

# Preventing Pediatric Vehicular Heatstrokes: Overcoming Prospective Memory Failure

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## Abstract

This paper seeks to increase awareness and prevent the avoidable occurrence of children dying from hyperthermia when caregivers unknowingly leave them in a vehicle. Pediatric vehicular heatstroke (PVH) is frequently a result of prospective memory (PM) failure – or failure to forget to do things in the future, rather than neglectful caregiving. Parents who have inadvertently left a child in a car often report experiences of “false memories” in which they vividly remember dropping the child off as they intended.

In this paper, we will explain how PM failures, false memories, and other contributing factors can lead to pediatric vehicular heatstroke. Since the vast majority of PVH tragedies happen to caring and attentive parents, this paper argues that all caregivers should take safety precautions to prevent hot car deaths. *The Bag in the Back* campaign has been developed to offer guidelines and strategies for preventing PVH. This campaign will be reviewed and can be used by pediatricians, daycare providers, and others to mobilize caregivers to take action in preventing PVH deaths and injuries.

## Introduction

Pediatric vehicular heatstroke (PVH) is one of the leading causes of non-traffic, non-crash vehicular child fatalities in the United States.<sup>1</sup> The incidence has increased dramatically since car seats were moved to the back seat, which prevents air bag injuries but removes the visual reminder that a child is in the car.<sup>2</sup> On average, there are 38 PVH fatalities in young children in stationary vehicles in the U.S. each year, for a total of 742 child fatalities on record between 1998 and 2017 and thousands of nonfatal injuries.<sup>3</sup> Just over half of the children involved in these hot car fatalities were unknowingly left by a parent or other caregiver.

Throughout the COVID-19 pandemic, the number of child fatalities due to vehicle hyperthermia has been the lowest since 1998, with a particularly large decline in children who were unknowingly left behind in cars (62% less compared with previous years).<sup>4</sup> Experts have proposed multiple explanations for the sudden drop in PVH figures: the global and nationwide lockdowns of 2020 changed patterns of our daily routines, and people stayed stationary and were driving 14% less, which significantly contributed to the annual decrease in PVH deaths in the United States.<sup>5</sup> Despite these figures being at an all-time low, researchers predict that once COVID restrictions are lifted and the economy returns, people will return to their prepandemic routines — such as driving to work or school — and PVH fatalities will increase. Therefore, there is now a sense of urgency for healthcare professionals, parents, caregivers and legislators to recognize this type of motor vehicle injury and fatality in both public and private discourse and further invest in the prevention of PVH deaths.<sup>6</sup>

A major barrier to preventing these avoidable deaths is the public's misunderstanding of how common memory failures, rather than neglectful parenting, lead to most instances of PVH. Even very loving and well-intentioned parents can mistakenly leave a child behind in a car.

*The Bag in the Back*<sup>7</sup> campaign is designed to educate parents, caregivers, doctors, and the general public about PVH. The campaign seeks to explain how prospective memory failures, the development of false memories of drop-off, and other contributing factors make it possible for caregivers to unknowingly leave a child in the car. The Bag in the Back campaign offers suggestions for how physicians and daycare providers can talk with parents about preventing PVH.

## The science behind vehicular heatstrokes

Pediatric vehicular heatstroke is a particular risk in geographical locations with prolonged periods of hot weather.<sup>8</sup> However, PVH has occurred in almost all states, including those in the far North, where an outdoor temperature in the mid-60s is sufficient to heat the car to over 110° F.<sup>9,10</sup>

Studies have found that on days when temperatures exceed 86° F, the temperature inside a vehicle can quickly reach 134° to 154° F. On average, in the first 10 minutes of being left in the sun, the temperature inside a vehicle rises by 19° F. In a 60-minute period, it can rise more than 40° F. When the outside temperature is 90° F, a child left in a vehicle can die in as little as 10 minutes.

Two factors make children more prone than adults to hyperthermia. First, a child's ratio of surface area to body mass is greater than that of an adult. Second, a child's thermoregulation is less than that of an adult. In addition, a child's body heat rises three to five times faster than an adult's, and a child's organs begin to shut down when the child's temperature reaches 104° F.<sup>11</sup> Fatal body temperature for a child is 107° F. Even though PVH death is still relatively rare, other problems such as vital organ damage and brain swelling can occur quickly, resulting in significant morbidity.

