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Event boundaries structure the contents of long-term memory in younger and older adults

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ABSTRACT

Event boundaries impose structure on how events are stored in long-term memory. Research with young adults has shown that associations within events are stronger than those that cross event boundaries. Recently, this effect was observed in both young and old adults using movie stimuli (Davis, Chemnitz, et al., 2021). Here, we test whether this effect extends to written narratives. Young and old participants read a series of narratives that were interspersed with temporal shifts in the storyline meant to elicit the perception of an event boundary. Later, participants were cued with sentences and were asked to recall the sentence that immediately followed. We expected participants would have worse memory when a cue and correct answer flanked a boundary than when it did not. In Experiment 1, we found that despite older adults' lower performance overall, both age groups had lower accuracy for cues that flanked a boundary, compared to cues that elicited a response from within the same event. Experiment 2 replicated the results from Experiment 1. Our results support past work that did not find age differences in event perception and demonstrate that older and younger adults may store events similarly in long-term memory.

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Episodic memory, or the vivid re-experiencing of the past, is essential for engaging in daily activities. In social settings, it is helpful to recall past experiences to avoid reintroducing yourself to someone you have already met, or in health settings it may be important to recall all the medications that you have taken that week. Unfortunately, the cognitive ability to retrieve past events from memory declines with age. As a field, cognitive ageing has amassed ample evidence of *how* episodic memory declines with age. For example, we know that older adults recall fewer event details than younger adults (e.g., Addis et al., 2008; Levine et al., 2002; St. Jacques & Levine, 2007; Wank et al., 2020), more false information (Devitt & Schacter, 2016 for review; c.f. Davis, Chemnitz, et al., 2021; Diamond et al., 2020) and the gist of events rather than specific details (e.g., Flores, Hargis,et al., 2017; Gallo et al., 2019). Although we can describe the ways in which episodic memory declines with age, there is substantial debate about the underlying mechanisms for *why* these observations occur. In the current experiment, we examined one possible explanation for age-related decline in episodic memory by testing whether older adults differ from younger adults in their perception of events and how those events are organised in long-term memory.

When someone recalls the details of an event, such as a morning before work, they tend to explain what happened by relaying a series of smaller events (e.g., I walked my dog, ate breakfast, brushed my teeth and checked the news). According to Event Segmentation Theory (EST; Zacks et al., 2007) and other influential models of event perception (see the Event Horizon Model; Radvansky, 2012), this recall pattern occurs because continuous experiences are automatically segmented into discrete units and stored in long-term memory as distinct events. During event perception, people construct event models in working memory that contain the details of an on-going event, comprised of dynamic sensory-perceptual information and prior knowledge (or schemas) from similar past events. Prior knowledge allows people to make predictions about what should occur next in sequence. When current event models do not match what a person has predicted, such that there are abrupt changes to spatial context, temporal framework or actor goals, then an *event boundary* is perceived (but see Wang & Egner, 2022, who demonstrate that event boundaries may also be driven by internal control processes). Event boundaries indicate that the current event model must be updated to incorporate the changes in the on-going experience (see Radvansky & Zacks, 2017; Zacks, 2020 for reviews).

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Past research in support of EST suggests that the perception of event boundaries is not only important for updating events in working memory, but also for encoding events into long-term memory. When people segment videos of an actor performing a daily activity (i.e., decide when one event ends and another begins, such as rinsing their car and polishing the wheels), people tend to be highly similar in where they indicate event boundaries (e.g., Speer et al., 2003; Zacks et al., 2010). Critically, people who are more similar to their peers in event segmentation tend to also have better episodic memory for those events, even after controlling for other cognitive abilities (Sargent et al., 2013; Zacks et al., 2006). The relationship between event boundaries and episodic memory is also made clear by other work showing that memory for an event can be improved if event boundaries are made more distinct by either cuing participants to them, or by encouraging active segmentation during event perception (as opposed to natural viewing) (Flores, Bailey, et al., 2017; Gold et al., 2017). Introducing event boundaries where they do not naturally exist can also benefit memory for both naturalistic events (Gold et al., 2017) and in more typical memory tasks, such as word list recall (Logie & Donaldson, 2021; Pettijohn et al., 2016). Together, this research emphasises the significance of event boundaries for episodic memory.

One reason that event segmentation may benefit episodic memory is because boundaries help to organise the contents of long-term memory. When event boundaries are detected, people rapidly reinstate the just-experienced event model (Silva et al., 2019; Sols et al., 2017) and hippocampal activity increases (Baldassano et al., 2017; Ben-Yakov et al., 2013; Ben-Yakov & Henson, 2018; Reagh et al., 2020), presumably reflecting binding of that event for long-term memory storage (see Ross & Easton, 2021 for review). Thus, episodic memories are not encoded randomly, they are structured such that episodes start and end within the confines of event boundaries. This structure that event boundaries provide can be observed behaviourally. For example, associations within events tend to be stronger than those that cross event boundaries, such that if participants are cued with details from the middle of an event, memory for what happens next is better than if the cue comes from just prior to an event boundary (i.e., the cue and correct answer flank an event boundary). This memory benefit for within-event cues has been observed in young adults with virtual reality (Horner et al., 2016), narratives (Ezzyat & Davachi, 2011) and movies (Davis, Chemnitz, et al., 2021). These findings and other similar work (DuBrow & Davachi, 2016; Polyn et al., 2009) demonstrate that event boundaries act as a mechanism to structure the contents of long-term memory.

It is clear that the ability to perceive event boundaries, update event models, and store those events in long-term memory is an essential component of episodic memory. What is currently unclear is whether these cognitive processes decline with advancing age and if they contribute to age-related deficits in episodic memory. EST proposes that event segmentation operates as a mechanism of attentional control, in that it requires the ability to sustain attention on currently relevant content (i.e., the current event) and regulate when additional processing resources need to be allocated, such as moments in time where there is high prediction error and event models must be updated (i.e., at event boundaries; Zacks et al., 2007). A theoretical framework for cognitive ageing outlined by Hasher and Zacks (1988; the Inhibitory Deficit Theory) proposes that ageing is accompanied by declining attentional control, which has downstream effects on other cognitive abilities. In support of this theory, there is a vast ageing literature to indicate that older adults have difficulties controlling their attention. For example, older adults take longer than young adults to filter distracting information (Jost et al., 2011; Schwarzkopp et al., 2016) and have deficits in the ability to reallocate attention to targets in visual working memory tasks (Henderson et al., 2020). Further, older adults' difficulties with attention have been shown to influence performance on associative memory tasks (e.g., Campbell et al., 2010, 2014; Davis, Foy, et al., 2021; James et al., 2016; Powell et al., 2018). In the context of event perception and episodic memory, the inability to maintain focus on current event models would render older adults unable to construct accurate models and/or update those models as effectively as young adults (Zacks & Sargent, 2010). If this is the case, then problems with event perception could explain age-related deficits in episodic memory.

