QUANTITATIVE MEASUREMENTS OF AUTOBIOGRAPHICAL MEMORIES

by

Adam T. Vogel

A Thesis
Submitted to the
Graduate Faculty
of
George Mason University
in Partial Fulfillment of
The Requirements for the Degree
of
Master of Arts
Psychology

Committee:

____________________ Director

____

____

____________________ Department Chairperson

____________________ Dean, College of Humanities and Social Sciences

Date: December 3, 2008

Fall Semester 2008
George Mason University
Fairfax, VA

Quantitative Measurements of Autobiographical Memories

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Arts at George Mason University

By

Adam T. Vogel
Master of Arts
George Mason University, 2008

Director: Giorgio Ascoli, Professor
Department of Psychology

Fall Semester 2008
George Mason University
Fairfax, VA

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

- CRAM: Cue-recalled autobiographical memories.
- SPAM: Spontaneous probability of autobiographical memories.
- AM: Autobiographical memories.
- STM: Short term memory.
- LTM: Long term memory.
- RpH: Rate per hour.
- d: Duration in seconds.
- t: Temporal window measured in seconds.
- Q_2: Second quantile or median.

ABSTRACT

QUANTITATIVE MEASUREMENTS OF AUTOBIOGRAPHICAL MEMORIES

Adam T. Vogel, MA

George Mason University, 2008

Thesis Director: Dr. Giorgio Ascoli

The scientific pursuit of the mind-brain relationship demands the ability to quantify subjective cognitive phenomena. I applied two new psychometric tools, called CRAM (Cued-Recalled Autobiographical Memories) test and SPAM (Spontaneous Probability of Autobiographical Memories), to probe the quantitative dimensions of autobiographical memories (AMs) in humans. In CRAM, a computer-based protocol first prompts the retrieval and temporary labeling of episodic memories by using word cues sampled from a word database with a frequency proportional to their natural language usage. Subjects then sequentially estimate when each event occurred and report the number of features for each of several elements (e.g. people, objects, location details, etc.) they can recall for every AM. This test has been also adapted for the web and is available at http://cramtest.info. Data collected from largely undergraduate participants (N = 191, M = 22 years old, SD = 7 years) confirmed classic results describing the temporal distribution of AMs as a steep, gender-independent power decay from the most

recent episodes to childhood amnesia. Analysis further revealed a much more modest dependence of the total content of individual AMs on the episode age (*M* = 18.7 *SE* = 0.24 elements overall vs. *M* = 16.1 *SE* = 0.32 and *M* = 23.5 *SE* = 0.26 for the most remote and recent tenths of life, respectively). Contrasting among features, *People* and *Episodes* were found to be the least and most susceptible to temporal degradation (-33% vs -100% lifespan reduction), respectively. Elements of *People* and *Context* were found to be more independent of other features (i.e. possibly “primary”) for females than males, while the opposite held true for location and temporal elements. SPAM is a separate experiment that assesses the number of AMs recalled per unit of time by stochastically sampling, through an automated paging system, the probability to be reminiscing one’s past episodes, and the duration of these recalls. A first pool of volunteers (*n* = 48, *Mdn* = 21 y.o., *MAD* = 3 yrs..) retrieved, on average, 21 (*SE* = 2.65) AMs per waking hour. Combining all results enables rather detailed inferences, such as “during a typical day, 45 elements are recalled from the middle fifth of one’s lifespan”. Storage of age-specific population statistics in a large-scale informatics database will allow future queries of multi-dimensional frequency maps of human memories. Practical implications of both the data and the experimental design include improved diagnosis and monitoring of diseases such as Alzheimer’s and critical assessment of eyewitness reports.

1. AUTOBIOGRAPHICAL MEMORIES:
Review and the State of the Art

The scientific pursuit of cognitive phenomena strives to understand the mind beyond the qualitative descriptor, and into quantitative terms. Progress towards creating objective metrics of the mind has been extremely difficult and often times stalls on one particular aspect, curtailing true advancement. In this thesis I will introduce different concepts of memories, focusing on autobiographical memory (AM), as a cognitive phenomenon accurately depicted by the prior sentence. In the first chapter, a quick taxonomy of memory is given followed by a literature review of the different methods used to study aspects, or an aspect, or AMs. The current status of results are discussed in the second part of chapter 1 with a focus on the temporal distribution of AMs. Chapter 2 presents the goals of the proposed studies which are described in chapter 3. In chapter 4, preliminary results of the temporal distribution, quantitative content and frequency of AMs are given. Conclusions and further development of the experiments are concluded in chapter 5.

1.1 Definitions and Taxonomy of Memories

A long established doctrine widely accepted in memory research is the distinction between short-term (STM) and long-term memories (LTM). Demonstrated in several neuropsychological studies, the ability of amnesiacs to perform well on STM tasks while being completely incapable at LTM tasks outlines a physical separation of memory organization in the human brain (Baddeley & Warrington, 1970; Bayley, Hopkins, & Squire, 2006; Knowlton, Musen, & Squire, 1993; Remondes & Schuman, 2004). STM, also known as working memory, is defined by the ability to consciously hold information for a temporal period of approximately 20 seconds. Miller (1956) had a very large impact on the theory of information processing (i.e. working memory) that has bled out into the mainstream population with the proposal that humans can cognitively maintain and manipulate 7 numbers (± 2). Updated by Nelson Cowan, it is now currently considered that an adult can use mnemonic strategies to retain about 7 unique items, however, in absence of a memory strategy the mind can concurrently hold only approximately 4 separate, simple items (Cowan, in press).

Short-term conceptually transitions onto long-term memories once the memory extends beyond 30 seconds. LTMs are categorized as either declarative (i.e., explicit) or non-declarative (i.e., implicit). The major distinction between these two categories emphasizes the notion of conscious recollection, where in, declarative memories are conscious recollections of events or facts (e.g., recalling the last time you went swimming) and non-declarative memories are characterized by various forms of unconscious memory (e.g., how to type at a keyboard). Declarative memory can be further subdivided into episodic and semantic memory. Episodic memories are recollections of spatially and temporally specific events while semantic memories refer to factual knowledge about the world. Numerous neuropsychological studies have found episodic and semantic memory to be dissociated in the brain (Connelly, et. al., 1997; Hopkins, Manns, & Squire, 2003). Non-declarative memory include emotional, motor, and cognitive procedural memory reflected as a learned behavioral sequence and response prompted by environmental cues. The current study investigates autobiographical memory, defined as the recollection of one's personal past that is unique in the context of time and space.

1.2 Research Methodology

1.2.1 *Cue Words*

The cue word method has helped elucidate the temporal distribution of AMs across ages and gender and has also provided a format for qualitative inquires. However, it's shortcomings are found in it's stunted historical use by becoming a standard with little deviation despite it's versatility.

In 1879, Galton cast the characters which would capture the spotlight in the quantitative study of AMs, contesting that until the phenomenon has been subjected to measurement and number it cannot assume the status and dignity of a science. Galton (1879) was the first to describe a method to study autobiographical memories (AMs) in a 'scientific' manner by recording timing details of spontaneous episodic recollections cued by words and objects. Galton began exploring quantitative aspects of memories when he noticed how everyday objects prompted memories that appeared to be associated with each other. His initial method consisted of a leisurely 450 yard stole in Pall Mall scrutinizing with attention every object that caught his eye until a memory or two arose. Eventually he exchanged the prompts found during his causal strolls down Pall Mall for a set of words. Galton was interested in using this method to describe the associative characteristics of memories and their temporal distribution.

After a century long hiatus, Galton's method was revised by Crovitz and Schiffman (1974) and Robinson (1976) and it has since largely defined the boundaries for autobiographical memory research. Currently the versions of Galton's method varies little between labs, e.g., memories can be associative to the word (e.g. the word "fish" and the memory of fishing for the first time) or completely autonomous (e.g., the word "plate" prompts a memory of the latest speeding ticket that you narrowly escaped). The primarily use of Galton's revised method has been to study the temporal distribution of the memories (Robinson, 1976; Monaghan & Rybash, 1999; Jansari & Parkin, 1996; Fitzgerald & Lawrence, 1984; Rubin & Schulkind, 1997; Bender, Bender et al., 2003). The general protocol for using cue words to study AMs involves three steps: (1) cue words are presented as prompts for participants to generate memories from, (2) successively after each memory recollection the memory is identified with a unique detail that allows the researcher and participant to revisit the memory later in the test, and (3) the memories are aged for the temporal period at which the event of the memory had occurred. Three styles of dating a memory have been used: (1) the age you were at the time of the event, (2) the date the event had occurred, and (3) the time lapsed from the time of the event.

The effect of priming by cue words has been studied and shown to impact different aspects of the data collected. Using object, affect, and activity word cues Robinson (1976) found consistent differences among the word classes. Object terms were positively correlated with response time ($r = 0.63$, $p < .01$) for males and females while median event age of cued memories were positively correlated with activity terms ($r = 0.56$, $p < .05$). Affect terms were not correlated to either response time or event age. Fitzgerald and Lawrence (1984) also found correlations between types of cue words and the event age and response time of AMs. Event age of memories cued by nouns and affect prompts were reported being at a 2:1 ratio, respectively, with a significant main effect, $F(3, 112) = 23.6$, $p < .001$, $w^2 = .031$. Additionally, response times were found significantly different between cue word types, $F(3, 112) = 41.9$, $p < .001$, $w^2 = .062$. Rubin (1980) identified six factors in a set of 125 words; spelling and sound, imagery and meaning, word frequency, recall, emotionality, and goodness which has been used to further examine cue word effects. Rubin and Schulkind (1997) found somewhat conflicting results for the decrease of relative reaction times for cue words with high imagery and meaningfulness and concert cue words. However, they found cue words to be poor predictors for memories falling in the reminiscence period (10 to 30 years old at the time of event). From these findings the importance of choosing and considering the effects of cue words on memory is clearly an a priori concern. Words chosen serendipitously may produce a ‘laboratory’ effect that will likely not exist in the natural environment; haphazardly chosen cue words may elicit an obscure memory system typically not experienced in the natural course of a day.

1.2.2 *Life-Narrative*

In the life-narrative method participants are asked to give a version of their life story, often highlighting memories of important events. Unlike cuing methods, which produce one memory per cue, the life-narrative method produces a stream of memories that need to be separated out into distinct instances. Typically, the interviews are tape recorded and transcribed for later analysis. The most common analytical use of this data focuses on the distinctiveness, detail and emotional level (i.e., Likert scale), the number of memories, repetition of memories, and number of transitional events (e.g., starting school). The temporal distribution of memories, though observed, is believed to be biased due to the propensity of participants to provide memories in a structural narrative form compared to unrelated memories cued by random words. However, comparing the distributions of AMs across time Bender et al. (2003) found that both life-narrative and cue word methods produced similar distributions, i.e., the distribution contained a childhood amnesia, reminiscence bump, and a retention function.

1.2.3 *Autobiographical Memory Interview (AMI)*

The Autobiographical Memory Interview (AMI) is concerned with measuring what can be remembered and is most commonly used to assess amnesic patients, although it can be used with neurologically normal participants. The interview consist of two components: (1) an autobiographical incidents schedule and (2) a personal semantic memory schedule (Baddeley, Kopelman, & Wilson, 1988). The autobiographical incidents schedule divides the participant's life into three periods–childhood, early adulthood, and recent–and requires 3 specific memories from each period (e.g., during primary school, first job or College/University, a journey in the last year). In the personal semantic schedule patients are tested for specific knowledge of facts from four sectors of their life (i.e. background information–birth place; childhood–age during first grade; early adulthood–name of first job; and recent information–where last Christmas was spent).

1.2.4 *Diary*

Due to the strain and need of reliable subjects, the initial attempts to use diaries for the study AMs consisted of case studies performed on the author of the research (Wagenaar, 1986; White, 1982). The conventional design of this method involves making daily entries of events. These events are then chosen at random and can be used as a measuring stick to determine accuracy or degree of association of the participants recollection. Contextual details from recorded events are commonly used as cues to observe how effective different aspects of events are for cuing the memory. For example, Catal and Fitzgerald (2004) coded a 20-year daily log from a 78 year old female participant and used event details of *who*, *what*, *where* and *when* to prompt the recall of the event content. They found that the most significant effect on the recollection of past events was the order of the cues, where contextual cues of *what* were the strongest initial cue and details of *where* the event occurred are the weakest cue. Furthermore, the amount of detail recalled is found to be effected by the cues and cue order. Single-cue memories recalled from *what* prompts had the highest mean score (M = 3.26) on details remembered, similarly, for combination-cue memories *what-when* produced the highest mean detail scores (M = 3.88).

In a six year case study of his personal memories, Wagenaar (1986) documented *who*, *what*, *where* and *when* information and measured the effectiveness of these elements, alone and in combination, to cue events and found that, in contrast to Catal and Fitzgerald (2004), cues specifying temporal periods were the least helpful for recalling the event. In the same study, Wagenaar noticed that there was never a complete memory failure, in that, provided with enough cues he was able to recall all the events recorded over the six year period. Though the memory for ten events (from the complete database) were initially unattainable, Wagenaar was able recall them after gathering more information of the events from the people listed in the *who* element.

Though several researchers have spent a considerable amount of effort detailing their daily life over lengthy periods of time the question of if the act of recording daily events distorts normal memory processing remained open. In a crafty design, Thompson (1982) addressed the effects of dairy keeping on memory recall by asking undergraduate participants to not only keep a dairy of their personal life but also that of their roommate's. Dairies were kept for 14 weeks and up until the final week the roommates remained unaware that they would be tested on the events being documented. No differences were found between participants who recorded their own daily events and the roommates who had their daily events recorded for them.

1.2.5 *Others*

Considered by Ebbinghaus to be one of the major types of memories, involuntary memories have received little consideration in memory literature particularly involuntary semantic memories (Kvavilashvilli & Mandler, 2004). An involuntary memory is defined as a recollection of the past that is experienced with no proceeding attempts of retrieving the memory and can thus be considered a type of AM. Involuntary memory studies are typically observed in clinical setting, most commonly with patients suffering from post-traumatic stress disorder. Due to the inherent elusiveness of this type of memory, documenting them as they occur, in contrast to retrospectively, has been the preferred method (Berntsen, 1996).

A method similar to word cuing, known as event cuing, uses a prior established memory to cue additional an memory. Brown and Schopflocher (1998) found that by using memories to prompt additional recollections they were able to study the organization of AMs. Participants first recalled a set of personal events from their past from which each event was used to prompt a second event. Participants were then requested to rate the relationship between the cue and cued memories and date the events of each memory. The results indicate AMs are often causally related and temporally proximal.

The questionnaire method (Greenberg, Rubin, & Schrauf, 2003) consist of a questionnaire to rate memories (on a Likert scale) for emotional level, importance, rehearsal, etc. Using a Liker-scale questionnaire like method, Catal and Fitzgerald (2004) scored events on a 4-point distinctiveness scale in which points were awarded based on the frequency of the event's occurrence in the log and the number of elements that the event had in common with other events. The proportionally distribution of events and their uniqueness rating (e.g., a highly unique memory constituted rarely duplicated elements of *who, what, where,* and *when*) was 21%, 52%, 23%, and 4% for memories scoring 1, 2, 3, and 4 on the distinctiveness scale, respectively.

