

## CURRICULUM VITAE

**David M. Diamond, Ph.D.**

### Current Position

#### Professor

Department of Psychology  
Cognitive, Neural and Social Division  
University of South Florida  
4202 East Fowler Ave. (PCD 4118G), Tampa, Florida 33620

Director, USF Center for Preclinical and Clinical Research on  
Post-Traumatic Stress Disorder  
Director, USF Neuroscience Collaborative Program

#### *adjunct appointment in:*

Department of Molecular Pharmacology and Physiology  
College of Medicine, University of South Florida

*Telephone:* Office: (813) 974-0480  
Lab (813) 974-3022  
FAX: (813) 974-4617  
*e-mail:* ddiamond@usf.edu  
*web site:* <http://psychology.usf.edu/faculty/diamond>

### Education and Degrees

B.S. in Biology University of California, Irvine, 1980  
Ph.D. in Biology University of California, Irvine, 1985  
Department of Psychobiology and  
Center for the Neurobiology of Learning and Memory

### Professional Memberships

Society for Neuroscience; International Brain Research Organization;  
NY Academy of Sciences; The American Institute of Stress; International Behavioral  
Neuroscience Society; The Institute For Traumatic Stress

### Honors and Awards

1985 University of California Regents Dissertation Award  
1994, 1995 Excellence in Research Award – VA Medical Center, Denver,  
1998 USF Faculty Equipment Award and International Travel Award  
2005 – 2015 VA Research Career Scientist Award  
2012 - Present Elected as a Fellow in the American Institute of Stress  
2015 Award for Outstanding Contribution to Science – Riga Diabetes  
and Obesity World Congress  
2015 USF International Travel Award

### Summary of Post-Graduate Academic Progress

1985 – 1986	Postdoctoral Researcher, University of California, Irvine, Center for the Neurobiology of Learning and Memory
1986 – 1997	Assistant Professor, Department of Pharmacology, University of Colorado Health Sciences Center, Denver, Colorado
1997 – 2003	Associate Professor, Departments of Psychology and Pharmacology, University of South Florida, Tampa, Florida
2003 – Present	Professor, Departments of Psychology, Molecular Pharmacology and Physiology, University of South Florida, Tampa, Florida
1988 – 2015	Research Scientist, Medical Research, Veterans Administration Medical Center, Denver, Colorado and Tampa, Florida
2007 – Present	Director, USF Center for Preclinical and Clinical Research on PTSD

### University/VA Hospital Service

#### University of South Florida

1997 – Present	<u>Chair</u> , Library Committee, Dept. of Psychology, USF
1997 – 2001	Equipment Committee, Dept. of Psychology, USF
1997 – Present	Computer (Technology) Committee, Dept. of Psychology, USF
1999	Faculty Search Committee, Dept. of Comm Sci/Disorders, USF
2000	Faculty Staff and Library Campaign, USF
2000	Faculty Search Committee, Dept of Psychology, USF (Lakeland)
2001 – 2003	Institutional Animal Care and Use Committee, USF
2001 – 2003	Department of Psychology By-Laws Revision Committee
2001 – 2002	<u>Chair</u> , CNS Graduate Admissions Committee
2008 – 2009	University-Task Force: Committee on Research and Scholarship
2002 – 2011	Department of Psychology Space Committee
2008 – Present	<u>Director</u> : USF Collaborative Neuroscience Program
2009	Department of Psychology Tenure and Promotion Committee
2009 – 2010	Scientific Advisory Board – USF Byrd Alzheimer's Center
2009 – 2011	Faculty Liaison to the USF Health Sciences & Research Workgroup
2011 – 2013	Translational Neuroscience Doctoral Program Committee
2009 – Present	<u>Chair</u> , Department of Psychology Awards Committee
2011 – 2015	USF/VA Neuroscience Building Planning Subcommittee
2012 – 2016	Institutional Animal Care and Use Committee, USF

#### Veterans Affairs Medical Center (Denver and Tampa)

1990 – 1997	Institutional Animal Care and Use Committee, VAMC, Denver
1998 – 2001	Research and Development Committee, VAMC, Tampa
2001 – 2015	Annual Grand Rounds Lectures to Endocrinology
2002 – 2016	<i>ad hoc</i> Chair, Member, Hazards and Biosafety Committee
2009 – 2016	USF-VA Veterans Reintegration Steering Committee
2009 – 2016	Research and Development Committee, VAMC, Tampa