Prior work suggests that older adults may have deficits in the ability to construct and update event models. Some studies have found that older adults are worse at event segmentation than younger adults. Zacks and colleagues (2006) found that older adults were idiosyncratic in their event segmentation and that less segmentation agreement was related to poorer memory for the events (see also Bailey et al., 2013). This finding was replicated and extended by Kurby and Zacks (2011, 2019), who showed that older adults also have difficulties recognising the hierarchical structure of event activities in comparison to younger adults. Other work has shown that it may require more effort for older adults to update their event models (Morrow et al., 1994, 1997) and that they may engage in different updating processes than young adults (Bailey & Zacks, 2015). Further, there is some neuroimaging evidence to suggest that age is related to idiosyncratic neural activity during event perception (Campbell et al., 2015; Geerligs et al., 2018) and attenuated hippocampal activation at event boundaries that relates to performance on a separate episodic memory task (Reagh et al., 2020). Although it is difficult to determine the cause of this idiosyncratic responding and dampened hippocampal response, it may reflect age-related deficits in event boundary detection or deficits in binding event details (or some combination of both).

Other work suggests no age-related decline in the ability to construct and update event models. For example, some studies (using various stimulus modalities, e.g., films and narratives) have not been able to replicate age differences in event segmentation (Kurby et al., 2014; Magliano et al., 2012) and have even shown preserved neural event segmentation with age (Kurby & Zacks, 2018). Past research from the discourse processing literature has shown that both older and younger adults slow down when reading event boundary sentences (e.g., Radvansky et al., 2003; Radvansky & Copeland, 2001), which is presumed to relate to event model updating (Zwaan, 1996; Zwaan et al., 1998; but see Pettijohn & Radvansky, 2016). Additionally, both age groups appear to effectively update event models at spatial, temporal or goal shifts in a storyline, as evidenced by prior event model information becoming less available following a shift compared to no shift (Radvansky et al., 2003; Radvansky & Curiel, 1998). Therefore, there is ample evidence to suggest that processing at the event level may remain intact with age. That said, most of these studies have measured event segmentation and event model updating in the short-term – few studies have investigated whether age affects the way event boundaries impose structure on episodic events in *long-term memory* (but see Folville et al., 2020). If older adults can detect event boundaries and update event models, it is possible that episodic memory declines are caused by deficits in how those boundaries are used to organise the contents of long-term memory.

Recently, Davis and colleagues (2021) tested this question using movie stimuli. In their experiment, younger and older adults watched an 8-min movie and were then cued with short movie clips that either came from the middle of a scene or just prior to a scene change (i.e., event boundary). Participants were asked to recall what happened next in the movie with the expectation that recalling the next event would be more difficult across event boundaries because the cue and correct answer should be from separate event models. Their results showed that both age groups had similar overall accuracy on the task and had the same memory benefit for clips that were taken from the middle of the event compared to the boundary cue. These findings suggest that older adults do not differ in how events are organised in long-term memory. That said, there were a few limitations with this design. Firstly, this effect was tested with only one movie (a suspenseful Alfred Hitchcock film). Thus, it is difficult to know whether this effect is specific to the movie or if it will generalise to other stimuli. Additionally, the boundary cues were decided by scene changes in the movie. Scene changes are natural boundaries, but the consequence is that the cues were not counterbalanced, such that each cue could not serve as both a within-event and boundary cue across participants. This leaves open the possibility that there may be something intrinsic about the cues in the middle of the event that were more memorable than the cues at the end of the scene. Another potential issue is that the cues were video clips from the film. It is well known that older adults have difficulties with self-initiated processes, such as retrieval searches and attentional control (Hasher et al., 2001; Hasher & Zacks, 1979), and that age differences in memory are minimised when greater environmental support is provided at retrieval (Craik & Byrd, 1982). The video cues at retrieval provide dynamic visual and auditory information that may have helped older adults (in particular) to reinstate the events. It is possible that if the perceptual components are stripped from the cues, older adults will have more difficulty retrieving the appropriate event model from long-term memory (potentially due to a lessened ability to supress interference from other similar event models; Radvansky et al., 2005). Ultimately, it is unclear whether older adults will still show this memory benefit for content within an event compared to between in a scenario in which there is less environmental support at encoding and from the cues at retrieval.

To test this question, we opted to use narrative stimuli. Narratives do not provide the same number of perceptual features that movies do and allow for greater experimental control over the memory stimuli. As such, narratives resolve the issues in Davis, Chemnitz, et al.'s (2021) previous design. Although narratives are not the same as our daily, dynamic experiences, narratives describe events and interactions that can serve as a reflection of real life (see Willems et al., 2020 for discussion on narratives in neuroscience). In the current experiment, we had younger and older adults read a series of narratives taken from Ezzyat and Davachi (2011). In each narrative, boundary sentences were points at which there was a temporal shift in the storyline as indicated by the adverb, "A while later … ", at the beginning of the sentence. "A moment later … " was also added to some sentences to serve as a within-event control. Following reading the stories, participants were cued with sentences from the narratives and asked to recall the sentence that followed. The sentence cues either preceded a boundary sentence (preboundary), were the boundary sentence, preceded the control sentence (precontrol), or were the control sentence. In their experiment, Ezzyat and Davachi found that young adults had worse memory for the preboundary cues compared to the other cue types, which did not differ in memory accuracy. We expected to replicate this finding in our sample of young adults. Further, if older adults have no deficit in using event boundaries to organise the contents of long-term memory, we expected to replicate Davis, Chemnitz, et al. (2021) and find a similar benefit for within-event cues compared to preboundary cues in older adults. Alternatively, if older adults' performance in Davis, Chemnitz, et al. was driven by the type of stimuli used (i.e., movies) or the lack of counterbalancing of the cues, we may find that older adults do not show this benefit for within- vs. between-event cues. Support for this prediction would be reflected by no difference in accuracy for the preboundary cue compared to the other cue types in older adults only. Additionally, we expect boundary sentences to be read more slowly than control sentences, in line with the previous work (Radvansky & Copeland, 2010; Rinck & Weber, 2003; Zwaan, 1996; Zwaan et al., 1998). Both boundary and control sentences have additional words at the beginning that should increase reading time in comparison to preboundary/precontrol sentences; however, only boundary sentences should require additional processing time to update one's event model in working memory. Thus, RTs serve as an implicit measure of event boundary perception during encoding.

