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

www.nhtsa.gov

DOT HS 811 632 July 2012

Reducing the Potential for Heat Stroke to Children in Parked Motor Vehicles: Evaluation of Reminder Technology

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 contents or use thereof. If trade names, manufacturers' names, or specific 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.

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT HS 811 632		

4. Title and Subtitle	5. Report Date
Reducing the Potential for Heat Stroke to Children in Parked Motor Vehicles: Evaluation of Reminder Technology	July 2012
	6. Performing Organization Code
7. Author(s) Arbogast, K. B., Belwadi, A., Allison, M.	8. Performing Organization
9. Performing Organization Name and Address Center for Injury Research and Prevention, Children's Hospital of Philadelphia 3535 Market Street, Suite 1150 Philadelphia, PA 19104	10. Work Unit No. (TRAIS) 11. Contract or Grant No. DTNH22-11-P-01309
12. Sponsoring Agency Name and Address National Highway Traffic Safety Administration Office of Applied Vehicle Safety Research 1200 New Jersey Avenue SE. Washington, DC 20590	13. Type of Report and Period Final Report 14. Sponsoring Agency Code

15. Supplementary Notes

Rodney Rudd was the Contracting Officer's Technical Representative (COTR) for this project.

16. Abstract

The primary objective of the study was to evaluate products that are designed to prevent children up to 24 months old from being left behind in closed, parked vehicles – a scenario that can result in heat stroke. This preliminary assessment was the first of its kind to evaluate this kind of product. The efficacy of heat stroke prevention technologies in sensing the presence of a child in a child restraint and alerting the caregiver if he or she walks away from the car without removing the child was evaluated. The study also examined the effects of child posture and the time/child movement associated with a typical commute on the efficacy of these devices.
It was found that across different evaluations, the devices were inconsistent and unreliable in their performance. They often required adjusting of the position of the child within the child restraint. The distance to activation varied across trials and scenarios, and the devices experienced continual synching/unsynching during use. For some of the devices evaluated, issues such as interference with other electronic devices and inability to function in the presence of liquids were common. In sum, the devices require considerable effort from the parent/caregiver to ensure smooth operation, and often that operation is not consistent.

17. Key Words	18. Distribution Statement
Heat stroke, hyperthermia, child restraint, reminder, notification	Document is available to the public from the National Technical Information Service www.ntis.gov

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22.
Unclassified		43	

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

Principal Investigator: Kristy B. Arbogast, Ph.D.

Co-Investigator: Aditya Belwadi, Ph.D.

Student: Mari Allison, B.S.

Abstract:

A total of 527 heat-stroke-related fatalities to children left in cars have been reported since 1998. On average, 38 children have died annually via this mechanism since 1998. In 2011, 33 such cases were reported (Null, 2012). There has been a recent rise in demand for technologies to prevent these deaths by reminding the caregiver that the child is in the car, as about half of these children have inadvertently been forgotten.

The primary objective of the study was to evaluate products which claim they are designed to prevent children up to 24 months old from being left behind in closed, parked vehicles, which have the potential to result in heat stroke. This preliminary assessment was the first of its kind to evaluate this kind of product. The efficacy of heat stroke prevention technologies in sensing the presence of a child in a child restraint and alerting the caregiver if he or she walks away from the car without removing the child was evaluated. The study also examined the effects of child posture and the time/child movement associated with a typical commute on the efficacy of these devices.

The study was divided into three phases. In the first phase, a detailed market assessment (via the Internet, contact with child passenger safety advocacy organizations, identification from lay press news stories, and direct contact from device inventors) was conducted to tabulate existing devices/technology on the market that are designed for heat stroke prevention. The second phase involved a systematic evaluation of several of these devices for a defined set of performance criteria. System, notification, and behavioral effectiveness for each device were evaluated across a range of surrogate occupant weights, child restraints, spilled liquids, and misuse scenarios. Finally, in a controlled, ventilated vehicle environment, human volunteer subjects were buckled in child restraints instrumented with one of three heat stroke prevention devices (identified for testing from phase II) and status of device activation and caregiver notification were recorded. Assessment was made twice – first immediately after the child was positioned in the parked vehicle, and then again after one of the investigators had driven a predetermined route to simulate a typical commute and parked the vehicle again.

In phase one, 18 technologies for heat stroke prevention were identified. Of these, three devices, the Suddenly Safe Pressure Pad, the ChildMinder Smart Clip System, and the ChildMinder Smart Pad were chosen to be further evaluated in the second and third phases of the study as they were the devices, currently on the market, that had technology that sensed the presence of a child in a child restraint.

In phase two, the three devices chosen were put through a battery of tests. The devices were evaluated with three convertible restraint seats and one infant child restraint, selected based on diversity of the cushion depth and seat pan contour. The products' sensing limits and ability to detect a child versus items of similar weights were determined. Further, misuse scenarios and

notification distance with interference such as a radio or a cell phone were established. Finally, liquids such as apple juice and saline were spilled on the devices to establish activation distances and working thresholds.

Phase three consisted of testing the devices with pediatric volunteer subjects statically and in a commute-simulation in a minivan. Guided by an Institutional Review Board-approved protocol, eight subjects were recruited meeting the following inclusion criteria: newborns (weight 3.5 to 6 kg; age 0 to 6 months), 1-year-old (weight 9.6 to 11.1 kg; age 9 to 15 months) and 2-year-old (weight 11.8 to 13.6 kg; age 21 to 27 months).

It was found that across different evaluations, the devices were inconsistent and unreliable in their performance. They often required adjusting of the position of the child within the child restraint, the distance to activation varied across trials and scenarios and they experienced continual synching/unsynching during use. For some of the devices evaluated, issues such as interference with other devices, inability to function in the presence of liquids, and variability in performance in the presence of a cell phone were common. In sum, the devices require considerable effort from the parent/caregiver to ensure smooth operation and often that operation is not consistent.

Public health principles state that a passive device is often more effective than an active device. Even in the context of ideal performance, these interventions require several active steps: (1) purchase, (2) proper installation, (3) proper use including transfer of key fob among caregivers, and (4) action by caregiver once successfully notified. None directly address the root cause of the hot environment that led to the potential for heat stroke.

Most important, it should be noted that these devices which integrate into a child restraint would not be applicable in scenarios where the child is playing and gets locked in the vehicle (30% of fatalities) or in a scenario where the parent/caregiver intentionally leaves the child in the vehicle (17% of fatalities) (Null, 2012).

Until the proposed technology can improve its performance and limit the actions required by the caregiver for correct use, it is likely that education of this potentially harmful event to the parent/caregiver can play a more significant role in reduction of heat-stroke-related fatalities.

1. Introduction

Heat stroke occurs when the body is unable to dissipate the heat that it produces and absorbs in situations of exposure to high temperatures, such as being trapped in an enclosed vehicle parked outdoors after being left unattended.

Magnitude of the problem:

The National Highway Traffic Safety Administration has started to collect information on such occurrences through its Not-in-Traffic Surveillance (NiTS) System. NiTS is a virtual data collection system, and its non-crash fatality component was based on data obtained from the Centers for Disease Control and Prevention's National Vital Statistics System (NVSS). Through its NiTS data collection system, NHTSA released statistics based on data from 2003 and 2004 and found that heat stroke is the most common non-traffic fatality scenario for children 14 and younger, accounting for 27 deaths per year according to the 2003-2004 data (NHTSA, 2009). The next release is scheduled for 2013.

Since 1990, Jan Null of San Francisco State University has been collecting media-based reports to abstract details on child fatalities due to vehicle-related heat stroke, since local news outlets frequently report on their occurrence (Null, 2012). Null estimates that in the United States, between 1998 and 2009, 494 children (approximately 37 children per year) have died when left unattended in hot vehicles. In 2010, 49 children died of heat stroke in automobiles in the United States and an additional 33 died in 2011, based on his unverified accounting.

Circumstances around the deaths:

More than half of the heat stroke deaths in cars that Null found between 1998 and 2009 were children under two years of age. Based on an examination of the media reports used to compile the data, Null concluded that the caregiver had forgotten 51 percent of the children, 30 percent of the children were playing in an unattended vehicle, and an adult intentionally left 17 percent of the children in the vehicle.

An additional source of field data, though not considered nationally representative, comes in the form of case studies that include anecdotal findings. Krous et al. (2001) included 10 child heat stroke cases collected from Southern California and South Australia; 8, which occurred in vehicles, while the other 2 occurred in beds. The cases had differing levels of detail, though some occurred with as little as one hour of exposure (3-month-old twins) where the measured body temperature had reached 42.2° C (108° F). Another study performed comprehensive media searches spanning an 8-year period using specific keywords, and researched cases of children 5 and younger (Guard and Gallagher, 2005). Their search yielded 171 fatalities, though an additional 4 cases were found involving children 6 and older. Of the 171 fatalities, 73 percent were children who had been left in a parked vehicle and 27 percent were children who gained access to a parked vehicle while playing. Of those children left behind by adults, 54 percent were forgotten and 27 percent were left intentionally, with circumstances in 18 percent of the cases being undetermined. Booth et al. (2010) compiled data from 231 child motor vehicle heat stroke fatalities that occurred between 1997 and 2007. Data were collected from the CDC's Compressed Mortality File and from Null's database at San Francisco State University. Thirty percent of the children were less than one year of age and 64 percent were from one to four years of age. In 25 percent of the cases, the children had been playing near or inside a vehicle before entering the vehicle and dying. Of the children left unattended, 76 percent were unintentional and 13 percent were confirmed as being intentionally left behind. Most of the cases (55.8%) occurred in the south, with the western part of the country accounting for 23.4 percent.

