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Items on which the exchange of views and data should continue or begin

Status report of the Informal Working Group regarding the safety of Children Left in Vehicles

Submitted by the Working Party on Passive Safety*

The present status report was adopted by the Working Party on Passive Safety (GRSP) at its seventy-sixth session (ECE/TRANS/WP.29/GRSP/76, paragraph 53). It is based on informal document GRSP-76-35. It is submitted to the World Forum for Harmonization of Vehicle Regulations (WP.29) and to the Executive Committee of the 1998 Agreement (AC.3) for consideration at their June 2025 sessions.

* In accordance with the programme of work of the Inland Transport Committee for 2025 as outlined in proposed programme budget for 2025 (A/79/6 (Sect. 20), table 20.6), the World Forum will develop, harmonize and update UN Regulations in order to enhance the performance of vehicles. The present document is submitted in conformity with that mandate.



I. Summary of terms of reference research questions

A. Question 1 – Factors driving and leading to the 3 typically known scenarios

1. The IWG agreed on the main factors driving and leading to the three typically known scenarios of Children Left in Vehicles (CLIV) Paediatric Vehicular Heatstroke (PVH) global field events. The three typically known scenarios were agreed by the Informal Working Group (IWG) as unknowingly left in the vehicle, knowingly left in the vehicle and gained access to the vehicle. The following are the main factors the IWG agreed on:

- Stress, fatigue, distraction and change in routine leading to memory failure
- Miscommunication between caregivers or guardians
- Ignorance of risk and lack of responsibility
- Children playing in or around unlocked cars
- Drugs, alcohol and maltreatment

2. These factors put CLIV at a higher risk of PVH.

B. Question 2 – Categories of vehicles in which PVH predominantly occurs

3. The categories of vehicles that PVH occurs in include vehicles of category M1, 1-1, M2, M3 and 1-2. We consider these categories, but each country uses these categories of vehicles differently. Some of these vehicles are often used as school buses, or for other transport of children.

C. Question 3 – Environmental and vehicle conditions in global field events

4. The IWG agreed that the following are the most common environmental conditions that are observed in CLIV PVH global field events:

- Risk of PVH is proportional to increasing ambient temperatures
- Increasing risk with increased time of exposure
- Higher direct solar irradiation
- Rapid rise in internal cabin temperatures
- Higher ambient humidity.

5. The common vehicle conditions are:

- Parked and mixed door lock status
- In-cabin temperatures at or above 39°C
- Tinted windows or privacy glass decreasing visibility.

D. Question 4 – Age groups and orientation of PVH victims

6. The IWG agreed that the vast majority of global cases occur in children aged 6 years and under. Children this age have decreased thermoregulation abilities.

7. The orientation of PVH victims in vehicles other than buses varies, with the majority being in the 2nd row. Most of the incidents occur with the child in a CRS, with the rest involving no CRS.

E. Question 5 – Countermeasures addressing the underlying safety concerns observed

8. The IWG has identified there are three broad categories of countermeasures; visual inspection by a person, indirect detection and direct detection.

9. C-NCAP, KNCAP, and Euro NCAP/ANCAP protocols were examined. Technical specifications from the Australian Bus Industry Confederation (BIC), KMVSS, Japanese ministry guidelines and Italy traffic law were presented.

F. Question 6 – Structure of the CLIV IWG

10. The IWG agrees to work to address a technical solution for new vehicle types.

11. The technical solution will look at two separate avenues for light passenger vehicles (M1, 1-1) and heavy-duty passenger vehicles (M2, M3, 1-2).

II. Problem Statement Formation

12. After studying field data and analysis, the IWG agrees this vehicle safety problem of PVH caused by CLIV leads to fatalities and non-fatal injuries. Adoption of technologies can help to reduce the number of PVH deaths and injuries that occur from the conditions and scenarios identified above.

III. Recommendation

13. The IWG recommends to start Phase 2. This would involve regulatory requirements for affected vehicle categories. The Contracting Party representatives of Australia, Korea, China, the United States of America and Canada agree to recommend initiating Phase 2 to develop a new GTR in parallel with a UN Regulation. The NGOs and other organizations present (Organization of Motor Vehicle Manufacturers (OICA), European Association of Automotive Suppliers (CLEPA), Consumers International (CI), Kids and Car Safety, Royal Automobile Club of Queensland (RACQ) and Australian Bus Industry Confederation (BIC)) support this recommendation.

Annex I

Informal Working Group into Children Left in Vehicles – Terms of Reference Australian Research and Discussion

I. Terms of Reference Question 1 and Question 2 Research

A. What are the factors driving and leading to the 3 typically known scenarios where Paediatric Vehicular Heatstroke (PVH) is observed in field events globally?

1. The three typically known scenarios where PVH are:
 - Unintentional — Children left behind in a vehicle unintentionally (Glenn et. Al, 2021)
 - Intentional — Children left behind in a vehicle intentionally (Glenn et. Al, 2021)
 - Gained Access — Children that have gained access to a vehicle and become trapped without the knowledge of the carer (Glenn et. Al, 2021).
2. These three scenarios have multiple factors influencing them. For the United States between 1990 – 2023, Unintentional made up 55 to 75% of cases, Intentional made up 15% and Gained Access made up 25%. The main factors are summarised below involving each of the three scenarios.