In Experiment 1, we collected data online from a sample of undergraduate students and local community-dwelling older adults. We replicated Davis, Chemnitz and colleagues' (2021) main finding that both age groups had worse memory when cues and the correct answer flank a boundary sentence compared to other within-event cues. In Experiment 2, we replicated our results from Experiment 1 using a new sample from an online participant recruitment platform. Here, we describe the methods and results from each experiment together for the sake of brevity.

Method

Participants

Ezzyat and Davachi (2011) had a sample of 23 young adults and tested the main effect of cue condition using a one-way analysis of variance (ANOVA), which yielded an effect size of $f = 0.62$; a large effect (Cohen, 1992). In the current experiment, we planned to run a 2 (Age: young, old) × 4 (Condition: preboundary, boundary, precontrol, control) mixed ANOVA. Davis, Chemnitz, et al. (2021) used a similar analysis with 24 older adults and 25 younger adults, but had insufficient evidence to detect an Age × Cue interaction ($BF_{incl} = 0.57$), thus we assumed that if an interaction existed, it would be a small effect. To determine sample size, an a priori power analysis using G*Power (Faul et al., 2007) was run (alpha = .05 and power = 80%). The results of the analysis indicated that to detect a small effect ($\eta 2p = .02$), 70 participants were required. Therefore, we aimed to collect data from 40 participants in each age group in both experiments to obtain a minimum sample of 35 per group.

In Experiment 1, older adults were recruited from a community participant pool and were compensated with admission to a draw for a $50 gift card to a local bookstore chain. Younger adults were recruited through SONA, the psychology department's online participant pool, and were compensated with one-course credit. Both groups were recruited in Canada and run online (due to the pandemic). Sixty-one younger adults and 40 older adults were tested. We excluded/replaced participants for the following reasons: Participants who obtained perfect accuracy and responded in the memory task in a way that suggested that they took notes during encoding (Young $N = 1$), participants who indicated that they did not pay attention during the task (Young $N = 19$, Old $N = 1$), participants who explicitly indicated, "do not keep my data" (Young $N = 2$), participants who failed all three attention checks (Young $N = 2$, Old $N = 1$), participants who had a reaction time standard deviation (SD) that was 3 SDs beyond the mean during the encoding task (suggesting that they may not have read the stories in one sitting or without distraction; Young $N = 1$). An additional two older adults exited the experiment prior to their data saving. The final sample included 36 younger adults, aged 18–28 years old (30 females; $M_{age} = 19.50$, $SD = 2.24$) and 36 older adults, aged 60–80 years old (26 females; $M_{age} = 68.90$, $SD = 5.70$).

In Experiment 2, participants were recruited through Prolific (an online participant platform; https://www.prolific.co/) and paid £8.00. The Prolific criteria were set such that participants had to be located in the United States, aged 18–28 or 60–80 years old, and have a minimum approval rate of 80. Prolific subjects were not approved if they timed out the task or did not attempt multiple tasks with some degree of effort (Young $N = 1$; Old $N = 1$). Data were collected and approved for 41 young adults and 39 older adults. Participants were excluded for having perfect accuracy and answers in the memory task that suggested that they took notes (Young $N = 2$), if they admitted that they did not pay attention during the task (Young $N = 1$, Old $N = 1$), and if they had a reaction time SD that was 3 SDs beyond the mean during the encoding task (Young $N = 2$). No participants failed the attention checks or indicated that we should not keep their data. The final sample included 36 younger adults, aged 18–28 years old (24 females; $M_{age} = 22.40$, $SD = 3.10$) and 38 older adults, aged 60–74 years old (26 females; $M_{age} = 65.10$, $SD = 4.70$).

To test whether there were age differences and/or differences in education and vocabulary across experiments, we entered these data into two separate 2 (Age: Young, Old) × 2 (Experiment: 1, 2) ANOVAs. First, older adults were more highly educated than younger adults, $F(1, 140) = 19.64$, $p < .001$. Participants in Experiment 2 trended towards being more educated than participants in Experiment 1, $F(1, 140) = 3.78$, $p = .054$. The interaction was not significant, $F(1, 140) = .004$, $p = .950$. On the Shipley Vocabulary test (Shipley & Burlingame, 1941), older adults had higher scores than younger adults, $F(1, 142) = 64.35$, $p < .001$, as is typically found in the literature (see Verhaeghen, 2003 for meta-analysis). There was also a

Table 1. Means and standard deviations for demographic variables.

	Experiment 1		Experiment 2	
	Young	*Old*	*Young*	*Old*
Age	19.50 (2.24)	68.90 (5.70)	22.40 (3.10)	65.10 (4.70)
Vocabulary	28.17 (4.40)	34.31 (3.01)	31.97 (3.55)	35.08 (2.77)
Education	12.60 (3.64)	15.40 (3.70)	13.81 (4.57)	16.69 (3.39)

Note. Standard deviations are in brackets.

main effect of Experiment ($p < .001$), however it was superseded by a significant Age Group × Experiment interaction, F (1, 142) = 6.92, p = .009. This interaction was driven by young adults in Experiment 1 having lower vocabulary scores than those in Experiment 2, t (70) = 4.04, $p < .001$. There was no difference in vocabulary between Experiments 1 and 2 for older adults ($p > .05$).[1] See Table 1 for demographics.

Narratives

Three narratives were adapted from Ezzyat and Davachi (2011; originally from Speer & Zacks, 2005). Each narrative contained a central character who was engaged in a daily activity (writing an essay, doing laundry at the laundry mat and cooking dinner). Throughout the narrative, two types of adverbs were added to the beginning of some of the sentences: For the *boundary sentences*, "A while later … ", and for the *control sentences*, "A moment later … " The boundary adverb indicates a long temporal shift in the storyline suggesting that the previous event has ended and a new one is beginning. For example:

(1) " … Sam thought about two other classes for which he had read the play.
(2) A while later, he took out a blank piece of paper and started outlining his report.
(3) Sam heard the phone ring but did not answer it.
(4) His sister told him it was for her since she was looking for a job.
(5) A moment later, he thought about her college graduation ceremony last month.
(6) Sam jotted down some notes about how to write his introduction … "

In this excerpt, the second line is the boundary sentence, and the fifth line is the control sentence. The sentence that proceeds the boundary and control are the preboundary and precontrol, respectively. Other sentences that are not assigned to condition are fillers that help construct the story (all story stimuli are available through the OSF link provided in the data availability statement). These adverbs were previously piloted in an experiment by Ezzyat and Davachi (reported in their supplemental materials), in which they show that participants perceived "A while later … " as a boundary more often than "A moment later … " Each narrative had three versions, which differed in placement of the adverbs such that once a sentence was used as a boundary in one version it was not reused as a boundary sentence in another (as with the control sentences), and these were counterbalanced across participants.

