research questions based on gaps identified through our review:

(1) Analyzing Isolated Interaction Patterns and Modalities for Safety in In-Car Gaming

Our review found that studies investigating safety or driving performance-related outcomes in in-car gaming tend to consider the activity as a whole. They do not account for the variety of interaction patterns and modalities inherent to game design. Existing research considering distraction through mobile phone use demonstrates that driving safety is a complex issue and that individual interaction patterns (e.g., dialing, browsing, etc.) must be considered separately [55]. Other research shows differences in cognitive workload based on the modalities used for feedback in human-machine interfaces in cars [22]. Similarly, within gaming, different modalities of feedback or input (e.g., visual input, auditory cues, haptic responses) can have different demands on a user's cognitive resources and driving safety. This necessitates that different game modalities and interaction patterns be isolated and analyzed separately in safety research. Therefore, we ask researchers to explore:

- **Q10:** Which specific interaction patterns and modalities in gaming correlate most strongly with relevant safety metrics across various driving contexts?
- **Q11:** How do specific interaction patterns and modalities influence safety metrics like reaction time, gaze behavior, and cognitive load?

(2) Developing Consistent Validation Methodologies for Safety-Critical Games

While several established industry standards and norms already exist for in-car information systems and driver distraction [cf. 26], the in-car gaming literature has yet to engage with them meaningfully. By integrating these established standards, in-car gaming research could significantly enhance the methodological rigor and comparability of its safety evaluations. Furthermore, studies investigating safety concerns of gaming in cars primarily used simulators or stationary vehicles rather than in real-world scenarios [29, 36, 47, 83, 87]. This is a critical limitation, as evidence shows that driving performance can differ significantly between simulator and real-road driving [8]. Therefore, we propose the following research questions:

- **Q12:** How can automotive safety standards incorporate game-specific validation protocols?
- **Q13:** What combination of simulator studies, real-world trials, and computational modeling best validates safety-critical gaming systems?
- **Q14:** What are relevant safety metrics for in-car gaming (e.g., gaze dispersion metrics, takeover time), and what are acceptable thresholds for them?

(3) Establishing Comprehensive Ethical Frameworks for In-Car Gaming

Building on the fragmented ethical discourse identified in our review, particularly the narrow focus on immediate safety risks, we observe a critical absence of comprehensive ethical frameworks for in-car gaming. Broader ethical considerations, extending beyond immediate safety, are largely overlooked. To advance the field of in-car gaming responsibly, research must elaborate ethical frameworks that promote safety, inclusivity, data transparency, responsible engagement, sustainability, and culturally diverse gaming in mobility. Research in this field should also address key challenges, such as clarifying liability in accidents involving in-car gaming systems, and contribute to defining guidelines to steer the field's development. Thus, we call for research that addresses the following:

- **Q15:** What vehicle- and mobility-specific aspects need to be considered to make in-car gaming accessible, inclusive, data transparent, sustainable, culturally diverse, and support users' overall well-being?
- **Q16:** How should existing legal and regulatory standards or frameworks evolve to guide ethics in vehicular entertainment?
- **Q17:** How should liability be apportioned between drivers, automakers, and software developers in accidents involving in-car gaming systems?

Systematic research is necessary to resolve the tension between in-car gaming safety risks and the potential for enhancement. Cross-disciplinary collaboration among game designers, automotive engineers, safety psychologists, and policymakers can ensure gaming innovations that undergo rigorous safety evaluation to move beyond generic warnings and create actionable guidelines for safe, ethically responsible, and engaging in-car gaming experiences.

*4.1.3 Addressing In-Car Gaming Challenges: From Reactive to Proactive Design.* Our review reveals that current in-car gaming research often adopts a reactive approach to contextual challenges, addressing issues after they emerge during evaluation. This is evident in two main challenges identified in our review: Firstly, motion sickness significantly impacts user experience in moving vehicles. To counteract motion sickness, current research suggests strategies like omitting text in games [10] or incorporating active screen breaks [30, 91]. These strategies align with general strategies for combating motion sickness, such as keeping eyes on the road or closing one's eyes [69]. Secondly, interruptions (e.g., need to take over, end of the journey) can negatively influence the gaming experience and lead to frustration and reduced retention [28]. To address interruptions, research suggests strategies like allowing players to leave the game anytime and resume later, adjusting the game's difficulty after a break, and implementing well-placed save points [2].