1. Forgotten in Vehicle due to Stress and Fatigue

3. The vast majority of cases were mistakes around forgetting children were in the car. In the United States, upwards of 75% of CLIV PVH cases between 1990 and 2016 were from being unintentionally left behind in the vehicle, and over 43% of all cases between 1999 and 2007 involved forgetting the child is in the vehicle (Hammett et. Al., 2021; Booth and Davis, 2010). Other studies put the proportion at 55% (Ho et. Al., 2020). This remains the case for international cases, where at least 20% of 455 confirmed international cases in our dataset involved the child being forgotten. This includes cases in China, Israel, Japan, EU countries (Belgium, France, Germany, Greece, Italy, Spain), Switzerland, Mexico and Canada. Forgotten Baby Syndrome (FBS) is the proposed name of this phenomenon, either forgotten in the car or mistakenly thought to have been dropped off at daycare (Ho et. Al., 2020). This is largely caused by a combination of any of the following: change in routine, following normal routine despite child presence, stress, fatigue, automatic routine (Ho et. Al., 2020).

2. Unintended Location

4. A significant portion of cases occurred at the caregivers' residences and workplaces despite the children being meant to go to day-care in most cases. 91% of gained access PVH cases in the United States of America (USA) occurred in the primary residence, with 5% being in a parking lot (KidsandCars, 2024). Most of the time this occurs due to the intention of dropping of the child at day-care (Chandler et. Al., 2024). For cases between 2005-2019, 41% of cases occurred at the child's home and 29% occurred at the caregiver's workplace (Chandler et. Al., 2024). 43% of cases between 1999 and 2007 occurred due to forgetting to drop off the child at day-care, leading to taking the child to an unintended destination (Booth and Davis, 2010). This is backed up by the US National Highway Traffic Safety Administration (NHTSA) who found that of the 2019 United States cases, the residence was the intended final location in 46% of cases, with day-care being 57% of the intended destination. Only 28% of cases were at the child's intended location (NHTSA, 2022).

3. Children Playing

5. Playing was a common cause of a large portion of children who either gained access or were left in the vehicle by parents. 17% of 1999-2007 cases involved the child playing in the vehicle, and 25% of children were playing around the time of the incident, which is common for gained access cases overall (Booth and Davis, 2010). Male children accounted for 75% of gained access cases of PVH.

4. Unlocked Cars

6. Most gained access cases occurred due to cars being unlocked at the residence of the caregivers. Approximately 28% of cases occurred due to children climbing into unlocked vehicles (Ho et. Al., 2020).

5. Drugs, Alcohol and Maltreatment

7. A sizeable minority of cases occurred when caregivers had consumed drugs and/or alcohol. The responsible caregiver at the time had drugs and/or alcohol involved in 10% of all cases between 1990-2016 that weren't gained access cases (Hammett et. Al., 2020). It was more pronounced with cases intentionally left in the vehicle, at 13%. (Hammett et. Al., 2020).

8. NFR CRS data showed 6% of children who died had an open Child Protective Services case at death, 13.9% had a history of child maltreatment and 4.7% had a disability or chronic illness (Chandler et. Al., 2024).

6. Ignorance

9. Parents regularly leave their kids in vehicles and are largely unaware of the dangers of leaving their kids in vehicles in hot weather or even mild weather. Parents in Saudi Arabia who were not knowledgeable that children must not be left alone in a locked car had double the risk of leaving children inside a locked car (Alowirdi et. Al., 2020). In US adults surveyed, only 12% believed they were at any risk of having a child overheat in a vehicle, and half had not heard any awareness campaigns, meaning half had heard awareness campaigns and a sizeable minority (~5-35%) still believed their child wasn't at risk (Sartin et. Al., 2023). Only 88% of respondents reported they do not leave children alone in their vehicles, meaning a sizeable minority do. However, of these US adults, 90% said they would be willing to adopt technologies to mitigate CLIV risk, and many of those believed they would be perceived as better caregivers if they did (Sartin et. Al., 2023).

B. In what type of vehicles is PVH occurring in field events globally?

10. The vehicles CLIV global events occur in are largely light vehicles with the rest being passenger transport vehicles. Commercial vehicles are mainly not involved in global field events.

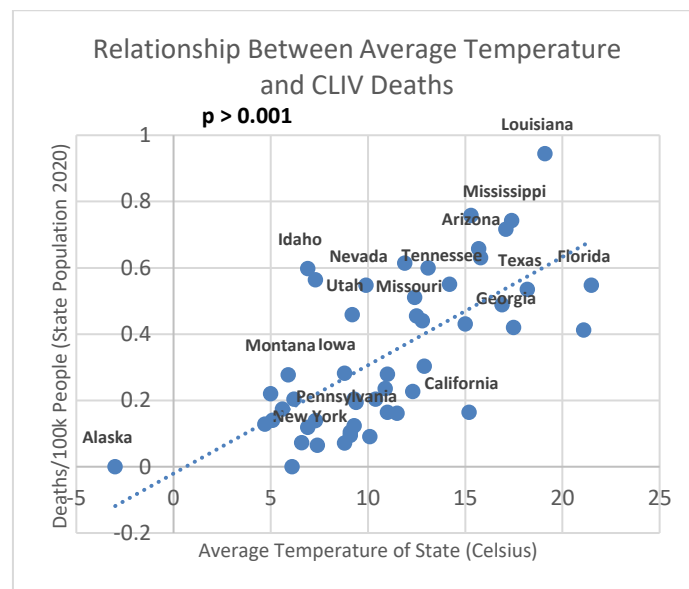
II. Terms of Reference Question 3 Research and Discussion Points

A. Under what environmental and vehicle conditions are global field events observed in which PVH occurs?

11. There are several environmental and vehicle conditions that are observed in global field events where PVH occurs. Notable environmental conditions include high and average ambient temperatures, during daytime hours and largely at the residence. Notable vehicle conditions include increased internal humidity. These should be accounted for, as a sizeable minority of parents have left their child alone in the car at least once (Alowirdi et. Al., 2020; Sartin et. Al., 2023).

