A Comparative Study on CPD Technical Requirements and Industrialization of Major Global NCAP Regimes

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Abstract

With the continuous growth of global vehicle ownership, fatal heatstroke incidents resulting from children being left unattended in vehicles have become a non-negligible public safety concern in road traffic safety. Child Presence Detection (CPD), as a targeted active safety technology, has been incorporated into the official assessment systems of multiple mainstream global New Car Assessment Program (NCAP) frameworks in recent years, and has become a critical indicator influencing the vehicle safety star rating. This paper systematically sorts out the evolution paths of CPD-related rules in major assessment systems including Euro NCAP[1], ANCAP[2], Asean NCAP[3], Latin NCAP[4] and China C-NCAP[5], conducts a horizontal comparison from dimensions such as technical path access, detection coverage, test scenarios, and warning and intervention hierarchies, and analyzes the common features and differentiated requirements among standards in different regions. It is found in this study that the global NCAP ecosystem is forming a unified technical orientation converging from "indirect perception" to "direct perception". After 2025, direct-perception-based solutions have become a mandatory prerequisite for obtaining valid assessment scores in the test. On this basis, this paper further combines the implementation characteristics of mainstream technical paths including vehicle-mounted millimeter-wave radar, UWB ultra-wideband and MEMS ultrasonic technology, discusses the core challenges faced in the current CPD technology implementation process, such as low-power operation, privacy protection and false alarm rate control, and prospects the future development trends of multi-sensor fusion and cross-system function collaboration. The research results can provide theoretical reference and practical basis for automobile manufacturers, component suppliers and policy makers to understand the global CPD standard landscape and formulate technical solutions adapted to different regional markets.

Keywords

Child Left Behind Monitoring; CPD; NCAP; Direct Perception Technology.

1. Introduction

The automotive cockpit is supposed to serve as a mobile safety space for occupants during travel. However, on a global scale, a large number of children are accidentally or intentionally left in enclosed vehicles every year, leading to tragedies of heat stroke and even death.Relevant statistics show that under direct sunlight, the internal temperature of an enclosed vehicle can rise above 40°C — a life-threatening threshold — within 15 minutes. Even if the ambient temperature is not extremely high, short-term retention in such an environment may cause irreversible damage to children's delicate bodies[6].For a long time, the prevention of such accidents has been highly dependent on manual reminders from drivers and guardians, lacking a systematic and automated technical fallback mechanism, which makes it impossible to fundamentally curb such safety risks.

To address this critical safety governance challenge, major global New Car Assessment Programme (NCAP) authorities have successively incorporated the child left-behind protection function into their safety scoring systems, and promoted active deployment of relevant technologies by automobile manufacturers through the market incentive mechanism for vehicle safety.Among them, Euro NCAP in Europe took the lead in incorporating CPD into the child protection section of its scoring system starting from 2023. Subsequently, Australia's ANCAP, ASEAN NCAP, Latin NCAP and China's C-NCAP have successively followed up, forming a global assessment promotion network covering Europe, Oceania, Southeast Asia, Latin America and China[7].At the same time, countries including the United States and Italy have also adopted legislative measures to mandate the phased installation of CPD systems on new vehicles, further accelerating the industrialization and large-scale deployment of this technology.

Against this backdrop, the CPD technical requirements across different NCAP systems share a consistent core orientation, while presenting notable discrepancies in implementation timelines, test details, and scoring rules.For automotive enterprises developing vehicle models targeting the global market, accurately grasping the CPD rule discrepancies across NCAP systems in different regions and avoiding compliance risks caused by a single technical solution failing to meet multi-market requirements has become a practical problem that must be resolved in the product development process.This paper systematically compares the content and evolution logic of CPD rules in the world's mainstream NCAP systems, clarifies the differences in safety orientation behind these standards, and provides theoretical and practical support for the automotive industry to build a more unified and efficient child left-behind protection technical system.

2. Literature Foundation of Global CPD-related Research and Standard Evolution

Existing research on in-vehicle child presence detection and protection can be roughly divided into three major categories: accident characteristic analysis, technical path evaluation, and standard & policy research. From the perspective of accident characteristics, early studies generally point out that the vast majority of fatal Pediatric Vehicular Heatstroke (PVH) incidents in road vehicles involve two typical scenarios: caregivers forgetting children left in the rear seats, and children entering the vehicle unsupervised after the vehicle is accidentally locked. Non-technical countermeasures that rely solely on paper reminders, in-vehicle voice alerts and other similar measures cannot establish reliable and effective protection against such accidents. This category of research has directly promoted the transformation of the automotive industry's safety philosophy from "management-based reminders" to "technical bottom-line protection".

