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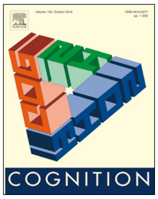

Differential effects of knowledge and aging on the encoding and retrieval of everyday activities☆

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ABSTRACT

We deconstruct continuous streams of action into smaller, meaningful events. Research has shown that the ability to segment continuous activity into such events and remember their contents declines with age; however, knowledge improves with age. We investigated how young and older adults use knowledge to more efficiently encode and later remember information from everyday events by having participants view a series of self-paced slideshows depicting everyday activities. For some activities, older adults produce more normative scripts than do young adults (*older adult activities*) and for other activities, young adults produce more normative scripts than do older adults (*young adult activities*). Overall, participants viewed event boundaries longer than within events (i.e., the event boundary advantage) replicating prior research (e.g., Hard, Recchia, & Tversky, 2011). Importantly, older adults demonstrated the boundary advantage for the older adult activities but not the young adult activities, and they also had better recognition memory for the older adult activities than the young adult activities. We also found that the magnitude of a participant's boundary advantage was associated with better memory, but only for the less knowledgeable activities. Results indicate that older adults use their intact knowledge to better encode and remember everyday activities, but that knowledge and event segmentation may have independent influences on event memory.

1. Introduction

A common complaint among the elderly is difficulty with remembering recently experienced events (Commissaris, Ponds, & Jolles, 1998). They often report forgetting appointments, where they placed familiar items such as their keys, and recently learned names (Cutler & Grams, 1988; Gilewski, Zelinski, & Schaie, 1990). Subjective memory complaints align with older adults' performance on a variety of laboratory tasks that include features that approximate memory in everyday situations. In comparison to young adults, older adults tend to have poorer memory for the items placed on a grocery list (West, Crook, & Barron, 1992), for information on medicine labels (Park, Morrell, Frieske, & Kincaid, 1992) and for activities they have recently performed (Kausler, Lichty, & Freund, 1985). These deficits may partially be due to older adults' inability to inhibit task irrelevant information (Hasher & Zacks, 1988), slower processing speed (Salthouse, 1992) and inefficient use of memory strategies (Bailey, Dunlosky, & Hertzog, 2009; Dunlosky & Hertzog, 2001).

Despite age-related decline (e.g., Kramer, Bherer, Colcombe, Dong, & Greenough, 2004), knowledge structures remain intact and may even improve with age (Cornelius & Caspi, 1987; Park et al., 2002). For instance, adults expand their vocabularies with age and can correctly remember more facts about the world (Botwinick & Storandt, 1980; Park et al., 2002). Further, past work has typically observed little to no age-related differences in situation model processing during language comprehension (Magliano, Kopp, McNerney, Radvansky, & Zacks, 2012; Radvansky & Dijkstra, 2007). Important for the current study, older adults' ability to remember the steps associated with routine daily activities (i.e., script knowledge) remains intact (Light & Anderson, 1983). Previous research has addressed how semantic knowledge may influence performance on laboratory memory tasks (e.g., learning word or picture lists) (West et al., 1992) though most of this work has often focused on how prior knowledge can lead to memory errors. For instance, older adults generate more stereotypic inferences when reading (Radvansky, Copeland, & von Hippel, 2010) and are more likely to falsely recall words in a list they did not encounter (Norman & Schacter,

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1997).

To date, no one has investigated how the use of knowledge accrued across the lifespan may improve both encoding and subsequent memory for naturalistic dynamic activities; however, several separate lines of research speak to it. Older adults are better able to retrieve information when the to-be-remembered information is consistent with their prior experiences (Castel, 2005) and when they can use their intact verbal knowledge (Matzen & Benjamin, 2013). Knowledge may also support older adults' ability to encode new information (Miller, Cohen, & Wingfield, 2006). To offset failures in perception, episodic, and working memory, older adults may rely more on their intact crystalized knowledge when encoding and retrieving information from dynamic everyday activities.

1.1. *Segmentation of events*

Every day we encounter a continuous stream of activity, and while the sensory input is continuous, perception of the activity is not. Behavioral and physiological evidence indicate that we encode and comprehend continuous information presented over time, in part, by segmenting it into discrete events (i.e., *event segmentation*) based upon prior experiences and knowledge for the actions occurring in the activity (Zacks, Speer, Swallow, Braver, & Reynolds, 2007; Zacks, Tversky, & Iyer, 2001). *Events* are moments in time that correspond to recurring actions that have a clear beginning and end. *Event boundaries* are moments between two events when both perceptual and conceptual changes occur and when new information needs to be processed (Huff, Meitz, & Papenmeier, 2014; Newtson, Engquist, & Bois, 1977; Zacks, 2004).

There are important individual and age-related differences in people's ability to identify event boundaries. That is, young adults segment more normatively than do cognitively healthy older adults (Kurby & Zacks, 2011) who, in turn, segment more normatively than older adults with mild dementia (Bailey, Kurby, Giovannetti, & Zacks, 2013). Such effects are especially important because those who segment more normatively also have better episodic memory for the activity, even after accounting for other measures of cognitive ability (i.e., working memory capacity, perceptual speed, general knowledge) (Sargent et al., 2013; Zacks, Speer, Vettel, & Jacoby, 2006). Importantly, older adults who segment more normatively also have better episodic memory, which suggests that age-related declines in episodic memory are, in part, due to older adults' struggle to effectively segment activity into meaningful events (Kurby & Zacks, 2019). Thus, memory for everyday activities could potentially be improved by improving one's segmentation ability (Gold, Zacks, & Flores, 2017; Richmond, Gold, & Zacks, 2017).

