A Research and Design on Automotive A-Pillar Vision Obstruction

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Abstract: A-pillars can obstruct the driver's view, creating a blind spot that affects driving safety. Therefore, it is necessary to design a new device that allows drivers to quickly identify traffic objects despite the visual obstruction of the A-pillars. This study proposes a new alternative solution. The design consists of two parts: a monitor and a surveillance camera. The monitor is located on the inside of the A-pillar and displays real-time traffic information captured by the surveillance camera outside the car, covering the driver's blind spot. The surveillance camera is mounted on the outside of the A-pillar and monitors the traffic information in the driver's blind spot via video. In a static simulated driving environment, researchers conducted experiments using this device to detect traffic objects, identify traffic objects, and measure detection difficulty. Finally, the experimental data were analyzed using SPSS V26 software. The results show that the proposed monitor system significantly outperforms the A-pillar in detecting traffic objects, detection difficulty, and the accuracy of identifying traffic objects. The proposed monitoring system can help drivers overcome the visual obstruction of the A-pillars, improve driving safety, provide better protection for pedestrians, other drivers, and animals, and assist automotive developers in overcoming the limitations of traditional A-pillars to develop car designs with fewer limitations.

Keywords: Automotive Pillars Obscuration; Field of Drivers' Vision; A-pillar Obstruction; Blind Area

1. Introduction

At present, most new automotive safety technologies focus on minimizing occupant injuries when accidents occur. While it is crucial to reduce the severity of injuries and fatalities through these technologies, preventing vehicle accidents should be a high-priority project [1,2]. The increasing complexity of road traffic objects and the visual obstruction caused by the A-pillar are significant factors contributing to traffic accidents [3-6]. Therefore, one of the important methods to improve ground traffic safety is to provide an unobstructed or optimized field of vision, which can increase the driver's reaction time for positive identification of other vehicles, road warning signs, and pedestrians [1,7]. Thus, it is necessary to design a new device that allows drivers to quickly identify traffic objects despite the visual obstruction of the A-pillar [8].

The focus of this study includes two aspects. The first key content is to propose a new alternative solution to solve the visual obstruction problem caused by automotive A-pillars. This solution consists of two parts: a monitor and a surveillance camera. As shown in Figure 1, the monitor is located on the inside of the A-pillar to display real-time traffic information captured by the surveillance camera outside the car, covering the driver's blind spot. The surveillance camera is mounted on the outside of the A-pillar and monitors the traffic information in the driver's blind spot via video. The lens on this surveillance camera has advantages such as high sensitivity, high brightness, strong light resistance, low distortion, vibration resistance, and uniform light [9]. Thus, when the driver makes a left turn, they can view the traffic information in the driver's blind spot outside the car through the display screen, avoiding the obstruction of the A-pillar. The proposed design aims to reduce accidents caused by seeing but not perceiving and provide drivers with extra reaction time to avoid possible collisions with other traffic objects. The prototype of this device was manufactured in collaboration with Huizhou Foryou General Electronics Co., Ltd., a leading Chinese automotive electronics company.

Another focus of this study is to investigate the driver's ability to detect and identify other traffic objects using this device. To this end, the study proposes two hypotheses, which are the main points of this research, as shown below. The correctness of these points will be verified through experiments.

1. Hypothesis #1 (H1) = The visual detection results of traffic objects with the proposed monitoring device to solve the A-pillar obstruction and the current A-pillar (old A-pillar) are significantly different.
2. Hypothesis #2 (H2) = The visibility of the proposed monitoring device is significantly better than the visibility of the current A-pillar.

Monitor located inside the A-pillar   Monitoring camera located outside the A-pillar

Figure 1. Schematic Diagram of the Monitoring Equipment's Working Principle

2. Literature Review

2.1 The Relationship between Automotive Pillars and Driver's Field of Vision

Pillars provide a structural framework around vehicle occupants. This structural framework offers a barrier between passengers and the external environment, protecting drivers and passengers in the event of an accident [3,7]. The style, shape, and size of the pillars depend on the vehicle's overall geometry, crashworthiness, and aerodynamic requirements. According to the SAE J941 human model, the A-pillar forms a pillar obstruction angle, denoted as Aθ [10,11]. Figure 2 shows the obstruction area formed by the A-pillar in a typical passenger car [1]. This depends on the vehicle's overall geometry and anthropometric differences in the driver's and driver's seat position (fore and aft, height). According to EEC 77/649 (European Economic Community), the obstruction angle of the A-pillar should not exceed 6O [12]. When the obstruction angle exceeds 6O, this regulation strictly questions the vehicle's safety. Studies have shown that only one-third of vehicles meet this standard [1, 7].