At the level of technical path research, a large number of indirect perception solutions based on door opening logic and seat pressure sensors that widely emerged in the early market have been proven by subsequent studies to have obvious limitations: such solutions cannot distinguish children from heavy objects, nor can they identify the scenario where children enter the vehicle on their own after the vehicle is locked. A large number of practical cases have verified that these solutions have a high risk of missed detection. With the maturity of technologies such as millimeter-wave radar and Ultra-Wideband (UWB), the technical route of direct vital sign perception has gradually become the industry consensus. Relevant studies have also progressively verified that such solutions possess irreplaceable advantages in scenarios including covering the footwell blind zone and detecting sleeping children through occluding coverings .

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At the level of standard and policy research, most existing literatures focus on the rule interpretation of a single New Car Assessment Programme (NCAP) system for Child Presence Detection (CPD), while systematic horizontal comparative studies on multi-regional global standards are still insufficient. Most studies focus on the impacts brought by the technical route transition of Euro NCAP in 2025, but the follow-up analysis on regional market rules such as ANCAP, ASEAN NCAP, and Latin NCAP is relatively insufficient. There are also very few discussions on the compliance cost issues brought by the differences in regional standards to the global product development of automotive enterprises. Targeting exactly this research gap, this paper incorporates the CPD rules of multiple mainstream global NCAP systems into a unified analytical framework, sorts out their commonalities and differences, and fills the deficiency of existing studies in the cross-regional standard comparison dimension.

From the perspective of research gaps, the current academic community has not yet systematically answered three core questions:

First, to what extent have the CPD rules of different global NCAP systems achieved unification in technical orientation?

Second, what impacts will the detailed discrepancies between standards in different regions exert on the technology selection and R&D investment of automotive original equipment manufacturers (OEMs)?

Third, what are the possibilities and practical barriers for the further convergence of CPD standards in the future?

The subsequent chapters of this paper will carry out systematic demonstrations around these three core research questions.

3. Horizontal Comparative Study on CPD Rules of Major Global NCAP Systems

3.1. Evolution Timeline and Overall Positioning of the Rules

There are distinct chronological discrepancies in the introduction rhythm of CPD assessment across different global NCAP systems, while their core objectives are highly consistent: to promote the upgrading of vehicles from "passive safety" to "full-scenario active protection" through the scoring mechanism.

Euro NCAP is the world's first institution to systematically establish a CPD assessment system. It officially incorporated CPD into the child protection section of its scoring system in 2023. In the initial stage, indirect perception solutions were allowed to obtain partial scores. The new version of the rules implemented on January 1, 2025 has completed a major upgrade, completely revoking the scoring eligibility of indirect perception solutions and only recognizing direct perception technologies, making it the strictest CPD assessment system in the current global context .

As the most influential New Car Assessment Programme in Oceania, ANCAP maintains a high degree of synergy with Euro NCAP in CPD rules, synchronously following up the direct perception technology requirements after 2025, so as to ensure that vehicles sold in the Australian and New Zealand markets can reach the same level of child presence detection protection as that in Europe.

Combined with the actual safety demands of the Southeast Asian regional market, ASEAN NCAP has gradually introduced CPD-related scoring items in its 2023-2025 assessment framework, prioritizing the high-frequency scenarios of rear-seat child left-behind. Meanwhile, it has set a relatively gentle technology transition rhythm based on the maturity of the regional industry, allowing the market to complete the switch from indirect perception to direct perception within a certain cycle.

Targeting the regional characteristics of Latin America with long-lasting high-temperature weather and higher risk of heat stroke for children left behind in vehicles, Latin NCAP regards CPD as a key starting point to improve the regional vehicle safety level. It has clarified the scoring weight of CPD in its recently updated assessment procedures, promoting the local market to gradually phase out low-end solutions that only have basic rear-seat reminder functions.

China's C-NCAP first introduced the child forgotten reminder assessment item in the 2024 version of the regulation. Subsequently, it refined the test scenarios and technical requirements in the 2027 version of the regulation. Combined with the actual usage habits of Chinese families for children riding in vehicles, it supplemented test requirements for segmented scenarios such as newborns and sleeping children, forming a CPD assessment system that conforms to the characteristics of the Chinese market.

3.2. Horizontal Comparative Analysis of Multi-dimensional Core Rules

To clearly present the common features and differentiated details of CPD rules across different global NCAP systems, this subsection constructs a unified comparison framework from 8 core dimensions including technical access, detection range, test scenarios, etc. The specific rule differences are shown in Table 1 below.