While child deaths from automobile-related heat stroke occur at a lower rate than those from traffic crashes, the nature of these deaths warrants attention. Children are at increased risk of vehicle-related heat stroke compared to adults for two reasons: First, children are more likely than adults to be left unattended and unable to exit a parked vehicle, and second, children's bodies are less able to manage the hot surroundings that can develop quickly in a parked automobile.

Several technologies have been designed to integrate with child restraints to detect the presence of a child in the child restraint and then notify the caregiver when they have left the vehicle without removing the child from the restraint. The overall objective of this study is to evaluate these currently available technology approaches designed to prevent children up to 24 months old from being left behind in closed, parked vehicles, which has the potential to result in heat stroke.

2.0 Market Assessment

A market assessment was performed via Web searches and consultations with child passenger advocacy organizations to identify the technology approaches available on the market today to prevent children from being left in closed, parked vehicles. This survey was limited to technology that is currently commercially available or enough details were available from the manufacturer to understand its function. The devices are listed in Table 1 below specifically highlighting if and how they sense the presence of a child. Note that this assessment was performed in summer 2011 and represents the market at that point in time. Other devices may have been introduced and/or these devices may have been removed from the market since the evaluation was completed.

Table 1: List of heat stroke prevention technologies

#	Product Name	Sensing Parameter
1	ChildMinder Smart Pad System	Pressure/force in child restraint
2	Deluxe Padded Safety Seat Alarm System	Pressure/force in child restraint
3	SafeBABI	Pressure/force in child restraint
4	*Child Presence Sensor	Pressure/force in child restraint
5	*Halo Baby Seat Safety System	Pressure/force in child restraint
6	*Car Seat Monitor	Pressure/force in child restraint
7	*Forget-Me-Not Car Seat System	Pressure/force in child restraint
8	*CAREseat Car Seat System Vehicle-based warning	Vehicle-based warning (Seat belt buckle)
9	BackSeat Minder	Time that the rear door was opened (vehicle-based)
10	Child Minder Smart Clip System	Buckled chest clip on child restraint
11	*Small Ones Safety (SOS)	Buckled chest clip on child restraint
12	Caregiver Reminder Bracelet	No sensing capability
13	Baby Bee Safe	No sensing capability
14	Toddler Wristband Safe "N" Secure Alarm System	No sensing capability
15	Toddler Wristband Safe "N" Secure Alarm System with parent alert button	No sensing capability
16	Baby Talk GPS Child Tracker	No sensing capability
17	*The Life Warn System	Vehicle Integrated System
18	Kiddie Voice Child Reminder	Vehicle Integrated System

* Concepts not brought to market (at the time of this report)

Eighteen products were identified with 11 of the 18 being commercially available. Those not commercially available are marked with an asterisk. Each technology is summarized below.

2.1 ChildMinder Smart Pad System ($69.95) - Pressure/force-based system

The ChildMinder Smart Pad System (Baby Alert International, Dallas, TX) is a passive child safety seat monitoring system comprised of the Smart Pad (sensing pad 152x101x4 mm; pad cover 198x130x23 mm), system base unit and a Key Ring Alarm Unit (Figure 1).

Figure 1: ChildMinder Smart Pad System
(www.babyalert.info/index.php?main_page=product_info&cPath=1&products_id=2)

The pad is inserted into the child restraint and senses the presence of a child due to the pressure applied to the sensor. There are five sensors distributed throughout the pad. The Smart Pad should be placed under the cushion of the child restraint. Once the child is seated in the child restraint, the Smart Pad System passively monitors the child in his/her child restraint. The Smart Pad System is activated when a child is seated in the child restraint at which time the base unit will begin to beep, indicating to the caregiver that he or she must synchronize the key ring alarm unit to the base unit. Synchronizing involves pressing and briefly holding a button on the key ring unit while in proximity of the base unit until the system quiets. An alarm sounds in the key fob in six seconds after a parent or caregiver walks more than 15 feet from a vehicle while the child remains seated in the child restraint.

2.2 Deluxe Padded Safety Seat Alarm System ($69.95) - Pressure/force-based system

The Deluxe Padded Safety Seat Alarm System (Suddenly Safe “N” Secure Systems Inc., Bensalem, PA) consists of a sensing pad (160x107x18 mm) that is inserted in the child restraint (under the cushion) and senses the force/pressure that is applied when a child is sitting on it. (Figure 2).

Figure 2: Deluxe Padded Safety Seat Alarm System ([www.shop.Suddenly Safensecuresystems.com/Deluxe-Padded-Safety-Seat-Alarm-System-D-201.htm](www.shop.SuddenlySafensecuresystems.com/Deluxe-Padded-Safety-Seat-Alarm-System-D-201.htm))

A single pressure sensor positioned in the center is contained in the pad. A radio frequency (RF) transmitter is enclosed in a case that contains two AA batteries. The receiver is on a key fob, and once synchronized and armed, emits a loud alarm and vibrates if the caregiver moves out of range. The range can be set from 6 to 50 feet. The synching process involves turning the switch to the synching position and holding it next to the transmitting device that is attached to the sensing pad.

2.3 SafeBABI (Safe Baby Alert Broadcast Interface) - Pressure/force-based system

SafeBABI (Texas Instruments, Dallas, TX) is a switch system that alerts the caregiver through the Texas Instruments eZ430 Chronos watch if a child is left in the child restraint (Figure 3).

Figure 3: SafeBABI
(http://processors.wiki.ti.com/index.php/SafeBABI)

The system is designed so that Texas Instruments CC1110 wireless device on the child restraint continuously transmits the state of a push-button switch placed under the child restraint padding to a Texas Instruments eZ430 Chronos watch. If the watch goes out of the wireless range (about 10 meters) and the last state reported to the watch was "switch closed," indicating that a child was in the seat, an alarm will begin to sound and the watch screen will display "baby."

This product requires extensive programming to function. Per the following Web site http://processors.wiki.ti.com/index.php/SafeBABI, the following steps must be taken:

1) Program the eZ430 watch with the eZ430 code located on the Web site;
2) Program one of the Texas Instruments Mini Wireless evaluation boards with the CC1110 code located on the Web site;
3) Desolder the master switch on the CC1110 evaluation board; and
4) Solder a push-button switch in place of the Master switch.

To operate the system:

1) Press the "#" button on the eZ430 Chronos watch until the word "baby" is displayed on the bottom half of the screen.
2) Press the down arrow on the watch to initiate a connection with the child restraint.
3) Turn on the Mini Wireless Kit attached to the child restraint.
4) When the two devices connect, the watch will display "seat found."
5) Once connected, the watch will now display whether the child is "in" or "out" of the seat.
6) As soon as the watch goes out of range of the wireless development kit (~10 meters), it will sound the alarm if the last message received was the "in" message.

2.4 Child Presence Sensor (*not on the market) - Pressure/force-based system

The child presence sensor (developed by NASA) is a system consisting of a sensor, transmitter, and receiver/alarm that works on a RF principle to notify the caregiver if the child is inadvertently left in the car. The part of the device that is placed in the child restraint is able to detect as little as 8 ounces. The sensor detects weight once the child is placed in the seat, transmitting a unique code to the driver-alarm module via a radio-frequency link. If it detects a child and the driver moves too far away from the car, the system will sound 10 warning beeps through a small device on the driver's key ring. If they do not return within 1 minute, the alarm will continuously sound and cannot be turned off without returning to the car to reset the system. This technology would be expected to retail at $20 to $30. NASA is seeking a partner to license and produce the technology. (www.nasa.gov/centers/langley/news/releases/2002/02-008.html)

2.5 HALO Baby Seat System ($149.00 for pre-order – currently not on market) - Pressure/force-based system

The HALO Baby Seat System (Sisters of Invention, LLC, Lexington, KY) is a pressure pad system designed to activate when a baby is placed in the child restraint (Figure 4).

Figure 4: Halo Baby Seat System
(www.sistersofinvention.com/index.html**)**

The pressure pad is placed under the child restraint cushion. When activated, the system alerts the caregiver through a key fob if he or she gets too far away from the car without removing the child from the child restraint. In addition, the system proposes to monitor vehicle temperature and sound the key fob-based alarm if the vehicle becomes too hot or cold. If the driver does not respond after a pre-determined time, a voice synthesizer in the pad will sound "baby in danger" to let passersby know that there is a child in the car. According to the Web site, there are plans to further upgrade the system to call a guardian's phone number, call 911, and interact with GPS systems. This system requires batteries. Although the product is not currently available, pricing has been set at $149 for the system, $24.95 for additional key fobs, and $53 for additional seat pads.

2.6 Car Seat Monitor (Cars-N-Kids) (*not on market) - Pressure/force-based system

The Car Sear Monitor **(**Cars-N-Kids) is designed to sense both the child's presence in the child restraint and movement of the car (Figure 5).