Figure 1:

United States Relationship Between Ambient Temperatures and CLIV Deaths by Population



1. Average and High Ambient Temperatures

12. To ensure that temperature is a factor, we analysed the correlation between CLIV deaths from 1990 per 100,000 people in every United States state and average state temperature. This is due to more accurate record keeping of these events in the United States. As in Figure 1, there was a highly statistically significant correlation, demonstrating a relationship between ambient temperature and CLIV PVH cases. This is in line with intuitions, but it is important to confirm for any future solution. It is based off statistical analysis of an extensive database on CLIV Cases analysed by Australia and provided by KidsandCars.

13. Of United States cases analysed by KidsandCars, 89% of cases occurred in temperatures higher than 26°C, and 98.7% higher than 15.5°C (KidsandCars, 2024). Most deaths occurred in the morning and afternoon as well, with cases between 7am - 4pm making up 73% of cases from 1990-2016 and 4am – 5pm making up 88% of cases from 1990 – 2024 (Hammett et. Al., 2020; KidsandCars, 2024). Very few cases occur in winter, with 65% of cases occurring in the summer months (Hammett et. Al., 2020; KidsandCars, 2024). In statistics, a normal distribution is used to describe data that adheres to a bell curve, with the peak of the bell being the average of data, and the data being progressively predictably less common the further from the average. The distribution of CLIV cases, with the average being June/July, represents a normal distribution.

14. This leads to the conclusion that any countries that experience temperatures greater than 15°C are at risk of CLIV PVH events, and any that experience regular temperatures above 26°C are in danger of chronic increased CLIV PVH events. It is likely that countries experiencing these temperatures have higher numbers of CLIV cases, as the probability of a child left in a vehicle succumbing to heatstroke increases significantly from these ambient temperatures.

2. Vehicle Conditions – Internal

15. Internal vehicle conditions influence the severity of CLIV cases significantly. Solar irradiation intensity is the amount of energy per square metre the sun delivers in watts/square metre. With a typical sustained solar irradiance of 700 -1000 watts/square metre, vehicle internal temperature increased to 40°C in 20 minutes and 42°C in 33 minutes (Xuhao et. Al., 2021). In simulations, an occupant between 1-5 years of age under these conditions would have a core temperature of 38°C after 72 minutes and would continue to climb fast to 39°C after 108 minutes. At this body temperature, it is recommended to bring children to the emergency room. This also doesn't consider that the body's set point temperature is adjusted to that level internally rather than forced on it externally when recommended to take the child to the hospital (Xuhao et. Al., 2021; IQWiG, 2022; Cleveland Clinic, 2021). Even more pernicious, there is significant body water loss, up to 1% of a child's body weight, at 72 minutes. This reduces the temperature necessary to induce heat stroke. For example, an ambient temperature of 34°C can have heat exhaustion possible at a sustained exposure of 40% humidity, but a high risk of heatstroke at 80% humidity in adults (Xuhao et. Al., 2021; Duzinski et. AL., 2013). This also doesn't consider that children are more susceptible to body temperature increases. This has dire implications, considering in 2019, 88% of CLIV cases were left in the vehicle for 2 hours or more (NHTSA, 2022). Therefore, with sustained internal temperatures and increased humidity, danger of heatstroke is likely. Non-fatal injuries as a result of heatstroke are complex. These are unaccounted for in this paper surrounding the consequences of CLIV and will be expanded upon in separate research.

3. Vehicle Location

16. In CLIV cases, oftentimes the vehicle is located outside or in a non-sheltered or non-air-conditioned environment. Of the 2019 CLIV field events in the United States, 72% of cases were not shaded at all, 14% partially and only 2% having shade, with vehicle colour having no direct influence (NHTSA, 2022). This means that CLIV PVH is significantly deadlier in direct or partial sun as standard solar irradiance is strongest directly, rather than indirectly under shade (Xuhao et. Al., 2021). Oftentimes, these cases occur when parked at the home residence or workplace, with the intended destination of the forgotten child being daycare. These are a result of either FBS, or an atypical routine causing misplacing the child (NHTSA, 2022). This is confirmed by miscommunication, forgetting to drop off at daycare and childcare provider mismanagement making up 63.6% – 66% of unknowingly left CLIV cases (Chandler et. Al., 2024; KidsandCars, 2024). It is likely that if the final destination were shaded, air-conditioned or an underground park where direct solar irradiance wasn't possible, CLIV cases could be avoided. However, many parents park in the open without shade, and most carparks are in the open air.

III. Terms of Reference Question 4 Research and Discussion Points

What age groups does PVH affect and how are the victims seated/orientated in the vehicle?

