How Does a Rearview Camera Influence Driver Performance and Confidence in Parking?

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ABSTRACT

Urban parking challenges continue to intensify as vehicle density increases and parking spaces become scarce, making efficient reverse maneuvering a critical driver skill. While reverse camera technology promises to enhance parking performance by eliminating blind spots and providing real-time visual feedback, limited empirical evidence exists regarding its actual behavioral impact across diverse driver populations. This controlled field study addresses this gap by systematically examining how camera technology transforms driver behavior during reverse parking maneuvers in realistic urban conditions. A comprehensive 2×2 factorial experiment was conducted using 18 participants (9 males, 9 females) who completed four standardized parking tasks: parallel and perpendicular maneuvers under both no-technology and camera-assisted conditions. The study was conducted in a controlled outdoor environment using a sport utility vehicle equipped with standard reverse camera technology. Results reveal significant behavioral adaptations and performance variations across technology conditions, gender, and experience levels. All experienced drivers demonstrated consistent visual scanning behavior during unassisted parking, indicating well-developed situational awareness strategies. Conversely, inexperienced drivers exhibited longer completion times when using camera technology, suggesting a cognitive adaptation period as they integrated multiple information sources such as dashboard display, side mirrors, and rearview mirror into their maneuvering strategy. Gender-based performance differences emerged across all experimental conditions, with female participants requiring longer completion times regardless of technology assistance or maneuver type. These findings provide critical insights for automotive manufacturers, urban planners, and driver education programs, highlighting the need for differentiated technology design and training approaches. The study contributes to the growing body of research on human-machine interaction in automotive contexts and offers evidence-based recommendations for optimizing camera-assisted parking systems.

Keywords: Reverse camera technology, parking behavior, driver assistance systems, human-machine interaction

INTRODUCTION

Parking is a routine task in driving but remains challenging, particularly during reverse maneuvers. Restricted visibility, blind spots, and the need for precise spatial control often make reversing more difficult than forward parking, leading to accidents, property damage, and pedestrian injuries, especially in crowded areas (Li, 2025).

Traditional aids such as rearview mirrors, side mirrors, and over-shoulder glances provide some visual information but only cover about 73% of the rear area, leaving blind zones along the sides of the vehicle as illustrated in Figure 1 (Maitra et al., 2017). Inexperienced drivers are especially prone to difficulties with distance judgment and alignment, which contributes to stress during driving (Yang & Wu, 2017).

Despite these challenges, many drivers still prefer reverse parking over forward parking, as it allows greater accuracy and provides safer exit from parking spaces. By reversing into a spot, drivers gain better visibility when leaving, reducing the risk of collisions with other vehicles and pedestrians (Findley et al., 2020). This preference highlights the importance of technologies that make reverse parking safer and more manageable.

To address these limitations, Advanced Rear Visualization (ARV) systems have been developed. A small camera mounted at the back of the vehicle captures real-time images of the rear surroundings, including shorter objects that may be hidden from a driver's view (McLaughlin et al., 2003; Xie & Hlynka, 2019). Automobile manufacturers have increasingly equipped vehicles with such driver assistance systems, including ultrasonic sensors and rearview cameras, to enhance safety during reversing (Kidd & McCartt, 2016).

Beyond safety, parking is also a major concern in urban areas and parking malls due to the growing demand for spaces. In such environments, efficient use of available parking aids can reduce the duration of parking maneuvers, particularly when reversing, thereby improving both safety and convenience.

METHODOLOGY

Study Design Overview

This study employed a controlled field experiment using a 2×2 factorial design to investigate the impact of camera technology on driver behavior during reverse parking maneuvers. The experimental design systematically compared driver performance across two primary variables: parking maneuver types (parallel and perpendicular parking) and technology conditions (no technology versus camera technology assistance). The factorial approach resulted in four distinct experimental conditions:

(a) Parallel parking with no technology assistance

(b) Parallel parking with camera technology assistance

(c) Perpendicular parking with no technology assistance

(d) Perpendicular parking with camera technology assistance

Each participant completed all four tasks in a controlled outdoor environment, allowing for within-subject comparisons while minimizing external variables. The study utilized a balanced participant pool of 18 drivers (9 males, 9 females) to examine potential gender-based differences in technology adoption and parking performance.