### **Department of Psychology Program**

Mary Newman, David Doan, Darien Peckham, Kimberly Canals, Julianne Parish

### **USF Campus-Wide Honors Program (Advisor)**

Sydney McClure, Kimberly Canals, Zayar Khin, Aditi Arynth, Savannah Dalrymple

### **Undergraduate Directed Research**

Nedda Jacques, Liz Reeher, Melissa LaBoy, Jennifer Alamed, Hayley Carr,  
Rebecca Diaz, Garbine Mijares, Alysha Palladino, Saritza Legault, Alisa Lee

### **Ph.D./Masters Thesis Advisor**

1998 – 2001	Michael Puls, Amie Wilbanks, Mary Newman (co-advisor)
1998 – 2004	Adam Campbell (Ph.D. awarded in 2004)
2000 – 2002	Leila Amiri
2001 – 2003	Doug Stimac
2004 – 2008	Phil Zoladz (Ph.D. awarded in 2008)
2006 – 2010	Shyam Seetharaman (M.A. awarded in 2009)
2005 – 2012	Josh Halonen (Ph.D. awarded in 2012)
2011 – 2015	Laura Bullard (Ph.D. awarded in 2015)
2014 – Present	Savannah Dalrymple

### **Courses Taught at the University of South Florida**

1997 - 1999	Physiological Psychology (Graduate)
1998	Learning and Behavior (Undergraduate)
1999	University Honors Seminar (Undergraduate)
1999 - 2015	Psychology of Learning (Undergraduate)
2001 - 2009	Graduate/Undergraduate Seminar: <i>Emotion, Memory and Brain</i>
2003 - 2011	Molecular Neuroscience (Graduate - Team Teaching Course)
2009 – 2016	Graduate/Undergraduate Seminar: <i>Myths and Deception in Medical Research</i>
2014, 2016	University Honors College Seminar (Undergraduate) Topic: <i>Medical Ethics</i>

### **Post-Doctoral Fellows**

University of Colorado (1990 - 1997)	Michael Mesches, Karen Mesches
University of South Florida (1997 – Present)	Collin Park, James Woodson, Rose-Marie Vouimba Seth Norrholm, Adam Campbell, Phillip Zoladz, Josh Halonen, Gef Farmer

### **Subset of Masters and Dissertation Committees**

#### **USF, Department of Psychology (Since 2000)**

Ph.D. Awarded, 2000	Jordan Litman	(Cognitive/Neural Sciences)
Ph.D. Awarded, 2002	Deadtrick Newsome	(I/O Psychology)
Ph.D. Awarded, 2002	Cong Liu	(I/O Psychology)
Ph.D. Awarded, 2002	Tony Laverghetta	(Cognitive and Neural Sciences)
Ph.D. Awarded, 2007	Chip Weir	(Clinical Psychology)
Ph.D. Awarded, 2008	Kimberly Badanich	(Cognitive/Neural Sciences)

## Professional Service

### Ad Hoc Grant Reviewer

Health Research Board, Ireland; National Science Foundation  
International Human Frontier Science Program  
International Science and Technology Center (Moscow)  
National Medical Research Council (Singapore)  
National Institutes of Mental Health; Qatar National Research Fund  
Natural Sciences and Engineering Research Council of Canada  
Netherlands Organization for Scientific Research  
The University of Houston Grants to Enhance and Advance Research  
VA (VISN 3) New Researcher Seed Grant Program; The Wellcome Trust  
New Researcher Discovery Grants (Canada)

### Recent Participation on Federal Study Sections and Committees

2002 NIH Integrative, Functional and Cognitive Neuroscience Study Section  
2003 VA Merit Review Study Section: Neurobiology  
2004 NIH Conte Center Panel: Neuroscience of Mental Disorders  
2004 VA Merit Review Study Section: Neurobiology  
2005 VA Merit Review Study Section: Mental Health Behavioral Science  
2006 NIH Conte Center Panel: Neurobiology of Learning and Memory  
2007 VA Merit Review Study Section: Mental Health Behavioral Science  
2007 Congressionally Directed Medical Research Programs/Dept. of Defense:  
PTSD Research Program/Neurobiology and Genetics Panel  
2008 VA National "Think-Tank" on PTSD Drug Discovery and Development  
2008 Congressionally Directed Medical Research Programs/Dept. of Defense:  
Psychological Health/Neurobiology and TBI Panel  
2009 Military Medical Research Program: PTSD Treatment Study Section  
2009-2011 NIMH "Pathway to Independence" K99 Study Section  
2011 VA Merit Review Study Section: Cellular and Molecular Medicine  
2012 Congressionally Directed Medical Research Programs/Dept. of Defense:  
Psychological Health/Neurobiology and TBI Panel  
2014 NIMH - Biobehavioral Research Awards for Innovative New Scientists  
2015 VA Investigator Eligibility Committee  
2016 NIMH Ruth L. Kirschstein National Research Service Award (NRSA)

