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NSTSCE

National Surface Transportation Safety Center for Excellence

Pediatric Vehicular Heatstroke

Review of Literature and Preventative Technologies

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Technology Impairment Infrastructure Mobility

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LIST OF ABBREVIATIONS AND SYMBOLS

CAN	Controller Area Network
DAS	data acquisition system
FMVSS	Federal Motor Vehicle Safety Standards
GM	General Motors
NSTSCE	National Surface Transportation Safety Center for Excellence
NHTSA	National Highway Traffic Safety Administration
OEM	original equipment manufacturer
PCC	Personal Car Communicator (Volvo)
PVH	Pediatric Vehicular Heatstroke
RDA	Rear Door Alert (Nissan)
ROA	Rear Occupant Alert (Hyundai)
RSR	Rear Seat Reminder (GM)
RSRT	Rear Seat Reminder Technology
TRUNC	Trunk Release Urgently Needed Coalition
VTTI	Virginia Tech Transportation Institute

CHAPTER 1. PEDIATRIC VEHICULAR HEATSTROKE

Pediatric vehicular heatstroke (PVH) was the leading cause of nontraffic child fatalities in the United States in 2018 (Kids and Cars, 2019). Since 1990, PVH, backovers, and frontovers, have consistently been the leading causes of U.S. nontraffic child fatalities (Zonfrillo, Ramsay, Fennell, & Andreasen, 2018). The Gulbransen Kids Transportation Safety Act of 2007 mandated the National Highway Traffic Safety Administration (NHTSA) to promulgate that all new vehicles be equipped with an expanded field of view behind the vehicle—via mirrors, sensors, cameras, or other technology—to combat backover child incidents (where drivers reverse into and injure or kill nonoccupants). Since the passing of this act, child fatalities have been decreasing (Zonfrillo et al., 2018). However, with the introduction of frontal airbags, which led to children being placed in the backseat for their own safety, cases of PVH have risen (Kids and Cars, 2019). On average, there are 38 PVH fatalities in the U.S. each year, for a total of 905 child fatalities on record and thousands of non-fatal injuries (Zonfrillo et al., 2018).

Heatstroke occurs when the heat stress is too much for a body to handle, generally occurring when the core body temperature rises above 104 °F (Bouchama & Knochel, 2002). With an increase in core temperature, organs begin to fail and have neurological dysfunction (Arguad et al., 2007). Vehicles create microclimates in which conditions for heatstroke are met even when outside conditions are still far from inducing heatstroke (Alunni, Crenesse, Piercechi-Marti, Gaillard, & Quatrehomme, 2015; Grundstein, Dowd, & Meentemeyer, 2010; King, Negus, & Vance, 1981; McLaren, Null, & Quinn, 2005; Vanos, Miffel, Poletti, & Selover, 2018). A study by McLaren et al. (2005) investigated low ambient temperatures and their effect on interior vehicle temperatures. Researchers recorded the cabin temperature of a dark car every five minutes for one hour with windows shut and cracked for comparison. Results demonstrated that the temperature inside the vehicle increased an average of 41°F over the hour with 80% of the temperature rise occurring within the first 30 minutes. This means that even on a 72 °F day, the interior of a vehicle can reach 117 °F within one hour with cracked windows having no effect on the final temperature of the vehicle.

A study by Vanos et al. (2018) investigated the impact of vehicle type and shade on the rise of temperature in a vehicle. Researchers used light-colored economy cars, sedans, and minivans left in the sun and under a solar canopy shade for 60 minutes. Results demonstrated that the temperatures were significantly lower in vehicles parked in the shade and that the minivan heated slightly slower than the other vehicles, largely due to the greater air volume in the minivan versus other vehicles. Researchers further extrapolated what this rise in temperature might mean for a child who might be in such a vehicle.

Children are not able to handle temperature changes as well as adults. A child's core body temperature rises more quickly in response to increased temperature than does an adult's (Garcia-Souto & Dabnichki, 2016; Grundstein et al., 2010; Tsuzuki-Hayakawa, Tochihara, & Ohnaka, 1995). One reason for the difference is that children have a 64% greater body-surface-area-to-mass exposure than adults, which allows them to absorb more energy from their environment than adults, and yet their ability to perspire is less efficient (Hoffman, 2001; Tsuzuki-Hayakawa et al., 1995). In addition, research suggests that for toddlers, core body temperature can also be associated with their body mass index (BMI), clothing, activity, and age (Garcia-Souto & Dabnichki, 2016). Young children are also often reliant on adults to complete

behavioral interventions for cooling, such as removing clothing, consuming fluids, or changing their location. Therefore, any situation with a child left in a hot vehicle will vary based on situational factors. Vanos et al. (2018) used an average 2-year-old male for modeling the effect of a vehicle's temperature on body core temperature and determined that after 1.43–2.4 hours (sun-exposed vs. shaded vehicles) the body core temperature would reach 104 °F. A previous study by Grundstein, Duzinkski, and Null (2017) concluded that, depending on the initial cabin temperature, conditions for heatstroke could occur in under 15 minutes, with heat-related injuries possibly occurring within 5 minutes when the initial car temperature was over 82 °F. Unfortunately, as the U.S. statistics indicate, such exposure times and temperatures are met and exceeded, resulting in child fatalities every year.

HOW DOES PVH HAPPEN?

There are three main reasons a child may suffer injury or pass away from PVH: (1) gaining access to a vehicle without parental knowledge, (2) being intentionally left in the vehicle, and (3) being unintentionally left in a vehicle (Null, 2019). Approximately 26% of PVH fatalities are due to children locking themselves in a car without parental knowledge of the incident. For example, Jasmine (5) and Nathan's (2) mother was napping with Nathan when Jasmine woke Nathan up and took him outside to play in the family vehicle, where they eventually passed away from the heat. Six-year-old Sidney went to play at a neighbor's house, but upon finding no neighbor at home, went to retrieve something from the unlocked family SUV, where she remained and lost her life. No family member had been looking for her, believing she was safe at a neighbor's house (Kids and Kars, 2019). To date, incidents such as these have called for behavioral interventions, such as teaching children that cars are not places to play and keeping vehicles locked and their keys inaccessible to children.

Caregivers intentionally leave children in the vehicle for a variety of reasons, perhaps unaware of the possible consequences. Current data show that 18% of PVH fatalities in the U.S. are from intentionally leaving children in vehicles (Null, 2019). Some reasons caregivers give for leaving children unattended in the vehicle are that they did not want to disturb a sleeping child or they used the child seat as a restraint so the caregiver could go to work, drink, go clubbing, sleep, or do drugs (Ferrara et al., 2013; Guard & Gallagher, 2005). In one case, Bryan Puckett passed away at 11 months old when his babysitter left him and her own son in a car for two hours while shopping on an 82 °F day. The caregiver said that she planned to only be gone for 10–15 minutes and hadn't wanted to disturb the sleeping baby (Kids and Cars, 2019). In another case, a Texas mother left her two toddlers in the car after they refused to get out in order to "teach them a lesson" and then went inside her home to take a nap for two to three hours, which led to the children's deaths (CBS News, 2018).

According to research by Null (2019), a little over half of PVH fatalities (53.9%) are a result of a caregiver forgetting to remove a child from a vehicle. Though this act seems to be impossible for people to comprehend, psychology and neuroscience researcher David Diamond explains that this behavior is real and can occur for several reasons (2019). Caregivers can lose awareness of the presence of a child while in the car or have a failure in their "prospective memory" system (when an action is to be executed in a future time). Intervening events during a drive, like stressors or distractions, can also cause a failure of prospective memory. For instance, Serenity Lyman was not even 3 months old when her father (who normally was not in charge of caring for

his daughter) left her in the vehicle after returning from work. He did not realize his fatal mistake until he woke up from his nap hours later (Kids and Cars, 2019). In another example, Jahzel Pinon had just turned 2 years old when her father placed her in a minivan to go with her mother and 4-year-old sister to a Headstart meeting. Jahzel's mother never knew Jahzel was in the car and unknowingly left her in the van for over two hours while she was at the meeting, ultimately leading to Jahzel's death by heatstroke (Kids and Cars, 2019). Finally, a stressed mother in Emporia, Virginia, struggling to find a sitter for her four children, after having found a sitter for her older children, forgot to drop off her 6-month-old son with another sitter before heading to work, leaving him in the car for her entire shift, leading to his death (NBC12, 2018).

Though the news often reports PVH fatalities, there are a number PVH cases that result in injuries instead of fatalities. Heatstroke can lead to neurological and functional impairment, as well as organ system dysfunction for a year or more after the heatstroke (Dematte et al., 1998). Michael was forgotten in a car for 1 hour and 15 minutes and suffered six strokes and damage to the cerebrum, cerebellum, and hippocampus (Kids and Cars, 2019). Nonfatal cases of children left in cars are most likely underreported due to fear of public embarrassment and shame. In fact, the United States is the only nation that has even kept statistics on PVH, though other countries are beginning to keep records of the problem (Null, 2019; Canada Safety Council, 2019; European Child Safety Alliance, 2019). In Australia, motorist associations and ambulances have documented the rescue of over 5,000 children a year unattended in a car, a majority toddlers (Child Accident Prevention Foundation of Australia, 2019).

