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Predicting remembering and forgetting of autobiographical memories in children and adults: A 4-year prospective study

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Abstract

Preservation and loss to forgetting of autobiographical memories is a focus in both the adult and developmental literatures. In both, there are comparative arguments regarding rates of forgetting. Children are assumed to forget autobiographical memories more rapidly than adults, and younger children are assumed to forget more rapidly than older children. Yet few studies can directly inform these comparisons: few feature children and adults, and few prospectively track the survival of specific autobiographical memories over time. In a 4-year prospective study, we obtained autobiographical memories from children 4, 6, and 8 years, and adults. We tested recall of different subsets of the events after 1, 2, and 3 years. Accelerated rates of forgetting were apparent among all child groups relative to adults; within the child groups, 4- and 6-year-olds had accelerated forgetting relative to 8-year-olds. The differences were especially pronounced in open-ended recall. The thematic coherence of initial memory reports also was a significant predictor of the survival of specific memories. The pattern of findings is consistent with suggestions that the adult distribution of autobiographical memories is achieved as the quality of memory traces increases (here measured by thematic coherence) and the rate of forgetting decreases.

Keywords

autobiographical memory; childhood amnesia; development; episodic memory; forgetting; prospective study

We like to think that the events of our lives are important and will be remembered, if not by others, than by ourselves. To aid in remembering, we employ a number of devices, such as taking photographs, keeping diaries and journals, and making videos of our experiences. We also know that in spite of these efforts, many of the events of our lives will be forgotten. The rate at which memories of personally relevant and significant events are lost to forgetting is of interest in both the adult and the developmental literatures, and within both literatures, there are comparative arguments. Specifically, children are argued to forget autobiographical memories more quickly than adults. The argument is based on the assumption that it is only in late adolescence or adulthood that such memories are represented in detailed and coherent fashion, and successfully knitted into a life narrative that permits their preservation over long periods of time (e.g., Bluck & Alea, 2008; Bohn & Berntsen, 2014; Fivush, 2011, 2012;

Fivush & Zaman, 2014; Habermas & de Silveira, 2008). Similarly, differential rates of forgetting are argued for some life periods relative to others. One notable example is before versus after the onset of childhood amnesia—a time from which adults (e.g., Pillemer & White, 1989; Wetzler & Sweeney, 1986) and children (e.g., Bauer & Larkina, 2014a; Peterson, Grant, & Boland, 2005; Reese, Jack, & White, 2010; Tustin & Hayne, 2010) recall few personal events and experiences. The amnesia is thought to occur due to an accelerated rate of forgetting during the period eventually obscured by the amnesia (before age 5 to 7 years), relative to after the period (e.g., Bauer & Larkina, 2014a, 2014b; Pillemer & White, 1989; Wetzler & Sweeney, 1986).

Few studies afford direct contrasts of the populations that can inform comparative arguments about relative rates of forgetting, namely, adults compared with children, and children before and after the onset of childhood amnesia. To the extent that the relevant populations are contrasted, with few exceptions, the studies are retrospective in nature. Yet importantly, retrospective studies can inform what *remains* in memory after forgetting, but by their design, they cannot directly inform what was *lost* to forgetting (see Bauer & Larkina, 2014b, for discussion). In the present research, we addressed these voids in the literature through a 4-year prospective study of the fates of autobiographical memories formed at different points in childhood (4, 6, and 8 years of age) and in adulthood. The study afforded direct comparison of rates of forgetting among children and adults, and by children before and after the onset of childhood amnesia (i.e., 4-year-olds and 8-year-olds, respectively, with 6-year-olds at the “inflection point,” Wetzler & Sweeney, 1986). Additionally, because participants provided narrative reports of their memories at the start of the study, we were able to test whether characteristics of the narratives (e.g., the amount of detail represented, the level of narrative coherence) contributed to the survival of memories over time.

Comparative Rates of Forgetting

The literature is well populated by controlled laboratory studies that contrast rates of forgetting among adults relative to children, and among children in the age ranges before versus after the onset of childhood amnesia (i.e., preschool years vs. school-age years). The studies reveal age-related improvements in memory using a variety of stimuli, including word lists (e.g., Brainerd, Holliday, & Reyna, 2004), scenes (Ofen, Kao, Sokol-Hessner, Kim, Whitfield-Gabrieli, & Gabrieli, 2007), and drawings (Billingsley, Smith, & McAndrews, 2002; Ghetti & Angelini, 2008; see Ghetti & Lee, 2014, for a review). In short, over a given delay (typically minutes to hours or days), older participants have higher levels of memory relative to younger participants. Age differences are especially pronounced in tests of recall versus recognition (e.g., Ghetti, DeMaster, Yonelinas, & Bunge, 2010; Naus, Ornstein, & Kreshtool, 1977; Schneider & Pressley, 1997; Schwenk, Bjorklund, & Schneider, 2009), and when individuating details are required, such as the source of an experience (e.g., Cycowicz, Friedman, Snodgrass, & Duff, 2001; Drumme & Newcombe, 2002; Riggins, 2014).

Relative to studies of laboratory materials, there are few comparative studies of rates of forgetting of autobiographical memories. Autobiographical memories differ from memories of lists of words, scenes, and drawings, in that they are memories of events that are

personally relevant and significant, such as the first day of school, winning the spelling bee competition, parental divorce, college acceptance and graduation, birth of a child, and death of a loved one. They are events that make up one's life story or personal past; they are events about which one has a subjective or individual perspective (e.g., Bauer, 2015; Fivush, 2011, 2012). Recall of these events is accompanied by vivid recollection and even re-living of the experience (e.g., Tulving, 2002, 2005). Because of the different status of episodic and autobiographical memories, laboratory studies of episodic memory may not adequately inform whether children and adults, and younger relative to older children, differ in the rate of forgetting of autobiographical memories.

Competing Predictions Regarding Autobiographical Memories

There are reasons to make competing predictions about relative rates of forgetting of autobiographical memories within childhood and between childhood and adulthood. On the one hand, the differences between episodic and autobiographical memories lead to the prediction that rates of forgetting may be more comparable in the domain of autobiographical memory than in the domain of episodic memory. The fact that autobiographical memories are personally relevant and significant is a principal reason to make this prediction. It is clear that even children place personal significance on the events of their lives. In Bauer, Hättenschwiler, and Larkina (2015), children 12 to 14 years and young adults (college students) provided ratings of their perceptions of events and memories from various points in the past, including two periods in early childhood (i.e., 1-5 years and 6-10 years). Relative to the young adults, the children rated the events as equally important and significant both at the time of the event and in the present. They rated their memories as more vivid and more complete, relative to the young adults.

There also is suggestive evidence that children have better memory for more personally relevant or significant events, relative to less autobiographical events and experiences. Pathman, Samson, Dugas, Cabeza, and Bauer (2011), directly compared memories for more and less "autobiographical" experiences, in two age groups of children (ages 7-9 and 9-11 years) and adults. The participants visited a local museum and took photographs of exhibits. They also viewed a laptop slideshow of photographs taken by other participants, and made aesthetic judgments about the pictures (to ensure processing of them). One to two days later, participants were tested for recognition of the photographs they had taken ("autobiographical" condition) and photographs they had viewed on the laptop ("episodic" condition), among distractors. Overall, participants had higher levels of correct recognition in the autobiographical relative to the episodic condition (see Cabeza et al., 2004 for a similar finding among adults). Of specific relevance to the present research, in the episodic condition, both child groups had lower levels of recognition relative to the adults, whereas in the autobiographical condition, performance of the older children was comparable to that of the adults. Children 8 to 10 years of age also performed similarly to adults in a study in which both age groups were required to make precise temporal judgments about the order in which they photographed the events of their lives over a 4-week period (Pathman, Doydum, & Bauer, 2013). Thus on memory tasks that approximate autobiographical events and experiences, age-related differences between children and adults are minimized.

There also are reasons to expect differential rates of forgetting among adults relative to children and among older relative to younger children. There are two major bases for this prediction. The first stems from the fact that although episodic and autobiographical memories have different qualities and features, they are governed by basic properties of memory that transcend the differences, thus permitting generalization of findings from the laboratory-based episodic memory literature to the domain of autobiographical memory. As discussed in detail elsewhere (e.g., Bauer, 2015), a rate-limiting variable that would impact both types of memory is the developmental status of the neural substrate that supports them. Because the neural network implicated in these forms of memory is slow to develop, we may expect less efficient and less effective encoding, consolidation and storage, and retrieval of autobiographical as well as episodic memories among younger than older children and among children relative to adults. The challenges posed by a relatively underdeveloped memory system may be especially apparent for autobiographical memories which typically are tested via recall versus recognition (Cabeza et al., 2004, and Pathman et al., 2011, 2013, are notable exceptions to this rule). The search and access demands of recall tend to exaggerate age-related differences, relevant to recognition (e.g., Ghetti et al., 2010; Naus et al., 1977; Schneider & Pressley, 1997; Schwenk et al., 2009). Similarly, because autobiographical events and experiences are characterized by information that individuates them from other events and experiences (e.g., information that specifies the source of an experience; e.g., Cywocicz et al., 2001; Drummey & Newcombe, 2002; Riggins, 2014), it is reasonable to expect that older participants would have more robust memory, relative to younger participants. It also is reasonable to predict that the differences would be especially apparent over longer delays, potentially spanning a lifetime.

The second basis from which to expect different rates of forgetting across participant groups stems from the descriptions that individuals provide about their memories, and from the observed distribution of autobiographical memories across the lifespan. Relative to children, adults provide longer, more detailed, and more narratively coherent reports about autobiographical events and experiences (e.g., Bauer & Larkina, 2014a; Reese, Haden, Baker-Ward, Bauer, Fivush, & Ornstein, 2011). The same pattern is apparent for younger relative to older children (e.g., Habermas, Negele, & Mayer, 2010; Reese et al., 2011; Van Abbema & Bauer, 2005). Longer and more detailed narratives imply more robust memories; greater coherence in a narrative implies a better organized representation that should be more resistant to forgetting (although see Bauer, 2015). Moreover, it is only in later adolescence or adulthood that narratives of past events are integrated with one another to fashion a life story or autobiography (e.g., Fivush & Zaman, 2014; Habermas & Bluck, 2000; Thomsen, 2009; see Bohn & Berntsen, 2014), that serves as a further aid to remembering over the long term.

Seemingly reflective of increases in the quality of memories over time, the distribution of autobiographical memories is characterized by a steadily increasing number of memories in the corpus, beginning at approximately age 7 to 8 years. In the period of roughly 10 or 15 to 30 or 35 years, the number of memories is actually greater than would be expected by forgetting alone, a phenomenon known as the “reminiscence bump” (e.g., Gluck & Bluck, 2007; Jansari & Parkin, 1996). Conversely, prior to 7 to 8 years, the number of memories is smaller than expected by forgetting alone. This “childhood amnesia” component of the

distribution (Pillemer & White, 1989) has been linked to accelerated forgetting in childhood relative to adulthood (Bauer, Burch, Scholin, & Güler, 2007; Bauer & Larkina, 2014a). Specifically, whereas the distribution of adults' autobiographical memories over time is well characterized by the power function (e.g., Bauer & Larkina, 2014a; Crovitz & Schiffman, 1974; Rubin & Wenzel, 1996; Rubin, Wetzler, & Nebes, 1986), the distribution of children's memories is better characterized by the exponential function, implying accelerated forgetting. In sum, both the number of memories in the corpus from different periods of life, and the level of detail and coherence with which the memories are reported, are consistent with suggestions of differential rates of forgetting of autobiographical memories in adults than children and in older than younger children.

Limitations of the Existing Literature

The literature available to directly address the competing predictions just outlined is thin. The ideal research design is one that documents memories of personally relevant events at one point in time in children of different ages and in adults, and then tracks the memories over time to determine the rate at which they are forgotten. In contrast to this ideal, most of the literature on autobiographical memory features either children or adults, but not both. Most studies of adults' autobiographical memories are retrospective, relying on cue words or prompts to elicited memories of past events (e.g., Rubin, 1982). There are prospective studies as well, yet they tend to involve a single individual (Linton, 1975; Wagenaar, 1986; White, 1982, 1989, 2002), or a single significant event (a "flashbulb" experience; e.g., Brown & Kulik, 1977; Neisser & Harsch, 1992; Conway, Skitka, Hemmerich, & Kershaw, 2009; Pillemer, 1984), and none has included children as well as adults.