Berntsen and Rubin (2003) sampled specific memories by asking 1,307 participants, between 20 and 94 years of age, their age when they felt the most afraid, proud, jealous, in love, and angry. Participants were further asked their age when they experience their most important event of their life and whether it was positive or negative. Results show different distributions for negative and positive memories for the age of the memory were positive memories (e.g., most proud, in love, etc) retained the reminiscence bump while negative memories (e.g., most angry, sad, etc.) lack the bump. The authors suggest that, in agreement to the modern life course of Western culture, culturally shared life scripts exist for positive but not negative events (Berntsen & Rubin, 2003; Berntsen & Rubin, 2004).

1.3 Temporal Distribution

Though there are several methodologies used in memory research, in essence they all address the same question; what is the distribution of memories as a function of time? When the temporal distribution of AMs is plotted 3 distinct components are apparent; childhood amnesia, a reminiscence bump, and a retention function. Childhood amnesia is characterized as a near complete extinction of memories recalled from ages 0 and 5 years. The reminiscence bump is seen as a steep increase in the proportional memories recalled between the ages of 10 and 30 years. The retention function, best defined mathematically by the power function $y = a * t^{-b}$, consisting of a rapid decrease and evening off of memories recalled from the most recent 10 to 20 years (Bender, et al., 2003; Jansari & Parkin, 1996; Poon, Rahhal, & Rubin, 1998). Each component of the AM distribution is incredibly robust. Using scents to cue memories, in contrast to word cues, all three components of the distribution were observable (Chu & Downes, 2000; Goldsmith, Groth, & Rubin, 1984). Figure 1 shows a review of the temporal distribution of AMs by Poon, Rahhal, and Rubin (1998) of four studies. All four studies concluded from their data the three characteristic components, listed above, of AMs. Rubin and Schulkind (1997) report the malleability of the distribution for priming biases by using AM examples from early or late life in their instructions, however, changes were only slight shifts in the distribution while the functions fitted to the distribution remained in the same general form. Explicit attempts to find gender differences in the temporal distribution of memories have failed (Rahhal, Rubin, & Schulkind, 1999).

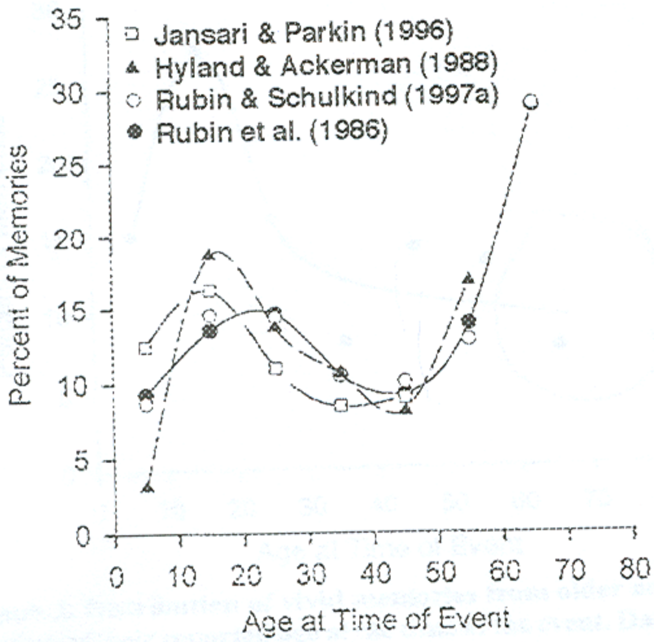


Fig. 1. Taken from Rahhal, Rubin, and Poon (1998) the temporal distribution of autobiographical memories from 4 studies are shown. Each study found the existence of a childhood amnesia, reminiscence bump, and retention function in their data.

Mackavery, Malley, and Stewart (1991) coded the diaries of 49 psychologists for episodic and non-episodic memories (non-episodic being defined as memories consisting of events lasting over hours, days, weeks, or years, e.g. the memory of marriage). When they plotted the temporal distribution of these two types of memories they found similar distributions.

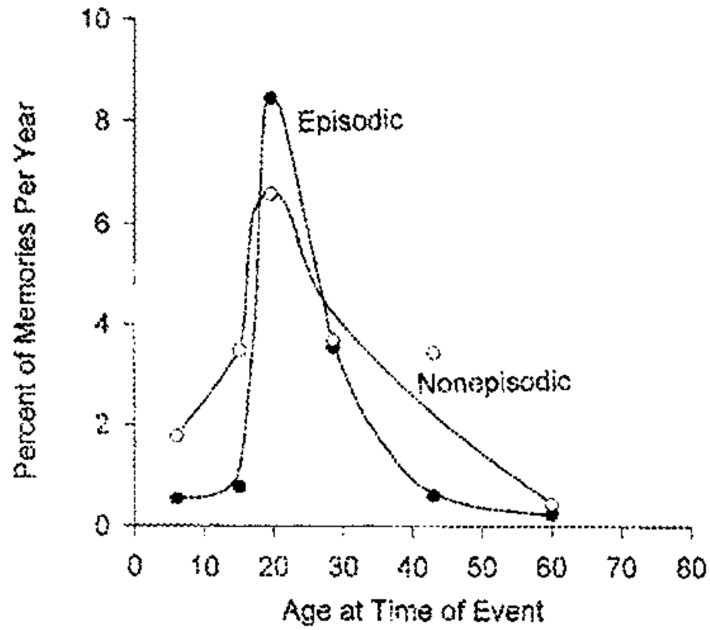


Fig. 2. Components of the temporal distribution of AMs can be seen for other types of memories as well. Mackavey, Malley, and Stewart (1991) observed a prominent reminiscence bump in their data of episodic and nonepisodic (defined as memories of events lasting longer than a day, e.g. the recollection of married life) memories.

Using a remember-know paradigm, in which participants report, post-hoc, whether the memory they had documented was of an event that they remembered happening or knew happened, Monaghan an d Rybash (1999) collected temporal data (figure 3) of memories and found essentially the same distribution was shared between the two. Under this paradigm memories reported as being remembered to have happened are assumed to be episodic while memories reported as known to have occurred are assumed to be semantic in nature.

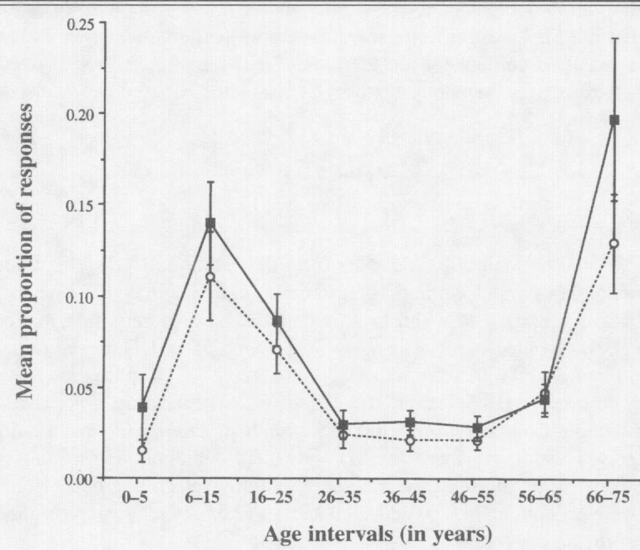


FIGURE 1. Mean proportion (and standard error) of remember (R) responses and know (K) responses for personal memories dated within specific age intervals. Open circle = R response. Filled square = K response.

Fig. 3. Monaghan and Rybash (1999) used a Remember-Know paradigm in which events that were reported as remembered were assumed to reflect episodic memories while events reported as known to have occurred were assumed to be semantic memories. Both types of memories contained the 3 distinct components of the AMs distribution.

1.3.1 *Childhood Amnesia*

While retention is a function of time lapsed, childhood amnesia is a function of time from birth. Similar to the retention of later memories, the childhood distribution is well documented with little variance between genders, ages, and methods. In a meta-analysis (figure 4), Rubin (2000) analyzed over 11,000 memories, collected from numerous studies, documents the presence of childhood amnesia that are nearly identical between genders. Childhood amnesia is also found irrespective to age groups (ie. from 20s to 70s in 10 year increments). Furthermore, it was found that methodology had no effect on this temporal distribution component; four different methods, word-cue, exhaustive search, interview, and focused, produced the same distribution of childhood memories.

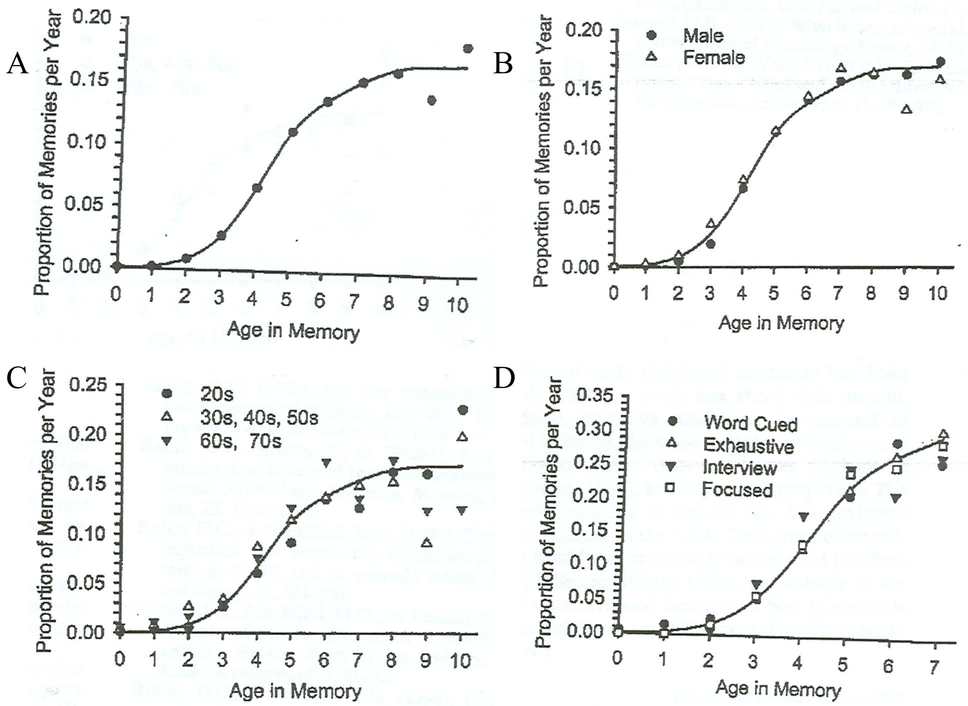


Fig. 4. Childhood amnesia can be seen not only in the (A) overall dataset but also between (B) genders, (C) age groups, and (D) methods (Rubin, 2000)

In the grand scheme of modeling the temporal distribution of AMs, including independent functions for childhood amnesia and the retention function allows a greater ability to fit the data of participants of different ages.

1.3.2 *Reminiscence Bump*

The component of the temporal distribution of AMs known as the 'reminiscence bump' has been well studied by numerous empirical observations (Rubin & Schulkind, 1997; Jansari & Parkin, 1996; Poon, Rahhal, & Rubin, 1998). The reminiscence bump is characterised by an increase in memories recalled between the ages of 10 and 30 (Rubin & Schulkind, 1997; Monaghan & Rybash, 1999) and is best observed in data from older adults (>45 years of age). In figure 5, we can see that the reminiscence bump extends beyond the domain of AMs and is observable in the distribution of important memories. In a study performed by Formholt and Larsen (1991) Alzheimer's patients (figure 5a) were asked to identify memories from their personal past that they felt were important. Although Alzheimer’s patients produced fewer memories overall when compared to controls, the temporal distribution between the two groups were reflective of one another. Additional research (Rubin & Schulkind, 1997; Fitzgerald, 1996), shown in figure 5b and 5c, further reveals a similar distribution of personally important memories as a function of age at the time of event. Yet again, Schuman and Scott (1989) (figure 5d, 5e, and 5f) found that, consistent with the reminiscence bump, when participants were asked to describe important events from their past a disproportional amount came from the period of life when participants were in their 10s, 20s, and 30s.

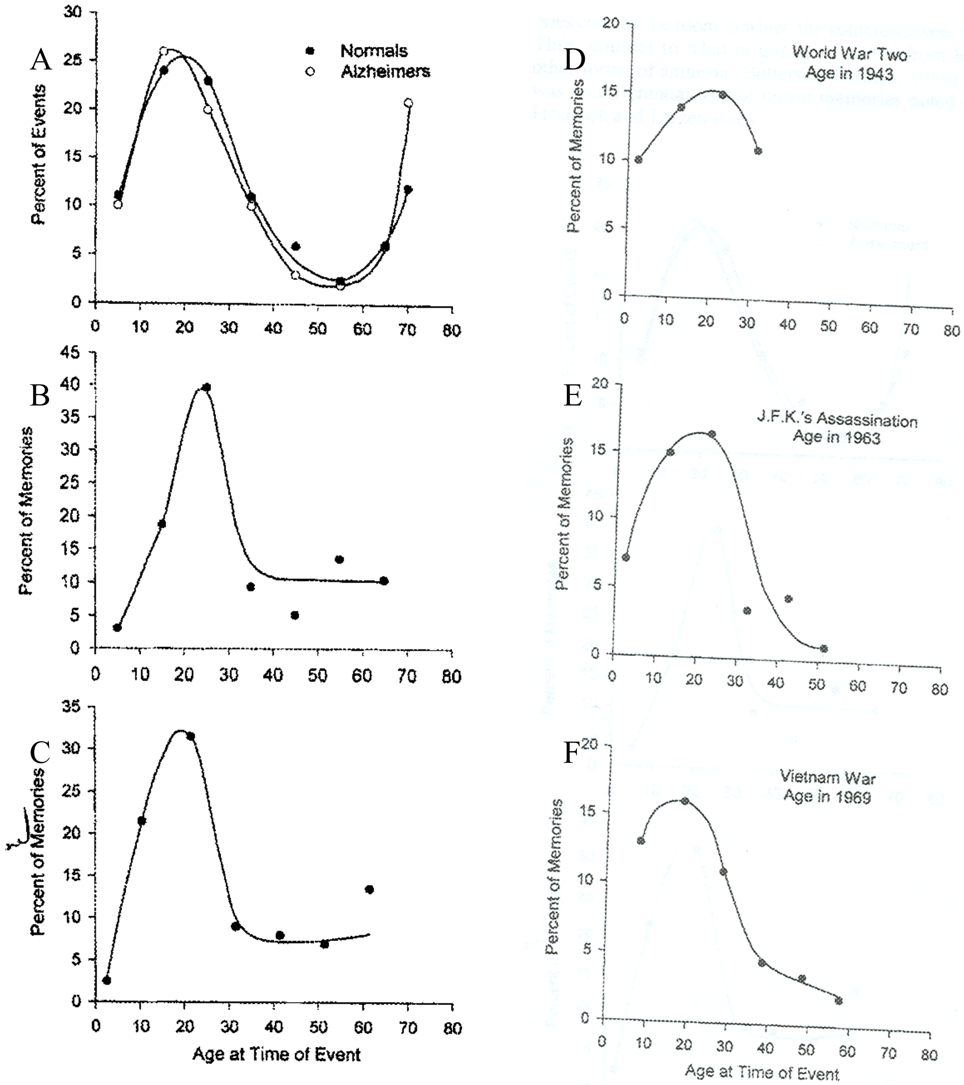


Fig. 5. (A-C) Participants were ask to recall memories they felt were personally important and to report the age at the time of the event. (D-F) Schuman and Scott (1989) asked participants to define 1 or 2 of the most important events in the last 50 years. They found that participants were much more likely to report an event if it had occurred during their teenage to early adulthood (10-30 years old).

