U.S. Department
of Transportation
**National Highway
Traffic Safety
Administration**

NHTSA

DOT HS 813 223

April 2022

Testing of Unattended Child Reminder Systems

DISCLAIMER

This publication is distributed by the U.S. Department of Transportation, National Highway Traffic Safety Administration, in the interest of information exchange. The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the Department of Transportation or the National Highway Traffic Safety Administration. The United States Government assumes no liability for its content or use thereof. If trade or manufacturers' names or products are mentioned, it is because they are considered essential to the object of the publication and should not be construed as an endorsement. The United States Government does not endorse products or manufacturers.

NOTE: This report is published in the interest of advancing motor vehicle safety research. While the report may provide results from research or tests using specifically identified motor vehicle equipment, it is not intended to make conclusions about the safety performance or safety compliance of those motor vehicles, and no such conclusions should be drawn.

Suggested APA Format Reference:

Prasad, A. K., & Wetli, A. E. (2022, April). *Testing of unattended child reminder systems* (Report No. DOT HS 813 223). National Highway Traffic Safety Administration

Technical Report Documentation Page

1. Report No. DOT HS 813 223	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle Testing of Unattended Child Reminder Systems		5. Report Date: April 2022	
		6. Performing Organization Code NSR-130	
7. Authors Aloke K. Prasad, National Highway Traffic Safety Administration Alaine E. Wetli, Transportation Research Center Inc.		8. Performing Organization Report No.	
9. Performing Organization Name and Address National Highway Traffic Safety Administration Vehicle Research and Test Center P.O. Box 37 East Liberty, OH 43319		10. Work Unit No. (TRAIS)	
		11. Contract or Grant No.	
12. Sponsoring Agency Name and Address National Highway Traffic Safety Administration 1200 New Jersey Avenue SE Washington, DC 20590		13.Type of Report and Period Covered Final Report	
		14. Sponsoring Agency Code	
15. Supplementary Notes			

16. Abstract

NHTSA tested aftermarket, prototype, and original equipment manufacturer (OEM) unattended child reminder systems available for purchase or testing in the summer of 2020. Generalized functional assessment methodologies to document the systems' capabilities were developed. The study intended to assess new systems and technologies introduced since the previous study was conducted in 2015. Nine systems representing the variety of underlying technologies were tested. The results showed that each aftermarket and prototype system could meet their own design criteria and alert the caregiver when the vehicle was turned off with the child still in the vehicle. In addition, the OEM systems met criteria and alerted caregivers with displays or audio alerts as designed. Based on the observations made in the study, all the systems worked as designed to alert caregivers when children are left unattended in vehicles, although the systems performed differently in addressing the variety of potential real-world situations, some of which were encountered in the Special Crash Investigations case reviews of pediatric vehicular heatstroke fatalities in 2019.

17. Key Words		18. Distribution Statement	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 89	22. Price

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized section

Table of Contents

Table of Figures

Table of Tables

1 Background

From 1998 to 2019 there were 858 deaths due to pediatric vehicular heatstroke (PVH)[1] in the United States. PVH occurs when a child is left unattended in a hot vehicle until the child experiences a heatstroke. A heatstroke can occur when body temperature exceeds 104 °F,[2] overwhelming the person's thermoregulatory mechanism. Even if the child is left in the vehicle for a short period of time, the child's core temperature can rise quickly, leading to a heatstroke. As the core temperature increases, cells could be damaged, leading to organ failure and possible death. Children's thermoregulatory systems are less efficient than adult systems, causing their body temperatures to warm at a rate potentially three to five times faster. This puts children at a higher risk for heatstroke if left unattended in vehicles.

From 1998 to 2019 an average of 39 PVH deaths were recorded per year in the United States, with 53 PVH deaths being recorded in the year 2019.[1] The lowest year for PVH deaths was 2015 at 25 deaths, while the highest recorded deaths occurred in 2018 and 2019 at 53 deaths, as shown in Figure 1. Of those reported deaths from 1998 to 2019, 54.2 percent were categorized as involving a child being forgotten in an unattended vehicle. Forty-six percent of cases involving a child being forgotten occurred when the caregiver or guardian mistakenly believed they had dropped the child off at childcare or preschool. The two other major situations reported for a child being left unattended in the vehicle included the child gaining vehicle access unknown to the caregiver and the caregiver knowingly leaving the child in the back seat. The annual number of fatalities[1] per category of "forgotten," "knowingly left,"[3] and "gained access" are shown in Figures 2 to 4. The lines on these plots represent a 5-year running average (starting at 2002) of the annual fatalities and the overall average. From 2015 to 2019 the number of PVH cases showed an increasing overall trend for the categories of "forgotten" and "knowingly left," while it decreased for the category of "gained access."

In 2019 vehicle manufacturers committed to equipping essentially all passenger vehicles with rear designated seating positions and adjacent doors with a rear seat reminder as a standard feature by 2025.[4]

[1] Null, J. (2021, January 5). *Heatstroke deaths of children in vehicles* [Web portal]. Noheatstroke.org.
[2] Harvard Health Publishing. (2019, January 2). *Heat stroke (Hyperthermia)* [restricted web page]. www.health.harvard.edu/a_to_z/heatstroke-hyperthermia-a-to-z
[3] This report uses the term "knowingly left" to remain consistent with the data set. "Knowingly left" is an industry term used to denote the caregiver's awareness that the child was in the vehicle prior to the incident. The term "knowingly left" is not intended to denote or imply legal intent or culpability.
[4] Alliance of Automobile Manufacturers, Inc., & Association of Global Automakers, Inc. (2019, September). *Leading automakers' commitment to implement rear seat reminder systems*. www.autosinnovate.org/-safety/heatstroke/Automakers%20Commit%20to%20Helping%20Combat%20Child%20Heatstroke.pdf

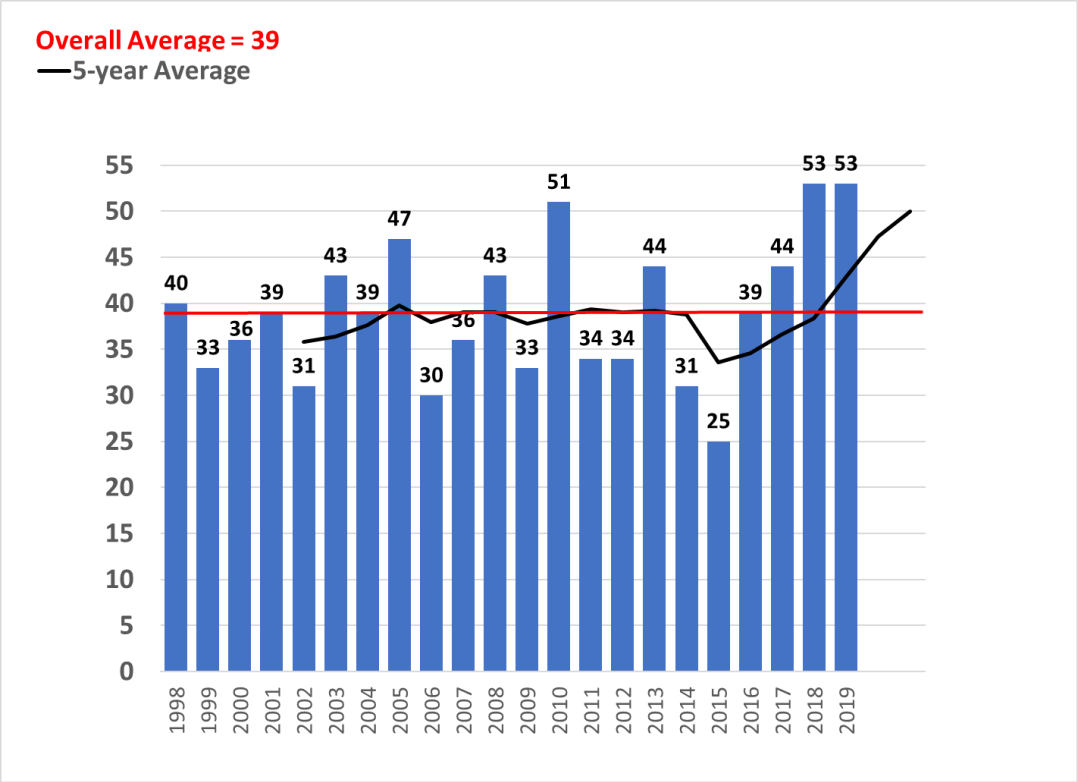

Figure 1. PVH Deaths From 1998 to 2019 (see Editor's Note)