PUBLIC HEALTH CAMPAIGNS FOR PVH

To address the issue of children being unintentionally left in cars, a number of organizations worldwide have developed public health campaigns. The National Safety Council developed an online course to inform individuals about PVH (National Safety Council, 2019). This online course is free and offers a certificate of completion. This course educates participants on how and why PVH occurs, as well as on preventative measures to ensure it does not happen to them. Educational campaigns, such as "Look Before You Lock" by NHTSA and "Don't Leave Me Behind" in the state of Arizona, aim to educate parents on steps to ensure that they never accidently forget their child in the car. Recommendations from these programs include the following:

- Make it a routine to check the back seat every time you park.
- Leave important articles such as a purse or phone in the back seat to prompt you to open the rear door and check the back seat.
- Place a stuffed animal in the car seat and move it up to the front seat as a reminder of when you have your child in the car seat.
- Make sure childcare providers call you should your child not arrive as scheduled.

In addition, these campaigns also offer strategies to make sure children do not gain access to vehicles on their own.

- Keep vehicles locked.
- Keep keys out of the reach of children.
- Check vehicles when a child goes missing.

Other behavioral suggestions include adding a daily reminder to your computer or telephone to ensure you have dropped your child off with their caregiver and confirming pick-up and drop-off plans with your partner whenever there is a change in schedule (European Child Safety Alliance, 2019). In Australia, "Kidsafe Victoria" has taken a different approach and has installed "Do not leave children unattended in cars" signs in parking lots. To improve understanding of how temperatures can reach high and deadly levels in such a short time, Australia also created "The Unconventional Oven" ad campaign, which demonstrates how a piece of meat is cooked inside a car after only 90 minutes. Unfortunately, research suggests that caregivers do not gain knowledge through public service announcements, which is how many of these campaigns are disseminated. Rather, caregivers believe this information should come through channels such as doctors' offices instead (Williams & Grundstein, 2018).

LAWS ON CHILDREN AND CARS

Public health campaigns to combat trunk entrapment, power window incidents, backover incidents, and PVH have sparked legislation at both the state and federal levels (see Table 1). Previous public health campaigns in other areas have demonstrated the great change that can be made through legislation. An organization called the Trunk Release Urgently Needed Coalition (TRUNC) was created in 1999 due to the number of incidents involving trunk entrapments. Since 1970, over 900 incidents involving trunk entrapment were reported (Kids and Cars, 2019**)**. Trunk entrapment incidents occurred unintentionally (children exploring or adults performing installation/repair work inside the trunk) or intentionally (carjacking or kidnapping). In 2001, nearly two years after TRUNC was establish, NHTSA released Federal Motor Vehicle Safety Standard (FMVSS) No. 401 requiring all passenger cars with a truck compartment to have a trunk release mechanism.

Kids and Cars is an organization which focuses attention and education on the tragedies that can occur when children are left unattended in or around vehicles. This organization brought public attention to the over 50 children who were killed and the many injured since 1999 due to accidentally engaging the power window of a vehicle. NHTSA estimated that 2,000 people were injured in 2007 due to power-window-related injuries (National Center for Statistics and Analysis, 2009). Shortly after NHTSA's findings were released, FMVSS 108 was passed requiring all passenger vehicles to have a pull-up/push down switch to help prevent injuries and deaths from power windows.

Advocacy work to reduce back-over fatalities steered Congress to pass the Gulbransen Kids Transportation Safety Act of 2007. This Act led NHTSA to release FMVSS No. 111, which requires passenger cars, multipurpose passenger vehicle, low-speed vehicle, truck, bus, and school bus with a gross vehicle weight rating of 4,536 kg or less to display a rearview image to reduce backover incidents. Since this ruling, the number of back-over fatalities of children has begun to decrease (KidsandCars.org, 2019). This issue to advocacy to legislation to outcomes path is currently being followed with PVH.

Table 1. Laws and trends.

Type	Issue	Advocacy	Legislation Level	Regulation/Act	Outcomes
Trunk Release	Trunk entrapment	TRUNC & KidsandCars.org	Federal	FMVSS No. 401	All new passenger cars require trunk release mechanism.
Power Windows	Deaths due to power windows	KidsandCars.org	Federal	FMVSS No. 118	Power window switches are required to have pull-up/push down switch.
Rear Camera	Back-over deaths	Gulbransen & KidsandCars.org	Federal	FMVSS No. 111	Passenger vehicles, multipurpose passenger vehicles, trucks, buses, school buses, and motorcycles are required to have a display of the rear road surface view.
Heat Stroke	PVH	KidsandCars.org, NoHeatStroke.org	Federal	Hot Cars Act 2019 (Introduced) H.R. 3593	All new passenger motor vehicles weighing less than 10,000 pounds gross vehicle weight require visual and auditory alert for rear seat occupant once motor is deactivated. In addition, the bill suggests requiring systems that also detect the presence of any occupant who has entered an unoccupied vehicle independently.
Heat Stroke	PVH	KidsandCars.org, NoHeatStroke.org	Federal	Hot Cars Act 2019 (Introduced) S. 1601	All new passenger motor vehicles weighing less than 10,000 pounds gross vehicle weight require visual and auditory alert for operator to check the rear seat after motor is deactivated.

Twenty-one states have a range of legislation attempting to mitigate the problem of children left in vehicles. The Good Samaritan Act allows an individual to break into a vehicle in order to save a vulnerable individual or pet from a vehicle. Some states have laws for daycare vehicles and school buses to have reminder systems integrated in the vehicles. The Leaving Unattended Child in Vehicle Act allows the state to prosecute the person(s) responsible for leaving a child in the vehicle; however, the specifics vary from state to state (Null, 2019). For example, Texas law allows a child to be left alone in a vehicle for 5 minutes, Kentucky allows 10 minutes, and Washington state does not limit the amount of time one is allowed to leave a child unattended in a vehicle as long as it is not parked near an establishment serving alcohol. However, there is currently only one bill at the federal level to combat PVH. In May of 2019, U.S. Senator Roger Wicker presented the Hot Cars Act, which directs the Department of Transportation to issue a rule requiring all new passenger motor vehicles less than 10,000 pounds to be equipped with rear seat reminder technologies (RSRT) that would alert (audibly and visually) individuals inside and outside of a vehicle of the presence of an occupant in the rear seat (Congress, 2019a). In June 2019, Rep. Tim Ryan reintroduced the Hot Cars Act of 2017 to the U.S. House of Representatives. This bill is the same as the one introduced to the Senate except that it has an additional requirement for a system to detect occupants who may have entered the vehicle independently and who are unable to exit independently (Congress, 2019b). Should this technology be mandated for all new relevant vehicles, it is pertinent to find an alert that is effective with minimal false alerts and affordable.

CHAPTER 2. REAR SEAT REMINDER TECHNOLOGY

NHTSA previously evaluated aftermarket RSRT and found it to be too unreliable and difficult for a consumer to install (Arbogast, Belwadi, & Allison, 2012; Rudd, Prasad, Weston, & Wietholter, 2015). Their evaluation concluded that multiple devices on the market had syncing and connection issues that hindered their functioning. NHTSA also completed a functional assessment of RSRT in hope of providing guidance for companies on developing more robust reminder technologies than the ones currently on the market. Both studies made a significant impact on rear seat reminder products. Multiple companies with RSRT products, such as Small Ones Safety, Childminder, Aviso, and others, either updated their inventory, removed their products from the market, or changed the focus of the company (for example, see Appendix A).

Even though these studies were impactful, they still had their limitations. Both studies looked at aftermarket technology that is now more than 4 years old. They did not have the opportunity to test built-in manufacturer RSRT, and the effectiveness of the alerts from these different aftermarket technologies was not addressed. However, most importantly, researchers did not evaluate the abilities of these technologies to alert caregivers through various scenarios where a child could experience heatstroke in a vehicle (such as gaining access to the vehicle unknown to the caregiver).

TYPES OF REAR SEAT REMINDER TECHNOLOGY

The four types of RSRT currently available are generally classified as pressure-based, child-restraint-based, vehicle-based, or sensor-based systems.

Aftermarket Pressure-based Technology

Pressure-based technology uses pressure pads to detect the presence of a child or pet and determine if an alert should be issued to the driver after the driver exits the vehicle. Pressure-based systems activate once pressure is applied to the system's pad. The pad is connected to the driver's phone via Bluetooth. If the system is still active and the driver travels too far away from the connected device, the driver receives an alert to check the back seat of the vehicle. These systems are offered as aftermarket features and are generally easy for drivers to install in their own vehicles. Some systems offer a feature allowing alerts to be sent to multiple contacts if the driver cannot be reached. Table 2 summarizes the features of three pressure-based technologies: Never4GetUs, Driver's Little Helper, and Sense A Life. More details on each technology follow the table.

Table 2. Pressure-based technologies.