### Host to Visiting Scientists and Students

2002 – 2003 Vernon Haynes, Ph.D., Professor, Dept. of Psychology, Youngstown  
State University, Youngstown, Ohio  
2003 Ryan Wright, Graduate Student, Arizona State University, Arizona

### Scientific Advisory Boards

2002 – 2004 *Non-Linear Dose-Response Relationships in Biology,  
Toxicology and Medicine*, Univ Massachusetts, Amherst  
2006 - 2009 *Workshops on the Stress, Memory and Brain Plasticity*;  
Genova, Italy; Amsterdam, Netherlands; Villars-sur-Ollon, Switzerland  
2015 - Present *The Nutrition Coalition*; Scientific Advisory Board Member

## **Outside Member of University Committees**

### Dissertation Committees

Ph.D. Awarded, 2003, Irit Akirav, Univ. of Haifa, Israel, Dept. of Psychology  
Ph.D. Awarded, 2006, Dario Dieguez, Univ. of Texas, Dept. of Psychology

### Undergraduate Honors Committees

Arizona State University  
Honors Thesis Committee, 2007 Gillian F. Hamilton  
Honors Thesis Committee, 2007 Jessica Wilson

### Tenure and Promotion Review Committees

Terrence Deak, Ph.D., 2006, Binghamton University, New York,  
Department of Psychology  
Irit Akirav, Ph.D., 2010, University of Haifa, Israel,  
Department of Psychology  
Geoff Potts, Ph.D. 2011, University of South Florida,  
Department of Psychology  
Marina Bornovalova, 2013-2015, Univ of South Florida,  
Department of Psychology  
Jennifer Bosson, 2015, Univ of South Florida,  
Department of Psychology  
John Howland, 2016, University of Saskatchewan,  
Department of Physiology

## **Mentorship to Young Investigators**

NIH Centers of Biomedical Research Excellence (COBRE)  
Mentor to Tania Roth, Ph.D. – University of Delaware  
NIMH Predoctoral Fellowship to Dave McQueen - University of South Florida

## **Book Editor**

*"The Stressed Synapse: Synaptic Stress and Pathogenesis of Neuropsychiatric Disorders"*, Expected Publication date: 2015  
Edited by D.M. Diamond, G. Sanacora and M. Popoli

## **Membership on Editorial Boards**

- *The Journal of Neuroscience Methods* (2004 – Present)
- *Nonlinearity in Biology, Toxicology and Medicine* (2004 – 2006)
- *Dose Response* (2006 – Present); *Neural Plasticity* (2006 – Present)
- *Brain and Behavior* (2011 – Present)
- *Journal of Integrative Psychology and Therapeutics* (2013 – Present)
- *Journal of Pharmacology and Drug Metabolism* (2013 – Present)
- *Frontiers in Behavioral Neuroscience* (2007 – Present)
- *Stress, Brain and Behavior* (2014 – Present)
- *World Journal of Neurology* (2012 – Present)
- *Nutritional Neuroscience* (2016 – Present)

## **Guest Editor**

*Nonlinearity in Biology, Toxicology and Medicine (2003-2006)*

Issue theme: *Non-linearities Among Arousal, Memory and Brain Functioning*

*Behavioral Sciences (2011-2012)*

Issue theme: *From Synapses to Syndromes in Stress Research: Translational Approaches to the Study of the Neurobiology of Stress-Related Mental Disorders*

*Frontiers in Molecular Psychiatry (2012 – 2013)*

Issue Theme: *Epigenetic pathways in PTSD: How traumatic experiences leave their signature on the genome*

