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Event Segmentation Ability Uniquely Predicts Event Memory

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Abstract

Memory for everyday events plays a central role in tasks of daily living, autobiographical memory, and planning. Event memory depends in part on segmenting ongoing activity into meaningful units. This study examined the relationship between event segmentation and memory in a lifespan sample to answer the following question: Is the ability to segment activity into meaningful events a unique predictor of subsequent memory, or is the relationship between event perception and memory accounted for by general cognitive abilities? Two hundred and eight adults ranging from 20 to 79 years old segmented movies of everyday events and attempted to remember the events afterwards. They also completed psychometric ability tests and tests measuring script knowledge for everyday events. Event segmentation and script knowledge both explained unique variance in event memory above and beyond the psychometric measures, and did so as strongly in older as in younger adults. These results suggest that event segmentation is a basic cognitive mechanism, important for memory across the lifespan.

Keywords

Event cognition; Episodic memory; Cognitive aging

1. Introduction

Memory for everyday events (*event memory*) is critical for normal functioning and supports, for example, one’s capacity to understand instructional videos, to give eyewitness testimony and to answer the ubiquitous question: What happened? To perceive the continuous activity

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of everyday life as discrete events, one must segment ongoing experiences into meaningful temporal units. Consistent with work showing benefits of chunking for human memory (e.g., DeGroot, 1978; Gobet et al. 2001), research into event memory has shown a relationship between how events are segmented and how they are remembered (e.g., Boltz, 1992; Ezzyat & Davachi, 2011; Newtson & Engquist, 1976; Schwan, Garsoffky & Hesse, 2000). The current study investigates the possibility that the relationship between event segmentation and event memory is a causal one.

Newtson and colleagues (1973, 1976) developed a paradigm to assess how an observer segments an everyday activity into meaningful events. Participants watch a video of someone performing the activity—for example, checking out groceries at the store—and are asked to press a button whenever they believe one unit of activity (or event) has ended and another has begun. In this example, a participant might press the button after each successive item is scanned and bagged. Studies using this paradigm have established a connection between event segmentation and event memory. For example, superior recognition and recall memory has been observed for activity occurring near event boundaries (Newtson & Engquist, 1976; Schwan, Garsoffky & Hesse, 2000). Editing movies by deleting intervals *containing* event boundaries impairs memory for the movies more than deleting intervals *between* event boundaries (Schwan & Garsoffky, 2004). Similarly, inserting commercial breaks or pauses into films at event boundaries can improve memory, and inserting such breaks between event boundaries can impair memory (Boltz, 1992; Schwan et al, 2000).

Recent work has shown that long-term associations are stronger within than between events. In particular, cued recall of target information from a narrative is better if the cue and target come from the same event, compared to when the cue and target come from different events (Ezzyat & Davachi, 2011). Consistent with this finding, memory for details viewed five seconds before testing was reduced if an event boundary occurred during the interval between the appearance of the detail and the memory probe (Swallow, J. M. Zacks & Abrams, 2009; Swallow et al., 2011). In addition, recognition of probes from previous compared to current events was associated with greater activation in brain regions that handle longer-term memory, including the hippocampus and parahippocampal gyrus. These studies provide strong evidence that how experience is segmented into events is important for how that experience is remembered.

Why might event segmentation be predictive of memory, specifically for everyday events? Much of what researchers have learned about episodic memory comes from studies using lists or series of discrete stimuli such as syllables, words or pictures (e.g., Bjork & Whitten, 1974; Buschke, 1973; Deese, 1959; Ebbinghaus, 1885). By constructing these memory test materials, experimenters create a series of minor events that are intended to be the “episodes” of later episodic memory. The problem of how the activity is segmented into episodes in these experiments can be safely ignored because the highly structured situation constrains participant’s segmentation almost perfectly: The segments can be assumed to be the words, pictures, lists, etc. On the other hand, for an everyday event such as checking out from the grocery store, the problem of segmentation is immediately evident. Putting milk in a bag, for example, may be perceived as one small event. The beginning and end of this event may be defined by, among other things, the motion characteristics of the clerk’s arm, the interaction with the milk carton, the clerk’s perceived goals, or some weighted combination of these factors. Some people may spontaneously chunk activity into units that are effective for memory encoding and later retrieval; others may fail to identify effective units during perception, and their subsequent memory may suffer as a result. Thus, event segmentation, like other cognitive mechanisms such as spatial attention and memory retrieval, is a process that may vary in its effectiveness across individuals and thus can be studied as an ability. Our concern in this research is this individual difference, that is, *segmentation ability*.

Better segmentation ability is associated with better subsequent memory (Bailey et al., in press; Kurby & J. M. Zacks, 2011; J. M. Zacks et al., 2006). In these studies, participants watched movies of actors engaged in everyday activities (e.g., washing a car) and segmented them by pressing a button whenever they believed one unit of activity ended and another began. Segmentation ability was defined as the degree to which an individual agreed with the sample as a whole about where event boundaries occurred in the movies. In all three studies, individuals showing greater segmentation ability remembered the movies better. This raises an important question: Are segmentation ability and memory correlated because both are supported by a general cognitive capacity, or does segmentation ability uniquely predict memory? This is the primary question addressed in the current study.

To answer additional questions regarding healthy aging, this study examined the relationship between event perception and memory across the adult lifespan. Age related deficits in episodic memory are well documented (for review see R. T. Zacks, Hasher & Li, 2000). Because segmentation appears to be a mechanism that contributes to memory performance, understanding whether and how this contribution changes across the lifespan might be useful for efforts to address age related memory deficits. Previous studies of event segmentation and episodic memory showed poorer event memory in older compared to younger adults (Kurby & J. M. Zacks, 2011; J. M. Zacks et al., 2006). These studies also showed reduced event segmentation ability in older compared to younger adults. These results lead us to the following questions. If event segmentation ability and event memory both decline with age, does segmentation ability mediate the age – event memory relationship? Furthermore, if there is a unique relationship between segmentation ability and episodic memory, does this relationship persist in healthy aging?

To address the questions posed here, we used an individual-differences approach to test for relationships among event segmentation ability, event memory, and general cognitive abilities in a lifespan sample of cognitively normal adults. The specific measures used to assess segmentation ability and event knowledge are discussed in section 1.1, and the measures used to assess general cognitive abilities are discussed in section 1.2.

1.1 Domain-Specific Cognitive Determinants of Event Memory

We refer to variables that measure abilities specific to the perception and understanding of events as *event understanding variables,* to distinguish them from measures of general cognitive abilities such as working memory and processing speed, which are discussed below in section 1.2. The selection of event understanding variables used in the present study was motivated by Event Segmentation Theory (EST; J. M. Zacks et al., 2007). Briefly, EST proposes that everyday experience is interpreted in the context of *event models*: mental representations maintained in working memory that describe what is happening right now. Event models contribute to perception by facilitating predictions regarding what is likely to happen in the immediate future. When relevant dimensions of the ongoing event change, the event model becomes outdated, leading to prediction errors. The system uses those prediction errors as a signal that the model needs to be updated. For example, when watching a clerk bag groceries, one forms a mental model that allows predictions, e.g., the clerk has placed an item in the bag and will now reach for the next item. However, when the last item has been bagged and the clerk is ready to take payment, the old model will generate inaccurate predictions and a new model needs to be established. EST posits that when an event model is updated people perceive an event boundary. When an event model is updated, its contents are determined by the current perceptual input, the current state of working memory, and long-term knowledge and memory for previous events.

Segmentation ability has previously been assessed using several measures. The primary measure in this study was s*egmentation agreement*, a measure of the degree to which an individual identifies event boundaries that also are identified by the group (Kurby & J. M. Zacks, 2011; J. M. Zacks et al., 2006). Event segmentation is inherently subjective, so it is not possible to objectively assess segmentation accuracy. However, previous studies have shown good agreement across observers in where event boundaries occur (Newtson, 1976) and even better agreement within individuals across time (Speer, Swallow & J. M. Zacks, 2003). Given that individuals tend to agree with one another regarding the locations of event boundaries, it seems that normative segmentation is adaptive and reflects segmentation ability. The fact that segmentation agreement predicts subsequent memory supports this proposal.