Feature	Never4GetUs	Driver's Little Helper	Sense A Life
Detection			
Weight Sensor	x	x	x
Bluetooth	x	x	x
Optical Sensors			x
Interior Alerts			
Auditory Alert	x		x
Visual Alert	x		
Smartphone Linked			
Auditory Alert		x	x
Visual Alert		x	x
Temperature Monitor		x	x
Miscellaneous			
Hierarchy Alerts*		x	x
Price**	$30	$43	$150

**Levels of alerts are issued to the driver*
***Price based on average cost to consumers*

Never4GetUs

The Never4GetUs uses two pads, one for the driver (Pad-D) and one for the person, pet, or object for which the driver needs a reminder (Pad-C; Never Forget Us, 2017; Figure 1). The two pads connect to each other via patented technology. The system activates once pressure is applied to Pad-C. Once the driver removes their weight from Pad-D, the system issues a visual and/or auditory reminder to check the back seat.

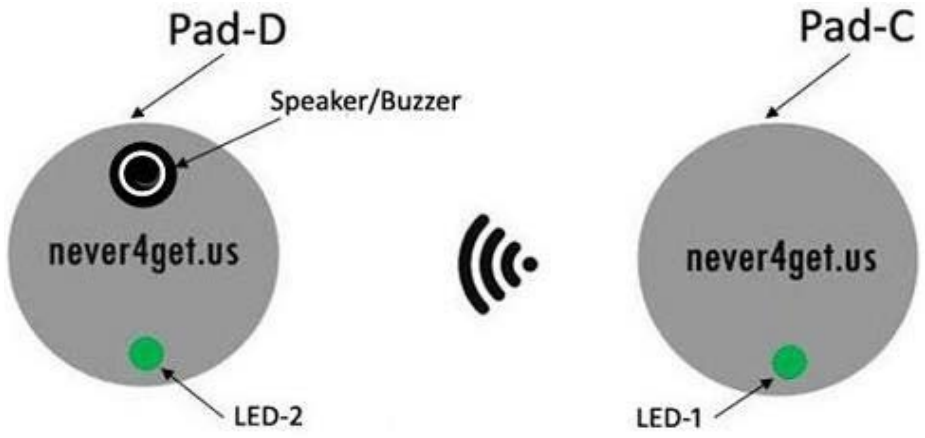


Figure 1. Diagram. Never4GetUs technology (source: Never4get.us).

Driver's Little Helper

The Driver's Little Helper system works with any car seat (Driver's Little Helper, n.d.). The sensor pad sits between the car seat cover and molding and connects to a battery pack (Figure 2). Once it is properly installed, the pad wirelessly connects to the driver's smartphone via Bluetooth and provides the current interior temperature of the vehicle and status of the vehicle (driving, parked, etc.) via the Driver's Little Helper app. When the driver exits the vehicle and the pad senses a child in the car seat, the system sends an alert to the driver's phone. There is also an option for the system to contact other individuals from the driver's contact list in case the driver cannot be reached**.**

Figure 2. Photo. The Driver's Little Helper technology (source: Fatherly.com).

Sense A Life

The Sense A Life system uses a sensor attached to the child's car seat that detects the presence of a child through a pressure pad and synchronizes with an optical sensor attached to the driver's seat that detects when the driver exits the vehicle (Sense A Life, n.d.). Additionally, the Sense A Life system connects to the driver's smartphone and provides the current interior temperature of the vehicle. Once the child is in the car seat, the pad activates the system and an auditory alert, "child sensor activated," is issued to the driver. Another auditory alert is given to the driver upon exiting the vehicle to remind the driver of the child in the back seat. If the child is not removed from the seat, the driver receives a message on their smartphone via the Sense A Life app (Figure 3). The driver has the option to snooze the alert or notify the system that the child was removed. The user receives alerts to charge the devices through the app. A full recharge can take up to 4 hours.

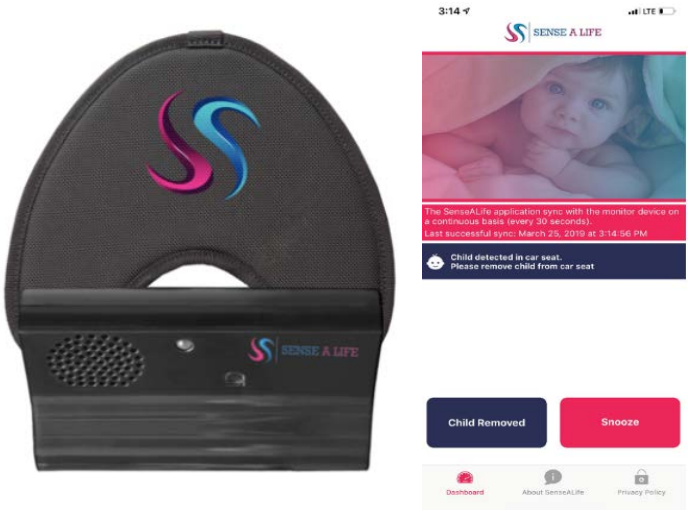


Figure 3. Photo. Sense A Life technology (source: Sensealife.com).

Child-restraint-based Technology

Child-restraint-based technology uses sensors that clip onto or that are built into child restraints and that synchronize with an attachable key fob or smartphone via Bluetooth. This technology can detect if a child is unbuckled, and some have extra features to track vehicle movement and interior temperature of the vehicle. Generally, the driver receives an alert at a predetermined distance from the vehicle while a child restraint is still buckled. Table 3 compares the features available on two child-restraint-based reminder technologies, iAlert True Fit and ChildMinder SoftClip. These two products are described in more detail following the table.

Table 3. Child-restraint-based technologies.

Feature	iAlert True Fit	ChildMinder SoftClip
Detection		
Sensors in Clips	x	x
Bluetooth	x	x
Smartphone Linked		
Auditory Alert	x	
Visual Alert	x	
Temperature Monitor	x	
Miscellaneous		
Hierarchy Alerts*	x	
Key Fob		x
Price**	$300	$49.95

**Levels of alerts are issued to the driver*
***Price based on average cost to consumer*

True Fit iAlert

The True Fit iAlert car seat system (Figure 4) connects to the driver's phone via Bluetooth (Truefit I Alert, 2013). The system activates once the child is in the car seat. The system senses when the child is in the car seat via patented technology and provides information to the driver's smartphone such as the current cabin temperature of the vehicle and status of the vehicle (driving, parked, etc.) via the iAlert app. The driver will receive a visual and auditory alert on their phone if the child gets out of the car seat while the vehicle is in motion or if the driver leaves the child in the vehicle while stopped for 1 to 5 minutes (amount of time chosen by user). If the driver does not respond to the initial auditory and visual alerts via the app, a text and/or email will be sent to the driver's phone.

Figure 4. Photo. True Fit iAlert car seat (source: Albeebaby.com).

ChildMinder SoftClip

The ChildMinder SoftClip (Figure 5) has sensors built into restraint clips that connect to a key fob via Bluetooth (Baby Alert International, 2019). The system activates once the restraints are connected. If the system senses that the key fob is too far away from the buckled restraints, the driver receives an auditory alert through the key fob. The product has seen multiple iterations since NHTSA reviewed it in 2012. Throughout iterations, consumers have complained about connection issues, difficult instructions, and false alerts (constant beeping even after the child is unbuckled).

Figure 5. Photo. ChildMinder SoftClip technology (source: Amazon.com).

Vehicle-based Technology

Vehicle-based technologies addressing PVH typically come pre-installed in the vehicle at the time of purchase. If these systems are added later, professional installation is required (see next section, Aftermarket Vehicle Integrated Technology). These technologies use a variety of sensors that detect if the back door was opened before entering the vehicle (indicating the possibility of a child in the rear seat), vital signs present in the vehicle, or movement in the rear seat of the vehicle even when the vehicle is turned off. If the vehicle detects the condition the alert has been designed for, it notifies the driver of the situation. Most of the vehicle-based systems comply with the Hot Cars Act by providing both an auditory and visual alert to the driver, but not always to individuals outside the vehicle.

Table 4 highlights features available for six original equipment manufacturer (OEM) technologies: General Motors (GM) Rear Seat Reminder (RSR), Hyundai Rear Occupant Alert (ROA), Kia Rear Occupant Alert (ROA), Nissan Rear Door Alert (RDA), Tesla Dog Mode, and Volvo Heartbeat Sensor. More details on each system follow the table.

Table 4. Vehicle-based technologies (OEM).

Feature	GM Rear Seat Alert	Hyundai Rear Occupant Alert	Kia Rear Occupant Alert	Nissan Rear Door Alert	Tesla 8.0/Dog Mode	Volvo Heartbeat Sensor
Detection Type						
Door Logic	x	x	x	x		
Ultrasonic Sensors		x	x			
Vitals						x
Interior						
Audio Alert	x					
Visual Alert	x	x	x	x	x	
Exterior						
Audio Alert		x	x	x		x
Visual Alert		x	x			x
Haptic Alert		x	x			x
Smart Phone Linked						
Audio Alert		x	x			
Visual Alert		x	x			
Miscellaneous						
Key Fob						x
Hierarchy Alerts*		x	x	x		
Mitigation					x	
**Levels of alerts are issued to the driver*						

General Motors Rear Seat Reminder (RSR)

GM was the first in the industry to provide an auditory and visual alert focused on reminding a driver to check the rear seat. The GM RSR relies on a process called "door logic" that utilizes sensors in the door to detect if the rear door was opened and closed within 10 minutes of the engine starting, or if the rear door was opened while the vehicle was on. If the door logic detects that one of those actions took place, the driver receives a visual message, "Rear Seat Reminder/Look in Rear Seat," in the instrument cluster along with five auditory alert chimes to remind the driver to check the rear seat when the vehicle is turned off (General Motors, 2018; Figure 6). The driver can clear the message from the instrument cluster; no other alerts are issued if the driver continues to exit the vehicle without clearing the message. The RSR system is delivered to the consumer already activated, but drivers have the option to turn it off through the settings menu. The driver does not receive an alert when exiting the vehicle while the vehicle is on. The rear seat alert feature debuted in some of GM's 2017 model vehicles and was made a

standard feature in most of their 2018 model vehicles (Thomas, 2017). See Appendix B for more information about the GM RSR from the owner's manual.