## **Ad Hoc Journal Reviewer**

*American Journal of Physiology*

*Behavioral and Brain Functions*

*Biological Psychiatry*

*Brain Research*

*British Journal of Medicine and Medical Research*

*Cerebral Cortex*

*European Journal of Neuroscience*

*Hippocampus*

*International Journal of Neuropsychopharmacology*

*Journal of Neurochemistry*

*Journal of Neuroimmunology*

*Journal of Neuroscience Methods*

*Journal of Neuroscience Research*

*Medical Science Monitor*

*Nature Reviews Neuroscience*

*Neurobiology of Aging*

*Stress*

*Methods and Findings in Experimental and Clinical Pharmacology*

*Neuropsychopharmacology*

*Physiology and Behavior*

*The Journal of Neuroscience*

*Pharmacology, Biochemistry and Behavior*

*Proceedings of the National Academy of Sciences*

*Progress in Neuro-Psychopharmacology & Biological Psychiatry*

*Psychological Reports: Perceptual and Motor Skills*

*The Journal of Pharmacology and Experimental Therapeutics*

*Behavioural Brain Research*

*Behavioral Neuroscience*

*Brain and Cognition*

*Brain Research Bulletin*

*Experimental Brain Research*

*Experimental Neurology*

*Hormones and Behavior*

*Journal of Neurophysiology*

*Synapse*

*Journal of Gerontology*

*Journal of Physiology*

*Molecular Psychiatry*

*Neural Plasticity*

*Science*

*Neuropharmacology*

*Clinical Pharmacology*

*Neuroscience*

*Physiological Reviews*

*Trends in Neurosciences*

*Psychobiology*

## Community Service

### Interactions with the Community

- 1999 Tampa Museum of Science and Industry  
*Representative of the Tampa Bay Society for Neuroscience*
- 1999 - 2001 Ridgewood High School Externship Program  
*Mentor to Kalah Mueller*
- 1999 Hillsborough High School International Baccalaureate Program  
*Mentor to Zach Thomas*
- 2002 USF "Lunch with a Scholar"  
*Lecture to community leaders on stress, brain and memory*
- 2004 - 2008 The Learning-Brain Expo, Orlando, Florida  
*Lectures to the community about the brain and memory*
- 2011 USF "Dinner with a Scholar"  
*Lecture to community leaders on nutrition myths and health*
- 2012 North Tampa Bay Rotary Club  
*Lecture on the Neurobiology of PTSD*
- 2015 Institute for Human & Machine Cognition, Ocala, Florida  
*Lecture: "Demonization and Deception in Cholesterol Research: Separating Fact From Profitable Fiction"*

## Funding (Grants and Awards)

### Previous Support

- 1990 - 1994 **Principal Investigator**, Veterans Affairs Merit Review Award,  
*"Etiology of the Stress-Induced Inhibition of Hippocampal Plasticity";*  
\$230,774
- 1991 - 1994 **Principal Investigator**, Office of Naval Research,  
*"Analysis of the Inverted-U Relationship Between Corticosterone and Hippocampal Plasticity";* \$343,704
- 1994 - 1997 **Principal Investigator**, Veterans Affairs Merit Review Award  
*"Neurobiology of Stress Effects on the Hippocampus";* \$274,632
- 1994 - 1997 **Principal Investigator**, Office of Naval Research,  
*"Corticosteroid Effects on Hippocampal Function";* \$315,804
- 1996 - 1997 **Principal Investigator**, Office of Naval Research,  
*"Antagonism of Stress Effects on the Hippocampus by DHEA";* \$12,600
- 1997 - 2000 **Principal Investigator**, Veterans Affairs Merit Review Award,  
*"Long-term Effects of Stress on Memory and Hippocampal Function";*  
\$448,962
- 2000 - 2005 **Principal Investigator**, Veterans Affairs Merit Review Award,  
*"Neuroendocrine Basis of Stress Effects on Memory and Brain Plasticity"*  
\$1,206,500
- 2002 - 2003 **Principal Investigator**, Servier Pharmaceuticals, France  
*"Effects of Tianeptine on the Stress-Induced Suppression of Hippocampal Function",* \$68,000
- 2000 - 2005 **Co-Investigator**, National Institutes of Aging  
*"Functional Consequences of Vaccination in AD Tg Mice"* \$2,212,500