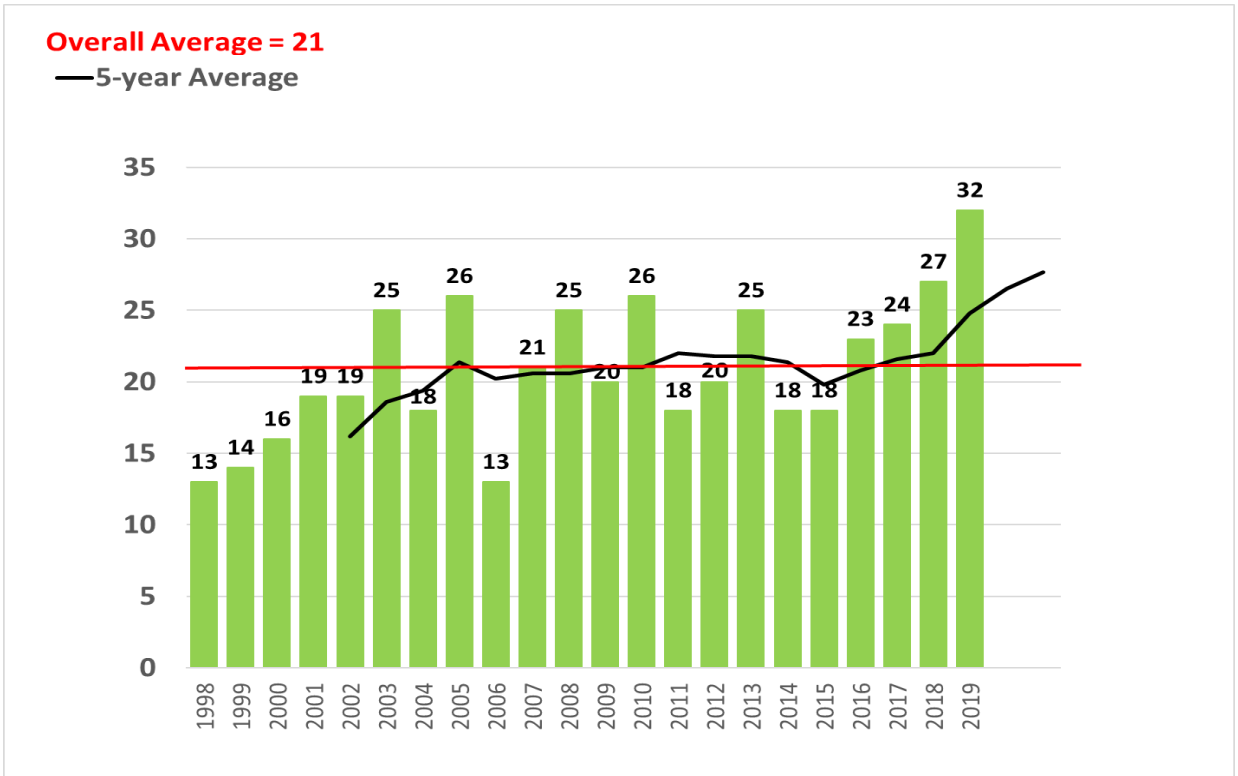

Figure 2. PVH Deaths (Forgotten) From 1998 to 2019

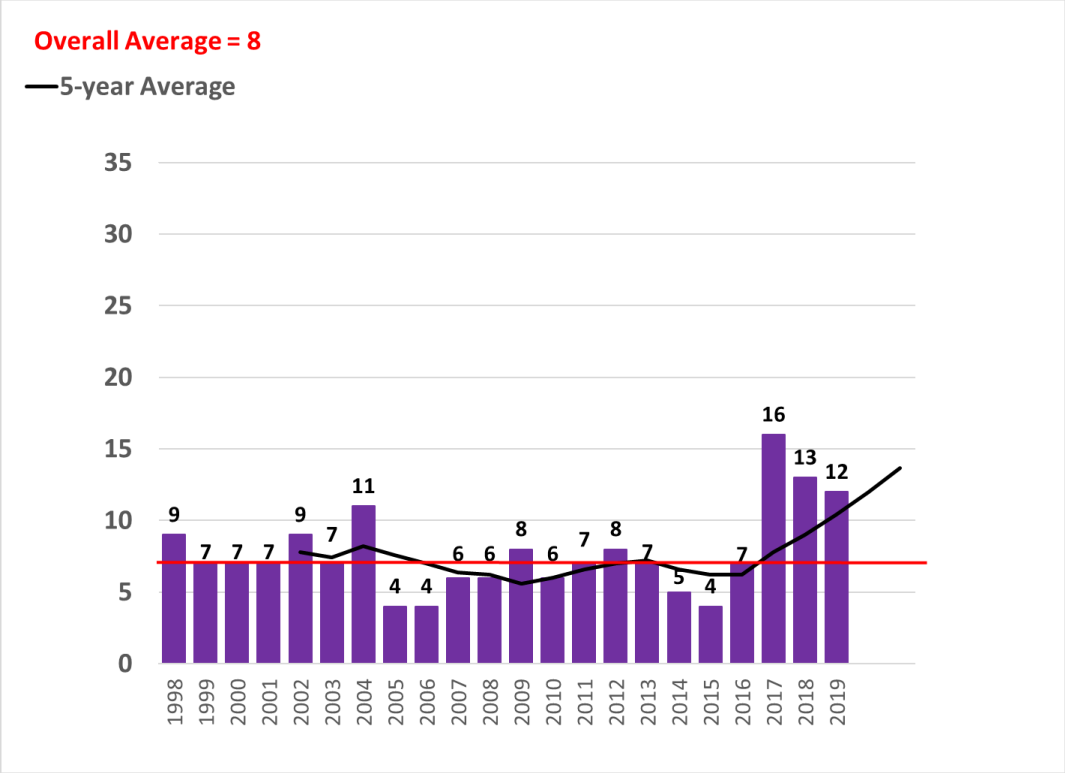

Figure 3. PVH Deaths (Left) From 1998 to 2019

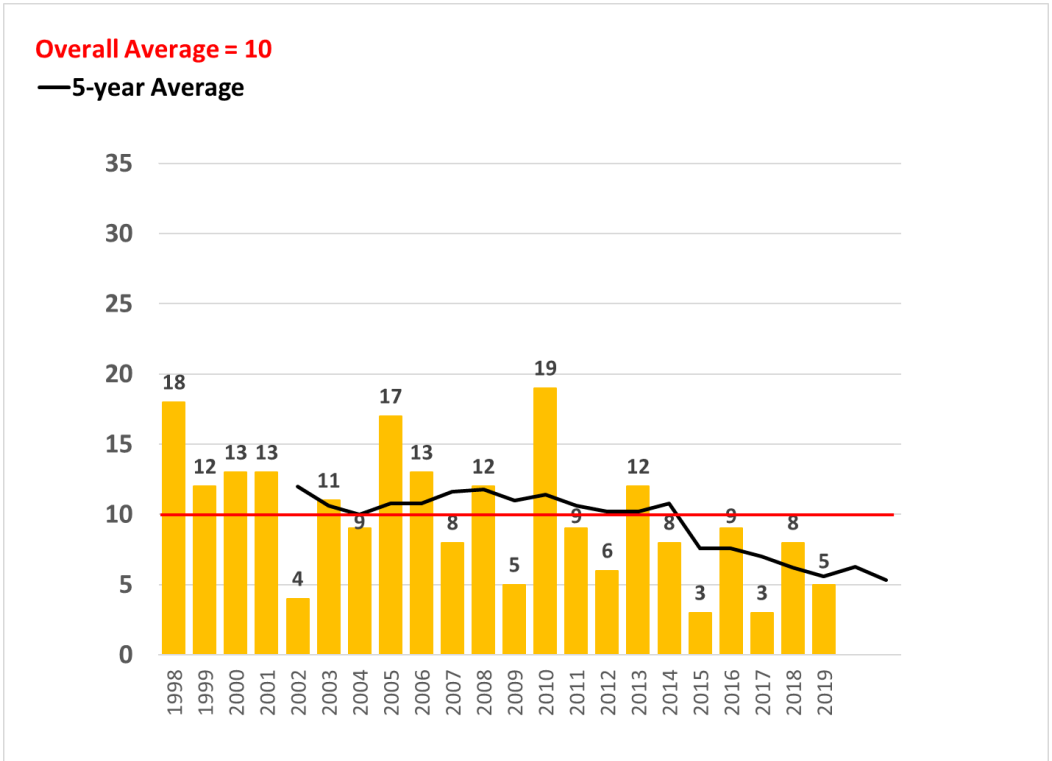

Figure 4. PVH Deaths (Gained Access) From 1998 to 2019

NHTSA responded to these PVH fatalities by producing educational material and resources, supporting a paid media campaign to support awareness of the issue,[5] and conducting heatstroke working group meetings with key safety advocates to elevate the issue with major retailers and transit providers. These activities and campaigns together work to raise awareness of heatstroke fatalities by all three mechanisms reported (forgotten, knowingly left, gained access). In July 2015 NHTSA conducted a functional assessment of the seven aftermarket unattended child reminder systems (UCRSs) available at that time.[6] Those seven systems were the following.

- Aviso Child-in Car Alert
- ChildMinder Elite Pad System
- ChildMinder SoftClip
- Forget Me Not
- SOS
- Suddenly Safe 'N' Secure Wireless Child Protection System
- True Fit I-Alert

Based on this study, NHTSA concluded that UCRSs would ideally incorporate the following.

- No effect on child car seat crash performance (if aftermarket)
- Minimal additional action from driver/parent to operate following initial installation
- Feedback to user to indicate functionality
- End-of-trip convenience reminder and left-behind alert
- Fail-safe features
- Robust operating capabilities – battery life, temperature range, appropriate child size, compatible child restraints system (CRS) type, etc.

Since the 2015 functional assessment, additional aftermarket and prototype UCRS have come on the market along with systems included in the vehicles as original equipment manufacturer (OEM) features. For the study described in this report, NHSTA tested recently available aftermarket, prototype, and OEM UCRSs at the Vehicle Research and Test Center (VRTC). The literature review, identification, and procurement of the UCRS were carried out in spring and summer of 2020. During this period, some systems were advertised but found to be discontinued or not in production and were not available for inclusion in this study.

A particular outcome of the functional assessment does not constitute an endorsement by NHTSA or a designation of a UCRS being compliant with any safety standard.

[5] National Highway Traffic Safety Administration. (n.a.). *Where's baby? Look before you lock* [web page and portal]. www.nhtsa.gov/campaign/heatstroke

[6] Rudd, R., Prasad, A., Weston, D., & Wietholter, K. (2015, July). *Functional assessment of unattended child reminder systems* (Report No. DOT HS 812 187). National Highway Traffic Safety Administration. www.nhtsa.gov/sites/nhtsa.dot.gov/files/812187_unattendedchildremindersystems.pdf

2 Updated Unattended Child Reminder Systems

This section describes the features and capabilities of the UCRSs tested in this updated assessment. A literature review and market survey were conducted to determine the updated systems available, to identify additional technologies on the market, and to have discussions with OEMs about the systems installed in their vehicles.

Each aftermarket system included either a physical device or a software application connected to a smartphone. These systems were not installed or included with the vehicles, and would work across different vehicle makes, model years, and manufacturers. In spring 2020, four vehicle manufacturers were identified that offered OEM UCRSs in current production vehicles. These detection systems were included as a feature of the vehicles and could be turned on or off once the vehicles were acquired.

Four aftermarket systems were selected, none of which was tested in the 2015 assessment study. These systems were selected based on the availability of the system and the type of technology used to detect the unattended child or alert the caregiver. These aftermarket systems were tested in a 2014 Jeep Grand Cherokee. The fifth system, the prototype millimeter-wave, radar-based system by Panasonic-Ficosa, was tested in a 2011 Ford Explorer. The radar-based system was tested in the Ford Explorer as the vehicle had to be retro-fitted by the supplier. To ensure the timeliness of this study, the Jeep Cherokee was used to test the aftermarket systems. Note that the selection of vehicles for this study is unlikely to affect the effectiveness of these systems capabilities.

In addition to the aftermarket and prototype systems, four OEM systems were selected: Toyota, Subaru, Chevrolet, and Hyundai. These systems were selected based on availability in Spring 2020 and the type of technology used to either detect the child or alert the caregiver. Three of the four vehicles used rear-door logic to alert the driver, while one vehicle used both an ultrasonic system and rear-door logic. The four vehicles used with OEM UCRSs were a 2020 Nissan Titan, a 2020 Subaru Forester, a 2019 Chevrolet Equinox, and a 2020 Hyundai Palisade. All UCRSs are listed in Table 1 and summarized in sections 2.1 and 2.2 below. Additional system details are in Appendix A (aftermarket and prototype) and Appendix B (OEM). The list of vehicles in which the UCRSs were tested are reported in Table 2.