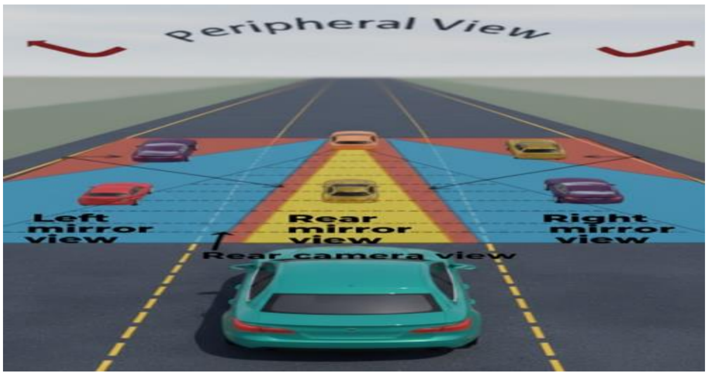

Figure 1. Difference between rear mirror view (red color), side mirror view (blue color) and rear camera view (dashed area) (Maitra et al., 2017)

Participants

A total of 18 participants (9 males, 9 females) volunteered for the study. An equal number of male and female participants was designed to support fair representation and reduce gender-based sampling bias. Participants were recruited from the Universiti Teknikal Malaysia Melaka (UTeM) community, including both staff and students, to ensure access to a motivated and accessible participant pool, with inclusion criteria including age (20–50 years), a valid driver's license held for at least two years, and regular driving activity. Age groups were 20–30 years ($\bar{x}$ = 24.86, s = 1.17), 30–40 years ($\bar{x}$ = 34.83, s = 3.19), and 40–50 years ($\bar{x}$ = 41.50, s = 1.87). "Experienced drivers" were defined as those with 5+ years of driving and frequent use of vehicles under diverse conditions; "inexperienced" referred to 2–4 years with limited exposure. All participants met the experienced driver criteria ($\bar{x}$ = 8.3 years, range: 2–17 years). All participants were informed about the study purpose and procedures, and verbal consent was obtained before participation.

Vehicle Configuration and Camera System

The research vehicle was a 2013 Honda CR-V, featuring a factory-installed rearview camera system that displayed video on a 5-inch color LCD intelligent-Multi Info Display (i-MID) screen located at the top center of the dashboard. This central placement provided a clear and easily accessible view for the driver during reversing maneuvers. Importantly, the vehicle was not equipped with an ultrasonic rear parking sensor system, allowing for the observation of natural visual scanning behavior without automated alerts. To assess glance patterns, three cameras were used: two HD cameras (Eken H9R 4K, 25fps Sport Action camera) were mounted on adjustable holders fixed to the left and right sides of the dashboard to record mirror checks and head orientation. A third camera was attached to a headstrap mount worn by the participant to capture their forward field of view and off-road glances. The dashboard display and camera configuration are shown in Figure 2, which shows the participant wearing the head-mounted camera, with the left and right cameras clearly visible.

Figure 2. Interior camera position

Test Environment Setup

The parking maneuvers were conducted at the parking area of Universiti Teknologi Malaysia Melaka (UTM Melaka), a controlled outdoor facility selected for its accessibility, safety, and standardized infrastructure suitable for behavioural driving research. All trials were performed during daylight hours under clear weather conditions, ensuring consistent natural lighting and optimal visibility for participants and data recording systems.

The experimental setup was designed to simulate real-world parking scenarios while maintaining standardized area constraints. Figure 3 illustrates the parallel parking maneuver, in which the participant vehicle reversed into a designated space measuring 6 meters in length and 2.5 meters in width. The space was positioned along the left side of a traffic lane and bounded by a concrete curb on its left edge. Two orange traffic cones were placed at the rear end of the space to simulate adjacent parked vehicles, with a 0.5-meter gap between each cone and the curb to reflect realistic parking boundaries. The participant began the maneuver from a forward-facing position aligned with the lane and reversed into the space using only visual feedback.