Figure 5: Car Seat Monitor by Cars-N-Kids
(www.carseatmonitor.com/index.php)

A small sensor pad (credit card sized) is placed under the cushion of the child restraint. The device is synchronized with an app downloaded onto a smartphone (Android OS only). When a child is placed in the child restraint, the associated force activates the device. If the vehicle comes to a stop for more than 4 seconds, the phone vibrates and/or sends a text message. The purpose is to remind the driver that the child is present before he or she gets out of the car. The product is also programmed to sound a short alarm in the event that the child climbs out of the seat during the drive. This device requires batteries. The product retail price is currently unknown.

2.7 Forget-Me-Not Car Seat System (*not on the market) – Pressure/force-based system

The Forget-Me-Not Car Seat System (Bonnie Kenoly: bkenoly@decisionanalyst.com) sounds an alarm when a child or infant is left in the child restraint in the car, when the parent or caregiver has left the car. The system comes with a pad that is inserted under the child restraint cushion, which senses the force that is applied when the child is in the child restraint. The child restraint comes with an alarm that is attached to the parent or caregiver's key ring. When the child is left in the car, and the parent or caregiver gets further than 20 feet from the child restraint, the alarm sounds on their key ring. The alarm can be set to sound at either 10 feet or 20 feet distance.

2.8 Backseat Minder ($139.99, $249.99 with prepaid installation) – Vehicle-based warning system

The Backseat Minder (CSO RADIO, Lakewood, NJ) is based on the concept that placement of a child in a child restraint in the rear rows of the vehicle takes more than 3 seconds. Any time a child is placed in the rear rows of a vehicle, the driver will be forced to open the rear door. The system senses that the door was open more than three seconds and if more than 3 seconds, activates when the car is started. Then when the vehicle is turned off, a distinct chime will sound. The chime can only be turned off by pressing a button located on the inside of the car's rear doors.

The manufacturer claims that it is not possible to seat a child in a car in less than three seconds but one can put a coat or a bag in that time. Opening the door for less than three seconds will not activate the system. The system also will not activate if the car is not started within several minutes after the rear door is opened. This technology must be professionally installed. (www.backseatminder.com)

2.9 CAREseat Car Seat Systems (*not on the market) - Vehicle-based warning system

The CAREseat system is a modified child restraint that integrates with vehicle electronics to remind the caregiver if he or she leaves the child in the car. The system detects whether the child restraint buckle is fastened to determine if there is a child present. When the driver turns the car off, takes the keys out, and opens their door, an audible chime will sound. If at that point the driver locks the car without removing the child, the vehicle's horn will sound, and if there is still no response after about 20 seconds the vehicle's panic alarm will go off. As a last step, the system proposes to contact OnStar so that an operator can send authorities to the vehicle. This technology is not yet on the market and must be integrated with the vehicle electronics. The OnStar component of the proposed device will only work with those vehicles such equipped. (www.careseat.com/index.html)

2.10 ChildMinder Smart Clip System ($69.95) – Child restraint-based warning system

The ChildMinder Smart Clip System (Baby Alert International, Dallas, TX) is designed for a child in a child restraint (Figure 6). The ChildMinder Smart Clip System replaces the child restraint's chest clip. The receiver/key ring alarm unit is placed on an automotive key ring. The system reminds the parent/caregiver with an alarm six seconds after the parent/caregiver has moved more than 15 feet from the child in the child restraint. The manufacturer claims that the ChildMinder Smart Clip System does not compromise the crash protection provided by the child restraint.

Figure 6: Smart Clip System
(www.babyalert.info/index.php?main_page=product_info&cPath=1&products_id=3)

2.11 Small Ones Safety (*not on the market) – Child restraint-based warning system

Small Ones Safety (SWG Safety, Batavia, OH) is designed for a child in a child restraint. (Figure 7) The Small Ones Safety (SOS) system replaces the child restraint's chest clip and is compatible with all North American vehicles built since 1996. Once installed, it requires no further action by the parent or any driver. The device synchronizes with a key fob and reminds the parent/caregiver with an alarm when the key fob is moved a certain distance from the vehicle. Limited details existed as to its specific function.

The SOS system works in a single vehicle, or across a pool of vehicles. It can be moved to another vehicle in seconds, and can track multiple unique seats, with each seat functioning properly in one or many SOS equipped vehicles (Figure 7).

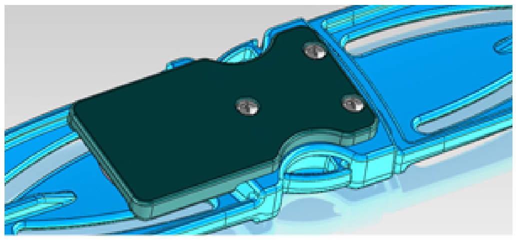
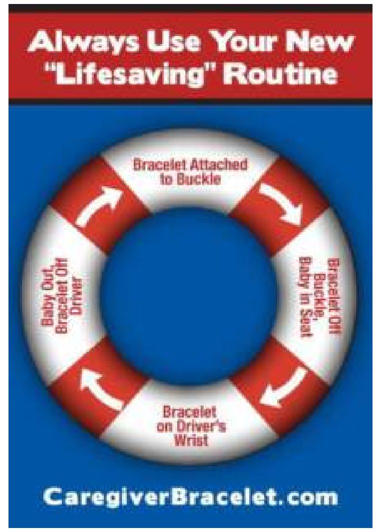


Figure 7: Small Ones Safety (www.swgsafety.com/)

2.12 Caregiver Reminder Bracelet ($9.95) – Reminder only/no sensing system

The Caregiver Reminder Bracelet (manufacturer: John Grago) is a bracelet that can be attached to the buckle of the child restraint when the child is not in the vehicle. Once you place the child in the child restraint, the caregiver wears the bracelet. Once the caregiver reaches his or her destination, the bracelet serves as both a tactile and visual reminder (Figure 8a and 8b). In addition, the aluminum key attaches to the plastic photo holder on the key ring and provides an auditory clue (when moved around). When the child is taken out of the child restraint, the bracelet is placed back on the child restraint buckle.



(a) (b)

Figure 8: (a) Caregiver Reminder Bracelet (b) Bracelet usage routine (www.caregiverbracelet.com)

2.13 Baby Bee Safe Tag ($4.99) – Reminder only/no sensing system

Baby Bee Safe (OLGS, LLC., Sapulpa, OK) is a large tag that is attached to the child restraint when it is unoccupied (Figure 9). The tag is then clipped to the parent or caregivers key ring when their child is placed in the child restraint. The tag is so large that when the keys are removed from the ignition, it is nearly impossible to place it in the pocket or purse without noticing it. It serves as a visual and tactile reminder that the child is still in the vehicle.

Figure 9: Baby Bee Safe (www.babybeesafe.net/default.html)

2.14 Toddler Wristband Safe "N" Secure Alarm System ($29.95) – Distance-based sensing system

The Toddler Safe "N" Secure Alarm System (A-410) (Suddenly Safe "N" Secure Systems Inc., Bensalem, PA) is not specifically a heat stroke prevention technology but is designed to monitor the location of your child relative to a receiver carried by the caregiver (Figure 10).

The transmitter is attached to the child's wrist via the supplied keys so it is not easily removed. If the caregiver goes beyond 6 to 50 feet (desired distance can be set) from the child, the receiver will sound a loud alarm and vibrate. It also has a search mode that can be activated on the receiver to help aid in finding the child if they are hiding or locked in a car.

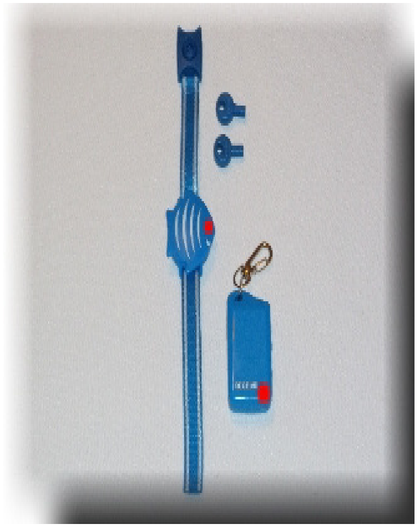


Figure 10: Toddler Wristband Safe "N" Secure Alarm System (www.shop.Suddenly Safensecuresystems.com/Toddler-Wristband-Safe-N-Secure-Alarm-System-A-410.htm)

2.15 Toddler Safe "N" Secure Alarm System with parent alert button

This device also comes in another model that also includes a parent alert button that the child can press in case of need. (Figure 11) Called the Toddler Safe "N" Secure Alarm System with Parent alert button (Suddenly Safe "N" Secure Systems Inc., Bensalem, PA), it sells for $39.95.

Figure 11: Toddler Safe "N" Secure Alarm System with parent alert button (http://www.shop.Suddenly Safensecuresystems.com/Toddler-Wristband-Safe-N-Secure-w-Parent-Alert-Button-in-Blue-PB-501.htm)

2.16 Baby Talk GPS Child Tracker ($124.95) – GPS-based sensing system

Baby Talk GPS Child Tracker (Baby Alert International, Dallas, TX) is also not specifically designed for heat stroke prevention but rather is used to determine if a child has arrived at a predetermined destination such as daycare or preschool. (Figure 12) It is essentially a mobile phone that requires the use of a SIM card. The device is programmed via computer and its internal GPS notifies the caregiver's phone when the child has arrived at the desired destination. The caregiver can also monitor the child by remotely turning on the microphone. The system requires that one phone stays with the child.