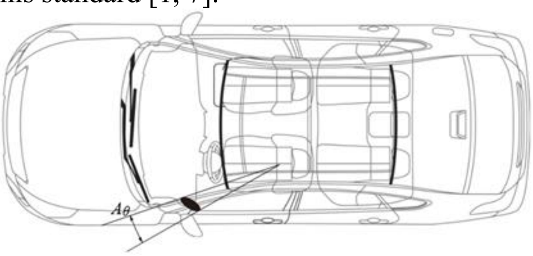

Figure 2. The Shaded Area on the A-Pillar Region Indicates the Portion of the Pillar that Obstructs the Driver's View

Vehicles should minimize the presence of any obstructions (steering wheel, rearview mirrors, pillars, dashboard, etc.) to improve visual quality and comfort [7,13]. The frame around the driver and passengers, known as "pillars," is the main obstruction element in a car [13]. The permanent presence of pillars continuously obstructs and threatens driving safety [1,3,4,7]. Drivers mostly eliminate such obstructions by moving their heads in the lateral plane [14]. However, this method does not necessarily avoid or reduce potential loss of vision. Literature reviews and current vehicle design trends indicate that pillar geometry and size are the primary causes of visual obstructions and are key elements in vehicle design [15]. As the overall design of car bodies becomes more streamlined, the size of the A-pillar in the lateral plane becomes larger, which also means a larger range of vision obstruction.

2.2 Overview of Vision Obstruction Problems Caused by Pillars

The primary sensory input that drivers use to maneuver and control the vehicle is visual perception [16]. It is estimated that vision provides 90% of the sensory input during driving [4]. Haslegrave's study found that near-field objects have a considerable impact on visual obstruction [11,17-19]. Studies show that if binocular vision does not exceed 40%, objects cannot be correctly detected and identified, increasing the risk of accidents [20]. Poor binocular vision reduces the ability to avoid obstacles or take the correct actions [4, 19].

Permanent obstacles near the eyes can lead to loss of vision or cognitive expectation (inability to scan specific categories of road users). This ultimately results in incorrect information recognition while driving [4]. It is also noted that loss of peripheral vision significantly impacts real-world accidents, and the risk of accidents increases with the severity of vision loss [21]. In such cases, subjects with peripheral vision loss exhibit a tendency to compensate for vision loss through lateral eye movements. This may also include lateral neck movements to increase the field of vision, which may increase reaction time [18,21]. Literature reviews also show that as the peripheral visual angle away from the central fovea (or line of sight) increases, the detection distance of peripheral vision significantly decreases [11,21]. This is important in situations requiring early detection, such as detecting vehicles through curves or at intersections [22].

The A-pillar has been identified as the primary obstruction to the driver's field of vision. The A-pillar causes vision obstruction during lane changes, urban driving, parking, and turning. Studies have found that the A-pillar may limit the fundamental visibility of road signs, other vehicles, and pedestrians [3]. Recent research indicates that the size and angle of the steering column significantly affect vision obstruction during lane changes [15]. It is also noted, though not explicitly stated, that the geometry of the A-pillar may influence the turning trajectory, potentially contributing to traffic accidents at intersections, curves, and pedestrian crossings [13,15]. Studies also found that the thickness of the pillars affects visual obstruction. Notably, slender A-pillars provide better visibility compared to thick A-pillars, and some manufacturers offer slim pillars to increase visibility [1,6].

A study by Matthew Reed indicated that the A-pillar creates large blind spots in the areas close to the vehicle's driving path. This is associated with increased collision risk with pedestrians during vehicle turns [23]. A similar study shows that the detection of distant targets is affected when the pillar width exceeds the observer's interocular distance [24].