These strategies enhance the player experience by responding to usability challenges. However, they are reactive solutions rather than fundamental design considerations that risk perpetuating suboptimal adaptations of non-automotive game paradigms. To move beyond this, we have identified the following research gaps:

(1) **Considering Automotive Constraints Proactively in Design**

Current solutions (e.g., pause options, visual breaks) to the challenges invoked by the specific context treat symptoms rather than root causes [91]. To advance the field, we propose elaborating design frameworks that proactively treat automotive-specific constraints as foundational design requirements rather than post-hoc fixes. An example is the proactive consideration of the different roles, i.e., the driver and passenger, when designing gameplay mechanics. For instance, Maurer et al. [47] turned the driver's dual role (operator + player) into a collaborative mechanic, rather than treating it as a constraint. We suggest that challenges like motion sickness or interruptions should be reframed as design opportunities rather than obstacles to mitigate, to enable designing novel gameful experiences [cf. 31]. Therefore, we propose the following questions for future research:

- **Q18:** What automotive-specific constraints need to be considered when creating engaging in-car gaming experiences, and how should designers proactively consider them in the design process?
  - **Q19:** What could be appropriate design patterns for addressing these challenges that support entertaining and meaningful gaming experiences in practice?
- (2) Exploring Technological Opportunities for Context Awareness in In-Car Gaming
- While related research in the field of gaming in public transport has begun to explore technological solutions for predicting interruptions (e.g., anticipating player interruptions based on route data or vehicle stops) and dynamically adapting gameplay [90], we found no corresponding approaches in in-car gaming research. Technological solutions could be utilized to deal with the special requirements of the context of in-car gaming. Therefore, we propose that future research consider solutions, such as context-aware computing, prediction, and procedurally generated content, to dynamically adapt the game experience to the vehicle's specific environment. Therefore, we ask:
- **Q20:** How can algorithms be used to automatically adapt gameplay and game mechanics to traffic dynamics?
  - **Q21:** How can traffic or vehicle sensor data be used to procedurally generate game content responsive to the driving context?
  - **Q22:** What effects do such context-aware and adaptively generated in-car gaming experiences have on user experience and motion sickness?

By proactively considering context challenges in the design, researchers can move beyond merely adapting existing games for the car environment and instead pioneer innovative in-car gaming experiences that fully embrace automotive-specific context characteristics and dynamics as integral gameplay elements.

Our analysis of trends found in the pool of reviewed papers led us to identify gaps in the research field and derive several open research questions, highlighting the necessity for more academic research in the field of in-car gaming. While current research is mainly driven by prototype studies, future research should also consider methodological and theoretical contributions, such as design guidelines or frameworks. Furthermore, we also encourage comparative studies that study different solutions or application scenarios to create knowledge beyond the investigation of one single game in a specific situation. Importantly, the issues and opportunities identified in this review, like leveraging context-aware technologies and designing for dynamic environments, extend beyond in-car gaming. They resonate with broader games research, including mobile, AR, and pervasive games. By addressing the questions raised in this review, valuable insights can be gained to improve in-car gaming experiences and provide transferable insights for the broader landscape of digital games.

## 4.2 Limitations

While our scoping review has provided a comprehensive overview of the existing literature on in-car gaming, it is important to acknowledge and address certain limitations. First, the scoping review methodology involves a broad examination of the literature to identify key themes, trends, and research gaps, which may result in the inclusion of studies with varying methodological rigor. Including literature with less methodological rigor could introduce bias or limitations in the synthesis of the studies' findings. Future studies could consider using more stringent inclusion criteria to mitigate this issue.