The developmental literature is equally limited in the ability to address questions of differential rates of forgetting by children of different ages. Although many developmental studies of autobiographical memory are prospective, the most common design is to query children about different events at each time point in a longitudinal study (e.g., Harley & Reese, 1999), or to ask about a combination of the same and different events at each time point (e.g., Reese, Haden, & Fivush, 1993). As in the adult literature, studies that have tracked the fates of specific memories over time tend to focus on single significant events, such as a tornado (e.g., Ackil, Van Abbema, & Bauer, 2003), hurricane (Fivush, Sales, Goldberg, Bahrick, & Parker, 2004), or a fire alarm protocol (Pillemer, Picariello, & Pruett, 1994). Others feature either children recalling events from different points in the past, and thus over different delays (Cleveland & Reese, 2008; Fivush & Schwarzmueller, 1998), or children of different ages recalling events from the same point in the past (Bauer & Larkina, 2014b; Van Abbema & Bauer, 2005). Morris, Baker-Ward, and Bauer (2010) and Peterson, Warren, and Short (2011) are exceptions in that both featured later tests of recall of events after a fixed delay by children of different ages at the time of experience. In both cases, children younger at the time of the events exhibited faster rates of forgetting relative to children older at the time of the events. These studies inform the possibility of differential forgetting by younger relative to older children. Yet neither study afforded comparisons of rates of forgetting by children and adults, because neither study included adults.

In addition to comparisons of rates of forgetting by children of different ages at the time of experience of events, Morris et al. (2010) and Peterson, Morris, Baker-Ward, and Flynn (2014, using data from Peterson et al. [2011]) permitted tests of possible determinants of the survival of children's autobiographical memories over time, above and beyond the ages of the participants (4 to 8 years and 4 to 13 years, respectively) and the delays involved (1 year and 2 years, respectively). In both studies, logistic multilevel modeling was used to examine the predictive utility of features of the narrative reports about the events that the children provided at the time of initial testing. Examination of narrative features is motivated by arguments that memories that are represented in a detailed and coherent fashion will be better preserved over time (e.g., Bauer, 2015; Fivush, 2011, 2012; Fivush & Zaman, 2014). Consistent with this suggestion, Morris et al. (2010) found that when descriptions of events featured more interpretation of the experiences and elaborations of them, the events were 2.5 times more likely to be remembered 1 year later than when the descriptions lacked these features. In contrast, the breadth of information included in the narrative descriptions (whether the report featured all of the narrative elements of *who*, *what*, *where*, *when*, *why*, and *how*) did not add to the prediction of survivability of the memories. Peterson et al. (2014) reported a similar pattern.

Present Research

The purpose of the present research was two-fold. The first purpose was to address the possibility of differential rates of forgetting of autobiographical memories by adults and children, and by older children and younger children. The second major purpose was to test whether the characteristics of initial memory reports were predictive of the likelihood of survival of specific memories over time. To further these goals, we enrolled children 4, 6, and 8 years of age, and adults in a prospective study. The child age groups were chosen to be on either side of the childhood amnesia divide (4- and 8-year-olds), and at the "inflection point" (6-year-olds), thus permitting comparison of rates of forgetting at this critical juncture in the distribution of autobiographical memories. Inclusion of adults permitted direct comparison of rates of forgetting in children and adults. At the time of enrollment, we collected a corpus of personal memories from each participant, thus satisfying the requirement of documentation that the participants had formed memories of the events. We then tested the participants for recall of different subsets of the original corpus after delays of 1, 2, and 3 years. We evaluated levels of recall in response to open-ended prompts and under more supportive recall conditions.

The data from the child age groups after the 1-year delay formed the basis of Morris et al. (2010). The present analysis is the first report of any of the adult data, and also took advantage of the entire 4-year space of time of the study, thus allowing for test of recall of events and experiences over delays that are representative of the lifespan of autobiographical memories. We expected higher levels of recall after shorter relative to longer delays for all age groups. We also predicted an interaction of delay and age, such that younger participants would evidence more accelerated forgetting relative to older participants. We expected age group differences to be especially pronounced in open-ended testing, relative to under more supportive recall conditions. Finally, we characterized the memory reports provided at the time of enrollment along a number of narrative dimensions, thus permitting test of whether

qualities of the reports of the memories were predictive of their survival over time. Consistent with both theory and prior developmental research, we expected that narrative coherence would emerge as the strongest predictor.

Method

Participants

The participants were 101 children (53 female, 48 male) and 35 adults. The adults were mothers of a subset of the child participants. Maternal participants were pseudo-randomly selected at the time of enrollment of their children, with the constraint that an approximately equal number of mothers were selected from each of the child age group (two mothers each had two children in the study). At the beginning of the study, children were ages 4, 6, and 8 years, and the adults were an average of 37 years of age (see Table 1, Panel a, for details). All of the families were drawn from a participant pool maintained by the Institute of Child Development, University of Minnesota, USA. The participant pool was entirely volunteer. The families were primarily Caucasian (94%); none was of Hispanic descent. Based on parental report of occupation and education, the families were of middle to upper-middle socioeconomic status (at the beginning of the study, 84% of mothers and 85% of fathers had a technical degree or more). At the time of the inception of the study, the sample was reflective of the community from which it was drawn.

There were four assessment points, each spaced approximately one year apart (Table 1, Panel b). At each assessment point, children took part in two test sessions, spaced approximately one week apart; adults participated in only one session at each assessment point (see below). The University of Minnesota institutional review board approved the protocol prior to the start of the study. At each data collection point, written parental consent was obtained for each child and when the mother also was a participant, for her own participation. Children ages 7 years and older provided written assent for their participation; children younger than 7 gave verbal assent. At the end of the second session at each assessment point, children received a toy, and parents and parent participants were given a gift certificate to a local merchant.

An additional 34 families (34 children, 12 adults) were enrolled but did not complete all points of data collection and thus are not included in the analyses: the loss to attrition was 22 families before the 1-year delay, 8 families before the 2-year delay, and 4 families before the 3-year delay. Attrition was approximately evenly distributed across the child age groups (23%, 23%, 30% from the 4-, 6-, and 8-year-old groups, respectively). The demographic characteristics of the families lost to attrition did not differ from those of the families retained. The majority of families (59%) were lost to contact: they did not return recruitment phone calls or letters. Three families (9%) moved out of the area, and 11 families (32%) withdrew from the study, indicating that they did not have time to continue participation. Thus we had 75% retention of the sample over all 4 points of data collection.

Materials and Procedure

All testing took place in a university laboratory setting. Testing rooms were outfitted with tables and chairs and child-friendly decorations. Participants visited the laboratory annually for 4 years. At each assessment point, the children took part in two 1-1.5 hour sessions, approximately 1 week apart. The adults had one 1-hour session at each assessment point. Over the course of the four years of data collection, nine female experimenters administered the tasks. The two sessions (children only) within an assessment point were conducted by the same experimenter; participants were tested by different experimenters at each assessment point. Task procedures were outlined in a written protocol, and the experimenters regularly reviewed and discussed videotaped sessions to ensure protocol fidelity.

The data presented in this report are part of a larger battery of tasks administered over the course of the longitudinal study. For present purposes, the focus is on children's and adults' memories for events and experiences reported in autobiographical memory interviews conducted at the initial assessment. Participants were tested for recall of different subsets of the events after 1 year, 2 years, and 3 years (see below). For the children, the memory interviews were conducted over the course of the two sessions to avoid fatigue; the adult participants discussed all autobiographical events in one session. As noted above, the data from the initial assessment and 1-year delay for children only were published in Morris et al. (2010). For purposes of the present study, different analyses were conducted. The child data from the 2-year and 3-year delays and the adult data all are presented for the first time in this report.

Initial assessment—Approximately 4 months prior to their first visit to the laboratory, parents of the child participants received a blank calendar in the mail. They were instructed to note on the calendar at least one unique event per week in which their children participated. Parents were asked to select events that were of interest to their children (e.g., family outings, special school or afterschool events, celebrations) and to avoid routine events unless something unique happened in the course of the event. For example, they were asked to avoid recording “grocery store,” unless something unique happened in the course of the otherwise routine trip, such as the car had a flat tire. Adult participants received a separate blank calendar for themselves, along with similar instructions. They were further instructed to note different events from those recorded for their children, if possible. For both children and adults, the calendar entries were brief “titles” of events experienced; narrative descriptions of the events were not elicited or provided. Families brought the completed calendars to the laboratory when they made their first visit.

Upon arrival at the laboratory for the first visit, participants took part in an activity that is not the focus of the present report. During this time, an experimenter used the completed calendars to select events for the memory interviews. Specifically, calendars typically featured 16 events: one event for each of 4 weeks for 4 months. The experimenter numbered the events sequentially and then used a random-number generator to select the subset of events that would be queried in the interviews. The target number of events was 9, permitting test for recall of 3 unique events each randomly assigned to be tested after the 1-year, 2-year, and 3-year delays (see Figure 1 for a schematic representation of the design).

For child participants, once the target events were selected, the experimenter engaged the child in a task during which time the child's parent was asked to write a brief description (i.e., two to three unique details) of each event. To generate the descriptions, the parent was prompted by the title of the event that had been recorded on the calendar. These titles and details were used by the experimenter in the interview with the child.

Once the events were selected and for children, unique details were provided, the experimenter initiated the memory interviews. For children, the experimenter began by saying "Your mom/dad wrote down some things you've done and it's my turn to talk with you about them. Some of the things happened more recently and some of them happened a long time ago. Since I wasn't with you during these times, it's up to you to tell me everything you can about each one. When you're done, I'll ask you a few questions." For adults, the experimenter initiated the interview by saying "I am going to ask you about some things from your calendar. Some of the things happened more recently and some of them happened a long time ago. It's up to you to tell me everything you can about each one. When you're done, I'll ask you a few questions."

For each event, the experimenter began with a general prompt in the form of a title for the event (taken from the participants' calendars): "What can you tell me about X?" For children, if this prompt failed to elicit a report, the experimenter provided additional cues, which came from the parents' descriptions of the events. Note that additional cues were not available for adults (since there was no independent informant to provide them). The experimenter encouraged participants to continue their reports using generic prompts, such as "Tell me more," "Do you remember anything else?" After the participant's unstructured report had been exhausted, the experimenter asked a series of 7 direct *wh-* memory probes about the event: who was there, what else did you do, where did you X, when did you X, why did you X, how did you X, and how did you feel about X? Participants were instructed to answer these questions even if they had already provided this type of information during the open-ended portion of the interview.

Assignment of events to delay intervals of 1, 2, and 3 years—As noted above, the target number of events to be discussed at the initial assessment was 9, permitting test for recall of 3 unique events randomly assigned to be tested after the 1-year, 2-year, and 3-year delays. Events were considered to be recalled if the participant provided at least 2 unique pieces of information about the event (see Bauer & Larkina, 2014b; Fivush & Schwarzmüller, 1998; Reese et al., 1993, for a similar criterion). When participants failed to provide at least 2 unique pieces of information, additional events were sampled from the calendars. All adult participants and all 8-year-olds met the criterion for recall for all 9 of the required memories. However, not all 4- and 6-year-olds provided 9 memories that met the criterion even after sampling the additional events. Specifically, three 6-year-olds provided only 8 memories that met the criterion. Among 4-year-olds, 8 children provided 7 or 8 memories that met the criterion, 3 children provided 5 or 6 memories, and 3 children provided only 2 ($n = 1$) or 3 ($n = 2$) memories that met the criterion.

For each participant, the events recalled at the initial assessment were randomly assigned to be tested after 1, 2, and 3 years, with different events tested after each delay (see Figure 1).

Whenever possible, only events recalled at the initial assessment (i.e., events for which participants provided a minimum of 2 unique pieces of information) were tested after the delays. However, to make the session protocols consistent across participants, for 12.5% of the sample (14 4-year-olds and 3 6-year-olds, as described above), at least one event that was not recalled at the initial assessment was included in a later protocol; for all but one participant, each delay featured at least 1 event recalled at the initial assessment. The exception was that one 4-year-old recalled only 2 events at the initial assessment. For this participant, one wave of data collection featured 0 events recalled at the initial assessment. Events that were not recalled at the initial assessment were not included in the analyses (total number of events excluded $N = 44$ out of 1224 potential memories, 3.6%). Thus the analyses were based on only these events that were recalled at the initial assessment.