Figure 6. Photo. GM rear seat alert message (source: GMC.com).

Hyundai Rear Occupant Alert (ROA)

Hyundai's ROA has a hierarchy of alerts. Similar to its competitors, Hyundai uses door logic to send an initial "Check Rear Seat" alert to the driver via the instrument cluster (Hyundai News, 2017). If the driver does not clear the visual alert, the system does not send any more alerts to the driver unless an additional detection method notes that there may be an individual left in the second-row seating. The ROA system uses ultrasonic sensors built into the headliner to detect movement in the rear seats after the vehicle is locked and turned off for up to 24 hours. If the system detects movement in the rear seats, the vehicle will begin honking and flashing the vehicle lights every 25 seconds for up to eight times (Figure 7). The driver can only disable the alert by unlocking and opening the rear door. The driver can also opt in to receiving a text message and email via the MyHyundai Blue Link app as part of the alert. Hyundai's ROA system is delivered to the consumer active but can be disabled through the user settings. Hyundai plans to incorporate the ROA system into all of their 2019 models (Hyundai News, 2017). See Appendix C for more information about Hyundai's ROA.

Figure 7. Photo. Hyundai ROA (source: Hyundainews.com).

Kia Rear Occupant Alert (ROA)

Kia's ROA has a hierarchy of alerts comparable to the Hyundai ROA. Like its competitors, Kia uses door logic to send an initial "Check Rear Seat" alert to the driver via the instrument cluster (Kia, 2019). Similar to Hyundai's ROA, if the driver clears the visual alert, the system does not send any more alerts to the driver unless an additional detection method notes that there may be an individual left in the second-row seating. The Kia ROA system uses sensors built into the headliner to detect movement in the rear seats after the vehicle is locked and turned off for up to 24 hours. If the system detects movement in the rear seats, the vehicle will begin honking and flashing the vehicle lights every 25 seconds for up to eight times. The driver can only disable the alert by unlocking and opening the rear door. Unintended movement from wind, bugs, etc., while the windows are down or loose items falling inside the vehicle can cause a false alert. Vehicles with remote start can interrupt the ROA movement detection. Kia's ROA system is delivered to the consumer active but can be disabled through the user settings. Currently this feature is only available in the 2020 Kia Telluride model. See Appendix D for more information about Kia's ROA.

Nissan Rear Door Alert (RDA)

Nissan's RDA is similar to GM's system. The Nissan system activates any time the vehicle detects that the rear door was opened and closed within 10 minutes of the engine starting. The driver will first receive a visual message, "Rear Door Alert is activated," as notification that the system is activated (Nissan News, 2018; Figure 8). Nissan allows the driver to dismiss the message, disable the alert, or ignore the visual message. If the driver chooses to dismiss the message or ignore it, the system will remain enabled for the trip; however, if the driver disables the alert, the alert will be temporarily disabled for that trip. At the end of a trip, a visual alert is sent to the driver, "Check Rear Seat for All Articles," with options to dismiss the alert. Nissan's RDA differs from GM's RSR by continuing to alert the driver of a possible person, pet, or object in the rear seat through six distinctive honks if the driver does not dismiss the visual message from the instrument cluster. The driver may not receive an alert if the engine is turned off then on in a short period of time or if a passenger enters or exits the vehicle during a trip. Nissan delivers the vehicle to the consumer with RDA disabled; drivers have the option to enable this alert through the settings menu. The driver can customize the alert by going through the vehicle settings and select to only receive the first level of alert (visual alert) instead of the using the hierarchy system, which would then utilize the horn. Nissan has made the RDA a standard feature for eight of its 2019 models, with plans to make it a standard feature for all of its four-door vehicles by 2022 (Nissan News, 2018). See Appendix E for more information about the Nissan RDA.

Figure 8. Photo. Nissan RDA alert message (Source: Nissannews.com).

Tesla

Tesla has the only OEM feature that passively controls the cabin temperature of a parked vehicle. With Tesla's 8.0 update in 2016, the cabin temperature of the vehicle is prevented from rising above 105 °F by turning on the air conditioning (Lambert, 2019). Tesla also has a "Dog Mode" feature that uses the infotainment screen within the Tesla to show the cabin temperature of the car with a message to bypassers. The driver must activate this feature each time they want to use it. Before the driver exits the vehicle, they must start Dog Mode by tapping the fan icon at the bottom of the touchscreen while the vehicle is parked, then toggle keep climate on to "DOG" and choose the desired cabin temperature the vehicle should maintain. Once the driver exits the vehicle and closes the door, a message, "My owner will be back soon," along with the current temperature, will appear on the infotainment screen (Figure 9). The message displayed on the screen updates depending on the set cabin climate of the vehicle (Lambert, 2019). Based on review of the Tesla Model X owner's guide, Tesla does not do anything to remind the driver to check the vehicle for a child or pet (Tesla, 2019).

Figure 9. Photo. Tesla dog mode (source: Electrek.co).

Volvo's Personal Car Communicator (PCC)

Volvo's Personal Car Communicator (PCC) system uses a different method from the door logic seen in GM, Nissan, Kia, and Hyundai vehicles to remind the driver of a possible forgotten child or pet. Volvo's PCC uses a heartbeat sensor that detects signs of life in the vehicle. The heartbeat sensor records the vibrations of a child or pet's beating heart and can alert the driver of a sleeping child forgotten in the vehicle (Volvo, 2003). The heartbeat sensor accomplishes this by measuring vibrations in the vehicle's chassis and can be impaired in areas with high levels of noise or vibrations (Volvo, 2008). Once the driver exits the vehicle and locks the doors, the heartbeat sensor activates and detects signs of life. A visual, haptic, and auditory alert is transmitted to the key fob to alert the driver that there may be someone in the vehicle (Figure 10). Haptic feedback enables the vehicle to communicate information to the driver and/or passenger through the sense of touch (e.g. vibration of the steering wheel or seat during a lane change event). The feature has a range of 300 feet and can be manually activated in cases where the driver suspects an intruder hiding in the vehicle (Volvo, 2003). This feature can only be found integrated into the alarm system of Volvo V70 and S80 models from 2007 to 2010. The research team does not know the reason why Volvo removed this feature from their current vehicles and did not replace it with a comparable reminder system. See Appendix F for more information about the Volvo heartbeat sensor.

Figure 10. Photo. Volvo personal car communicator key fob (source: Volvonews.com).

Aftermarket and Research and Development Vehicle Integrated Technology

Aftermarket rear seat alerts can be installed in almost any vehicle after purchase and require professional installation. Three aftermarket systems are discussed below: the Brilliant Back Seat Reminder System, Ride N Remind, and VitaSense. Table 5 highlights features available for these three aftermarket vehicle-based technologies.

Table 5. Vehicle-based technologies (aftermarket and research and development).

Feature	Brilliant Back Seat Reminder System	Ride N Remind	VitaSense
Detection Type			
Door Logic	x	x	
Radio frequency			x
Interior			
Auditory Alert	x	x	x
Visual Alert			x
Exterior			
Auditory Alert		x	x
Visual Alert			x
Haptic Alert			x
Smartphone Linked			
Auditory Alert			x
Visual Alert			x
Miscellaneous			
Hierarchy Alerts*	x	x	x
Mitigation**			x
Price***	$130	$130	Research and Design

**Levels of alerts are issued to the driver*
***Controls interior temperature*
****Price based on average cost to consumer not including installation where necessary*

Brilliant Back Seat Reminder System

The Brilliant Back Seat Reminder System (Figure 11) is an aftermarket system that requires a professional mechanic for installation. Like the GM, Nissan, and Hyundai systems, this system uses door logic. An interior auditory alert is issued to the driver upon turning off the vehicle and remains on until the back door is opened and a confirmation button installed in the C pillar is pressed (Brilliant Backseat Reminder System, 2019).

Ride N Remind

Ride N Remind (Figure 11) is another aftermarket system that requires a professional mechanic for installation. Similar to Brilliant Back Seat, GM, Nissan, and Hyundai, this system uses door logic. An interior auditory alert is issued to the driver upon turning off the vehicle and remains on until the back door is opened and a confirmation button installed in the C pillar is pressed. If the driver ignores the initial alert and does not press the confirmation button in the back, the car alarm is activated as a secondary alert for the Ride N Remind System (Ride N Remind, n.d.). Reviews for the Ride N Remind are high, with consumers loving that they do not have to do

anything to activate the system. Consumer reviewers commented that they like how it blends in with the vehicle and does not seem like an aftermarket add-on feature (Amazon, n.d.).

Figure 11. Photo. Brilliant Backseat and Ride N Remind systems (sources amazon.com and youtube.com).