According to a study by the UK Department for Transport, "looked but did not see" accidents account for 20% of all road accidents [2]. Unfortunately, the impact of A-pillar obstructions on "looked but did not see" accidents was not specifically stated in this study. However, experts suggest that motorcycles and bicycles are often obstructed by the left-side A-pillar. Theoretically, the design of the A-pillar should allow for optimal vision to avoid "looked but did not see" accidents [25].

In conclusion, pillar obstructions (especially A-pillar obstructions) have potential safety issues when vehicles approach another traffic object on a predetermined route and during maneuvers/turns under urban traffic conditions [15].

2.3 Designs and Research to Avoid or Reduce Pillar Vision Obstruction

Currently, to address the issue of visual obstruction by automotive A-pillars, automotive companies and researchers have actively conducted research and proposed the following design solutions:

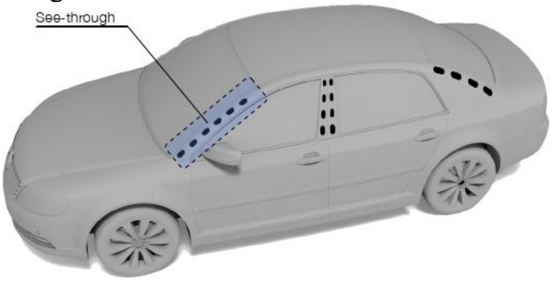

Figure 3. Demirel Proposed A See-Through A-Pillar[1]

Figure 4. Volvo Proposed A Skeletonised A-Pillar[1,2]

Creating a see-through area in the blind spot of the left-turn A-pillar to reduce its impact on vision and enhance the clarity of the field of view. For example, Demirel and Volvo have proposed pillars with see-through holes. Drivers can observe the external road conditions through these holes, as shown in Figures 3 and 4. To ensure normal vehicle use, high-strength transparent materials, such as resin, need to be used to fill the hollowed-out areas. These see-through pillars can effectively reduce the range of obstruction and blind spots, meeting actual driving needs. However, this method has certain limitations in practical applications, mainly because it reduces the strength of the A-pillar and may pose safety hazards to the vehicle [14,26].

1) Using slimA-pillars to reduce the area of vision obstruction. The driver's field of view depends on the size of the A-pillar; in other words, the smaller the A-pillar, the wider the field of view. Citroen proposed a slimA-pillar as a solution to limited visibility [1], as shown in Figure 5. Citroen calculated the visibility angle of this slim A-pillar but did not calculate the impact load and compression load that this pillar could withstand. The obstruction angle of this pillar is smaller than that of a normal A-pillar, but the vehicle structure requires a sturdy A-pillar.

Figure 5. Citroen C4 Picasso's Slim A-Pillar

2) Researchers have proposed installing multiple cameras on the vehicle to achieve a 360° view around the vehicle, process the basic situation of the images, and display blind spot images on the in-car display. However, this solution still has certain drawbacks, mainly in that it is difficult to intuitively see the driving environment, and it requires switching between scenes and screens, which can cause driver distraction and negatively impact driving safety [14].

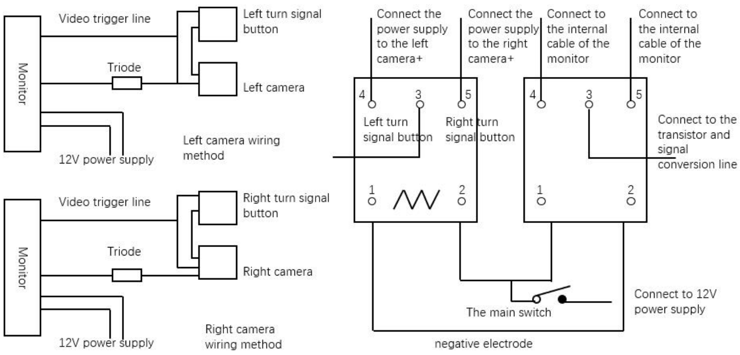

Figure 6. Wei Proposed A Left-Turn A-Pillar Blind Spot Monitoring System [2]

Wei proposed a left-turn A-pillar blind spot monitoring system [14], consisting of a camera and a display screen, as shown in Figure 6. This system activates when the driver uses the turn signal, allowing the driver to observe road information through the display screen. However, this does not align with the driver's habitual behavior of observing road conditions before turning.