Figure 12: Baby Talk GPS Child Tracker (www.babyalert.info/index.php?main_page=product_info&cPath=2&products_id=48)

2.17 Life Warn System (*not on market) – Vehicle-based technology

The Life Warn System is a vehicle-based solution. After the engine is turned off, the system instantly and continuously scans the interior cabin/cargo and trunk space for exhaled carbon dioxide (CO_2). It uses multiple sensors located throughout the cabin space and can sense humans or animals left behind. The system also has the ability to restart the engine, unlock doors, and open the trunk for emergency responders.

2.18 Kiddie Voice Child Reminder ($289.95) – Vehicle-based technology

Kiddie Voice Child Reminder (ATWEC Technologies Inc., Memphis, TN) is a vehicle-based system primarily advertised for school buses. The system integrated with the vehicles' electronic control unit (ECU) and automatically arms itself each time the ignition switch is turned on. The system is activated whenever the ignition key is switched off. An electronic voice warning message begins prompting the driver to check the vehicle for passengers. It can only be deactivated by the driver, walking to the rear interior of the vehicle and manually depressing the cancel button. During this walk to the rear of the vehicle, the driver is prompted to check each seat for occupants. A secondary visual inspection is automatically accomplished as the driver returns to the front of the vehicle to exit. The manufacturer requires the product be fitted by a certified installer. **(**www.kiddievoice.com/**)**

3.0 Evaluation of the Effectiveness of Countermeasures for Heat-Stroke-Related Deaths in Motor Vehicles

The goal of the second task was to develop and implement a methodology to evaluate the effectiveness of currently available technologies for heat stroke fatality prevention in determining the presence of a child, alerting the caretaker, and influencing the behavior of the caretaker. This methodology will address the following research questions:

1. System Effectiveness
    a. Does the system successfully recognize the presence of children of different sizes, ranging from birth to 24 months old?
    b. Is the system compatible with the range of makes and models of child restraints currently on the market?

2. Notification Effectiveness
    a. Does the system successfully notify the responsible party of the presence of the child?
    b. Is the system dependent on the location of the alarm (e.g., on the key fob or on the child restraint) and/or the location of the responsible party (e.g., inside the car,

outside the car, far away from the car)? If so, what is the feasible proximity of effectiveness?

3. Behavioral Effectiveness
    a. Does the system successfully prevent the caretaker from leaving the child in the child restraint?

This effort has been broken down into the following tasks:

- Determine the products' sensing limits and ability to detect a child versus items of similar weight.
- Assess the effect of the following parameters on the products' sensing ability in
    - Misuse scenarios; and
    - Spilled liquids.
- Assess the effectiveness of the notification method of each device.

From Table 1, devices currently on the market that (a) contained sensing technology for the child and (b) did not require vehicle integration were chosen to be further evaluated in the second and third phases of the study. Three devices met these criteria: the Deluxe Padded Safety Seat Alarm System (referred hereafter as "Suddenly Safe Pressure Pad"), ChildMinder Smart Clip System, and ChildMinder Smart Pad.

Three convertible child restraints (Priori Maxi Cosi, The First Years True Fit, and the Safety 1st Complete Air 65) and one infant seat (Chicco Key Fit) were selected based on diversity of seat pan contour and cushion thickness. They were installed as per manufacturer instructions in both forward- and rear-facing orientations in the second row outboard seating position (behind the driver) of a 2006 Chrysler Town and Country minivan. The Chicco Key Fit infant seat was installed in rear-facing position only, with and without the base (Figure 13).

Safety 1st Complete Air 65

Priori Maxi Cosi

The First Years True Fit

Chicco Key Fit infant child seat

Figure 13: Safety 1st Complete Air 65, Priori Maxi Cosi, the First Years True Fit, and the Chicco Key Fit Infant child restraint used in the study

3.1 Determine products' sensing limits and ability to detect a child versus items of similar weights

In analyzing the pressure pad devices (Suddenly Safe Pressure Pad and ChildMinder Smart Pad), first the weight limits of each sensor were quantified. The pressure pad was placed on a hard level surface. A flat board made of high-density polyurethane, measuring 220x150x5 mm, was placed over the entire device to distribute the pressure and weight starting with 0.5 kg was added in half-kg increments until the device was armed. The minimum weight at which each device armed was noted as the products' lower limit of sensing capability (Figure 14). Devices should be able to detect as little as 2 kg (weight of a 5th percentile female at birth) and still function at more than 15 kg (weight of a 95th percentile male at 24 months). This range was chosen as an appropriate range across which such devices should function.

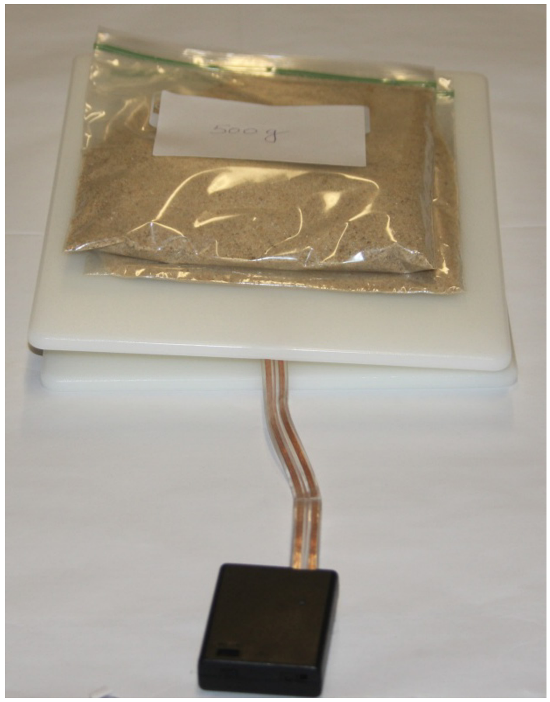


Figure 14: Method for determination of minimum activation weight of each device

The Suddenly Safe pressure pad activated at 1 kg weight while the ChildMinder pressure pad activated at 5 kg weight.

Once the lower limit of sensing capability was determined, each child restraint, properly secured in the vehicle according to manufacturer's instructions, was fitted with each device. A predetermined set of objects were placed in the child restraint one at a time, including a bag of sand weighing 10 kg, a backpack weighing 2.5 kg, and two baby dolls weighted to represent a newborn (3.4 kg, Figure 15a) and a 24-month-old child (12.5 kg, Figure 15b). Arming of the device was evaluated (Table 2) and the process repeated for each technology using eight different child restraint scenarios: one infant seat with and without a base and three convertible seats made by different manufacturers and representing diverse seat bottom profiles assessed in both rear- and forward-facing positions. Activation was assessed after initial placement of the weighted surrogate in the child restraint and if the device did not activate on the initial attempt, the weighted surrogate was shifted around up to three times to attempt to activate the device.

Figure 15a: Newborn (3.4 kg) in a rear-facing Safety 1st Complete Air 65 convertible seat

Figure 15b: 24-month-old child (12.5 kg) in a forward-facing Safety 1st Complete Air 65 convertible seat

Table 2: Activation for each of the pressure pads in different seating configurations

Device	Child Restraint	Object	Armed Status: Rear-Facing	Armed Status: Forward-Facing
Suddenly Safe Pad	Safety 1st Air	Sand Bag (10 kg)	●	●
		Backpack (2.5 kg)	●	●
		Baby Doll (12.5 kg)	●	●
		Baby Doll (3.4 kg)	●	●
	Maxi Cosi	Sand Bag (10 kg)	●	◌
		Backpack (2.5 kg)	⊗	⊗
		Baby Doll (12.5 kg)	⊗	⊗
		Baby Doll (3.4 kg)	⊗	⊗
	First Years	Sand Bag (10 kg)	●	◌
		Backpack (2.5 kg)	⊗	⊗
		Baby Doll (12.5 kg)	⊗	⊗
		Baby Doll (3.4 kg)	⊗	⊗
Child Minder Pad	Safety 1st Air	Sand Bag (10 kg)	●	◌
		Backpack (2.5 kg)	⊗	⊗
		Baby Doll (12.5 kg)	◌	●
		Baby Doll (3.4 kg)	⊗	⊗
	Maxi Cosi	Sand Bag (10 kg)	◌	◌
		Backpack (2.5 kg)	⊗	⊗
		Baby Doll (12.5 kg)	◌	●
		Baby Doll (3.4 kg)	⊗	⊗
	First Years	Sand Bag (10 kg)	●	●
		Backpack (2.5 kg)	●	●
		Baby Doll (12.5 kg)	●	●
		Baby Doll (3.4 kg)	●	●

Device	Child Restraint	Object	Armed Status: Rear-Facing	Armed Status: Rear-Facing Without Base
Suddenly Safe Pad	Chicco Infant	Sand Bag (10 kg)	◌	●
		Backpack (2.5 kg)	◌	◌
		Baby Doll (12.5 kg)	●	●
		Baby Doll (3.4 kg)	●	⊗
Child Minder Pad		Sand Bag (10 kg)	◌	●
		Backpack (2.5 kg)	◌	◌
		Baby Doll (12.5 kg)	●	●
		Baby Doll (3.4 kg)	●	⊗

● Armed at the first attempt ◌ Armed after shifting the object ⊗ Did not arm even after three shifts

3.2 Assess the effect of misuse scenarios on the products' sensing ability

One misuse scenario for the pressure pad technologies may be inappropriate positioning of the device within the child restraint, from either incorrect installation or shifting over time. Therefore, the devices were tested in various positions under the child restraint cushion, including off-center placement towards the lateral edges of the child restraint and positioning further towards the front of the seat, rather than the all the way in the back center of the seat bottom (Figure 16). These assessments were performed with the 12.5 kg doll.