- 2002 – 2008 **Co-Investigator**, National Institutes of Mental Health  
*“Significance of Stress-Induced Hippocampal Atrophy”* \$750,000
- 2004 – 2008 **Principal Investigator**, Servier Pharmaceuticals, France  
*“AMPA Receptor Modulator and Amyloid Accumulation in an Animal Model of Alzheimer’s Disease”*; \$68,500
- 2005 – 2008 **Principal Investigator**, Servier Pharmaceuticals, France  
*“Influence of S 24795, a nicotinic modulator, on memory performance and accumulation of  $\beta$ -Amyloid in APP+PS1 transgenic mice”*; \$158,000
- 2005 – 2009 **Principal Investigator**, Veterans Affairs Merit Review Award,  
*“Effects of Stress on Memory: Brain Circuits, Mechanisms and Therapeutics”*  
 \$625,000
- 2005 – 2015 **Veterans Affairs Career Scientist Award**, \$1,100,000
- 2007 – 2008 **Principal Investigator**, Allergan  
*“Effects of Cognitive Enhancing Agents on Spatial Memory”*; \$35,000
- 2005 – 2009 **Principal Investigator**, Servier Pharmaceuticals, France  
*“Influence of Agomelatine on memory and brain plasticity”*; \$71,000
- 2008 – 2009 **Mentor**, Veterans Affairs Research Fellowship  
*“Cranial Electrical Stimulation as a Treatment for Combat-Related PTSD: A Double-Blind, Randomized, Controlled Trial”*; \$4,000
- 2008 – 2011 **Principal Investigator**, Allergan  
*“Pharmacological Reversal of Stress-Induced Sequelae”*; \$77,000
- 2010 – 2014 **Principal Investigator**, Veterans Affairs Merit Review Award,  
*“Neural Mechanisms and Therapeutics in Animal Model of PTSD:”*; \$600,000
- 2011 – 2013 **Principal Investigator**, Veterans Reintegration Program and  
 USF Neuroscience Collaborative; *“G-CSF, Stem Cell and Dietary Treatments in an Animal Model of TBI”*; \$90,000
- 2011 – 2013 **Co-Principal Investigator**, Department of Defense,  
*“Battlefield-Related Injury Translational Research, Post-Traumatic Disease and Disability - Veterans Reintegration Strategy”*; \$1,350,000
- 2012 – 2014 **Mentor** (to David MacQueen), National Institutes of Health,  
*“The Effects of Nicotine on a Translational Model of Working Memory”*; 91,642
- 2012 **Co-Principal Investigator**, National Science Foundation,  
*“MRI: Acquisition of a CAREN Virtual Reality System for Collaborative Research in Assistive and Rehabilitation Technologies”*; \$450,000
- 2014 – 2015 **Co-Investigator**, State of Florida, \$245,000  
**PI: Kevin Kip, Ph.D., USF, College of Nursing**  
*“Pilot Randomized Controlled Trial of Jiu Jitsu (JJ) Training Versus Conventional Physical Exercise (CPE) Among U.S. Service Members and Veterans With Symptoms of Post-Traumatic Stress Disorder”*
- 2014 – 2015 **Co-Investigator**, Chris T. Sullivan Foundation, \$600,000  
**PI: Kevin Kip, Ph.D., USF, College of Nursing**  
*“Accelerated Resolution Therapy for Veterans With Post-Traumatic Stress Disorder”*



### **Current Support**

2015 – 2017 **Co-Investigator**, Department of Defense, \$125,000

**PI: Joseph Francis, Ph.D., Louisiana State University**

*“Inflammation, Oxidative Stress, and Neuroprotective Mechanisms in the Pathophysiology of PTSD in an Animal Model: Measuring the Therapeutic Effects of Blueberries, Exercise, and Prolonged Exposure Therapy”*

2016 – 2019 **Co-Principal Investigator**, NIMH **\$524,000**

*“Optimization of glucocorticoid receptor (GR) passive antagonists for the treatment of post-traumatic stress disorder (PTSD)”*

### **Primary Research Projects**

#### **Effects of Stress on Brain, Memory and Synaptic Plasticity**

**Summary:** The effects of emotionality, and specifically stress, on learning and memory are complex. Intense stress or trauma can produce pathologically strong and intrusive memories, and also impair concentration and increase forgetfulness. This research program investigates the behavioral, electrophysiological, endocrine and neurobiological basis of the effects of emotionality on learning and memory in rats.