We also considered two other measures of segmentation ability that have been used previously, *Alignment* is the degree to which high-level events (e.g., washing your hands) consist of groups of smaller events (e.g., turning on the water, putting soap on your hands, lathering the soap, etc.; J. M. Zacks, Tversky & Iyer, 2001; Kurby & J. M. Zacks 2011). *Enclosure* reflects the degree to which groups of fine units are "enclosed" by coarse units (Hard, Recchia & Tversky, 2011). As will be seen, segmentation agreement proved to be a substantially more reliable psychometric measure in this sample, and agreement was therefore the measure of segmentation ability used in the primary analyses. Henceforth, the term segmentation ability refers to segmentation agreement. Details on the computation of each measure are provided in Section 2.2

Event knowledge measures assess the integrity and depth of an individual's knowledge regarding what generally happens in certain situations. Drawing on work in narrative comprehension (e.g., Rumelhart, 1975; Schank & Abelson, 1977; van Dijk & Kintsch, 1983), theories of event cognition have proposed that specific event models are informed in part by structured, long term representations of generalized classes of events, known as scripts or schemata (Rosen, Caplan, Sheesley, Rodriguez & Grafman, 2003; Zwaan & Radvansky, 1998). We refer to scripts and event schemata here as event knowledge. For example, during a specific visit to the grocery store one's event model may include unperceived features that are filled in by an event schema comprising knowledge about what generally occurs at the grocery store. Event knowledge may be considered a specific type of *general knowledge*. Whereas tests of general knowledge assess vocabulary and memory for specific, isolated facts (e.g., who was Cleopatra?), event knowledge benefits from understanding relationships between the features of generalized events. For example, to describe what generally happens at the grocery store, it helps to know that, as you enter, produce is generally to the right and dairy to the left, and that you must select items before paying, and pay before leaving. Because event schemata encode hierarchical relationships between units of activity within stereotypical events, and because they inform event models, they might also be important for event segmentation. Event knowledge could affect event memory directly, or indirectly, through its effect on segmentation.

According to EST, the perception of event boundaries involves multiple cognitive and neural mechanisms interacting in a specific way. To summarize, perceptual processing leads to predictions about the near future and is biased by event models maintained in working memory. Event models in turn are updated when predictions are erroneous. During updating, event models are influenced by long-term episodic memory, general semantic knowledge, and event-specific semantic knowledge. (For specific proposals regarding the neurophysiological aspects of these mechanisms, see J. M. Zacks et al., 2007.)

Age related declines are well established in several of the abilities thought to contribute to event segmentation (e.g., working memory). Therefore, we might expect poorer event segmentation associated with older age. However, the relationship between age and event perception may not be so simple. There may be qualitative differences in how younger adults perceive and understand events they have seen hundreds of times compared to how older adults perceive those same events after thousands of viewings. For example, EST posits that event segmentation is guided, in part, by general knowledge, scripts and schemas, which change as we accumulate life experience. Research suggests that older adults use this type of knowledge in comprehending written narratives to compensate for declines in other areas (Arbuckle, Vanderleck, Harsany & Lapidus, 1990; Radvansky & Dijkstra, 2007). We expect that differences in general processing factors such as working memory play a large role in any age differences in event segmentation. However, it is also possible that in segmenting events older adults rely more on scripts and schemas than younger adults. Thus, regardless of age differences in segmentation ability, the relative contributions of component mechanisms, and in essence, the style of event segmentation might change across the lifespan. We ask whether the relationship between segmentation and memory is consistent across the lifespan to test the possibility that age related differences in segmentation style differentially support episodic memory.

1.2 General Cognitive Determinants of Event Memory

There are a number of cognitive abilities that likely contribute to how one understands and remembers events. We administered a battery of cognitive tests chosen to assess theoretically plausible mediators of the relationship between segmentation ability and event memory. The goal was to test the hypothesis that segmentation ability predicts event memory *independently* of any effects of general cognitive abilities. Below we describe the general cognitive factors included in the current study and why they were chosen.

Working memory (WM) supports the capacity to maintain information in an activated state and manipulate it. The perception and segmentation of even the simplest events involves the ability to integrate information from various sources (e.g., visual and auditory perception, long term memory) and across dimensions (e.g., space, time, characters, goals). Several theories propose that working memory supports multidimensional representations of immediate events, which we refer to as event models (e.g. Baddeley, 2000; J. M. Zacks, Speer, Swallow, Braver & Reynolds, 2007). As described above, event models provide a context that guides the processing of ongoing experience, and are hypothesized to play an important role in the segmentation of experience into events.

Executive function (EF) is the ability to adaptively control behavior in response to goals and task demands. Psychometric measures of WM and EF are highly correlated (e.g., McCabe et al., 2010), both explain significant amounts of variance in episodic memory performance (e.g., Bugiaska, et al., 2007; Rosen & Engle, 1997), and both generally decline with age (e, g., Moscovitch & Winocur, 1992; Salthouse, 1990). Furthermore, WM and EF have both been shown to mediate the relationship between age and episodic memory (e.g., Bugiaska, et al., 2007; Salthouse, Atkinson, & Berish, 2003; Troyer, Graves & Cullum, 1994).

Perceptual *processing speed* is correlated with performance across a range of cognitive tasks (e.g., Faust, Balota, Spieler & Ferraro, 1999; McCabe et al., 2010). Age related declines in processing speed are well established (e.g., Park et al., 1996). However, even controlling for age, processing speed has been shown to correlate with high-level cognitive abilities (Coyle, Pillow, Snyder & Kochunov, 2011; Fry & Hale, 1996).

There is likely to be considerable overlap in the cognitive mechanisms underlying memory for everyday events and those underlying typical laboratory measures of *episodic memory* (e.g., for lists of words). However, everyday event memory and typical laboratory episodic memory tasks differ in important ways. For example, compared to word lists, everyday events are more likely to be encoded in the context of pre-existing knowledge structures, reflecting a lifetime of experience with similar events. Also, lists or series of discrete stimuli used in laboratory episodic memory tasks present, at least superficially, more explicit cues to segmentation than do everyday events. As a result of these differences, segmentation ability may relate differently to memory for word lists than to event memory. Older adults have been found to perform worse than younger adults on both laboratory and event memory tasks. However, event memory tasks may offer a richer encoding context and therefore ameliorate some age differences (R. T. Zacks, Hasher & Li, 2000; Koutstaal, Schacter, Johnson, Angell & Gross, 1998; J. M. Zacks et al., 2006).

Finally, general knowledge about objects and facts could contribute to constructing effective event models. General knowledge, an expression of crystallized intelligence (Gc), plays a substantial role in many complex cognitive tasks (Carroll, 1993; Friedman et al., 2006). Significantly, general knowledge usually shows *gains* rather than losses with age (e.g., Park et al., 1996). Therefore, we might expect general knowledge, as well as script and schema knowledge, to mediate age-related differences in segmentation and episodic memory.

The constructs outlined above reflect abilities that are considered general because they predict performance on a range of tasks that humans perform in the laboratory, including tests of fluid intelligence (e.g., Engle, Tuholski, Laughlin & Conway, 1999; Fry & Hale, 1996; Kane & Engle, 2000; Unsworth & Spillers, 2010). These general abilities likely underlie much of the processing involved in higher-level cognition. Therefore, we might expect individual differences in event segmentation to be explained by these general cognitive factors. On the other hand, if event segmentation is supported by a particular interaction among these general systems then event perception, as a distinct cognitive activity, may not be measured well by individual psychometric tests of basic cognitive abilities. It is also possible that event segmentation ability reflects the operation of neural and cognitive mechanisms that are not captured by established cognitive ability tests. We therefore hypothesized that selective measures of event segmentation would uniquely predict event memory, above and beyond any contribution of basic cognitive abilities.