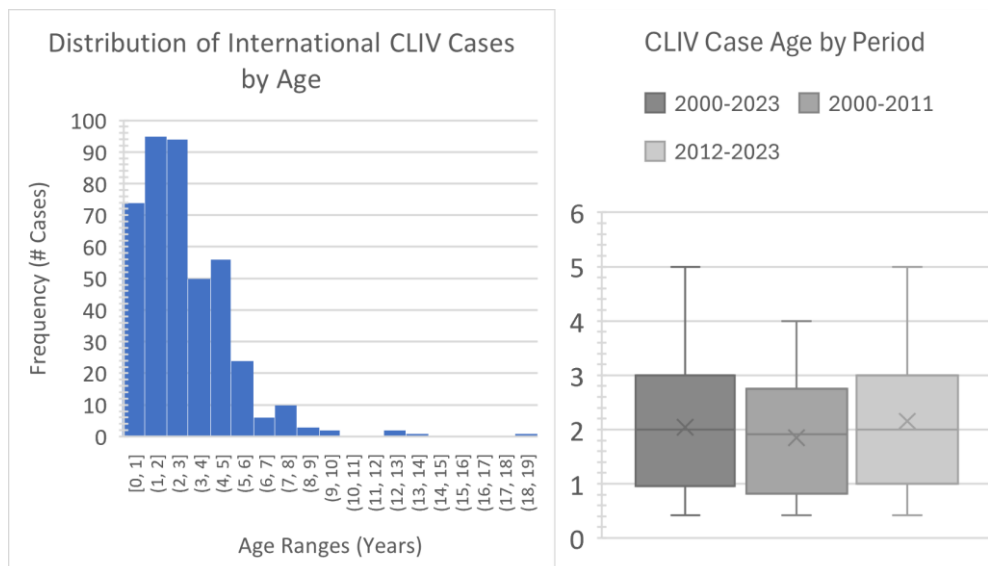
17. There is a consistent trend of children aged 5 and under making up the vast majority of CLIV cases, with some cases being older, and the average being between 1 and 3 years old. There are very few documented cases with orientation and seating position, however, NHTSA indicates a mix of rear and front facing CRS, which has some implications for countermeasure development and implementation.

1. Average Age of Mortality Skews Young

Figure 2:

(a) Number of Cases by Age Range for International Dataset Excluding United States Data

(b) Australian CLIV Deaths Boxplot by Time Period (X = mean, middle line = median, tails represent extend of maximum/minimum ranges)



18. Data varies on the average and median ages depending on the dataset. Excluding the detailed United States data, all 446 recorded international CLIV PVH deaths have an average of 3 years 3 months and median age of 3 years respectively. The Australian dataset skews younger, with an average age of 2 years 2 weeks for CLIV PVH deaths, which skews slightly older for more recent deaths as in Figure 2. For the United States dataset, the average age for 1990 – 2016 CLIV PVH deaths was 1 year and 4 months, with the median being 1 year and 1 month (Hammett et. Al., 2021). Using a benefit cost for Australia, if we take the higher CLIV PVH victim average of 3 years 3 months, the fatality cost is approximately \$7.233 Million AUD. This would change depending on the currency and country of analysis.

19. This average age being low leads to some conclusions for any potential solutions, relating to sensor position and orientation. The age of most cases is 5 years old or younger, 82.7% for non-USA cases and 99% for USA cases. This makes it highly likely that a child will be in a CRS system, which a direct or indirect sensor would need to consider.

2. Seat Orientation

20. There is very little data about orientation of the CLIV, however, one NHTSA study explored this for all confirmed recorded CLIV PVH cases in the USA during the calendar year of 2019. Of these children, approximately 70% were restrained in a Child Restraint

System (CRS), 17% were not restrained and 13% were unknown. Of those that were restrained in a CRS, 33% were rear facing, 42% were forward facing and 25% were unknown CRS type (NHTSA, 2022). Of all known cases, 20% were in an unknown CRS type, 27% were rear facing, 33% were front facing and 20% were not restrained in a CRS. This doesn't seem to be significantly different to the broader United States population (NHTSA, 2023).

21. This leads to conclusions expanding upon those in the previous section, that any potential countermeasure addressed by a regulation must keep in mind the possibility of a CRS being present. In addition, it must be neutral for the front or rear facing orientation of the CRS. Therefore, any CLIV solution should consider a child entering the vehicle and being situated in the middle of the rear seat and behind the front seats, in addition to other standard seating positions.

IV. Terms of Reference Question 5 Research and Discussion Points

A. What are possible solutions/countermeasures which address the underlying safety concerns observed in the field?

22. There are several countermeasure systems that could prevent CLIV. Various sensor types at varying costs can either directly detect or infer occupancy. Some established testing methods by the European New Car Assessment Programme (Euro-NCAP) and the Australasian New Car Assessment Program (ANCAP) propose that direct detection of an occupant should be a criterion.

1. Broad Categories of Countermeasures

23. Detection methods broadly fall under two different categories, outline by the CLEPA research document submitted in CLIV IWG Session 3 (CLEPA CLIV-03-02-Rev1e):

- Indirect Sensing – Inferring the presence of a child through system logic and behaviour of the driver with the vehicle in a journey. No direct signs of life detected, only inferring child presence
- Direct Sensing – detecting certain signs of life through sensing capabilities to see if a child has been left in a vehicle

24. There is a prevalence of memory failure causing the forgetfulness seen by caregivers for CLIV. This can limit the effectiveness of advertising campaigns. The relative effectiveness of these campaigns is addressed in other research submitted. Therefore, countermeasures should be considered for determining the presence of occupants to prevent most CLIV cases.

25. The following sections will compare these two broad categories at determining CLIV.

2. Principles for Countermeasures

26. There are several methods to address CLIV with countermeasures with a lot of variation. Therefore, the IWG should consider some underlying principles explored in countermeasure considerations. This allows the group to consider the scope of a regulation, understand how a technologically neutral regulation may be made and decide which principles are most important for a regulation to prevent CLIV.