To shorten the length of the task for online testing, two modifications were made to the original narratives: We chose three of the six stories from the original experiment and reduced the number of boundary and control sentences. This resulted in six boundary and six control sentences per story (total of 18 each) and an equivalent number of preboundary and precontrol sentences.

Procedure

The experiment was approved and carried out in line with the requirements instituted by the Office of Research Ethics at Brock University. In Experiment 1, undergraduate participants were given the experiment link through SONA to complete the task at their own convenience. Older adult community participants were scheduled an appointment with a research assistant who helped them access the link and troubleshoot technological issues. The research assistant was available to answer questions about the task instructions, but it was emphasised that the experiment contained all necessary instructions to complete the task on their own. Anecdotally, few older adults spoke with the research assistant after beginning the task. In Experiment 2, both older and younger adult participants were tested through Prolific and participated in the task at their own convenience. All data were collected online; consequently, the size of participant's monitors could not be controlled, but a minimum size requirement for the browser was set to 800 × 400 pixels and the allowable web browsers were Google Chrome and Mozilla Firefox. The tasks were programmed with JavaScript using the jsPsych library, version 6.0.4 (de Leeuw, 2015; https://www.jspsych.org/7.0/) and hosted on an Amazon Web Server.

The procedure was closely in line with the method used in Ezzyat and Davachi (2011). During the encoding task, participants read all three stories one sentence at a time, at their own pace, controlled by a button press (font size: 25px). Each sentence was presented centrally on a white background in black text, with a brief fixation (1000 ms) between sentences. Participants were told when one story finished and the next began, at which time they were given 15 s to rest their eyes. The order of the stories was randomly selected from three possible sequences via a JavaScript function at the beginning of the experiment script. Reaction time (RT) to advance the screen was collected to measure sentence reading time.

Following encoding, participants completed a 2-back task to serve as a filler (~5 min; stimuli were numbers) and then completed a cued-recall task. In this task, participants were cued with a sentence from the narratives on a white background in black text (font size: 25px) shown in the same temporal order as they were presented at encoding. The sentence cues were either *boundary* or *control* sentences with the adverbs removed or were the sentences that came immediately before the boundary (*preboundary*) or control sentences (*precontrol*). For each preboundary-boundary and precontrol-control pair, only one sentence from the pair was selected as the cue. For example, if the preboundary sentence was selected as the cue, the sentence that immediately followed (boundary) was not also a cue. This way, the correct answer to a preboundary cue was not also a cue itself. This resulted in a total of nine trials/condition. On each trial, participants were prompted to recall what happened next in the story as accurately as possible. If they could not remember what happened next, they were asked to recall the next thing that they could remember. Responses were typed into a response box and there was no time limit to respond. When participants were done responding, they clicked a green *Continue* button with their cursor to start the next trial.

Following the cognitive tasks, participants completed the Shipley Vocabulary test, and some demographic questions (e.g., age, sex, English as a first language), including questions about current stress and sleep.[2] Following the demographic questions, participants were asked to indicate what best described their attention level during the experiment out of the following three options: "I had a lot of difficulty paying attention during this task", "I'm not too sure", "I had no difficulty directing my attention to this task". Then, based on their attention level, they answered whether their data should be used ("Yes", "No", "I don't know what this means"). The responses to these questions were used as exclusion criteria, such that if a participant indicated that they had difficulty with attention and/or not to use their data, they were excluded. As an additional attention check, participants also briefly described the instructions for each task after they were presented (for the 2-back, it was after the practice trials). If participants were unable to explain the task instructions for all three tasks, they were excluded. The entire experiment took approximately 1-hour to complete.

Results

Data were analysed using mixed effects modelling, which can better account for variability across individual sentences and stories than a standard ANOVA approach.[3] Analyses were done in R (version 4.0.3) using the lme4 package (Bates et al., 2015). For RT analyses, data were submitted to a linear mixed effects model using the lme() function. For the accuracy analyses, data were submitted to a logistic mixed effects model using the glmer() function. The sjPlot package (Lüdecke, 2021) was used to generate confidence intervals and *p*-values. All models were built hierarchically such that single random and fixed effects were added until additional predictors did not improve model fit (e.g., Sommet & Morselli, 2017). In these cases, the most parsimonious model was retained. To determine model fit, models were compared using a likelihood ratio test. For all primary analyses, five models were tested. First, to determine the random effects structure, two intercept only models were tested, which included a model with Participant, then with the addition of Narrative. Participant and Narrative were treated as random effects at both the intercept and slope. To test the main questions of interest, each predictor variable was added as a fixed effect in turn: Condition, then Age, then the Condition × Age interaction. See Table 2 for descriptive statistics.

Table 2. Reading time and cued-recall accuracy means and standard deviations.

	Experiment 1		Experiment 2	
	Young	*Old*	*Young*	*Old*
Reaction time				
Preboundary	8.00 (.46)	8.24 (.45)	7.74 (.58)	7.96 (.52)
Boundary	8.15 (.45)	8.34 (.42)	7.89 (.56)	8.09 (.51)
Precontrol	8.02 (.51)	8.22 (.45)	7.71 (.58)	7.95 (.55)
Control	8.12 (.46)	8.31 (.41)	7.83 (.56)	8.06 (.51)
Accuracy				
Preboundary	.36 (.48)	.18 (.38)	.23 (.42)	.23 (.42)
Boundary	.40 (.49)	.19 (.39)	.24 (.43)	.33 (.47)
Precontrol	.40 (.49)	.24 (43)	.27 (.44)	.27 (.45)
Control	.42 (.50)	.26 (.44)	.28 (.45)	.30 (.46)

Note. Reaction times are the log-transformed values. Accuracy is represented as proportion correct. SDs are in brackets.

Reaction time

Reaction times from the encoding task were trimmed using the *trimr* R package (Grange, 2015). Within each participant, RTs less than 200 ms were removed, then reaction times ± 3 SD beyond the mean were trimmed. On average, older adults retained 99% of trials (SD = .01) in Experiment 1 and 98% (SD = .01) in Experiment 2 and young adults retained 98% of trials (SD = .01) in Experiment 1 and 98% (SD = .01) in Experiment 2. To adjust for the positively skewed RT distribution, the RTs were log transformed. Age was entered into the linear mixed model as a categorical variable (young, old) and Condition was entered as an orthogonal contrast. The first contrast compared preboundary and precontrol to boundary and control. We expected that the boundary and control sentences would take longer to read than the preboundary and precontrol sentences due to the addition of the adverbs extending the length of the sentence (in line with Ezzyat & Davachi, 2011). The second contrast compared boundary to control. We expected that boundary sentences may be read more slowly than control sentences, which is expected to reflect event updating at the boundary (Radvansky & Copeland, 2001; Zwaan, 1996). Then, the final contrast compared preboundary to precontrol. There was no reason to suspect that these conditions would differ in reading time.