2. Method

2.1 Participants

Participants were 233 adults, ranging in age from 20 to 79 years, recruited from the St. Louis community using the Volunteers for Health participant pool maintained at the Washington University in St. Louis School of Medicine. Participants received $10 per hour compensation.

2.2 Event Understanding Variables: Event Segmentation, Memory and Knowledge

To measure event segmentation and event memory, participants viewed three movies, each depicting an actor engaged in an everyday activity (see Fig. 1). Movies were filmed as one continuous shot from a fixed, head-high perspective with no change in lens zoom, to mimic the experience of observing a live event. Participants were asked to segment each movie by pressing a key to indicate where they judged that one meaningful unit of activity had ended and another had begun (e.g., Newtson, 1976). Participants were instructed to identify the largest units they found meaningful (coarse segmentation) on their first viewing, and the smallest units they found meaningful (fine segmentation) on their second viewing. Including both coarse and fine segmentation allowed us to calculate hierarchical alignment and enclosure scores (described below). Participants completed coarse segmentation for all three movies before completing fine segmentation. Before both coarse and fine segmentation, participants practiced segmenting a movie of an actor building a boat out of toy blocks (duration 155 s). If they identified fewer than three coarse or six fine event boundaries, participants were asked to identify “a few more” units and the practice movie was repeated.

Segmentation ability was defined in this study as the degree to which an individual agreed with the sample as a whole about where event boundaries occurred in the movies, or segmentation agreement (Kurby & J. M. Zacks, 2011; J. M. Zacks et al., 2006). To create a segmentation norm for the sample, we divided each movie into one-second bins and calculated the proportion of participants that identified a boundary within each bin. We then coded each participant’s segmentation using the same one-second bins; each bin contained a one if the participant segmented during that second, or a zero if they did not. Then, for each participant and movie, we calculated the correlation between the individual’s segmentation and the group norm. Each participant’s observed correlation (r_{obs}) was scaled based on the highest and lowest correlations possible given the number of boundaries identified (r_{max} and r_{min}, respectively) according to the following formula: $\textit{segmentation ability} = (r_{obs} - r_{min})/(r_{max} - r_{min})$. This resulted in a segmentation ability score with a range from zero to one that was independent of the number of identified event boundaries, or mean event duration (Kurby & J. M. Zacks, 2011).

Although agreement was the main variable used to characterize individual differences in event segmentation ability, we also computed measures of hierarchical organization in segmentation, or the degree to which coarse events comprise groups of related finer events. *Alignment* reflects the degree to which each identified coarse boundary coincides temporally with an identified fine boundary (J. M. Zacks, Tversky & Iyer, 2001). For each coarse boundary in a given movie the temporal distance to the closest fine boundary for that movie is calculated. Alignment is the average of these distances, adjusted for the average distance expected due to chance given the number of coarse and fine boundaries identified. *Enclosure* reflects the degree to which groups of fine units are “enclosed” by coarse units (Hard, Recchia & Tversky, 2011). If a sequence of four fine-grain events ($F_1 – F_4$) make up a coarse-grain event C, the end of the last of the four fine events (F_4) should occur shortly before the end of coarse event C. To score enclosure, for each coarse boundary the closest fine boundary is identified, and it is noted whether the coarse boundary follows or precedes the fine boundary. The enclosure score for one participant’s viewing of one movie is the proportion of coarse boundaries that follow, rather than precede their closest fine boundary (see Fig. 2).

Event memory was assessed using a recall test, a recognition test, and an order memory test. For the recall test, immediately after viewing and segmenting each movie for the first time, participants were given seven minutes to write or type, in as much detail as possible, what happened in the movie they just watched. For each movie, we constructed a list of the basic actions performed by the actor, using criteria described by Schwartz (1991, termed “A-1” units therein). Event recall scores were the number of correctly recalled actions (inter-rater kappa = 0.84 [$p < .001$], 95% CI [0.78, 0.90]). After recall, recognition memory was tested. On each of twenty recognition memory trials, participants chose which of two still frames was from the movie. Lures were taken from similar movies utilizing the same actor and setting. (For example, for the “setting up for a party” movie, the actor set the table and then hung streamers. One of the lure images showed the room with streamers hung but the table not yet set. Other lures were created by changing the objects involved or the locations of objects or the actor.) Finally, order memory was tested. Participants were given 12 randomly ordered still frames from the movie, each printed on a 10 cm x 15cm card, and asked to arrange them in the order in which they appeared in the movie. (See J. M. Zacks, Speer, Vettel & Jacoby, 2006 for more details on recognition and order memory tests.) Importantly, order memory performance is measured with an error score, so lower numbers indicate better order memory.

To assess event knowledge, often referred to as script or schema knowledge, participants were given three minutes to write down in order, from beginning to end, all the steps involved in each of three everyday activities: shopping for groceries, getting ready for work, and going out to eat. A step was counted as correct if it corresponded to one of the 16 most commonly reported steps for that activity as defined by norms reported by Rosen et al. (2003).

2.3 Procedure

Testing occurred in two 150-minute sessions that took place on different days within one week of each other. Participants began session 1 by segmenting the practice movie at a coarse grain. When criteria had been reached (at least three coarse or six fine event boundaries) participants segmented the “making breakfast” movie at a coarse grain, and then completed the recall, recognition and order memory tasks. This was repeated for the other two movies (setting up for a party, and planting window boxes, see Fig. 1). Then, the first set of measures from Table 1 was administered: Reading Span, Operation Span, Symmetry Span, Shape Comparison, Reading with Distraction, and Synonym and Antonym Vocabulary. In session 2, participants segmented all the movies at a fine grain and then completed the remaining psychometric measures in Table 1 and the Short Blessed Test (SBT) dementia screen (Katzman et al., 1983). The recall, recognition and order memory tasks were not repeated in Session 2. Between sessions 1 and 2, participants completed another dementia screen, the AD8 (Galvin et al., 2005), and a brief questionnaire covering demographic information, information about health and exercise habits, and educational history.[2]

2.4 Exclusion Criteria and Missing Data

Twenty-five participants were excluded for missing the second session ($n = 8$), failing to pass both dementia screens [3] ($n = 9$), failing to segment at least two of the experimental movies ($n = 5$), failing to follow instructions ($n = 1$), or experimenter error ($n = 2$). The remaining 208 participants comprised 17–18 adults of each gender from each decade of life, 20s through 70s.

To address outlying observations, we regressed each variable onto age, and then screened the residuals for values over 3.5 standard deviations from the total sample mean (univariate outliers); we replaced the 22 values that met this criterion (.8% of the data), along with 98 missing values (1.2% of the data), using the expectation maximization (EM) procedure in SPSS 19.0. Twenty participants produced at least one outlying data point, 45 participants were missing at least one data point, and six participants produced at least one outlier and were missing at least one data point. The variables were approximately normally distributed (|skewness| < 2.0, |kurtosis| < 2.0, except for reading with distraction, for which kurtosis = 3.0).

3. Results

Descriptive statistics for young, middle-aged, and older adults are presented in Table 2. Very few participants ($n = 11$) were current undergraduate or graduate students. Older adults had significantly higher levels of education than younger or middle-aged adults. Younger adults outperformed older adults on tests of working memory (WM) capacity, executive functioning (EF), and perceptual speed, whereas older adults outperformed younger adults

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[2] Order was fixed so that any order effects would be consistent across individuals in order to maximize the power for detecting individual differences.