Delay intervals of 1, 2, and 3 years—The 1-year, 2-year, and 3-year delay memory interviews were administered following the same procedure as described for the initial assessment, with the exception that after the general prompt in the form of a title for the event (the same titles used in the initial assessment, taken from the participants' calendars), the experimenter provided a cue to aid in determination of the time-slice in which the event occurred, such as, "It happened when you were about 4 years old," or "It was two years ago." The balance of the interview proceeded as at the initial assessment.

Coding and Reliability and Data Reduction

The interviews were videotaped and later transcribed verbatim. All transcripts were reviewed for accuracy. All coding took place from the written transcripts. For all data collection points, all on-task contributions were parsed into propositional units defined as a unit of meaning that included subject-verb construction and either contained unique information about the events (e.g., "I went to the park") or no content (e.g., "I don't know"). All children's transcripts were parsed by one individual. To estimate the reliability of parsing, 25% of the transcripts were parsed by an independent rater. Interrater agreement for proposition parsing of the children's narratives was 94% (range 92-99%). All adult transcripts were parsed by one of three individuals. Reliability was calculated on 20% of the transcripts, and averaged 97% (range 91-97%). The primary coders' judgments were used in all analyses.

Initial assessment—The first step in coding was to determine whether for each event, the participant provided at least 2 unique pieces of information and thus could be considered to have recalled the event. The experimenters made on-line judgments of this criterion as the interviews took place. For purposes of analysis, we used off-line judgments based on the transcripts of the conversations. A master coder trained two individuals each of whom then coded 50% of all transcripts. To assess the reliability of judgments, the master coder independently re-coded a randomly selected 20% of the transcripts with approximately equal proportionate representation of age groups. Reliability was 98% (range 90-100%). All disagreements between primary and reliability coders were resolved through discussion. Note that because the veracity of recall was not the subject of the research, memory reports were not assessed for accuracy.

For events that met the criterion for recall, the narrative reports were coded for length, breadth, and coherence. These attributes of the narratives were used (a) as a basis for determination of whether events that would be tested for recall after delays of 1, 2, and 3 years differed in uncontrolled ways; and (b) as possible predictors of recall after delays of 1, 2, and 3 years. For length and breadth, the entire memory interview was coded. Separate scores were calculated for the open-ended portion of the interview and for the entire memory report, including responses following additional cues and to *wh*-questions.¹ The measure of length was the total number of propositions provided by the participant, thus reflecting overall talkativeness and involvement in the conversation (reliability of coding indicated above). The measure of breadth reflects the completeness of the narrative. It was quantified by tallying the number of different narrative categories included in the report: information about (1) who participated (*who*), (2) the actions involved (*what-action*), (3) the objects involved (*what-object*), (4) when the event took place (*when*), (5) where the event took place (*where*), (6) why the event occurred or unfolded as it did (*why*), (7) description of physical attributes of the event (*how-description*), and (8) evaluation or subjective perception of the event (*how-evaluation*). The narrative categories are the same as those used in prior related research (e.g., Bauer & Larkina, 2014a, 2014b). For each event, participants received 1 point for inclusion of a token reflective of the category, regardless of the number of tokens provided. The maximum narrative breadth score was 8. All children's transcripts were coded by the same individual. To estimate the reliability of coding, 25% of the transcripts were coded by an independent rater. Interrater agreement was 95% (range 91-99%). All adults' transcripts were coded by one individual; 20% of the transcripts were coded by an independent rater. Interrater agreement was 99% (range 93-100%). The primary coders' judgments were used in all analyses.

To assess the coherence of the narrative reports, we used the Narrative Coherence Coding Scheme (NaCCs) developed by Reese et al. (2011). Narrative coherence is the overall quality of the narrative in terms of how well the story can be understood by a naive listener or reader. Because they are external to the participants' own narrative, responses to *wh*-questions were not coded. Thus only the portion of the narrative provided in response to the open-ended prompt was scored. The full NaCCs coding scheme includes assessment of three dimensions: context, chronology, and theme. In the current research, only the chronology (relating event components along a timeline) and theme (maintaining and elaborating on a topic) dimensions were assessed. The context dimension (orienting in time and space) was not coded because the experimenters often provided information about place and/or time in their prompts about the events. We assessed chronology using the participants' responses during the longest section of the interview during which she or he was not interrupted by an experimenter's prompts (e.g., "Was there anything else?" or "Tell me more"). This practice resulted in a number of cases for which the chronology dimension either could not be coded or was coded as 0 (61% of transcripts). Due to the large amount of missing data, we did not include the chronology dimension in analyses.

Footnote 1: Participants' contributions to the entire conversations (including open-ended and cued recall and responses to *wh*-questions) were coded for length and narrative breadth. This coding is different from reported in Morris et al. (2010) in which length was measured by the number of words in open-ended recall only, and breadth was coded only for the *wh*-portion of the interviews using 6 out of 8 *wh*-categories.

For the final narrative coherence dimension of theme, we used all of the participants' responses following the open-ended prompt (but before the *wh-* questions). The dimension was coded on a 4-point scale, from 0-3. A rating of 0 indicated that the narratives were substantially off-topic, a score of 1 was assigned to the minimally developed narratives, and narratives rated as 2 were substantially developed through evaluations, interpretations or causal links. Narratives coded as 3 included all of the previous characteristics with additional links to other autobiographical experiences and/or self-concept. Reliability of coding of the children's reports originally was established in Morris et al. (2010), based on approximately 10% of the children's transcripts. For present purposes, we recalculated reliability on the subset of the child sample included in the current research (including only those participants for whom we had all 4 assessment points of data). The intraclass correlation was .90. For coding of the adults' transcripts, two individuals independently recoded a practice set of the children's transcripts, reaching reliability of greater than .85 (intraclass correlations). One individual then coded all of the adults' transcripts. The second individual recoded 25% of the transcripts for reliability. The intraclass correlation was .89.

Delay intervals of 1, 2, and 3 years—We used a number of criteria to determine whether the events that were recalled at the initial assessment were recalled again after the 1-, 2-, and 3-year delays. The first criterion was whether the participant provided 2 or more unique pieces of information about the event. If fewer than 2 unique pieces of information were provided, the event was considered not-recalled (Insufficient information). For reports that met this basal criterion, we further asked whether the narrative featured evidence that the participant recalled a specific instance of an event, as opposed to a general category of events. Events for which the narratives featured little or no evidence of recollection of a specific past event were considered not-recalled (General information). Finally, for events that featured specific details, we compared the 1-year, 2-year, or 3-year memory report with the initial assessment report of the nominally same event to determine whether the recalled event was the same as the target event, or a non-target event (Different event). Examples of narratives that did and did not meet these criteria are provided in Appendix A.

For purposes of scoring and reliability, we made separate assessments for open-ended testing and across the open-ended, additional cue (children only), and *wh-* (children and adults) phases of testing. One individual coded all transcripts. For purposes of estimating the reliability of coding, an independent rater coded 20% of the randomly selected transcripts with approximately equal representation of time points and age groups. The open-ended portion of the interview was that for which the experimenter provided only the title of the event and either the participant's age or information about how long ago in time the event took place. Events for which the narrative report met the above criterion in the open-ended portion of the interview were considered recalled in open-ended testing. Interrater agreement on whether an event was recalled in open-ended testing was 87% (intraclass correlation .85). We also scored the number of events for which the narrative report met the above criterion when we considered not only the information provided in open-ended testing, but also the information provided after additional cuing (children only), and in response to the *wh-* questions (children and adults). Interrater agreement on whether an event was recalled based

on all sections of the interview (overall recall) was 83% (intraclass correlation .73). For both open-ended and overall recall, all coding disagreements were resolved by discussion.

Analytic Approach

The primary purposes of the present research were to determine (a) whether the survival of memories differed as a function of delay (i.e., 1, 2, and 3 years) and participants' ages at the times of the events (initial assessment); and (b) whether any of the characteristics of the memory reports provided at the time of the events (initial assessment) predicted the survival of the memories over time. These purposes are best addressed with logistic multilevel modeling (e.g., Guo & Zhao, 2000; Morris et al., 2010; Peterson et al., 2014; Raudenbush & Bryk, 2002). Logistic multilevel modeling permits examination of how predictors measured at various levels of data and cross-level interactions affect the outcome variable (e.g., Guo & Zhao, 2000). Specifically, it permits predictors on the level of the individual memory (such as narrative characteristics at the initial assessment and delay between assessment points) and at the level of the person (age at the initial assessment). In addition, multilevel modeling takes into account the interdependency of multiple observations per person (up to 9 memories per participant), correcting for the biases in parameter estimates resulting from dependency of the observations (Wright, 1998). Moreover, multilevel modeling allows for variation across participants in the number of observations and also allows for missing data without excluding participants (Raudenbush & Bryk, 2002). Accordingly, we conducted logistic multilevel modeling using a PROC GLIMMIX procedure using SAS for Windows software (Version 9.3). Fully unconditional models were estimated for both open-ended and overall recall to ensure variability between participants (i.e., Level 2) and within participants (i.e., Level 1). The intraclass correlation was calculated with an intercept variance of $\tau_{00} = 0.813$ for the open-ended recall model and $\tau_{00} = 0.539$ for the overall recall model; the variance of the standard logistic distribution σ^2 , where $\sigma^2 = \pi^2 / 3 = 3.29$ (Guo & Zhao, 2000; Snijders & Bocker, 2004). The results of this analysis indicated that 20% and 14% of the variability in remembering was between participants in open-ended and overall recall, respectively (the values for within-participants variability were 80% and 86%, respectively). The results of the unconditional models established that there was sufficient variability on both levels for further MLM analyses. The specific equations are in Appendix B.

Results

We present the results in three sections. In the first, we provide descriptions of the corpus of memory reports elicited at the initial assessment. This corpus is the foundation for questions about levels of recall after the subsequent delays of 1, 2, and 3 years. In the second section, we report the levels of recall after the 1-, 2-, and 3-year delays, both in open-ended testing and overall (i.e., across all phases of the interview: open-ended, after additional cuing [children only], and in response to *wh*-questions [children and adults]). In the third section, we report the results of analyses in which we used the narrative characteristics of the initial assessment reports to predict the retention of individual memories after delays of 1, 2, and 3 years.

The Corpus of Memories at the Initial Assessment

To accommodate the design of the study, the target number of events to be recalled at the initial assessment was 9 per participant, thus allowing for 3 unique events to be tested after delays of 1, 2, and 3 years (see Figure 1). The number of target events for each age group and for the sample as a whole is indicated in Table 2. As described above, the minimum criterion for an event to be considered recalled was that the participant provide at least 2 unique pieces of information about the event (as noted above, the information was not assessed for accuracy). The information could be provided either in response to a general, open-ended prompt or in response to additional cuing (children only) or *wh*-questions (children and adults). Not all participants met the criterion for all 9 of the events that were randomly selected from their event calendars, thus requiring selection of additional events. The actual total number of events queried is reflected in Table 2. A one-way analysis of variance (ANOVA) revealed that the average number of events queried at the initial assessment differed as a function of age group, $F(3, 132) = 4.37, p < .0057, \eta^2 = 0.09$, and was significantly larger for the 4-year-olds than for all other age groups, which did not differ from one another (Tukey $p < .05$).

The success of the queries also differed by age group, $F(3, 132) = 15.37, p < .001, \eta^2 = 0.26$. Across all phases of testing (overall recall), the 4-year-olds recalled the smallest proportion of the events about which they were interviewed (.82), relative to all other groups, which did not differ from one another (.95, .97, .99, for 6-year-olds, 8-year-olds, adults, respectively). Although the adults and 8-year-olds did not recall 100% of the events about which they were interviewed, in both of these age groups, all participants recalled the target number of 9 events. Three (of 34) 6-year-olds recalled only 8 events (sample $M = 8.91, SD = 0.29$). Among 4-year-olds ($N = 37$), 8 children recalled 7 or 8 events, 3 children recalled 5 or 6 events, and 3 children recalled 2 or 3 events (sample $M = 7.89, SD = 1.99$).