VitaSense

The VitaSense is a device currently in the research and development phase that is designed to be installed and integrated in the vehicle at time of purchase. The VitaSense system emits a 24-GHz low-power radio frequency signal from a transmitter installed in the vehicle headliner to detect the presence of a child in the vehicle (Mousel, Larsen, & Lorenz, 2017). If it detects a child, once the vehicle engine is shut off, an alert is issued to the driver. VitaSense can be configured to utilize the vehicle's Controller Area Network (CAN) to counteract PVH passively by turning on the air conditioner and/or rolling down the windows, and actively by alerting the driver and bystanders by using the horn, chimes, or alarm system (Figure 12). The system can detect a child through obstacles such as clothing and blankets. The creators of VitaSense tested the effectiveness of detection with their prototype and claim that it was sensitive enough to detect the small breathing movements of a sleeping infant in difficult conditions, such as through the

sunshade of a rearward-facing child seat. See Appendix G for more information about the VitaSense system.

Figure 12. Illustration. Radio frequency detection system VitaSense (source: iee.lu).

Other Sensor-based Technologies

Other sensor-based technologies to help combat PVH do not use any of the previously described methods of detection, such as clips or weight sensors, and are not vehicle-based. These technologies are aftermarket and intended for the consumer to install in any vehicle. Table 6 compares Olea Sensors, Elepho eClip, and the Kars4Kids app. More details on each can be found below the table.

Table 6. Other sensor-based technologies.

Other Based Systems	Olea Sensors	Elepho eClip	Kars4Kids App
Detection Type			
Vitals	x		
Bluetooth		x	x
Smartphone Linked			
Auditory Alert	x	x	x
Visual Alert	x	x	x
Haptic Alert	x	x	x
Temperature Monitor		x	
Price**	R&D	$50	Free

**Levels of alerts are issued to the driver*
***Price based on average cost to consumer*

Olea Sensor

The Olea Sensor (Figure 13) attaches to the interior roof of the vehicle and uses patented technology to detect vital signs throughout the vehicle (Olea Sensor Networks, 2019). It is designed to detect motionless and sleeping or vulnerable individuals. The Olea Sensor connects to the driver's smartphone via Bluetooth. In order to minimize false alerts, the user will not receive an alert until they are at least 2 meters away from the device.

Figure 13. Photo. Olea sensors system (source: Oleasys.com).

Elepho eClip

The Elepho eClip attaches to the restraints of the car seat belt and uses Bluetooth technology to connect to the driver's smartphone and sends alerts via the Elepho app (Elepho, n.d.). The driver must switch on the eClip to activate it. Once it is activated, the driver will receive an alert on their phone if they are more than 15 feet away from the device. The eClip can also send an alert to specific contacts listed in the driver's phone. The eClip can also monitor the cabin temperature of the vehicle and notify the driver if the cabin temperature is too hot or cold for their child (Figure 14). The Elepho eClip also offers a key fob option for consumers that do not own a smartphone. They will receive the alerts in the same fashion; however, they will not be able to receive updates of the cabin temperature of the vehicle.

Figure 14. Photo. Elepho eClip (source: elepho.com).

Kars4Kids Safety App

The free Kars4Kids Safety app (Figure 15) reminds the driver to check the rear seat of the vehicle (Kars4Kids, n.d.). The app relies on the Bluetooth technology of the vehicle and phone. When the Bluetooth connection is removed, an alert is sent to the driver. Vehicles without Bluetooth capabilities cannot use the app. The driver syncs their phone to the Bluetooth system of the vehicle and turns on the app. When the driver turns the engine off, removing the Bluetooth connection, the alert is triggered and sent. The app can be personalized to the driver's schedule and is only available through the Google Play app store.

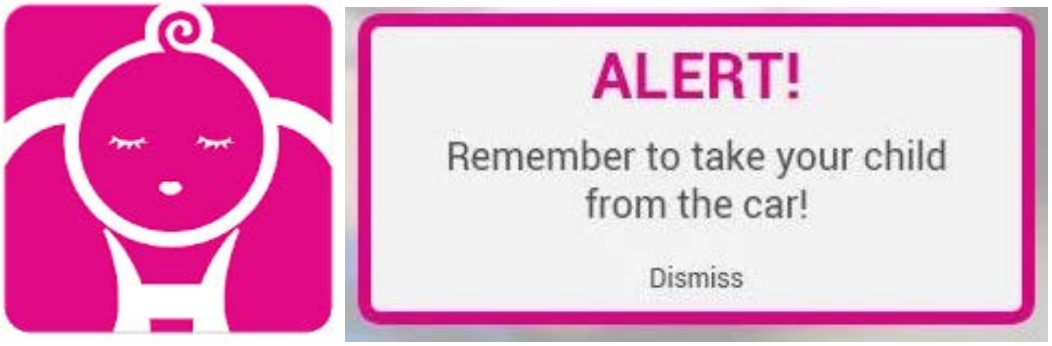


Figure 15. Screen capture. Kars4Kids mobile application (source: play.google.com).

CURRENT RSRT LIMITATIONS

Even though current RSRTs are more robust and reliable than previous developments, they still lack the ability to catch all of the most common PVH scenarios. Only one of the technologies reviewed seemed as if it would notify a driver if a child gained access to the vehicle without the driver's knowledge. Only Tesla and VitaSense are capable of passively preventing heatstroke conditions in the vehicle. Most of the technologies reviewed do not provide more than one way to detect a rear occupant or more than two ways to alert the driver. Some have only one level of an alert, which drivers may easily miss. Layering detection methods in the vehicle could help with false alerts, and adding a hierarchy of alerts could help save a life should the first alert fail to reach the appropriate party. There is still heavy reliance on phones, batteries, and Bluetooth

connectivity for many systems. Not everyone keeps their phone on them or the volume high enough to hear an alert, batteries often die before they are replaced, and Bluetooth connectivity can get interrupted, so these alerts alone may not always be sufficient. Drivers may also confuse the auditory and visual alerts with other vehicle alerts with similar sounds (door ajar, keys left in vehicle, low tire pressure, etc.). Some of the RSRT alerts are optional, require driver action to activate, and can be disengaged by the driver. The ability to disengage the feature is desirable for those who purchase the vehicle and do not have children; unfortunately even those individuals with children may believe that they do not need this feature and disengage it (General Motors representatives Maureen Short, Tricia Morrow, and Suzanne Johansson, personal communication, October 1, 2018). This technology needs to be effective, reliable, minimize possible negative unintended consequences, and not provide "false alerts" to be constantly engaged, just like the rear camera, seat belt reminder, and others, to avoid irritating the consumer. Some of the technologies have an added feature to contact another individual in the consumer's contact list; however, this could be unfavorable to the driver due to the possible embarrassment of having someone else know that they left their child or pet in the vehicle. This might lead the owner to disable the feature or avoid the product entirely. GM surveyed owners with the rear seat alert option in their vehicles and noticed that a huge hurdle was determining the effectiveness of the feature since people were unlikely to report if it successfully aided them in remembering their child, especially since most parents do not believe they would ever forget their child in the first place. However, GM's RSR consumers that were surveyed did admit that the system reminded them to check the rear seat for forgotten items. Consumers complained about false alerts, chimes getting drowned out by other alerts, and did not like paying for a feature for children when they did not have any. Around half of the people surveyed left the feature on, and the people who turned it off admitted that they do not have children in their vehicles.

Most of the OEM technologies do not actually detect a child, pet, or object in the vehicle. The door logic only detects if the rear door is opened and then closed, not whether there is an actual child in the back seat. Hyundai's ROA is the only OEM system that actually detects movement in the rear seat of the vehicle; however, movements have to be fairly large and the system has trouble detecting a sleeping child in the vehicle (Monticello, 2018). Since this technology could be mandated for all car manufactures in the near future due to the Hot Cars Act, it is pertinent to find a consumer-accepted, affordable, and effective solution to PVH. Unfortunately, the effectiveness of these technologies is unknown. In order to continue to improve RSRT technology, an evaluation of current technologies must be completed.

SUGGESTIONS FOR REAR SEAT DETECTION TECHNOLOGY DEVELOPMENT AND ACCEPTANCE

Technology developed to prevent PVH should have features in place to cover all three of the common ways children suffer from PVH: gaining access without parental knowledge, being intentionally left in the vehicle, and being unintentionally left in the vehicle. In addition, these technologies need to have wide consumer acceptance so that they are not disabled. More specifically, future iterations of the technology should:

- Be intuitive to use;

- Minimize false alerts so that consumers do not disable the system or become dismissive of them;
- Use a hierarchy of alerts that continues to attempt to get someone's attention (driver or passerby) until the situation is resolved/checked;
- Utilize the vehicle's abilities to contact emergency personnel via On-Star, Hyundai BlueLink, etc.
- Incorporate multiple detection methods that do not depend only on the doors being locked so that situations in which children gain access to vehicles without parental knowledge could be detected;
- Include passive systems which try to regulate the environmental conditions of the vehicle should life be detected in the vehicle and temperatures are becoming too high (such as turning on air conditioning, etc.);
- Address unintended consequences of technology implementation.

Technological solutions will also need to be supplemented with consumer-side education and incentives, such as outreach from doctors to parents, incorporation of PVH as a topic into driver's education courses, and possible insurance credits for people who purchase in-vehicle RSRT technology.