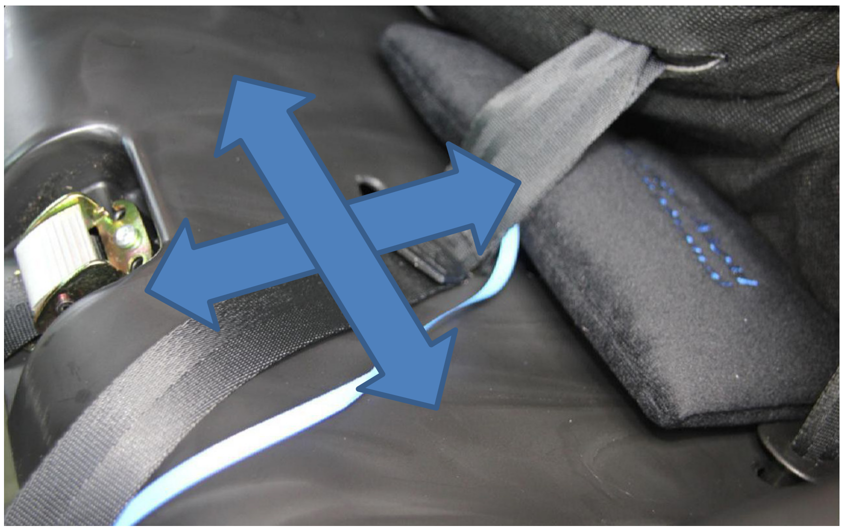


Figure 16: Misuse scenario for the pressure pad (shifted laterally and toward the back of the child restraint)

Table 3: Misuse Scenarios

Device	Child Restraint	Misuse Scenario	Armed Status
Suddenly Safe Pad	Safety 1st Air	Neutral position	🟢
		Lateral shift	🟢
		Backward shift	🔴
	Maxi Cosi	Neutral position	🔴
		Lateral shift	🔴
		Backward shift	🟢
	First Years	Neutral position	🟢
		Lateral shift	🟢
		Backward shift	🟢
	Chicco Infant	Neutral position	🟢
		Lateral shift	🟢
		Backward shift	🟢
Child Minder Pad	Safety 1st Air	Neutral position	🟢
		Lateral shift	◌
		Backward shift	🟢
	Maxi Cosi	Neutral position	◌
		Lateral shift	🔴
		Backward shift	🟢
	First Years	Neutral position	🟢
		Lateral shift	🔴
		Backward shift	◌
	Chicco Infant	Neutral position	🟢
		Lateral shift	🟢
		Backward shift	🟢

🟢 **Armed at the first attempt** ◌ **Armed after shifting the object** 🔴 **Did not arm even after three shifts**

For the ChildMinder Clip, the misuse scenario was that if the clip was put on but not fully clicked into proper position. For all four seats tested, the Clip "did not arm" under this misuse scenario.

3.3 Determine effectiveness of products' notification

In this effort, the products' notification method for each of the three devices was assessed. First, for each of the three devices, the distance the notification device (i.e., key fob) must get from the sensing device (i.e., pressure pad) in order for notification to commence was recorded ("activation distance"). Once the notification device activated, the decibel level of the notification alarm was recorded with the notification device in the investigator's pants pocket using a handheld sound level meter (30-130 dB range). The investigator then retraced his steps and returned to the base unit recording the distance (from the original starting point at the vehicle) at which the notification deactivated ("deactivation distance"). Five trials for each device were carried out, with the distance from base to notification unit being in a straight line from the vehicle without any interposing structure between (Table 4). This assessment was conducted with one of the child restraints – the Safety 1st convertible child restraint and the 12.5 kg doll.

Table 4: Activation distance, deactivation distance and alarm sound level for each of the devices tested using the Safety 1st convertible child restraint

Trial #	Parameters	Suddenly Safe Pad	ChildMinder Pad	ChildMinder Clip
Trial 1	Activation distance (ft.)	138	144	40
	Deactivation distance (ft.)	56	40	0
	Sound level (dB) pocket	74	68	72
Trial 2	Activation distance (ft.)	160	64	56
	Deactivation distance (ft.)	45	40	0
	Sound level (dB) pocket	69	68	74
Trial 3	Activation distance (ft.)	96	70	58
	Deactivation distance (ft.)	78	24	0
	Sound level (dB) pocket	72	68	75
Trial 4	Activation distance (ft.)	150	80	64
	Deactivation distance (ft.)	120	24	0
	Sound level (dB) pocket	68	74	73
Trial 5	Activation distance (ft.)	161	68	46
	Deactivation distance (ft.)	80	20	0
	Sound level (dB) pocket	72	74	74
Average ± S.D.	**Activation distance (ft.)**	**141.0±26.8**	**85.2±33.4**	**52.8±9.7**
	Deactivation distance (ft.)	**75.8±28.7**	**29.6±9.6**	**0.0±0.0**
	Sound level (dB) pocket	**71.0±2.5**	**70.4±3.3**	**73.6±1.1**

Secondly, the role of interposing structures was also evaluated. In these trials, the vehicle was parked near a concrete wall and the "driver" walked around the wall after leaving the car with the base unit in the child restraint (Table 5). The distance recorded was the straight line distance between the base unit and the point at which the notification began.

Table 5: Activation distance behind a concrete wall

Trial #	Activation Distance / Errors	Suddenly Safe Pad	ChildMinder Pad	ChildMinder Clip
Trial 1	Activation distance (ft.)	40	40	40
	Errors	None	None	None
Trial 2	Activation distance (ft.)	72	24	38
	Errors	None	None	None
Trial 3	Activation distance (ft.)	56	52	45
	Errors	None	None	None
Trial 4	Activation distance (ft.)	64	24	42
	Errors	None	None	None
Trial 5	Activation distance (ft.)	56	56	42
	Errors	None	None	None
Average ±S.D.	**Activation distance (ft.)**	**57.6±11.9**	**39.2±13.9**	**41.4±3.8**

Potential interference was assessed by evaluating the activation distance with the vehicle radio on, during an active cell phone conversation and a combination of a radio and an active cellphone. (Table 6)

Table 6: Activation distance with the radio, active cellphone and a combination of both

Interference	Trial #	Activation/Deactivation Distance (ft.)	Suddenly Safe Pad	ChildMinder Pad	ChildMinder Clip
None	**Average of 5 trials (Table 4)**	**Activation distance**	**141.0±26.8**	**85.2±33.4**	**52.8±9.7**
		Deactivation distance	**75.8±28.7**	**29.6±9.6**	**0.0±0.0**
With Radio	Trial 1	Activation distance	138	150	40
		Deactivation distance	120	70	0
	Trial 2	Activation distance	52	52	56
		Deactivation distance	48	20	0
	Trial 3	Activation distance	140	78	36
		Deactivation distance	100	70	6
Average±S.D.		**Activation distance**	**110.0±50.2**	**93.3±50.7**	**44.0±10.5**
		Deactivation distance	**89.3±37.1**	**53.3±28.8**	**2±3.4**
With Cell Phone	Trial 1	Activation distance	100	12	48
		Deactivation distance	90	0	0
	Trial 2	Activation distance	48	49	26
		Deactivation distance	47	30	23
	Trial 3	Activation distance	92	12	38
		Deactivation distance	80	8	33
Average±S.D.		**Activation distance**	**80.0±28.0**	**24.3±21.3**	**37.3±11.1**
		Deactivation distance	**72.3±22.5**	**12.6±15.5**	**18.6±16.9**
With Radio and Cell Phone	Trial 1	Activation distance	46	30	20
		Deactivation distance	44	25	0
	Trial 2	Activation distance	80	30	52
		Deactivation distance	65	0	0
	Trial 3	Activation distance	54	25	16
		Deactivation distance	48	20	0
Average±S.D.		**Activation distance**	**60.0±17.7**	**28.3±2.8**	**29.3±19.7**
		Deactivation distance	**52.3±11.1**	**15.0±13.2**	**0.0±0.0**

3.4 Evaluation of inter-device interference

To test for Type I error, one of the devices (D1) was switched on but not activated/synched, indicating that there is no child in the child restraint; while the other device (D2) was activated and synched and its notification system remained in the vehicle with the sensing unit. As the caregiver walked away with the D1 notification system, we evaluated any false positives on the D2 alert system. To test for Type II error, one vehicle had a system that was not activated (D1), but the notification device (i.e., key fob) was left in the car along with the sensing device. The second vehicle had an activated system (D2), and the D2 driver walked away simulating the driver leaving the child in the seat. (Figure 17) In both scenarios for all three devices, the performance of the notification system of D2 was recorded. Only Suddenly Safe demonstrated any interference error (Table 7).