It is important to note that our choice of Scopus and Web of Science as reputable databases comes with the understanding that their coverage differs from other, less restrictive databases, such

as Google Scholar. While cross-checking the references in the papers and a preliminary search in other databases indicated that Scopus and Web of Science sufficiently covered key venues relevant to our research questions, future research could benefit from exploring additional databases to capture literature that this review may have missed.

We chose to work with a data charting table defined after familiarizing ourselves with the literature to facilitate teamwork and ensure consistency [59]. We allowed inductive adjustments during the review process to avoid missing unanticipated insights by modifying the data charting table as new topics emerged [59]. This approach balances a structured framework with openness to new insights, a common challenge in qualitative research. However, it is important to acknowledge that a more systematic and less inductive-exploratory approach might have led to different findings. The limitations of data charting and inductive adjustments should be considered when interpreting our findings.

We covered only literature specifically on gaming to understand the intersection of gaming and cars. Nonetheless, it is important to acknowledge that other relevant literature exists, such as on non-driving related tasks in general, [53, 55, 88, 89], gamification in cars [5, 21, 73, 82], and other technologies in the mobility context. Such literature can be beneficial for researchers and practitioners in the field as it can offer further insights into design considerations for in-car gaming. For example, studies on texting and mental workload during takeovers, or on VR or AR experiences in the car beyond gaming, can inform in-car game design. Future research could incorporate findings from such related domains to enrich research in the field of in-car gaming.

## 5 Conclusion

This scoping review provides a comprehensive analysis of existing research on in-car gaming, an increasingly relevant phenomenon driven by the convergence of gaming and cars. By synthesizing the content of 42 papers, we provide an overview of this emerging research field, highlighting diverse developments across design, psychology, and technology in five identified research substreams. Our work summarizes current research priorities and identifies relevant characteristics structured according to the most frequently considered research objects: the game, the game device, the vehicle, and the user.

The findings reveal the potential for in-car gaming to become a new and unique domain of entertainment, with profound implications for how we implement and view gaming in vehicles. We conclude with three research trends and research questions derived from our review for navigating this emerging field. As gaming continues to grow in popularity, especially alongside advances in automotive automation, we want to encourage researchers to engage with the question of whether in-car gaming can provide novel gaming experiences.

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## A Search Queries

### A.1 Scopus

(TITLE-ABS-KEY (gaming OR game\*) AND TITLE-ABS-KEY (in-vehicle OR in-car OR automotive OR automobile OR passenger OR rear-seat) AND NOT TITLE-ABS-KEY (game\_theory))

### A.2 Web of Science

((TI=(gaming OR game\*) OR AB=(gaming OR game\*) OR AK=(gaming OR game\*)) AND (TI=(in-vehicle OR in-car OR automotive OR automobile OR passenger OR rear-seat) OR AB=(in-vehicle OR in-car OR automotive OR automobile OR passenger OR rear-seat) OR AK=(in-vehicle OR in-car OR automotive OR automobile OR passenger OR rear-seat))) NOT (TI=(game\_theory) OR AB=(game\_theory) OR AK=(game\_theory))

## B Data Charting Form

Table 3. Data charting form

Item	Description
<b>General Information</b>	
Type of Paper	Conference paper; Journal article
Discipline	
Author Location	
<b>Research Objective + Contribution</b>	
Research Question	
Main Finding	
Contribution Type	Artifact; Theoretical; Empirical; Technological
Method	Design research; Secondary research; Empirical study; Simulation
Target Group	
<b>User Evaluation/Empirical Study</b>	
Country	
Type of Data	Quantitative; Qualitative; None
Setting	Lab; Driving Simulator; Field; Online
Variables	
Participants	N; Age; Gender; ...
Result	
<b>Game-Related Information</b>	
Platform	Bring your own device (phone, tablet); Integrated into infotainment system; Console/PC; Wearables (Glasses)
Augmented Reality	Yes; No
Input Channels	
Output Channels	
Category of Game	
Social	Yes, cooperative; Yes, competitive; No
Motion Sickness	
Duration	
<b>Vehicle-Related Information</b>	
Car	Car, driver in full control; Car, shared control with takeover; Car, full automation
Role in Vehicle of Player	Driver; Passenger

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