Poon, Rahhal, and Rubin (1998), interested in the reminiscence bump and general knowledge, studied the distribution of semantic memories with a focus on memories from the ages 10-30 years. Participants were given packets containing several questionnaires of multiple choice questions regarding top news stories, the World Series, and the Academy Awards. They were instructed to answer the questions as quickly as they could. In figure 6a-c, percent correct is plotted over the participant's age at the time of event. For older adults, Poon, Rahhal, and Rubin report a significant increase during the ages in the 20's and 30's for correctly answered questions regarding important news stories, Academy Awards, and the summed results of all three topic questions. Though with further inspection, however, it can be argued that the variance of the mean standard errors betray a truly distinguishing bump.

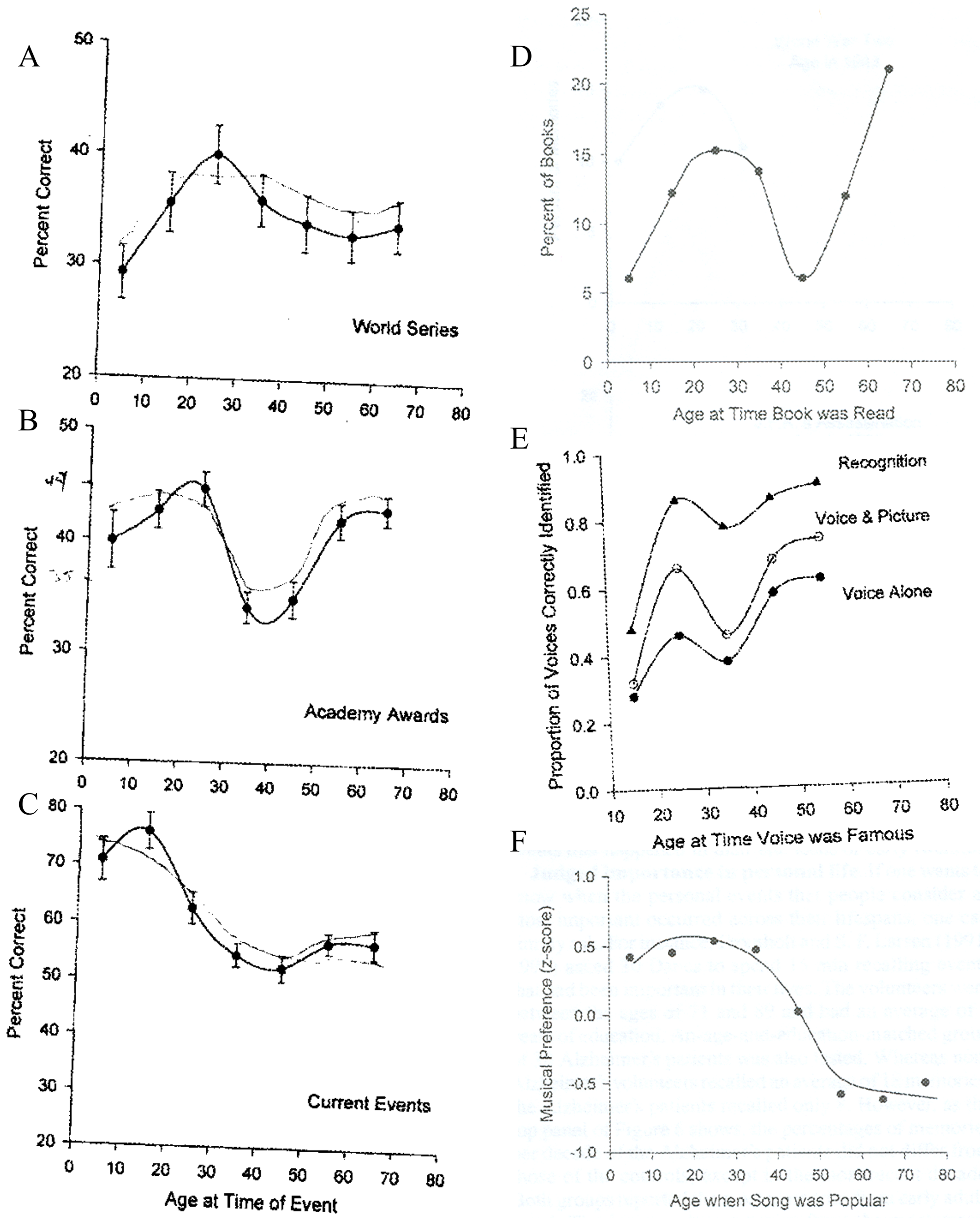

A
World Series
Percent Correct
B
Academy Awards
Percent Correct
C
Current Events
Percent Correct
Age at Time of Event
D
Percent of Books
Age at Time Book was Read
E
Recognition
Voice & Picture
Voice Alone
Proportion of Voices Correctly Identified
Age at Time Voice was Famous
F
Musical Preference (z-score)
Age when Song was Popular

Fig. 6. (A-C) Rahhal, Rubin, and Poon (1998) presented participants with multiple-choice questions covering 3 domains (i.e., World Series, Academy Awards, and Current Events). Participants appear to perform best on questions taken from their 10-30 year age bin. (D) Participants report a proportionally greatest amount of books that left a memorable impression on them between the ages of 15 and 30 (data from S. F. Larsen, 1998). (E) Correct identification of famous celebrities were highest for celebrities whom reached their popularity during participant's early adulthood (data from Meudell, Northen, Snowen, & Neary, 1980). (F) The musical preference of individuals were most represented by songs that gained popularity between the ages of 10 and 40 of the participant. All graphs were taken from Rahhal, Rubin, and Poon (1998).

Larsen (1996) further investigated the extent of the distribution in identity forming moments by questioning 57 participants (mean age of 68) to identify the decade/s during which they had read a book that provided a particularly memorable reading experience (figure 6d). A peak was observable for the ages between 10 and 40, however, as Larsen points out, some parts of the distribution may have simple explanations. For example, a lack of reading ability may account for the low value in the first decade.

Jansari and Parkin (1996) proposed that the reminiscence bump is not a phenomenon of older participants but rather a primacy bias which is set into motion by the importance of first time memories. Jansari and Parkin argue that a disproportionate number of first-time events (e.g. first time riding a bike) come from earlier periods of life and that these memories are held in our consciousness with much more conviction than memories of events that are, respectively, less important. Associating memories from the same temporal period, as shown to occur in event cuing methods, are then believed to be triggered. In a paradigm that restricts participants from recalling memories from their most recent past (non-recency condition) and using intervals of 5-years (instead of decades in previous studies) Jansari and Parkin (1996) report a significant increase of memories recalled between the ages of 6 and 15 years for younger participants (36-40 and 46-50 years old) while having only a minimal effect on older participants (56-60 years old). However, when the curvature of memories from the recency condition is proportionally adjusted to the non-recency condition the two distributions loss any significant differences. In addition, Jansari and Parkin found no qualitative differences found between remote and late memories. Jansari and Parkin (1996) conclude that after controlling for association bias reaction times were significantly less for earlier memories though these findings have been inconclusive in other studies (Fitzgerald & Lawrence, 1984; Rubin & Schulkind, 1997).

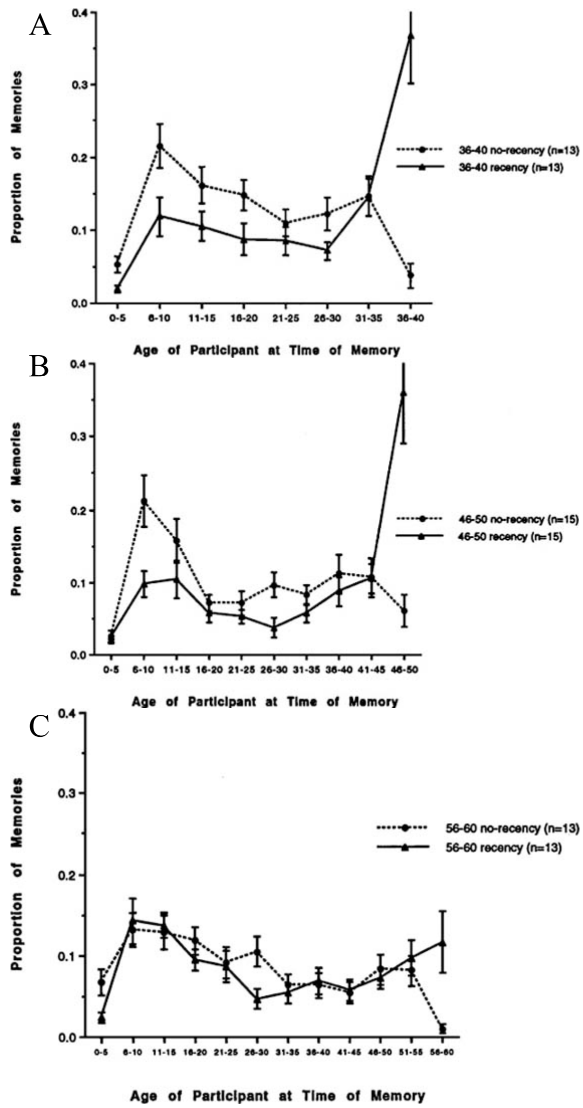


Fig. 7. Parkin and Jansari (1996) found that by restricting younger participants (36-50) from recalling memories from their most recent 2.5 years a (A-B) reminiscence bump developed in their temporal distribution of AMs while in contrast the no-recency restriction had no effects for (C) older participants (56-60 years old).

There are several non-cognitive explanations for the reminiscence bump, however, no single theory is agreed upon. The most well know is the coming to age explanation, that is, early adulthood is a period of identify formation. The predominant goal of this period is to weave together an adult identity through the development and understanding of who you are and what you are socially, vocationally, and ideologically. Viewing identity as a narrative of the important aspects of one's life–developing much of one's identity during early adulthood–there would be more events in that narrative from early adulthood than would be expected from a monotonic forgetting function. Assuming that personal identity forming events are relatively more important than other personal events we would expect to see an autobiographical-like distribution of the most important memories as illustrated in figure 5.

Examining the distribution of important memories to account for the reminiscence bump, Rubin and Schulkind (1997) found a sharp peak in memories recalled at ages 17 and 18 for participants 20 years old. Participants at 35 years of age showed a slight bump in the 20 to 25 age range, however, considering the confidence intervals a monotonic retention function fits the data. Older participants (70 to 73 years old) had a clear concentration of important memories in the age range of 20 to 30 years. From these findings it appears (at least in part) that important memories cannot fully explain the reminiscence bump.

1.3.3 *Retention Function*

The retention function is incredibly robust; it is observed using a variety of cues and controls (or lack there of). For instance, comparing visual and olfactory cues to word cues, Rubin, Groth, and Goldsmith (1984) found no differences in the retention function of the most recent 10 to 20 years of memories.

Rubin and Wenzel (1996) conducted a meta-analysis on 210 published papers on retention. Only a small subset (5 studies) of the dataset came from AM research but provided enough information to perform a mini-meta-analysis. They fit the datasets to transformed versions of the hyperbolic, exponential, and power function and found the power function to be the best descriptor of the data with 88% of variance accounted for.

1.4 Beyond Temporal Distribution

Neuropsychological research has contributed greatly to the current understanding of the fundamental brain structures that are critical for memory processing, i.e., the hippocampus, prefrontal cortex, and medial temporal lobe (Bayley, Hopkins, & Squire, 2003; Levine, 2004; Ferbinteanu, Kennedy, & Shapiro, 2006). Addressing the question of whether the hippocampus is necessary for formation and maintenance of semantic memories Hopkins, Manns, and Squire (2003) studied 6 patients with bilateral localized lesions of the hippocampus. Patients were shown, in contrast to controls, to have a significantly harder time recalling and recognizing facts from news events from 0-5 years preceding anterograde amnesia. A second experiment in the same paper, required participants to identify the living status of famous people. Controlling for the ability of neurologically normal participants to use episodic strategies to elucidate semantic information the authors excluded results in which controls were able to associate an episodic recollection with the person in question, a 14% decrease in the number of correct answers provided by controls was observed. Controls and patients were equally apt at distinguishing famous people, however, patients did significantly poorer at correctly identifying the life status of the person. Though several t-tests were ran with no correction for inflation, the evidence of this study argues for the dependence of semantic memory on the hippocampus. Bayley, Hopkins, and Squire (2003) report their null findings on remote autobiographical memories for hippocampal (N = 6) and medial temporal lobe (N = 6) damaged patients. The view that remote AMs go through some process that affords them independence from both the hippocampus and medial temporal lobes appear to be support by the results. Patients (M = 59 years old) differed very little from controls (M = 54 years old) in the evaluation of main aspects of memories taking from the first third of their life. Patients and controls were able to recall a similar level of richness and episodic and semantic details. Furthermore, the repetition of details, latency and duration, and prompts given by the interviewer per memory were found to be constant between groups.

In an imaging study conducted by Bookheimer et al. (2005) used a *remember-know* paradigm found the hippocampus to differentiate anatomical locations for encoding and retrieving processes involving remembered items. Two separate scans were performed on 10 volunteers, the first scan during encoding and the second during retrieving. A subregion-by-task phase (encoding vs. retrieval) ANOVA on response amplitudes for *remember* trials was performed. Comparing activation related to successful recollection encoding to activation associated with successful recollection across hippocampal subregions an interaction was found between the two factors in the left hemisphere indicating differential processes in the CA2, CA3, and DG versus the subiculum region. The CA2-3-DG system was found to be more active during encoding while the subicular region was more activate during retrieval of episodic memories. Other studies have found similar results for both hemispheres (Bookheimer, et. al, 2003).

2. AIMS OF RESEARCH

Prior research has helped elucidate the temporal distribution of AMs. However, other fundamental dimensions of AMs have escaped quantitative characterization. As progress continues in sciences such as computational neuroscience, cognitive neuroscience, biopsychology, and neurophysiology, the ability to describe phenomena of the mind in a quantitative metric remains a critical endeavor. Here two new psychometric tools, CRAM (Cued-Recalled Autobiographical Memories) test and SPAM (Spontaneous Rate of Autobiographical Memories), are introduced and were used to probe the quantitative dimensions of AMs in humans. CRAM quantitatively characterizes the content of AMs while SPAM measures the probability, for a given temporal period, that a person will be experiencing an AM.

The aims of the current studies are: (1) Develop, test, and refine a new method that samples AMs with a naturalist word-cuing protocol representative of a lexicon commonly used in everyday dialogues and reproduce the temporal distribution of AMs reported with other cue-word methods. (2) Develop a set of quantitative descriptors to characterize the content of AMs. This data concerns the number of features recalled, in each of several elements (e.g., people, object, location, etc.) as a function of youth (the age of the memory), gender and other group differences. (3) Measure the probability, for a given temporal period, that a person will be experiencing an AM. Exploring the frequency of AMs will allow us to describe the natural rate of AMs experience and further perform exploratory inquires in regards to age specific effects (e.g., do young adults reminiscence at a higher frequency but for shorter durations than elderly adults). (4) Combine the quantitative content data of CRAM with the results of the probability measurement of SPAM into an amalgamation that characterizes the nature of AMs in terms of probability, to recall a given content from a specific youth of an event. The overarching and long-term goal of this research is to further map this function (content v. youth) across subject age, thus creating a 3-dimensional “surface”. The dependent variable would be the average number of features recalled in a given time (e.g., one hour), or it could be further broken down by feature element (number of people, objects, temporal and spatial details, etc.) The independent variables would be the age of the subject at the time of recall and the age of the subject at the time of the recall event (youth). The practical applications of such a surface map are numerous, e.g., assessing and monitoring the progression of certain neurological disorders (e.g., Alzheimer's disease, post traumatic stress disorder, Korsakoff's syndrome, anterior/retrograde amnesia, etc.) and performing exploratory analyses between groups. Furthermore, theories of memory reconstruction may be aided from additional application of the protocols. By contrasting the surface map of children’s AMs to that of adult’s for events from the same early periods of life one could potentially investigate the nature of decoding, and in essence reconstruction, of memories as a function of cognitive development.