[3] To pass the dementia screens required scores of less than 5 on the SBT and less than 2 on the AD8.

on tests of vocabulary and general knowledge. The correlation matrix in Table 3 shows, most notably, that segmentation ability and event knowledge were both robust predictors of event memory as measured by event recall. Also notable, age was correlated with none of the event understanding variables. The ability variables correlated positively with each other. In most cases, the variables representing each construct tended to correlate more strongly with each other than with the other variables, and thus composite variables created by averaging *z* scores for measures within each construct had good internal consistency reliability (αs>.70). The exception was EF (mean. $r = -.02$, α=.25).

The average duration of the events identified in the movies (time between boundaries) was 26 s for coarse segmentation and 10 s for fine segmentation. Both coarse and fine event duration correlated negatively with segmentation ability, $r(206) = -.33$ and $-.42$, respectively ($p < .001$ for both), and event recall memory $r(206) = -.18$ and $-.30$, respectively ($p < .01$ for both). Because event duration was manipulated via explicit instructions (to identify larger or smaller units of activity) and individual variability in duration was minimized by the shaping procedure, we do not treat it as an outcome variable of primary interest in the structural models. However, we checked to see if event duration (mean duration across coarse and fine segmentation conditions) mediated the relationships of primary interest, those among segmentation ability, event memory and age, using the method described by Baron and Kenny (1986). Controlling for event duration decreased the correlation between segmentation ability and event memory very little, from $r = .48$ to $r = .44$. A Sobel test for mediation did not approach significance ($z' = .25$, $p > 0.05$). However, segmentation ability fully mediated the relationship between event duration and event memory: r dropped from −.23 to −.02, and a Sobel test confirmed significant mediation ($z' = 4.70$, $p < 0.001$). No significant relationships were observed between event duration and event knowledge or any of the general cognitive factors. Finally, controlling for event duration did not result in significant relationships between age and segmentation ability or between age and event memory. The correlation between age and event duration was positive but not significant ($r = .13$, $p > .05$). Kurby and J. M. Zacks (2011) found that older adults identify fewer, longer events than younger adults, whereas Magliano, Kopp, McNerny, Radvansky and J. M. Zacks (2011) showed that older adults identified shorter events. Current data do little to clarify the relationship between age and event duration.

3.1 Structural Equation Modeling

The major question of this study was whether event segmentation ability constitutes a unique ability factor that independently predicts memory for everyday events. We used structural equation modeling to answer this question. We report several fit statistics to characterize model fit. The Chi-square (χ^2) test evaluates whether the observed covariance matrix deviates from the model-implied covariance matrix; non-significant values are indicative of good fit. We also report the comparative fit index (CFI) and root-mean squared error of approximation (RMSEA); CFI values of .95 or higher and RMSEA values of .06 or lower are indicative of good model fit (Hu & Bentler, 1999).

3.1.1 Confirmatory factor analyses—We first performed confirmatory factor analyses (CFAs) to establish a measurement model with latent variables representing the hypothesized factors. An initial model for the *general cognitive ability* constructs included WM capacity, EF, laboratory episodic memory, perceptual speed, and general knowledge, with three indicators per construct (see Table 1). The model did not converge; inspection of factor loadings indicated that this was because the EF variables did not form a latent variable.[4] Therefore, we dropped the EF construct and corresponding measures from the model; we also added a correlated error for operation span and reading span, given that these tasks had the same memoranda, and a cross-loading from Gc to word list memory, based on the results of a preliminary exploratory factor analysis.[5] Factor loadings and correlations are presented in Table 4. We designate this Model 1; fit was good, $\chi^2(46)=106.78$, $p<.01$, CFI=.95, NFI=.92, RMSEA=.08. The measurement model for the event understanding variables included event segmentation, event recall[6], and event knowledge, with three indicators per construct: segmentation ability and recall memory for each of the three movies, and knowledge for the three everyday events tested, respectively. Factor loadings and correlations are presented in Table 5. We designate this Model 2; fit was excellent, $\chi^2(24)=12.26$, $p=.98$, CFI=1.00, NFI=.98, RMSEA=.00.

To investigate the equivalence of the measurement models across age, we followed a standard procedure in research on cognitive aging (e.g., Salthouse & Ferrer-Caja, 2003) and created young and older adult groups by a median split (age 50).[7] (This is an admittedly arbitrary split, but a finer discrimination would have resulted in very low statistical power and precision; see Kline, 2000.) For both Model 1 and Model 2, we performed multiple-groups CFAs in which we tested a series of progressively more restrictive versions in which (a) the indicators had separate loadings on the factors, (b) equality constraints were imposed on the factor loadings, (c) equality constraints were imposed on factor variances, and (d) equality constraints were imposed on factor correlations. See Table 6. For the ability measurement model (Model 1), the chi-square difference test indicated significant loss of fit from Model 1a to Model 1b. However, the other fit statistics indicated that the fit of Models 1a and 1b was negligibly different across age groups (e.g., CFI= .96 vs. .94), and factor loadings were very similar across age groups (mean difference = .04).

We performed the equivalent analyses on the event measurement model (Model 2). The chi-square difference test was statistically significant for Model 2b vs. 2c, indicating factor variances differed across groups. Inspection of factor variances revealed that this was because of greater variability in event recall for young adults than older adults. However, the other fit statistics for Models 2b vs. 2c were very similar across age groups (e.g., CFI = 1.00 vs. .99). Thus, although the measurement models were not statistically equivalent across the young and older groups, the deviations were slight, and there is no indication that the latent variables had different meanings across the groups.

3.1.2 Structural models—

We tested the structural model shown in Figure 3. (Path coefficients reported next are significant at least at $p<.05$ unless otherwise specified.) Most important, event segmentation and event knowledge each positively, and uniquely, predicted event recall (.21 and .23, respectively). Controlling for all other influences, those individuals with higher segmentation ability, and those with greater event knowledge, tended to remember more about the events they had witnessed. Age negatively predicted WM capacity (−.42), episodic memory (−.54), and perceptual speed (−.69), and positively predicted general knowledge (.33). WM capacity positively predicted segmentation ability (.53). Effects of WM capacity and episodic memory on event knowledge were positive but did not approach significance, while the effect of education was positive and near significant (.18, $p=.054$). Effects of age (treated as continuous) on event recall (.07), event knowledge (.17), and segmentation ability (.19) were all non-significant. Model fit was good, $\chi^2(194)=310.13$, $p<.001$, CFI=.95, NFI=.88, RMSEA=.05. Because previously observed age deficits in

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[4] Executive Function is a complex construct encompassing diverse components (e.g., inhibition, task switching, updating, strategic planning) and it appears that the three measures used in this study tapped different aspects of EF (e.g., Miyake et al., 2000)

[5] Adding the correlated errors and cross-loading improved model fit, but we ran all analyses without these parameters and all results were nearly identical.

[6] Recall memory is presented as the primary event memory measure. Analyses of recognition and order memory (presented below) showed questionable reliability for these measures.

[7] Descriptive statistics for young and older adult groups formed by median split are shown in the supplementary materials available online.

segmentation ability and event memory did not replicate, we were unable to test the hypothesis that segmentation ability mediates the relationship between age and event memory.

All possible paths in this model were tested, but only paths with significant ($p < .05$) coefficients are shown. The full model showing all path coefficients is available in the supplementary materials available online.

To test for age-related differences in the predictors of event recall, we estimated separate models for younger and older adults, again splitting at 50 years old. Model fit was good, $\chi^2(360)=464.67$, $p<.001$, CFI=.95, NFI=.82, RMSEA=.04, and the predictor constructs accounted for 73% and 69% of the variance in event recall for younger and older adults respectively. The effect of event segmentation on event recall was numerically higher in older adults (.34) than younger adults (.21), but constraining this path to be equivalent across groups did not result in significant loss of model fit, $\Delta\chi^2(1)<1$. There was also no significant loss of model fit after constraining each of the other paths from the predictor constructs to event recall to be equivalent across age groups (all $\Delta\chi^2$s, n.s.).