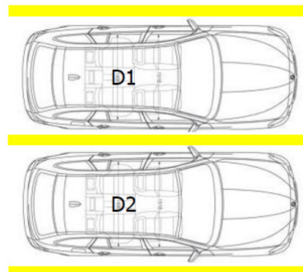


Figure 17: Type I and Type II Errors

Table 7: Device Interference

	Suddenly Safe Pad	ChildMinder Pad	ChildMinder Clip
Type I Error (i.e., D2 alarm went off while it remained in the vehicle with the sensing unit)	**Yes**	No	No
Type II Error (i.e., D2 alarm did not go off even though the notification unit was a distance from the sensing unit)	No	No	No

3.5 Evaluation of effect of liquid spills on device

Finally, in order to evaluate liquid spills, two different spill scenarios were designed and evaluated. In the first scenario, four ounces of apple juice was poured on the controller (pressure pad-based devices) and on the clip. Activation and deactivation distance immediately after the liquid was spilled and every 5 minutes thereafter (for a total of 25 minutes) was recorded (Figure 18). For the second scenario, four ounces of saline solution (to simulate bodily fluids) was poured on the sensing pad (since the probability of bodily fluids seeping onto the pad is greater as the child is seated on it) and on the clip (Figure 19). As in scenario 1, activation and deactivation distance immediately after the event and every 5 minutes thereafter was recorded.

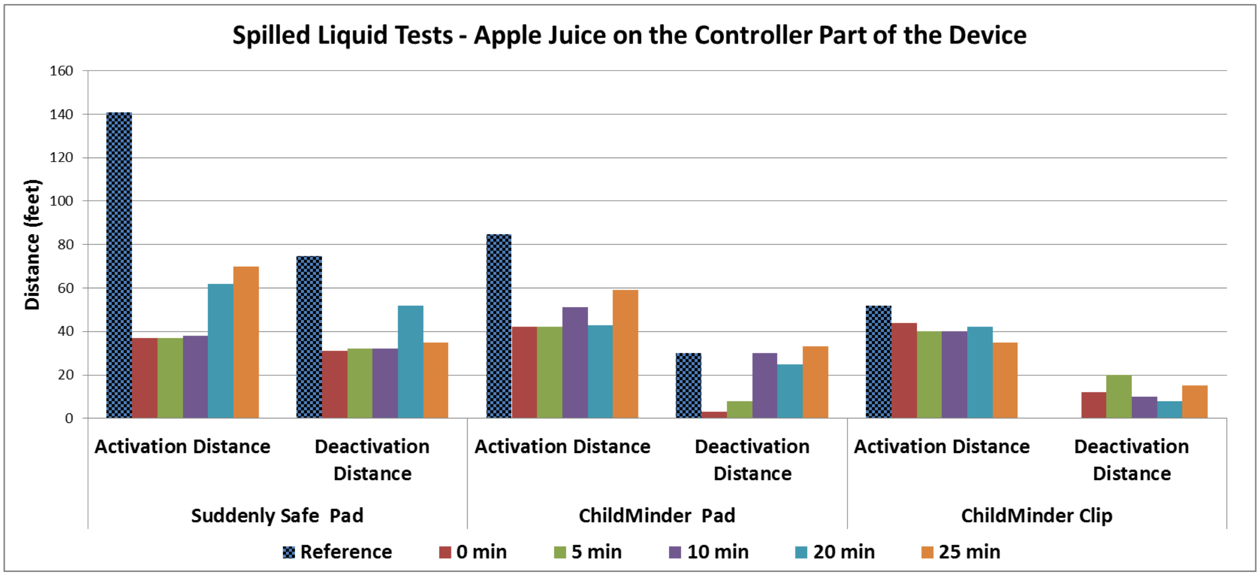


Figure 18: Spilled Liquid Tests - Apple Juice on the Controller Part of the Device

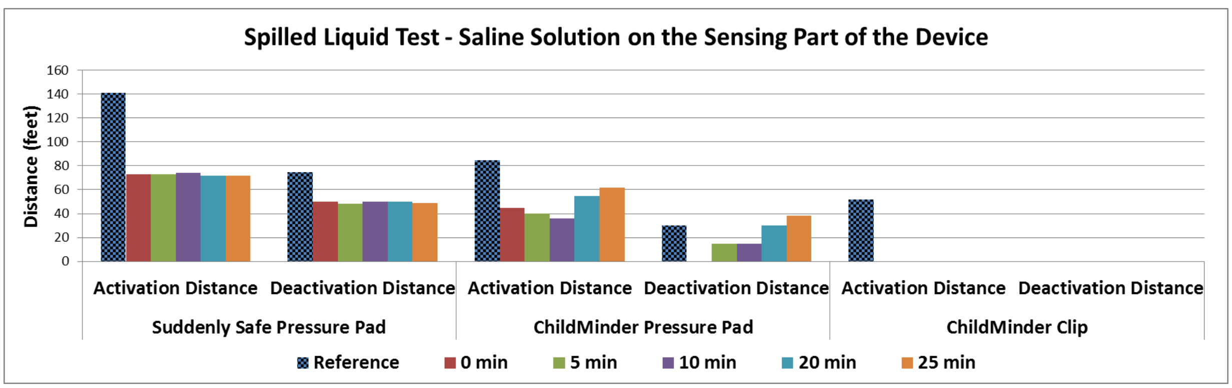


Figure 19: Spilled Liquid Tests – Saline Solution on the Sensing Part of the Device

3.6 Evaluation of the technology with human volunteer subjects

For the third phase of the study, in a controlled, ventilated vehicle environment, volunteer human subjects were buckled in child restraints instrumented with one of three heat stroke prevention devices, and the status of device activation and caregiver notification were recorded. Assessment occurred twice – first immediately after the child had been positioned in the parked vehicle, and then again after one of the investigators had driven a predetermined route to simulate a typical commute and parked the vehicle again. All procedures were approved by the Children's Hospital of Philadelphia Institutional Review Board.

3.6.1 Inclusion criteria and subject recruitment

The inclusion criteria for the study were males or females that fit in one of following three size and age categories,

a) Newborn sized: weight 3.5-6 kg; age 0 to 6 months
b) Average 1-year-old: weight 9.6-11.1 kg; age 9 to 15 months
c) Average 2-year-old: weight 11.8-13.6 kg; age 21 to 27 months

The weight limits were determined from the 25th and 75th weight percentiles for that age according to the Centers for Disease Control and Prevention male growth chart (**www.cdc.gov/growthcharts/data/set1clinical/cj41c017.pdf**). Children free from illness and disease with approved parental/guardian permission (informed consent) were enrolled. Subjects with the following conditions that prevented restraint in a typical child restraint or participation in the study procedures were excluded.

- Subjects with casts.
- Subjects with skeletal malformations.
- Subjects dependent on medical equipment.
- Subjects requiring a car bed restraint.

3.6.2 Static Technology Assessment

For the static assessment inside the parked vehicle, all three of the heat stroke prevention devices were assessed with each subject but in only one of the child restraints to minimize the time burden on the young subjects. The newborn-sized children were tested with the devices in the rear-facing infant restraint (Chicco Key Fit), each subject in the average 1-year-old group was tested with the devices in one of the three convertible restraints secured in the rear-facing position, and each subject in the average 2-year-old group was tested with the devices in one of the three convertible restraints secured in the forward-facing position (Priori Maxi Cosi, the First Years True Fit, or the Safety 1st Complete Air 65). (Figure 20)

