



## Behavioral and neuroanatomical investigation of Highly Superior Autobiographical Memory (HSAM)

Aurora K.R. LePort<sup>a,\*</sup>, Aaron T. Mattfeld<sup>a</sup>, Heather Dickinson-Anson<sup>a</sup>, James H. Fallon<sup>c</sup>, Craig E.L. Stark<sup>a</sup>, Frithjof Kruggel<sup>b</sup>, Larry Cahill<sup>a</sup>, James L. McGaugh<sup>a</sup>

<sup>a</sup> Center for the Neurobiology of Learning and Memory, Department of Neurobiology and Behavior, University of California, Irvine, CA 92697, USA

<sup>b</sup> Department of Biomedical Engineering, University of California, Irvine, CA 92697, USA

<sup>c</sup> Department of Anatomy and Neurobiology, University of California, Irvine, CA 92697, USA

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### ABSTRACT

A single case study recently documented one woman's ability to recall accurately vast amounts of autobiographical information, spanning most of her lifetime, without the use of practiced mnemonics (Parker, Cahill, & McGaugh, 2006). The current study reports findings based on eleven participants expressing this same memory ability, now referred to as Highly Superior Autobiographical Memory (HSAM). Participants were identified and subsequently characterized based on screening for memory of public events. They were then tested for personal autobiographical memories as well as for memory assessed by laboratory memory tests. Additionally, whole-brain structural MRI scans were obtained. Results indicated that HSAM participants performed significantly better at recalling public as well as personal autobiographical events as well as the days and dates on which these events occurred. However, their performance was comparable to age- and sex-matched controls on most standard laboratory memory tests. Neuroanatomical results identified nine structures as being morphologically different from those of control participants. The study of HSAM may provide new insights into the neurobiology of autobiographical memory.

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### 1. Introduction

Highly Superior Autobiographical Memory (HSAM) is a newly described ability in which individuals are able to recall events from their personal past, including the days and dates on which they occurred, with very high accuracy. Previously termed “hyperthymestic syndrome,” it was first studied in an individual referred to as A.J. (Parker, Cahill, & McGaugh, 2006). HSAM is distinct from other types of superior memory as participants with this ability perform autobiographical remembering without the apparent use of mnemonic skills. Typically, individuals with superior memory encode and retrieve domain-specific and/or relatively meaningless information utilizing strategies acquired through practice (e.g., street maps of entire cities, pi out to 22,514 decimal places, and long displays of words or digits; Ericsson, Delaney, Weaver, & Mahadevan, 2004; Hunt & Love, 1972; Gordon, Valentine, & Wilding, 1984; Wilding & Valentine, 1997). Even the extreme memory abilities of one of the most famous mnemonists, patient S., described by Luria (1968), did not entail *autobiographical* remembering. Patient S. described living his personal life “as in a haze” (p. 159).

Since the publication of Parker et al. (2006) numerous individuals have contacted our research group professing either to have HSAM, or to know someone who does. We have identified ten new HSAM participants (in addition to A.J.) utilizing a screening process developed to identify HSAM characteristics.

Here we report a detailed analysis of both cognitive function and brain structure of the eleven HSAM participants (including A.J.). Cognitive assessment involved a battery of memory tests both general in nature and specific to autobiographical memory. We examined potential differences in the neuroanatomy of the HSAM participants, as compared to that of age- and sex-matched controls, using structural magnetic resonance imaging (MRI). A substantial literature indicates that changes in human brain structure can be associated with changes in behavior, including memory (Golestani, Paus, & Zatorre, 2002; Bohbot, Lerch, Thorndyraft, Iaria, & Zijdenbos, 2007; Boyke, Driemeyer, Gaser, Buchel, & May, 2008; Draganski et al., 2006; Fujie et al., 2008; Scholz, Klein, Behrens, & Johansen-Berg, 2009). For the present project, four neuroanatomical methods were used. The first two, Voxel Based Morphometry Grey-Matter (VBM-GM) and Voxel Based Morphometry White-Matter (VBM-WM) allowed for the comparison, between groups, of the local concentration of grey and white matter found in any given voxel throughout the brain (Ashburner & Friston, 2000). The third, Tensor Based Morphometry (TBM) was used to detect

\* Corresponding author. Address: #7 Qureshey room Research Laboratory, University of California, Irvine, CA 92697-3800, USA. Fax: +1 949 824 8439.

E-mail address: [aleport@uci.edu](mailto:aleport@uci.edu) (A.K.R. LePort).

group-related differences in the shape of regions of the brain (Chung et al., 2001). The fourth, Diffusion Tensor Imaging-Fractional Anisotropy (DTI-FA) allowed for a means of quantifying and comparing differences in white-matter structure (Beaulieu, 2009; Moseley et al., 1990). We present here the results of these cognitive and neuroanatomical analyses.