27. The National Surface Transportation Safety Center for Excellence (NSTSCE) found several types of direct and indirect sensing countermeasures that aimed to prevent CLIV (Glenn et. Al., 2021). In analysing these countermeasures, they developed principles for creating countermeasures for CLIV in aftermarket and Original Equipment Manufacturer (OEM) solutions (Glenn et. Al., 2021). This study involved vehicle models made in 2020 and prior. Aftermarket and OEM solutions mainly involved indirect sensing, such as inferring a rear occupant through a minimum rear-door opening time. There were also other door logic systems in place. Some aftermarket solutions had restraint-based technologies that alerted if

a CRS was still clipped in the car. One indirect system was an aftermarket button system similar to buses, where the owner is alerted and must turn off the alert with buttons placed in the rear of the car (Glenn et. Al., 2021).

28. Some direct sensing methods were analysed, including pressure-based pads and an ultrasonic sensor OEM solution. Based on analysing their analysis of the available technologies, the best countermeasure system to prevent CLIV was the Hyundai/Kia ultrasonic system. This system included an initial rear seat reminder with a direct sensing ultrasonic sensor that detected motion in the rear seats, triggering escalation signals. Most solutions didn't work for journeys with multiple stops, and most couldn't prevent all 3 main CLIV scenarios. Based on their analysis, they proposed several principles for countermeasures to successfully detect CLIV, either from current or future technology. Below are some summarised examples from this list, with the full list being in Figure 1 of the Appendix:

- OEM Systems enabled on delivery
- Provide feedback to the user regarding system activation and arming
- Activated under normal behaviour for having an occupant in the rear seat
- If door logic is used, set a minimum amount of time a rear door needs to remain open to minimize nuisance alerts
- Actual occupant detection via methods such as movement, weight, or other means
- Detection capabilities always armed regardless of lock status for gained access scenarios
- Distinctive audio alert completely different from and given priority over any other alerts
- Passive intervention features activated if occupant is detected and not removed
- Window of time or distance that a caregiver can be outside a vehicle without issuing an alert
- Levels of alerts given (e.g.: initial, escalation)
- Alert issued when vehicle is in accessory mode

29. One key statement is that minimising nuisance alerts will decrease the amount of people ignoring alerts for CLIV. Many OEM solutions gave alerts due to false positives or false negatives. They conclude that systems which reduce nuisance alerts typically detect actual signs of life rather than inferring.

30. Direct sensing had a capability advantage when compared with indirect sensing, as it gave significantly less false positives. In addition, people will at many times open the rear doors when there are no children present for longer than the minimum time for many door-logic-based solutions. Due to the nature of memory failure in the case of CLIV, the drivers would likely come to ignore signals with too many false positive alerts.

31. It's important to note that are countermeasures that could be seen as indirect but are typically detecting occupancy. These may infer signs of life rather than directly detect them, including a pressure sensor in the seats sensitive to weight shifting or a carbon dioxide monitor in the vehicle. However, indirect sensing is generally classed as more rudimentary inference with use of door logic. Euro-NCAP protocols define these terms more specifically.

3. Detection Testing Protocols

32. Euro NCAP and ANCAP have largely similar methods for testing CLIV detecting systems. They developed testing guidelines for CLIV detection, or Child Presence Detection (CPD), that involve scoring against indirect and direct sensing systems (ANCAP, 2024). They also give definitions of direct and indirect sensing:

- Direct Sensing - The ability to detect the absolute presence of a human inside the vehicle by means of tracking heartbeat, respiration, movement, or any other sign of

life. Direct sensing may or may not allow categorisation and localisation of the subject(s)

- Indirect sensing - The ability to derive the potential presence of a subject or object inside the vehicle based on logic using information such as door opening, pressure or capacitive sensing etc. Indirect sensing does not distinguish between live persons or objects.

33. Rewards are given based on several factors. These include escalation warnings and an initial warning after the vehicle is locked, a maximum time of 10 seconds delay for system assessing occupancy, a maximum time before system detection of 10 minutes after door closure for gained access scenario (with or without locking).

34. In 2023 and 2024 ANCAP tests, signals can be audible or visual, but must consist of at minimum one type. 2025 tests will require both audio and visual warnings. These 2023/2024 tests must have the warnings be heard or seen by someone exterior to the vehicle, must come from the vehicle or key, continue for at least 3 seconds (until cancelled) and be distinctive and differ from usual signals. These align with some principles of CLIV preventative technologies by NSTCE at the Virginia Tech transport Institute outlined in the previous section (Glenn et. Al., 2021). The 2025/2026 test warnings must have the distinctive signal, possibility of delaying warning for no more than 10 minutes, and may have cancellation by acknowledgment of warning.

35. Rewards are also given for intervention, though only on direct sensing equipped vehicles that give initial and escalation warnings in all testing scenarios. These interventions must actively reduce the threat of hyperthermia.

36. Scoring is broken down by 2023-2024 and 2025 onwards in the table below:

Table 1:

Breakdown of Euro NCAP and ANCAP Protocol for Testing Systems that Detect CLIV

Sensing Type	Warnings and Intervention	Points (2023/2024)		Scenario 1 & 2 Points (2025/2026)		Scenario 1, 2 & 3 Points (2025/2026)	
		All Passenger Seats	Rear Seats Only	All Passenger Seats	Rear Seats Only	All Passenger Seats	Rear Seats Only
Indirect	Alert	N/A	0.25	0	0	0	0
Indirect	Initial warning	1	1	0	0	0	0
Direct	Initial Warning	1.5	1.5	0	0	0	0
Direct Only	Initial and Escalation	3	1.5	2	1	3	1.5
	Initial, Escalation and Intervention	4	2	3	1.5	4	2

37. Overall, Euro NCAP and ANCAP class direct sensing as more capable to prevent CLIV, illustrated by being able to score much higher than the maximum score of indirect sensing with a direct sensing system. ANCAP and Euro NCAP will award no points for indirect sensing from 2025 onwards based on their public guidelines as of August 2024.