## What is prospective memory failure?

Researchers and scientists have long studied how memory is formed, stored and recalled. In neuropsychology, memory has been broadly divided into two categories: retrospective memory (RM) and prospective memory (PR).<sup>12</sup> Retrospective memory is the memory we store of people, times, contexts, words and events encountered or experienced in the past. In contrast, prospective memory involves remembering something or remembering to do something after a delay, such as stopping by the pharmacy on the way home from work. Both of these memory formations are linked, though when people are asked to think or describe memory loss in their own lives, they commonly refer to and think about retrospective memories, such as forgetting someone's address, phone number or other facts. Although most people tend to think of memory failure in terms of RM failure, multiple studies indicate that the most common memory failures in everyday life are errors in prospective memory.<sup>13</sup>

The distinctive feature of prospective memory failure is an error in the use of stored information to plan and execute an action set to occur in the future.<sup>14</sup> PM failures are fairly common, and the human mind experiences various PM-related memory errors and disruptions on a daily basis. Some common examples of PM failures include planning to call a friend at lunchtime but instead going straight to the cafeteria as you normally would; not remembering to take your medication before going to bed because you had to stop to clean up a spill; and not interrupting an otherwise routine drive home to stop at the grocery store as you had planned.

Errors in multitasking, ongoing habitual activity "being on autopilot", and the absence of a reminder cue (e.g., seeing a child in the rearview mirror, a drop-off reminder from a phone, or a sound of a child on the back seat) often contribute to PM failures. Successful performance of prospective memory requires multiple cognitive operations including forming, organizing and initiating a plan; retaining the memory of the intention over a delay period; performing the intention at the right time; and then remembering that the intended action took place. The essence of a PM failure therefore is the loss of awareness to "remember to" remember at just the right time.<sup>15</sup> Most PM failures are relatively harmless or minor annoyances, but it is crucial to increase awareness as these memory failures can create hazardous conditions.

The vast majority of parents do not understand that a common PM failure could result in inadvertently leaving a child in a hot car. However, over 25% of U.S. parents with children under 3 years of age acknowledge that at some point, they have lost awareness of the presence of a child in the back seat of the car.<sup>16</sup> While driving a child, it is common for parents to think about other people and situations, especially when their child is quiet or sleeping. In the case of PVH, as thoughts shift during the drive, a prospective memory failure can lead the parent to forget the planned action of dropping off their child.

Parents or caregivers whose children have suffered from PVH often report changes in their normal routine on the day of the PVH event. Such changes include taking a new route to work, getting an unexpected phone call, or not normally being the one to drop off the child. These routine changes can cause inattentive blindness (i.e., not perceiving something that is in plain sight) and trigger a memory failure that leads to the parent losing hold of the original plan. This scientific anomaly of PM failure also explains why parents who have unknowingly left a child in the car often go about their routine activities after the memory failure — at that point, the habit memory has suppressed the prospective memory.<sup>17</sup> When the brain creates a false memory, parents are oblivious to the fact that their child has been left in a hot car.

## False memories

False memories have intrigued cognitive psychologists for nearly a century. Multiple studies show that the creation of false memories is common in associative memory tests in both clinical and nonclinical environments.

In a clinical environment, the Deese–Roediger–McDermott (DRM) paradigm<sup>18–20</sup> is most commonly used when studying false memories. In this approach, people are given a list of words that share a common theme such as "school" (e.g., desk, education, locker, learning, recess). The list, however, lacks a word that is common and semantically related to the theme, such as "teacher." When people are queried as to which words were on the list, a high percentage of people falsely recall that the word "teacher" was on the list. Hence, the assumption that "teacher" was on the list becomes a false memory.<sup>21</sup> Based on some reports in similarly conducted studies, up to 70% of the participants will recall or recognize the "false" word with the same probability as the words that actually appeared in the middle of the study list.<sup>22</sup>

In a nonclinical setting, false memories have been reported in multiple and various settings. For example, a person who realizes at lunchtime that they do not have their lunch bag at work, even though they can clearly picture themselves grabbing it off the kitchen counter at home, has created a false memory. A person who imagines sending a quick email to a friend and then later when the friend asks why there was no reply, feels puzzled because they clearly remember sending it. In a survey conducted in 2018 by the Sofia Foundation, 93% of adults report having had these types of false memory formations at some point in their lives.<sup>23</sup> Although most people have experienced the strange feeling of a false memory, many do not realize how this common phenomenon can put them and their children at risk.