3) The concept of electronic transparency. It is similar to projection methods but with different display methods. The screen cannot fully adhere to the A-pillar, causing parallax and projection effects that are easily affected by light, resulting in mediocre performance [14]. Continental introduced a "Virtual A-Pillar" technology, as shown in Figure 7. This technology uses surround-view cameras and OLED screens embedded in the A-pillar to allow the driver to observe the external environment in real-time through the OLED screen. Additionally, Continental's solution provides a dynamic view by monitoring the driver's head movements [27].

Figure 7. Virtual A-Pillar Technology from Continental

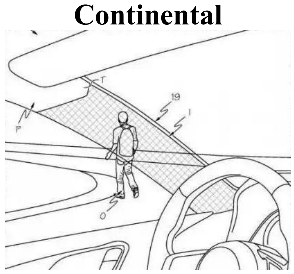

Figure 8. Toyota A-Pillar Refractive Material Patent

4) Using the principle of physical light refraction to make the A-pillar "transparent," as shown in Figure 8. Toyota mentioned in a patent

application that this technology requires cameras and expensive materials and equipments, so it has not been put into practical use

5) Lane Change Decision Aid System (LCDAS). LCDAS uses sensors such as radar and cameras to detect adjacent lanes and the rear of the vehicle, gather movement information of objects around the vehicle, and combine it with the current vehicle state for judgment. It ultimately reminds the driver through sound and light signals, helping the driver determine the best time to change lanes and preventing traffic accidents caused by lane changes. It also helps prevent rear-end collisions [28]. LCDAS includes three functions: "blind spot monitoring," "approaching vehicle warning," and "lane change warning." While LCDAS uses speed sensors, radar, and camera devices to detect vehicles, it cannot directly view the blind spot of the A-pillar. Cameras and radar can also be affected by adverse weather conditions such as haze, fog, and heavy rain [13, 14, 29].

3. Methodology

In this experiment, subjects performed a visual detection task of detecting and identifying traffic objects in a stationary driving simulator environment, where traffic scenes were projected onto an LCD monitor, as shown in Figure 9. Specifically, subjects were asked to detect traffic objects (pedestrians, bicycles, and motorcycles) within the pillar obstruction area through both the monitor and the A-pillar. The A-pillar represented the solid A-pillar seen by drivers in conventional cars. The monitor represented a modified version of the pillar with an external surveillance camera and an internal display screen. Data related to subjects' feedback and driving performance were collected through object detection forms and user questionnaires.

3.1 Pillar Obstruction Simulation

The experiment used the 2015 Ford Kuga as the driving simulator because the car's A-pillar blind spot is minimal [30] and offers a broad field of view [31]. In the experiment, an LCD monitor was used. The LCD monitor was positioned within the pillar obstruction angle. Static images from Baidu Maps related to the driver's viewpoint were projected onto the LCD monitor. These images represented the real road environment for constructing virtual traffic scenes, as shown in Figure 9.

3.2 Traffic Objects

Figure 9. Static Simulation Driving Experiment Scene Setting

A realistic traffic scene was created using static images from Baidu Maps. Bicycles, pedestrians, and motorcycles were chosen as traffic objects. Each traffic object was placed within the pillar obstruction angle. The traffic environment was at an intersection near Renmin Si Road in Shuikou, Huicheng District, Huizhou, Guangdong Province (latitude 40°25'26.64"N, longitude 86°54'28.46"W). This intersection is known for its busy traffic, composed of many pedestrians, motorcycles, bicycles, and family cars. Each traffic object was positioned within the obstruction angle. Static images were then taken from the driver's perspective. These images represented the driving scenes corresponding to the A-pillar obstruction.

Under the A-pillar obstruction condition, the reference vehicle was in the leftmost lane, as it was attempting a left turn. Traffic objects were located on the left side of the A-pillar obstruction angle. This scenario represented a very typical pillar obstruction situation occurring on sidewalks.

In the experiment, three traffic objects were displayed on the screen within the A-pillar obstruction angle Aθ, as shown in Figure 9. The visual task included checking crosswalks, monitoring vehicles changing lanes, and observing other traffic objects. Table 1 shows the allocation of traffic objects for the A-pillar and monitoring equipment detection.