3. METHODS

3.1 CRAM (Cue-Recalled Autobiographical Memories)

The CRAM (Cue-Recalled Autobiographical Memories) test is made up of four parts: (1) non-identifiable information is collected, (2) 30 word-cued autobiographical memories are identified and labeled, (3) the events in 28 of the 30 AMs are dated, and (4) the recall of 8 contextual features are counted for a subset of the memories. Two formats were used to collect data, i.e., an Excel and a web-browser format, all the data was collected in-house. Both formats consisted of the same procedure as outlined above and described below (see Appendix A for screen-shots and further description of test procedure).

Part one consists of participants providing their month and year of birth, gender, and if English is their native language. In part two, a set of 7 words are presented, from which, one memory is to be prompted. Participants are instructed to read through the set of words and label (with either a unique word or phrase) the first AM that comes to mind, if no memory is cued by the word set participants are able to call up a new set of words. 30 spontaneous autobiographical memories are successively cued and labeled for later recall. In part 3, participants' biographical information (month and year of birth) is used to divide their lifespan into 10 equal temporal bins–from this point on these temporal bins will be referred to as *youth* bins–representing periods of the participant's life by 10 percent increments. To control for learning effects (i.e., any confound relating to the participant's performance prior familiarity of the procedure), the first two AMs recorded are excluded from the following parts of the test. The remaining 28 AMs are dated according to the youth of the memory. Three different methods–your age (e.g., from 3 years 8 months to 5 years 5 months), date of event (e.g., from 5/1991 to 2/1993), time lapsed (e.g., from 14 years 6 months ago to 12 years 9 months ago)–were made available to use to date each memory. Participants were encouraged to use (and switch between) the wording that best facilitated an accurate dating of the youth of the memory. Part four involved sampling 10 of the memories with a bias (taken from the temporal distribution of AMs) towards representing memories from all youth bins, particularly remote memories. For example, if a participant has memories for only 5 of the 10 youth bins the earliest memories would be chosen over recent memories once all available youth bins had been sampled at least once. Participants were instructed to count as many elements as they could recall for each memory with regard to eight contextual features, i.e., *Episodes*, *Context*, *Times*, *Details*, *Things*, *Feelings*, *People*, and *Places* (see Appendix B for definitions and examples). The order of the categories were randomly presented between subjects. Optional additional guidance (Appendix C) was provided for participants in the form of a detailed description of what constitutes an element of a feature.

3.1.1 *Word Sampling*

The words used to cue memories were sampled based on their usage frequency from the 100,000,000-word British National Corpus consisting of adjectives, cardinal and ordinal numbers, proper and common nouns in all their forms, and non-auxiliary verbs. Using the word filter freeware resource of the Discusware web tool applications (www.discusware.com), a list of 187 obscene or otherwise questionable terms was created. Potentially offensive terms were removed from the word pool including (but not limited to) the original and all derivatives of the seven terms that the U.S. Supreme Court ruled cannot be used on television (FCC v. Pacifica Foundation, 438 U.S. 726, Decided July 3, 1978). The total usage count of the remaining list was 1,190,195 corresponding to 13,241 distinct terms. Cue words were sampled from this "demographic" (i.e. conversational) master list with a weight proportional to their frequency by a custom-made Visual Basic macro (for Excel format) and PHP/Java script (for browser format), with the additional constraint that the plural and singular forms of the same regular nouns and the first- and third-person forms of the same regular verbs could not be resampled within the same test. The preceding criteria created cue-word sets which are reflective of a natural lexicon, curtailing the use of esoteric words and hence creating cues that are most likely to be encountered in the natural setting of everyday life. For example, a participant begins labeling his memories. He is presented with the following set of words: noise, abrupt, cashier, belt, juice, flee, and shells. The number of times that these words appeared in the electronic database of the British National Corpus is 215, 11, 7, 109, 136, 6, and 10 times, respectively.

Only a proportion of dated memories were randomly selected (weighted by youth) for content counting, therefore two datasets were acquired with the CRAM test: (1) data concerning the temporal distribution of the memories (n = 5866 memories) and (2) data capturing the quantitative content of the memories (n = 1526). The latter dataset included the variables of the former (i.e., test format, gender, English as a native language, month and year of birth, and youth of memory) and, in addition, variables of the eight contextual features.

3.1.2 *Outliers*

Prior to data analysis, outliers were screened, treated, and classified according to the flowchart presented below:

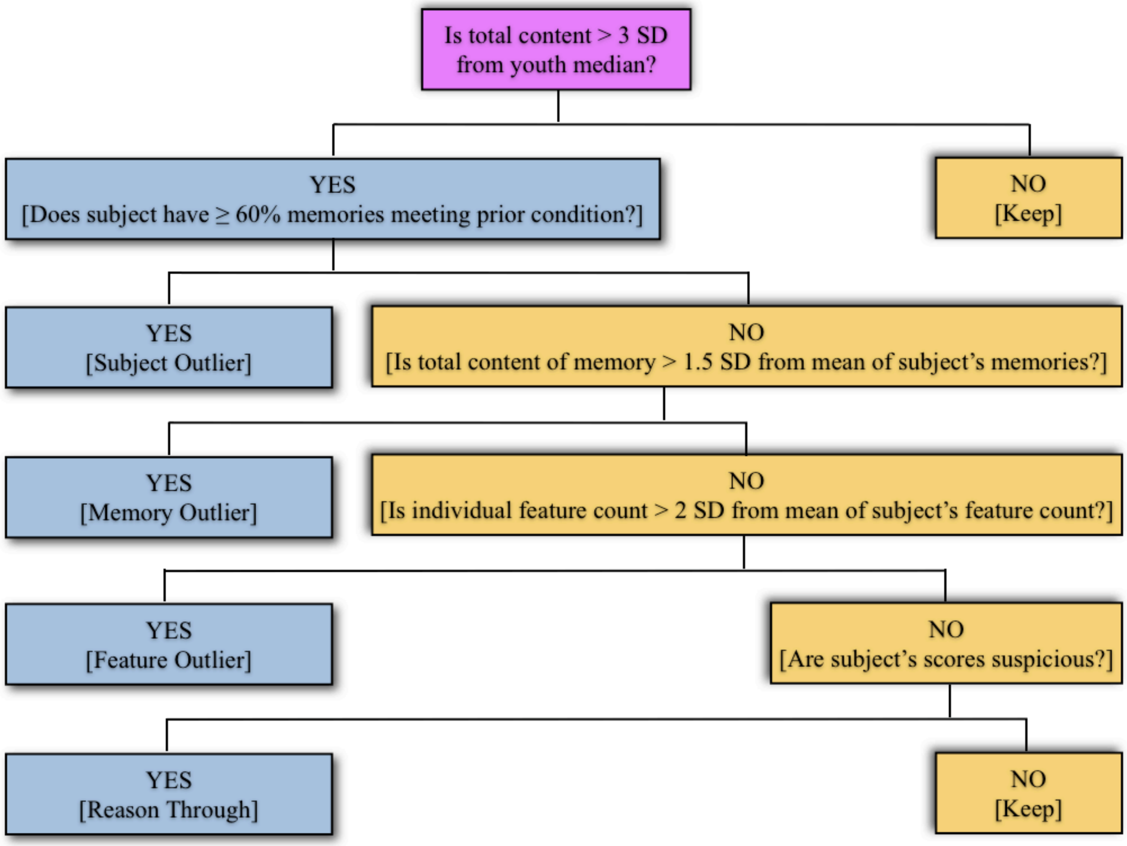


Fig. 8: <u>Example</u>: a memory found to have a total content of 122 elements meets the first conditional level. None of the participant's remaining memories had a total content greater than 3 standard deviations from the youth's median score so the memory continues onto the third level. Though the memory had a total content greater than expected at level one, the total content did not fall outside of the participant's own variance thus moving the memory onto the fourth level. At this point the memory was found to contain a number of People far beyond the variance observed in the remaining memories of the participant (100 compared to an average of 3 People recalled). The memory is defined as a "feature outlier" and excluded from data analysis.

The finial level, suspicious data, was included for memories that appeared to be quite unreasonable but met all the preceding criteria, e.g., one memory contained 9 elements for each feature (total content of 72). From this level, two additional types of outliers were defined: zero scores (i.e., memories that scored zero on all features) and repeating scores (i.e., memories from the same participant receiving the exact same scoring). Though the reason for exclusion of the former is apparent the rejection of repeating memory data only applied to two memories and was therefore viewed as statistically unsound. From 1,618 scored memories, 3 were feature outliers, 39 were memory outliers, 4 (38 memories total) were subject outliers, 1 was a suspicious outlier, 2 were repeating outliers, and 9 had scores of zero. All statistical analyses were performed using this subset of data (n = 1526).

3.2 SPAM (Spontaneous Probability of Autobiographical Memories)

Participants were given a packet consisting of the definition of AMs with paired examples of AMs and non-AMs (see Appendix D), an outline of the protocol design, a consent form, and a form to record general biographical information and test variables (e.g., frequency of calls allowed per day).

The protocol's general design capitalizes on the near universal possession of a common technology, the mobile phone. All participants were required to have a cellular phone accessible to them for the duration of the experiment due to the paging protocol of the study. Using a modem connection from a laptop, an autodialer program was written to randomly call participants throughout a given time period at a variable number of times a day. Both the hours and daily frequency of the calls (M = 18 calls a day) were set by the participant. The experiment required approximately 300 samples (i.e., calls) and due to the inherent nature of missing calls here and there several experiments were extended by a day or two surmounting to an average of 317 calls.

Log booklets were provided to participants to record their data during the study. When participants receive a call they were asked to perform a mental check on whether they had been experiencing an AM at that very moment and to estimate the duration of the memory up to when their phone had rung. Otherwise, a dashed line was used to indicate no AM had been in mind at the moment their phone had rung. The experiment requires approximately 300 calls per subject. Participants were encouraged to program a specific ring-tone (if this cellular option was available) for the number used by the autodialer to allow for a more instant response to the call, otherwise the cellular phone's caller ID was used to identify a memory call.

4. RESULTS

The current studies are an attempt to expand the current quantitative language used in AM psychometrics by addressing discrete measurable dimensions of AMs. In temporal distribution measurements, the distribution of memories is greatly influenced by the age of the memory while in contrast to this, AMs were found to contain a fairly consistent average of 18 elements with only modest effects attributable to the age of the memory. The recall of measured features roughly fit into three levels (low, medium, and high), where *Places* and *People* had the highest level of recall, and *Episodes* and *Context* were recalled the least. Furthermore, each feature's level of recall, relative to all features, was preserved across youths. An analysis of regression coefficients produced two statistically different decay rates for features, consisting of a minimal (*Places*, *People*, and *Things*) and maximal (*Context*, *Times*, and *Episodes*) time decay group. By in large, gender was found not to have a significant effect on the number or distribution of elements recalled across the eight features, however, fundamental memory features may differ between genders (i.e., *Places* for males v. *People* for females). The duration of an AM typically lasted 24.7 secs and did not differ by subject age, gender, or native language. The probability of sampling an AM at a given moment was, *Mdn* = 13%. Using AM duration and sampling probability, we were able to calculate the frequency of AMs for a given temporal period: hourly = 21, daily = 289, monthly = 8,681, and yearly = 104,173 AMs (note that each rate was calculated using equation 1, therefore, the rates reported here are not multiples of each other; days were defined as 14 hours). Similar to memory duration, no group differences were found for sampling probability and, thus, rates.

4.1 TEMPORAL DISTRIBUTION

The majority of the data was acquired from George Mason University undergraduate students through the University's online recruitment site. Participants received course credits following successful completion of the experiment. 120 participants (89 females, 31 males) were tested using the Excel format while the remaining 84 participants (64 females, 20 males) used the web-browser format. Temporal distributions between the two formats were found to be nearly identical (Figure 9 insert).

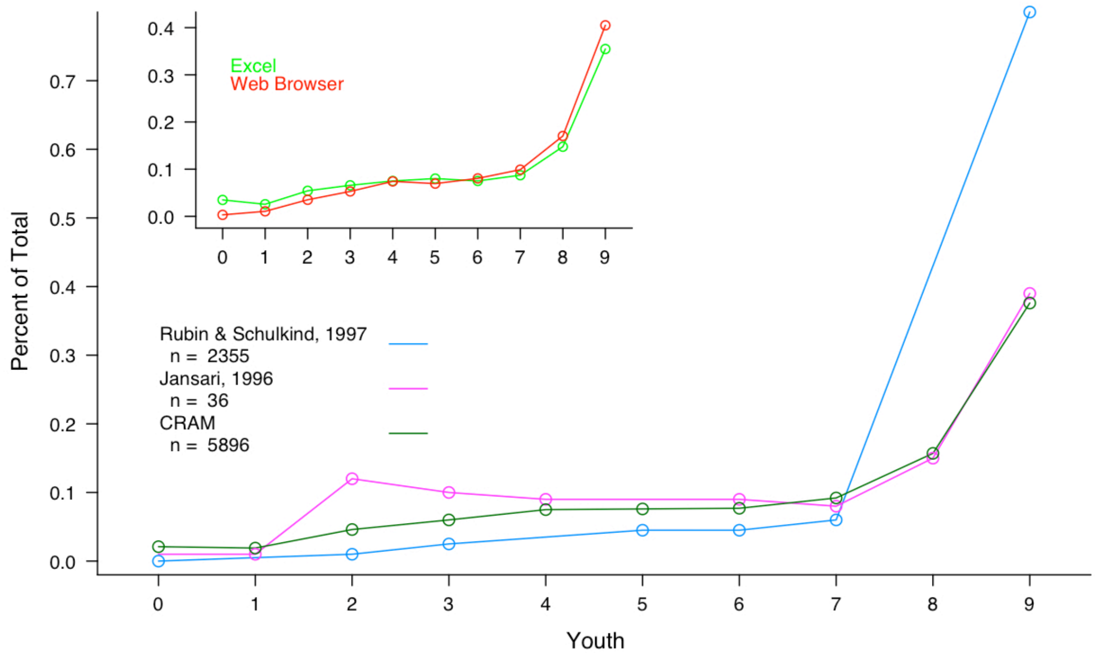


Fig. 9. Temporal distribution of AMs. Consistent with previous findings, the temporal distribution of memories collected through CRAM shows a monotonic slope for college age participants. The majority of AMs came from events that had occurred within the most recent two tenths of a life-span, as indicated by the exponential increase of the retention function. Note, memory age from previous findings reported here were converted into youths and thus not all youths could be represented for previous work, e.g., Rubin (1997) youth 8. No distribution differences were found between formats (insert). Data replotted from Rubin (1997) and Jansari and Parkin (1996); n = number of memories.

As seen in figure 9, the temporal distribution of memories collected with CRAM is consistent with previous research using similar participant age pools. The discrepancy seen in Rubin (1997) at youth 9 can be accounted for by the event age to youth conversion, i.e., the event ages presented in Rubin (1997) did not fall within the range of youth 8 and thus increased the proportion of memories accounted for by youth 9.

4.2 CRAM

In considering test length, only a proportion of the dated memories were randomly selected (weighted by youth) for content counting; of the 5,896 memories temporally labeled, 1,526 memories were also scored for content. 111 participants (83 females, 28 males) were tested using the Excel format while the remaining 80 participants (62 females, 18 males) used the web-browser format. No significant differences were found between the two test formats.