We also tested models examining the role of hierarchical organization in segmentation, using alignment and enclosure as measures of segmentation ability instead of agreement. The effects of alignment (−.08) and enclosure (−.16) factors on recall memory were non-significant. These measures of hierarchical segmentation also showed relatively poor reliability: Chronbach’s alpha across the three movies was .86 for segmentation agreement, but was .60 and .51 for alignment and enclosure, respectively.[8]

3.2 Regression Analyses

One way event knowledge might influence event memory is through event segmentation. If so, we might expect event knowledge to affect event memory differently depending on the integrity and efficiency of event segmentation mechanisms. To test this possibility, we performed a hierarchical regression analysis to determine whether effects of event knowledge and segmentation ability on event recall were additive or interactive. We regressed event recall onto age and education (Step 1), composite variables representing the general cognitive abilities (Step 2), event knowledge and segmentation ability (Step 3), and the segmentation ability-by-event knowledge interaction (Step 4). Above and beyond age and education, the general cognitive ability constructs accounted for 32.1% of the variance; event knowledge and event segmentation added another 7.5%, with significant unique contributions of 3.5% and 3.0%, respectively (see Table 7). There was no evidence for an event knowledge-by-segmentation ability interaction (R^2=<.01), and thus high levels of segmentation ability and event knowledge were independently associated with superior event recall.

To test whether prediction of event recall by segmentation ability was movie-specific, we regressed each of the three event recall variables (one for each movie) onto the three segmentation ability variables (again, one for each movie). For each movie, the segmentation variable that made the largest unique predictive contribution to memory was a

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[8] We also tested models using recognition or order memory rather than recall as the criterial memory variable. Segmentation had zero-order correlations of .48 with recall, .25 with recognition, and −.37 with order memory ($df = 206$, $p < .001$, for all). We tested the model shown in Figure 2 assessing event memory using the recognition and order memory measures instead of the recall measure. Effects of segmentation ability on recognition memory (−.04) and order memory (−.16) were non-significant. The correlations between segmentation and recognition and order memory are somewhat smaller than those observed previously (Kurby & J. M. Zacks, 2011; J. M. Zacks, Speer, Vettel & Jacoby, 2006). One possibility is that these measures were contaminated by the preceding recall test. A related observation is that the item-level reliability of the recognition and order memory tests was lower than that for recall: Chronbach’s alpha across the three movies was .79, .47 and .50 for recall, recognition and order memory, respectively.

segmentation variable for *another* movie, and the common R^2, reflecting variance accounted for by what the segmentation variables shared in common, was much larger than each of the unique R^2, reflecting variance uniquely accounted for by the segmentation variables (see Table 8). Therefore, the relationship between segmentation ability and event recall was not movie-specific.

4. Discussion

The ability to segment the continuous flow of experience into meaningful events uniquely predicted memory for that experience, and this relationship was observed in both older and younger adults. The identification of a basic perceptual mechanism that is important for remembering everyday experiences throughout the lifespan is relevant for memory research broadly. Working memory capacity and laboratory episodic memory predicted event recall (see Table 3), but only indirectly, through other variables in the model (see Fig. 3).[9] In contrast, segmentation ability and event knowledge *uniquely* predicted event recall. This suggests that memory for human activity may involve qualitatively different mechanisms than those measured by common tests of (laboratory) episodic memory. Furthermore, efforts to understand memory for everyday experience, and related age effects, would benefit from consideration of event structure and event cognition in general.

4.1 Segmentation and Memory

These results replicate the finding that normative event segmentation is adaptive because it predicts subsequent memory (Kurby & J. M. Zacks, 2011; J. M. Zacks et al., 2006). The results do not establish a causal relationship between event segmentation ability and memory, but the fact that the association persisted after controlling carefully for general cognitive abilities rules out a class of mechanistic models in which event segmentation ability and event memory are both due to common general cognitive abilities. This leaves two possibilities: First, adaptive event segmentation could be causally responsible for the formation of representations that are effective for later memory. Thus, individual differences in segmentation would be the cause of individual differences in event memory. Second, individual differences in both segmentation and event memory could share a common cause. Studies manipulating the ease with which a movie can be segmented, for example, by inserting commercial breaks at event boundaries or event middles, have shown that this manipulation influences memory (e.g., Boltz, 1992; Schwan et al, 2000). Future experiments might use a segmentation training or practice regimen to manipulate segmentation ability in order to more definitively test for a causal link between segmentation ability and memory. However, by eliminating a number of variables as potential mediators of the segmentation-memory relationship the current study represents a considerable step towards establishing a causal link. Current results may serve to guide future searches for potential mediators. If such a mediator exists, it likely is specific to the domain of event understanding, because it was not captured by the psychometric battery assessing general cognitive abilities.

If adaptive segmentation facilitates recall, by what mechanisms does this occur? One possibility is that adaptive segmentation reflects the temporal modulation of attentional resources in a manner that facilitates episodic memory. Research shows that event boundaries correspond to periods of increased attention to and processing of incoming perceptual information (e.g., Newtson & Engquist, 1976; Schwan et al., 2000). Furthermore, attention to perceptual information specifically at event boundaries facilitates recall (Schwan & Garsoffky, 2004), presumably because boundaries correspond to critical periods of

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[9] A test of mediation (Baron & Kenny, 1986) showed that segmentation ability alone was a partial mediator of the relationship between WM and event memory. The WM – event memory correlation dropped from .55 to .43 when controlling for segmentation ability, and a Sobel test showed this to be significant mediation ($z' = 4.07$, $p < 0.001$).

relatively high levels of change in salient dimensions, e.g., time, space, character, goals (J. M. Zacks, et al., 2010). So better segmentation may help memory because it guides attention to those features of experience that are particularly important for event understanding and recall.

Event Segmentation Theory (EST) points to another mechanism by which good event segmentation might benefit recall (J. M. Zacks et al., 2007). According to EST, normative segmentation depends on updating event models in working memory at appropriate timepoints, and the consequent inclusion of important event features in subsequent event models, as suggested above. However, the *maintenance* of models in working memory during periods of relative stasis is also critical for adaptive event segmentation. Thus, good segmentation entails not only the attentional selection of critical event features, but also the sustained activation of these features, and increased probability of capture by longer term memory systems. The central role for working memory in event segmentation, proposed by EST, is supported by current results showing that working memory was in fact the only psychometric construct that independently predicted segmentation ability.

4.2 Segmentation and Event Knowledge

The prediction of EST that event knowledge is important for event segmentation ability was not supported by the current results. These factors were correlated ($r = .33$) but this relationship was not significant in the structural model. Although segmentation ability and event knowledge both benefit event memory, regression analyses show they do so independently of one another. This constrains theories of how event knowledge might facilitate event memory. Knowledge regarding what typically happens during the making of breakfast, for example, might independently benefit both the encoding and retrieval of a particular breakfast making episode by a number of conceivable mechanisms (e.g., Bower, Black & Turner, 1979). However, the absence of an interaction with segmentation ability suggests that event knowledge influences event memory not through facilitating segmentation, but more directly. For example, forgotten steps or sequential information regarding a specific episode might be correctly filled in with script consistent event knowledge.

According to EST, segmentation occurs in response to prediction errors, or mismatch between event models and ongoing events. The content and structure of event models thus serve to guide event segmentation. This content and structure is theorized to come largely from event knowledge. It may be that the individual differences in event knowledge that are predictive of differences in segmentation are too subtle to be detected by our event knowledge measures. However, the current results suggest that event segmentation may rely less on generalized event representations than previously supposed. Theories, such as EST, might be updated to reflect this. For example, incoming perceptual input may be of relatively greater importance to the predictive functionality of event models than generalized event schemas.

4.3 Age

Another notable finding was that event knowledge did not differ across age levels. In this sample, knowledge regarding the basic steps involved in going shopping, eating out, and getting ready for work as measured by our script knowledge task was the same at 25 and 65 years of age. Together with the finding that the relationship between segmentation ability and event memory was stable across the lifespan, this underscores the similarities in how younger and older adults segment events.