Table 1. Allocation of Traffic Objects for A-Pillar and Monitoring Equipment Detection

Pillar Type	Traffic Object	Trial
Current A-Pillar	Pedestrian	2
	Bicycle	2
	Motorcycle	2
onitoring Equipment	Pedestrian	2
	Bicycle	2
	Motorcycle	2

3.3 Data Collection Procedure

The specific procedures followed during the experiment are shown in Figure 10:

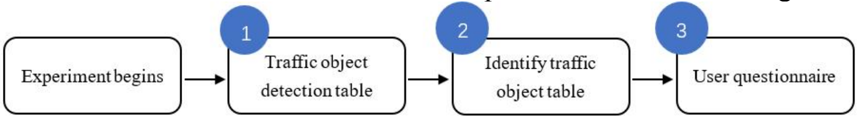

Figure 10. Data Collection Procedure

1) After the experimental preparations were completed, the traffic object detection experiment began. Simulated images representing A-pillar obstructions were displayed on a large monitor, with each image randomly displayed every 3 seconds, as shown in Figure 9. Subjects' data were collected by filling out traffic object detection forms.

2) There were three levels of question sets related to the traffic object detection form. In the first level, subjects were asked if they detected a traffic object. In the second level, subjects were asked about the type of traffic object they saw. Finally, subjects were asked to fill out a user questionnaire on the difficulty of detecting the traffic object.

3) After completing all simulation tasks and questionnaires, subjects needed to sign a human subjects log and exit the experiment.

4) Subjects could exit the experiment at any time during the process.

3.4 Research Variables

In the experiment, researchers collected subjects' responses through three sub-experiments. There were three dependent variables, including: (1) detecting traffic objects, (2) identifying traffic objects, and (3) the difficulty of detecting traffic objects.

Detecting traffic objects was a binary variable used to test whether subjects could detect traffic objects through the monitor and the A-pillar. Similarly, identifying traffic objects was a binary choice where subjects selected the correct traffic object from three options. The difficulty of detecting traffic objects was a scored data. Table 2 summarizes the data types, variables, and hypotheses related to the experiments conducted in this study.

Table 2. Data Types, Variables, Units, and Hypotheses Related to the Experiments in this Study

Dependent Variable	Type	Hypothesis
Detecting Traffic Objects	Binary	H1, H2
Identifying Traffic Objects	Binary	H1, H2
Difficulty of Detecting Traffic Objects	Score	H1, H2

3.5 Experimental Participants

Nielsen believes that 5 users can find out about 85% of the problems, and 15 users can find all usability issues in a design [32]. In iterative testing, the number of users is usually controlled between 5-10. There is an insignificant correlation between age and SUS scores (SUS scores decrease with increasing age), and no gender effect [33, 34]. Crouch and McKenzie proposed that less than 20 participants in a qualitative study can help mitigate some of the bias and validity threats inherent in qualitative research [35]. Consequently, the “sweet spot” sample size for many qualitative research studies is 15 to 20 homogeneous interview participants. This study assumes a very conservative response rate to obtain at least 20 usable responses. Therefore, this study will recruit 30 people aged from 18 to 70 with a driver's license and no relevant operational diseases or physical disabilities [36] for testing.

3.6 Data Analysis and Statistical Techniques

This section analyzes the experimental data to further understand whether the monitor improved in detecting traffic objects. Table 3 summarizes the measurement methods, measurement targets, and statistical methods used in the experiment. This section will be divided into three different subsections to explain the data of each level in the traffic object detection form.

Level 1, Analysis of Success Rate in Detecting Traffic Objects

In this section, subjects were asked whether they saw traffic objects on the monitor. Table 4 summarizes the data of successfully identifying traffic objects through the monitor and the A-pillar, respectively. It can be seen that the monitor achieved a higher success rate in detecting traffic objects compared to the old A-pillar. Figure 11 shows that at least a 93.3% improvement was achieved when using the monitoring equipment.