Table 1. Descriptive Statistics of Total Content Recalled by Group

	Format[†]		Gender		English	
	Web Browser	Excel	Female	Male	Native	non-Native
n^*	811	715	1180	346	1144	382
Mean	19.15	18.12	18.72	18.48	18.26	18.8
SD	9.75	8.79	9.2	9.76	9.44	9.29
t-tests**	$t = 2.19$, p-value = 0.087		$t = 0.43$, p-value =1		$t = 0.98$, p-value = 0.995	

[†]Welch's two sample t-test used. *n = number of memories scored for content. ***t*-tests were based on 1523 df.

4.2.1 *Total Content Within Groups and Youths*

On average, a given memory contained 18.7 elements (*SD* = 9.32). A series of two-tailed *t*-tests were conducted to look for differences in mean total content within format, gender, and English groups (Table 1). The variances between formats were statistically unequal and prompted the use of a Welch two sample *t*-test, student's *t*-tests were used for gender and native groups. No significant differences were found within any of the groups. Furthermore, 3 separate two-way ANOVAs were ran to explore for potential group by youth interactions. No significant interactions were found for any of the groups (Figure 10A-C).

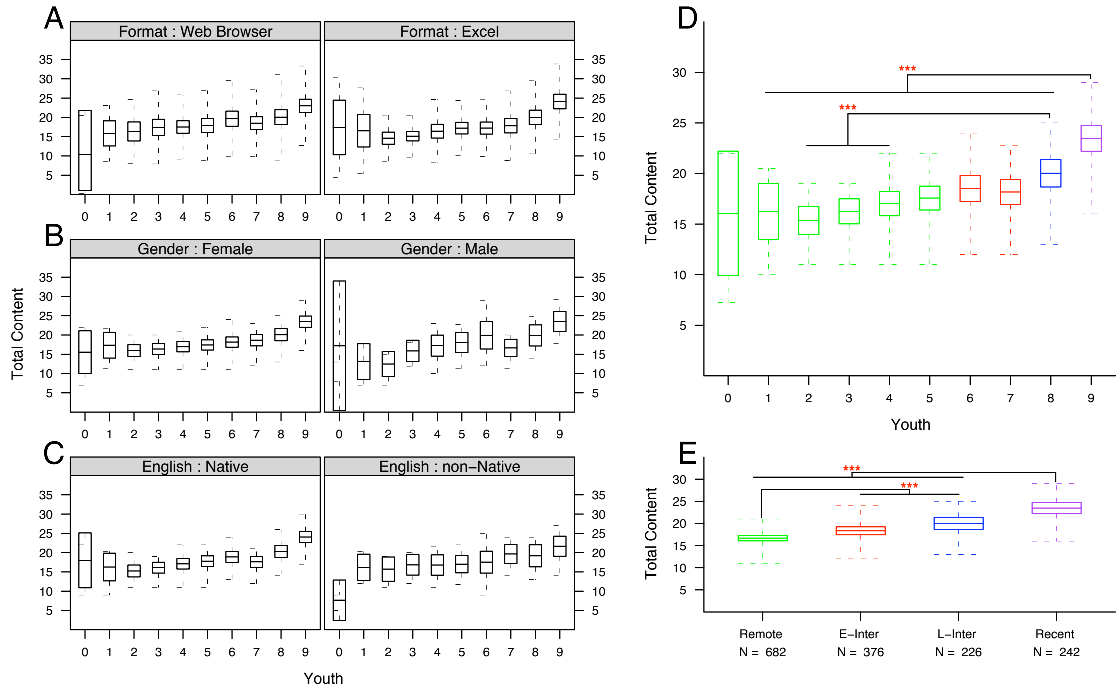


Fig. 10. Total content averages across youths. Mean number of elements recalled per memory by youth for (A) format, (B) gender, and (C) English as a native language. (D) Significant youth differences were found between youth 9 v. youths 1 through 8 and youth 8 v. youths 2 through 4. Lack of homoscedasicity was found to have no statistical effects on results as compared to the square root transformation of the data. (E) Four temporal periods were created from youth aggregations based on Helmert contrasts producing significant differences. Statistical differences were found between all periods except early- and late- intermediate periods. Means are represented by horizontal lines within individual boxes, boxes show 95% confidence intervals, and whiskers indicate first and third quantiles. *** = p < 0.001.

A log-linear Poisson regression (a glm that is analogues to a logistic regression) with a contrasts sum matrix (giving the deviations of each youth from the overall mean) was conducted to assess the temporal generality of total content (composited of all data). The overall total content mean of memories could not be generalized across the temporal dimension but is instead partly predicted by the youth of the memory, X^2 (9, n = 1526) = 472.5, $p < 0.001$.[1] Next, a Welch pairwise t-test was ran to examine total content differences between youths. Memories from youth 8 significantly contained more elements than memories from youths 2 through 4 while memories from youth 9 consisted of a greater number of elements than youths 1 through 8 (Figure 10D). Further descriptive statistics are presented in Table 2.

Table 2. Descriptive Statistics Total Content by Youth

	Youth									
	0	1	2	3	4	5	6	7	8	9
n*	16	46	99	153	183	185	182	194	226	242
Mean	16.06	16.24	15.36	16.26	17.02	17.57	18.52	18.18	20.03	23.47
SD	12.55	9.62	7.08	7.8	8.26	8.19	8.84	8.83	10.42	10.07

*n = number of memories scored for content.

[1] Further analysis in the form of a Welch ANOVA confirms this finding, $F(9, 267) = 11.5$, $p < 0.001$, $\eta_p^2 = 0.07$. A linear model constructed from the contrasts sum matrix showed memories from youths 3 and 4 (M = 16.3 and M = 17, respectively) significantly contained fewer elements than the overall mean, M = 18.7, while memories from youth 9 typically consisted of a greater number of elements, M = 23.5.

Given that the pairwise majority of youths did not significantly differ from each other, with respect to total content, an exploratory aggregation of youths was conducted. Youths were sequentially grouped into 4 classes (i.e., remote, early-intermediate, late-intermediate, and recent memories) as determined by the results of an ANOVA test with Helmert contrasts (Table 3).[2] Remote memories embodied youths 0 through 5, early-intermediate memories pertained to memories from youths 6 and 7 while late-intermediate consisted of memories from youth 8, finally, youth 9 constituted recent memories (Figure 10E). Following confirmation of a main effect, $F(3, 583) = 32$, $p < 0.001$, $\eta_p^2 = 0.07$ (Welch ANOVA; Table 3), Welch's pairwise *t*-test showed significant differences between all periods with the exception of early- and late- intermediate periods. The non-statistical difference observed between early- and late- intermediate periods, despite the foreshadowing results of the Helmert contrasts, is most likely due to the temporal scale of youths. That is, if memories had been dated using smaller increments of time significance may have afford; Helmert contrasts between youth 7 and prior youths was near significant at $p = 0.064$.

[2] Helmert contrasts compares each variable level to the mean of the subsequent levels. Thus we were able to test which youths significantly differed from the running average ascending from youth 0.

Table 3. Helmet Contrasts, Resulting Youth Aggregation and Pairwise Significances

	Helmert Contrasts				
	Mean	Estimate	Std. Error	*t*-value	*p*-value
Intercept	16.1	17.87	0.33	54.72	0.001***
Youth 1	16.2	0.09	1.31	0.07	0.946
Youth 2	15.4	-0.26	0.53	-0.49	0.621
Youth 3	16.3	0.09	0.29	0.32	0.751
Youth 4	17	0.21	0.20	1.06	0.288
Youth 5	17.6	0.23	0.15	1.56	0.119
Youth 6	18.5	0.30	0.12	2.51	0.012*
Youth 7	18.2	0.18	0.10	1.86	0.064
Youth 8	20	0.35	0.08	4.35	0.001***
Youth 9	23.5	0.62	0.07	9.13	0.001***

	Welch's ANOVA				
	Mean	Estimate	Std. Error	*t*-value	*p*-value
Intercept	16.7	16.68	0.35	48.29	0.001
Early-Inter.	18.3	1.66	0.58	2.86	0.004
Late-Inter.	20	3.34	0.69	4.83	0.001
Recent	23.5	6.78	0.68	10.05	0.001

	Welch's Corresponding p-values		
	Remote	Early-Inter.	Late-Inter.
Remote	-	-	-
Early-Inter.	0.017**	-	-
Late-Inter.	0.001***	0.258	-
Recent	0.001***	0.001***	0.001***

4.2.2 *Feature Content*

To test temporal effects within individual features, an initial multivariate analysis of variance with Pillai's trace criterion was performed, $F(72, 12128) = 3.08$, $p < 0.001$ (Figure 11A). Unlike total content, the assumption of normality among the features was not met, therefore, a square root transformation of the data was performed prior to all feature statistical analyses. All descriptive statistics are reported in their original unit of measurement.

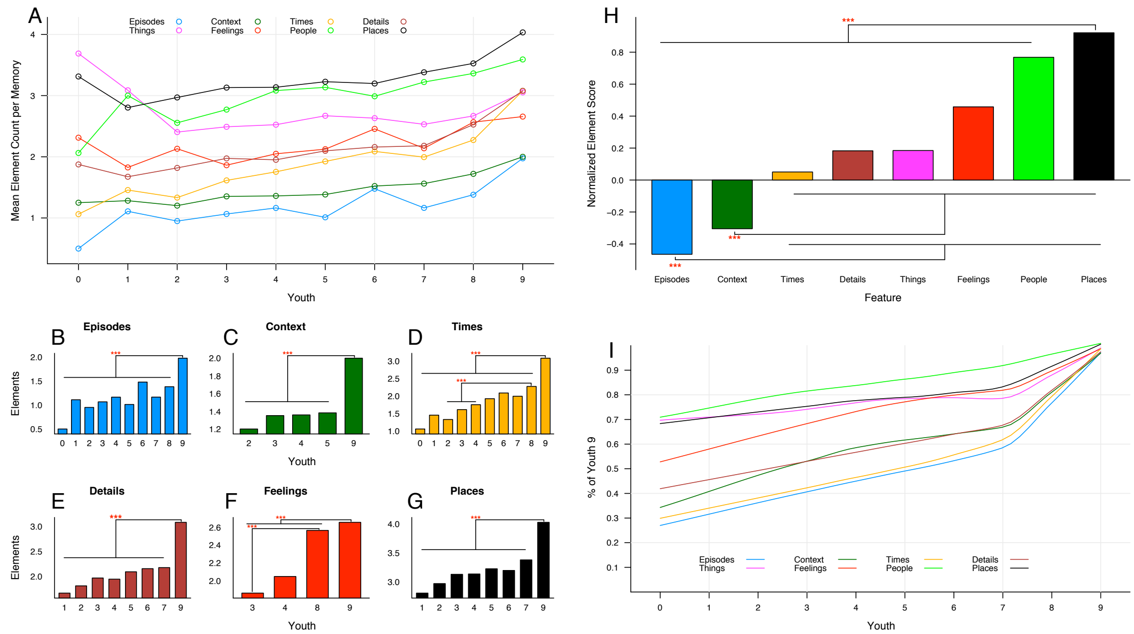


Fig. 11. Feature content of AMs. (A) The number of elements recalled was observed to vary between features. Elements of Places and People had the highest level of recall while elements of Episodes and Context were the least represented in a memory. Relative feature frequencies were largely maintained throughout the age of memories. (B-G) Of the eight features, six were found to have significant frequency differences between youths. In all 6 cases, youth 9 contained more elements than the earlier youths indicated by the significant bar of the respective feature. Significant differences were also found for youth 8 in Times and Feelings. (H) Features were normalized to the grand median and MAD of all features and are aligned in order of least to greatest. Welch t-tests were ran for features with ≥ 1 median differences, all test of differences were found to be significant. (I) Comparing regression coefficients, two statistically different decay rates were observed among the eight features; People, Places, and Things were found to have minimal temporal decay respective to Context, Times, and Episodes. Decay rates of Feelings and Details were found to generalize between both rates. All features appear to share a relatively steep degradation between youths 9 and 7. *** = p < 0.001.

An analysis of variance was conducted for each feature (Table 4). No effects of youth were found for either *Things* (*Mdn* = 2, *MAD* = 1.48) or *People* (*Mdn* = 2, *MAD* = 1.48), however, the element counts in all remaining features statistically showed to increase with youth at $p < 0.001$.[3] To specifically find which youths differed within each feature, a series of Welch's pairwise *t*-tests were conducted, significant results are reported in Figure 11B-G. Except for *Times* and *Feelings,* all significant youth differences were encompassed by youth 9.

Tabel 4. Model Results of Analysis of Variance for Features as a Regressor of Youth.

	Median	MAD	Model SS	Residual SS	*F*	*p*-value	N_p^2
Episodes	1	1.48	44.48	864.80	8.66	0.001	0.05
Context	1	1.48	20.21	719.21	4.73	0.001	0.03
Times	2	1.48	63.13	650.81	16.34	0.001	0.09
Details	2	1.48	33.45	860.20	6.55	0.001	0.04
Things	2	1.48	4.05	742.65	0.92	0.509	0.01
Feelings	2	1.48	14.91	536.44	4.68	0.001	0.03
People	2	1.48	9.33	836.87	1.88	0.051	0.01
Places	3	1.48	12.43	468.24	4.47	0.001	0.03

4.2.3 *Differences Between Features*

When comparing recall differences between features additional (to that of Bonferroni) control of probability inflation was adopted through restricting test of significance only to those features exhibiting median differences ≥ 1 element. Running multiple (18) Welch *t*-

[3] Effects of unequal variances were assessed by comparing the former results to those of Welch ANOVA tests, no significant differences were observed.

tests on all pairwise features satisfying the prior condition, significant differences were found for all comparisons as shown in Figure 11H-features are presented as normalized to the grand median and pooled absolute median deviation, note the linear relationship between features and level of recall. Next we examined decay rates and compared them between features (Figure 11I). Within subjects, each feature's youth element counts were transformed into percentages of youth 9. For subjects with more than one contextually scored memory from youth 9 the mean of the respective feature counts was used. Subjects who did not have a memory from youth 9 were excluded from analyses. For each feature, a linear regression was created using the square root of the preceding transformation with youth serving as the independent variable. Student's *t*-tests were used to test for differences between feature coefficients (Dalgaard, 2002). Features statistically separated into two main decay rates. *People*, *Places*, and *Things* were all found to have significantly lower decay rates than those of *Context*, *Times*, and *Episodes*. *Feelings* and *Details* were found to generalize between the two groups, differing only between the extreme cases in each group.

Exploring for differences in correlation trends between features, correlation averages for each feature were computed from Spearman's correlation matrix (excluding eigenvalues). Features varied in their level of dependency, in which, *Places* was the most independent feature, mean $r_s = 0.269$ and *Episodes* the most dependent, mean $r_s = 0.305$. Between *Places* and *Episodes*, the ascending order of the remaining features' mean spearman correlations are listed here: *Times*, *People*, *Things*, *Feelings*, *Context*, *Details*.

With the consideration of variable dependencies, two sample *t*-tests [4] were performed for all pairwise (28 total) combinations of feature mean correlations and alpha was adjusted using the false discovery rate (FDR) method (Benjamini & Hochberg, 2001). In all pairwise comparisons, the feature, *Places,* was statistically the most independent feature.