**Notable Findings:** My research has investigated the effects of stress and stress hormones on hippocampal synaptic plasticity *in vitro*, and in anesthetized and behaving rats. We have found that exposing rats to an ethologically relevant stressor (i.e., predator exposure) impaired the induction of synaptic plasticity (primed burst potentiation) which is a physiological model of memory. In studies on memory and stress, we have found that predator exposure selectively impaired hippocampus-dependent memory. In recent work, we have developed an animal model of post-traumatic stress disorder (PTSD), which is a powerful disorder of memory produced in people by exposure to a horrific experience. We have also provided the first evidence of intrusive emotional memories in our rat model of PTSD.

#### **Treatments for Combat Veterans and Civilians with PTSD**

**Summary:** Traumatic stress produces long-lasting and pathological effects on human behavior and brain functioning. I am currently working with a team of researchers at USF on a highly effective non-pharmacological treatment for PTSD, which is referred to as Accelerated Resolution Therapy (ART), a revolutionary new approach to the treatment of PTSD that is much shorter and less invasive than conventional treatments for PTSD. In brief, ART is an evidence-based type of psychotherapy used in treating symptoms of psychological trauma and other emotional problems (e.g. depression, substance abuse). It was developed in 2008 as a combination of evidence-based psychotherapies and use of eye movements. It is effective in as little as 5 sessions or less for treatment of PTSD.

As of August, 2016, our group has published 6 papers peer-reviewed medical journals and 1 review on the effectiveness of ART in the treatment of PTSD in civilian and combat subjects.

## **Cognitive and Neurobiological Perspectives on Why Parents Lose Awareness of Children in Cars**

### **Background and Historical Perspective**

One aspect of my research program is the study of how normal (i.e., attentive and loving) parents, without any evidence of abuse or neglect of their children, and without evidence of drug abuse or organic brain dysfunction, *unintentionally and unknowingly*, leave their children in cars. Under conditions in which the ambient temperature is warm enough and the car is exposed to direct sunlight, heat builds within the car and the child may die or become brain damaged as a result of hyperthermia. It is difficult to understand how a parent can leave a child in a car, and yet, it appears to occur at an alarmingly high rate. A survey of 1000 parents which was presented at the National Lifesavers Conference on Highway Safety Priorities in 2014 reported that approximately 25% of all parents with children under 3 reported that at some time during a drive they had forgotten that their child was in the car with them (<http://www.safekids.org/press-release/new-study-14-parents-say-they-have-left-child-alone-inside-parked-vehicle-despite>).

I have found that children have been forgotten in cars by non-parental caretakers and mothers and fathers at all levels of socioeconomic status and education, including well-educated and highly responsible people, such as a physician, teacher, news reporter, judge, prosecutor, pediatrician, firefighter, dentist, hospital administrator, daycare owner and professors. Children dying in hot cars has been discussed in the media, including an article in the Washington Post which won the Pulitzer Prize: ([http://www.washingtonpost.com/wpdyn/content/article/2009/02/27/AR2009022701549\\_pf.html](http://www.washingtonpost.com/wpdyn/content/article/2009/02/27/AR2009022701549_pf.html)). Considering how widespread, fatal and tragic this phenomenon is, it is important to understand it from a scientific perspective, and more importantly, to prevent it from occurring.

### **Cognitive and Neurobiological Perspectives**

When I began studying forgotten children in cars in 2004, over 100 children had already died after being left in hot cars ([www.KidsandCars.org/statistics.html](http://www.KidsandCars.org/statistics.html); [www.noheatstroke.org](http://www.noheatstroke.org)). Since that time, over 200 more children have died or suffered brain damage from heat stroke after being forgotten in hot cars. As a behavioral neuroscientist I have studied this phenomenon from neurobiological and cognitive perspectives. I have interviewed parents, studied police reports, served as an expert witness in civil and criminal cases and contributed to media segments and documentaries on the topic. Based on my research into these cases and my expertise in the study of the brain and memory, I have developed an explanation as to how this phenomenon occurs: This type of memory failure is the result of a suppression of the brain's "prospective memory" system by its "habit memory" system.