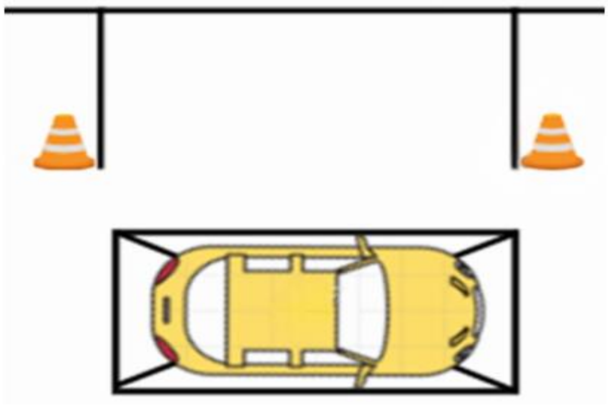

Figure 3. Parallel parking maneuver

Figure 4 depicts the perpendicular parking maneuver, where the participant reversed into a rectangular zone of identical dimensions (6 m × 2.5 m), defined by painted boundary lines on the pavement. Two stationary vehicles were positioned on the left and right sides of the participant's vehicle to replicate typical constraints encountered in urban parking environments. The maneuver commenced with the participant facing forward and aligned with the space, followed by a reverse entry at approximately a 90-degree angle.

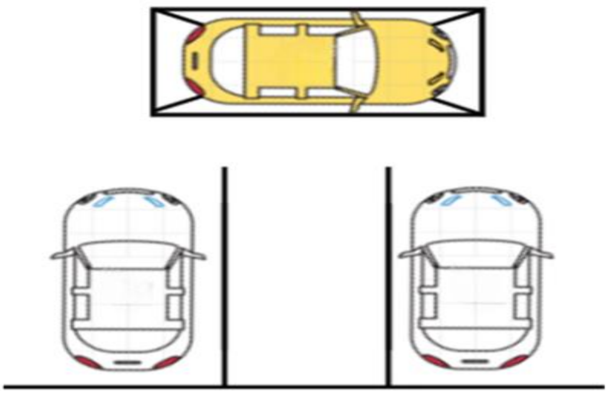

Figure 4. Perpendicular parking maneuver

Prior to data collection, the site was prepared to ensure consistency across trials. This included cleaning the pavement surface, refreshing the parking boundary markings with high-visibility white paint, and precisely positioning the cones and adjacent vehicles according to standardized protocols. These measures minimized spatial variability and ensured uniform task difficulty throughout the study.

Experimental Tasks and Conditions

Two types of parking aids were used by the participants (no technology and camera technology). In the no-technology condition, no parking aid system was used; hence, side mirrors and rearview mirror were fully utilized to complete the tasks. For the camera technology condition, a continuous rear-view environment was displayed on the i-Mid when the vehicle was put in reverse mode. This study examined driver performance across four distinct parking conditions, combining two types of parking (parallel and perpendicular) with two levels of technological support (no technology and camera technology):

(a) Parallel parking with no technology: Execution using only side and rearview mirrors

(b) Parallel parking with camera technology: Execution with rearview camera displayed on the i-MID

(c) Perpendicular parking with no technology: Mirror-only reversal into the bay

(d) Perpendicular parking with camera technology: Reversal with camera assistance

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In the no-technology condition, participants had no access to the built-in rearview camera display, relying solely on traditional visual cues from mirrors. In the camera technology condition, shifting into reverse automatically activated the rear camera, projecting a continuous view of the area behind the vehicle onto the centrally mounted i-MID screen. To control for order and learning effects, the four tasks were presented in a randomized order for each participant. A practice trial (not scored) was administered prior to the first experimental trial to minimize initial performance bias. A trial was considered successful if:

(a) The vehicle stopped completely within the marked boundaries

(b) There was no physical contact with cones (parallel) or adjacent vehicles (perpendicular)

(c) No part of the vehicle trespassed on the curb or crossed boundary lines

(d) The final position was stable and aligned with the parking space (deviation < 15° from centerline)

All trials were video-recorded and independently assessed by two observers, with discrepancies resolved through consensus.