Table 1. UCRS List

	System	Detection Technology	Product
1	Aftermarket	CRS Chest Clip and Smartphone Application	SensorSafe
2	Aftermarket	GPS Phone Application	Waze App
3	Aftermarket	Pressure Sensor	SteelMate Baby Car Seat Reminder
4	Aftermarket	Temperature Monitor	eClip

	System	Detection Technology	Product
5	Prototype	Radar-Based	Panasonic-Ficosa
6	OEM	Rear-Door Logic Alert #1	Chevrolet
7	OEM	Rear-Door Logic Alert #2	Nissan
8	OEM	Rear-Door Logic Alert #3	Subaru
9	OEM	Combination: Ultrasonic/Rear-Door Logic #4	Hyundai-Kia

*This is for the system installed for NHTSA. Capabilities may change for different OEMs using this system in their vehicles

Table 2. Testing Vehicle List

Test Vehicle Make and Model Year	Technology Type
2019 Chevrolet Equinox	Rear-Door Logic # 1
2020 Nissan Titan	Rear-Door Logic # 2
2020 Subaru Forester	Rear-Door Logic # 3
2020 Hyundai Palisade	Rear-Door Logic # 4/Ultrasonic
2015 Jeep Grand Cherokee	CRS Chest Clip
	GPS Phone Application
	Pressure Sensor
	Temperature Monitor
2011 Ford Explorer	Radar-Based System

2.1 Aftermarket and Prototype Systems

2.1.1 CRS Chest Clip

The CRS chest clip system (sold with selected compatible car seats) consists of a CRS clip sensor and a wireless receiver connected to the on-board diagnostic (OBD) port (Figure 5). The wireless receiver (inserted into the vehicle's OBD port) communicates with the CRS's smart chest clip via radio frequency. The wireless receiver chimes three times when the vehicle is turned off to remind the caregiver to check in the rear seat. This reminder feature is only activated if the chest clip is engaged and the vehicle is driven over 5 mph for at least 30 seconds.

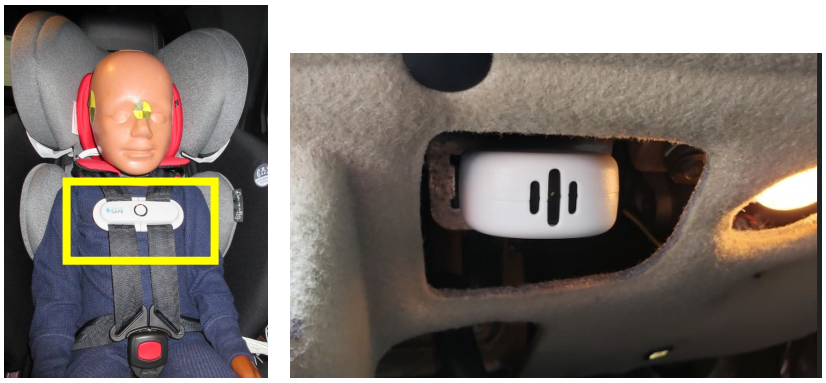

Figure 5. CRS Smart Clip and Wireless Receiver (OBD port)

The CRS chest clip communicates the need for alert and sends a signal via Bluetooth to the smartphone either during or after the drive. The CRS chest clip alerts the driver through the smartphone application during two situations: when the chest clip becomes unbuckled during the trip, or if the clip remains buckled and the driver leaves the vehicle (approximately 25 feet from the CRS clip). The alert comes in a form of an audio and display alert, both from the smartphone. An example of this smartphone display alert is shown in Figure 6.

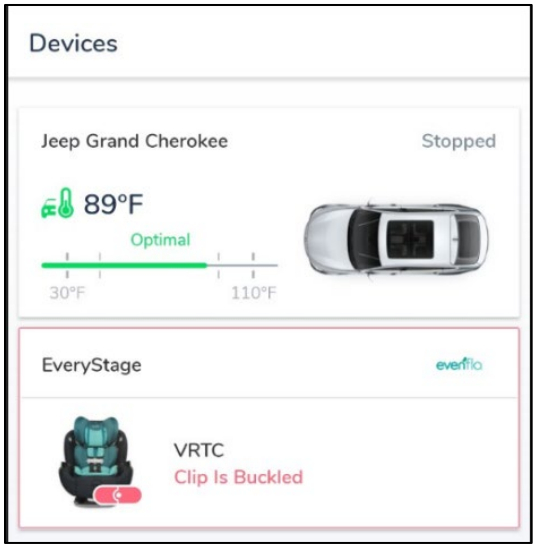

Figure 6. CRS Clip Smartphone Notification - Child Buckled in Rear Seat and Vehicle Off

In addition to the time and distance away from the clip, the system measures the inside temperature of the vehicle. If the temperature reaches above a system pre-set value of 93 °F, both audio and display alerts are given via the smartphone (if within Bluetooth range of approximately 25 feet).

2.1.2 Global Positioning System Smartphone Application

The smartphone application is a GPS navigational software. The application includes a feature to help prevent leaving a child unattended in the rear seat. Once the reminder feature is enabled in the smartphone application settings, the feature sounds an audible alert (unless the phone is in silent mode) and displays a visual alert on the phone screen when the vehicle reaches its entered and identified destination. The alerts are displayed only if the smartphone application is being

used to navigate to an entered destination. The alert displayed on the smartphone can be customized to display a specific alert message. Figure 7 shows an example of the smartphone application alert.

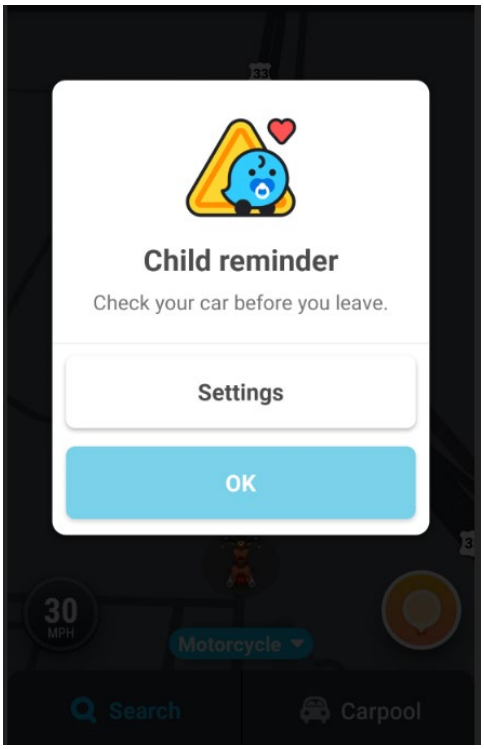

Figure 7. GPS Smartphone Application Alert Screen

2.1.3 Pressure Sensor

The pressure sensor system consists of a CRS pressure sensor pad, driver seat belt clip, and a cigarette (CIG) lighter display plugged into a cigarette lighter or 12-volt power socket. The pressure sensor pad and the seat belt clip communicate wirelessly via radio frequency with the CIG lighter display. All three devices include user-replaceable batteries.

The system is installed by placing the pressure sensor pad under the CRS cushion or child and the seat belt detection clip on the driver seat belt buckle. Figure 8 shows the three sensors in the device along with the displayed LED light.

Figure 8. Pressure Pad UCRS

When the system is armed, the CIG lighter display alerts the driver by flashing its LED display (Figure 9) and by an audio chime. The alert can be triggered when pressure is detected on the pressure pad and either the driver seat belt is unbuckled, or the CIG lighter power has been switched off (when the vehicle is turned off). The alert is also triggered when the vehicle is on, the driver seat belt is buckled, and the pressure pad loses pressure. This situation can happen when the child leaves the CRS while the vehicle is being driven. While the system is activated, the CIG display is green, and the display will turn red and chime if the sensor detects one of those two situations in which the caregiver should be alerted.

Figure 9. CIG Lighter Display Alerts – Unattended (Left) and Secured (Right)

2.1.4 Temperature Monitor

The temperature monitoring clip (Figure 10) is a UCRS that constantly monitors the temperature of the interior of the vehicle. This system includes a clip that is attached to the vehicle interior near the child (e.g., CRS, seat belt). The clip needs to be paired once with the smartphone. When powered on (using the on/off button), this clip connects to a smartphone application using Bluetooth.

Figure 10. Temperature Monitoring Clip

When the smartphone is on and the application is running, the sensor provides the temperature to the application every few seconds. A temperature maximum can be set in the application, alerting the caregiver via the smartphone when the sensor detects a temperature that exceeds the pre-set value (Figure 11). In addition to the temperature monitoring, when the caregiver with the smartphone initially exceeds 25 feet from the sensor, an audio and display alert is displayed on the smartphone. That alert can be dismissed, and the temperature monitoring clip resumes monitoring the temperature if the phone is brought within Bluetooth range (approximately 25 feet) in a short period of time.

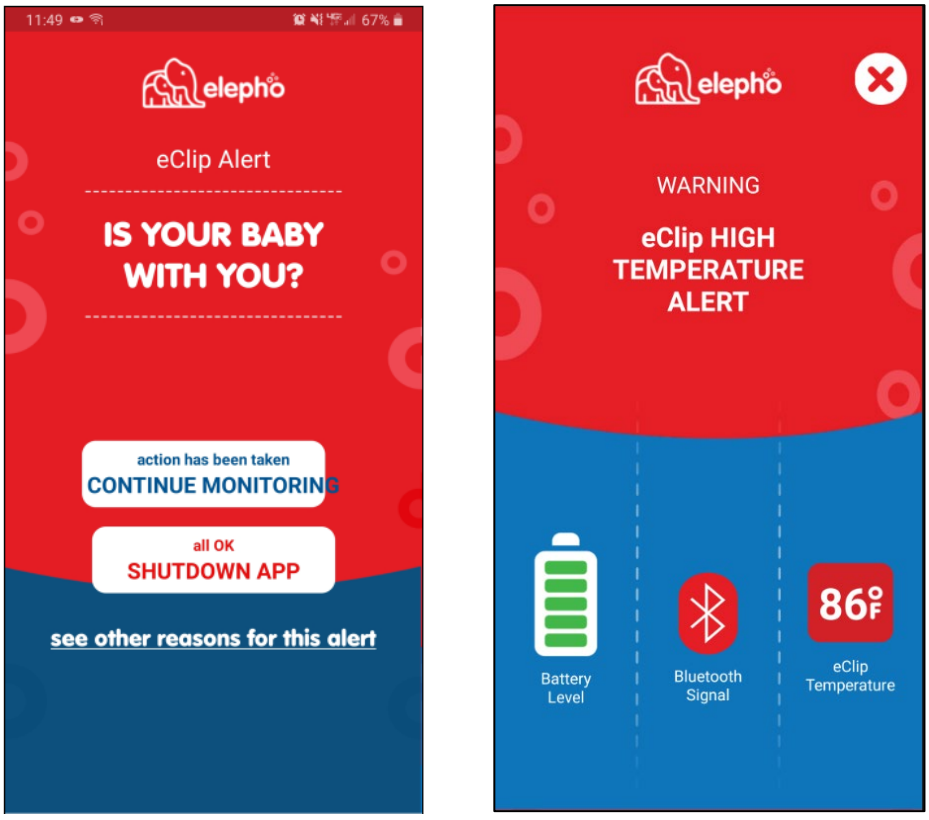

Figure 11. Temperature Monitor Smartphone Display Alerts

2.1.5 Radar-Based

The system described in this section is a prototype sensor technology currently under development by suppliers for use by vehicle manufacturers in integrating such occupant sensing system into their vehicles. The alert capabilities and sensor locations will vary based on manufacturer. It is currently not available for aftermarket purchase, installation, and use by individual consumers.