Psychologists define prospective memory by its three features: (1) the person has an intention to perform an action at a later time when circumstances permit; (2) there is a delay between forming and executing the intention, a delay which typically is filled with activities not directly related to the intended action; and (3) there is typically an absence of an explicit prompt indicating that it is time to retrieve the intention from memory—the individual must “remember to remember.” In the current context, prospective memory refers to the plan to transport a child to a location, usually daycare, during the

course of a multi-stop drive, or to retrieve a child from the car at the termination of a drive.

Habit memory, by contrast, refers entirely to actions going on in the present. Habit memory involves tasks with repetitive actions which are performed automatically, as in driving from one location to another, such as from home to work with minimal conscious effort. The habit memory system has been referred to as our brain's "autopilot" system.

I discussed the capacity for interactions between our prospective and habit memory systems to produce catastrophic outcomes in an article published in *The Conversation*, entitled: "An epidemic of children dying in hot cars: a tragedy that can be prevented". In that article I explained how people lose awareness of children in cars and the brain memory systems that are involved in this process. Specifically, there are two independent brain memory systems with structures that are involved in prospective and habit-based memory processing. The prospective memory system involves two brain structures, the hippocampus (HC) and prefrontal cortex (PFC), which work together to optimize the conscious planning of future activities and memory multi-tasking. The habit-based memory system is based on the functioning of the basal ganglia (BG), a brain structure that enables people to accomplish well-established routine behaviors with minimal conscious effort.

A relatively benign example of BG domination over the HC-PFC system is when a person has the plan (prospective memory) to stop at a store for groceries on the way home from work. However, the person drives right past the store, oblivious to the plan to stop there for groceries. An explanation for this type of memory error is that the habit-based memory system (BG) suppressed the prospective (HC-PFC) memory system from interrupting the drive home to stop at the store. The memory of the plan to stop at the store is reactivated only when the person is exposed to a distinct cue, such as an empty refrigerator, upon returning home. The person reports that during the drive, he/she had lost awareness of the plan (and therefore forgot) to stop at the store on the way home.

The importance of prospective memory failures, however, is not always as benign as forgetting to buy groceries. There are documented examples of prospective memory-related fatal or potentially fatal tragedies: airline pilots and ground flight crew memory errors have caused the loss of life in plane crashes, police officers have forgotten their loaded guns in public restrooms and dogs have died of hyperthermia after they were forgotten in cars.

Cases of forgotten children in cars involve a failure of the prospective memory system to function properly. An explanation for this failure is that the parent's brain habit memory system outcompetes their brain's prospective memory system. In all of the cases I've studied, the parent begins the drive with the plan to bring the child to a destination, but at some point during the drive the parent reports having lost awareness of the child in the car. In these cases the parent travels directly to the final destination

(typically home or work), and in the process, exits the car without awareness that the child is still in the car.

### **Features in Common in All Cases: Impaired Prospective Memory When a Parent Loses Awareness of the Child in the Car**

Although each case involves different circumstances, they share elements in common. The primary feature which is common to all cases is that the route the person took on the day in which the child was forgotten overlapped with similar routes the parent had driven previously, or, in a subset of cases, the parent had never before driven on that route with the child. Therefore, the most important feature of these cases is that the parent depended solely on his/her prospective memory to distinguish the drive with the child on that day from similar routes the parent had driven on other days that did not include the child.

There are three categories of driving routes in cases of forgotten children in cars. The first category is a multi-stop route, in which the parent had planned on making more than one stop during a drive, one of which was to take the child to a daycare provider. The second category is a single-stop route, typically to take a child to daycare provider, and then the parent had planned to drive to another destination, typically where the parent was employed. The third category is a non-stop route, in which the parent had a single destination, such as to go home or shopping, with the plan to retrieve the child from the car upon arriving at the destination. The common factor in all of these cases is that at a critical choice point along the drive, whether it was a multi-, single- or non-stop drive, all parents report having lost awareness that the child was in the car.