In Experiment 1, the initial intercept model containing only Participant indicated that RTs were highly correlated within participants, as would be expected (ICC = .46). The inclusion of Narrative as a random effect improved model fit [$\chi^2(1) = 88.67$, $p < .001$; ICC = .47], thus both random effects were retained for the main analysis. The addition of Condition to the model improved fit [$\chi^2(3) = 137.11$, $p < .001$], as did Age [$\chi^2(1) = 7.93$, $p = .005$]; however, the addition of the Condition × Age interaction did not [$\chi^2(3) = 4.07$, $p = .254$]. Therefore, the best model included a main effect of Condition and a main effect of Age (see Table 3 for RT model summaries). The estimates for this model show that the first contrast was significant,

Table 3. Reaction time model summaries for best fit models.

	Experiment 1			Experiment 2			Combined		
Predictors	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*
Intercept	8.28	8.16–8.39	**<0.001**	8.01	7.88–8.15	**<0.001**	8.14	8.04–8.24	**<0.001**
Contrast 1	0.11	0.09–0.13	**<0.001**	0.13	0.11–0.15	**<0.001**	0.12	0.11–0.13	**<0.001**
Contrast 2	−0.03	−0.06 – −0.00	**0.023**	−0.04	−0.07 – −0.01	**0.004**	−0.04	−0.06 – −0.02	**<0.001**
Contrast 3	0.00	−0.03–0.03	0.979	−0.02	−0.05–0.01	0.209	−0.01	−0.03–0.01	0.362
Age group (Young)	−0.20	−0.35 – −0.06	**0.004**	−0.22	−0.41 – −0.04	**0.019**	−0.21	−0.34 – −0.09	**0.001**
Random effects									
σ^2	0.11			0.13			0.12		
τ_{00}	0.09 $_{\text{Participant}}$			0.17 $_{\text{Participant}}$			0.15 $_{\text{Participant}}$		
	<0.00 $_{\text{Story Number}}$			<0.00 $_{\text{Story Number}}$			<0.00 $_{\text{Story Number}}$		
ICC	0.45			0.56			0.55		
N	72 $_{\text{Participant}}$			74 $_{\text{Participant}}$			146 $_{\text{Participant}}$		
	3 $_{\text{Story Number}}$			3 $_{\text{Story Number}}$			3 $_{\text{Story Number}}$		
Observations	5105			5224			10329		
Marginal R^2/Conditional R^2	0.061/0.485			0.054/0.584			0.052/0.569		

Note. Contrast 1: preboundary, precontrol vs. boundary, control. Contrast 2: boundary vs. control. Contrast 3: preboundary vs. control.

$B = 0.11$, $SE = 0.01$, $t = 11.56$, 95% CI [0.09, 0.13], indicating that boundary and control sentences were read more slowly than the preboundary and precontrol sentences, likely a result of the additional words in these sentences. Critically, the second contrast was also significant, $B = -0.03$, $SE = 0.01$, $t = 2.28$, 95% CI [−0.06, −0.00], such that boundary sentences were read more slowly than control sentences, in line with Radvansky and Copeland (2001). The final contrast comparing preboundary to precontrol sentences was not significant, $B = 0.00$, $SE = 0.01$, $t = 0.03$, 95% CI [−0.03, 0.03]. Lastly, the main effect of Age, $B = -0.20$, $SE = 0.07$, $t = 2.86$, 95% CI [−0.35, −0.06], indicates that on average older adults read the sentences slower than young adults.

Experiment 2 replicated the results from Experiment 1. The intercept only model that included Participant indicated that RTs were highly correlated within participants (ICC = .56). Then, including Narrative in the random effects model improved model fit [$\chi^2(1) = 34.74$, $p < .001$; ICC = .57]. When Condition [$\chi^2(3) = 178.63$, $p < .001$] and Age [$\chi^2(1) = 5.39$, $p = .020$] were added to the models, model fit was improved, but model fit did not improve with the addition of the interaction term [$\chi^2(3) = 2.36$, $p = .502$]. Therefore, in line with Experiment 1, the best model was the model with main effects of Condition and Age. The estimates from this model indicate that the first contrast comparing preboundary and precontrol to boundary and control was significant, $B = 0.13$, $SE = 0.01$, $t = 13.10$, 95% CI [0.11, 0.15], as was the second contrast comparing boundary to control, $B = -0.04$, $SE = 0.01$, $t = 2.92$, 95% CI [−0.07, −0.01]; the final contrast comparing preboundary to precontrol was not significant, $B = -0.02$, $SE = 0.01$, $t = 1.26$, 95% CI [−0.05, 0.01]. The main effect of Age indicated that on average, older adults responded more slowly than younger adults, $B = -0.22$, $SE = 0.10$, $t = 2.34$, 95% CI [−0.41, −0.04]. Therefore, across both experiments, we show that both older and younger adults read boundary and control sentences more slowly than the sentences that came immediately before them. Critically, both age groups also responded more slowly to boundary than control sentences, indicating that all participants allocated additional resources to update their event model at the boundary to a greater extent than the control.

Accuracy

Accuracy on the cued-recall task was scored by two research assistants who each coded half of the files. Pilot data (not included in the sample) from 10 participants were scored by both research assistants to calculate inter-rater reliability, which was sufficiently high (ICC = .92, 95% CI [.91, .94]; McGraw & Wong, 1996). We used the exact liberal scoring criteria as Ezzyat and Davachi (2011). This approach helped avoid floor performance in both groups and was sufficient to indicate whether a participant has associated the cue with the following sentence. Previous work has shown that surface-form memory (i.e., memory for exact words of a sentence) for text is rapidly forgotten in favour of gist-level memory for the event or situation (Kintsch et al., 1990; reviewed in Radvansky, 2008). Further, in Ezzyat and Davachi (2011), young adults' performance on the cued-recall task was low (Experiment 1 proportion correct range: .18–.33), despite using a liberal scoring criteria. Thus, here the criteria were set such that correct answers needed to only capture the gist of what happened next (i.e., not verbatim). However, correct responses needed to clearly represent the sentence that immediately followed and not events that happened later in the narrative. For example, correct next sentence recall for cue Sentence 4 was Sentence 5 ("A moment later, he thought about her college graduation ceremony last month"). Two examples of correct responses from younger adults are as follows: "He thought about his sister's graduation the last month" and "He started thinking about the college graduation ceremony that was last month". Two examples from older adults: "He thought about her graduation from college" and "He started thinking about when his sister graduated from college". An example of an incorrect answer from a younger adult was "He wrote notes for his introduction" and from an older adult, "She was graduating soon. She shared an apartment with Sam". For each trial, participants were assigned 0 for incorrect responses and 1 for correct responses. See Table 4 for accuracy model summaries.