Data Collection

The primary focus of this study was to assess parking duration and glance behavior during reverse parking maneuvers under two levels of technological assistance: no technology (mirror-only) and camera technology (rearview camera via i-MID display). The experiment was conducted in a controlled outdoor environment at the parking lot at the Universiti Teknikal Malaysia Melaka (UTeM) Technology Campus, with all trials performed during daylight to ensure consistent environmental conditions. Before testing, all participants attended a brief safety orientation, which included instructions on vehicle operation, speed control, emergency procedures, and the right to withdraw at any time. A researcher remained present during each trial to monitor safety, though no intervention was made unless a hazard arose.

Each participant performed the four tasks in a randomized order to minimize learning and order effects which were (1) parallel parking without a camera, (2) parallel parking with a camera, (3) perpendicular parking without a camera, and (4) perpendicular parking with a camera. Each trial began from a standardized starting point (Figure 5), and participants reversed into the designated space. Parking duration was recorded from reverse gear engagement to a complete stop within the space. Successful completion was verified using criteria including full containment within boundaries, no contact with cones or adjacent vehicles, and alignment within ±15° of the ideal position (Figure 6 and Figure 7).

Upon completion of all driving tasks, participants completed a post-experiment questionnaire assessing perceived workload, ease of use, and preference for parking aids.

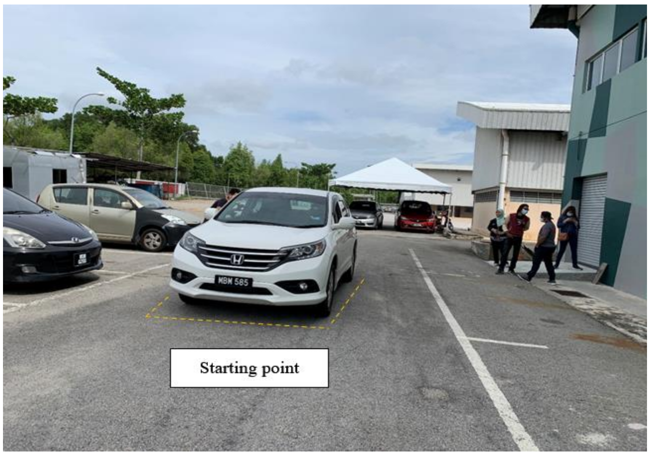

Figure 5. Standardized starting position for all parking maneuvers. The participant vehicle is aligned with the lane, ready to initiate the tasks.

Figure 6. Final vehicle position after successful parallel parking maneuver. The vehicle is fully contained within the designated space, bounded by a curb and two traffic cones.

Figure 7 Final vehicle position after successful perpendicular parking maneuver. The vehicle is centered within the marked bay, with adjacent vehicles on both sides.

RESULTS AND DISCUSSIONS

The experimental results revealed a significant relationship between the driver's experience and glance behavior during reverse parking maneuvers. Video analysis showed that all experienced participants made at least one glance toward the rearview display area when no camera technology was available, indicating a deliberate reliance on visual scanning strategies to compensate for limited rear visibility. A representative snapshot from the interior camera of an experienced participant during a reverse maneuver is shown in Figure 8, illustrating a clear glance toward the display. When the rearview camera was activated, participants exhibited more frequent but shorter glances to the i-MID screen, suggesting efficient integration of real-time visual feedback into the parking task. A representative glance behavior from an experienced driver is illustrated in Figure 8, captured via the interior-facing camera. These findings align with (McLaughlin et al., 2003), who evaluated two rear parking aid systems and reported that visual displays significantly enhance drivers' spatial awareness during reversing tasks. Their study found that camera-based systems reduce reliance on mirrors alone and support more accurate distance estimation, enabling drivers to park closer to curbs and avoid collisions. The current results support this conclusion, demonstrating that camera technology not only supplements but also transforms visual attention patterns in experienced drivers.