In addition, age did not significantly predict segmentation ability or event memory, either as measured by simple correlations or as independent contributions in the structural models. This was unexpected in light of previously observed age-related differences in these areas (Koutstaal, et al., 1998; Kurby & J. M. Zacks, 2011; Magliano et al., 2011; J. M. Zacks et al., 2006). However, it is consistent with the lack of age effects on event knowledge and highlights the potential preservation, rather than deterioration, of event processing mechanisms in older adults. Magliano et al. (2011) showed some support for the consistency of segmentation processes across age groups using pictorial and text stimuli. Although older adults showed slightly lower segmentation ability, there were notable similarities in the features that predicted older and younger adults' segmentation.

To understand the discrepancy between current and previous results regarding age effects, we considered specific differences in study designs. Whereas previous studies used extreme age groups designs, the current study used a continuous-sampling design. We examined the extremes of the age distribution in the current sample and compared participants in their 20s to those in their 70s, the approximate age ranges sampled in previous studies. The older group showed poorer event recall ($t = 2.05[68]$, $p = .045$) and poorer segmentation ability, although the latter difference did not approach significance. Examination of age related differences in event memory across the lifespan was complicated in the current study by the fact that we appear to have captured particularly low performing adults in their 50s and particularly high performing adults in their 60s. This pattern was observed across several cognitive measures (see Fig. 4). One possibility is that high functioning individuals in mid-life, busier with their careers and families, were less available to participate. The fact that older adults did not show typical cognitive declines suggests that sampling bias may have affected the pattern of age-related differences.

Another difference between the current and previous studies of event segmentation, event memory and aging is that younger groups in previous studies were composed of students at elite universities between 18 and 26 years of age and likely to be exceptionally high cognitive performers. The current study recruited from the general community, and included relatively few students (and even fewer Washington University students) in any of the age groups (see Table 2). Therefore, previous studies may have captured relatively high performing adults, at least in the younger age groups. In order to examine age effects on event segmentation and event memory in higher and lower memory performers separately we performed a median split on event recall within each decade of the current sample. Amongst all those in the lower memory performance halves of their respective age groups, virtually no age effects were observed. However, amongst higher performers, age was negatively correlated with event recall ($r[99] = -.35$, $p < .001$) and marginally so with event segmentation ($r[99] = -.19$, $p = .054$).[10] It is unclear why participants with poorer event recall would not show age related declines in segmentation ability and event recall. It may be that lower event segmentation and memory scores reflect simpler cognitive processes that are more durable in the face of age related changes in brain function. Higher performers, in essence, have further to fall. At this point, the lack of an age effect observed here is an anomalous result; however, given that the current study included a large sample size and recruited a relatively representative sample, it is a question that should be pursued further. The present demonstration that the unique relationship between segmentation and memory persists across age groups (also see Bailey et al., in press) is consistent with previous findings that older adults use situation models as readily as do younger adults (Morrow, Stine-Morrow, Leirer, Andrassy & Kahn, 1997; Radvansky & Dijkstra, 2007).

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[10] Mean age of the low and high performers was 49.05 and 48.88 years, respectively. Amongst high performers, segmentation ability did not mediate the relationship between age and event memory.

4.4 Event Duration

Finally, the current data shed some light on the role played by perceived event duration in the relationship between event segmentation and event memory. Although our experimental design minimized individual differences in event duration in order to focus on segmentation agreement, some differences did remain. Consistent with previous research (Hanson & Hirst, 1989; Lassiter, Stone & Rogers, 1988), the identification of more event boundaries (shorter duration events) was correlated with event memory ($r = .23$). However mediation analyses suggest that segmentation ability drives the relationship between event duration and memory. The finding that better segmenters tend to identify more, smaller events is interesting for what it indicates about segmentation ability. The correlation between segmentation ability and event duration was somewhat stronger in the fine than in the coarse segmentation condition ($r = -.47$ and $r = -.41$, respectively). Also, segmentation ability was more predictive of event memory in the fine than in the coarse segmentation data ($r = .47$, and $r = .40$, respectively). These numerical differences suggest that event segmentation mechanisms may operate optimally at somewhat shorter time scales. Alternatively, there may be differences in construct validity for fine and coarse segmentation; current behavioral measures of segmentation ability may reflect cognitive mechanisms underlying fine segmentation more accurately than those underlying coarse segmentation. Another possibility is that adaptive segmentation simply leads to missing fewer event boundaries.

4.5 Conclusions

In sum, these results show that the ability to segment ongoing everyday activity into meaningful events and one’s knowledge about such activity are both important determinants of how well people remember what happens in everyday life. Both predict memory above and beyond the contributions of general cognitive ability. Importantly, they do so across the adult lifespan. These results open the possibility that interventions to improve segmentation may be helpful in improving episodic memory in those experiencing memory difficulties, including older adults.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1. Event Stimuli

Stills taken from each of the three experimental movies: making breakfast, setting up for a party, and planting window boxes. Durations were 329 s, 376 s and 354 s, respectively.

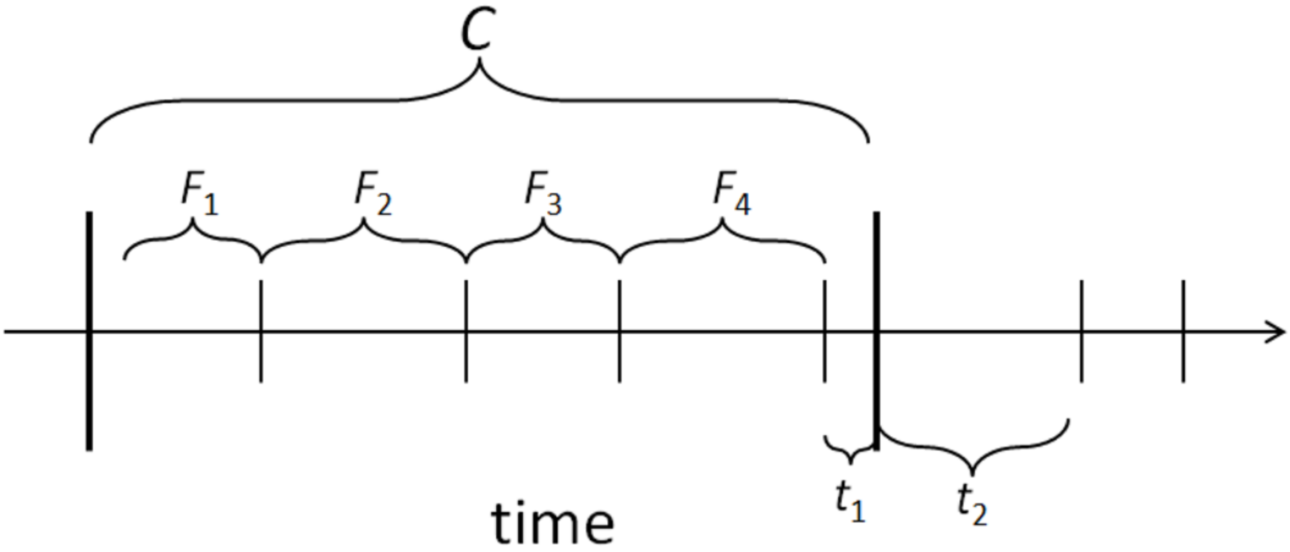

Figure 2. Enclosure

Enclosure is a measure of the extent to which larger (coarse: *C*) and smaller (fine: *F*) events are hierarchically arranged into super- and subordinate levels, respectively. Larger and smaller vertical lines represent boundaries between coarse and fine grain events, respectively. Enclosure was scored as the proportion of course event boundaries for which $t_1 < t_2$.