We next examined the characteristics of the narratives about the events that the participants recalled. They differed as a function of age group. As reflected in Table 3, in general, when describing past events, younger participants provided narratives that were shorter, less complete, and less thematically coherent. We evaluated the patterns statistically, using logistic multilevel models, with age group (4 years, 6 years, 8 years, adults) as a Level 2 predictor. Age group was a significant predictor in all models: $F(3, 132) = 99.55, 36.86$, and $51.38, p < .0001$, for length, breadth, and thematic coherence (respectively). The length of the reports that the participants produced (measured in propositions) did not differ for the 4- and 6-year-old children; all other contrasts were significant. All age groups differed from one another in the breadth or completeness of the narratives produced, with reliable increases in narrative breadth with age. All age groups differed from one another in the thematic coherence of their narratives, with reliable increases with age.

We next examined the characteristics of the narratives that were randomly assigned to be tested after delays of 1, 2, and 3 years; unique events were tested at each subsequent delay (see Figure 1). For each narrative characteristic, we conducted a multilevel model with Delay (1 year, 2 years, 3 years) as a Level 1 (the individual memory report) predictor. Delay was not a significant predictor in any model, $F(2, 268) = 0.53, F(2, 267) = 0.77$, and $F(2, 267) = 0.46, p > .20$, for length, breadth, and thematic coherence (respectively). Thus there

were not chance differences among the events randomly assigned to the different waves of testing.

In summary, at the initial assessment, 4-, 6-, and 8-year-old children and adults recalled a number of events from the relatively recent past (within 4 months). All of the adults and all of the 8-year-olds recalled the requisite number of 9 events. Among the 6- and 4-year-olds, 91% and 62% of the children recalled the requisite number of 9 events, respectively. Only events recalled at the initial assessment were included in analyses of recall after the 1-, 2-, and 3-year delays (though all participants were tested for recall of 3 events per wave, to maintain consistency in the protocol). The events randomly assigned to be tested after delay intervals of 1, 2, and 3 years did not differ on any of the measures of the characteristics of the narratives produced about the events (length, breadth, thematic coherence). Across age groups, there was variability on every narrative characteristic. We capitalized on the variability to predict patterns of remembering and forgetting over the next 3 years.

Recall after Delays of 1, 2, and 3 Years

Events recalled—Figure 2 is a graphic representation of the percentages of events recalled by each age group of children and the adults after each of the delay intervals (1, 2, and 3 years), both in open-ended testing (Panel a) and overall (open-ended plus in response to additional cues [children only] and *wh*- questions [children and adults]; Panel b).² Inspection of the figure suggests effects of age group and delay (1, 2, 3 years), with especially pronounced effects in open-ended testing. Paired *t*-tests comparing open-ended to overall performance indicated that for all three child groups, the percentages of events recalled increased reliably after cuing and *wh*- questions (all *p*s < .0001). For the adult group, open-ended and overall recall did not differ. In spite of the increases in recall for children and not for adults, effects of age remained apparent in overall recall.

To evaluate the effects statistically, we conducted logistic multilevel models with delay (1 year, 2 years, 3 years) at the level of the individual memory (Level 1), and age group (4 years, 6 years, 8 years, adults) at the level of the person (Level 2), as well as the interaction of Delay x Age group. Bonferroni adjustments were applied for multiple comparisons. In open-ended testing, the model revealed effects of delay, $F(2, 1032) = 32.65, p < .0001$, age group, $F(3, 1032) = 30.84, p < .0001$, and the interaction of Delay x Age group, $F(6, 1032) = 2.68, p = .014$. As expected, the likelihood of recall varied as a function of the length of the delay, such that recall was less likely as time passed. The specific patterns of recall varied across the age groups, as reflected in Table 4, Panel a. Among 4-year-olds and 8-year-olds, recall after 1 year was not more likely than recall after 2 years. Recall after 1 year was more likely than recall after 3 years, and recall after 2 years was more likely than recall after 3 years. Among the 6-year-olds and adults, recall after 1 year was more likely than recall after 2 years and after 3 years. The likelihood of recall after 2 years and 3 years did not differ.

Footnote 2: The percentages of events recalled after delay intervals of 1, 2, and 3 years were comparable for the sample as a whole and for the sample of children for whom a full complement of 9 events met the criterion for recall. Details are available from the authors.

To compare the effects of delay across the different age groups, we also examined the interaction of Delay x Age group with separate analyses for each delay. As reflected in Table 5, Panel a, after 1 year, relative to all child groups, adults were more likely to recall the events; the greatest difference in likelihood of recall was between the adults and the youngest children, with adults almost 56 times more likely to recall relative to 4-year-olds. Adults were 36 times and almost 16 times more likely to recall relative to 6- and 8-year-olds, respectively. After 2 years, adults were more likely to recall the events than both the 4- and 6-year-olds; the likelihood of recall by 8-year-olds and adults did not differ. After 3 years, adults were between 4 (6- and 8-year-olds) and 9 (4-year-olds) times more likely to recall the events than the children. There also were differences in the likelihood of recall for the oldest children relative to the youngest children. The differences were apparent in recall after both 1 and 2 years. The likelihood of recall after 3 years did not differ for the 8- and 4-year-olds. The 8-year-olds and 6-year-olds differed only after the 2-year delay. Finally, in open-ended testing, the likelihood of recall did not differ for 4- and 6-year-olds after any of the delays. Thus in open-ended testing, across all delay intervals, the adults were more likely to recall the events relative to the children in the two younger age groups. Adults also differed from the 8-year-olds after delays of 1 and 3 years. After the shorter delay intervals of 1 and 2 years, the oldest children also were more likely to recall the events relative to the youngest children.

In overall recall (across open-ended testing, additional cuing [children only] and *wh*-questions [children and adults]), the patterns of performance were more similar by age group though effects of delay were still pronounced. Specifically, for overall recall, the model revealed effects of delay, $F(2, 1032) = 38.90, p < .0001$, and age group, $F(3, 1032) = 14.06, p < .0001$. The interaction of Delay x Age group was not statistically significant (though it approached significance, $p < .06$). As reflected in Table 6, Panel a, across age groups, the likelihood of recall varied as a function of the length of the delay. Recall after 1 year was 4 times more likely than recall after 2 years, and 7 times more likely than recall after 3 years. Recall after 2 years was almost 2 times more likely than after 3 years. Across delay intervals, adults were roughly 5 times and 3 times more likely to recall the events than the 4- and 6-year-olds, respectively; the likelihood of recall by adults did not differ from 8-year-olds. In addition, 8-year-olds were roughly 4 times and 2 times more likely to recall the events than the 4- and 6-year-olds, respectively. The likelihood of recall by 4- and 6-year-olds did not differ. Thus relative to open-ended testing, when the participants were aided by additional cues and *wh*-questions, age effects were substantially diminished.

Events not recalled—Additional perspective on the pattern of remembering and forgetting across delay intervals and age groups is apparent when we consider the percentages of participants who recall 0, 1, 2, or all 3 of the events queried after each of the delay intervals. The percentages are reflected in Table 7 for open-ended (Panel a) and overall (Panel b) recall. To evaluate the patterns, we conducted separate Chi-square tests at each delay, for open-ended and overall recall. All six of the tests were significant, $\chi^2(9, N = 135) = 77.75, 44.08, \text{ and } 47.47$, for open-ended recall after delays of 1, 2, and 3 years, respectively ($ps < .0001$); $\chi^2(9, N = 135) = 46.54, 19.37, \text{ and } 28.88$, for overall recall after delays of 1, 2, and 3 years, respectively ($ps < .0001, .025, \text{ and } .001$, respectively). The tests

thus indicate that after each delay, the distributions of participants who recalled 0, 1, 2, or all 3 of the events differed by age group.

To determine the loci of the group differences, we conducted follow-up tests at each level of recall (0, 1, 2, or 3 events). As reflected in Table 7, Panel c, at the 1-year delay, the number of participants with a given level of recall (0, 1, 2, 3 events) differed by age group. In both open-ended and overall recall, 4-year-olds were over-represented in the group who recalled 0 of the target events, and adults were over-represented in the group who recalled all 3 of the target events. Specifically, in open-ended testing, whereas 31% of 4-year-olds recalled none of the events, none of the adults exhibited this low level of recall. Conversely, whereas 91% of adults recalled all 3 of the events on which they were tested, only 8% of 4-year-olds recalled all 3 of the events. These comparisons are consistent with the odds ratio data presented above, which indicated that after 1 year, in open-ended testing, relative to 4-, 6-, and 8-year-olds, adults were 56 times, 36 times, and 16 times more likely to recall the events from 1 year in the past, respectively. Though the effects of the *wh*- questions did not change the percentage of adults who recalled all 3 of the events after 1 year (it remained at 91%), the additional cues and *wh*- questions had the effect of facilitating 4-year-olds' recall, such that 33% of the youngest children recalled all three of the events after 1 year. In contrast, with the additional support for recall, only 17% of the 4-year-olds recalled none of the events.

At the longer delay intervals of 2 and 3 years, the number of participants with a given level of recall (0, 1, 2, 3 events) continued to differ by age group, especially in open-ended testing. In open-ended testing, after the 2- and 3-year delays, 33% and 67% of 4-year-olds recalled none of the events, respectively. The corresponding percentages for the adults were only 6% and 11%, respectively. Conversely, whereas 0% of the 4-year-olds recalled all 3 of the events in open-ended testing after the 2- and 3-year delays, the corresponding percentages for the adults were 37% and 34%. Considering overall recall, the distributions of participants who recalled 0, 1, 2, or all 3 of the events also differed by age at the 2- and 3-year delays, though the differences were not as reliable. Overall, the 4-year-olds tended to have lower levels of recall in contrast to the adults and older children.

When participants failed to recall an event, it was for 1 of 3 reasons: (a) they provided fewer than 2 unique pieces of information about the event, even after additional cuing (children only) and *wh*- questions (children and adults) (Insufficient information); (b) they failed to provide evidence that they were recalling a specific instance of an event, as opposed to a general memory (General information); or (c) they recalled a specific event but it was other than the target (Different event; see Appendix A for examples). The proportions of memories that were coded as not-recalled for each of these reasons at each delay is reflected in Table 8. To determine whether the reasons for failed recall differed by age group, we conducted one-way between-subjects ANOVAs for each category, for each delay (with the exception of the 1-year delay, which did not include the adults since there was no variance to be analyzed). After the 1- and 2-year delays, the distributions of reasons for failed recall did not differ by age group. In contrast, after 3 years, when younger children's recall failed, it tended to be because they provided an insufficient amount of information to be considered to have recalled the event, whereas when older children and adults' recall failed, it tended to be

because they recalled a different, non-target event. Specifically, after 3 years, the proportion of failed recall due to insufficient information about the target event was statistically significantly different across the age groups, $F(3, 99) = 8.16, p < .01, \eta^2 = 0.20$. After 3 years, 4- and 6-year-olds provided an insufficient amount of information more often than 8-year-olds. Four-year-olds also provided an insufficient amount of information more often than adults. Also, after 3 years, the proportion of failed recall due to recall of a different, non-target event was statistically significantly different across the age groups, $F(3, 99) = 7.00, p < .01, \eta^2 = 0.17$. Adults reported on different, non-target events more often than both 4- and 6-year-olds. Eight-year-olds also reported on different, non-target events more often than 4-year-olds.

Predicting Recall after Delays of 1, 2, and 3 Years

The findings for two potential predictors of recall after the 1-, 2-, and 3-year delay intervals—the length of the delay and age at the time of the event (age at the initial assessment)—have already been presented. Briefly, delay and age group were significant predictors of both open-ended and overall recall. Additionally, the Delay x Age group interaction was significant for open-ended recall only. In this section, we report the results of analyses of whether any of the characteristics of the narratives produced at the initial assessment were predictive of the survival of memories after delays of 1, 2, and 3 years, above and beyond the length of the delay, age group, and their interaction (open-ended recall only).