The radar-based system was a developed and installed by the sensor manufacturer specifically for a 2011 Ford Explorer supplied by NHTSA. This system used a radar sensor to detect small movements throughout the vehicle, as small as breathing of a sleeping infant. The system alerts when 3 movements are detected within 5 minutes. To avoid false positives, after three consecutive detections of movement are observed, an alert goes off via a method chosen by the OEM (horn, lights, smartphone, laptop, or any other system to which it is connected). In the Ford Explorer used for testing the system, after three detections, an alert was displayed on a laptop connected to the system (Figure 12).

The radar sensor unit consisted of a Doppler-based motion radar sensor using a 24 gigahertz (GHz) transceiver together with transmit and receive antennae arrays. These are all integrated in a final package that is about 65 by 40 by 12 mm^3, including the connector. The most suitable and recommended position to install the radar to get detection into the entire cabin was the center of the vehicle interior roof, although it could be tuned and installed at other locations and configurations. The system was installed in the 2011 Ford Explorer above the second-row seat in the middle of the bench (Figure 13). The radio frequency signal of the radar could penetrate through different vehicle materials, so no direct view between the radar and the moving subject was required.

This system is still in development and is not currently available as aftermarket or OEM equipment. It would be up to the OEM to further define the timeframe of alerts and to determine how the system is installed, where the system is installed, and through what platform it alerts the driver or caregiver.

Figure 12. Radar-Based System Alert on Laptop Display

Figure 13. Radar-Based System Installed in Ceiling Above Second Row

2.2 OEM Systems

All OEM systems tested were available from the manufacturer in vehicles as standard or optional equipment in Summer 2020.

2.2.1 Rear-Door Logic

Multiple OEMs have vehicles on the market that include technology to detect an unattended occupant in the rear seat using rear-door logic. Rear-door logic technology is based off the rear doors being opened within a specified time of the vehicle being turned off or front door opened. In this study, three of the four vehicles tested included only the rear-door technology when alerting the caregiver to check for rear-seat occupants. The fourth vehicle added an ultrasonic sensor to the rear-door logic.

The steps of arming and alerting each system are listed in Appendix B. First, the rear-door logic must be turned on or activated through the instrument cluster settings.[7] The system is activated by opening and shutting the rear door within a certain time before or after the ignition is turned on. Additionally, one system must be driven at approximately 5 mph or higher for the system to activate. Once the system is activated and the vehicle goes through an ignition cycle (turning on and off the engine, or exceeding 5 mph), a message will display on the instrument cluster (Figure 14) reminding the driver to check the rear seat. In one system, an audio alert via the vehicle's horn is sounded after the time limit in which the rear door is not opened is exceeded. Each vehicle includes a different time limit in which the engine is turned off and the rear door is not opened before an alert is displayed or audio alert is sounded. In most cases, the instrument cluster alert is immediately displayed across the instrument cluster after the ignition or accessory is turned off. Specific details on arming the system can be found in Appendix A and are tested in section 3.

Figure 14. Example of Rear-Door Logic Instrument Cluster Alert Display

2.2.2 Rear-Door Logic and Ultrasonic System

One system uses both rear-door logic and an ultrasonic motion sensor to detect a rear seat occupant. If the driver disables the rear occupant alert system using the User Settings Menu, it disables both alerts – the door alert cluster notification and the ultrasonic sensor. The rear-door logic is activated first and is considered its first alert working as previously described in section

[7] Steps for this activation of the rear-door logic were found in the vehicle's manual.

2.2.1. When the alert is displayed on the instrument cluster, the caregiver has an option to turn off the first reminder (in the display options). The ultrasonic sensor is activated after the driver door is opened and closed and the doors are locked. The ultrasonic system is activated within 20 seconds of the doors being locked after the door logic system alerted.

The ultrasonic sensor is made up of a cluster of sensors located center-rear on the roof/headliner, as shown in Figure 15. Ultrasonic sensor technology detects motion, but is not expected to detect small movements, such as the breathing movements of a sleeping child. If motion is detected inside the vehicle within 24 hours of the vehicle getting turned off and locked, the vehicle's horn will sound until the caregiver or another person comes back to the vehicle and shuts the alert off. The horn will sound for about 25 seconds and will continue to repeat up to 8 times (and stops) if the system continues to detect motion. The caregiver can either open the door via the vehicle keys or press any button on the key fob to turn off the alert. If the alerts are not responded to, the system will reset to the "ready state" again when the activation conditions are met on a future ignition cycle. In addition to the rear-door logic and ultrasonic sensor, this system optionally includes a cellular data connection to a smartphone. The cellular data connection feature was not activated or tested in this study but has the potential to allow this system to include additional alerts in different real-world situations.

Figure 15. Ultrasonic Sensor Location

3 Functional Assessment

3.1 Test Matrices

Each unattended child reminder system was tested using two different test matrices. First, each system's manual includes a description of the situations the UCRS is designed to cover. NHTSA tested each UCRS using those situations identified. This test matrix is referred to as "Test for Scenarios as Designed by the UCRS Manufacturer." Second, NHTSA's Special Crash Investigation (SCI) cases from 2019 were reviewed and sorted into four broad categories as a part of this study: Forgotten, Caregiver Confusion, Gained Access, and Knowingly Left. This test matrix is referred to as "Tests for Potential Real-World Scenarios." Further details of the SCI case review can be found in section 5.0.

3.2 Test Setup

Several devices tested in this study included Bluetooth connections to a smartphone through smartphone applications. Each smartphone application was tested on two separate smartphones: an Apple iPhone 8 (iOS 14.3) and a Samsung Note 9 (Android OS, version 10). The smartphone applications used by the selected aftermarket systems had similar alerts and functioning for both types of smartphones.

3.2.1 Procedure

An Evenflo SafeMax with SensorSafe (forward-facing) and a Britax B-Safe35 (rear-facing) CRSs were used in evaluating the chest-clip and radar-based systems. A baby doll (with simulated breathing) was used as the subject occupant for the assessment. The CRSs were placed at various locations throughout the vehicle to study the performance of the radar sensor in detecting small chest movement of the baby doll. The manufacturer's guidelines were followed for installing each UCRS. The performance of the ultrasonic sensor was evaluated by a human volunteer. Many of the CRS and human volunteers represented misuse situations but were included to test the sensor performance throughout the vehicle interior. Instructions in the vehicle manuals were followed to activate the rear seat occupant detection technology for the OEM systems. The functional assessment, documented with photographs, is shown in Appendix C.

For configurations that included a smartphone connection, the required application to allow the UCRS to work properly was installed on both the Android smartphone and the iPhone. Prior to each UCRS assessment, it was verified that the system and the smartphone applications were connected by either WiFi or Bluetooth.

3.2.2 Infant Baby Doll

An infant baby doll with automated breath movements was used with all rear occupant alert systems except the ultrasonic sensor technology. A few tests were performed with the infant baby doll and ultrasonic sensor technology, but as the technology was not expected to be able to detect the infant baby doll, the results were not included in the "Test for Scenarios as Designed by the UCRS Manufacturer" matrix. The baby doll used was an Ashton–Drake galleries Bella Rose Baby Doll that breathes, coos, and has a heartbeat (Figure 16). The baby doll measures 19 inches long and weighs 5.1 pounds. When the baby doll "breathes" the chest moves approximately 0.40 inches.

Figure 16. Baby Doll Used in Rear Seat Detection Testing

3.3 UCRS Assessment Methods

Each UCRS was assessed using both test matrices. Each test situation was repeated three times. For the ultrasonic and radar-based systems, each situation was tested in each seat, footwell, and the cargo area of an SUV. The capabilities of the ultrasonic and radar-based systems were not evaluated in the trunk of a sedan. The ultrasonic sensor did not detect breathing movements of the baby doll, as expected. Arm movements of a human volunteer were used in testing the ultrasonic system for scenarios as designed by the manufacturer. After each test, the assessment was reported as either meeting criteria (correctly alerting the caregiver or guardian during the specified situation) outlined in the matrix, or not meeting criteria where no alert occurred. Those tests that did not meet criteria were shaded yellow, while tests that did meet criteria were colored green.

Table 3 gives the results of the "Tests for Scenarios as Designed by the UCRS Manufacturer" matrix. All the systems worked as designed to alert the caregiver when a child is left unattended in the vehicle.

Table 4 illustrates the results of the "Tests for Potential Real-World Scenarios" (discussed in Section 5.0) matrix. Assessments made for the custom testing matrix were not expected to meet all criteria, as each technology was not developed to cover all the situations observed in the SCI case reports.

Table 3. Tests for Scenarios as Designed by the UCRS Manufacturer

Technology Type	Situation	Test Cycle		
		T1	T2	T3
CRS Chest Clip	CRS Clip Becomes Unfastened During Drive	✓	✓	✓
	CRS Clip Fastened and Vehicle Is Off	✓	✓	✓
GPS Phone Application	Display Reminder When Destination Reached	✓	✓	✓
Pressure Sensor	Vehicle Off and Pressure Remains on Pressure Disc	✓	✓	✓
	Vehicle On (In Drive) and Pressure Removed From Pressure Disc	✓	✓	✓
	Seatbelt Unbuckled and Pressure Remains on Pressure Disc	✓	✓	✓
Temperature Monitor	Constantly Monitors Temperature	✓	✓	✓
	Phone ~25ft Away From Clip	✓	✓	✓
	Temperature Exceeds Limit	✓	✓	✓
Ultrasonic Sensor	Detects Movement* in 2nd Row	✓	✓	✓
	Detects Movement* in 3rd Row	✓	✓	✓
Radar-Based	Detects Movement** in 2nd Row	✓	✓	✓
	Detects Movement** in 3rd Row	✓	✓	✓
Rear-Door Logic # 1	Technology Activated and Ignition Cycle Completed	✓	✓	✓
Rear-Door Logic # 2	Technology Activated and Ignition Cycle Completed	✓	✓	✓
Rear-Door Logic # 3	Technology Activated and Ignition Cycle Completed	✓	✓	✓
Rear-Door Logic # 4/Ultrasonic	Technology Activated and Ignition Cycle Completed	✓	✓	✓

* For the ultrasonic sensor, large movement of the forearm was considered "movement," including movement above the head as seen in the 3rd row detection.
** For the radar-based system the small breathing motions from the baby doll was considered "movement." The baby doll small breathing motion was not detected by the ultrasonic sensor.