Level 2, Analysis of Correct Identification of Traffic Objects

In the traffic object identification experiment, subjects were required to select the type of traffic object they saw during the simulated driving process. Different traffic objects were randomly projected onto the display screen. There were three options (pedestrian, motorcycle, and bicycle), one of which was the correct answer. A total of two rounds were conducted. Table 5 shows that the accuracy rate of subjects identifying bicycles through the monitor was about 93.3%, pedestrians about 95.0%, and motorcycles 91.7%. The accuracy rate of subjects identifying objects through the A-pillar was significantly lower, with only 5.0% for pedestrians and 6.7% for both bicycles and motorcycles. Figures 12 and 13 show the statistics of identifying traffic objects using the monitor and the A-pillar, respectively. It is evident that subjects found it easier to detect traffic objects through the monitor.

Table 3. Summary of Measurement Methods, Measurement Targets, Statistical Methods

Measurement Method	Measurement Target	Statistical, Numerical, and Visualization Methods
Detection Form	Traffic Objects Identification of Traffic Objects	Descriptive Statistics Bar Chart
Questionnaire	Difficulty of Detecting Traffic Objects	Descriptive Statistics Bar Chart

Table 4. Statistics of Traffic Objects Detected Through Monitors and A-Pillars

	Monitor		Old A-pillar	
	Frequency	Percent %	Frequency	Percent %
Correct Detection	30	100.0	4	13.3
Failed Detection	0	0	26	86.7

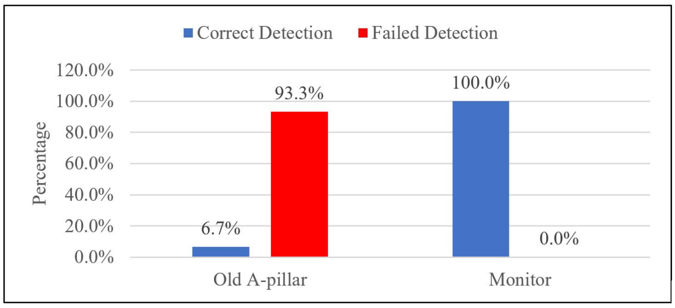

Figure 11. Comparison of Successfully Detected Traffic Objects through Monitors and A-Pillar

Table 5. Statistics on the Identification of Traffic Objects by Means of Monitor and A-Pillar

		Bicycle		Pedestrian		Motocycle	
Types	Identified	Frequency	Percent %	Frequency	Percent %	Frequency	Percent %
Monitor	Yes	56	93.3%	57	95.0%	55	91.7%
	No	4	6.7%	3	5.0%	5	8.3%
A-pillar	Yes	4	6.7%	3	5.0%	4	6.7%
	No	56	93.3%	57	95.0%	56	93.3%

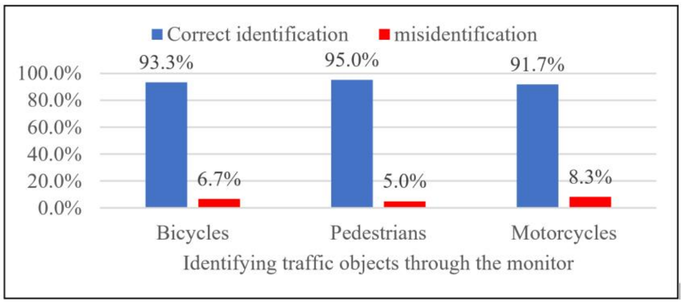

Figure 12. Statistics of Identifying Traffic Objects through the Monitor

Level 3, Difficulty in Detecting Traffic Objects

This section analyzes the difficulty level subjects experienced in detecting and identifying traffic objects. A Likert scale was used to rank the difficulty from "very difficult to detect" to "very easy to detect" traffic objects. The results indicate that subjects found it easier to detect traffic objects through the monitor. It can be seen that subjects unanimously agreed that it was more difficult to detect traffic objects through the A-pillar. The combined results of "easy to detect" and "very easy to detect" in Table 6 show that 93.3% of the subjects found it easier to detect traffic objects using the monitor. When using the A-pillar to identify traffic objects, 93.3% of the subjects found it "difficult to detect" or "very difficult to detect" traffic objects. Figure 14 shows the difficulty level of detecting traffic objects using the monitor and the A-pillar. Clearly, subjects found it easier to detect traffic objects through the monitor, while it was more difficult to detect or identify traffic objects through the A-pillar.