Age was entered into the general linear mixed model as a categorical variable (young, old) and Condition was entered as a Helmert contrast. The first contrast compared preboundary to boundary, precontrol, and control cues. Accuracy was expected to be worse in the preboundary condition compared to the other cue conditions because next-sentence recall crossed an event boundary while for the other cues it did not. The second contrast compared boundary to precontrol and control to test that accuracy for next-sentence recall within events was similar for the boundary and control conditions. Then, the third contrast compared precontrol to control, in which we predicted that there would be no difference in accuracy (in line with Ezzyat & Davachi, 2011).

In Experiment 1, the intercept only model with both Narrative and Participant was a better fit than Participant alone [Participant ICC: 0.13, Participant + Narrative ICC: .15; $\chi^2(1) = 14.54$, $p < .001$]. Both random effects were retained for the remaining analyses. Model fit improved when Condition [$\chi^2(3) = 10.16$, $p = .017$] and Age [$\chi^2(1) = 25.63$, $p < .001$] were added to the model, but not the interaction term [$\chi^2(3) = 1.99$, $p = .576$]. Therefore, the best model was the model with the main effects of Condition and Age. The coefficients from this model showed that the first contrast was significant, Odds Ratio (OR) = 1.32, *SE* = 0.12, 95% CI [1.07, 1.62], indicating that the preboundary cues yielded lower accuracy than all other cue types. The second, OR = 1.20, *SE* = 0.11, 95% CI [0.97, 1.49], and third contrast, OR = 1.11, *SE* = 0.13, 95% CI [0.87, 1.41], were not significant, suggesting that cues that probe next-sentence recall within events yield similar accuracy. The main effect of Age indicated that older adults recalled fewer sentences on average than young adults, OR = 2.46, *SE* = 0.16, 95% CI [1.79, 3.38].

In Experiment 2, the intercept model with Participant was the best model as adding Narrative did not improve model fit (Participant ICC: .06, Participant + Narrative ICC: .07; $\chi^2(1) = 0.77$, $p = .382$). The model with Participant only was retained for the remaining analyses, but it is worth noting that including Narrative as a random effect does not change the results. When Condition was added to the model it improved fit [$\chi^2(3) = 8.50$, $p = .037$], but neither Age nor the interaction term improved fit [Age: $\chi^2(1) = 1.14$, $p = .285$; interaction: $\chi^2(3) = 3.12$, $p = .373$]. Thus, in the Prolific sample older and younger adults showed similar recall. The coefficients from the Condition only model indicate that the first contrast (contrasting preboundary cues with all other sentence types) was significant, OR = 1.34, *SE* = 0.11, 95% CI [1.09, 1.65], but neither of the other contrasts reached significance (*ps* > .3), in line with the results from Experiment 1. Together, these results largely replicate the central findings from Ezzyat and Davachi (2011) that within-event associations are stronger than those that cross event boundaries. Our results also conceptually replicate Davis, Chemnitz, and colleagues' (2021) finding that ageing may not affect event boundary updating or organisation in long-term memory.

Combined experiment analyses

The results from both experiments show that despite older adults reading the stories more slowly and, in at least Experiment 1, performing worse on average on the cued-recall task, there was no evidence for the Condition × Age interaction. This finding suggests that older adults perceived event boundaries, updated their event models and stored events in long-term memory in the same way as younger adults. To confirm that this finding was not a result of low power to detect the effects of interest, we combined the data from Experiment 1 and Experiment 2 (Young $N = 72$; Old $N = 74$) and ran the same analyses for both reaction time and accuracy. These analyses largely replicated the reported results, such that adding the interaction term to the model did not improve model fit for both RT, $\chi^2(3) = 3.03$, $p = .386$, and accuracy, $\chi^2(3) = 1.04$, $p = .793$. These combined analyses suggest that power was not likely an issue.

Next, we tested the possibility that older adults' performance might be explained by their higher vocabulary scores. To test this, Shipley vocabulary scores were added to the best model (models with the main effect of Condition and Age) for both RT and accuracy using the combined experiment data. For RT, adding Shipley scores to the model marginally improved model fit, $\chi^2(1) = 3.87$, $p = .049$, such that better vocabulary related to faster reading times, $B = -0.02$, $SE = 0.01$, $t = 1.96$, 95% CI [−0.03, −0.00]. However, adding interaction terms for Condition x Shipley [$\chi^2(3) = 3.39$, $p = .34$] or Age x Shipley [$\chi^2(1) = 0.69$, $p = .41$], did not improve model fit, suggesting that Shipley performance did not influence these effects. For accuracy, adding Shipley vocabulary scores to the model did not improve fit [$\chi^2(1) = 1.32$, $p = .253$], suggesting that vocabulary did not influence accuracy on the cued-recall task. Together, these results suggest that our findings are not driven by group differences in vocabulary.

Discussion

In two experiments, with two different participant populations, we examined whether declines in episodic memory may be caused by deficits in event perception and/or long-term memory organisation for events. Participants read three narratives that included temporal shifts in the storyline meant to elicit the perception of event boundaries. We tested memory by cuing participants with sentences from the story and asking them to recall the sentence that immediately followed the cue. Our experiments yielded two findings. First, in line with previous work (e.g., Radvansky et al., 2003; Radvansky &

Table 4. Accuracy model summaries for best fit models.

	Experiment 1			Experiment 2			Combined		
Predictors	*Odds Ratios*	*CI*	*p*	*Odds Ratios*	*CI*	*p*	*Odds Ratios*	*CI*	*p*
Intercept	0.26	0.18–0.36	**<0.001**	0.35	0.30–0.40	**<0.001**	0.31	0.24–0.39	**<0.001**
Contrast 1	1.32	1.07–1.62	**0.010**	1.34	1.09–1.65	**0.006**	1.33	1.15–1.54	**<0.001**
Contrast 2	1.20	0.97–1.49	0.100	0.97	0.78–1.20	0.769	1.08	0.93–1.25	0.344
Contrast 3	1.11	0.87–1.41	0.414	1.12	0.87–1.42	0.381	1.11	0.94–1.32	0.231
Age group (Young)	2.46	1.79–3.38	**<0.001**	–	–	–	1.45	1.15–1.82	**0.001**
Random effects									
σ^2	3.29			3.29			3.29		
τ_{00}	0.32 Participant			0.22 Participant			0.35 Participant		
	0.04 Story Number			–			0.02 Story Number		
ICC	0.10			0.06			0.10		
N	72 Participant			74 Participant			146 Participant		
	3 Story Number			–			3 Story Number		
Observations	2592			2664			5256		
Marginal R^2/Conditional R^2	0.057/0.152			0.005/0.069			0.014/0.114		

Note. Contrast 1: preboundary vs. boundary, precontrol, control. Contrast 2: boundary vs. precontrol, control. Contrast 3: precontrol vs. control.