38. In July 2024 meetings with ANCAP officials, we were told that there seems to be very low uptake of CPD systems, with only one vehicle type analysed by ANCAP implementing direct sensing systems between 2023 and 2024. This is different to their partner organisation Euro-NCAP, which has tested at least 13 vehicles with some form of CLIV detection capability in 2024.

39. ANCAP officials stated that mostly Asian manufacturers are interested in implementing direct sensing in Australia. Most manufacturers use indirect sensing, due to no additional technology, with only a change of algorithms, software and door logic. Manufacturers sought to allow some points for a reminder alert as agreed in the 2019 US commitment, so Euro NCAP and ANCAP allowed 0.25 points for honouring that commitment (AAM, 2019).

40. This low uptake of direct sensing is due to a number of factors. One is the relatively small reward for achieving an effective CPD system. It's also common for a manufacturer to achieve a 5-star ANCAP/Euro-NCAP without a CPD system, as they already often achieve the necessary 5-star threshold of 80% for Child Occupant Protection scores. Lastly, direct sensing is more expensive, so it's often seen as a point of pride and a source of publicity value for safety feature advertisement. This leads to most manufacturers attaining an indirect sensing system, as it only requires sensors already present in many vehicles (e.g: door logic [minimum time to open rear door] with instrument cluster rear seat reminder).

41. The ANCAP officials mentioned that the ANCAP 2025/2026 protocols will likely shuffle the overall points system. Around this time, manufacturers may be more likely to implement direct sensing CPD systems after the reshuffle, as they will attain more points in the Child Occupant Detection category.

42. In conclusion, indirect sensing is less effective for detecting, inferring and preventing CLIV, due to a high false positive rate. Alerts are also more likely to be ignored over time by drivers in vehicles with only a rear seat reminder. As discussed in "Australia Heat Stroke CLIV-04-03-Rev1," it is thousands of times more likely that a child is left in a rear seat temporarily than dying from being left in the vehicle. As caregivers or non-caregivers become used to the reminder in most scenarios that are non, removing the purpose of the alert in a practical sense.

43. There was also discussion with ANCAP regarding how to test CPD systems, and we discussed CPD dummies currently on the market. This will be necessary for regulation development into the future.

4. CPD Dummies Requirements Analysis and Comparison

44. For testing based on the Euro-NCAP and ANCAP protocols, we analyse two known CPD dummies. These are the MESSRING CPD and the 4activeOD-newborn. They are very similar with some differences. They both have new-born versions of the CPD dummies, with MESSRING planning a 6-year-old CPD dummy. MESSRING has also recently partnered with Humanetics to deliver their CPD systems dummies to Humanitecs Customers (MESSRING [2], 2024) Table 2 shows the differences between the two new-born dummies:

Table 2:

Available CPD Dummies by MESSRING and 4active Compared (MESSRING [1], 2024; 4active, 2024)

	<i>MESSRING CPD Dummy</i>	<i>4activeOD-newborn</i>
Capabilities		
Breathing	Yes	Yes
Adjustable Breathing Rate	Yes	Yes
Euro-NCAP Breathing Patterns	Yes	Yes
Manual Posture Change (head, limbs, torso)	Yes	Yes
Head and Limb Movement	Yes	Yes
Metal Free (for detection)	Yes	Yes

	<i>MESSRING CPD Dummy</i>	<i>4activeOD-newborn</i>
Metal Free (no radar interferences)	Yes (Supply box excepted)	Likely (reported radar system compatibility)
User Defined Movement Patterns	Yes	Yes
Euro-NCAP Movement Patterns	Yes	Yes
Remote Operability	Yes (Application)	Yes
Power Supply Box	Yes	Unknown

45. The performance capabilities of each dummy are made to work for various types of detection systems. The 4active dummy states that it can be used for radar, camera, lidar, ultrasonic or WIFI sensing methods. With the movement capabilities, it's possible that other signs of life could be detected with this dummy. MESSRING doesn't specify compatibility with any other system other than radar. However, it's likely that similar sensing methods as the 4active Dummy, with the exception of sensing systems relying on movement other than breathing. CPD Dummy development based on the analysis of the available options are:

46. Indirect Sensing

- Indirect sensing only requires inference of an individual, so it wouldn't necessarily require a CPD dummy. It would require testing of the door logic to see if the system is armed and alerts are given. If a carbon-dioxide monitor is classed as an indirect sensor, a more sophisticated inference of occupancy, the CPD dummies wouldn't register due to mimicking breath without true respiration. However, a sensitive pressure sensor in the seat may detect the MESSRING 4active dummy movement.

47. Direct Sensing

- Direct sensing implies the direct detection of a sign of life that can indicate if a child has still been left in a vehicle. This could be done in a number of different ways, with various sensing methods, outlined in the "*Types of Sensors Available*" section of this report. Therefore, a CPD dummy must represent and replicate at least one sign of life for adequate "direct sensing" assessment.