(a)

(b)

(c)

Figure 8. Interior images captured by (a) head-mounted camera (b) right camera (c) left camera when the participant had a glance while reversing the vehicle with no technology used.

The effects of rearview camera technology on parking performance were examined across two maneuvers; parallel and perpendicular with two levels of driver experience. As shown in Figure 9, parking duration was longer when camera technology was used during parallel parking compared to the no-technology condition, while the opposite pattern emerged in perpendicular parking, where camera use reduced parking time relative to mirror-only conditions. This divergence suggests that the benefits of visual aids are not universal but depend on task complexity and user proficiency.

This interpretation is further supported by Figure 10, which compares performance between experienced and inexperienced participants under camera technology. Survey results indicated that 33.33% of participants had no prior experience using camera technology while reversing, highlighting a significant subset of users unfamiliar with this driver assistance system. Analysis of parking performance revealed that inexperienced participants achieved a minimum completion time of 0.66 minutes for the parallel parking maneuver and 0.89 minutes for the perpendicular maneuver (Figure 10a). In contrast, experienced participants as shown in Figure 10b recorded even shorter minimum times of 0.45 minutes (parallel) and 0.54 minutes (perpendicular), reflecting greater proficiency and confidence in spatial control. However, inexperienced participants also exhibited longer average parking durations across both tasks. This performance gap suggests that unfamiliarity with the rearview camera system may hinder efficient task execution. These findings align with the study by Reimer et al.(2010), which found that performing a new or unfamiliar task induces cognitive stress. In this context, stress manifests as increased mental workload, requiring drivers to simultaneously manage vehicle operation and monitor the display for rearview feedback. This dual-task demand can lead to divided attention, hesitation, and prolonged maneuver times which ultimately increases the cognitive load in an effort to avoid collisions.

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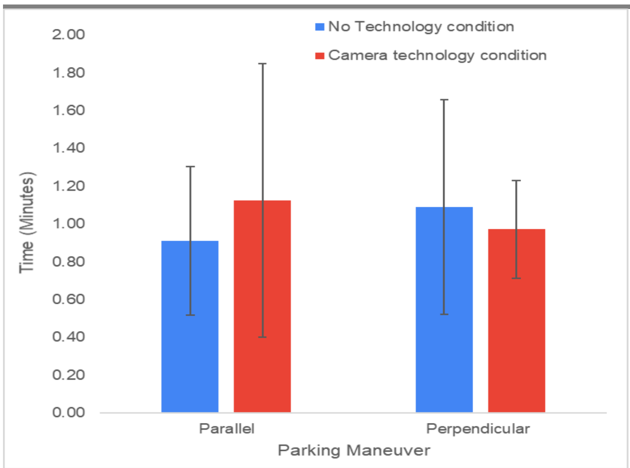
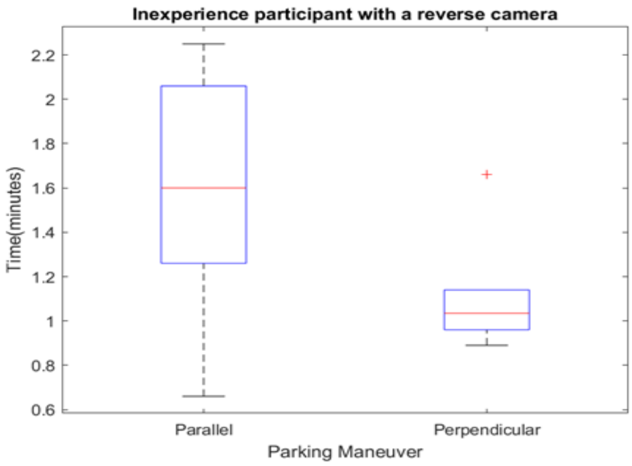
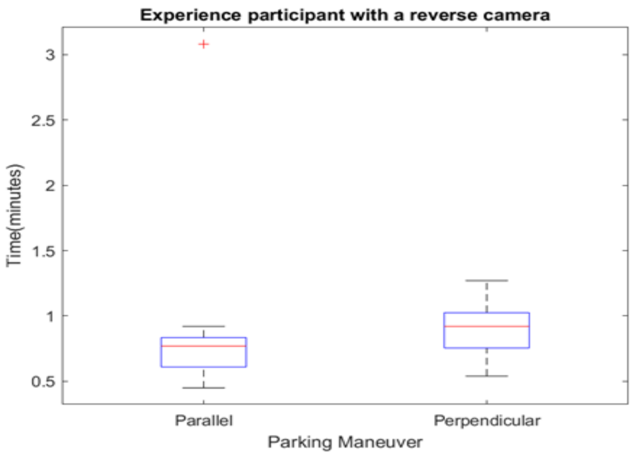