Copeland, 2001), both younger and older adults read boundary sentences more slowly than control sentences, suggesting that both age groups similarly perceived the event boundaries and allocated more processing resources to allow for event model updating. Second and most importantly, both younger and older adults had better next-sentence recall when memory was cued with sentences from the middle of an event compared to when the cue and correct answer crossed an event boundary. This finding suggests that both age groups used event boundaries to help segment and store the components of the narrative as discrete units in long-term memory. This does not appear to be an issue of insufficient power, as a combined analysis across both experiments yielded the same results. Further, we also demonstrated that vocabulary was not related to our effects of interest, so the current results cannot be explained by older adults' superior vocabulary. Our findings support past work that argues that there may be no age-related decline in event perception in narrative text and adds to this field by demonstrating that events are organised in long-term memory similarly in younger and older adults.

As expected, older and younger adults showed increased reading time for boundary sentences compared to control sentences. Originally, the effect of boundaries on reading time was presumed to reflect the allocation of additional processing resources that are required to update event models (Zwaan, 1996; Zwaan et al., 1998). This interpretation fits with recent work showing that pupil dilation and eye movement synchrony increases at event boundaries, presumably reflecting increased cognitive effort and increased attention to goal-relevant parts of an activity, respectively (Clewett & Davachi, 2017; Davis, Chemnitz, et al., 2021, supplemental analyses; Smith et al., 2021). More recently, Pettijohn and Radvansky (2016) have argued that increased reading time at event boundaries may actually be better accounted for by unexpectedness in the narrative (as shifts in time, goals or space may be surprising). For a particular shift in a storyline to be surprising or unexpected, it requires the reader to have constructed an accurate event model so that casual breaks can be detected moving from one event to the next. Regardless of the underlying cause of increased reading time, these slowdowns can still be considered a reflection of event model quality. Prior work has shown that older adults are slowed at event boundaries sentences similarly to young adults (Radvansky et al., 2003; Radvansky & Copeland, 2001) and in both experiments, we replicated this effect. Together, these findings add to the literature showing that older adults construct accurate event models and perceive temporal shifts in the storyline at event boundaries. Whether longer reading times at boundaries reflect the allocation of processing resources or violations of expectation requires a more thorough investigation beyond the scope of this paper.

Both younger and older adults showed worse memory for the preboundary cues than the other cue types, indicating that event boundaries serve to organise events in long-term memory. This finding directly replicates Ezzyat and Davachi (2011) and other similar work that has shown that younger adults have stronger associations for occurrences within an event than between events (Davis, Chemnitz, et al., 2021; DuBrow & Davachi, 2016; Horner et al., 2016; Polyn et al., 2009). Critically, our findings also conceptually replicate Davis, Chemnitz and colleagues (2021) who previously extended this finding to older adults using movie stimuli. Replicating this finding in older adults, especially using a well-controlled stimulus set in a different modality, is important for understanding age differences in episodic memory. The ability to segment on-going events into discrete units and store those units efficiently in long-term memory is important for event memory (e.g., Sargent et al., 2013). If older adults show deficits in either event boundary perception and/or long-term memory storage of those events, then it would provide insight into the potential mechanisms underlying age-related declines in episodic memory. Our findings suggest that the ability to detect event boundaries and use those event boundaries to organise long-term memory may not be impacted by age and may not contribute to age differences in episodic memory. This said, although we have now replicated this effect three times (previously with a movie and in two experiments documented here), our interpretations are based on a lack of an Age × Condition interaction. It is important for the field of ageing and event cognition that other groups replicate these results with larger sample sizes and to explore the extent of this effect with other stimuli and/or methods.

Despite older and younger adults showing the expected recall pattern for the cue conditions (i.e., better memory within events than between), overall memory performance on the cued-recall task was worse for older adults than younger adults in Experiment 1. The fact that older adults performed worse overall fits with the vast literature that shows that episodic memory declines with age. One possible explanation for older adults' poor accuracy for next sentence recall could be that they may experience more interference from other similar or proximal parts of the story (Rotblatt et al., 2015; Tolentino et al., 2012). Past work has shown that older adults experience more interference from previous events and are worse at actively supressing competing information from irrelevant event models (Radvansky et al., 1996, 2005; Wahlheim & Zacks, 2019), which can cause memory errors (Devitt et al., 2016; Kersten et al., 2013). Thus, older adults may update their event models and store those models in long-term memory in the same way as younger adults, but their next-sentence recall across all conditions may be generally worse due to deficient inhibitory control.

In Experiment 2, we did not find age differences in overall accuracy. This result appears to be driven both by Prolific older adults performing better than our community older adults, $p = .010$, $d = .63$, and by Prolific younger adults performing worse than our undergraduate sample, $p < .001$, $d = .95$ (see Table 2 for means). Differences in the older adult samples could be due to Prolific older adults' greater experience with cognitive tasks compared to our community sample of older adults, who only participate in research periodically. Indeed, the Prolific profiles of our older adult sample indicated that these participants had participated in anywhere from 18 to 1593 (median: 300) online tasks, which may have allowed them to develop effective strategies contributing to their overall higher accuracy (despite similar benefits for within-event cues; see Merz et al., 2022 for a similar report of high-performing older adults in online samples). As for the younger adults, it is possible that Prolific users performed worse than undergraduates due genuine cognitive differences between samples. However, this explanation is not probable given that years of education and vocabulary scores were numerically higher in the Prolific sample than the undergraduate sample (see Table 1). More plausibly, other factors, such as differences in motivation to complete the experiment or distractions in the environment, may be driving the difference between the young adult samples. Undergraduate participants who were unmotivated or inattentive during the task likely admitted this to us in our attention check question (19 undergraduates were excluded for this reason). Alternatively, Prolific users are paid for their time and according to Prolific guidelines, their work can be rejected if it is not completed with effort. Despite emphasising in the instructions that their honesty on the attention check would not affect payment, Prolific participants may have been more resistant to admit if they were inattentive resulting in overall lower accuracy in this group. This explanation makes sense given that we excluded only two (one young and one old) Prolific users for this reason. That said, these sample differences should not impact the interpretation of our data because our main question in these experiments was whether the within > between pattern differs between young and old, which it did not, and this effect was robust in both experiments. Inattention during the task in any group or individual participant should affect accuracy on all conditions equally. The differences in overall age effects across these participant populations may be an important consideration for all cognitive ageing researchers who are planning online research projects during the pandemic.