### **Factors That Contribute to the Loss of Awareness of a Child in the Car**

I have studied the conditions that appear to increase the likelihood that a child will be forgotten in a car. The following are categories of influences that would impair prospective memory and would also increase the dominance of habit memory over prospective memory:

- 1) Many, but not all, of the parents report that they had a strong stress or a highly distracting experience prior to or during the drive. Neuroscience research has shown that stress has a selective adverse effect on prospective, but not habit, memory. Although not obligatory, the stress or distracting experience helps us to understand why a subset of parents lost awareness of the child in the car.
- 2) As with stress, many, but not all, of the parents report that they had interrupted sleep on the night before the incident. Sleep deprivation has a selective adverse effect on prospective, but not habit, memory. Although not obligatory, sleep deprivation helps us to understand why a subset of parents lost awareness of the child in the car.
- 3) There is often a change in the driving route on the day of the incident that reduces the parent's awareness of the child in the car. For example, a parent may typically drive straight from home to daycare to work, but on the day of the incident, the parent changed the route, to drive, for example, from home to a fast food restaurant (for

breakfast). As a result of the change in route, in conjunction with a sleeping child, the basal ganglia triggers an autopilot response to take the person directly from the fast food restaurant to work, bypassing the planned route to daycare.

4) Parents that have forgotten children often report that they had routinely interacted with their child during a typical drive, but on the day of the incident the child was unusually quiet (presumably sleeping). The change in the interpersonal dynamics between the parent and child would be identified by the basal ganglia as a day in which the child was not present in the car. Therefore, the "autopilot system" would recognize the drive with a quiet child as one without the child; in the absence of child-specific cues, the basal ganglia would direct the parent to go directly to work, rather than to daycare.

### **Factors That Reduce the Likelihood a Child Will Be Forgotten in a Car**

As noted above, approximately 25% of all parents with children under 3 reported that at some time during a drive they had forgotten (lost awareness) that their child was in the car with them. If so many parents lose awareness of children in cars, why are hot car deaths of children not more common? There are numerous factors that can interfere with the process by which a child is left in a car, or if left in a car, will reduce the likelihood the child will be harmed by heat stroke. I have observed the following influences which have been reported by parents that had lost awareness of their child during a drive, but no harm had come to the child:

1) After losing awareness of the child, parents have reported the presence of a cue, a specific reminder, that the child is in the car. The child may make a sound, or something may be in the car, such as an item, such as a diaper bag, that needs to be retrieved in the front or back seat, which jogs a parent's awareness of the child in the car.

2) Environmental conditions are highly important. The greenhouse effect (whereby the interior of a car can be 30-40 degrees hotter than the exterior) is dependent on a car having full sun exposure on a sufficiently warm day, for a sufficient period of time. There are reports of children which were unharmed after being left in cars on days that were not warm enough to cause hyperthermia. In related observations, parents have reported leaving their child in a car in a covered parking facility, which therefore would leave the car's internal temperature equal to the ambient temperature in the parking structure.

3) Timing is important. If the ambient temperature is warm enough and the car is left in full sun exposure, a child may not develop hyperthermia if a parent returns to the car in a short period of time. There is an interaction among the ambient temperature, degree of sun exposure of the car and the time a person is away from a car before the interior of the car is sufficiently hot to cause harm to the child.

4) Oftentimes the parent that had lost awareness of the child was not alone, and one or more passengers may have taken note of the presence of the child. There are documented cases, however, in which two individuals both lost awareness of the presence of the child in a car, resulting in the child dying in a hot car.

5) There are numerous reports of bystanders who removed a child from a hot car. In my experience this has happened far more often when cars are parked in high pedestrian traffic areas, such as retail shopping parking lots, than when cars are parked at home or the parent's place of employment.

### **Universal Observation of a False Memory**

An important and universal observation of the reports from these parents and caretakers is based on their activity during the day after the child is left in the car. These parents go about their daily routine, sometimes for an entire day's work and they even use the car (with the deceased child in it) during the day, without the parent having any awareness the child is in the car. These people universally report having complete confidence that the child was safe, at the location where the parent had intended on taking the child. Indeed, many parents return to the daycare expecting to retrieve their child, only to be told that the child did not arrive at daycare that day. These individuals are then horrified to learn that their child spent the entire day in their car, with fatal consequences.

It is potentially of scientific value to explore the process by which the brain somehow creates the false memory that the person has fulfilled his/her task of bringing the child to daycare, or that the child was at home. It is notable that everyday routine activities that may involve the child, such as discussing the child with others, or having a picture of the child at the parent's workplace, do not serve as reminders that the child is in the car since the brain has provided the person with the false memory that the child is safe at home or at daycare. With the false memory in place, any reminders of the child during the day are considered a routine part of a normal day. The only cues that would be relevant to reactivating the prospective memory must be cues that would specifically indicate that the child is in the car, such as a phone call from a daycare employee inquiring as to why the child had not come to daycare that day.