Table 4. Tests for Potential Real-World Scenarios

Technology Type	Situation	Test Cycle		
		T1	T2	T3
CRS Chest Clip	Stop That Shuts Off Engine but Does Not Unclip CRS	✓	✓	✓
	Quick Time Period Between Engine Off and Caregiver Goes Into a building	✓	✓	✓
	CRS Clip Is Not Fastened to Begin Trip	×	×	×
	Child Gains Unmonitored Access Into Vehicle and Re-Clips Clip	×	×	×
GPS Phone Application	Unexpected Stop on the Way to Preset Destination Without Changing End Destination	×	×	×
Pressure Sensor	Child Is Leaning – Not Covering 100% of the Disc	✓	✓	✓
	Child Gains Unmonitored Access to the Vehicle and Applies Pressure to Disc by Sitting in CRS	×	×	×
Temperature Monitor	Ignores First Alert	✓	✓	✓
	Child Gains Unmonitored Access to Vehicle	×	×	×
Ultrasonic Sensor	Child Gains Unmonitored Access to Vehicle	×	×	×
	Detects Movement* in Cargo Area	✓	✓	✓
	Detects Movement* in Any Row by Baby Doll	×	×	×
	Child is Covered Up – Blanket/CRS Cover (All Rows)	✓	✓	✓
Radar-Based	Child Gains Unmonitored Access to Vehicle***	×	×	×
	Detects Movement** in 3rd Row by Baby Doll	✓	✓	✓
	Detects Movement** in Any Row by Child and Blanket Cover	✓	✓	✓
	Baby Doll Is Covered Up – Blanket/CRS Cover (All Rows)	×	✓	✓

Technology Type	Situation	Test Cycle		
		T1	T2	T3
Rear-Door Logic 1	Turns Vehicle On and Off Quickly (Does Not Drive)	✓	✓	✓
	Other Children in Vehicle Open Rear Doors From Inside After Ignition Turns off	✓	✓	✓
Rear-Door Logic 2	Turns Vehicle On and Off Quickly (Does Not Drive)	×	×	×
	Other Children in Vehicle Open Rear Doors From Inside After Ignition Turns off	✓	✓	✓
Rear-Door Logic 3	Turns Vehicle On and Off Quickly (Does Not Drive)	✓	✓	✓
	Other Children in Vehicle Open Rear Doors From Inside After Ignition Turns off	✓	✓	✓
Rear-Door Logic 4	Turns Vehicle On and Off Quickly (Does Not Drive)	✓	✓	✓
	Other Children in Vehicle Open Rear Doors From Inside After Ignition Turns off	✓	✓	✓

* For the ultrasonic sensor: Movement = forearm movement of child (human volunteer)
** For the radar-based system: Movement = the small breathing movement from the baby doll
*** As configured for this study. OEM's may choose to implement differently to add this capability

4 UCRS Testing Observations and Findings

4.1 Tests for Scenarios as Designed by the UCRS Manufacturer

While all UCRSs worked as designed to alert caregivers when children are left unattended in vehicles, certain limitations were noted when the systems were tested in the "Tests for Scenarios as Designed by the UCRS Manufacturer" test matrix. First, for all systems using Bluetooth, keeping in range of the Bluetooth (approximately 25 feet) was necessary. Testing was conducted both within test facility and outdoors. In some systems, the poor signal strength from interference from nearby buildings or objects between the vehicle and the smartphone delayed the alert until the signal was reconnected.

For the CRS chest clip system, the temperature was also monitored, and an alert would display if the temperature exceeded a preset temperature set by the system (if within Bluetooth range). Also, the OBD port would immediately give three chimes after the vehicle was turned off even if the CRS clip was engaged and no child was present in the back seat. This could increase the chance that the driver would routinely ignore the chimes. Additionally, the temperature could be monitored in the smartphone. A warning would flash across the phone display for temperature and distance from the CRS. The temperature at which the system issued an alert was preset and could not be adjusted in the application settings.

When the GPS phone application was tested, the alert was based on where the phone identified the destination location to be. A visual warning on the phone's screen may not appear if the system did not identify that the destination was reached or if the vehicle stopped yards short of the identified location.

The temperature monitor included an option to continue to monitor if the phone stayed within the Bluetooth range. The system only monitored for 30 minutes; however, the caregiver had the choice to ignore the initial distance-based alert and continue to monitor temperature for the full 30 minutes.

For the ultrasonic system, the tests were first conducted with the baby doll, but the breathing motion was not detected when set in the cabin. This was expected, based on known limitations of ultrasonic sensors. A small adult was then placed in each seat during the test and made a small arm movement. The system detected the small adult in all seats, as reported in Table 3.

4.2 Tests for Potential Real-World Scenarios

Tests were developed for this study after reviewing the SCI cases from the 2019 case year as detailed in Section 5.0 and evaluating other potential real-world scenarios. These test scenarios are documented in Table 4, "Tests for Potential Real-World Scenarios."

The CRS chest clip was tested based on a situation with a short turn-off, such as a gas stop, a situation where the caregiver could quickly get into a building, such as a close parking spot for work, a situation where the chest clip was not fastened to begin the trip, and a situation where the child gains unmonitored access. The chest clip did not give an alert for the last two situations – chest clip not fastened and unmonitored access.

The pressure pad was tested in situations where the sitting child did not cover 100 percent of the pressure pad, and the alert still occurred. Also, it would not reset and reactivate until the vehicle was restarted, restoring power to the accessory port plug, and the front seat belt was buckled.

For the temperature monitoring clip, an alert was displayed when the distance of the phone from the clip exceeded the Bluetooth range, approximately 25 feet. If the option to "Continue Monitoring" as shown in Figure 11 was selected and the caregiver with the phone stayed within Bluetooth range, the system continued to monitor the temperature and distance and provide alerts if the distance exceeded 25 feet or the temperature exceeded the set limit.

For the systems that included a phone application, it was observed that the loss of Bluetooth connection caused proximity alerts to occur. If the phone was brought back within Bluetooth range immediately, then the system would continue to monitor the proximity.[8] Additionally, with the proper setting on the phone, the phone would still alert even if it was on silent. The apps would need to be running, either on-screen or off-screen to function.

The ultrasonic sensor was tested using the forearm movement of the human volunteer. The ultrasonic sensor was not able (or expected) to detect movement as small as a baby doll's chest movement and thus was not tested with the doll in each seat or row. The movement detected in the cargo area occurred when the arm was raised above the back-seat head restraints. The ultrasonic sensor system detected the movement above the seat space but did not consistently detect the motion close to the floor.

The radar-based system was tested using a baby doll's small breathing motions. The baby doll was tested in all rows, footwells, under covers, and in the trunk. In all locations, except for one (passenger front seat footwell), the system was able to detect the breathing motion. The current design of the radar-based system is a prototype, and other situations tested such as the child gaining unmonitored access was determined as not being detected due to the system as tested needing a power source and set up to start monitoring. With further development, the system has the potential to detect motion if the situation of unmonitored access occurs.

Finally, OEM rear-door logic systems were tested in situations where the vehicle was turned off and on without the vehicle moving. All but one rear-door logic system alerted in this situation. For that system, the alert did not occur since a minimum vehicle speed of 5 mph must be achieved to activate the alert. For these systems, when there is a loss of battery power, the vehicle goes back to its original factory settings and the monitoring system must be turned on again by the user. Systems using only the rear-door logic alert drivers to check the rear seat at the conclusion of a trip when cargo such as groceries or other inanimate items, rather than children, may have been placed in the rear seat as well. The rear-door logic systems infer the possibility of an occupant in the rear seat from the sequence of door openings; therefore, as currently implemented, will not provide warnings to the driver in certain scenarios where an occupant may still be in the vehicle at the end of a trip.

None of these systems, as currently activated and triggered, provided an alert if a child gained unmonitored access to the vehicle.

[8] The Bluetooth range and connection characteristics are implemented differently for different smartphone hardware and software. The effect of such differences was not a part of this study

5 NHTSA Special Crash Investigation

NHTSA's National Center for Statistics and Analysis (NCSA) SCI team reviewed special cases involving pediatric vehicular heatstroke fatalities for 2019.[9] All details were listed and analyzed including the people involved, conditions leading up to the heatstroke, outdoor conditions, and circumstances of the incident. As a part of the VRTC study, the 50 cases were broadly sorted into four categories in which the heatstroke occurred, as shown in Table 5. Those four categories include "Forgotten," "Caregiver Confusion," "Gained Access," and "Knowingly Left."

Table 5. SCI Situations Covered by UCRS

SCI Situations	Rear Seat Logic	Rear Seat Logic/ Ultrasonic	Radar-Based	Pressure Sensor	CRS Clip/ODB Port	GPS Phone App	Temperature Monitor
Forgotten	X	X	X	X	X	X	X
Caregiver Confusion	X	X	X	X	X		X
Gained Access			*[10]				
Knowingly Left		*[10]	*[11]		X[12]		X[11]

For each category, multiple cases were included. For example, the category labeled "Forgotten" in the vehicle includes all situations that involve the caregiver placing the child in the vehicle and then, after turning the vehicle off, forgetting the child in the rear seat. Included in this category are situations where the caregiver goes into work leaving the child in the vehicle in the work parking lot and where the caregiver erroneously believes that the child had been dropped off at the daycare.

The "Knowingly Left" category could cover caregivers who knew they left the child unattended, but their intended plan was to momentarily leave the vehicle and return quickly, not foreseeing a distraction that prolonged their time away from the vehicle.

9 Wiacek, C. J., Firey, L. M. L, & Herrera, H. (in press). *NHTSA Special Crash Investigations: Comprehensive study of the 2019 U.S. pediatric vehicular hyperthermia fatalities*. National Highway Traffic Safety Administration.
[10] Requires a cellular-based alert system that was not enabled or tested by NHTSA.
[11] Not for the system as installed for NHTSA. However, this system could be developed to include on/off and exterior alert features which could cover some of these situations.
[12] If within Bluetooth range (approximately 25 feet).

In seven cases, the child gained unmonitored access to a parked, unlocked vehicle and was unable to get out. These cases were included in the category "Gained Access" to the vehicle.

Finally, the category of "Caregiver Confusion" includes situations where both caregivers in the vehicle thought that the other was removing or had removed the child out of the rear seat. This differs from "Forgotten" as two or more caregivers are involved and are aware of the presence of child at the end of the trip.