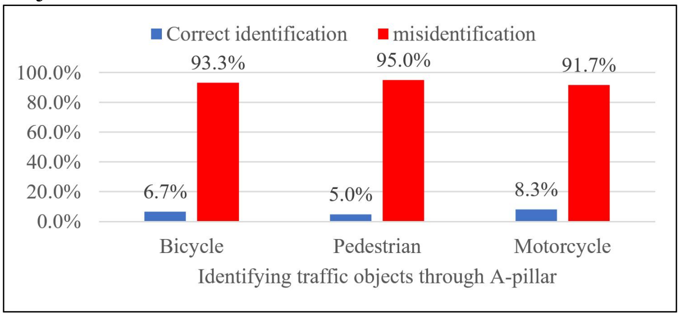

Figure 13. Statistics of Identifying Traffic Objects through the A-Pillar

Table 6. Statistics on the Ease of Identifying Traffic Objects by Means of the Monitor and the A-Pillar

	Monitor		A pillar	
Level	Frequency	Percent	Frequency	Percent
very hard to detect	0	0.0%	20	66.7%
hard to detect	0	0.0%	7	23.3%
Neutral	2	6.7%	3	10.0%
easy to detect	10	33.3%	0	0.0%
very easy to detect	18	60.0%	0	0.0%
total	30	100.0%	30	100%

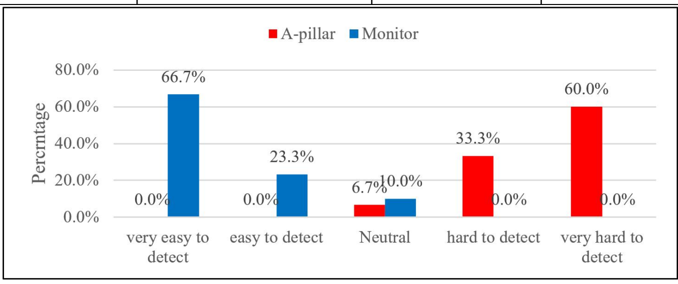

Figure 14. Comparison of the Ease of Identifying Traffic Objects through Monitors and A-Pillars

4 Result

The data collected from subjects during the experiment show that subjects could better detect traffic objects through the monitor compared to the A-pillar. The results of the traffic object detection experiment indicate that, as shown in Figure 12, the subjects' ability to detect traffic objects improved by an average of over 93.3% when using the monitor. As shown in Figure 15, the overall accuracy rate of subjects identifying traffic objects through the monitor was about 93.3%. In contrast, the accuracy rate of subjects detecting traffic objects through the A-pillar was very low, with only about 6.1% of subjects being able to correctly identify traffic objects.

The data collected from the traffic object identification experiment show that subjects could more easily identify the type of traffic objects through the monitor compared to the A-pillar. As shown in Figure 16, when identifying bicycles, the success rate of the monitor was 86.6% higher than that of the A-pillar; when identifying pedestrians, the success rate of the monitor was 90% higher than that of the A-pillar; and when identifying motorcycles, the success rate of the monitor was 83.4% higher than that of the A-pillar.

The data collected from the questionnaire on the difficulty of detecting traffic objects show that subjects found it easier to detect traffic objects through the monitor compared to the A-pillar. The results of the traffic object detection difficulty experiment indicate that, as shown in Figure 17, 90% of the subjects found it easier to detect traffic objects through the monitor, while 93.3% of the subjects found it difficult to detect traffic objects through the A-pillar.