Figure 9. Mean parking time for the parallel and perpendicular parking maneuvers for different technologies (no technology and camera technology). (Error bars reflect the standard deviation of the mean).



(a)



(b)

Figure 10. The difference in parking time for (a) inexperienced participants and (b) experienced participants with a reverse camera.

The histograms presented in Figure 11 illustrate gender-based differences in parking duration across two technological conditions. In the no-technology condition (Figure 11b), female participants consistently exhibited longer parking times than male participants. This suggests that, without visual assistance, females may adopt a more cautious approach to reversing maneuvers, potentially prioritizing accuracy over speed—consistent with findings by (Afshari et al., 2024), which indicate that women tend to be more risk-averse and detail-oriented

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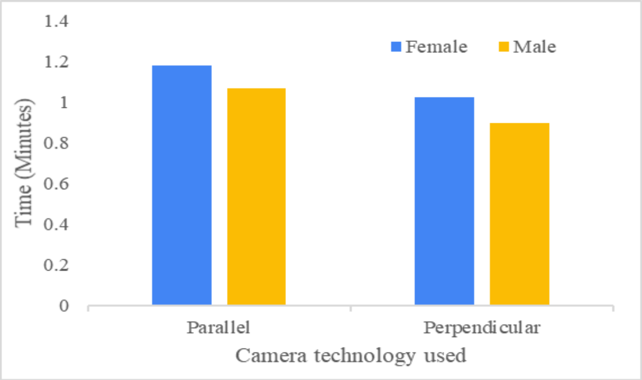
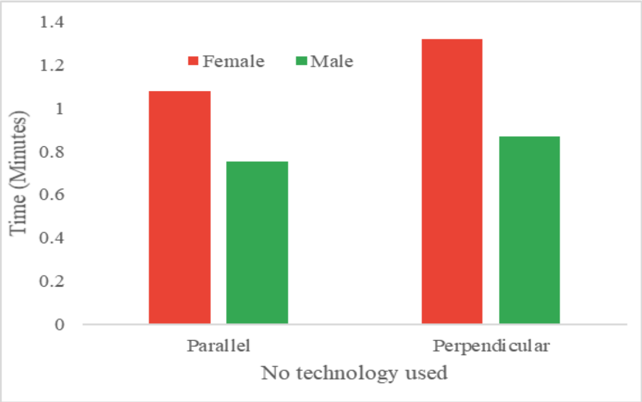
during driving tasks. However, camera presence during reverse parking made the parking duration shorter.

These results suggest that rearview camera technology can help mitigate gender-related differences in parking performance by providing supplementary visual feedback that supports spatial judgment and reduces uncertainty. This aligns with prior research indicating that technological aids enhance confidence and reduce cognitive load, especially for individuals who are more cautious or less experienced in certain driving scenarios (Mehdi Cina, 2024).



(a)



(b)

Figure 11. Mean parking time for the parallel and perpendicular parking maneuvers for (a) camera technology (b) no technology based on gender.

CONCLUSION

This study confirms that rearview camera technology plays a critical role in enhancing parking safety and efficiency. The presence of a camera during reversing was shown to significantly reduce parking duration, particularly among inexperienced drivers who often struggle with distance judgment and alignment. While experienced drivers continued to rely on traditional visual checks, they still benefited from the added perspective of the camera, demonstrating that the technology provides value across different driver groups. These results underscore the importance of equipping modern vehicles with reverse cameras to address blind spots, improve situational awareness, and minimize the likelihood of collisions with obstacles, property, or pedestrians.