48. There are advantages and disadvantages between the two dummies. While these two CPD dummies simulate many signs of life, there are several signs of life that could be detected. For example, the 4active CPD dummy has movement of limbs that could be detected by a sufficiently sensitive pressure sensor under the seat by detecting change in movement. It also works for most direct sensor categories, including radar, camera, LIDAR, WIFI sensing and others. However, a carbon-dioxide sensor wouldn't be tested with these dummies. Therefore, a regulation will need to clarify a threshold for appropriate CLIV sensing to allow CPD dummies to meet the testing requirements.

49. The Euro-NCAP/ANCAP protocol provides a guide for testing requirements and for direct and indirect sensing definitions to determine the testing requirements for both CPD dummies and CLIV regulation. As previously mentioned, they provide reasonable definitions for sensing types. They define direct sensing as detecting absolute presence of an occupant by a sign of life and indirect sensing as detecting the potential presence of an occupant while not distinguishing between people or objects. There are false alarm implications that these definitions do not overcome though, which will be addressed in other documentation and among the IWG attendees.

5. Sensor Types for CLIV and Occupancy Detection

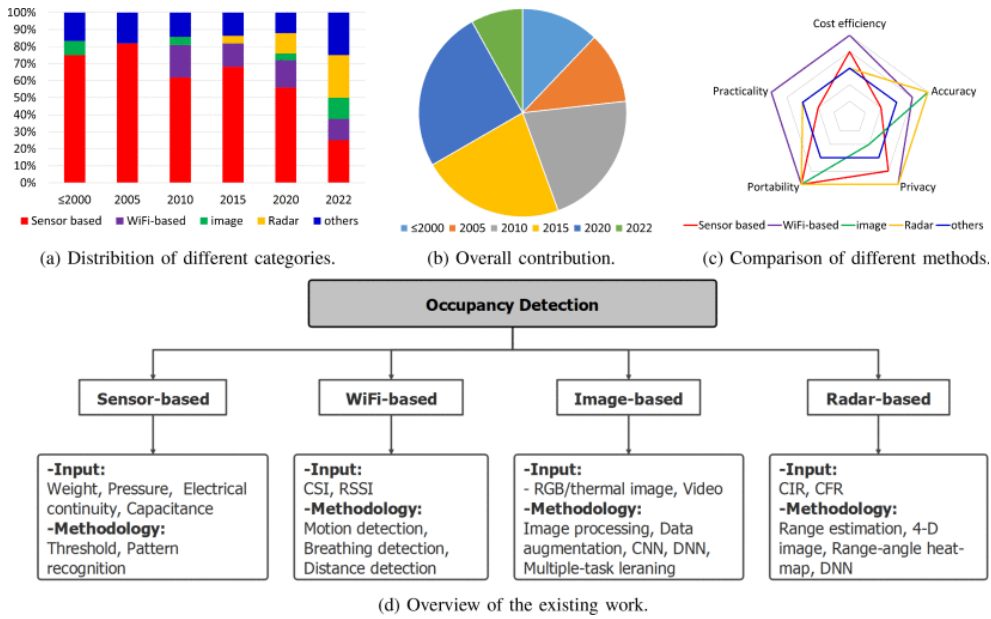
50. Any future regulation will seek to be technology neutral, so the group will need to ensure that we don't mandate one technology by implementing a regulation improperly. This

necessarily leads to an analysis of current occupant detection technologies that are currently available or in use by OEMs.

51. Broadly, there are several classes sensors and methods for detecting occupancy in vehicles. A comprehensive review of papers and patents found four major categories and classed their effectiveness under the categories of practicality, accuracy, privacy, portability and cost efficiency (Xiaolu et. Al., 2022). These findings are summarised in Figure 3.

Figure 3:

Related Research from Suitable Papers and Patents for In-vehicle Occupancy Detection (a) Categories of Sensor Detection Sensing Method Types by Time Periods (b) Share of publications by time period (c) Comparing the Different Occupant Detection Methods (d) Overview of Occupancy Detection Categories and Included Technologies



52. These occupancy technologies are mentioned to also be utilised as seatbelt reminders, however, further analysis from the IWG will be needed to determine if these technologies are appropriate (Xiaolu et. Al., 2022).

53. The sensor-based type is typically easy to design, manufacture and deploy with a more affordable cost. However, sensitivity to thresholds of weight, pressure, temperature, capacitance and electrical continuity can lead to high false positive or false negative rates (Xiaolu et. Al., 2022). WIFI-based occupancy/human presence detection is relatively cheap, can have a much lower false alarm rate of 0.5 - 5% depending on the type of WIFI and software used (Xiaolu et. Al., 2022; Li et. Al., 2018; Tao et. Al., 2019; Chong et. Al., 2020). WIFI-based detection downsides include reduced signal quality degrading WIFI signal accuracy, and differences in how large an adult's movements are compared to a child.

54. Image-based occupancy detection has advantages due to provided more better edge detection than WIFI, and a program using image-based sensors can be trained to recognise an occupant (Xiaolu et. Al., 2022). These methods include optical and thermal imaging, with varying degrees of accuracy (Géczy et. Al., 2020). Thermal imaging-based detection can have a counting accuracy ranging between 80 - 95% (Xiaolu et. Al., 2022; Nowruz et. Al., 2019).

55. Radar-based occupancy detection has emerged more recently as an effective occupancy detector due to better directionality, angular and range resolution (Xiaolu et. Al., 2022). Due to these characteristics, it can be used to look at breathing rates and heart rates in a vehicular environment (Eleonye, 2024). These systems have typically more consistent accuracy, usually at minimum 90% and typically 95-99% (Yao et. Al., 2022; Tao et. Al., 2022; Alizadeh et. Al., 2019; Gharamohammadi et. Al., 2021; Song and Shin, 2021).