Table 5 shows which of the seven UCRS technologies tested in this study would address the four different categories described above. An "X" was placed in the column if the system would alert the caregiver in at least one or more of the situations within the categories. All seven technologies covered the "Forgotten" situation in which the child was forgotten in the vehicle by the caregiver either driving to daycare or work. All but the GPS phone application covered a situation within the category of caregiver confusion. The GPS phone application did not cover the situation in which there was caregiver confusion, as the application would have notified the caregivers before the confusion would have occurred, as the alert happens when the location was reached not when the vehicle was turned off. No system could alert when a child gained unmonitored access to the vehicle, although the radar-based sensor potentially could. This system is a prototype, and while the system as installed for NHTSA did not cover these circumstances, it could be further developed to cover both the unmonitored access and knowingly left in vehicle situations.

Due to the continued monitoring of the temperature, both the CRS chest clip and temperature monitor have an 'X' in the knowingly left category column. However, both systems must be within Bluetooth range for that feature to alert the caregiver.

6 Summary

NHTSA conducted a study of aftermarket, prototype, and OEM UCRSs available for purchase and testing in the summer of 2020. Generalized functional assessment methodologies to document the systems' capabilities were developed, as done in the previous 2015 assessment. The intent of this study was to test the new systems and technologies introduced since the previous study. Nine systems representing the variety of underlying technologies were tested. The results showed that each aftermarket and prototype system could meet their own design criteria and alert the caregiver when the vehicle was turned off and with the child still in the vehicle. In addition, the OEM systems could meet criteria and alert the caregivers with a display or audio alert as designed. However, the rear-door logic systems infer the possibility of an occupant in the rear seat from the sequence of door openings, and as currently implemented, will not provide warnings to the driver in certain scenarios where an occupant may still be in the vehicle at the end of a trip. Note that countermeasures monitoring only the rear seat may not address situations where the child is in the front seat. Based on the observations made in the tests, all the systems worked as designed to alert caregivers when children are left unattended in vehicles, although the systems performed differently in addressing the variety of potential real-world situations, some of which were encountered in the SCI case reviews of PVH fatalities in 2019.

The reliability of radio and Bluetooth signals depends on the surroundings and interference from nearby radio sources. The functioning of smartphones often depends on the software versions and quality of hardware involved. The testing for this study was conducted outdoors and with one set of smartphones. A strong and reliable Bluetooth connection was needed for several of the smartphone applications to display the alert on the caregiver's phone. Bluetooth connection was often lost during testing, delaying the alert.

Other observations include that smartphone applications must be running on the phone for the alert to occur. If the phone was on, but the application was not running, the alert would not warn the caregiver even if the system itself was on. Also, for one rear-door logic and the CRS clip systems to activate, the vehicle must reach a speed of at least 5 mph. The doors must all be locked in the combination rear-door logic and ultrasonic system in order for its ultrasonic motion sensor to activate. Just the rear-door logic is functional if the doors are left unlocked and the driver leaves the child behind in the vehicle.

This study was an assessment of technologies for detecting unattended children as available in 2020. As new technologies enter the market to prevent PVH, further assessment of these systems may be required to assess these advances in occupant sensing and communication protocols.

Appendix A. Aftermarket and Prototype UCRS Details

	Detection Technology	Arming Conditions	Alert Conditions	Alert Characteristics
1	CRS Chest Clip[13]	The system is armed when the two components (chest clip transmitter, receiver plug) are installed. The system is designed to monitor for 12 hours. After 12 hours the system goes into sleep mode and the chest clip transmitter needs to be unclipped and clipped again to re-arm.	The system is set to respond after the vehicle has been driven for 30 seconds at 5 mph or higher. The system alerts the caregiver when any one of the following three scenarios occur: 1. Within 30 seconds of the chest clip transmitter being unclipped during a drive, 2. Two seconds after the vehicle is turned off after a drive, 3. When the vehicle is turned off, the chest clip transmitter is still clipped, and the caregiver walks approximately 25 feet away (within Bluetooth range).	The alert is a chime from the receiver plug for situations 1 and 2. The alert is a smartphone screen display and audio alert for situation 3.
2	GPS Phone Application	The system is armed through the settings of the application. The reminder can be turned on and is armed when a trip begins.	The application will alert the caregiver when the application has determined the destination has been reached.	The alert is a screen display reminder on the smartphone through the application.
3	Pressure and Seat Belt Sensors	The system is armed when the sensor pad is under the CRS, the display is plugged in, the driver's seat belt insert is stuck to the seatbelt, and the vehicle is turned on. Once vehicle power is on, the display turns on, and the system enters working mode by either buckling the seat belt or putting pressure on the sensor pad.	The system will alert in three different situations: 1. Pressure is removed from the sensor pad during a drive, 2. Pressure remains on the sensor pad after the vehicle power is turned off, 3. Pressure remains on the pad after the seat belt is unbuckled.	For all situations, the alert is an audio chime from the display.

[13] Works with model years 2009 and newer

	Detection Technology	Arming Conditions	Alert Conditions	Alert Characteristics
4	Temperature Monitor	The system is armed when the phone application is running, the eClip is installed next to the CRS in the on-switch position, and the application is connected to the eClip. Monitoring begins a few seconds after the eClip is paired.	The system alerts in two different situations: 1. The phone is about 25 feet from the eClip, 2. The temperature inside the vehicle exceeds the custom set temperature (if within Bluetooth range of approx. 25 ft).	The alerts are an audio alert and a smartphone display reminder.
5	Radar-Based System **(Note:** This system is under development.**)**	Arming the systems includes turning on the system and activating it manually.	The system alerts once motion is detected 3 times. This includes breathing movements of the baby doll.	The alerts are a smartphone screen display and an audio alert.

Appendix B. OEM Rear-Door Logic/Ultrasonic Technology Details

	Arming Conditions	Alert Conditions	Alert Characteristics
Rear-Door Logic 1	The system operates by monitoring the rear side doors' open and close cycles. The system will arm when the vehicle is started after a rear side door is opened or closed, or if the rear side doors are opened and closed when the engine is running, and vehicle is stationary.	If the rear doors are not opened again after the vehicle is turned off, the driver will receive an alert. The system will remain on if the vehicle is turned off and turned back on again within 30 minutes, and the rear side doors remained closed.	Display warning on the instrument cluster
Rear-Door Logic 2	The system is activated when a rear door is opened and closed within 10 minutes of the vehicle being driven at 5 mph or higher. If the vehicle is not driven within 10 minutes of the rear doors being opened and shut, the alert will deactivate.	The system will alert when it detects a rear door was opened and closed 10 minutes before a trip and the vehicle was put in park and turned off without opening the doors within a short period of time.	After vehicle is turned off, a display message will come across the instrument cluster. If the rear door continues to not be opened, the horn will honk three times within several minutes of no detection of rear door opening.
Rear-Door Logic 3	The system will arm when the rear door is opened within 10 minutes before the vehicle is turned on or any time after the vehicle is turned on. If the driver stops and turns off the engine, the system requires the rear doors to be opened and closed to be reactivated.	The system will alert when it detects a door was opened and closed before a trip but then was not reopened after the drive was over (with the ignition off and the vehicle in park).	Display warning on the instrument cluster
Combination - Rear-Door Logic 4	The first system to arm and alert is the rear-door logic. This system will alert if the front door is opened after the rear door is opened and shut.	The system alerts when the front door is opened after opening and closing the rear door and turning off the engine.	The system alerts with a two-tone chime after the engine is turned off, and a display message appears on the instrument cluster to remind the driver to check the rear seat.

	Arming Conditions	Alert Conditions	Alert Characteristics
Combination – Ultrasonic Sensor	The second alert is armed when the 1st alert is displayed, and the vehicle is then locked with the driver and passenger doors closed and in the vehicle in park.	The system alerts when any motion is detected. The system detects arm movements of a human volunteer. It does not detect breathing movements of the baby doll. The system monitors for movement up to 24 hours after the alert activates.	The system alerts with the vehicle's horn for about 25 seconds. If the system continues to detect motion, the alert operates up to 8 times. The system will reset to the 'ready state' again when the activation conditions are met on a future ignition cycle.

Appendix C. Testing Photographs

For each UCRS, photographs were taken throughout the testing. Those photographs of both the test set up and alert display are shown below.

CRS Clip (sold with selected compatible car seats)