Table 1 Differences and Comparison of CPD Rules Across Different NCAP Systems

Comparison Dimensions	Euro NCAP 2026 Edition	ANCAP 2025 Edition	Current ASEAN NCAP Version (2023-2025)	Current Latin NCAP Version	China C-NCAP 2027 Edition
Technical Access Rules	Only direct perception schemes are eligible for scoring, while indirect perception schemes are completely disqualified from scoring	Fully aligned with Euro NCAP 2025 Edition, only direct perception schemes are recognized	During the transition period, indirect perception schemes can obtain basic scores, and a full switch to direct perception will be implemented in 2027	Direct perception schemes are assigned higher weights, while indirect perception schemes can only obtain a small number of bonus points	Taking direct perception technology as the core evaluation direction, covering child detection across all age groups
Mandatory Detection Range	All passenger seats in the entire vehicle, driver footwell, footwells of each row, excluding the luggage compartment	Fully consistent with Euro NCAP 2025 Edition	All rear seat areas, with future expansion to footwell blind spots	Conventional rear occupant areas, prioritizing high-frequency child seating positions	All occupant seats + rear footwell, covering typical scenarios such as children under blankets and sleeping children
Core Test Scenarios	Driver forgetting children, caregivers intentionally leaving children behind, 3-6-year-old children entering the vehicle independently, with newly added hidden sub-scenarios in the driver's seat/footwell	Following the three core scenarios defined by Euro NCAP, with additional extreme high-temperature environment validation	Focusing on the top two high-frequency scenarios, the third scenario will be incorporated into subsequent upgrade plans	Prioritizing the assessment of the scenario where children enter idle vehicles independently, to adapt to regional accident characteristics	Referring to the three basic scenarios, and supplementing localized scenarios of children covered by blankets and children sleeping in footwells
Warning and Intervention Hierarchy	Initial exterior vehicle alert after locking → upgraded warning with horn and hazard lights 90 seconds later → remote push notification + active intervention via automatic ventilation and cooling	The three-layer warning logic is aligned with Euro NCAP, with enhanced requirements for mobile APP interconnection	Prioritizing the initial and upgraded acousto-optic warnings, while high-level interventions are not mandated for the time being	Focusing on strengthening the vehicle's local acousto-optic warnings, to reduce the reliance on remote communication	Local instrument panel prompt tone + door locking reminder → horn honking and hazard light flashing → multi-terminal linked alarm via mobile APP
System Minimum Operating Duration Requirement	Continuous low-power operation for at least 15 minutes after the engine is turned off	Fully consistent with Euro NCAP requirements	Continuous operation for at least 10 minutes after vehicle locking	Continuous operation for at least 10 minutes after vehicle locking	Continuous operation for at least 15 minutes after vehicle locking, to cover the extended duration requirements under high-temperature environments
Age Range Covered by Child Dummies	Covering the full age range from newborn to 6 years old, and distinguishing between awake and sleep states	Fully aligned with Euro NCAP requirements	Focusing on covering child dummies aged 1 to 6 years old	Focusing on covering child dummies aged 3 to 6 years old	Multi-age coverage including newborn, 1-year-old, 3-year-old and 6-year-old, with key verification on extremely low respiratory amplitude detection in sleep state
Score Status of Indirect Perception Schemes	0 points, completely excluded from the scoring sequence	0 points, completely excluded from the scoring sequence	A maximum of 1 base point can be obtained, and the full score of CPD cannot be achieved	Only a small number of bonus points can be obtained, which cannot be included in the core safety star rating weight	No separate score is available, and it is only regarded as a basic reminder function that is not included in the special CPD scoring
Local Characteristic Adaptation Points	Strictly compliant with EU child occupant safety regulations, with emphasis on full-scenario robustness	Adapted to the high-temperature and long-daylight environment in Oceania, with enhanced reliability verification under extreme conditions	Adapted to the vehicle configuration gradient for the Southeast Asian market, with a gentle technology transition period set	Adapted to the characteristics of the Latin American region, where the proportion of old vehicles is high and accidents caused by children breaking into idle vehicles are frequent	Aligned with the riding habits of infants and young children in Chinese families, the detection logic for sleeping children in the rear row is optimized

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3.3. Analysis of Industrial Logic Behind Regulatory Differences

It can be clearly observed from the above multi-dimensional comparison that the CPD rules of different global NCAP schemes are not formulated in complete isolation. Instead, they present an overall pattern of "high coordination in core directions and differentiated adaptation in detailed requirements". As a benchmark global CPD regulatory framework, Euro NCAP completed a full shift from indirect sensing to direct sensing in 2025, which has in effect become the technical baseline for the whole industry. By fully aligning with these rules, ANCAP has directly achieved equivalent mutual recognition of CPD safety performance between the Oceania market and the European market, greatly reducing redundant development costs for multinational automakers.