An individual is at particular risk for developing false memories around the location of their child when their normal routine changes, when the order of performing a task changes, or when the task gets interrupted by something that does not usually happen. Even simple interruptions such as a road accident, a phone call, or an unusual stop can cause a person's brain to lose hold of a planned action (e.g., drop-off at daycare). Afterward, it is extremely easy for the brain to check off the missing step as completed, because the imagined event is mistaken for an actual event. In terms of PVH, parents and caretakers have universally reported being certain they had taken the child to the target location, typically home or daycare. The DRM paradigm helps to clinically explain how these false memories can occur and that we all are vulnerable to them.

## Multitasking and distraction as contributing factors

In the field of neurobiology, PM failures are often identified when the brain structures are in a mode of competing with each other. Trying to focus on more than one task at a time is commonly referred to as multitasking. However, multitasking is a myth.<sup>24</sup> In reality, the human brain is not capable of performing two tasks at the same time. Instead, the brain handles tasks sequentially, switching between one task and another.<sup>25</sup> In extreme examples, multitasking and changes in habitual patterns contribute to catastrophic memory errors, as the brain can lose its awareness rapidly.<sup>26</sup>

In a 2003 study, researchers noted that PM failures were most likely to occur in times of transition, typically when a person leaves one environment to go to another (e.g., when leaving from home to go to work).<sup>27</sup> This study reported that PM failures were at their highest rate of occurrence when people were preoccupied with another action or focused on various environmental factors.

## Multitasking and distraction as contributing factors (cont.)

These findings are consistent with the literature demonstrating that stress, distractions and interruptions, as well as simply processing ongoing yet intervening events, are all potential causes for errors in PM. One study shows that even mild distractions contribute to memory failures.<sup>28</sup> Forgetting one's intentions in a demanding situation can happen in a matter of seconds, and a person's awareness of an intention can be lost in response to a distracting stimulus.<sup>29</sup>

## Effects of sleep deprivation on prospective memory

Multiple studies in the field of human health have shown that sleep loss affects basic elements of cognitive function. Not getting an adequate amount of sleep increases failures to carry out intended actions, which can have severe consequences in safety-critical situations.<sup>30</sup> Reports show that particular elements of cognitive function, such as the experience of attention — selectively concentrating on a discrete aspect of information — deteriorate as a result of sleep deprivation. Ultimately, failures in attention can lead to a loss of awareness of future intentions.

Sleep loss and the associated complex memory processing errors can increase the occurrence of false memories. When a person is sleep deprived, the brain's ability to form accurate and real associations deteriorates, and instead the mind fills in gaps with the information it retrieves from similar situations in the past.<sup>31</sup> Differentiating false formation of memories and natural associative processes is, therefore, not always easy, especially when fatigued.

## The role of education and information

The Bag in the Back campaign is designed to raise awareness of how prospective memory failures can lead to PVH. The campaign's primary goal is to provide a comprehensive but targeted approach to inform and educate the general public about PVH. When parents and caregivers realize they are at risk of experiencing a catastrophic memory failure, they are more likely to take preventive measures to make sure they do not experience a memory failure that results in them inadvertently leaving a child in the car.

By providing accurate and up-to-date information, the campaign hopes to reduce stigma around PM failure and childcare, and to provide a safe space for parents and caretakers to discuss the topic of PVH without judgment.

Parents look to experts for guidance on safety practices, especially in areas where they may not be well informed. Because there are many misconceptions (e.g., "I could never forget my child because she is my highest priority."), it is particularly important for safety information about PVH to be included as part of prenatal workshops, postpartum education and well visits in the pediatrician's office.

## How to talk about PVH with parents?

Parents can be educated about PVH. It is well documented that we are all at a high risk of vulnerability to memory errors, and studies show that a high percentage of parents, both in the United States and elsewhere, report times when they have lost awareness of children in the back seat of their cars. Previous research confirms that the leading cause of death for children left unattended in motor vehicles is stroke and hyperthermia.<sup>32</sup>

Because the role of common memory failures are misunderstood, there is often great outrage from the public when a child is inadvertently left to die in a hot car. The occurrence of PVH is seen as a result of negligence, and parents or caretakers may be charged criminally.<sup>33</sup> This often leads to perpetuating the myth that PVH only happens to bad parents. As a result, this topic is highly stigmatized and parents, believing they are good parents, are not likely to adopt essential safety practices that could prevent them leaving a child unknowingly in the car. A strong education program can be a way of successfully disseminating information about PVH. If parents hear from trusted sources that PVH is a real risk and that it can be prevented by taking simple precautions, PVH deaths could be prevented.

## How does the campaign work?

The Bag in the Back campaign promotes a simple but smart way to avoid a preventable tragedy, encouraging parents and caregivers to develop a habit of putting a bag or a personal item in the back seat so that every time they leave their vehicle, they are forced to open the back door to retrieve the item. In the event that a parent has lost awareness of the child through a PM failure, they are likely to see the child when they access the back seat.