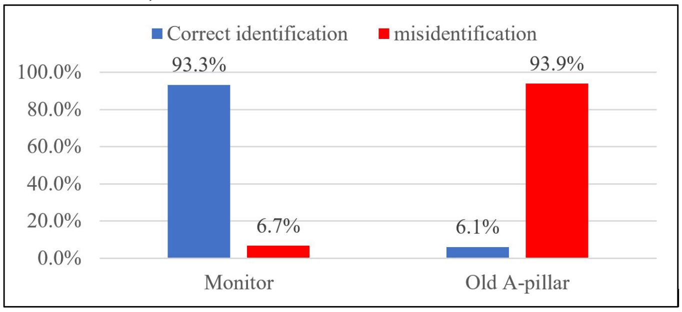

Figure 15. Comparison of Correct Traffic Object Identification

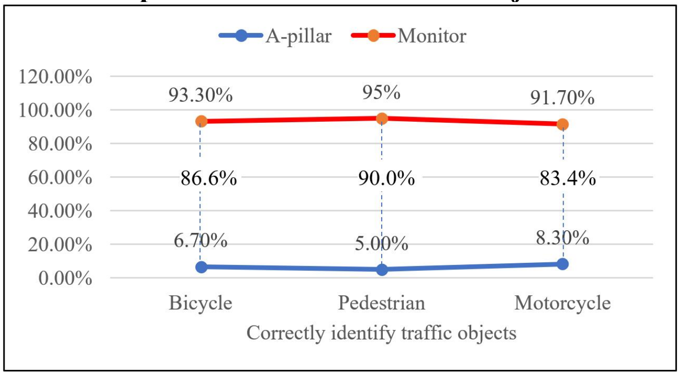

Figure 16. Comparison of Success Rates in Identifying Different Categories of Traffic Objects

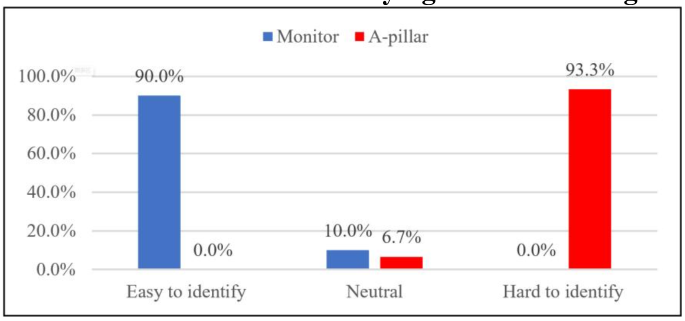

Figure 17. Comparison of Difficulty in Detecting Traffic Objects through the Monitor and the A-Pillar

5. Discussion

5.1 Hypothesis #1

Hypothesis #1 (H1) = The proposed monitoring equipment for addressing A-pillar obstruction and the current pillar (old pillar) show significant differences in visual detection of traffic objects.

The results of the traffic object detection experiment indicate that subjects showed an improvement of approximately 93.3% in detecting traffic objects using the monitor. Subjects' ability to identify traffic objects improved by 87.2% when using the monitor compared to the A-pillar. From these results, it can be concluded that the monitor shows significant differences in visual detection of road elements compared to the A-pillar design.

5.2 Hypothesis #2

Hypothesis #2 (H2) = The visibility of the proposed monitoring equipment is significantly better than the visibility of the current A-pillar.

Figure 17 shows that 90% of subjects found it easy to detect traffic objects, while 93.3% of subjects found it difficult to detect traffic objects using the A-pillar. Subjects rated the monitor better than the A-pillar in terms of overall visibility and visual safety (successful detection of traffic objects). Subjects also found that the monitor placed fewer demands on the driver (subjects) compared to detecting traffic objects using the old pillar design.

From these results, it can be concluded that the visibility of the monitor is significantly better than that of the A-pillar when detecting traffic objects.

6. Conclusion

The main focus of this study is to design a monitoring device to address the visual obstruction problem caused by automotive pillars and to study subjects' ability to detect and identify traffic objects using this device. Compared to the old A-pillar, the monitor provided better performance in detecting traffic objects. The proposed monitoring device can help drivers overcome the visual obstruction problem of traditional A-pillars, improving driving safety. The monitoring device can also provide better protection for pedestrians, other drivers, and animals. It can help automotive developers overcome the limitations of traditional A-pillars and develop car designs with fewer limitations.

Subjects' detection and identification of traffic objects mainly relied on subjective judgment. Subjective judgment is easily influenced by various factors, such as the selection of traffic objects (e.g., traffic objects being too small), the subjects' own abilities (e.g., subjects' poor mood, vision level, and distractions), the contrast between traffic objects and the environment. These factors will affect the accuracy of identification, posing challenges for this study and warranting further research by researchers. Advances in automotive electronics technology are showing a growing trend. Enhanced technologies such as blind spot monitoring, lane departure warnings, automatic parking, and rearview cameras are becoming part of the safety packages in mid- to high-priced cars, but their performance in real-time events still requires in-depth study.

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