As representative assessment schemes for emerging markets, Asean NCAP and Latin NCAP do not directly copy the stringent rules from mature markets. Instead, they set transition schedules combined with the industrial maturity and accident characteristics of regional markets. Asean NCAP retains basic scoring eligibility for indirect sensing solutions during the transition period to prevent overly aggressive standards from pushing up vehicle retail prices and slowing the popularization of safety functions. Latin NCAP specifically raises the assessment weight for the scenario of "children entering unattended vehicles by themselves", precisely responding to the practical safety demand of frequent accidents involving children accidentally accessing unoccupied local vehicles. Such differentiated rule design ensures steady improvement of CPD safety levels in regional markets while avoiding the issue of "high standards without practical implementation" divorced from local industrial realities.

C-NCAP also shows remarkable characteristics of localized adaptation. Targeting the frequent scenario in Chinese families where sleeping infants are wrapped in blankets during rides, it has specially supplemented test requirements for detection under coverings, filling the coverage blind spots of general international rules in such segmented scenarios. This rule design philosophy of "following mainstream international directions plus localized scenario optimization" ensures that China's CPD technology will not lag behind amid the global industrial upgrading wave, and can truly address practical safety pain points in the local market[8].

From the perspective of industrial implementation, this differentiated global standard system puts forward brand-new requirements for automakers' global product development capabilities:If a separate CPD system is developed for each regional market, it will substantially increase costs for hardware redundancy, algorithm tuning and certification testing;However, development strictly based on the minimum requirements will render products ineligible to enter high-end markets such as Europe and Oceania to obtain five-star safety ratings. The optimal solution adopted in the current industry is to develop a base solution directly against the full direct-sensing and full-cabin coverage requirements of Euro NCAP 2026 Edition as the unified technical baseline. Regional adaptation logic for corresponding localized test scenarios can then be activated for different regional markets via software configuration switches. One single hardware architecture can satisfy CPD assessment requirements of all major global NCAP schemes, maximizing cost control of development while guaranteeing safety performance.

4. Characteristic Analysis of Mainstream Direct Sensing Technical Routes for CPD

Against the backdrop that global NCAP schemes are fully shifting toward direct sensing technology, three mainstream mass-production technical routes have been established in the industry, namely 60 GHz millimeter-wave radar[9]、ultra-wideband (UWB) technology, and MEMS ultrasonic sensors[10].

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60 GHz millimeter-wave radar is one of the most widely adopted CPD technical solutions at present. Independent of lighting conditions and featuring strong privacy protection, this technology can penetrate coverings such as fabrics and accurately detect subtle respiratory and heartbeat movements. Low-power 60 GHz radar sensors can operate continuously for more than 15 minutes after vehicle power-off, fully meeting Euro NCAP requirements on system operating duration after locking. Meanwhile, they can achieve full coverage of the entire cabin, including footwell areas.

As another mainstream technical route, ultra-wideband (UWB) technology features high precision, strong penetration capability and high anti-interference performance. It can accurately monitor subtle activities such as respiration and heartbeat of living occupants inside the cabin. Stable detection can be achieved even when a child is fully covered by blankets or located in visual blind zones like footwells, effectively preventing false detections triggered by objects left in the vehicle. At present, CPD solutions based on UWB technology have passed authoritative certifications including C-NCAP and achieved mass deployment in vehicles.

The MEMS ultrasonic sensor solution features advantages of compact size, a field-of-view angle up to 180°, and easy concealed installation. By transmitting and receiving panoramic ultrasonic waves, it can realize precise detection at respiration level based on differences in target motion, respiration and environmental conditions, fully complying with the technical standards of mainstream NCAP schemes.

By contrast, although camera-based solutions also belong to direct sensing technology, they have obvious drawbacks such as reliance on lighting conditions, serious privacy concerns, and complete failure once blocked. Therefore, they have not become the mainstream option in the industry. Traditional indirect sensing solutions, however, cannot directly identify vital signs and carry high risks of false and missed detections. They have lost scoring eligibility in mainstream NCAP schemes released after 2025 and are gradually phased out of the market.

5. Core Challenges and Development Trends in the Industrial Implementation of CPD

The large-scale global deployment of CPD technology still faces three core challenges.

First of all, there is the challenge of low-power operation. When the vehicle is ignited off and locked, the CPD system needs to maintain detection capability for an extended period without excessively draining the vehicle battery, so as to prevent vehicle no-start failures afterwards. This imposes stringent requirements on hardware power consumption control of sensors as well as software sleep-wakeup strategies.