Developing a detection and alert system that incorporates these suggestions while educating the public could have a massive impact on decreasing the number of PVH incidents. However, it is also important to test the technology currently available to consumers. It has been years since the last testing of RSRT technology, and presently it is unknown how effective the current RSRT technology is at detecting and notifying a driver to check the rear seat.

CHAPTER 3. PROPOSED EVALUATION DESIGNS FOR CURRENT REAR SEAT REMINDER TECHNOLOGY

Based upon the information gained through the literature review, the research team developed two experimental design options to test the effectiveness of current vehicle-based technologies.

EFFECTIVENESS OF OEM REAR SEAT REMINDER TECHOLOGY ALERTS

The research team suggests conducting an experiment to test the effectiveness of current OEM systems, specifically their ability to capture the driver's attention and communicate the need to check the rear seat for an object. The experiment would require 50 participants, 10 participants for each OEM device and 10 for the baseline. The Virginia Tech Transportation Institute (VTTI) would equip a vehicle that can mimic the five OEM alert systems previously discussed: GM, Hyundai, Kia, Nissan, and Volvo. The participants would be given a tablet to complete a questionnaire and then asked to hold on to the tablet for the duration of the experiment. Researchers would not inform the participants of the true intentions of the experiment, but instead tell them that the experiment is to test out a navigation system on a car. Before beginning the drive, researchers would ask participants to place the tablet in the pocket behind the driver's seat. The participants would then drive public roads on a predetermined route while completing navigation tasks for approximately 45 minutes. After the participants return to the VTTI campus and park, the experimenter would trigger one of the OEM rear seat reminders (determined by the experimental design) as a prompt to remind them of the tablet in the rear of the vehicle. The participants' eye-glance behavior and reactions will be recorded by VTTI's data acquisition system (DAS), and researchers will compare data across the baseline and OEM systems. In addition, researchers will make cross-system comparisons of participants who remembered, forgot, or were successfully reminded of the tablet via the alert. Researchers will also collect questionnaire data after the participants experience the alert to record their opinions and reactions. This design gathers data to analyze the reaction of participants to the various alerts and get individual feedback on alert exposure.

EVALUATION OF OEM AND AFTERMARKET REAR SEAT REMINDER ALERTS

Researchers suggest conducting a functional evaluation of OEM and aftermarket RSRT technology, focusing on both the alerts and their methods to detect individuals in the vehicle. VTTI would acquire representative vehicles and some aftermarket RSRT. The team would test the features and capabilities of the technology through real-life scenarios. Upon critically analyzing the capabilities and functions of each technology under various scenarios, researchers would rate their reliability and functionality. This research design allows researchers to provide a functional assessment of all systems and give feedback on them for suggested improvements.

APPENDIX A. AVISO CHILD-IN-CAR ALERT WEBSITE MESSAGE

The Aviso Child-in-Car Alert

HEATSTROKE LAYERS OF PROTECTION LINKS

2017 UPDATE:

Aviso Reminder Systems, LLC offered the **Child-in-Car Alert** for several years. It is now obvious that aftermarket reminder devices will NOT significantly reduce the number of heatstroke fatalities. Child reminder warnings must be built into ALL cars.

Therefore, we are changing our focus. We will now concentrate on advocating for legislation to require that all rear seat-equipped light passenger vehicles be built with child reminder and alert warnings.

For years, cars have been built with warnings to remind us not to leave the keys in the ignition, not to leave a door open, or that a seat belt is unfastened. Programming new cars to give child reminder warnings upon parking, and to honk the car horn if the child seat is still occupied several minutes after parking, is simple and inexpensive.

(Aviso Reminder, 2017).

APPENDIX B. GM OWNER'S MANUAL: REAR SEAT REMINDER

Rear Seats

Rear Seat Reminder

If equipped, the message REAR SEAT REMINDER LOOK IN REAR SEAT displays under certain conditions indicating there may be an item or passenger in the rear seat. Check before exiting the vehicle.

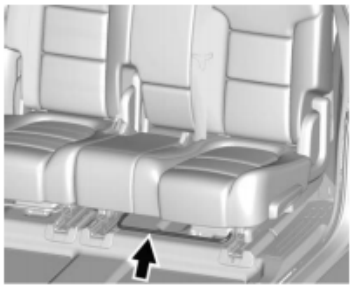
This feature will activate when a second row door is opened while the vehicle is on or up to 10 minutes before the vehicle is turned on. There will be an alert when the vehicle is turned off. The alert does not directly detect objects in the rear seat; instead, under certain conditions, it detects when a rear door is opened and closed, indicating that there may be something in the rear seat.

The feature is active only once each time the vehicle is turned on and off, and will require reactivation by opening and closing the second row doors. There may be an alert even when there is nothing in the rear seat; for example, if a child entered the vehicle through the rear door and left the vehicle without the vehicle being shut off.

The feature can be turned on or off. See *Vehicle Personalization* ⇨ *152*.

Rear Seat Adjustment

The second row seats slide forward for more room.



To adjust the seat position:

1. Remove objects on the floor in front of or on the second row seat, or in the seat tracks on the floor.
2. Lift the lever below the seat cushion and slide the seat forward or backward.
3. Push and pull on the seatback to ensure the seat is locked in place.

Entering and Exiting the Third Row

⚠ Warning

Using the third row seating position while the second row is folded, or folded and tumbled, could cause injury in a sudden stop or crash. Be sure to return the seat to the passenger seating position. Push and pull on the seat to make sure it is locked into place.

(General Motors, 2018).

APPENDIX C. HYUNDAI OWNER'S MANUAL: REAR OCCUPANT ALERT

- **The Safe Exit Assist (SEA) system will not operate if there is a malfunction with the Blind-Spot Collision Warning (BCW) system as follows:**
  - **When the BCW warning message appears**

    When the BCW sensor or the sensor surrounding is polluted or covered
  - **When the BCW does not warn or warns wrongly**

For more details, refer to cautions and limitations in "Blind-Spot Collision Warning (BCW)" in chapter 5.

⚠ WARNING

- **The system does not detect every obstacle approaching the vehicle exit.**
- **The driver and passenger are responsible for any obstacles while exiting the vehicle.**

  Always check the surrounding before you exit the vehicle.

Rear Occupant Alert (ROA) System (if equipped)

The Rear Occupant Alert (ROA) system is provided to help prevent exiting the vehicle with the rear passenger left in the vehicle.

- 1st alert
  - When you open the front door after opening and closing the rear door and turning off the engine, the "Check rear seats" warning message appears on the cluster.
- 2nd alert
  - After the 1st alert the 2nd alert operates when any movement is detected in the vehicle after the driver's door is closed and all the doors are locked. The horn will activate for about 25 seconds. If the system continues to detect a movement the alert operates up to 8 times.
  - Unlock the door with the remote key or smart key to stop the alert.
  - The system detects movement in the vehicle for 24 hours after the door is locked.
- The 2nd alert is activated only after the prior activation of the 1st alert.
- You can activate or deactivate the Rear Occupant Alert (ROA) system from the User Settings mode in the cluster LCD display. The option can be found under the following menu:

  User Settings → Convenience → Rear Seat Alert

(Hyundai, 2018)

APPENDIX D. KIA REAR OCCUPANT ALERT

Rear Occupant Alert (ROA) system (if equipped)

The Rear Occupant Alert (ROA) is provided to help prevent exiting the vehicle with a rear passenger left in the vehicle.

- 1st alert
  - When you open the front door after opening and closing the rear door and turning off the engine, the "Check rear seats" warning message appears on the cluster.
- 2nd alert
  - After the 1st alert the 2nd alert operates when any movement is detected in the rear seat after the driver's door is closed and all the doors are locked. The horn will activate for about 25 seconds. If the system continues to detect a movement the alert operates up to 8 times.

4 — 21

4

  - Unlock the door with the remote key or smart key to stop the alert.
  - The system detects movement in the vehicle for 24 hours after the door is locked.

The 2nd alert is activated only after the prior activation of the 1st alert.

You can activate or deactivate the ROA from the User Settings mode in the cluster LCD display. The option can be found under the following menu:

User Settings → Convenience → Rear Occupant Alert

CAUTION

- Make sure that all the windows are closed. If the window is open, the alert may activate by the sensor detecting an unintended movement (e.g., wind or bugs).

Cluster

Steering wheel

- If you do not want to use the Rear Occupant Alert (ROA) system, press OK button on the steering wheel when the 1st alert is displayed on the cluster. Doing so will deactivate the 2nd alert once.
- If boxes or objects are stacked in the vehicle, the system may not detect the obstacle. Also, the warning may generate if the box or object falls off.
- The sensor may not operate normally if the senor is obscured by foreign substances.
- The alert may activate if movement in the driver or passenger seat is detected.
- The alert may activate with the doors locked due to car wash or surrounding vibration or noise.
- Inside movement detection is stopped under remote start (if equipped) status.

(Kia, 2019).

APPENDIX E. NISSAN OWNER'S MANUAL

REAR DOOR ALERT

The Rear Door Alert system functions under certain conditions to indicate there may be an object or passenger in the rear seat(s). Check the seat(s) before exiting the vehicle.