## Who is the target audience?

Ultimately The Bag in the Back campaign is targeting parents and caregivers of children age 0 to 12 years. However, the campaign recognizes the difficulties in getting the message to such a wide audience. Parents have reported that knowledge about PVH through public service announcements and public health campaigns is not reaching them adequately.<sup>34</sup> Caregivers and parents would benefit from this information coming through more personal channels. Therefore, this paper is aimed toward healthcare providers, childcare practitioners and daycare providers who routinely share important safety information with parents. Additionally, PVH prevention measures in the workplace could be implemented through an employer's health and safety program or their employee wellness programs.<sup>35</sup>

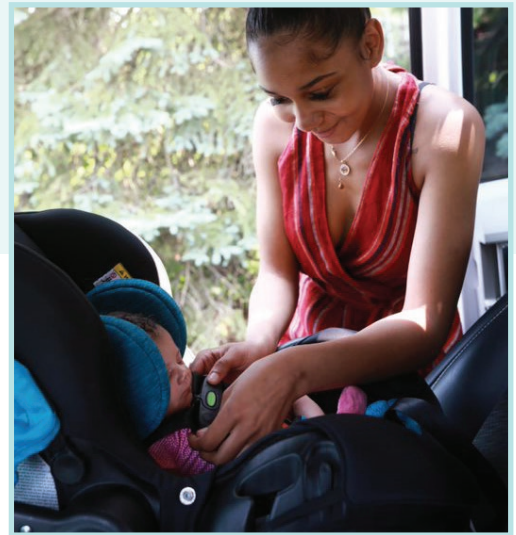


Photo courtesy of Buckle Up for Life

## Conclusion

In 2019, 53 children in the U.S. died in a hot car.<sup>36</sup> Though during the global COVID-19 pandemic the numbers of PVH fatalities decreased by about 38% in 2020, the long-term patterns of these tragedies stayed alarmingly similar. Most pediatric vehicular heatstrokes occurred in the Southern U.S., and most happened because parents either unknowingly or knowingly left their children in stationary vehicles.<sup>37</sup> During this time, PVH was not linked to memory loss as frequently as in previous years, primarily because the patterns of daily routines changed, frequent driving decreased and schools and daycares were closed.<sup>38</sup> However, as COVID-19 vaccines are now available and the pandemic lockdown restrictions have dissipated, it's crucial to get out the message that all vehicle hyperthermia is preventable and all parents are at risk of forming false memories that could lead them to inadvertently leaving a child in a stationary vehicle.

Countless studies have shown that the human brain is capable of memory failures, including skipping planned actions and creating false memories. A caregiver can easily believe their child is safe at school, home or daycare when they have, in fact, been left in the back seat of a parked vehicle. Stress, sleep deprivation, distraction and habit memory are all capable of overriding short-term memory and forming associations with correlating and semantically close-related events. These stress-related memory loss incidents are particularly expected to increase now that home restrictions have been lifted. By sharing stories and having a platform to discuss these issues, awareness can lead to the adoption of life-saving practices. The Bag in the Back Program is a simple and efficient forward, and it can prevent countless tragedies in the future.



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## Appendix I

Results from 2018 Survey by The Sofia Foundation for Children's Safety. Responses to the following question: "Have you ever thought you did any of the following when you really hadn't?"

	All Survey Respondents (n = 949)		Survey Respondents with Child 3 Years or Younger (n = 512)	
	# Yes	% Yes	# Yes	% Yes
Told someone something	590	62%	318	62%
Taken your vitamins or medication	480	51%	257	50%
Locked your house	474	50%	240	47%
Sent an email / called someone	430	45%	219	43%
Put food in the refrigerator	391	41%	218	43%
Paid a bill	391	41%	191	37%
Brought your lunch, computer or something else you needed for work	365	38%	193	38%
Turned off the oven, a burner, the iron or other fire hazard	347	37%	169	33%
Closed the garage door	340	36%	177	35%
Removed your keys from the car	297	31%	155	30%
Removed food from the microwave	262	28%	154	30%
Removed groceries from the car	198	21%	92	18%
Locked your desk / office	119	13%	63	12%
Set the alarm on your house	117	12%	53	10%
Picked up or dropped off your child	37	4%	15	3%
Removed your child from the car	21	2%	12	2%
Removed your pet from the car	8	1%	3	1%
No, none of these	71	7%	37	7%