Secondly, there lies the challenge of false alarm rate control. Objects left inside the cabin such as throw pillows, plush toys and electronic devices can easily trigger false alarms of the system. Frequent false alarms will seriously reduce user trust in the system. How to constrain the false alarm rate within an user-acceptable range while guaranteeing zero missed detection constitutes a core problem that all technical solutions must address.

Lastly comes the challenge of privacy protection. Since the CPD system involves sensing of occupants' vital signs inside the cabin during operation, user privacy must be guaranteed throughout the whole process from hardware design to data processing to avert disputes over data security.

Looking ahead, the development of CPD technology will show three distinct trends[11]. First, multi-sensor fusion will become the mainstream direction. Cross-validation of signals from multiple sensors such as millimeter-wave radar, UWB and MEMS ultrasonic sensors can further improve detection accuracy and reduce false alarm rates. Second, CPD will be deeply integrated with cockpit safety functions including the driver monitoring system (DMS), occupant monitoring system (OMS) and vehicle intrusion detection to form an integrated intelligent cockpit perception architecture, greatly cutting hardware redundancy and improving the comprehensive system value. Third, CPD standards of various global NCAP schemes will further converge. Test scenarios will cover more age groups, more hidden positions and more extreme environments. Artificial intelligence algorithms will be widely adopted for the analysis and recognition of vital sign signals to achieve more accurate occupant classification and behavior judgment.

6. Conclusion

The continuous adoption and rule iteration of child presence detection (CPD) technology for child left-behind protection by major global NCAP systems are driving an important boundary expansion of the vehicle safety framework： Vehicle safety protection scenarios have finally extended comprehensively from "in-motion crash protection" to "stationary protection after vehicle ignition-off and locking", filling the long-neglected safety gap of children trapped inside parked vehicles.This paper systematically compares the CPD rules of five major assessment schemes, namely Euro NCAP, ANCAP, ASEAN NCAP, Latin NCAP and China C-NCAP. It clarifies the underlying feature of the global standard landscape, i.e., "highly consistent core objectives with differentiated regional fine-tuning", and verifies that the upgrade from indirect sensing to direct sensing has become an irreversible global industrial consensus[12][13].

The rule design of NCAP schemes in different regions essentially represents a dynamic balance between safety objectives and local industrial realities. Benefiting from mature automotive industrial foundations, European and Oceania markets have taken the lead in implementing stringent standards featuring full direct sensing and complete cabin coverage, establishing the performance baseline for global CPD technologies. By contrast, Southeast Asian and Latin American markets adopt gradual transition periods to prevent excessive technical barriers from hindering the popularization of safety functions, enabling more ordinary consumers to obtain basic child left-behind protection at affordable costs.C-NCAP incorporates localized test scenarios to better adapt CPD technology to the actual riding habits of infants and young children in Chinese families, avoiding the problem that internationally adopted rules may be poorly suited to local conditions. Such differentiated rule framework neither falls into the dilemma of “inadequate standards failing to deliver effective safety protection” nor goes to the extreme of “overly stringent standards divorced from industrial realities”, forming a global governance pathway that balances advancement and feasibility.

Looking ahead, the further popularization of CPD technology requires joint efforts from the automotive industry and regulatory authorities.For automotive manufacturers, the optimal technical route is no longer to develop a separate CPD system for each regional market. Instead, manufacturers can adopt the most stringent requirements of Euro NCAP 2026 as a unified hardware baseline, adapt to localized test scenarios of different regions via software configuration switches, and employ one architecture to meet NCAP assessment requirements across multiple global markets. This approach maximizes development cost control while guaranteeing safety performance.For regulatory authorities, further promotion of mutual recognition of test results among different NCAP schemes can reduce resource waste caused by repeated certification, enabling the safety value of CPD technology to reach more consumers worldwide at lower costs.

In the long term, CPD will no longer function as an independent in-vehicle safety feature. It will be deeply integrated with cockpit perception functions such as driver monitoring systems, full cabin occupant monitoring systems, and vehicle intrusion detection, constructing an integrated safety perception network for intelligent cockpits[14]。 With the maturity of multi-sensor fusion technology and the iteration of low-power algorithms, the missed detection rate of CPD systems will approach zero asymptotically, and the false alarm rate will be maintained within fully user-acceptable ranges. Ultimately, the root cause of heatstroke accidents resulting from children being left unattended in vehicles will be completely eliminated. Every vehicle will become a mobile safety space that protects children in full-scenario and all-time conditions. This is not only a significant advancement in automotive safety technology, but also a substantial implementation of life safety responsibility for children undertaken by the global automotive industry.

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