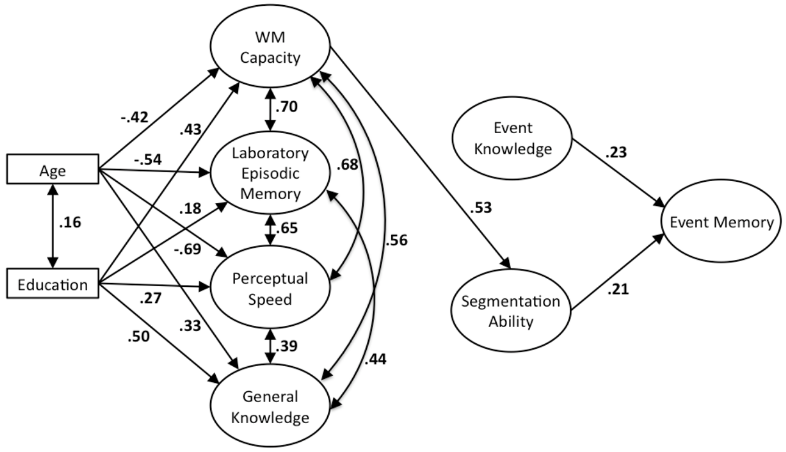

Figure 3.

Structural Equation Model Showing Relationships Among Demographic, Psychometric, and Event Understanding Variables

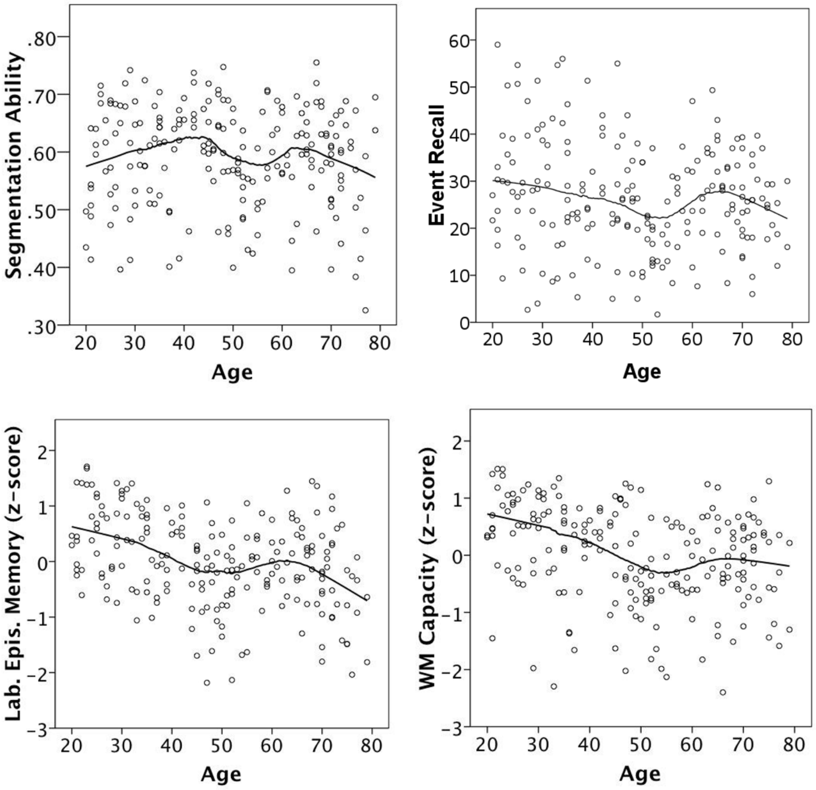

Figure 4. Examples of atypical age effects

Partially smoothed Loess curves are shown (40% of the data are fit) to illustrate the dip in performance observed for participants around 50 years of age. Linear correlations with age are as follows. Segmentation Ability: $r = .06$, $p = .37$; Event Recall: $r = .14$, $p = .06$; Laboratory Episodic Memory: $r = .34$, $p < .001$; Working Memory Capacity: $r = .28$, $p < .001$.

Table 1

Description of cognitive measures for each construct.

Construct	Measure	Description	Source
Working Memory (WM)			
	Reading Span	Remember series of letters while making simple judgments about sentences	Turner et al. (1989)
	Operation Span	Remember series of letters while solving simple math problems	Turner et al. (1989)
	Symmetry Span	Remember series of locations while making simple symmetry judgments	Turner et al. (1989)
Laboratory Episodic Memory(LEM)			
	Selective Reminding	Study 16 pictures of objects, 4 recall attempts (1 delayed) w/ reminding of missed items	Buschke (1973)
	Verbal Paired Associates	8 word pairs read aloud, then 1st word in each pair given as recall cue, 4 – 7 trials (1 delayed)	Wechsler (1997)
	Word List Recall	Study 30 words for 2 min., 5 min. for free recall (2 trials)	Small et al. (1999)
Executive Function (EF)			
	Reading with Distraction	Read passages aloud ignoring distracting, embedded text	Connelly et al. (1991)
	Trail Making	Connect circles alternating between numerical and alphabetical order	Armitage (1945)
	Ruff Figural Fluency	Draw as many unique patterns as possible in 1 min. by connecting dots	Ruff (1987)
Processing Speed (PS)			
	Shape Comparison	Identify which of two shapes is most similar to a sample	Chen et al. (2007)
	Letter Comparison	Determine if two letter strings are same or different	Salthouse et al. (1991)
	Pattern Comparison	Determine if two simple line patterns are same or different	Salthouse et al. (1991)
General Knowledge (GK)			
	Information Test	Answer general knowledge questions	Wechsler (1997)
	Synonym Vocabulary	Choose synonyms from among 5 possible choices	Salthouse (1993)
	Antonym Vocabulary	Choose antonyms from among 5 possible choices	Salthouse (1993)

Table 2

Descriptive Statistics by Age Group (years)

	Young (20–39)		Middle (40–59)		Older (60–79)	
Occupation = student:	**16% (11/71)**		**0% (0/68)**		**0% (0/69)**	
Measure (Construct)[a]	***M***	***SD***	***M***	***SD***	***M***	***SD***
Reading Span (WM)	21.01	6.11	19.12	6.41	20.10	6.08
Operation Span (WM)	21.69	6.57	18.12	6.91	19.33	7.19
Symmetry Span (WM)	15.52	6.11	10.71	5.59	9.64	5.70
Selective Reminding (LEM)						
Immediate (out of 48)	36.79	4.28	32.99	5.66	32.94	5.39
Delayed (out of 16)	12.87	2.26	11.60	2.34	11.76	2.50
Verbal Paired Ass. (LEM)						
Immediate (out of 24)	14.69	2.57	11.85	3.20	12.04	3.14
Delayed (out of 8)	5.70	.58	4.96	1.11	4.96	1.23
Word List Recall (LEM)	18.17	6.24	16.77	5.24	17.75	5.00
Read. with Distraction (EF)	.40	.20	.54	.31	.50	.23
Trail Making (EF)	1.26	.78	1.53	.86	1.20	.64
Ruff Figural Fluency (EF)	79.37	27.22	69.96	23.59	72.26	21.91
Shape Comparison (PS)	.81	.19	1.03	.25	1.14	.26
Letter Comparison (PS)	8.09	1.96	6.40	1.58	6.46	1.53
Pattern Comparison (PS)	14.76	3.05	11.89	2.28	11.47	1.67
Information Test (GK)	17.04	6.04	16.10	5.56	21.07	4.28
Synonym Vocabulary (GK)	.43	.28	.45	.26	.73	.25
Antonym Vocabulary (GK)	.44	.27	.41	.25	.69	.27
Event Recall	28.91	13.51	23.88	10.64	26.71	9.48
Event Knowledge	8.43	2.65	7.7	2.51	8.4	2.17
Segmentation Ability	.59	.09	.59	.09	.58	.09
Education (years)	14.45	2.66	14.22	2.38	15.53	2.63

[a] WM=Working Memory; LEM=Laboratory Episodic Memory; EF=Executive Function; PS=Processing Speed; GK=General Knowledge

NOTE: Scores are proportion correct except as follows: Span scores =total number of items recalled for which corresponding processing task was correct; Reading with Distraction = (low distraction - high distraction)/low distraction reading times; Similarly, Trail Making = (B-A)/A, time to completion; Ruff = total unique designs; Letter/Pattern Comparison = items completed in 20 s.; Shape Comparison = average time in s. to complete 1 trial. More information about specific tasks is reported in Table 1.