To identify potential predictors at the level of the memory, we conducted a series of separate logistic multilevel models (Raudenbush & Bryk, 2002) for each of the initial assessment variables of narrative length, breadth, and thematic coherence, including them in the model along with delay, age group, and the Delay x Age group interaction (open-ended only). In predicting open-ended recall, breadth and thematic coherence were significant predictors, $F(1, 1019) = 5.78, p = .016$, and $F(1, 1028) = 3.96, p = .003$, respectively. Breadth and thematic coherence also predicted overall recall, along with narrative length, $F(1, 1019) = 8.11, p = .0045$, $F(1, 1019) = 5.97, p = .0005$, and $F(1, 1017) = 5.64, p = .018$, respectively. These predictors were included in the final models. Preliminary analyses also revealed that although thematic coherence was coded on a 0-3 scale, there were no differences between scores of 0 and 1 and scores of 2 and 3: $t(1028) = -0.26, p = .80$, and $t(1028) = -1.28, p = .20$. Accordingly, in the final models, thematic coherence was re-coded into 2 possible values: low (scores of 0 and 1) and high (scores of 2 and 3). Finally, we tested models with interactions between delay and the narrative measures and age group and the narrative measures. None of the possible interactions was significant. Thus these interaction terms were not included in the final models.

The final model for predicting open-ended recall included delay, age group, the interaction of delay and age group, and the narrative characteristics of breadth, and thematic coherence (with age group a between-person Level 2 predictor, and the other measures as within-person Level 1 predictors). Although breadth was a significant predictor when it alone was entered into the model, with thematic coherence included as well, narrative breadth was not predictive of open-ended recall, $F(1, 1018) = 1.62, p = .20$. Thematic coherence was a significant predictor, $F(1, 1018) = 8.51, p = .0036$. Even after accounting for the effects of

delay and age group, as well as their interaction, events that were narrated with high thematic coherence at the initial assessment (scores of 2 or 3) were almost 2 times more likely to be recalled than events narrated with low thematic coherence at the initial assessment (scores of 0 or 1) (odds ratio = 1.62; Confidence Interval 1.17-2.24). As reflected in Table 4, Panel b, inclusion of thematic coherence into the model did not substantially impact the predictive utility of delay. That is, contrasts that were significant without thematic coherence in the model remained significant after it was entered into the model. In contrast, as reflected in Table 5, Panel b, inclusion of thematic coherence into the model tended to reduce the predictive utility of age at the initial assessment. For example, with thematic coherence in the model, the odds ratios of adults' recall relative to children's after the 1-year delay fell to roughly 36 times, from 56 times, for 4-year-olds; to 26 times, from 36 times, for 6-year-olds; and to 13 times, from 16 times, for 8-year-olds. Nevertheless, with the exception of the contrast between the likelihood of recall after 2 years by the 8-year-olds and 4-year-olds, all of the contrasts that were significant before thematic coherence was entered remained significant. Thus for events that originally were described in narratives with high thematic coherence (at the initial assessment), subsequent between-age group differences in the likelihood of recall after the delays became less pronounced, though still remained.

The final model for predicting overall recall included delay, age group, and the narrative characteristics of breadth, length, and thematic coherence. As was the case in open-ended recall, although breadth was a significant predictor when it alone was entered into the model, in the full model, narrative breadth was not predictive of overall recall, $F(1, 1021) = 3.28, p = .07$. Similarly, although length was a significant predictor when it alone was entered into the model, in the full model, narrative length was not predictive of overall recall, $F(1, 1021) = 0.96, p = .33$. In contrast, thematic coherence was a significant predictor, $F(3, 1021) = 6.41, p = .012$. Even after accounting for the effects of delay and age group, events that were narrated with high thematic coherence at the initial assessment were approximately 1.5 times more likely to be recalled than events narrated with low thematic coherence at the initial assessment (odds ratio = 1.59; Confidence Interval 1.11-2.2). As reflected in Table 6, Panel b, inclusion of thematic coherence into the model did not substantially impact the predictive utility of delay. In contrast, inclusion of thematic coherence into the model reduced the predictive utility of age at the initial assessment. Indeed, with thematic coherence in the model, the only contrast that remained significant was between 8-year-olds and 4-year-olds, such that across delay intervals, 8-year-olds were approximately 2.5 times more likely to recall the events than the 4-year-olds. None of the other contrasts between age groups was significant. Thus with the aid of additional cues (children only) and *wh*-questions (children and adults), for events originally described in narratives with high thematic coherence (at the initial assessment), subsequent between-age group differences in the likelihood of recall after the delays were virtually eliminated.

Discussion

The present research addressed two major goals: (a) to test the possibility of differential rates of forgetting of autobiographical memories by adults relative to children, and by older children relative to younger children; and (b) to test whether characteristics of initial memory reports were predictive of the likelihood of survival of specific memories over time.

To address these goals, we documented memories of autobiographical events and experiences in children 4, 6, and 8 years of age and in adults and then tested recall of different subsets of the events 1, 2, and 3 years later. Importantly, the narrative descriptions of the events that the participants provided at the initial assessment did not differ as a function of future random assignment to delay intervals for 1, 2, or 3 years. In contrast, across age groups, there was variability on each of the narrative measures of length, breadth, and thematic coherence. We capitalized on the variability to predict patterns of remembering and forgetting over the next 3 years.

Summary and Implications

Different subsets of the findings are consistent with different predictions about relative rates of forgetting of autobiographical memories between adults and children and between older and younger children. Specifically, the findings from the open-ended phase of testing are consistent with the suggestion of age-related differences in rates of forgetting, such as observed in traditional tests of episodic memory. In contrast, the findings based on overall recall are more consistent with suggestions that forgetting rates may be more comparable for autobiographical memories than for episodic memories. The phases of testing are discussed in turn, followed by discussion of rates of forgetting more broadly, and effects of delay.

Open-ended recall—The findings from the open-ended phase of testing indicate different rates of forgetting for adults and children, and for older children relative to younger children. After the 1-year delay in particular, and at each of the subsequent delays, there was substantial difference in rates of remembering and thus, forgetting, as a function of age. For example, after 1 year, whereas in open-ended testing, adults failed to recall only 3% of the events on which they were tested, 4-year-olds failed to recall 61% of the events (see Figure 2, Panel a). Quantified in the terms of logistic multilevel modeling, after 1 year, adults were almost 56 times more likely to recall the events than the 4-year-olds. Adults also had a greater likelihood of recall than either 6- or 8-year-olds, with likelihood estimates of approximately 36 times and 16 times, respectively. Thus all three of the child age groups evidenced accelerated forgetting, relative to the adults; the difference in rate of forgetting was most pronounced among the youngest children. The differences in levels of recall of adults and children continued at delay intervals of 2 and 3 years, though they were not as substantial (and adults and 8-year-olds did not differ after 2 years). The levels of recall by the oldest children, the 8-year-olds, also differed from those of the 4- and 6-year-olds. The differences were not as striking as for adults and were confined to the 1- and 2-year delays. Specifically, after 1 year, 8-year-olds were 3.6 times more likely to recall events than 4-year-olds; after 2 years, they were 2.5 times more likely to recall events than both 4- and 6-year-olds.

Addition of thematic coherence into the predictive model had the effect of reducing the differences in the likelihood of recall by adults relative to children and by older relative to younger children. Scores of 0 and 1 on the thematic coherence scale (Reese et al., 2011), indicate that the narrative about the event was either off topic (score of 0); or that a topic was discernable, but was not developed with causal linkages among the actions of the event, and was largely devoid of elaborations and personal evaluations (score of 1). In contrast, scores

of 2 and 3 indicate that the narrative featured interpretations of the actions, elaborations of them, or both (score of 2); or that in addition to interpretations and elaborations, the memory was connected to other autobiographical events and experiences, future plans, or the self (score of 3). When the variability associated with this feature of the narratives about the events provided at the initial assessment was controlled, after 1 year, adults were 36 times (versus 56 times) more likely to recall events relative to 4-year-olds, 26 times (versus 36 times) more likely to recall events relative to 6-year-olds, and 13 times (versus 16 times) more likely to recall events relative to 8-year-olds. The differences between the older and younger children also were reduced. Thus a high degree of thematic coherence in an original memory report made it more likely the event would be recalled at a later time. The age of the participant at the time of the initial assessment nevertheless remained a strong determinant of subsequent recall owing to the fact that the majority of narratives provided by 4- and 6-year-olds at the initial assessment were low in thematic coherence (scores of 0 or 1: 72% and 70% for 4- and 6-year-olds, respectively), whereas the majority of narratives provided by 8-year-olds and adults were high in thematic coherence (scores of 2 or 3: 57% and 84% for 8-year-olds and adults, respectively).

The finding that patterns of performance during the open-ended phase of testing are indicative of accelerated forgetting by children relative to adults, and by younger children relative to older children, are consistent with patterns apparent in traditional tests of episodic memory. The similarity was to be expected given that memory was tested in a recall paradigm, and that the criterion for an event to be considered recalled was provision of multiple unique pieces of information about the events (i.e., at least 2), that would, moreover, differentiate the specific episode from the general class of similar events. These requirements are more difficult to meet for younger than older participants. Moreover, the similarity was to be expected given that older participants typically provide longer, more complete, and more narratively coherent memory reports, relative to younger participants (e.g., Bauer & Larkina, 2014b; Reese et al., 2011). Higher quality narratives are associated with higher levels of recall. These differences were apparent in our samples at initial testing. Finally, the similarity was to be expected given evidence from retrospective studies of accelerated forgetting in children relative to adults. Specifically, whereas the distribution of adults' autobiographical memories over time is well characterized by the power function (e.g., Bauer & Larkina, 2014a; Rubin & Wenzel, 1996; Rubin et al., 1986), the distribution of children's memories is better characterized by the exponential function, implying accelerated forgetting (Bauer et al., 2007; Bauer & Larkina, 2014a; see Bauer, 2015, for discussion). Consistent with this pattern, in the present investigation, the levels of recall observed in the open-ended phase of testing were indicative of accelerated forgetting among children relative to adults, and among younger relative to older children.

Overall recall—In contrast to the findings based on open-ended recall, the findings based on overall recall are more consistent with suggestions that rates of forgetting may be more comparable in the domain of autobiographical memory than in the domain of episodic memory. Overall recall was based on information provided in open-ended testing plus information provided in response to additional cues (children only) and *wh-* questions (children and adults). The additional support for recall facilitated children's performance,

thereby diminishing differences in percentages of events recalled across participant groups. For example, after 1 year, the percentage of events recalled by 4-year-olds increased from 39% in open-ended testing to 67% overall, substantially reducing the contrast between their levels of recall and those of adults (who recalled 97% of events). Across delays, adults were roughly 5 times and 3 times more likely to recall the events than 4- and 6-year-olds, respectively. In addition, 8-year-olds were 2 times and almost 4 times more likely to recall the events than the 6- and 4-year-olds, respectively. There were no other differences among the age groups.

Addition of thematic coherence into the predictive model further reduced age-related differences in the likelihood of recall. Indeed, it virtually eliminated them. The only contrast between age groups that remained significant once the variance associated with thematic coherence was controlled was between 8-year-olds and 4-year-olds, with the older group 2.6 times more likely to recall than the younger group. The dramatic change in children's performance when aided by cues and *wh*- questions relative to open-ended testing made clear the latent potential for recall that otherwise was not apparent (in open-ended testing). The potential was especially salient for events originally described with a high degree of thematic coherence. The fact that adults had higher levels of recall even in open-ended testing, and were not further aided by the additional support of *wh*- questions, is testament to their greater autonomy in recollecting the events of their lives, even after delays of 1 to 3 years. Adults' greater autonomy may be due in part to their tendency to form detailed and coherent memory representations at the time of events, as evidenced by the observation that 84% of adults' narratives at the initial assessment were high in thematic coherence.

Similarities in patterns of performance across age groups also were apparent when we considered reasons for failed recall over the entire protocol (i.e., overall recall). After 1 and 2 years, there were no differences among the groups in the reasons for failure to recall an event. That is, the groups did not differ in the proportions of events for which an insufficient amount of information was provided; for which only non-specific information was provided; and for which specific information was provided, but it was about a different event from the target. Only after 3 years did differences emerge, such that when recall failed, for 4- and 6-year-olds, it was because they tended to provide an insufficient amount of information about the target event, whereas for 8-year-olds and adults, it was because the participants reported on a different, non-target event.