The Rear Door Alert system is initially disabled. The driver can enable the system using the vehicle information display. For additional information, refer to "Vehicle information display warnings and indicators" in this section.

When the system is enabled:

- The system is activated when a rear door is opened and closed approximately 10 minutes before the vehicle is started. When the vehicle is started and the system is activated, a visual message appears in the vehicle information display. For additional information, refer to "Rear Door Alert is activated" in this section.
- If a rear door is opened and closed but the vehicle is not started within approximately 10 minutes, the system will not be activated. A rear door must be opened and closed and the car started within 10 minutes for the system to activate.

When the Rear Door Alert system is activated:

- When the driver puts the vehicle in the P (Park) position, a notification message appears in the vehicle information display with the options to "Dismiss Message" or "Disable Alert" if desired.
  - Select "Disable Alert" to temporarily disable for that stop.
  - No selection or "Dismiss Message" will keep the alert enable for that stop.
- If the alert is enabled when a driver exits the vehicle, a message will appear in the vehicle information display that states "Check Rear Seat for All Articles."

  If "Horn & Alert" setting is selected:
  - An audible horn sound will occur after a short time unless a rear door is opened and closed within a short time to deactivate the alert.
  - If the doors are locked before the alert is deactivate by opening a rear door, the horn will sound.
  - If the trunk is opened before a rear door is opened, the horn will be delayed until after the liftgate is closed.

NOTE:

If "Alert Only" setting is selected, the message alert will still be shown in the vehicle information display but the horn will not sound.

⚠ WARNING

- **If the driver selects "Disable Alert", no audible alert will be provided regardless of rear door open/close status.**
- **There may be times when there is an object or passenger in the rear seat(s) but the audible alert does not sound. For example, this may occur if the engine is turned off and then on again in a short period of time during a trip, or if rear seat passengers enter or exit the vehicle during a trip.**
- **The system does not directly detect objects or passengers in the rear seat(s). Instead, it can detect when a rear door is opened and closed, indicating that there may be something in the rear seat(s).**

Instruments and controls 2-59

(Nissan, 2019).

APPENDIX F. VOLVO OWNER'S MANUAL: PERSONAL CAR COMMUNICATOR HEARTBEAT SENSOR

02 Locks and alarm

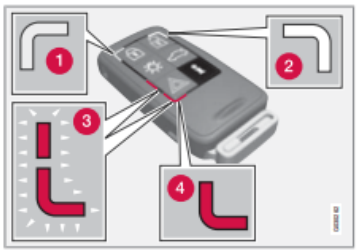
Remote key and key blade

02

NOTE

If none of the indicator lights flash when the information button has been pressed several times from different places in relation to the vehicle, contact an authorized Volvo service technician.

The indicator lights 2 provide information according to the illustration:



1. Steady green light: the vehicle is correctly locked.
2. Steady yellow light: the vehicle is not locked.
3. Alternatively flashing red lights (Heartbeat sensor): if the two heartbeat sensor lights flash, this indicates that someone may be inside the vehicle. These lights are only activated if the alarm has been triggered.
4. Steady red light: the alarm has been triggered.

Range

The PCC's lock and unlock functions have a range of approximately 60 ft. (20 m) from the vehicle.

NOTE

- The approach lighting, panic alarm, and the functions controlled by the information button have a range of approximately 300 ft (100 m) from the vehicle.
- Buildings or other obstacles may interfere with the function of the PCC.

Outside of the PCC´s range

If the PCC is more than approximately 300 ft (100 m) from the vehicle when the information button is pressed, no new information will be received. The PCC most recently used to lock or unlock the vehicle will show the vehicle's most recently received status. The indicator lights will not flash when the information button is pressed while the PCC is out of range.

If more than one PCC is used to lock/unlock the vehicle, only the one used most recently will show the correct locking status.

NOTE

If none of the indicator lights illuminate when the information button is pressed, this may be because the most recent transmission between the vehicle and the PCC was interrupted or impeded by buildings or other objects.

Heartbeat Sensor

The heartbeat sensor function 3 is a complement to the vehicle's standard alarm, and indicates at a distance of up to 300 ft (100 m) that someone may be in the vehicle. The heartbeat sensor only functions if the alarm has been triggered.

NOTE

The heartbeat sensor registers a person's heartbeat in the form of vibrations in the vehicle's chassis. For this reason, the sensor's function may be impaired in areas with high levels of noise or vibrations.

Keyless drive

Vehicles equipped with the optional Personal Car Communicator have the keyless drive

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(Volvo, 2008).

APPENDIX G. VITASENSE INFORMATION

VitaSense

a sense for innovation

emitted signal

reflected signal

Detecting forgotten children

To combat this problem, IEE has developed VitaSense – the world's first vehicle-based sensing system to detect at-risk unattended children. VitaSense detects the breathing of sleeping children who are at risk of being entrapped, and this information can be used by the vehicle to warn parents or other adults that there is a child still in the vehicle. This type of warning can help prevent children dying from vehicular heatstroke.

A radio frequency-based solution

VitaSense uses radio technology to detect vehicle occupants based on their movements.
The transmitter emits radio signals that are reflected by objects or occupants. Because an occupant moves, the signal he or she reflects is different from that of an inanimate object. This allows VitaSense to discriminate between a person and an object, based on the pattern of the reflected signal. Quite simply, objects are not detected as people.

VitaSense is able to detect even minor movements of vehicle occupants. In fact, it is so sensitive that it can detect the breathing of sleeping babies.

A safe technology

VitaSense operates in the ISM band (24 GHz), a radio frequency used for industrial, scientific, and medical applications. At this frequency, the low-power radio signals are reflected by the human body – making it the ideal technology for the interior motion detector.
In operation, the power transmitted by the system is a mere 4 mW (milliwatts) – a fraction of what other devices send out. In comparison, a Wi-Fi connection emits around 100 mW and a cell phone between 500 and 1,000 mW.

About Us

IEE is a worldwide pioneer in passenger presence detection and one of the leading suppliers of advanced automotive interior sensing solutions. Founded in 1989 and headquartered in Luxembourg, it has operations in Europe, America and Asia. The innovation driven company has a long history in developing and manufacturing cutting-edge sensing systems for automotive industry, building management and eHealth. IEE employs 4,100 people worldwide and more than 10% of the company's workforce is engaged in Research & Development.
For more information, please visit **www.iee.lu**

VitaSense

a sense for innovation

Vehicular heatstroke can be fatal

Each year, on average 37 children die of vehicular heatstroke in the U.S. And, although exact numbers are not recorded, even more children suffer disabilities due to organ or brain damage.

Even though it seems unthinkable to forget a child in car, a review of the incidents shows that distraction, a change in the daily routine, or misunderstandings play a major role. It can potentially happen to anybody. When children were intentionally left in the car, the caregiver either ignored the risk of leaving a child inside a car, or it simply took them longer to get back to the vehicle than initially planned.

These incidents are not merely a U.S. phenomenon. Although a lack of comprehensive databases masks the problem to a certain extent, there are documented cases of fatalities in other parts of the world as well.

Vita Sense

Key Advantages

- **High sensitivity:** VitaSense is sensitive enough to detect the minor movements of a sleeping baby
- **Independence:** VitaSense works independently of any child restraint system (CRS) and is therefore not dependent on correct use and installation
- **Robust sensing technology:** VitaSense is not impacted by clothing or blankets, and is even capable of detecting a child through the sunshade of a rear-facing CRS
- **Flexibility:** As VitaSense is integrated into the vehicle, a number of warning and notification options can be implemented, depending on the vehicle's capabilities

(VitaSense, 2018).

REFERENCES

Alunni, V., Crenesse, D., Pierccechi-Marti, M., Gaillard, Y., & Quatrehomme, G. (2015). Fatal heat stroke in a child entrapped in a confined space. *Journal of Forensic and Legal Medicine, 34,* 139-144.

Amazon. (n.d.). Ride N Remind - Back Seat Reminder System. Retrieved from https://www.amazon.com/Ride-Remind-Reminder-Professional-installation/dp/B018RLACN8/ref=sr_1_1?keywords=ride+n+remind&qid=1556620144&s=gateway&sr=8-1-spell

Arbogast K. B., Belwadi, A., & Allison, M. (2012). *Reducing the potential for heat stroke to children in parked motor vehicles: Evaluation of reminder technology* (DOT HS 811 632). Washington, DC: National Highway Traffic Safety Administration.

Arguad, L., Ferry, T., Le, Q., Marfisi, A., Ciorba, D., Achache, P…Robert, D. (2007). Short- and long-term outcomes of heatstroke following the 2003 heat wave in Lyon, France. *Journal of the American Medical Association, 167*(20), 2177-2183.

Aviso Reminder. (2017). The Aviso Child-in-Car alert. Retrieved from http://avisoreminder.com/

Baby Alert International. (2019). Retrieved from https://www.babyalert.info/

Bouchama, A., & Knochel, J. (2002). Heat stroke. *New England Journal of Medicine, 346,* 1978-1988.