Figure C-1. Wireless Receiver and Chest Clip

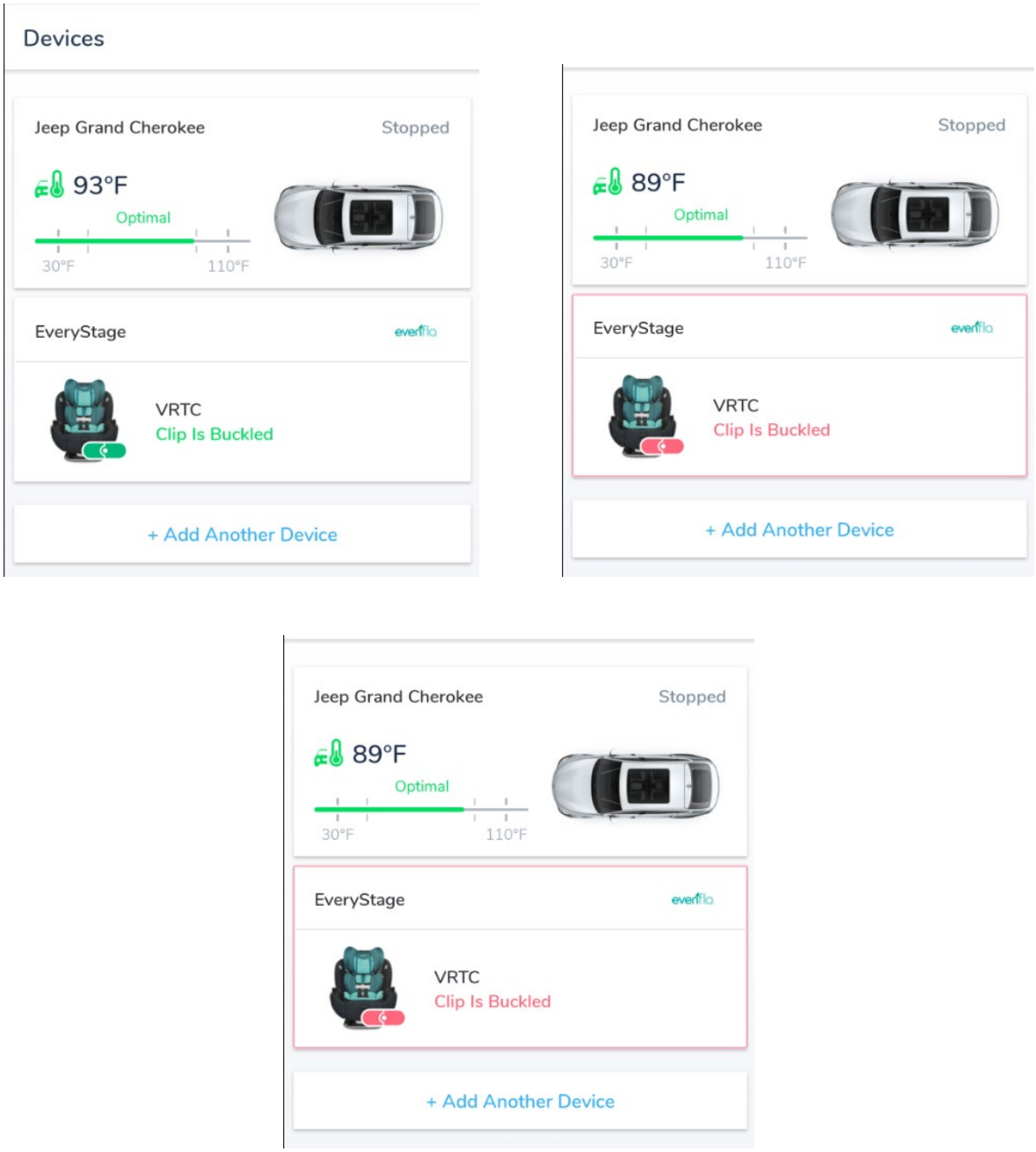

Figure C-2. Smartphone Setup Screens for the Chest Clip

Figure C-3. Smartphone Alert Screens for the Chest Clip

GPS Phone Application

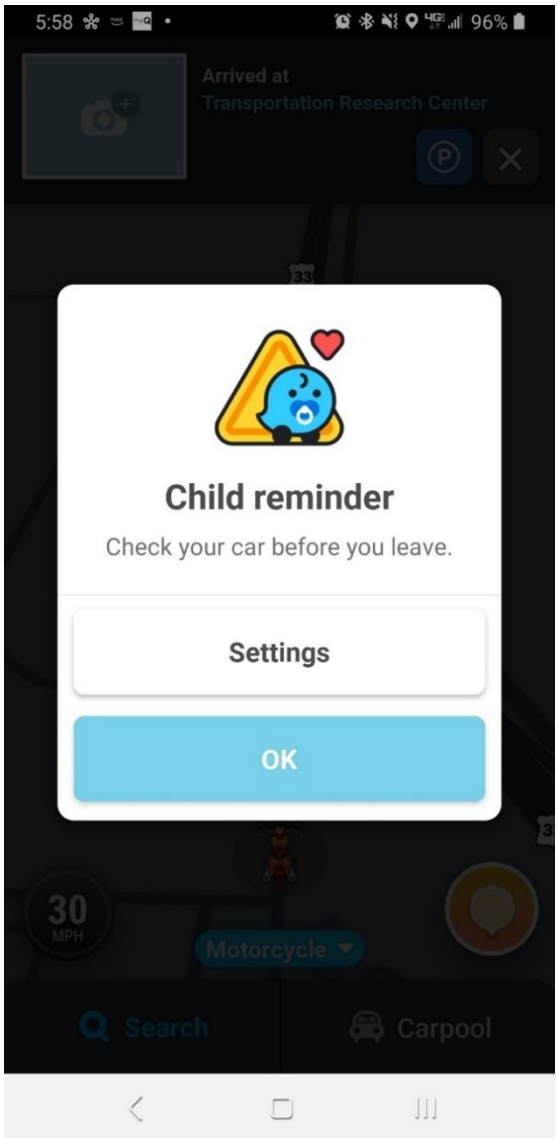

Figure C-4. Smartphone GPS Application Alert Screen

Pressure Sensor

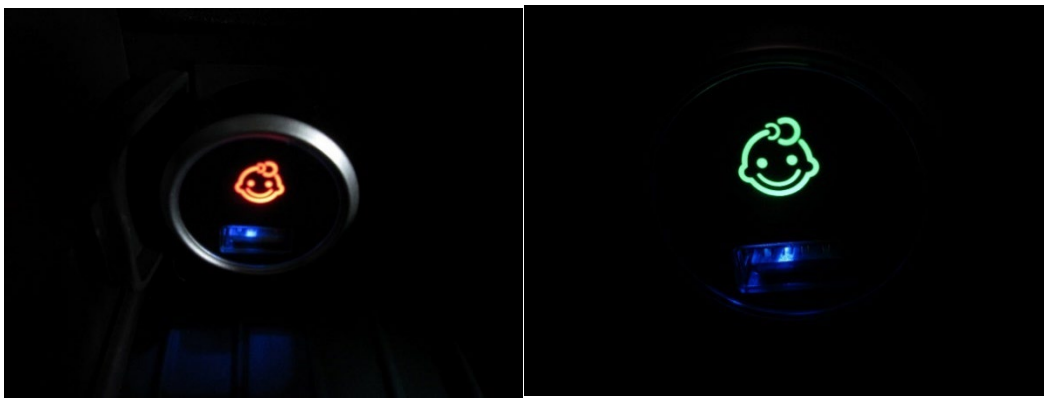

Figure C-5. Cigarette Lighter Display

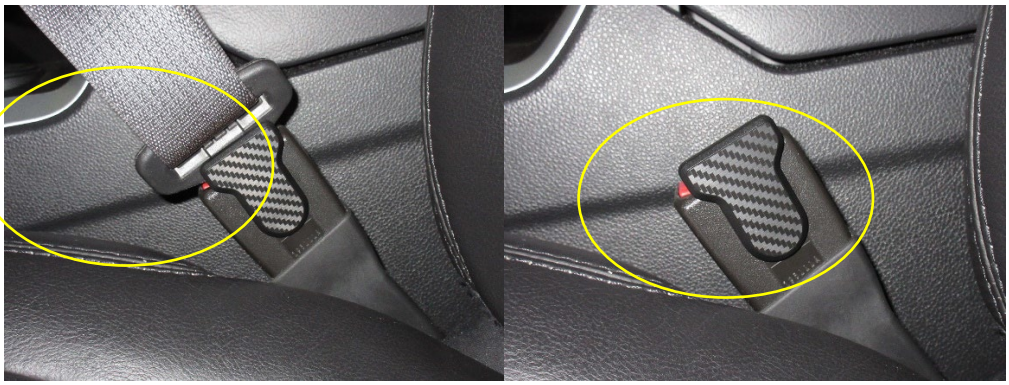

Figure C-6. Driver Seat Belt Clip

Figure C-7. Pressure Sensor

Temperature Monitor

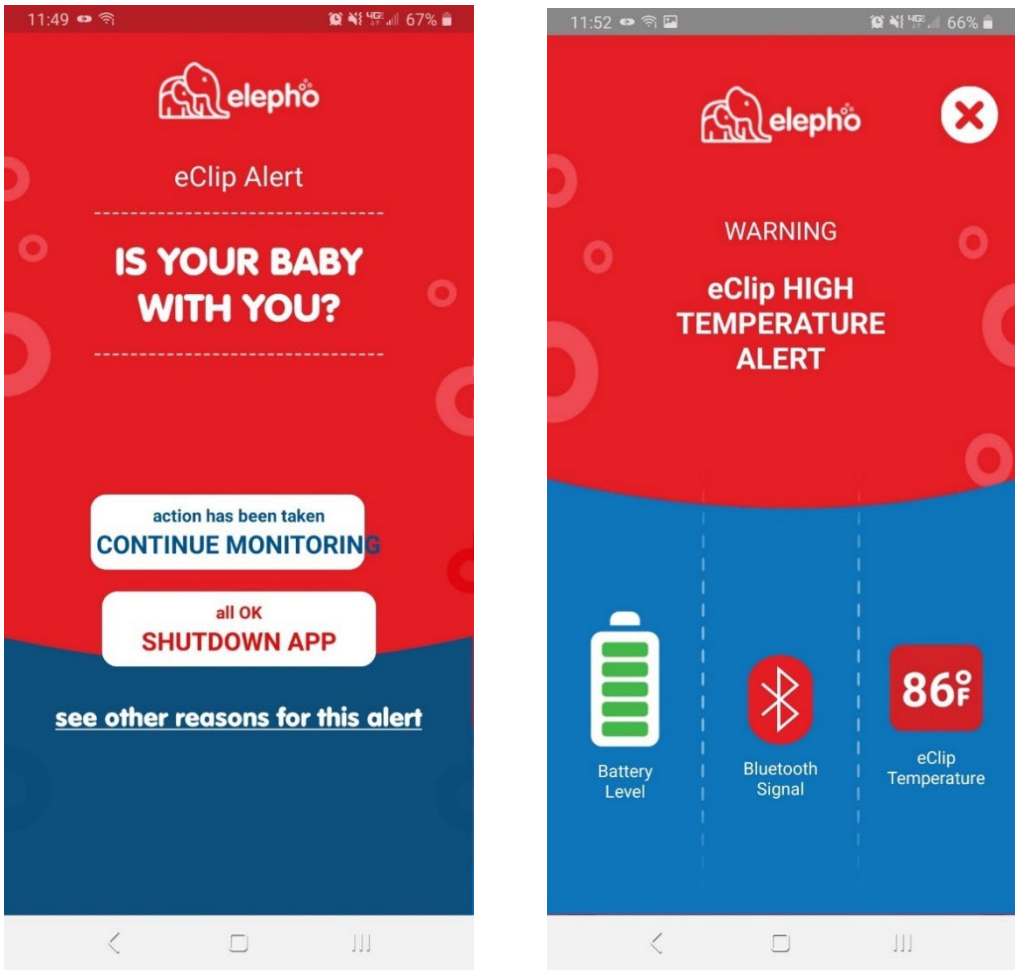

Figure C-8. Smartphone Alert Screens

Radar-Based

Note: The tests marked as "Misuse" are for testing the capabilities of the radar-based system to detect infants and small children under misuse conditions. Certain tested conditions can happen if a child gains unmonitored access to the vehicle.

The car seats were placed in the vehicle for the purpose of locating the doll at the corresponding location on the seats. Children should always be transported in car seats suitable for the age and size of the child and installed per instructions.

Children should always be properly restrained in car seats and transported in the back seat whenever possible.

Children should NEVER be transported in the front seat unless the passenger air bag has been disabled.