Beyond improving accuracy and safety, the continuous use of rearview cameras contributes to increased driver confidence during challenging parking scenarios, especially in crowded urban settings or high-traffic conditions. This confidence not only decreases stress while driving but also promotes more efficient use of limited parking spaces, an increasingly important factor in dense city environments. Such benefits highlight the broader societal value of widespread adoption of parking-assist technologies.

However, the study also identified limitations in the performance of rearview cameras, most notably the glare effect, which reduces image clarity, increases parking duration, and in certain situations could contribute to accidents (van den Berg TJ, 2009). As cameras act as an extension of the driver's vision, addressing these shortcomings is essential to ensure their reliability in diverse lighting conditions. Future research will therefore investigate the impact of glare on driving performance in greater detail and explore design improvements or supplementary driver-assist features that can mitigate this drawback.

Overall, the findings of this study support the continued integration and refinement of camera-based driver assistance systems. By reducing parking difficulty, enhancing safety, and improving driver confidence, rearview cameras represent an essential step toward safer and more intelligent vehicle technologies.

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REFERENCES

1. Afshari, A., Azadnia, A., Ghasemzadeh, M., Yazdani, S., Razzaghi, A., Daneshi, S., & Hushmandi, K. (2024). Driving Safer: A Look at How Men and Women Use Advanced Driver Assistance Systems. In Russian Open Medical Journal (Vol. 13, Issue 4). Russian Open Medical Journal. https://doi.org/10.15275/rusomj.2024.0404
2. Findley, D. J., Nye, T. S., Lattimore, E., Swain, G., Bhat, S. K. P., & Foley, B. (2020). Safety effects of parking maneuvers. Transportation Research Part F: Traffic Psychology and Behaviour, 69, 301–310. https://doi.org/10.1016/j.trf.2020.02.002
3. Kidd, D. G., & McCartt, A. T. (2016). Differences in glance behavior between drivers using a rearview camera, parking sensor system, both technologies, or no technology during low-speed parking maneuvers. Accident Analysis and Prevention. https://doi.org/10.1016/j.aap.2015.11.030
4. Li, X. (2025). Advances in Multimodal Sensor Fusion and Deep Learning for Autonomous Truck Reverse Parking. https://doi.org/10.54254/2755-2721/154/2025.TJ23107
5. Maitra, B., Cheranchery, M. F., & Prasad, P. (2017). Rules For Safe Driving. In Training Manual for Drivers (Issue February).
6. McLaughlin, S. B., Hankey, J. M., Green, C. A., & Kiefer, R. J. (2003). Driver Performance Evaluation of Two Rear Parking Aids. Proceedings of the 18th Enhanced Safety of Vehicles Conference, 46 cm.
7. Mehdi Cina. (2024). Mirroring Human Behaviour and Machine in Autonomous Cars. Faculty of Applied Sciences.
8. Reimer, B., Mehler, B., & Coughlin, J. F. (2010). An Evaluation of Driver Reactions to New Vehicle Parking Assist Technologies Developed to Reduce Driver Stress. In New England University Transportation Center (Issue November). https://doi.org/10.13140/RG.2.1.3317.3361
9. van den Berg TJ, van Rijn LR, Kaper-Bongers R, Vonhoff DJ, Völker-Dieben HJ, Grabner G, Nischler C, Emesz M, Wilhelm H, Gamer D, Schuster A. (2009). Disability glare in the aging eye. Assessment and impact on driving. Journal of Optometry, 2(3), 112–118. https://doi.org/10.3921/joptom.2009.112
10. Xie, K., & Hlynka, M. (2019). Forward and Reverse Parking in a Parking Lot. Applied Mathematical Sciences, 13(22), 1091–1102. https://doi.org/10.12988/ams.2019.99128
11. Yang, H., & Wu, Z. (2017). Effect of novice driver's car-following characteristic on roadway segment capacity. Advances in Mechanical Engineering, 9(7). https://doi.org/10.1177/1687814017711853