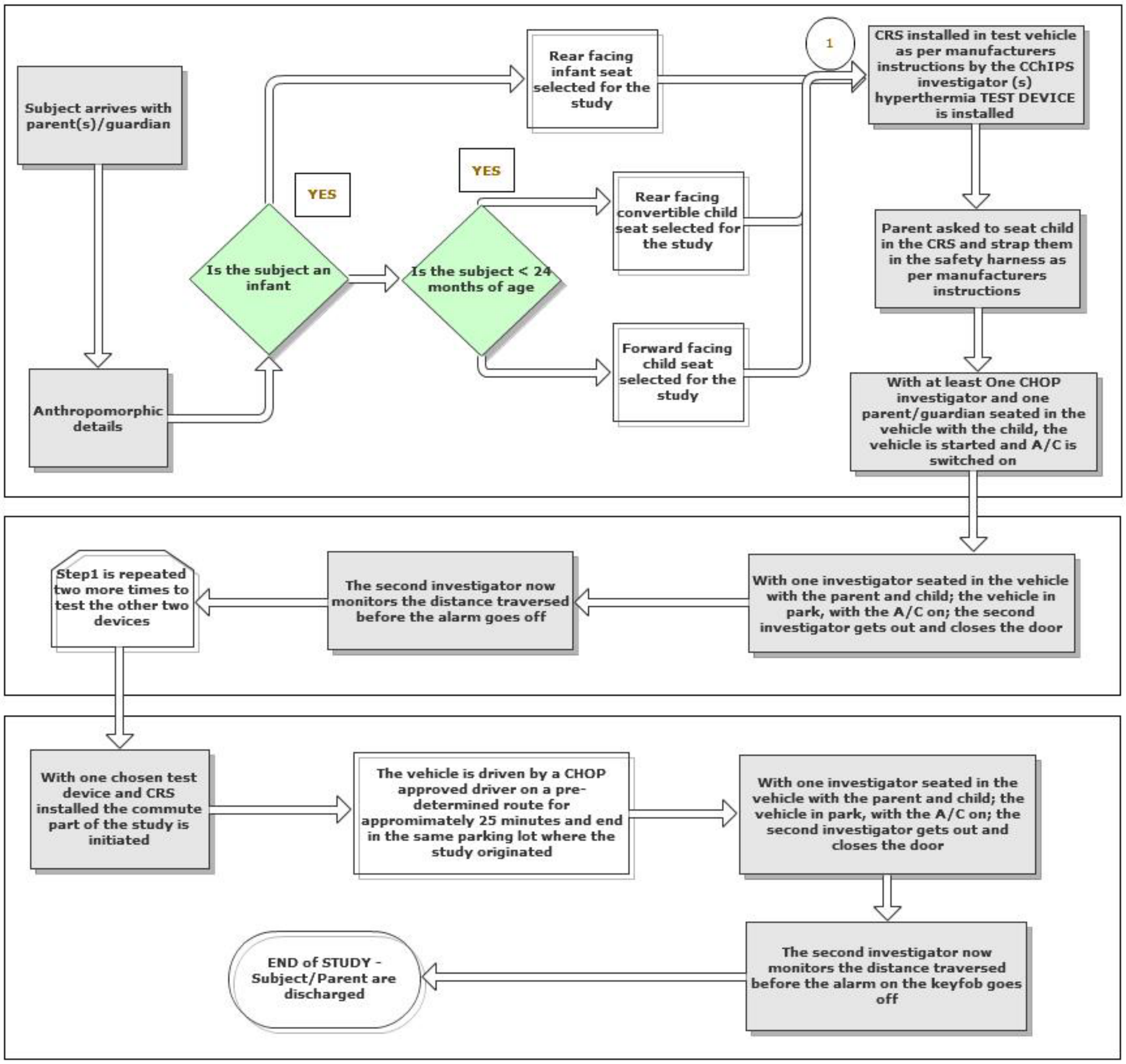


Figure 20: Evaluation methodology for the heat stroke test devices with human volunteer subjects

The child restraint assigned to the subject was installed using a LATCH attachment following the manufacturer's instructions in the left outboard rear seating position of a 2006 Chrysler Town and Country minivan. The first heat stroke device (randomly chosen from among the three) was properly installed in the child restraint, and the vehicle and its air conditioning turned on. Once the vehicle had reached a comfortable temperature, the parent was asked to sit in the right rear outboard passenger seat of the vehicle in sight of the child, and the child was properly fastened into the restraint by the parent. The investigator armed the heat stroke device, remained in the vehicle during the 5-minute waiting period, and recorded any device errors that occur during this period (i.e., false alarms, system needing to be re-synched). After 5 minutes, with one investigator seated in the vehicle with the parent and the child in the child restraint, the other investigator left the closed vehicle with the notification system (i.e., key fob) of the heat stroke device. As the investigator walked away from the vehicle, the distance to activation of the key fob was recorded. As the investigator returned back to the vehicle, the deactivation distance from the vehicle was also recorded. The procedure was repeated for the other two heat stroke prevention devices after removing the child after each device tested and installing the next one.

Eight volunteer subjects were recruited for the study. There was 1 subject in category a (newborn), 5 in category b (1-year-old) and 2 subjects in category c (2-year-old). Table 8 summarizes the subject anthropometrics, activation and deactivation distance for each of the devices. Figure 21a, 21b and 21c show a 27 month old subject with ChildMinder Pressure Pad, ChildMinder Clip, and the Suddenly Safe Pad respectively in a forward facing Safety 1st convertible child restraint.

(a) (b) (c)

Figure 21: Subject #1c in the forward facing Safety 1st Child Restraint with (a) ChildMinder Pad (b) ChildMinder Clip (c) Suddenly Safe Pad

Table 8: Static measurements of the human volunteer subjects

#	Weight (kgs)	Age (months)	Restraint Details: Child restraint make	Restraint Details: Seating position (FF/RF)	Static Evaluation: Device	Activation distance (ft)	Deactivation distance (ft)	Notes
1c	11.8	27	Safety 1st	FF	ChildMinder Pad	Did not activate	Did not activate	Did not activate either by shifting the subject or the pad
					Suddenly Safe Pad	82	68	Could not get device to synch, installed a second device and it worked successfully
					ChildMinder Clip	48	0	no issues
2a	6.3	4	Chicco Infant	RF with Base	ChildMinder Pad	74	56	no issues
					Suddenly Safe Pad	78	60	no issues
					ChildMinder Clip	45	0	no issues
3b	10	14	Priori Maxi Cosi	RF	ChildMinder Pad	72	32	no issues
					Suddenly Safe Pad	100	Did not activate	Did not synch. Sliding down on the seat bottom due to curvature of child seat seating area. Folding the pad worked to some extent
					ChildMinder Clip	88	15	no issues
4b	10	16	First Years True Fit	RF	ChildMinder Pad	88	48	no issues
					Suddenly Safe Pad	Did not activate	Did not activate	Did not synch after six attempts
					ChildMinder Clip	64	30	no issues
5b	10	15	Safety 1st	RF	ChildMinder Pad	96	0	Required two attempts to successfully synch
					Suddenly Safe Pad	16	0	Did not synch
					ChildMinder Clip	64	0	no issues
6c	11	26	First Years True Fit	FF	ChildMinder Pad	80	0	no issues
					Suddenly Safe Pad	110	80	no issues
					ChildMinder Clip	68	0	no issues
7b	9.8	11	First Years True Fit	RF	ChildMinder Pad	64	0	no issues
					Suddenly Safe Pad	80	3	Required three attempts to successfully synch
					ChildMinder Clip	76	18	no issues
8b	10	14	Safety 1st	RF	ChildMinder Pad	110	23	no issues
					Suddenly Safe Pad	112	26	Required two attempts to successfully synch
					ChildMinder Clip	72	3	no issues