The finding that patterns of performance when recall was aided by additional cues (children only) and *wh*- questions (children and adults) were more similar for adults and children, and for older children and younger children, is consistent with suggestions that rates of forgetting may be more comparable for autobiographical memories than for episodic memories. This expectation stems from the greater personal relevance and significance of autobiographical memories, relative to standard laboratory episodic memories (e.g., Bauer, Hättenschwiler, et al., 2015). The pattern also is to be expected from empirical findings that relative to more traditional episodic memory tasks, on tasks that more closely approximate autobiographical events and experiences (e.g., judgments regarding photographs taken by participants), age-related differences between children and adults are less pronounced (e.g., Pathman et al., 2011, 2013).

The influence of the addition of thematic coherence into the model predicting the survivability of memories over time is consistent with this line of reasoning. As noted above, consideration of thematic coherence virtually eliminated age-related differences in overall recall. In contrast, although the length and breadth of memory narratives provided some additional predictive power when they alone were in the statistical models, when all the potential predictors were considered, only the thematic coherence of the initial memory reports remained a significant predictor. Narratives are judged to be highly thematically coherent to the extent that they feature interpretations and evaluations of events, and connections to other personal events and experiences, future plans, and the self. From a theoretical standpoint, memories that are represented in this fashion are expected to be especially well equipped to weather the ravages of time (e.g., Bluck & Alea, 2008; Bohn & Berntsen, 2014; Fivush, 2011, 2012; Fivush & Zaman, 2014; Habermas & de Silveira, 2008). Although narrative reports are not isomorphic with memory representations (representations may have features not revealed in a narrative: see Bauer, 2015, for discussion), when a narrative is detailed and coherent, we may reasonably assume that the representation that gave rise to it also is detailed and coherent. For these well-organized and elaborated memory representations, the cues and questions provided by the experimenter afforded participants access to memory traces they were challenged to access when recall was less well supported. The same cues were less effective at facilitating retrieval of memory traces that lacked these elements (as reflected by less thematically coherent narratives).

Comparative rates of forgetting—Importantly, whether we consider open-ended or overall recall, rates of forgetting differed for younger and older children, and for children and adults. Among the child age groups, the rate of forgetting of 4-year-olds was accelerated relative to that of 8-year-olds. The rate of forgetting of 6-year-olds (the childhood amnesia “inflection point” age group), was more similar to younger children. The age-related differences among the child groups were diminished for highly supported recall of events originally described with a high degree of thematic coherence. Yet few 4- and 6-year-olds produced highly thematically coherent narratives at the initial assessment (28% and 30%, respectively). The rate of forgetting among 4- and 6-year-olds also was accelerated relative to adults; the patterns of differences between 8-year-olds and adults was more variable.

Considered as a whole, the pattern of findings among the child age groups is consistent with prior prospective studies. For example, in Bauer and Larkina (2014b), different subgroups of children who were tested for recall of events at 4 years of age were tested again 1 to 5 years later. By the age of 8 years, a significant reduction in the percentage of events recalled was observed, such that prior to age 8, children recalled 60% or more of the events experienced at age 4 years, whereas at ages 8 and 9 years, they recalled fewer than 40% of the events (see also Van Abbema & Bauer, 2005). In the present research, after only a 1-year delay, the children in the 4-year-old age group recalled more than 60% of the events, whereas after the 3-year delay, recall had fallen to 32%. Moreover, across age groups, the pattern of findings is consistent with Bauer and Larkina (2014a), the sole retrospective study that directly compared rates of forgetting among children (7 to 11 years of age) and adults. In both studies, we observed accelerated forgetting for all child groups relative to adults. As well, in

both studies, we observed deceleration of the rate of forgetting throughout childhood. In the present research, deceleration was apparent in smaller likelihood estimates for older children compared to adults than for younger children compared to adults (e.g., at the initial assessment, adults were 16 times and 56 times more likely to recall events than 8- and 4-year-olds, respectively). In Bauer and Larkina (2014a), deceleration was apparent in smaller *b* parameters of the power function (an index of the rate of forgetting; e.g., Wixted & Ebbesen, 1997) across the age range of 7 to 11 years (i.e., from 2.22 to 1.62). The similarity in patterns is striking given that the approach in the present study was prospective whereas the approach in Bauer and Larkina (2014a) was retrospective.

Effects of delay—The effects of the 1-, 2-, and 3-year delays were relatively consistent across age groups, phases of testing, and when thematic coherence was and was not included in the predictive model. As would be expected, the likelihood of recall was greater after the shorter delay of 1 year relative to the longer delays of 2 and in particular, 3 years. As discussed above, in open-ended recall, age-related differences in the likelihood of remembering were especially pronounced after 1 year. Reflecting this pattern, in contrast to adults, children exhibited sharper reductions in levels of recall between their initial reports and 1-year delayed testing. As a result, subsequent reductions in levels of recall between Delays 1 and 2 and Delays 1 and 3 appeared smaller (likelihood ratios of 1.4-5.1), relative to adults (likelihood ratios of 14.6 and 20.7; see Table 4). Reflecting the fact that cues and *wh*-questions facilitated children's performance, in overall recall, the pattern of effects of delay did not differ across the age groups (see Table 6). All contrasts were significant, indicating higher likelihoods of recall after 1 year relative to 2 and 3 years, and after 2 years relative to 3 years. Unlike effects of age which were altered by the addition of thematic coherence into the predictive model, all contrasts that were significant before thematic coherence was considered remained significant after it was considered. Thus even memory representations described with a high degree of thematic coherence at the initial assessment were susceptible to the ravages of time.

Complementary Processes in Action

The overall pattern of findings in the present research can be well understood through the lens of the complementary processes account outlined in Bauer (2015; see Bauer, 2007, for a preview of the perspective). Major tenets of the account are that the adult distribution of autobiographical memories is achieved as (a) the quality of memory traces increases over the course of development, through addition of more, better elaborated, and more tightly integrated features that characterize autobiographical memories; and (b) the vulnerability of memory traces decreases, as a result of more efficient and effective neural, cognitive, and specifically mnemonic processes, thus slowing the rate of forgetting. In brief (see Bauer, 2015, for a more elaborated discussion), the quality of memory traces increases over the course of development as the concepts that give episodic memories their autobiographical character themselves develop. As summarized in Bauer (2014, 2015; see also Nelson & Fivush, 2004), over the course of childhood and beyond, there are elaborations of the self concept and a subjective sense of self, of the understanding of the representational nature of mind, of spatial and temporal concepts and conventions, and of language and narrative, to name a few. As a result of these developments, more and more of these features are included

in memory traces; the elements are more fully elaborated, making it easier to differentiate one experience from another; and the different aspects of memory traces become more tightly integrated, making them more resistant to forgetting. Memory traces also become better integrated with one another, based on elements or features in common, lending to autobiographical memory the quality of a life story or life narrative. In the present research, these changes were manifest in the thematic coherence dimension. Memory narratives that were high on the dimension of thematic coherence were better remembered, relative to memory narratives low on this dimension.

Simultaneous with increases in the quality of memory traces are decreases in the vulnerability of the traces to forgetting. Decreases in memory trace vulnerability are a result of more efficient and effective neural, cognitive, and specifically mnemonic processes, that are responsible for transforming labile patterns of neural activation resulting from experience into enduring memory traces that can be retrieved at a later time. Briefly, memory representations are made up of individual bits and pieces of experience that are encoded in synaptic connections between individual neurons distributed across the cortex. They begin their lives as patterns of neural activity that give rise to conscious experience of events. Their continued existence as “memories” depends on subsequent processing carried out by a multi-component neural network that includes structures in the medial-temporal lobe, as well as the neocortex. Their subsequent retrieval entails re-creation of the pattern of neural activity that gave rise to the event in the first place (see Eichenbaum & Cohen, 2001; Kandel & Squire, 2000; Manns & Eichenbaum, 2006; Zola & Squire, 2000; for reviews of these processes).

The efficiency and efficacy with which these cognitive and mnemonic processes are carried out is intimately tied to the developmental status of the neural substrate responsible for them. As explained in detail elsewhere (see for example, Bachevalier, 2014; Bauer, 2007, 2009, 2013, 2015; Ghetti & Lee, 2014; Nelson, de Haan, & Thomas, 2006, for reviews), portions of the neural network implicated in episodic and thus autobiographical memory develop early, whereas many of the structures (or aspects thereof), as well as the connections within and between them, undergo a protracted developmental course that continues well into adolescence. As a result, we may expect changes in the way in which the network functions throughout childhood (and even beyond). Early changes support the emergence of the capacity to form, retain, and later retrieve self-relevant memories of past events; later changes herald more efficient and effective function and a concomitant reduction in the rate of forgetting. In the present research, we had no direct measures of neural or cognitive processes. Instead, these changes were manifest in the deceleration of the rate of forgetting across childhood, and from childhood to adulthood.

In summary, over developmental time, individual memory representations include more and more of the features that characterize autobiographical memories and the features themselves are better elaborated and more tightly integrated with one another. The result is higher quality mnemonic materials. In the present research, these changes were apparent in memory narratives that were longer, more complete, and more thematically coherent; thematic coherence was predictive of recall (see also Peterson et al., 2014, for similar findings). At the same time, there are developments in the neural substrate operating on the

available representations, both in terms of the structures involved and in the level of connectivity of the network of structures. The developments herald more efficient and effective cognitive and mnemonic processing, resulting in decreases in the vulnerability of memory traces and thus, in the rate of forgetting. The net effect is that more and more memories survive to be recalled at later points in time, producing the patterns of remembering and forgetting observed in the present research.

Limitations of the Research

One potential concern with the present research is that although many features of the design were identical for children and adults, not all were. Some of the differences concern event selection; others concern the testing protocol. First, children did not nominate their own events. Instead, events were drawn at random from calendars maintained by the children's parents over a 4-month period prior to the initial assessment. In contrast, the adults in the study—the children's mothers—maintained their own calendars. This difference raises the possibility that the selected events may have been differentially relevant or significant to the children and the adults, and thus perhaps differentially memorable. The events also may have been differentially distinctive. We do not have independent documentation of the meaning, significance, or distinctiveness of the events and thus cannot address this possibility directly. We point out, however, that for all age groups, events were selected at random from the calendars, thus imposing a common degree of chance for all. As well, all of the events included in the analyses were recalled at the initial assessment. Thus we know that at least initially, all events were remembered by both the children and the adults (though as noted above, we made no assessment of the accuracy of recall, for either children or adults). Moreover, we maintain that the ecological validity of the method is sufficient benefit to offset the cost of this concern. The calendars from which the events were drawn featured at least one event per week in which the children participated. Parents were specifically instructed to select events that were of interest to their children. As a result, the events we probed were representative of the day-to-day lives of our participants. As such, they were the events of which autobiographical or personal memories are made. Nevertheless, in future research, it would be desirable to either have all participants maintain their own calendars or to have all calendars maintained by another family member (e.g., a partner or spouse, in the case of adults). It also would be desirable to obtain subjective ratings of the meaning, significance, and distinctiveness of the events at the time of experience of them.

Second, there was one notable difference in the testing protocol for the child and adult groups, such that additional cues about the events were available for the children but not for the adults. In the case of the children, the cues were provided by the children's mothers in the form of some details about the events. In contrast, there was no independent informant to provide additional details about the adults' events. The absence of cues may have limited the benefit that adults may otherwise have derived from the additional support provided in the overall versus open-ended phases of testing. It may also have contributed to the tendency for adults to "error" by discussing a non-target rather than a target event, a pattern observed in both the 2- and 3-year delay data (see Table 8). In future research, it would be desirable to have an independent source for details about the events for all participants.

There also are some potential concerns regarding the generalizability of the findings of the present research. One especially notable limitation is that only women were included among the adult participants. Thus the extent to which the present patterns of findings would generalize to adult males is unknown. The decision to include only women was pragmatic. We anticipated that the parent most likely to accompany a child participant to the laboratory would be the mother. As such, the parent most likely to agree to participate as a subject in the research would be the mother. Given the goal of retaining a high percentage of the sample over a long period of time (4 years), and the expectation that fathers would be more difficult to both recruit and retain, we decided to enroll only women. A goal for future research would be to overcome the challenges of recruiting and retaining samples of fathers, perhaps by adopting on-line or other electronically-supported data collection methods.