## 2. Materials and methods

A multi-step, Institutional Review Board (IRB) approved process was developed to identify and test HSAM participants. Individuals, who contacted us proclaiming to have HSAM, were screened over the telephone and if they met criteria, were formally consented. One hundred and fifteen adults, claiming to have HSAM, were screened with the Public Event Quiz (the first screening quiz, described below). Forty-one of those adults scored well enough to advance to the 10 Dates Quiz (the second screening quiz, described below). Thirty-six of the forty-one adults were screened with the 10 Dates Quiz (five did not respond when contacted) and 31 passed it (achieving a score of 65% or above). Eleven of these adults (4 females, 7 males, age range 27–60, average age = 43; six right-handed, three left-handed, and two ambidextrous) came to the laboratory for an interview, during which participants discussed their memory ability, cognitive testing was performed and detailed anatomical data, via a structural MRI, were collected. A behavioral questionnaire, designed to determine possible common qualities of the HSAM participants, was administered via the telephone at a later time point. Each of these procedures is discussed below in detail. All research data were collected through a protocol approved by the University of California, Irvine IRB and informed written consent was obtained from all eleven participants.

Three different sets of age- and sex-matched controls were used for the screening, cognitive battery and MRI. All were adults recruited actively via contacts in the adjacent community, of whom none claimed to have HSAM or other superior memory abilities. All gave written informed consent in compliance with the IRB of the University of California, Irvine for behavioral testing and the usage of MRI scans.

**Screening Controls.** Thirty age- and sex-matched controls (15 males, 15 females, age range 26–67, average age = 43.9) were screened for the study using the Public Events Quiz of which 13 were given the 10 Dates Quiz (6 males, 7 females age range 28–62, average age = 50).

**Cognitive Battery Controls.** Fifteen age- and sex-matched controls (5 males, 10 females, age range 23–56, average age = 36.8) received the cognitive battery.

**MRI Controls.** Structural MRI data was compiled from nineteen age- and sex-matched healthy controls previously scanned by a collaborating research group (10 males, 9 females, age range 23–66). Controls were determined, via the Edinburgh Handedness Inventory, to be right-handed (see Section 3).

### 2.1. Screening procedures

The Public Events Quiz consisted of thirty questions presented over the telephone. It contained two types of questions: fifteen asked for the date of a given significant public event that took place within the individuals' lifetime (e.g., When did Jimmy Carter win the Nobel Peace prize?); fifteen asked for the significant public event that took place on a given date that fell within the individual's lifetime. In addition, for all 30 questions, individuals were asked to state the day of the week the date fell on. The order of presentation of the two types of questions was interchanged. The significant public events given were selected from five different categories: Sporting events, political events, notable negative

events, events concerning famous people and holidays. The participant received one point for each correctly identified category (i.e., the event, the day of the week, the month, the date and the year) and could achieve a total of 88 possible points. Percentages scored were calculated for each individual claiming to have HSAM as well as each screening control. A score of 50% or above qualified an individual claiming to have HSAM to advance to the second even more challenging round of screening, the 10 Dates Quiz.

The 10 Dates Quiz consisted of ten computer generated random dates, ranging from the individuals' age of fifteen to the day of testing. It was administered via the telephone with no time limits. Individuals were asked to provide three different categories of information for each of the 10 dates generated: (1) the day of the week; (2) a description of a verifiable event (i.e. any event that could be confirmed via a search engine) that occurred within  $\pm$  one month of the generated date; (3) a description of a personal autobiographical event the individual participated in. One point was awarded for the correct day of the week, for giving a verifiable event confirmed as true, and/or for giving a personal autobiographical event. A maximum of three possible points per date could be achieved (thirty points total). The percentage scored for each category as well as the total score, the average of all three categories, was calculated. A total score of 65% or above qualified the individual as an HSAM participant and for further, in person, behavioral and neuroanatomical testing.

### 2.2. Cognitive battery

Following the screening procedure, eleven HSAM participants were brought to the laboratory and examined with a cognitive battery consisting of thirteen behavioral tests assessing autobiographical memory, various types of learning and memory, obsessional tendencies hand dominance and depression levels. The choice of tasks was driven by our prior experience with HSAM individuals and by our desire to assess different aspects of their memory ability. The battery took approximately an hour and a half to complete. Three participants failed to complete the entire battery. The number of participants who took each test is detailed in the results.

#### 2.2.1. Autobiographical Memory Task (AMT)

Autobiographical memory was assessed following a modified cued-recall procedure based on Pohl, Bender, and Lachmann (2005). Each participant was asked to recall five specific personal events, chosen such that answers could be verified for accuracy. Participants had no prior knowledge of which personal events would be asked. The five specific events were: First day at university; First day of elementary school; 18th birthday celebration; Address and description of the first place they resided after moving out of parents' house; Last final exam in college.

Participants were asked to recall verbally each event in as much detail as possible and encouraged to include details such as dates, weather, names of others present and location. At the conclusion of the test, participants were asked to supply the following items for verification of the accuracy of their memories: College transcripts, correspondence from first address, kindergarten or 1st grade class photo, pictures from 18th birthday celebration, diaries and calendars.

Two separate scores were devised, one for 'AMT Verifiable Details Score' and one for 'AMT Total Details Score'. Details for the 'AMT Verifiable Details Score' were verified via personal documents, calendars, or web searches (using sites such as historical weather databases, Google Maps and news articles) and given one point if accurate. See Appendix A for examples that illustrate the verification process. The percentage correct out of all verifiable details was calculated. Details for the 'AMT Total Details Score' were not verified. One point was given regardless of whether a

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