4.2.4 *Feature Gender Differences*

Though females statistically recalled more elements of *Feelings* than males, $t = 3.66$, $p = 0.002$ ($M = 2.34$, $M = 2.05$, respectively) per memory, no further count differences were found among the remaining features. Although, intriguing differences in feature correlation trends were observed. Similar to the correlation analysis method used for the composite dataset, feature correlation matrices were computed for both genders but with two differences. First, only the diagonal eigenvalues were extracted from each gender's correlation matrix and second, differences in gender sample sizes (see Table 1) were corrected for by creating three sets of 346 randomly selected female observations. All three female correlation matrices were tested against the correlation matrix of males and the results were averaged. Though statistical trends were observed (Fig. 12B), FDR adjusted *p*-values did not obtain significance.

---

[4] For all *t*-tests, both the diagonal and between-features eigenvalues were removed. For example, in comparing *People* and *Details* the correlations between *People:People* and *Details:Details* were removed from their respective matrix and *People:Details* values were removed from both matrices.

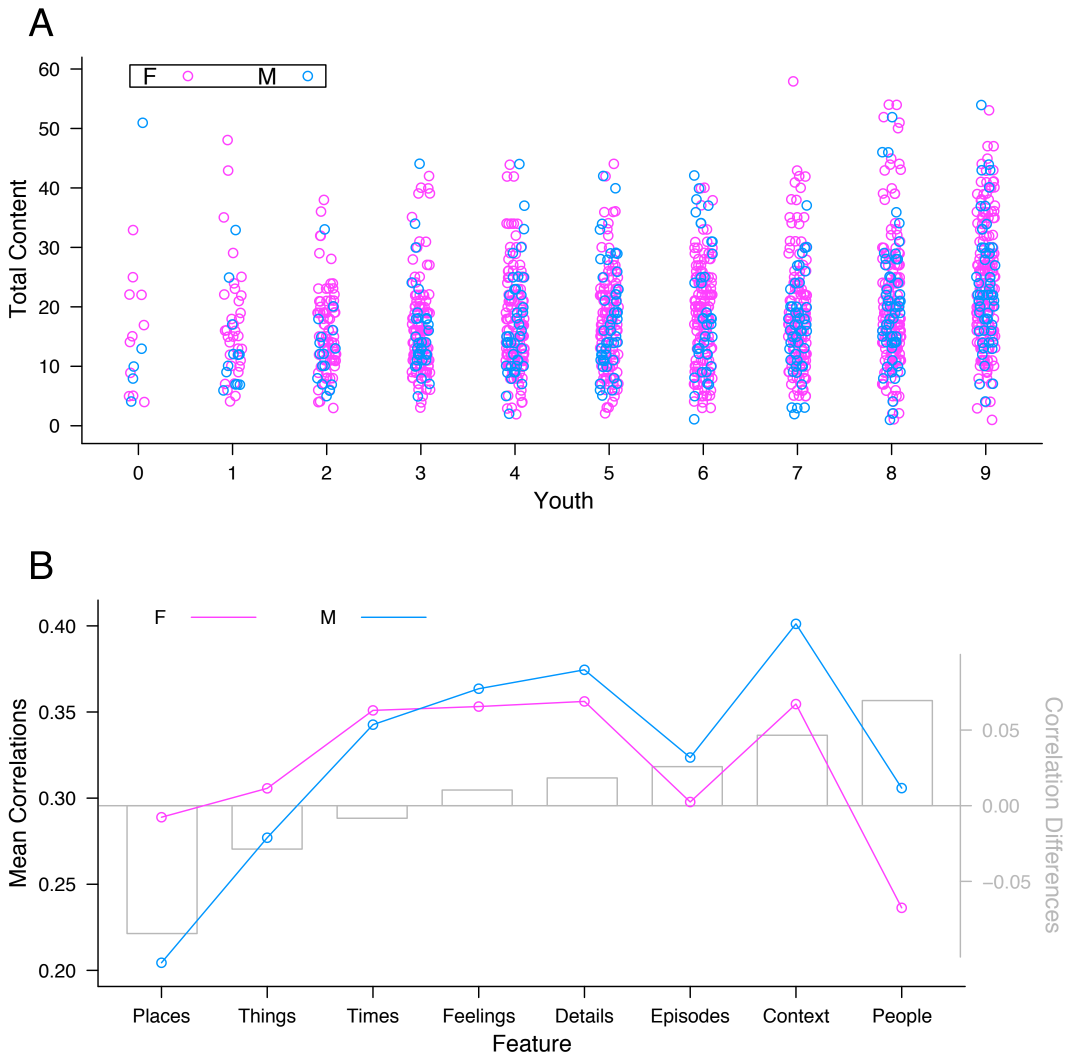


Fig. 12. Total content and correlation differences between genders. (A) Total content for all youths was found to be congruent between females and males. (B) Feature correlation matrices were calculated for females and males. The absolute value of each feature's correlations were averaged for both genders. Females' mean feature correlations were then subtracted from males'. Females recollection of Places and Things had a higher degree of predicability than for males, in contrast, males recollection of People and Context was more dependent than for females. *Trend lines are included to illustrate the logical order of the x-axis, they do not represent a continuous variable.

4.3 SPAM

Similar to the data collection of CRAM, the majority of the data for SPAM was acquired from George Mason University undergraduate students through the University's online recruitment site. Participants received research credits following successful completion of the experiment. Due to the design of the experiment, participants were required to possess a cellular phone.

4.3.1 *Frequency, Probability, and Duration of AMs*

Assuming participants, on average, were in the middle of reported AMs, all recorded memory durations were multiplied by 2. The average duration of an AM was 24.7 secs (SD = 11.7). Using Welch's two sample t-tests, no significant differences were found in memory durations between genders or native English speakers (Table 5). Furthermore, age of participant was not a significant predictor of memory duration, $F(1, 53) = 2.87$, $p = 0.096$, though a trend is observed.

Table 5. Descriptive Statistics of SPAM by Group and Overall

		Gender		English		Overall
		Female	Male	Native	non-Native	
	n	31	24	43	12	55
Memory	***Mean***	23.5	26.2	23.5	28.9	24.7
Duration*	***SD***	11.2	12.5	11.8	11	11.7
Sampling	***Mdn***	13%	15%	12%	15%	13%
Probability	***MAD***	7%	11%	9%	5%	9%
Rate per	***Mdn***	15	18	18	17	21
Hour	***MAD***	10.4	9.7	10.4	8.2	11.4

*In secs.

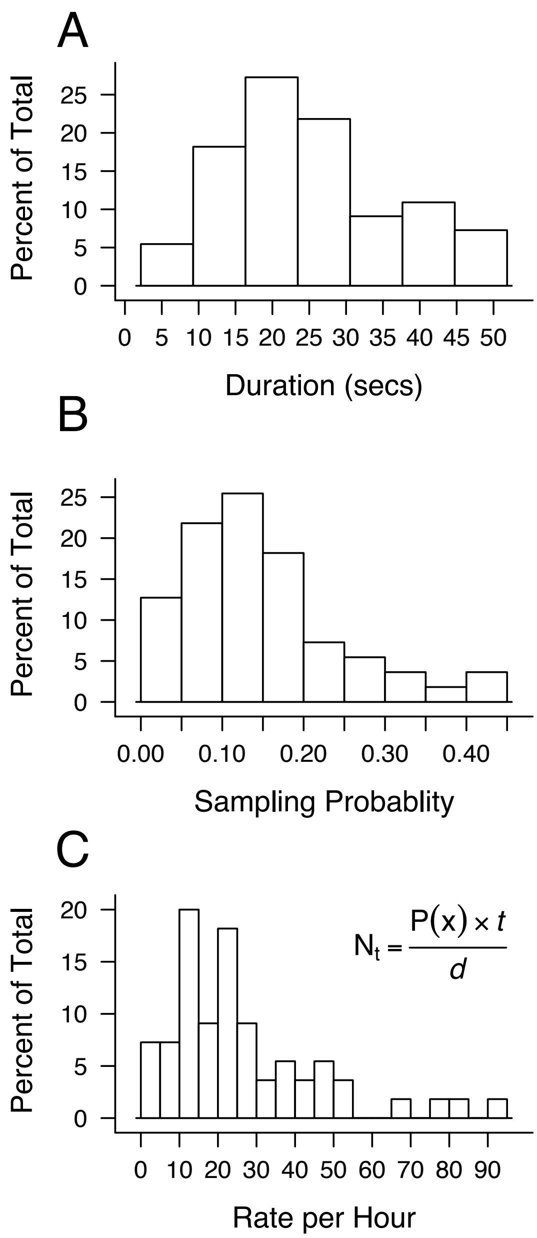


Fig. 13. Duration, sampling probability, and rate of AMs. (A) On average, the duration of a AM was 24.7 secs (SD = 11.7). No memory duration differences were found between genders, native English speakers, or participant's age. (B) The sampling probability was computed as a ratio of hits to total calls (Mdn = 0.13, MAD = 0.09) and also did not significantly differ between groups. (C) For each participant, an hourly rate of AMs was computed using their sampling probability and median memory duration. The median memory rate per hour = 21, MAD = 11.4.

The sampling probability for AMs (hits over total calls) was calculated for each participant, *Mdn* = 13% (*MAD* = 9.3%) and is presented in Figure 13B. Using each participant's sampling probability and median memory duration, we were able to calculate the frequency of AMs within a given temporal period:

$$N_t = \frac{P(x) \times t}{d}$$

[1]

where N_t = number of memories in period t, P(x) = memory sampling probability, and d = median duration of memory. Here, we used the temporal period of an hour (Figure 13C) and found the median hourly rate of recall (RpH) of 21 memories (*MAD* = 11.4), corresponding to approximately 8 mins (RpH * duration) of personal recollection an hour.

5. DISCUSSION AND FUTURE RESEARCH

The current studies are an attempt to expand the current quantitative language used in AM psychometrics by addressing discrete measurable dimensions of AMs. Despite the extended history of AM research, quantitative descriptors beyond its temporal distribution have been quite elusive. In the current studies, we presented two new psychometric tools in an effort to aid in the enrichment of the quantitative dimensions used in AM research.

In relation to the temporal distribution of AMs, several attempts have been made to explain it peculiar reminiscence bump component, however, no single theory is agreed upon. The most well know is the “coming to age” explanation, which argues that early adulthood is a period of identify formation and thus contains an abundant amount of AMs. Under this theory, we may than expect AMs from the same period to be relatively rich in content as opposed to its remote and recent counter parts. In contrast to the effects of memory age found in the temporal distribution of AMs, only the most modest of temporal effects were observed within the quantitative content measured by CRAM. For both genders, AMs contained a reasonably consistent average of ~18 (SE = 0.239) elements per memory. Memories from the most recent 2/10^{ths} of a person’s life were found to significantly increase in content by approximately 25%, an amount that is far less than what is observed in the proportional distribution of AMs. Even with the aggregation of youths, to amplify temporal differences, effects were on the order of ~2 elements over a life-span.

Among the individual features we empirically observed a clustering of recall levels which were maintained over all youths, as shown in Figure 11A. Elements of *Places* and *People* consistently made up the largest portion of total content while *Episodes* and *Context* typically provided the fewest elements. The ambiguity seen for the earliest youths can be attributed to small sample sizes (refer to table 2 for descriptive statistics).

As predicted by total content, temporal effects within individual features were also modest. Six of the eight features were found to contain significant youth differences, all of which were attributable to youth 9 and, in two of the features, youth 8. Along with *Places*, the two features lacking significant youth differences (*Things* and *People*) constituted the low remote to recent memory change group. In contrast, *Context*, *Times*, and *Episodes* showed the largest temporal effect. Though temporal proportional gradients within features was observed, it is important to note that even a large change in percent over time is conceptually modest, e.g., the 1:2 ratio of elements recalled for *Episodes* between youths 3 and 9 corresponds to a decrease of 1 element. Compare this to the ~1:8 ratio of the same youths within the temporal distribution, where youth 3 contained 271 AMs and youth 9 contained 2,219.

As observed by Catal and Fitzgerald (2004) memory cues pertaining to the “what” of the event produced the greatest amount of details recalled by the participant, while the cue-order, “what-when”, afforded an even greater number of details. Of the eight features measured by CRAM, *Places* was found to be the most independent feature in AMs. Furthermore, the remote to recent memory of *Places* is among the highest of all features. *Times* and *People* shared similar characteristics and these results may indicate that a fundamental skeleton of features may underlie AMs. If AMs are supported by an underlying structure of core features, the results procured by CRAM indicate *Places* as a very likely candidate for being such a feature. In contrast, elements of *Episodes* were observed to be one of the most dependent and temporally variable among the features. Further considering the dual sets of relatively variable and invariable features within AMs, we might expect to observe differentiation of these sets between genders. Though element counts between females and males, by and large, differed in no meaningful way we did find differences in correlational trends. Running a series of two-sample *t*-tests we found a statistical trend of differences in which *Places* and *Things* were the most independent features for males while, for females, the most independent features were *People* and *Context*.

Since CRAM is an assessment of cued memories, further research will be needed to confirm whether the quantitative characteristics observed here also accurately describe spontaneous AMs. However, assuming that characteristics are the same, or at least similar, we can begin to explore the properties of feature recall with respect to frequency and temporal distribution through the composite data of CRAM and SPAM. By multiplying the product of the frequency and mean total content for a given youth by the hourly rate of AMs we can calculate an expected temporal distribution for the number of elements recalled in a given hour:

$$F(X)_k = f_k \times \text{RpH} \times \overline{X}_k \qquad \textbf{[2]}$$

where F(X) = the total element frequency X distribution for youth *k*, *f* = the temporal distribution, RpH = the rate per hour, and X bar = mean total content. In a typical hour, approximately 340 elements are recalled from our past. The majority of these elements (~ 200 elements) come from the most recent $2/10^{ths}$ of our lifespan (Figure 14A). Equation 2 can quite easily be rewritten to calculate the temporal distribution of individual features:

$$F(x)_k = f_k \times \text{RpH} \times Q_{2ik} \qquad \textbf{[3]}$$

where Q_2 = the median number of elements recalled for feature *i* in youth *k*.