Event Segmentation Theory would predict that older adults should have worse event perception than young adults due to deficits in attention that should lead to inaccurate construction of event models and inefficient event model updating. If older adults are unable to construct and update accurate event models, then it should be evident in how events are stored in long-term memory. Work by Zacks and colleagues suggests that event perception is impaired in older adults because they tend to have a worse agreement in where they perceive event boundaries and poor recognition of event structure (Kurby & Zacks, 2011, 2019; Zacks et al., 2006; c.f. Kurby et al., 2014; Kurby & Zacks, 2018). However, our current results fit with other research that suggests event perception is relatively preserved with age. There is evidence that both older and younger adults allocate additional processing resources at event boundaries (Radvansky et al., 2003; Radvansky & Copeland, 2001) and update event models at these time points (Magliano et al., 2012; Radvansky et al., 2003, 2015; Radvansky & Copeland, 2006), which they store as discrete units in long-term memory (Davis, Chemnitz, et al., 2021). A good question at this point then is what is causing the mixed results in the literature? One possible explanation is the use of different stimuli. Much of the work that has found age differences in event perception has been with videos of daily activities (e.g., setting up a printer and washing dishes), whereas Davis, Chemnitz et al. used a Hollywood film. In the current study, we specifically selected narratives to reduce perceptual features that may have helped older adults encode and retrieve events in Davis, Chemnitz, et al. However, it is possible that *both* Hollywood movies and narrative texts are easier for older adults to segment and store in memory than other types of naturalistic stimuli. Movies and narratives include explicit cues at boundaries (i.e., "A while later … " in narratives, or scene changes in movies), that should encourage segmentation for all readers/viewers and may be particularly beneficial for older adults who have difficulties with attentional control (Hasher et al., 2007). Indeed, experiments that have found preserved event cognition in ageing tend to be with tasks that used narrative text (e.g., Radvansky et al., 1996, 2003; but see Radvansky et al., 2015 who did not find age differences in event model updating with spatial contexts, or Magliano et al., 2012 with picture stories).

To further explore age differences in long-term memory for episodic events, it may be important to use non-narrative, naturalistic stimuli that do not have obvious cues for event updating, such as real-life events (e.g., tours; Diamond et al., 2020; Diamond & Levine, 2020), or videos of daily activities (commonly used by Jeff Zacks and colleagues). If age differences in event segmentation and long-term memory are observed with these stimuli, it would suggest that older adults experience difficulty with event processing when attention must be self-initiated. That said, evidence against our results being a consequence of stimulus selection comes from work by Folville et al. (2020). In this experiment, older and younger adults did various real-life events around a university campus (e.g., go to a bookshop, buy a drink and a postcard), while their experiences were recorded with wearable cameras. When participants were later asked to replay each event, the researchers found that the rate of temporal compression for the different events was the same across both age groups. Although this research did not explore event boundaries per se, their findings suggest that the structure of how episodic events are organised in long-term memory is preserved with age. Together, it is clear that research on how age affects the structure of long-term memory for events is limited and thus, further exploration of this topic is warranted.

Another possible explanation for the mixed findings is that event segmentation and event boundary perception is influenced by prior knowledge (Zacks et al., 2021). The construction of an accurate event model requires that a person attends to the appropriate incoming information, but event models also receive input from past similar events that help people make predictions about what should happen next (Kurby & Zacks, 2021; Wahlheim & Zacks, 2019). Indeed, knowledge for everyday events has been shown to predict event memory above and beyond other cognitive abilities (Sargent et al., 2013). It is well known that ageing is characterised by declining episodic memory, but intact or even increasing semantic knowledge (Umanath & Marsh, 2014 for review). Thus, it is possible that older adults can overcome deficits in attentional control that affect event perception by leveraging their prior knowledge about an event.

This prediction was recently supported by an eye-tracking study showing that knowledge improves predictive processing during naturalistic viewing in both younger and older adults (Smith et al., 2021). They showed that older adults were less likely to view goal-relevant information or have synchronous eye movements at event boundaries than young adults (but see Davis, Chemnitz, et al., 2021). However, this age difference did not hold up when participants were unfamiliar with a given activity (e.g., installing a video console for older adults or balancing a cheque book for younger adults). That is, all participants spent more time viewing goal-irrelevant information in the scene when the activity was unfamiliar to them. This familiarity effect extended to memory for the events, such that both younger and older adults had better memory for events they were familiar with than those that they were not. Thus, it is possible that some cognitive ageing experiments use events that are less familiar to older adults, leading to artificially reduced performance. In the current experiment, we did not ask participants how familiar they were with the activities that they read. Fortunately, by adding Narratives as a random effect in our model, we accounted for any variability caused by differences between the narratives. It would be important for future work to consider how knowledgeable participants are about the activity they are watching or reading because knowledge may play a larger role in event perception than previously appreciated (Kurby & Zacks, 2021; Newberry & Bailey, 2019; Pitts et al., 2021).

In summary, the results from our experiments add to the growing body of literature which suggests that older adults can detect event boundaries. We have also shown that both younger and older adults can use event boundaries in narratives to organise the contents of long-term memory. This effect was previously demonstrated with movies; however, to our knowledge, we are the first to extend this finding to narratives. Older adults' experience deficits in episodic memory, but given these data and previous work on event perception, it is possible that this deficit is not caused by deficiencies in event perception or how those events are ultimately structured in long-term memory. Future work should continue to explore what may be driving age differences in some of the event cognition literature as well as other causes of age-related episodic memory decline.

Notes

1. In Experiment 1, one young adult and one older adult did not report their age, but selected the appropriate age group bracket in a separate question. In Experiment 2, one older adult did not report their sex. Two older adults did not report their education: one in Experiment 1 and one in Experiment 2.
2. In Experiment 1, participants filled out the Multifactorial Memory Scale (Troyer & Rich, 2002), however, due to experimenter error, the wrong sub-section was used so it was not analysed, and in Experiment 2, it was excluded from the procedure.

3. It is worth noting that the overall results from the analyses using a mixed ANOVA do not substantially differ from the results reported here.

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Data availability statement

All data, analysis code and materials can be found on Open Science Framework (OSF): https://osf.io/4za2q/?view_only=1d1cba00343342f8b07cdb5fcfeca413.

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