Another limitation on the generalizability of the findings of the present research stems from the fact that our sample was predominantly middle to upper-middle socioeconomic status, with more than 80% of parents holding a technical degree or more. Additionally, the sample was racially and ethnically homogeneous. On the other hand, the results of the present research are a close replication of the patterns observed in Bauer and Larkina (2014a), which featured a substantially more heterogeneous sample as well as a different design (retrospective report vs. prospective investigation). Nevertheless, in future research, it would be desirable to recruit a more heterogeneous and more broadly representative sample. As well, as in any longitudinal study, attrition is a concern. In the present research, we retained 75% of the sample over all 4 years of the study. Most of the attrition was before the 1-year delay (22 families vs. 12 families before the 2- and 3-year delays combined). Fortunately, we did not suffer differential attrition as a function of age group or performance in the study, based on the available measures.

Future Directions

In addition to broadening the sample of children and adults, future research should investigate a broader range of potential determinants of rates of forgetting among children of different ages and adults. As discussed in the context of the section on complementary processes (above), a range of component cognitive abilities contribute to developments in autobiographical memory in childhood in particular. Measures of children's understanding of the representational nature of mind, self concept, and metacognitive awareness, for example, stand to inform the variability observed in rates of forgetting. As well, measures of basic cognitive and mnemonic processes, such as working memory, source memory, and executive function, for example, may further illuminate the sources of variance in long-term recall of autobiographical events and experiences. It also would be desirable to obtain measures of the socio-cultural variable of maternal reminiscing style (e.g., Fivush, 2011; Nelson & Fivush, 2004). It is well documented that the manner in which children and parents talk about past events impacts the quality of children's narratives both concurrently and over time (e.g., Reese et al., 1993). Indeed, the fact that in the present research, some subset of the events likely were shared by children and their mothers and thus may have been the subject of reminiscing, might be a source of concern. We note that only a subset of events from the calendars were included in the study (9 events drawn from an average of 16 over a 4-month period) and that events were randomly assigned for testing after different

delays. Thus any variance associated with shared experiences that may have been discussed by children and their mothers should have been evenly distributed over the design.

Finally, neuroimaging work can be expected to shed light on the neural processes, structures, and networks that support autobiographical memory. We have used event-related potentials (ERPs) to examine retrieval of autobiographical memories in response to cue words in 7- to 10-year-old children (Bauer, Stevens, Jackson, & San Souci, 2012). Extending the investigation to adults and examining relations between ERP responses and narrative descriptions of the events could be informative as to processing differences that may relate to differential rates of forgetting. To date, functional Magnetic Resonance Imaging (fMRI) has been used to inform sources of age-related variance in episodic memory (e.g., Ofen et al., 2007; Paz-Alonso, Ghetti, Donohue, Goodman, & Bunge, 2008). We recently extended the approach to investigate 7- to 11-year-old children's and adults' retrieval of autobiographical memories in response to cue words. We found that age differences in levels of activation were especially pronounced in the initial search and access phase of retrieval, relative to the later elaboration phase (Bauer, Pathman, Inman, Campanella, & Hamann, 2015). This finding is broadly consistent with the pattern observed in the present research, of more pronounced age group differences in open-ended testing—which makes substantial demands on search and access functions—than in testing supported by additional cuing and *wh*- questions that could aid in elaboration of the memory report. Indeed, a consistent finding in prior related research is that effects of age and the length of a delay are most pronounced in the open-ended retrieval phase of testing, giving rise to variability in the number of events recalled. Yet assuming a memory representation can be accessed, there are few differences in the narrative report of the event (e.g., Bauer & Larkina, 2014b; Larkina & Bauer, 2012; Van Abbema & Bauer, 2005).

Conclusions

The present research provides critical new data on comparative rates of forgetting of adults and children and of older children relative to younger children. Differences in forgetting rates for adults relative to children are expected on the grounds that it is only in late adolescence or adulthood that autobiographical memories are represented in detailed and coherent fashion, and successfully knitted into a life story or life narrative that permits their preservation over long periods of time (e.g., Bluck & Alea, 2008; Bohn & Berntsen, 2014; Fivush, 2011, 2012; Fivush & Zaman, 2014; Habermas & de Silveira, 2008). Within childhood, differential rates of forgetting are expected in the period before versus after the onset of childhood amnesia, a transition marked by deceleration in the rate of forgetting (e.g., Bauer & Larkina, 2014a, 2014b; Pillemer & White, 1989; Wetzler & Sweeney, 1986). In the present research, the open-ended phase of testing revealed pronounced age-related differences in forgetting across the age groups. Thus when challenged to search for and access a specific past event in memory, children relative to adults and younger relative to older children were less successful. Differences in rates of forgetting remained when overall performance was considered, though they were less pronounced. In both phases of testing, the thematic coherence of the original memory report was a significant predictor of the survival of individual memories; it was a stronger predictor of open-ended relative to overall recall. The findings are broadly consistent with the complementary processes account of the

development of autobiographical memory (Bauer, 2015). They indicate that to understand the achievement of the adult distribution of autobiographical memories, we must consider the interaction between increases in the quality of memory representations that are formed, and decreases in their vulnerability to forgetting.

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Appendix A

Examples of events that were coded as not recalled after a delay.

Example 1: An event coded as not-recalled after 3 years because no information about the target event was provided (from a 4-year-old girl at the initial assessment)

Wedding Reception at Tom and Jane's

E: Do you remember the wedding reception at Tom and Jane's?

C: No.

E: This was 3 years ago. Do you remember anything?

C: Oh, no I don't remember.

E: And you wore your pretty dress. Anything?

C: Nothing.

E: Nothing?

Example 2: An event coded as not-recalled after 3 years because no specific event details were provided (from a 8-year-old girl at the initial assessment)

First Level 4 swimming lesson

Open-ended recall

E: Now the next thing was when you started swim lessons and this was for Level 4.

C: Level 4?

E: Yes, that was 3 years ago so when you were 8.

C: I have no clue.

E: Anything?

C: It was at Oak Pointe because it always is. And I don't know anything else.

E: That's okay. Do you remember anything else about that when you started Level 4?

C: The water was cold. It is always really cold.

WH- questions

E: Who was there at the first swim lesson?

C: Me, and my mom I guess.

E: And where were your swimming lessons, where was that?

C: Oak Pointe Intermediate School.

E: And why did you take swimming lessons?

C: Because my parents made me.

E: And what did you do when you started swimming the Level 4 lessons?

C: Probably we practiced strokes.

E: And when did you have your first level 4 swim lesson?

C: The lessons were in the spring but I don't remember about the first one.

E: In the spring, all right. How were you dressed for your first swim lesson?

C: I was wearing a swimsuit, either the black one or blue one.

E: Okay, and how did you feel about starting your swim lessons?

C: Mad. Because I really dislike them all.

E: All right, do you remember anything else about starting Level 4?

C: No.

Example 3: An event coded as not-recalled after 2 years because event details provided did not match the report at the initial assessment (from a 4-year-old boy at the initial assessment)

Playing Hidden Treasure at Stuart's house

Open-ended recall

E: Tell me about when you played "Hidden Treasure" at Stuart's house.

C: That's too long ago.

E: Well, do you remember anything about that time?

C: I remember the last time I played soccer there.

E: What about when you played Hidden Treasure?

C: I don't know. But I remember I went on their swing, and I had a little snack there too.

E: Do you remember playing a board game? Do you remember anything about that?

C: No.

Appendix B

A multilevel model with delay (i.e., number of years after the initial assessment) as a Level 1 predictor and age at the initial assessment (codes as a categorical variable Age Group) as a Level 2 predictor:

$$\text{Level 1 (within-person): } \logit(\text{REMEMBER})_{ij} = \beta_{0ij} + \beta_{1ij}(\text{delay}) + r_{it}$$

$$\text{Level 2 (between-person): } \beta_{0i} = \gamma_{00} + \gamma_{01}(\text{Age Group}) + u_{0i}$$

$$\beta_{1i} = \gamma_{10} + \gamma_{11}(\text{Age Group})$$

In each equation, the indices i and j are used to denote individual participants and memories, respectively. In Level 1, the intercept, β_{0ij} is defined as the expected probability of remembering for memory j of participant i , and β_{1i} slope represents the associated change in log odds of remembering. The error term, r_{it} , represents a unique effect associated with participant i (i.e., how much an individual fluctuates in remembering over multiple events). The individual intercept β_{0i} and slope β_{1i} become the outcome variables in the Level 2 equations, where γ_{00} represents the overall mean probability of remembering for the sample. Further,

- γ_{01} corresponds to the effects of age group on the log odds of remembering above and beyond the effects of delay.
- γ_{10} corresponds to the effect of delay on remembering.
- γ_{11} is the cross-level interaction testing whether the relationship between delay and remembering varied as a function of participants' age group.
- u_{0i} represents the degree to which individuals vary from the sample as a whole.

Additional Level 1 predictors were added in the different models, including narrative breadth, length, and thematic coherence. In the models with multiple Level 1 predictors, the appropriate slopes were added.

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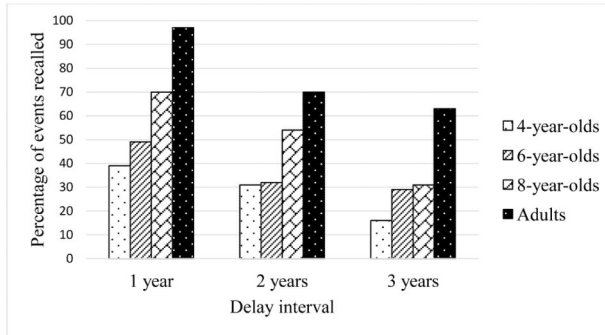
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Events Tested After Delays of 1, 2, and 3 Years

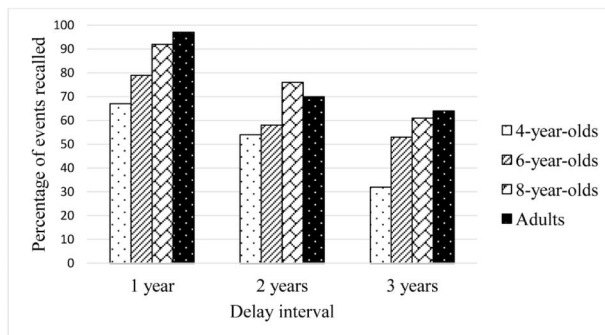
Events recalled at the Initial Assessment	Events tested after 1-year delay	Events tested after 2-year delay	Events tested after 3-year delay
Event 1	Event 2		
Event 2	Event 8		
Event 3	Event 4		
Event 4		Event 6	
Event 5		Event 5	
Event 6		Event 3	
Event 7			Event 7
Event 8			Event 9
Event 9			Event 1

Figure 1. Schematic representation of the study design. At the initial assessment, from each participant, we obtained a corpus of 9 event memories (Events 1-9). Participants were tested for recall of 3 unique events after each of the delay intervals of 1 year, 2 years, and 3 years. For each individual participant, random assignment was used to determine the delay interval over which a given event would be tested. The figure depicts an example random assignment of Events 1-9 to each of the 1-, 2-, and 3-year delay intervals.

Panel a



Panel b

**Figure 2.**

The percentages of events recall after delay intervals of 1, 2, and 3 years, for 4-, 6-, and 8-year-old children and adults. After each delay interval, participants were tested for 3 unique events recalled at the initial assessment. Panel a reflects the percentages of events recalled in open-ended testing; Panel b reflects the percentages of events recall overall (in open-ended testing, and in response to additional cues [children only] and specific *wh*- questions [children and adults]).