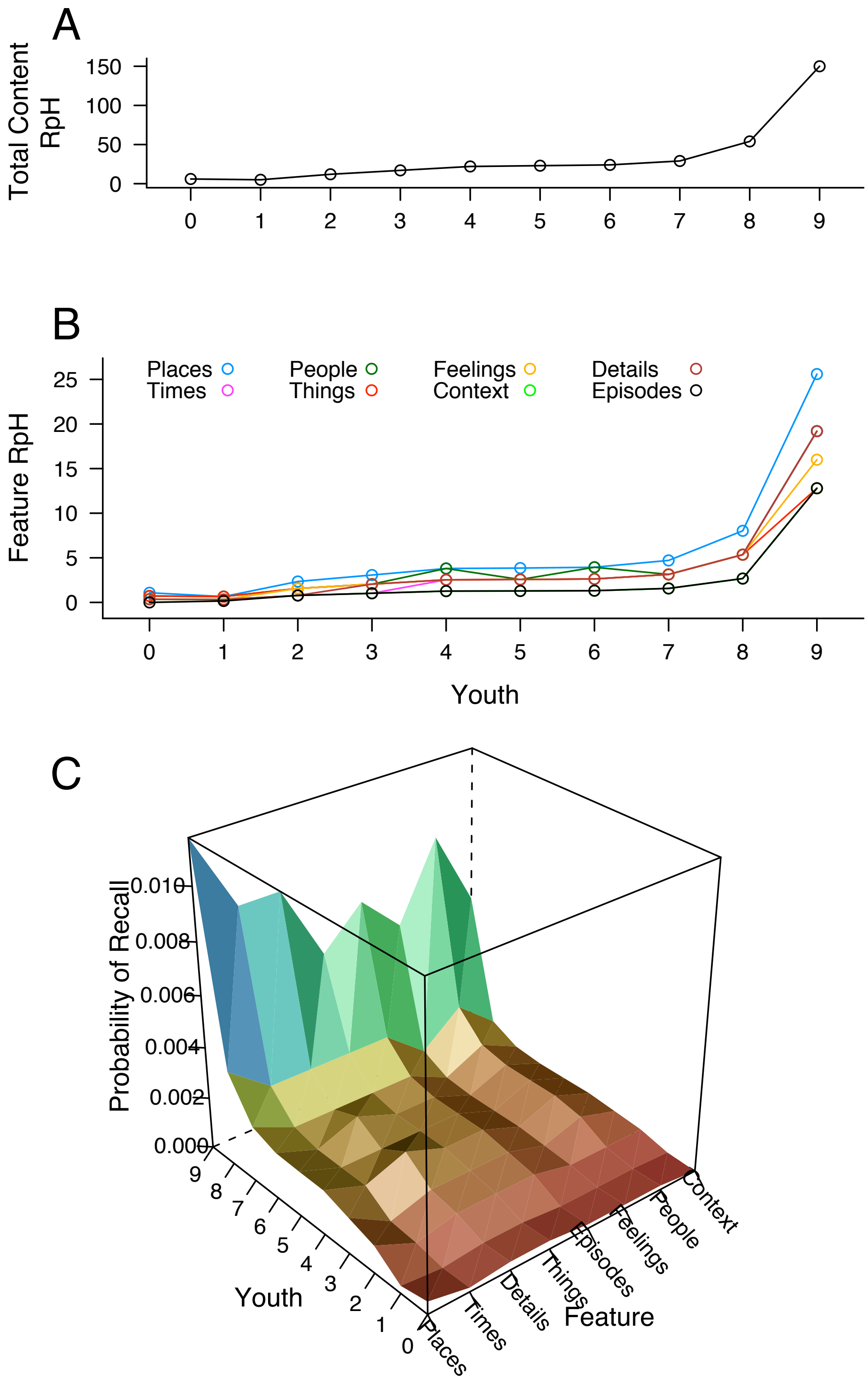
Figure 14B shows the expected distribution of elements by feature and youth under the assumption that cued and spontaneous AMs share the same characteristics documented by CRAM. From this distribution we are able to address novel quantitative descriptions of AMs, e.g., in a given hour a person will typically recall 1 person from their earliest years of life, 3 *Feelings* from their mid-life, and 28 *Places* from their most recent decile. Equation 3 can be further extended as a probability distribution by squaring the hourly rate, multiplying by the median memory duration over 3,600, and dividing by the sum of all features:

$$P(x)_k = \frac{f_k \times RpH^2 \times Q_{2ik} \times \frac{d}{3600}}{\sum_{i=1}^{n} Q_{2ik}}$$

[4]

where d = median memory duration in seconds, Q_2 = the median number of elements recall per memory, 3,600 = hour in seconds, and n = number of measured features. Equation 4 gives the probability, at any given (waking) moment, that a specific feature from a single temporal period is being reminisced by a person, as presented in Figure 14C. The most likely elemental recollection to be sampled at any instance is a place experienced by the person within their latest decile, P = 1.2%. On average, the probability of recollection of any feature from the first 4 tenths of life is 0.05%. Between the 5th and 8th tenths of life, the average probability is 0.12%, 9th P = 0.23%, and for the most recent tenth the mean probability is 0.79%.

Though equation 4 makes the same assumptions of the former equations, a critical additional assumption is made when memory duration is added into the equation. That is, further testing will need to follow to explore for duration differences between remote and recent AMs. If remote AMs have longer reminiscence durations than recent memories, we can expect the probability of recalling remote features to rise. However, if there are no differences in duration we can expect a probability distribution very similar to that shown in Figure 14C.



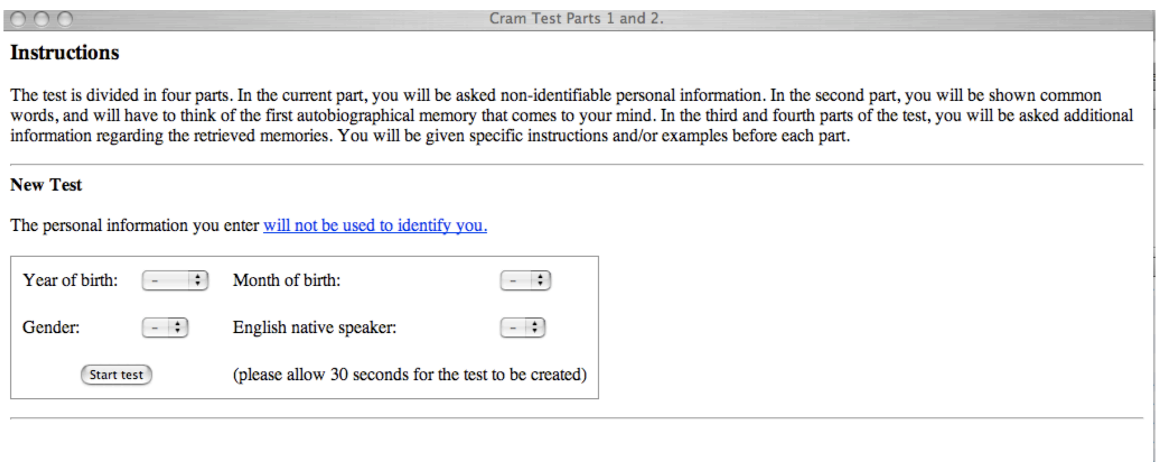
A
Total Content RpH
150
100
50
0
0 1 2 3 4 5 6 7 8 9
B
Places
Times
People
Things
Feelings
Context
Details
Episodes
Feature RpH
25
20
15
10
5
0
0 1 2 3 4 5 6 7 8 9
Youth
C
Probability of Recall
0.010
0.008
0.006
0.004
0.002
0.000
9 8 7 6 5 4 3 2 1 0
Youth
Places
Times
Details
Things
Episodes
Feelings
People
Context
Feature

Fig. 14. Hourly rate and recollection probability distribution of features. (A) An hourly rate of ~340 elements recalled from the past was found using equation 2, were the majority of these elements come the from the last 2 deciles of the life-span. (B) The hourly recall rate for individual features. (C) The distribution probability of spontaneous recall for individual features and youths.

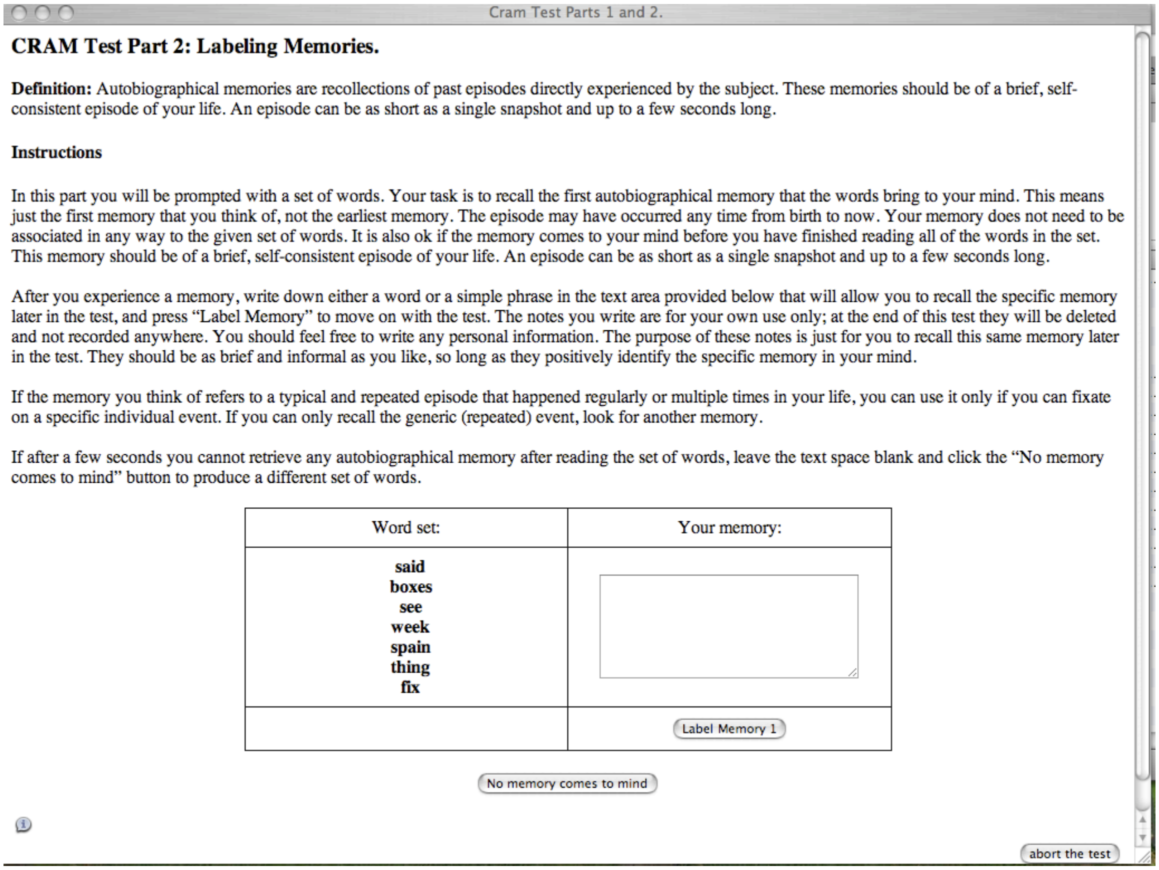
The tools presented in the current paper offer a great potential to further the development of cognitive psychology in general. Storage of age-specific population statistics in a large-scale informatics database will allow future queries of multi-dimensional frequency maps of human memories (www.cramtest.info). Practical implications of both the data and the experimental design include improved diagnosis and monitoring of diseases such as Alzheimer's and critical assessment of eyewitness reports.

APPENDIX A: *Screenshots Illustration of CRAM*

The CRAM test was administered in two different formats (Excel and a web-browser), the screen-shots below are taken from the web-browser format (http://cramtest.info), both used the same protocol design. Four parts define the CRAM test, namely (1) collection of personal information, (2) labeling of memories, (3) dating memories, and (4) counting element features for a subset of memories.



Part 1: *Personal Information*. Basic biographical information is collected from participant's (i.e., year and month of birth, gender, and English as a native language).



Part 2: *Labeling Memories*. Participants are presented with a set of 7 words and are instructed to read through the list. The first autobiographical memory to spontaneously come to mind is then labeled with either a unique word or phrase that will allow that participant to recall the memory later in the test. If no memory is cued from the initial set of words, participants are able to refresh the set with new words until a memory is recalled. A total of 30 memories are cued during this portion of the test.

CRAM Part 3: Dating Memories

CRAM Part 3: Dating Memo...

CRAM Test Part 3: Dating your Memories.

Your life span has been divided into 10 periods, as shown in the table below. In this part your task is to date the memory you previously recorded. There are three methods by which you can estimate the age of your memory: your age at the time of the event, the date of the event, or the time elapsed since the event. Choose whatever method is easiest for you. Select the time period which most accurately reflects when the event happened. If you are not sure between two or more periods you can select more than one, but try pinpointing the time frame. After you date the memory, press the button below to move on to the next part of the test.

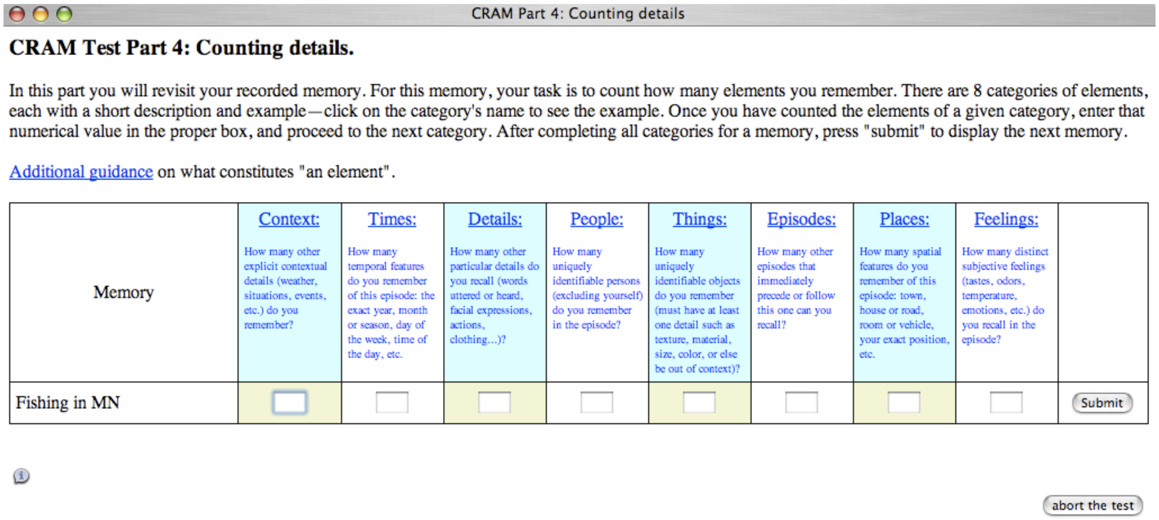
Memory:	Fishing in MN

Choose:	By Your Age		By Date		By Time Lapsed	
	From	To	From	To	From	To
☐	birth	1 year 11 months old	Jan 1987	Jan 1989	20 years 9 months	18 years 9 months ago
☐	2 years	4 years old	Feb 1989	Feb 1991	18 years 8 months	16 years 8 months ago
☐	4 years 1 month	6 years 1 month old	Mar 1991	Mar 1993	16 years 7 months	14 years 7 months ago
☐	6 years 2 months	8 years 2 months old	Apr 1993	Apr 1995	14 years 6 months	12 years 6 months ago
☐	8 years 3 months	10 years 3 months old	May 1995	May 1997	12 years 5 months	10 years 5 months ago
☐	10 years 4 months	12 years 4 months old	Jun 1997	Jun 1999	10 years 4 months	8 years 4 months ago
☐	12 years 5 months	14 years 5 months old	Jul 1999	Jul 2001	8 years 3 months	6 years 3 months ago
☐	14 years 6 months	16 years 6 months old	Aug 2001	Aug 2003	6 years 2 months	4 years 2 months ago
☐	16 years 7 months	18 years 7 months old	Sep 2003	Sep 2005	4 years 1 month	2 years 1 month ago
☐	18 years 8 months	20 years 7 months old	Oct 2005	now	2 years	now

Date memory 1

abort the test

Part 3: *Dating Your Memories*. Once 30 memories are labeled, participants moves onto dating the event in each memory (i.e., the memory's youth). Memories, with their corresponding labels, are sequentially presented one-by-one for the participant to date. Three methods were provided to date the memory (i.e., by participant's age, by date, and by time lapsed since the event occurred).



CRAM Part 4: Counting details

CRAM Test Part 4: Counting details.

In this part you will revisit your recorded memory. For this memory, your task is to count how many elements you remember. There are 8 categories of elements, each with a short description and example—click on the category's name to see the example. Once you have counted the elements of a given category, enter that numerical value in the proper box, and proceed to the next category. After completing all categories for a memory, press "submit" to display the next memory.

Additional guidance on what constitutes "an element".