Additionally, a Frequency Modulated Continuous Wave (FMCW) mm-wave radar could determine if a vehicle is occupied or not with 100% accuracy (Alizadeh, 2019). The mechanics of a radar occupancy detection system are described thoroughly in a 2021 study (Lazaro et. Al., 2021)

56. Ultimately, there are several methods of detecting CLIV and many different types of technologies that can be used for this purpose. Therefore, developing a regulation will likely limit manufacturers to a specific type of technology, maintaining its technological neutrality.

6. Sensor Cost Estimations

57. Each sensor has different costs for any vehicle manufacturer seeking to implement them. Light vehicle manufacturers will need to consider the expense of these different technologies if a CLIV regulation were in place. Costings for existing light vehicle CLIV detection systems are hard to source due to equipment manufacturers not disclosing specific implementation, installation, software or other costs of these systems.

58. NHTSA sought consultation through Ricardo PLC's Strategic Consulting branch and commissioned a paper on the costs of some OEM and aftermarket CLIV detection technologies (Document ID: NHTSA-2011-0066-0110/NHTSA-2011-0066-0113) (NHTSA, 2023, Boggs and Richardson, 2023). They broke down each component into individual parts and estimated manufacturing costs, material type, cost and weight. Manufacturing costs were estimated using Asset Centre Costing methodology, accounting for material, labour, machine and equipment costings in manufacturing. The report disclaims that it involves several assumptions and that while they assume the underlying data to be correct, the conclusions would change if it were false.

59. They estimated the retail cost for rear-seat reminder technologies were zero due to no additional incremental hardware required to give the rear seat reminder alert (Boggs and Richardson, 2023). Many vehicle models other than the model tested have implemented near-zero cost rear seat reminders under the 2019 United States Manufacturer commitment. implemented voluntarily by 20 vehicle manufacturers making up about 98% of new passenger cars sold in the United States.

60. The OEM solutions that had costs estimated were both Hyundai Motor Company vehicles, the Hyundai Palisade ultrasonic sensor and the Genesis GV70 short-range radar system. These both aim to detect children in the rear seat only. For costing the OEM systems, they assumed a vehicle production volume of 200,000 units, specific manufacturing burdened labour rates for South Korea, and specific depreciation scheduling of equipment/tooling rates and scrap rates. Table 3 breaks down the estimated cost of these systems.

Table 3

NHTSA Consultation Report Estimated Cost Breakdown of Systems that Detect Occupants to Reduce PVH [\$ = USD] (Boggs and Richardson, 2023; NHTSA, 2023)

<i>System Type</i>	<i>End User Cost Increase</i>	<i>Total Manufacturing Cost (incl. Selling General, Admin Exp)</i>	<i>Total Manufacturing Cost (Base)</i>	<i>Printed Circuit Board (PCB) Cost</i>	<i>Sensor Cost</i>
Hyundai Pallisade Ultrasonic Rear Occupant Alert	\$ 20.33	\$ 16.21	\$ 15.01	\$ 8.61	\$ 4.80
Genesis GV70 Radar Rear Occupant Alert	\$ 19.49	\$ 15.55	\$ 14.40	\$ 12.75	
Evenflo – SensorSafe Chest Clip	\$ 20.19	N/A	\$ 6.73	\$ 6.73	
BeSafe – smart buckle sensor	\$ 38.59	N/A	\$ 12.86	\$ 10.17	

61. In general, the sensors and PCB made up the majority of costs. Most of these costs were material and direct labour related. The appendices of this report also provide methodology for the estimated cost breakdown for each component. The consultancy report states they don't warrant the conclusions contained in the report as there may be material differences between forecasts and actual results. Therefore, it's important to mention that these costs are estimated, and the OEM representatives would have more insight into these costs.

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Authors: M. Royds, A. Nilar, D. Kutschkin

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Annex II

Full List of Countermeasure Principles from NSTSCE (Glenn et, al., 2021)

Suggestions for rear seat occupancy detection alert systems:

- Be enabled upon delivery to the customer (OEM systems)
 - Provide feedback to user regarding system activation and arming
 - Optional customization (name, picture for designated occupant)
 - Activated under normal behaviour for having an occupant in the rear seat
 - If door logic is used, set a minimum amount of time a rear door needs to remain open (indicating a passenger needing assistance getting in the vehicle vs. putting an item in the back) to minimize nuisance alerts
 - Low battery life warning (if aftermarket)
 - Detection capabilities for gained access scenarios always armed regardless of door lock status
 - Distinctive audio alert completely different from any other alerts (not merely differing by number of times issued, etc.)
 - Actual occupant detection via methods such as movement, weight, or other means for issuing alerts
 - Integrated with the vehicle and given priority over other vehicle alerts
 - Ability to dismiss or disable alert system at various points
 - Visual alerts displayed immediately in instrument cluster when engine is turned off or in the direction of the driver door window when a driver door is opened since that is likely the direction a caregiver will be looking upon exiting the vehicle
 - Alert issued when vehicle is in accessory mode
 - Have a window of time or distance that a caregiver can be outside a vehicle without issuing an alert
 - Passive features activated if occupant is detected (i.e., temperature control)
 - Levels of alerts to contact caregiver directly by phone, followed by bystanders, emergency contacts, and/or emergency personnel.
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