Table 1

Sample Characteristics (Panel a) and Average Delay between Assessment Points (Panel b)

Variable	Group (Age at Initial Assessment)				
	Overall	4-year-olds	6-year-olds	8-year-olds	Adults
Panel a: <i>Sample Characteristics</i>					
Number of participants	136	37	34	30	35
Participant gender (F/M)	88/48	16/21	19/15	18/12	35/0
Age at initial assessment (in years, <i>M</i> , <i>SD</i> , range)	n/a	4.18 (0.06) 4.07-4.40	6.19 (0.05) 6.10-6.28	8.20 (0.04) 8.12-8.28	37.41 (4.23) 27.49-45.07
Panel b: <i>Mean, SD, and range for Delays between Assessment Points (in days)</i>					
Initial assessment to 1-year delay	359 (34) 270-442	369 (34) 308-442	360 (37) 270-440	364 (34) 300-440	344 (28) 276-404
1-year delay to 2-year delay	332 (26) 264-403	326 (24) 264-366	330 (24) 278-365	331 (29) 292-403	343 (25) 286-393
2-year delay to 3-year delay	358 (18) 301-450	359 (23) 301-450	358 (16) 336-421	354 (18) 314-386	357 (16) 315-391

Table 2

Number of Events Queried and Recalled at Initial Assessment

Age group (N)	Target No. of Events	Total No. of Events Queried	M No. of Events Queried	SD/range
4-year-olds (37)	333	360	9.73	1.17/9-15
6-year-olds (34)	306	322	9.47	0.82/9-12
8-year-olds (30)	270	278	9.27	0.52/9-11
Adults (35)	315	318	9.09	0.28/9-10
Total (136)	1224	1278	9.40	0.82/9-15

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Table 3

Means (and Standard Deviations) of Characteristics of Event Memory Reports at Initial Assessment Measure

Age group (<i>N</i>)	Measure		
	Narrative length (in propositions)	Narrative Breadth (max. = 8.0)	Thematic Coherence (max. = 3.0)
4-year-olds (37)	24.58 (13.20)	6.16 (1.72)	1.07 (0.73)
6-year-olds (34)	26.83 (13.21)	6.92 (1.30)	1.25 (0.59)
8-year-olds (30)	37.23 (21.36)	7.50 (0.84)	1.56 (0.62)
Adults (35)	80.98 (37.49)	7.92 (0.34)	2.06 (0.61)

Note: For length and breadth, the entire memory interview was coded; for thematic coherence, only the open-ended portion of the interview was coded.

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Table 4

Odds Ratio (95% CI) of Logistic Multilevel Models Predicting Recall in Open-ended Testing by Delay and Age at Initial Assessment. Results of a Significant Delay x Age Group Interaction presented for each Age Group in the Primary Model (Panel a) and the Full Adjusted Model (Panel b)

Age at Initial Assessment	Comparisons Between Delay Intervals					
	Delays 1 and 2		Delays 1 and 3		Delays 2 and 3	
	Odds ratio	CI	Odds ratio	CI	Odds ratio	CI
Panel a: <i>Primary Model</i>						
4-year-olds	1.4	(0.7–2.9)	3.5**	(1.5–8.0)	2.4*	(1.1–5.8)
6-year-olds	2.1*	(1.1–4.4)	2.4*	(1.2–4.9)	1.1	(0.5–2.4)
8-year-olds	1.8	(0.9–4.0)	5.1***	(2.3–11.1)	2.7**	(1.3–5.8)
Adults	14.6***	(3.3–65.2)	20.7***	(4.7–91.7)	1.4	(0.7–2.9)
Panel b: <i>Full Adjusted Model</i>						
4-year-olds	1.5	(0.7–3.2)	3.7**	(1.6–8.6)	2.4*	(1.1–5.8)
6-year-olds	2.2*	(1.1–4.5)	2.4*	(1.2–4.9)	1.1	(0.5–2.3)
8-year-olds	1.7	(0.8–3.9)	5.3***	(2.4–12.0)	3.0**	(1.4–6.6)
Adults	14.2***	(3.2–63.7)	20.8***	(4.7–92.5)	1.5	(0.7–3.0)

Notes.

CI—Confidence Interval. Primary Model predictors: Delay and Age at initial assessment; in the Full Adjusted Model Odds Ratio and CI adjusted by including narrative measures of breadth and thematic coherence.

* $p < .05$;

** $p < .01$;

*** $p < .001$.

Table 5

Odds Ratio (95% CI) of Logistic Multilevel Models Predicting Recall in Open-ended Testing by Delay and Age at Initial Assessment. Results of a Significant Delay x Age Group Interaction presented for each Age Group in the Primary Model (Panel a) and the Full Adjusted Model (Panel b)

Age at Initial Assessment	Delay					
	1 year		2 years		3 years	
	Odds ratio	CI	Odds ratio	CI	Odds ratio	CI
Panel a: <i>Primary Model</i>						
Adult vs. 4 year	55.7 ^{***}	(10.4–298.5)	5.4 ^{***}	(2.2–13.2)	9.3 ^{***}	(3.5–24.9)
Adult vs. 6 year	36.2 ^{***}	(6.8–194.0)	5.3 ^{***}	(2.2–12.8)	4.2 ^{***}	(1.8–9.9)
Adult vs. 8 year	15.6 ^{***}	(2.8–85.89)	2.0	(0.8–4.9)	4.4 ^{***}	(1.6–9.4)
8 year vs. 4 year	3.6 ^{**}	(1.4–8.7)	2.7 [*]	(1.1–6.6)	2.4	(0.9–6.8)
8 year vs. 6 year	2.3 [^]	(0.9–5.6)	2.6 [*]	(1.1–6.4)	1.1	(0.4–2.7)
6 year vs. 4 year	1.5	(0.7–3.6)	1.0	(0.4–2.5)	2.2	(0.8–6.1)
Panel b: <i>Full Adjusted Model</i>						
Adult vs. 4 year	35.9 ^{***}	(6.5–199.8)	3.8 ^{***}	(1.5–9.7)	6.3 ^{***}	(2.3–17.7)
Adult vs. 6 year	25.8 ^{***}	(4.7–140.9)	4.0 ^{***}	(1.6–9.8)	3.0 ^{**}	(1.2–7.3)
Adult vs. 8 year	12.9 ^{***}	(2.3–71.9)	1.0	(0.7–4.0)	3.3 ^{**}	(1.3–8.2)
8 year vs. 4 year	2.8 [*]	(1.1–7.2)	2.4 [^]	(0.9–6.0)	1.9	(0.7–5.5)
8 year vs. 6 year	2.0	(0.8–5.0)	2.5 [*]	(1.0–6.1)	0.9	(0.3–2.3)
6 year vs. 4 year	1.4	(0.6–3.3)	1.0	(0.4–2.4)	2.1	(0.8–5.9)

Notes.

CI—Confidence Interval. Primary Model predictors: Delay and Age at initial assessment; in the Full Adjusted Model Odds Ratio and CI adjusted by including narrative measures of breadth and thematic coherence.

[^]
 $p < .10$;

^{*}
 $p < .05$;

^{**}
 $p < .01$;

^{***}
 $p < .001$.

Table 6

Odds Ratio (95% CI) of Logistic Multilevel Models Predicting Overall Recall by Delay and Age at Initial Assessment in the Primary Model (Panel a) and the Full Adjusted Model (Panel b)

Main Effect	Level contrasts	Odds ratio	CI
Panel a: <i>Primary Model</i>			
Delay	Delay 1 vs 2	4.1 ^{***}	(2.4–7.1)
	Delay 1 vs 3	7.1 ^{***}	(4.2–12.2)
	Delay 2 vs 3	1.7 ^{**}	(1.2–2.5)
Age at Initial Assessment	Adult vs 4 year	5.3 ^{***}	(2.4–11.8)
Assessment	Adult vs 6 year	2.9 ^{**}	(1.3–6.5)
	Adult vs 8 year	1.4	(0.6–3.2)
	8 year vs. 4 year	3.9 ^{***}	(1.9–8.1)
	8 year vs. 6 year	2.2 [*]	(1.1–4.5)
	6 year vs. 4 year	1.8 [^]	(0–3.5)
Panel b: <i>Full Adjusted Model</i>			
Delay	Delay 1 vs 2	3.3 ^{***}	(2.1–5.1)
	Delay 1 vs 3	5.7 ^{***}	(3.7–8.9)
	Delay 2 vs 3	1.7 ^{**}	(1.2–2.5)
Age at Initial Assessment	Adult vs 4 year	1.1	(0.8–4.6)
Assessment	Adult vs 6 year	1.2	(0.5–2.7)
	Adult vs 8 year	0.8	(0.3–1.7)
	8 year vs. 4 year	2.6 ^{**}	(1.2–5.4)
	8 year vs. 6 year	1.5	(0.7–3.1)
	6 year vs. 4 year	1.7	(0.9–3.3)

Notes.

CI – Confidence Interval. Primary Model predictors: Delay and Age at initial assessment; in the Full Adjusted Model Odds Ratio and CI adjusted by including narrative measures of length, breadth, and thematic coherence.

[^]
 $p < .10$;

^{*}
 $p < .05$;

^{**}
 $p < .01$;

^{***}
 $p < .001$.

Table 7

Percentage of Participants Who Recalled 0, 1, 2, or 3 Events at Each Delay for Each Age Group in Open-ended Testing (Panel a) and Overall (open-ended plus Wh- questions) (Panel b), and Results of Chi-square Tests for Group Differences at Each Level of Recall (Panel c)

Delay and No. Events		Age Group (Age at Initial Assessment)				χ^2 (3, N = 135)
		4-year-olds	6-year-olds	8-year-olds	Adults	
Panel a: <i>Open-ended</i>						
1-year delay	0	31	21	3	0	17.87***
	1	39	32	17	0	18.34***
	2	22	29	47	9	12.68***
	3	8	18	33	91	62.25***
2-year delay	0	33	32	20	6	9.92*
	1	53	47	27	14	14.57**
	2	14	15	23	43	10.54*
	3	0	6	30	37	23.12***
3-year delay	0	67	41	37	11	22.85***
	1	25	38	33	23	2.55 ns
	2	8	12	30	31	9.24*
	3 [^]	0	9	0	34	29.91***
Panel b: <i>Overall</i>						
1-year delay	0 [^]	17	0	0	0	17.27***
	1 [^]	14	15	0	0	10.05*
	2	36	41	23	9	11.10*
	3	33	44	77	91	32.29***
2-year delay	0	17	12	3	6	4.21 ns
	1	42	32	17	14	8.98*
	2	28	26	30	43	2.73 ns
	3	14	29	50	37	10.45*
3-year delay	0	44	15	7	11	18.98***
	1	31	38	27	23	2.12 ns
	2	19	21	43	29	5.79 ns
	3	6	26	23	37	10.38*

Note:

Table entries are in percentages whereas statistical tests were conducted on raw numbers.

[^]
Fischer's exact test ($p < .001$).

*
= $p < .05$;

**
= $p < .01$;

= $p < .001$.

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Table 8

Mean Proportion (SD) of Memories Coded as Not-recalled Because the Reports Featured Insufficient Information, only General Information, or Information about a Different Event at Each Delay for Each Age Group

	<u>Age Group (Age at Initial Assessment)</u>			
	<u>4-year-olds</u>	<u>6-year-olds</u>	<u>8-year-olds</u>	<u>Adults</u>
	(Number of memories coded as not-recalled)			
1-year delay	(<i>N</i> = 22)	(<i>N</i> = 17)	(<i>N</i> = 7)	(<i>N</i> = 3)
Insufficient info.	.36 (.43)	.26 (.44)	.43 (.53)	0
General info.	.41 (.47)	.44 (.46)	.43 (.53)	1.00
Different event	.22 (.37)	.29 (.44)	.14 (.38)	0
2-year delay	(<i>N</i> = 26)	(<i>N</i> = 23)	(<i>N</i> = 15)	(<i>N</i> = 22)
Insufficient info.	.46 (.45)	.45 (.45)	.41 (.48)	.27 (.43)
General info.	.38 (.45)	.39 (.40)	.17 (.31)	.32 (.43)
Different event	.16 (.30)	.16 (.33)	.42 (.42)	.41 (.45)
3-year delay	(<i>N</i> = 36)	(<i>N</i> = 25)	(<i>N</i> = 23)	(<i>N</i> = 22)
Insufficient info.	.73 (.35)	.55 (.41)	.23 (.36)	.39 (.46)
General info.	.22 (.30)	.31 (.38)	.41 (.47)	.20 (.32)
Different event	.05 (.14)	.14 (.31)	.36 (.46)	.42 (.45)