Table 3

Correlations Between Variables

Variable		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Age	–																	
Working Memory																			
2	RSpn	−0.12	–																
3	OSpn	−0.16	0.72	–															
4	SSpn	−0.43	0.51	0.50	–														
Executive Function																			
5	Rw/D	−0.19	0.12	0.13	0.17	–													
6	Ruff	−0.18	0.39	0.36	0.56	0.09	–												
7	Trls	0.05	0.19	0.23	0.22	0.12	0.10	–											
Laboratory Episodic Memory																			
8	SRem	−0.33	0.31	0.26	0.36	0.07	0.26	0.07	–										
9	VPA	−0.41	0.35	0.31	0.44	0.14	0.35	0.15	0.49	–									
10	WL	−0.07	0.58	0.48	0.40	0.12	0.51	0.25	0.44	0.47	–								
Perceptual Speed																			
11	Let	−0.39	0.43	0.47	0.50	0.17	0.46	0.15	0.45	0.45	0.50	–							
12	Pat	−0.54	0.37	0.40	0.48	0.26	0.47	0.03	0.39	0.34	0.39	0.62	–						
13	Shp	−0.55	0.24	0.21	0.43	0.21	0.37	−0.02	0.38	0.34	0.28	0.52	0.58	–					
General Knowledge																			
14	Syn	0.41	0.38	0.30	0.04	−0.01	0.30	0.30	0.03	0.15	0.46	0.14	−0.02	−0.10	–				
15	Ant	0.31	0.34	0.26	0.08	0.03	0.25	0.24	0.04	0.16	0.44	0.17	0.03	−0.10	0.77	–			
16	Gen	0.27	0.41	0.41	0.22	0.09	0.38	0.35	0.09	0.23	0.52	0.24	0.08	0.01	0.70	0.67	–		
Event Understanding/Memory																			
17	EvK	−0.06	0.41	0.39	0.30	0.08	0.35	0.26	0.22	0.25	0.48	0.38	0.30	0.14	0.28	0.26	0.33	–	
18	Seg	−0.06	0.39	0.37	0.29	0.11	0.33	0.16	0.21	0.23	0.43	0.25	0.23	0.24	0.18	0.13	0.31	0.33	–
19	EMe	−0.13	0.53	0.41	0.44	0.27	0.40	0.25	0.32	0.42	0.63	0.48	0.39	0.32	0.36	0.32	0.40	0.52	.48

Threshold value for $p = .05$ is $r = .14$, for $p = .01$, $r = .18$, and for p = .001, r = .23.

N=208. RSpn, Reading Span; OSpn, Operation Span; SSpn, Symmetry Span; Rw/D, Reading with Distraction; Ruff, Ruff Figural Fluency; Trls, Trailmaking; SRem, Selective Reminding; VPA, Verbal Paired Associates; WL, Wordlist Memory; Let, Letter Comparison; Pat, Pattern Comparison; Shp, Shape Comparison; Syn, Synonym Vocabulary; Ant, Antonym Vocabulary; Gen, General Information; EvK, Event Knowledge; Seg, Event Segmentation; EMe, Event Recall. Scores for Rw/D, Trls and Shp were inverted (multiplied by −1) so that for all measures, higher scores indicate better performance.

Table 4

Measurement Model for General Cognitive Ability Constructs

	WM	Episodic	Perceptual	General Knowledge
Reading Span	.70			
Operation Span	.74			
Symmetry Span	.70			
Selective Reminding		.68		
Paired Associates		.67		
Wordlist Memory		.62		
Letter Comparison			.80	
Pattern Comparison			.79	
Shape Comparison			−.68	
Synonym Vocabulary				.89
Antonym Vocabulary				.85
General Information				.80
Factor correlations				
Working Memory Capacity	–			
Episodic Memory	.75	–		
Perceptual Speed	.78	.78	–	
General Knowledge	.41	.18	.09	–

Note. Operation Span x Reading Span correlated error, *r*=.42.

Loadings not shown were set to zero.

Table 5

Measurement Model for Event Understanding Variables

Variable	Event Knowledge	Segment. Ability	Event Memory
Event Knowledge – Breakfast	.48		
Event Knowledge – Party	.72		
Event Knowledge – Planter	.83		
Segmentation Ability – Breakfast		.80	
Segmentation Ability – Party		.85	
Segmentation Ability – Planter		.82	
Event Recall – Breakfast			.75
Event Recall – Party			.76
Event Recall – Planter			.80
Factor correlations			
Event Knowledge	–		
Segmentation Ability	.40	–	
Event Recall	.65	.58	–

Loadings not shown were set to zero.

Table 6

Confirmatory Factor Analyses Testing for Factorial Invariance

	χ^2(df)	*p*	CFI	NFI	RMSEA	$\Delta\chi^2$(df)	*p*
Ability Model							
Model 1	106.78 (46)	<.01	.95	.92	.08	–	
Model 1a	141.63 (92)	<.001	.96	.89	.05	–	
Model 1b	165.45 (101)	<.001	.94	.87	.06	23.82 (9)	<.01
Model 1c	170.79 (105)	<.001	.94	.86	.06	5.43 (4)	.25
Model 1d	175.50 (112)	<.001	.94	.86	.05	4.71 (7)	.70
Event Model							
Model 2	12.26 (24)	.98	1.00	.98	.00	–	
Model 2a	52.40 (48)	.31	.99	.94	.02	–	
Model 2b	54.09 (54)	.47	1.00	.93	.00	1.69 (6)	.95
Model 2c	64.18 (57)	.24	.99	.92	.03	10.09 (3)	.02
Model 2d	66.60 (60)	.26	.99	.92	.02	2.42 (3)	.49

Note. Nested model comparisons compare each model to preceding model. For the Ability Model, correlated errors (Operation Span x Reading Span) were constrained to equivalence in Model 2d.

Table 7

Hierarchical Regression Analysis Predicting Event Recall

	Total R^2	**ΔR^2**	**ΔF**	**df**	β	***t***
Step 1	.137	.137	16.33***	2, 205		
Age					−.190	2.89
Education					.350	5.33
Step 2	.459	.321	29.85***	4, 201		
Working Memory Capacity					.199	2.79
Episodic Memory					.283	3.92
General Knowledge					.216	2.78
Perceptual Speed					.168	2.27
Step 3	.534	.075	15.97***	2, 199		
Event Knowledge					.213	3.87
Segmentation Ability					.204	3.57
Step 4	.535	.001	0.55	1, 200		
Event Know. × Segment. Ability					−.037	−0.74

Note. Composite variables created by averaging z scores for variables representing each construct.

* $p<.05$,

** $p<.01$,

*** $p<.001$

Table 8

Regression Analyses Predicting Event Recall

		Segmentation Ability			
		Unique R^2			
Event Recall	**Total R^2**	**Breakfast**	**Party**	**Planter**	**Common R^2**
Breakfast	$.163^{**}$	$.021^{*}$	$.019^{*}$	.000	.123
Party	$.193^{**}$	$.033^{**}$	.010	.003	.146
Planter	$.175^{**}$	.010	$.021^{*}$	.005	.139

Note. For each analysis, *df* = (3, 204). Common R^2 = Total R^2 - Σ(Unique R^2s). Unique R^2s are squared semi-partial correlations.

[*] p<.05;

[**] p<.01