Figure C-9. Cargo Floor Test (See note on Page C7)

Figure C-10 Cargo Floor With Blanket (See note on Page C7)

Figure C-11. Driver Floor (See note on Page C7)

Figure C-12. Driver Floor With Blanket (See note on Page C7)

Figure C-13. Driver Seat, No CRS (See note on Page C7)

Figure C-14. Driver Seat With Blanket but No CRS (See note on Page C7)

Figure C-15. Front Passenger Forward-Facing CRS (See note on Page C7)

Figure C-16 Front Passenger Forward-Facing CRS With Blanket (See note on Page C7)

Figure C-17. Front Passenger Floor (See note on Page C7)

Figure C-18. Front Passenger Floor With Blanket (See note on Page C7)

Figure C-19. Front Passenger, No CRS (See note on Page C7)

Figure C-20. Front Passenger With Blanket but No CRS (See note on Page C7)

Figure C-21. Front Passenger Rear-Facing CRS (See note on Page C7)

Figure C-22 Front Passenger Rear-Facing CRS With Blanket (See note on Page C7)

Figure C-23. Second-Row Left Seat Forward-Facing CRS (See note on Page C7)

Figure C-24. Second-Row Left Seat Forward-Facing CRS With Blanket (See note on Page C7)

Figure C-25. Second-Row Left Seat Floor (See note on Page C7)

Figure C-26. Second-Row Left Seat Floor With Blanket (See note on Page C7)

Figure C-27. Second-Row Left Seat, No CRS (See note on Page C7)

Figure C-28. Second-Row Left Seat With Blanket but No CRS (See note on Page C7)

Figure C-29. Second-Row Left Seat Rear-Facing CRS

Figure C-30. Second-Row Left Seat Rear-Facing CRS With Blanket

Figure C-31. Second-Row Middle Seat Forward-Facing CRS (See note on Page C7)

Figure C-32. Second-Row Middle Forward-Facing CRS With Blanket (See note on Page C7)

Figure C-33. Second-Row Middle Seat Floor (See note on Page C7)

Figure C-34. Second-Row Middle Seat Floor With Blanket (See note on Page C7)

Figure C-35. Second-Row Middle Seat, No CRS (See note on Page C7)

Figure C-36 Second-Row Middle Seat With Blanket but No CRS (See note on Page C7)

Figure C-37. Second-Row Middle Seat Rear-Facing CRS

Figure C-38. Second-Row Middle Seat Rear-Facing CRS blanket

Figure C-39. Second Row Right Seat Forward-Facing CRS (See note on Page C7)

Figure C-40. Second Row Right Seat Forward-Facing CRS with Blanket (See note on Page C7)

Figure C-41. Second Row Right Seat Floor (See note on Page C7)

Figure C-42. Second Row Right Seat Floor with Blanket (See note on Page C7)

Figure C-43. Second-Row Right Seat, No CRS (See note on Page C7)

Figure C-44. Second-Row Right Seat With Blanket but No CRS (See note on Page C7)

Figure C-45. Second-Row Right Seat Rear-Facing CRS

Figure C-46. Second-Row Right Seat Rear-Facing CRS With Blanket

Figure C-47. Third-Row Left Seat Forward-Facing CRS (See note on Page C7)

Figure C-48. Third-Row Left Seat Forward-Facing CRS With Blanket (See note on Page C7)

Figure C-49. Third-Row Left Seat Floor (See note on Page C7)

Figure C-50. Third-Row Left Seat Floor With Blanket (See note on Page C7)

Figure C-51. Third-Row Left Seat, No CRS (See note on Page C7)

Figure C-52. Third-Row Left Seat With Blanket but No CRS (See note on Page C7)

Figure C-53. Third-Row Left Seat Rear-Facing CRS

Figure C-54. Third-Row Left Seat Rear-Facing CRS With Blanket

Figure C-55. Third-Row Right Seat Forward-Facing CRS (See note on Page C7)

Figure C-56. Third-Row Right Seat Forward-Facing CRS With Blanket (See note on Page C7)

Figure C-57. Third-Row Right Seat Floor (See note on Page C7)

Figure C-58. Third-Row Right Seat Floor With Blanket (See note on Page C7)

Figure C-59. Third-Row Right Seat, No CRS (See note on Page C7)

Figure C-60. Third-Row Right Seat With Blanket but No CRS (See note on Page C7)

Figure C-61. Third-Row Right Seat Rear-Facing CRS

Figure C-62. Third-Row Right Seat Rear-Facing CRS With Blanket

Ultrasonic Sensor/Rear-Door Logic

Conditions shown here represent a small adult seated in a vehicle seat and floor/cargo area, with arm movement, to test the door logic and occupant sensors. **All occupants should be properly seated and use seat belts**.

Figure C-63. Driver Seat

Figure C-64. Driver Seat With Blanket

Figure C-65. Driver Seat Floor

Figure C-66. Driver Seat Floor With Blanket

Figure C-67. Passenger Seat

Figure C-68. Passenger Seat With Blanket

Figure C-69. Passenger Seat Floor

Figure C-70. Passenger Seat Floor With Blanket

Figure C-71. Middle-Row Left Seat

Figure C-72. Middle-Row Left Seat With Blanket

Figure C-73. Middle-Row Left Seat Floor

Figure C-74. Middle-Row Left Seat Floor With Blanket

Figure C-75. Middle-Row Right Seat

Figure C-76. Middle-Row Right Seat With Blanket

Figure C-77. Middle-Row Right Seat Floor

Figure C-78. Middle-Row Right Seat Floor With Blanket

Figure C-79. Third-Row Left Seat

Figure C-80. Third-Row Left Seat With Blanket

Figure C-81. Third-Row Left Seat Floor

Figure C-82. Third-Row Left Seat Floor With Blanket

Figure C-83. Third-Row Middle Seat

Figure C-84. Third-Row Middle Seat With Blanket

Figure C-85. Third-Row Middle Seat Floor

Figure C-86. Third-Row Middle Seat Floor With Blanket

Figure C-87. Third-Row Right Seat

Figure C-88. Third-Row Right Seat With Blanket

Figure C-89. Third-Row Right Seat Floor

Figure C-90. Third-Row Right Seat Floor With Blanket

Figure C-91. Cargo Area

Figure C-92. Cargo With Blanket

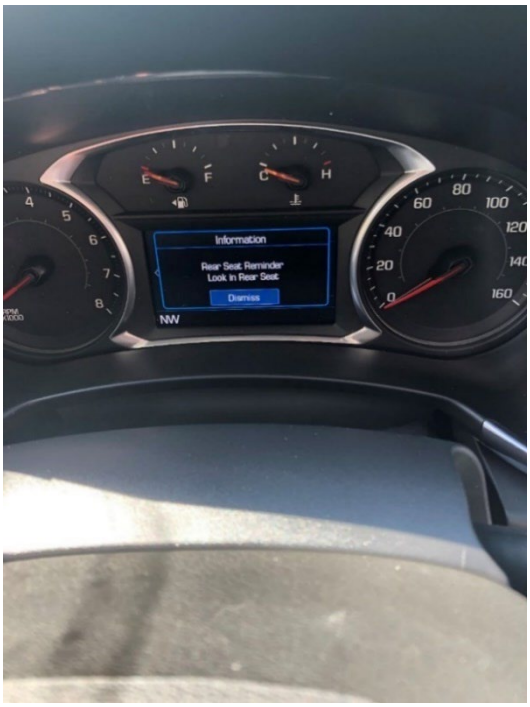

Figure C-93. Rear-Door Logic Alert #1 Instrument Cluster Display

Figure C-94. Rear-Door Logic Alert #2 Instrument Cluster Displays

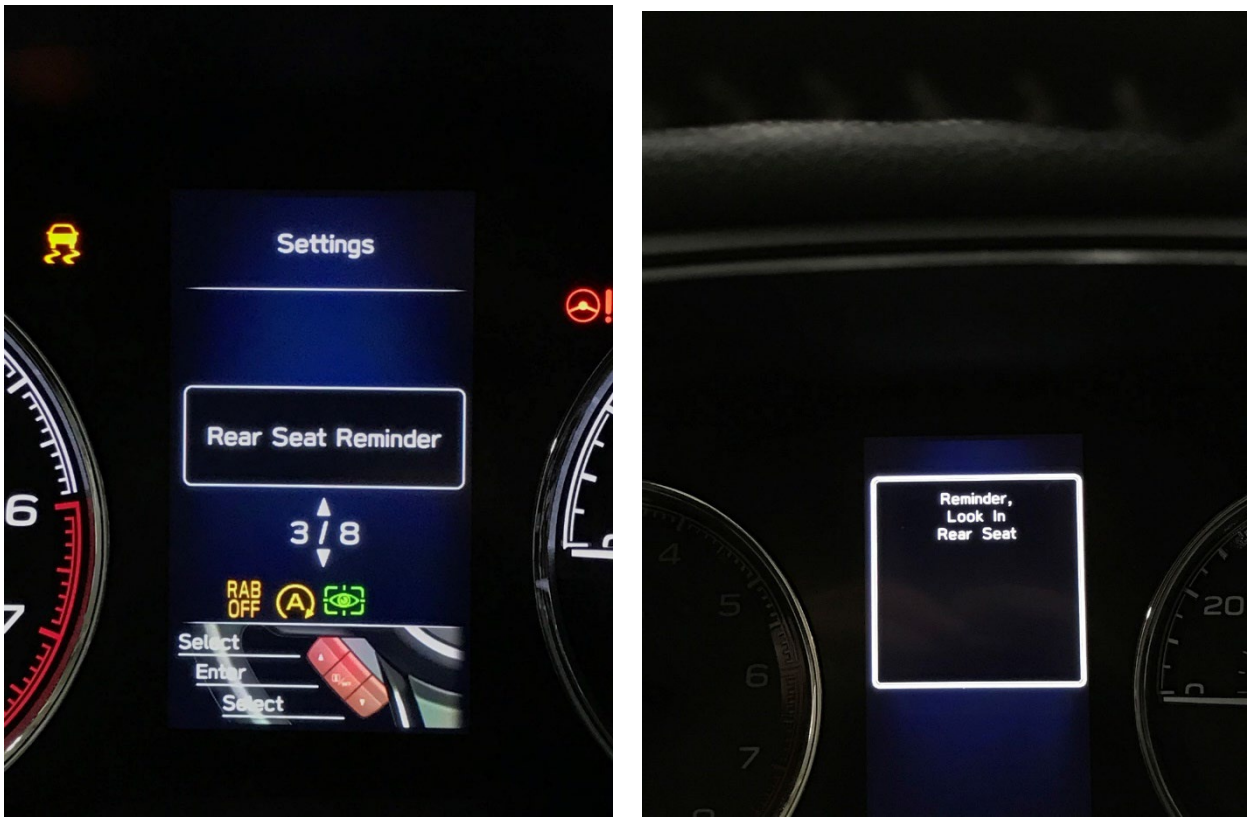

Figure C-95. Rear-Door Logic Alert #3 Instrument Cluster Displays

DOT HS 813 223
April 2022

U.S. Department
of Transportation

**National Highway
Traffic Safety
Administration**

15383-032522-v6