Memory	Context: How many other explicit contextual details (weather, situations, events, etc.) do you remember?	Times: How many temporal features do you remember of this episode: the exact year, month or season, day of the week, time of the day, etc.	Details: How many other particular details do you recall (words uttered or heard, facial expressions, actions, clothing...)?	People: How many uniquely identifiable persons (excluding yourself) do you remember in the episode?	Things: How many uniquely identifiable objects do you remember (must have at least one detail such as texture, material, size, color, or else be out of context)?	Episodes: How many other episodes that immediately precede or follow this one can you recall?	Places: How many spatial features do you remember of this episode: town, house or road, room or vehicle, your exact position, etc.	Feelings: How many distinct subjective feelings (tastes, odors, temperature, emotions, etc.) do you recall in the episode?	
Fishing in MN									Submit

abort the test

Part 4: *Counting Details*. A subset of the memories (determined by a computer program script) is selected from which participants are to count as many unique elements they can recall for eight feature (e.g., *context*, *times*, *details*, etc.). Each feature is defined and followed by an example memory with a element count for the corresponding feature (see Appendix B). Similar to Part 3 (*dating memories*), the labels provided by the participant are represented for the recall of the memory. Additional guidance was provided which entailed a detailed explanation of what constitutes an element and feature with memory examples being provided when appropriate for further clarification (see Appendix C).

APPENDIX B: *The Features of CRAM*

Eight contextual features are defined and presented with a corresponding memory example to each participant. The definition of each element remained visible for this entire segment in the Excel format, while in the web-browser format the definitions collapsed after the first scored memory. The user is able to expand these definitions at any point following the first memory scored.

Place

How many spatial elements do you remember of this episode: town, house or road, room or vehicle, your exact position, etc.

Example given: You recall chatting with a friend in her apartment in New York, but not whether in the living room or bedroom, nor whether sitting or standing. Count 2 points (for the apartment and the town, even if knowing the apartment "automatically" specifies the town).

Time

How many temporal elements do you remember of this episode: the exact year, month or season, day of the week, time of the day, etc.

Example given: You remember getting a speeding ticket while driving to church. You can't remember the exact year, nor time of the day, but you recall it was Summer and Sunday. Count 2 points.

People

How many uniquely identifiable persons (excluding yourself) do you remember in the episode?

Example given: You were at some party. Your best friend John was there, and so was his second wife, whose name you don't recall. The host, Marc, was there, and some of his relatives, but you cannot remember which. Count 3 points (John, his wife, and Marc).

Things

How many uniquely identifiable objects do you remember (must have at least one detail such as texture, material, size, color, or else be out of context)?

Example given: If you were inside a bedroom, the window doesn't count as an object (since almost all bedrooms have one), unless you remember that it was open, or that it had pink curtains… Same with a bed, a closet, etc. If, on the other hand, you remember there were skates on the floor, an apple on the table, or something not usually found in the standard bedroom, then you should count those objects.

Feelings

How many distinct subjective feelings (tastes, odors, temperature, emotions, etc.) do you recall in the episode?

Example given: It was the last day of school. You had a stomachache, the room smelled like fish and it was too warm. Still, you felt very happy. Count 4 points.

Context

How many other explicit contextual details (weather, situations, events, etc.) do you remember?

Example given: You remember that on that same day, the Lakers' won the league, your grandma was at the hospital, and it was freezing cold outside. Count 3 points.

Details

How many other particular details do you recall (words uttered or heard, facial expressions, actions, clothing…)?

Example given: It was your first date. When you arrived, she said; "late at your first date!?", and you smiled. She had already ordered a drink. Count 3 points.

Episodes

How many other episodes that immediately precede or follow this one can you recall?

Example given: John, cued with the word "car", recalled when he first went on a go-cart and was at the start line waiting for the "go!". He uses this memory to score the previous 7 categories. In this category "Episodes," he counts how many episodes he remembers that happened immediately before or after this one. John remembers putting his helmet on, moving to the start line, his first turn right, his first passing, and the final victory. This counts for 5 episodes. He also recalls that later in the day he ate pizza, but this should not be counted, because the event is temporarily discontinuous. Count 5 points.

APPENDIX C: *CRAM Additional Guidance*

Further description is provided to aid participants in clarification of what does and does not constitute a element of an feature. How to handle features that can be characterized by more then one feature is also outlined here.

A detail could be practically defined as the minimum element of information you would include in a very extensive and exhaustive account of this episode in a hypothetical personal diary. As with a personal diary, you would not describe over and over objects or people you are very familiar with.

Suppose that the episode consisted of an argument you had with an old friend in your kitchen. Even if you can probably visualize in your recollection many details of the kitchen, such as the position of the refrigerator, the color of the walls, and whether you had a gas or electric stove, these are not really part of the specific episode. You would not describe them in your diary, because they would be implied by the fact that the episode occurred in your kitchen. Thus, you should not count these details in the test. Similarly, you should not count the fact that your friend had blond hair and blue eyes. However, if the argument degenerated and the friend broke a dish on your head, you should probably count that dish as an object even if you had seen it many times before in the kitchen.

If, on the other hand, you are describing a hotel room you spent one night at, then every uniquely identifiable detail you can remember should count. You can't, however, consider "the room had a door, a bed, and a lamp" as three valid details, unless you remember something specific about them.

If in another recalled episode you changed a flat tire, and remember that you had to unscrew as many as 16 bolts, should you count 16 details? Not unless you remember something specific for each and every bolt. In your diary you would probably write that there were 16 bolts, and this single element of information should be counted as one detail. Similarly, if you recall a dinner with 12 people, but only specifically remember 3 of them, you should count three details under "people" and one under "context" (corresponding to the fact that there were 12 people). If you remember that one person at dinner was a lawyer, but you don't remember his face nor any other detail about him, should he count as a person? You can count him in, or alternatively you could count the fact that one person in the group was a layer as an "other" detail (it would in any case count as one detail overall).

In general, there is no objectively "right" or "wrong" way to exactly count details in a remembered event. What matters most is what you consider a detail in your memory, and as such you are the ultimate decision maker. No need to agonize over the specific category of the element. The distinctions between various categories are often 'soft', and you can decide just based on your intuitive preference.

APPENDIX D: *Definition and Examples of Episodic Memories in SPAM*

Participants are provided a definition and paired examples of episodic and non-episodic memories. They are instructed to read the following handout after which additional episodic/non-episodic memory examples are presented and discussed.

Episodic Memories (EM)

Definition: An episodic memory is a memory from your personal past; a memory of something that you have personally experienced in your lifetime. This memory could be of an event that occurred from the very moment you were born to the last second you just lived. The event in the memory is typically less than 3 hrs and is specific to a place. The memory itself of the event is typically short in time (1 to 60 seconds). That is to say, it is like a Kodak moment—minus the sappiness.

NO (Not An) EM Example: You remember a 3 hour long trip to your grandmother's house and thinking how much longer it felt with an annoying little sister to share the time with.

Why Not? This memory would not to be considered an EM because the memory is of an event that was 3 hours long.

YES (An) EM Example: You are remembering that once on a 3 hour ride to your grandmother's house, you saw a cow for the first time. You can see the cow again through your mind's eyes and you remember what you felt when you saw the cow (curious or afraid for example) and the smell of manure, mmm.

Why? This is an EM because the event that you are remembering is specific to a moment in your life. That is, this event probably only lasted a few minutes; the event did not stretch out over +3 hours, days, weeks, etc. Also, re-experiencing the feeling and smell of that event is a sign of mental time travel—which is a hallmark of EMs.

YES (An) EM Example: You are remembering the moment your dog ran through the door of your home after being lost for two days. You are re-living the feeling of happiness and relief that Murdock (your dog) is safe and licking your face like a giant lollipop. You can actually feel his wet tongue on you face, that's how much you're into this memory.

Why? This is an EM because you are obviously re-living some portions of this event (i.e. emotional and physical feelings). Also, this memory is of an event that happened personally to you.

NO (Not An) EM Example: You remember a story about a person that when after two days of hopelessly looking her dog, a neighbor brings it over to her. After about a week of giving her dog extra love and extra long walks to makeup for lost time, she realizes that this is not her dog.

Why Not? This is not an EM because it is not an event that happened to you, this is a memory of an event of someone else's life.

NO (Not An) EM Example: You remember that for the past week, every time you turn you head fast you get a shooting pain down your spine. You can still feel what this pain was like.

Why Not? This is not an EM because the event repetitive; you have experienced this event several times in your life.

YES (An) EM Example: You remember that for the past week, every time you turn you head fast you get a shooting pain down your spine. Specifically, you remember the first time that it happened was when someone called out your name and you jerked your head around to see who it was.

Why? Though this is a memory of an event that has happened several times over your life, you are remembering one specific instance that it happened.

REFERENCES

REFERENCES

Baddeley, A. and Warrington, E. (1970). Amnesia and the distinction between long and short-term memory. *Journal of Verbal Learning*, 9, 176-189.

Bayley, P. J., Hopkins, R. O., & Squire, L. R. (2003). Successful recollection of remote autobiographical memories by amnesic patients with medial temporal lobe lesions. *Neuron*, 38(1), 135-144.

Bayley, P. J., Hopkins, R. O., & Squire, L. R. (2006). The fate of old memories after medial temporal lobe damage. *Journal Neuroscience*, 26(51), 13311-13317.

Bender, L., Fromholt, P., Larsen, P., Mortensen, D., & Rubin, D. C. (2003). Life-narrative and word-cued autobiographical memories in centenarians: Comparisons with 80-year-old control, depressed, and dementia groups. *Memory*, 11(1), 81-88.

Benjamini, Y., & Yekutieli, D. (2001). The control of the false discovery rate in multiple testing under dependency. *Annals of Statistics*, 1165-1188.

Berntsen, D. (1996). Involuntary autobiographical memories. *Applied Cognitive Psychology*, 10, 455–460.

Berntsen D. & Rubin D.C. (2003). Life scripts help to maintain autobiographical memories of highly positive, but not highly negative, events. *Memory & Cognition*, 31(1), 1-14.

Berntsen, D. & Rubin, D. C. (2004). Cultural life scripts structure recall from autobiographical memory. *Memory & Cognition*, 32(3), 427-442.

Bookheimer, S. Eldridge, L. Engel, S., Knowlton, B. & Zeineh, M. (2005). A dissociation of encoding and retrieval processes in the human hippocampus. *Behavior/ Systems/Cognitive*, 25(13), 3280-3286.

Brown, N., & Schopflocher, D. (1998). Event clusters: An organization of personal events in autobiographical memory. *Psychological Science*, 9(6), 470-475.

Catal, L., & Fitzgerald, J. M. (2004). Autobiographical memory in two older adults over a twenty-year retention interval. *Memory & Cognition*, 32(2), 311-323.

Chu, S., & Downes, J. (2000). Long live Proust: The odour-cued autobiographical memory bump. *Cognition*, 75(2), B41-B50.

Connelly, A., Gadian, D., Mishkin, M., Van Paesschen, W., & Vargha-Khadem, F. (1997). Differential effects of early hippocampal pathology on episodic and semantic memory. *Science*, 227, 376-379.

Crovitz, H. F. & Schiffman, H. (1974). Frequency of episodic memories as a function of their age. *Bulletin of Psychonomics Society*, 4, 517-518.

Ferbinteanu, J., Kennedy, P., & Shapiro, M. (2006). Episodic memory–from brain to mind. *Hippocampus*, 16, 691-703.

Fitzgerald, J. M., (1996). Intersecting meanings of reminiscence in adult development and aging. In D. C. Rubin (Ed.), *Remembering our past: Studies in autobiographical memory* (pp. 360-383). Cambridge, MA: MIT Press.

Fitzgerald, J. M. & Lawrence, R. (1984). Autobiographical memory across the life-span. *Journal of Gerontology*, 39(6), 692-698.

Fromholt, P. & Larsen, S. F. (1991). Autobiographical memory in normal aging and primary degenerative dementia (dementia of the Alzheimer type). *Journal of Gerontology: Psychological Sciences*, 46, 85-91.

Galton, F. (1879). Psychometric experiments. *Brain*, 2, 149-162.

Greenberg, D., Rubin, D. C., & Schrauf, R. (2003). Belief and recollection of autobiographical memories. *Memory & Cognition*, 31(6), 887-901.

Goldsmith, D., Groth, E., & Rubin, D. C. (1984). Olfactory cuing of autobiographical memory. *American Journal of Psychology*, 97(4) 493-507.

Hopkins, R., Manns, J, & Squire, L. R. (2003). Semantic memory and the human hippocampus. *Neuron*, 38, 127-133.

Jansari, A. & Parkin, A. (1996). Things that go bump in your life: Explaining the reminiscence bump in autobiographical memory. *Psychology and Aging*, 11(1), 85-91.

Knowlton, B., Musen, G., & Squire, L. R. (1993). The structure and organization of memory. *Annual Review of Psychology*, 44, 453-495.

Kvavilashvili, L., & Mandler, G. (2004). Out of one's mind: A study of involuntary semantic memories. *Cognitive Psychology*, 48(1), 47-94.

Larsen, S. F. (1996). Memorable books: recall of reading and its personal context empirical approaches to literature and aesthetics. Norwood, NJ.

Levine, B. (2004). Autobiographical memory and the self in time: Brain lesion effects, functional neuroanatomy, and lifespan development. *Brain and Cognition*, 55, 54-68.

Mackavey, W., Malley, J., & Stewart, A. (1991). Remembering autobiographically consequential experiences: Content analysis of psychologists' accounts of their lives. *Psychology & Aging*, 6, 50-59.

Miller, G. (1956). The magical number seven, plus or minus two: some limits on our capacity for processing information. *The Psychological Review*, 63(2), 81-97.

Monaghan, B. & Rybash, J., (1999). Episodic and semantic contributions to older adults' autobiographical recall. *The Journal of General Psychology*, 126(1), 85-96.

Poon, L., Rahhal, T. & Rubin, D. C. (1998). Things learned in early adulthood are remembered best. *Memory & Cognition*, 26(1), 3-19.

Rahhal, T., Rubin, D. C., & Schulkind, M. (1999). A study of gender differences in autobiographical memory: Broken down by age and sex. *Journal of Adult Development*, 6, 61-71.

Remondes, M. & Schuman, E. (2004). Role for a cortical input to hippocampal area CA1 in the consolidation of a long-term memory. *Nature,* 431, 699-702.

Robinson, J. (1976). Sampling autobiographical memory. *Cognitive Psychology*, 8, 578-595.

Rubin, D.C. (1980). 51 properties of 125 words: a unit analysis of verbal behavior. *Journal of Verbal Learning and Verbal Behavior*, 19, 736-755.

Rubin, D. C. (2000). The distribution of early childhood memories. *Memory*, 8(4), 265-269.

Rubin, D. C. & Schulkind, M. (1997). Distribution of important and word-cued autobiographical memories in 20-, 35-, and 70-year-old adults. *Psychology and Aging*, 12(3), 524-535.

Rubin, D. C., Wenzel, A. (1996). One hundred years of forgetting: A quantitative description of retention. *Psychological Review*, 103(4), 734-760.

Thompson, P. (1982). Diary-keeping as a sex-role behavior. *Bulletin of the Psychonomic Society*, 20, 11-13.

Wagenaar, W., (1986). My memory: A study of autobiographical memory over six years. *Cognitive Psychology*, 18, 225-252.

White, R. (1982). Memory for personal events. *Human Learning*, 1, 171-183.

CURRICULUM VITAE

Adam T. Vogel graduated from Saint Louis Park High School, Minnesota, in 1999. He received his Bachelor of Arts from Hamline University in 2006. He received his Master of Arts in Psychology from George Mason University in 2008. Currently, Adam T. Vogel is pursuing his PhD in Neuroscience at the University of Minnesota.