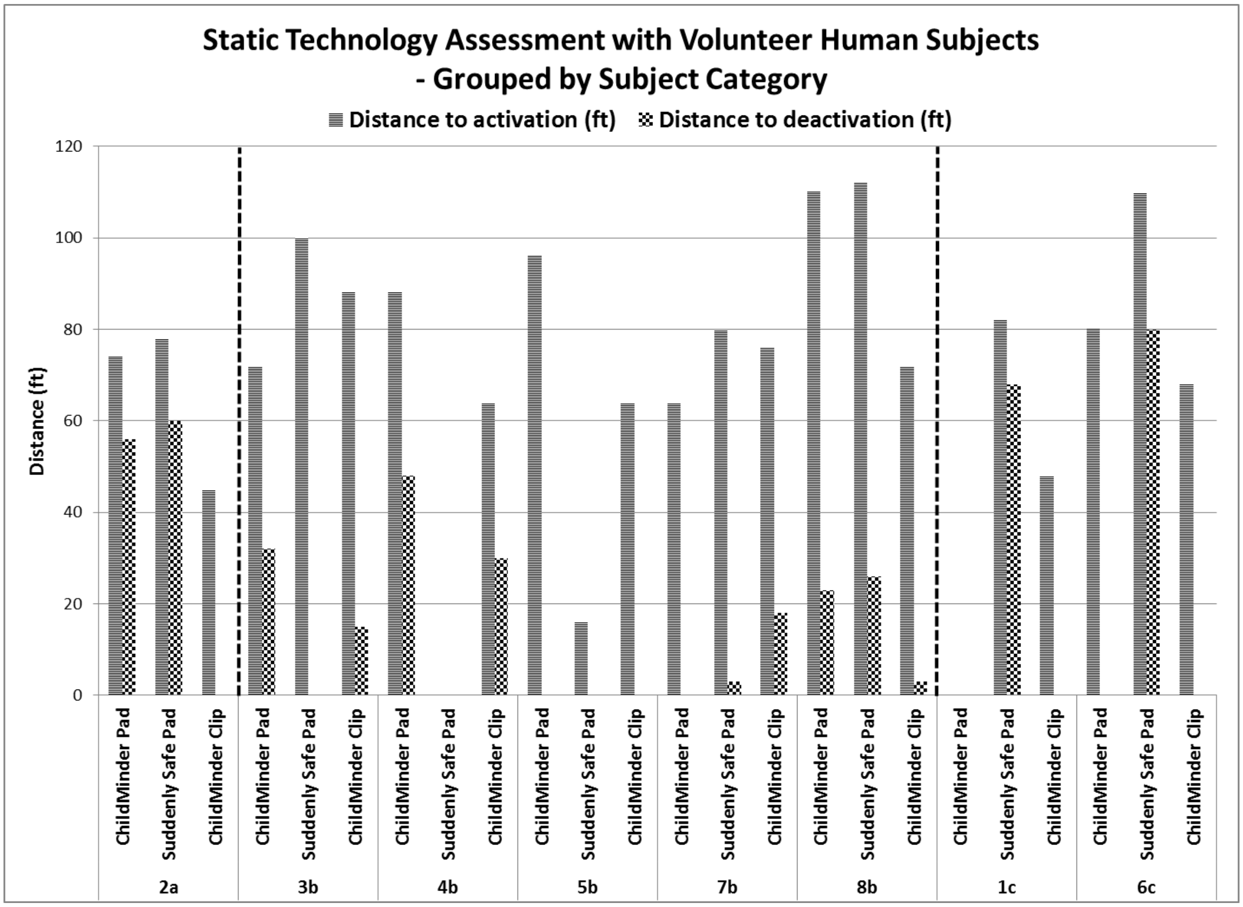


Figure 22: Static technology assessment – grouped by subject category

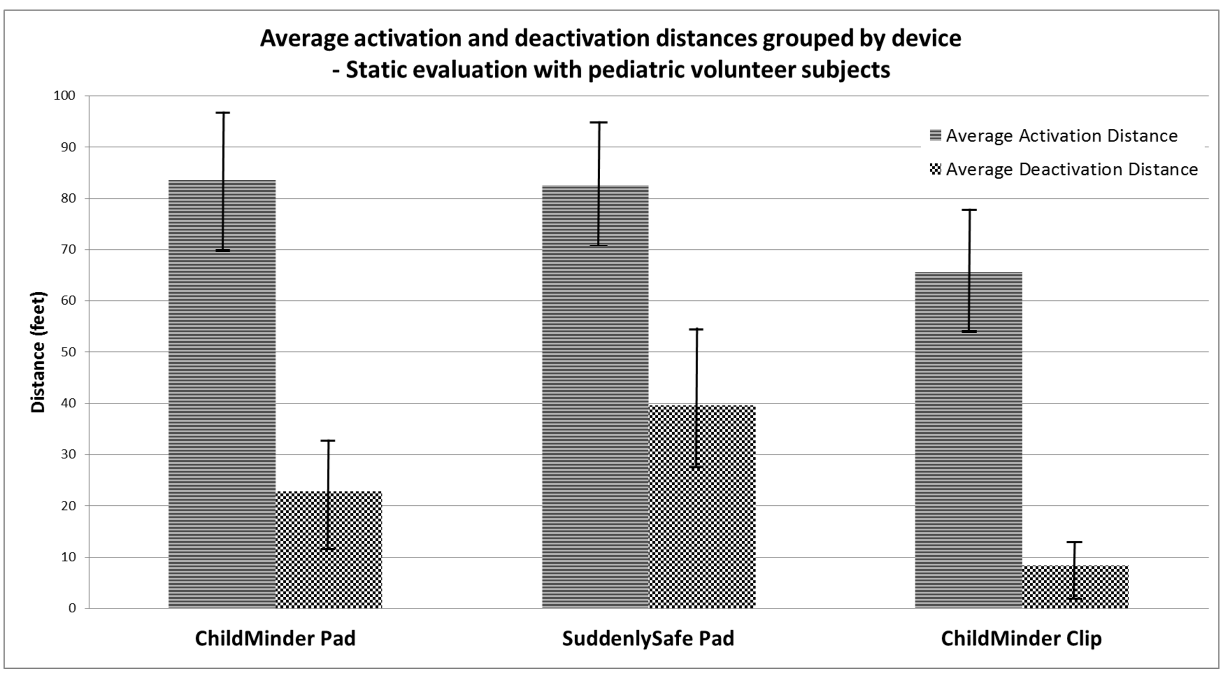


Figure 23: Average activation and deactivation distances grouped by device

Figure 23 shows the average distances to activation and deactivation grouped by the device. It is interesting to note the large standard deviation associated with each device.

3.6.3 Commute-Simulation Assessment

For the commute-simulating phase of the technology evaluation, each subject was evaluated with one restraint and one of the three heat stroke devices. Each subject was paired with a child restraint chosen at random from the set (with the newborn being paired with the infant seat) and one of the three heat stroke devices chosen at random.

With the heat stroke device in place, the child restraint secured, and the child fastened in the child restraint according to manufacturer's instructions, one of the investigators drove the minivan on a predetermined route (consisting of eight left and right hand turns) at an average speed of 15 mph for 3.6 miles in the University City neighborhood of Philadelphia. All drivers were approved drivers according to internal CHOP policy. The parent/caregiver was seated next to the subject in the rear seat of the vehicle and was asked to keep the child engaged ensuring that the child moved around in the seat.

The child's behavior (i.e., positioning, movement or crying) during the ride was recorded. After the drive, with the parent/caregiver and one investigator in the vehicle, the other investigator walked away to simulate a caregiver forgetting their child in the car. The ability of the device to sense the child's presence and notify the parent was recorded, along with the distance the investigator was from the car when notification occurred. The purpose of this task was to closely simulate an event in which a caregiver may forget a child in the car, and determine whether factors associated with a real child in an actual moving vehicle (i.e. time and occupant shifts of position) influence the efficacy of the device.

Table 9 tabulates the activation and deactivation distance of the test device for each child restraint and subject evaluated.

Table 9: Commute-simulation technology assessment with human volunteer subjects

Subject #	Subject Details		Restraint Details		Commute-Simulation Evaluation			
	Weight (kg)	Age (months)	Child restraint make	Seating position (FF/RF)	Device	Activation distance (ft)	Deactivation distance (ft)	Notes
1c	11.8	27	Safety 1st	FF	ChildMinder Clip	30	25	Key fob beeped once after 21 minutes of driving for about 4 seconds
2a	6.3	4	Chicco Infant	RF with Base	Suddenly Safe Pad	56	42	No issues
3b	10	14	Priori Maxi Cosi	RF	ChildMinder Pad	58	42	Synched and un-synched 11 times during the drive
4b	10	16	First Years True Fit	RF	ChildMinder Clip	48	24	Clip beeped twice
5b	10	15	Safety 1st	RF	Suddenly Safe Pad	0	0	Beeped 7 times during the drive. Un-synched at the end of the drive
6c	11	26	First Years True Fit	FF	ChildMinder Pad	85	5	No issues
7b	9.8	11	First Years True Fit	RF	ChildMinder Clip	56	0	Un-synched and synched 14 times during the drive
8b	10	14	Safety 1st	RF	Suddenly Safe Pad	72	48	No issues

It should be noted that during the commute, the devices were erratic in staying synchronized with the key fob. The movement of the vehicle along with the motion of the child in the child restraint led to the devices commonly alternating between synchronized and unsynchronized states.

4.0 Overall Conclusions:

In this preliminary qualitative evaluation, none of the three heat stroke devices tested was found to be completely reliable and consistent in their ability to detect children. The test battery each device was subjected to was within the expected device capabilities and included a diverse set of expected use scenarios. The two pad sensing devices worked well in some of the inanimate sensing scenarios and did not arm or required substantial shifting of the object to arm in others. The most frequent problems occurred with the child restraint that had the most padding indicating that the padding was distributing the load of the child surrogate in a way that the sensor in the device could not detect the surrogate.   For a given device, the activation distance varied across trials and scenarios, and for some devices, we detected issues such as interference with other devices, inability to function in the presence of liquids, and variability in performance in the presence of a cell phone. While these issues were not common, false positives and false negatives with such a device are undesirable.

In the static and commute-simulating human subjects evaluation, performance varied. Statically, the harness clip device worked well and armed each time; however during the driving portion, it often beeped during the drive or experienced continual synching/unsynching during use. Such regular synching/unsynching could lead to frustration by the consumer and abandonment of the device. The two pad devices often required adjusting the position of the child to get the device to arm when evaluated statically and in some cases, we were unable to arm the device at all. During the commute evaluation, the performance of the pad devices was variable. With some subjects, they performed well and with some the synching and beeping problems continued.

These devices were evaluated in late 2011 and it is possible that improvements to the devices have been made since the evaluation. It should also be noted that these devices, which integrate into a child restraint, would not be applicable in scenarios where the child is playing and gets locked in the vehicle (30% of fatalities) or in a scenario where the parent/caregiver intentionally leaves the child in the vehicle (17% of fatalities). In sum, the devices require considerable effort from the parent/caregiver to ensure smooth operation and often that operation is not consistent.

5.0 REFERENCES

Austin, R. (2008, December). NiTS *2007: Noncrash Fatality Database User's Manual.* (Report No. DOT HS 811 065). Washington, DC: National Highway Traffic Safety Administration.

Booth, J. N., Davis, G. G., Waterbor, J., & McGwin, G. (2010). Hyperthermia deaths among children in parked vehicles: An analysis of 231 fatalities in the United States, 1997-2007. *Forensic Science, Medicine and Pathology*, *6*, 99-105.

Guard, A., & Gallagher, S. 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.

Krous, H. F., Nadeau, J. M., Fukumoto, R. I., Blackbourne, B. D., & Byard, R. W. (2001). Environmental hyperthermic infant and early childhood death. *American Journal of Forensic Medicine and Pathology*, *22*(4), 374-382.

NHTSA. (2009a, January). *Traffic Safety Facts: Not-in-Traffic Surveillance 2007 – Highlights*. (Report No. DOT HS 811 085). Washington, DC: Author.

NHTSA (2009b, June). *Traffic Safety Facts: Not-in-Traffic Surveillance 2007 – Children*. (Report No. DOT HS 811 116). Washington, DC: Author.

Null, J. (2012). Hyperthermia Deaths of Children in Vehicles. *Golden Gate Weather*. Retrieved from http://ggweather.com/heat.

DOT HS 811 632
July 2012

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

NHTSA
www.nhtsa.gov

8796-072412-v5a