Brilliant Backseat Reminder System. (2019). Retrieved from https://www.rearviewsafety.com/brilliant-backseat-reminder-system-rvs-blb.html

Canada Safety Council. (2019). Hot car warning. Retrieved from https://canadasafetycouncil.org/hot-car-warning/

CBS News. (2018). Mom who left kids in hot car to “teach them a lesson” gets max sentence in their deaths. Retrieved from https://www.cbsnews.com/news/mom-who-left-kids-in-hot-car-to-teach-them-a-lesson-gets-max-sentence-in-their-deaths/

Child Accident Prevention Foundation of Australia. (2019). Kidsafe Victoria. Retrieved from http://www.kidsafevic.com.au/

Congress. (2019a). Hot Cars Act 2019 S. 1601. Retrieved from https://www.commerce.senate.gov/public/_cache/files/ea5577f0-efe0-4c7d-b116-02dd0c25ea73/3A9C1E7140037D82EDFF5A77A389FDBF.edw19596.pdf

Congress. (2019b). Hot Cars Act 2019 H.R. 3593. Retrieved from https://timryan.house.gov/sites/timryan.house.gov/files/HOT%20CARS%20Act%202019.pdf

Dematte, J., O'Mara, K., Buescher, J., Whitney, C., Forsythe, S., McNamee, T., … Ndukwu, M. (1998). Near-fatal heat stroke during the 1995 heat wave in Chicago. *Annals of Internal Medicine,129*(3), 173-181.

Diamond, D. (2019). When a child dies of heatstroke after a parent or caretaker unknowingly leaves the child in a car: How does it happen and is it a crime? *Medicine, Science and the Law, 59*(2), 115-126.

Driver's Little Helper. (n.d.). Retrieved from https://www.amazon.com/Monitor-Drivers-Little-Helper-869188000116/dp/B018WLTHTI

Elepho. (n.d.). eClip baby reminder for your car. Retrieved from https://elepho.com/product/eclip-baby-reminder-for-your-car/

European Child Safety Alliance. European Child Safety Alliance. (2019). Retrieved from childsafetyeurope.org

Ferrara, P., Vena, F., Caporale, O., Del Volgo, V., Liberatore, P, Ianniello, F., Chiaretti, A., … Riccardi, R. (2013). Children left unattended in parked vehicles: A focus on recent Italian cases and a review of literature. *Italian Journal of Pediatrics, 39*(1), 71.

Garcia-Souto, M., & Dabnichki, P. (2016). Core and local skin temperature: 3-24 months old toddlers and comparison to adults. *Building and Environment, 104*, 286-295.

General Motors. (2018). Acadia/Acadia Denali owner's manual. Retrieved from: https://my.gmc.com/content/dam/gmownercenter/gmna/dynamic/manuals/2019/GMC/acadia/2019-gmc-acadia-owners-manual.pdf

Grundstein, A., Dowd, J., & Meentemeyer, V. (2010). Quantifying the heat-related hazard for children in motor vehicles. *Bulletin of the American Meteorological Society, 91*, 1183-1192.

Grundstein, A., Duzinski, S., & Null, J., (2017). Impact of dangerous microclimate conditions within an enclosed vehicle on pediatric thermoregulation. *Theoretical and Applied Climatology, 127*, 103-110.

Guard, A., & Gallagher, S. (2005). Heat related deaths to young children in parked cars: An analysis of 171 fatalities in the United States, 1995–2002. *Injury Prevention, 11*, 33-37.

Hoffman, J. (2001). Heat-related illness in children. *Clinical Pediatric Emergency Medicine, 2*(3), 203-210.

Hyundai. (2018). Hyundai owner's manual. Retrieved from https://owners.hyundaiusa.com/content/dam/hyundai/us/myhyundai/glovebox-manual/2019/santa-fe/2019%20TM%20OM.pdf

Hyundai News. (2017). Hyundai motor announces new rear occupant alert reducing child heat hazards. Retrieved from https://www.hyundainews.com/en-us/releases/2383

Kars4Kids. (n.d.). Kars4Kids Safety app - Never forget your kid in the car. Retrieved from https://www.kars4kids.org/safety-app/

Kia. (2019). 2020 Telluride owner's manual. Retrieved from https://di-uploads-pod4.dealerinspire.com/lawrencekia/uploads/2019/01/2020-Telluride-Owners-Manual-compressed-bw.pdf

Kids and Cars. (2019). Retrieved from https://www.kidsandcars.org/

King, K., Negus, K., & Vance, J. (1981). Heat stress in motor vehicles: A problem in infancy. *Pediatrics, 68*(4), 579-582.

Lambert, F. (2019). Tesla releases "Dog Mode" to keep your puppies safe and cool inside their cars. Retrieved from https://electrek.co/2019/02/13/tesla-dog-mode-2/

McLaren, C., Null, J., & Quinn, J. (2005). Heat stress from enclosed vehicles: Moderate ambient temperatures cause significant temperature rise in enclosed vehicles. *Pediatrics, 116*(1), e109-e112.

Monticello, M. (2018). 2019 Hyundai Santa Fe Rear Occupant Alert aims to protect kids from hot cars. *Consumer Reports*. Retrieved from https://www.consumerreports.org/car-safety/hyundai-santa-fe-rear-occupant-alert-aims-to-protect-kids-from-hot-cars/

Mousel, T., Larsen, P., & Lorenz, H. (2017). Unattended children in cars–radiofrequency-based detection to reduce heat stroke fatalities. Proceedings from the *25th International Technical Conference on the Enhanced Safety of Vehicles (ESV) National Highway Traffic Safety Administration, Detroit, MI*.

National Center for Statistics and Analysis. (2009). *Not-in-traffic surveillance 2007- Highlights*. (Traffic Safety Facts. Report No. DOT HS 811 085). Washington, DC: National Highway Traffic Safety Administration.

National Safety Council. (2019). Kids and hot cars. Retrieved from https://www.nsc.org/road-safety/safety-topics/child-passenger-safety/kids-hot-cars?utm_source=hs_email&utm_medium=email&utm_content=71585120&_hsenc=p2ANqtz-_ZHBg5Cl2mXDbjWrt1rsrdwQZT4tWyWC9QcnN5Pnk0QZRTyRXI2B1IrY7rbt4nWwq-SrDaZCIlj57AKI8vKWKhoT4oIw&_hsmi=71585120

NBC12. (2018). Mom in hot car death: "It never crossed my mind until I got off." Retrieved from http://www.nbc12.com/story/38875205/mother-who-left-boy-in-hot-car-says-childs-death-was-accident/

Never Forget Us. (2017). Never4get.us!. Retrieved from http://www.never4get.us/

Nissan. (2019). 2019 Rogue owner's manual and maintenance operation. Retrieved from: https://owners.nissanusa.com/content/techpub/ManualsAndGuides/Rogue/2019/2019-Rogue-owner-manual.pdf

Nissan News. (2018). Rear door alert technology to become standard on all four-door Nissan nameplates. Retrieved from https://nissannews.com/en-US/nissan/usa/releases/rear-door-alert-technology-to-become-standard-on-all-four-door-nissan-nameplates

Null, J. (2019). Heatstroke deaths of children in vehicles. Retrieved from https://www.noheatstroke.org

Olea Sensor Networks. (2019). Connected car. Retrieved from https://www.oleasys.com/connected-car

Ride and Remind. (n.d.). Ride & Remind Backseat Reminder System. Retrieved from http://ridenremind.com/

Rudd, R., Prasad, A., Weston, D., & Wietholter, K. (2015). *Functional assessment of unattended child reminder systems* (Report No. DOT HS 812 187). Washington, DC: National Highway Traffic Safety Administration.

Sense A Life. (n.d.). Retrieved from https://www.sensealife.com

Tesla. (2018). Model X owner's manual. Retrieved from https://www.tesla.com/sites/default/files/model_x_owners_manual_north_america_en.pdf

Thomas, E. (2017, July). GM's child-reminder feature is a simple, clever way to save lives; the carmaker has added it to several models. Retrieved from https://www.consumerreports.org/car-safety/gm-child-reminder-feature-simple-clever-way-to-save-lives/

Truefit I Alert Car Seat. (2013). Retrieved from https://vimeo.com/65068524

Tsuzuki-Hayakawa, K., Tochihara, Y., & Ohnaka, T. (1995). Thermoregulation during heat exposure of young children compared to their mothers. *European Journal of Applied Physiology, 72,* 12-17.

Vanos, J., Middel, A., Poletti, M., & Selover, N. (2018). Evaluating the impact of solar radiation on pediatric heat balance within enclosed, hot vehicles. *Temperature, 5*(3), 276-292.

Vitasense. (2018). Vitasense. Retrieved from https://www.iee.lu/media/5ba113380e1f6_180620-fs-vitasense-print-us-letter-web.pdf

Volvo. (2003). Volvo personal communicator. Retrieved from https://www.media.volvocars.com/us/en-us/media/pressreleases/941

Volvo. (2008). Volvo V70 and XC70 owner's manual: Web edition. Retrieved from https://volvornt.harte-hanks.com/manuals/2009/2009_V70/V70_XC70_OM_US_MY09-web.pdf

Williams, C., & Grundstein, A. (2018). Children forgotten in hot cars: A mental models approach for improving public health messaging. *Injury Prevention, 24*(4), 279-287.

Zonfrillo, M., Ramsay, M., Fennell, J., & Andreasen, A. (2018). Unintentional non-traffic injury and fatal events: Threats to children in and around vehicles. *Traffic Injury Prevention, 19*(2), 184-188.