1.2. *Boundaries are special*

Event boundaries are thought to be of greater information value as they are locations when a lot of change occurs and event models are updated (Huff et al., 2014). Because there is high inter- and intraindividual agreement in where boundaries are perceived (Speer, Zacks, & Reynolds, 2007) attending to these moments is important for comprehension of the activity (Schwan, Garsoffky, & Hesse, 2000). In fact, prior work using a covert measure of event segmentation (e.g., viewing time) has shown that when observers view self-paced slideshows depicting an action, they view slides depicting event boundaries longer than slides within an event, the *boundary viewing time advantage* (Hard, Recchia, & Tversky, 2011; Kosie & Baldwin, 2019a, 2019b). Presumably, this effect occurs because processing time is facilitated during an ongoing event when the incoming information aligns with our current understanding of the event. However, processing time is slowed at event boundaries when the incoming information is not coherent (Gernsbacher, 1990) or predictable (Zacks, Kurby, Eisenberg, & Haroutunian, 2011) and, thus, the event model must be updated. This additional processing time at event boundaries may occur as the observer perceives the completion of one action and constructs an event model for the new action (Gernsbacher, 1990).

Given that people differentially process event boundaries, it should be no surprise that event boundary content is privileged in memory. People remember information at event boundaries better than they remember within event content (Newtson & Engquist, 1976; Silva, Baldassano, & Fuentemilla, 2019; Swallow, Zacks, & Abrams, 2009). Further, removing event boundaries in a film impairs event memory (Schwan & Garsoffky, 2004), whereas making them more salient by either stopping a narrative at an event boundary or by cueing participants to event boundaries improves it in both young and older adults (Boltz, 1995; Gold et al., 2017; see however, Thompson & Radvansky, 2016).

1.3. *Bottom-up vs. top-down influences on event segmentation*

According to Event Segmentation Theory (EST), information from our current environment is represented in an *event model* in working memory, which is heavily influenced by perceptual factors. For example, event boundary perception coincides with changes in motion, actor body position, and changes in luminance (Cutting, Brunik, & Candan, 2012; Newtson et al., 1977). EST also proposes that event models are influenced by semantic knowledge (Zacks et al., 2007) and there is a growing body of evidence to support this notion (dance expertise Blasing, 2015; figure skating expertise Levine, Hirsh-Pasek, Pace, & Michnick Golinkoff, 2017; context and perspective Newberry & Bailey, 2019).

Though the aforementioned studies provide evidence that segmentation can be influenced by conceptual factors, the effects appear to be small and inconsistent, depending on the way in which semantic knowledge is operationalized. For example, top-down manipulations in the form of attitudes and novelty have had little effect on event perception (Huff et al., 2017). Perhaps even more surprisingly, segmentation behavior does not change when a film is watched either forward or backward (Hard, Tversky, & Lang, 2006) and participants still demonstrate the boundary advantage (i.e., people spend longer viewing event boundaries) whether slides are presented in a chronological or scrambled order (Hard et al., 2011). Such results indicate that event segmentation may be largely driven by perceptual bottom-up changes (Cutting et al., 2012), rather than one's knowledge. Further, Sargent et al. (2013), using structural equation modeling, found that event knowledge improves memory but does not exert a direct influence on the moment-to-moment perceptual processing associated with event segmentation.

Alternatively, it is possible that segmentation is influenced by conceptual factors, but methodological constraints in the prior work prevented such an effect from being observed. For instance, the top-down manipulations (i.e., fan attitude, scrambled order) may not have been strong enough or may not have removed enough contextual information to alter event segmentation processes. Moreover, Sargent et al. (2013) assessed general event knowledge rather than knowledge for the specific activities for which segmentation and memory were measured. It is possible that semantic memory may influence event encoding in a domain-specific fashion. That is, having a well-formed script for one activity (e.g., going out to eat) may not influence event perception for a video about a different activity (e.g., grocery shopping). Work in the expertise literature aligns with this claim: experts typically show domain specific effects of knowledge on segmentation (Newberry, Feller, & Bailey, submitted; Blasing, 2015; Levine et al., 2017) and memory (for review see Ericsson & Smith, 1991). If one does not have the relevant knowledge to aid in the understanding of an activity, then sensitivity to event structure may be impaired.

Taking these ideas together, semantic knowledge may influence segmentation behavior when relevant knowledge is available. This is particularly important for older adults, who demonstrate a decline in their perceptual/cognitive abilities (e.g., Kramer et al., 2004) but not in semantic knowledge (Cornelius & Caspi, 1987; Park et al., 2002). Thus, older adults may rely more on their prior knowledge than young adults when encoding an activity.

1.4. Hypotheses

The main goal of the current experiment was to evaluate how relevant semantic knowledge influences the encoding of everyday activities, and how these processes differ by age. Due to the perceptual-cognitive declines observed with age, older adults may rely on their well-formed event schemas more so than young adults when encoding and retrieving novel information (Castel, 2005; Light & Anderson, 1983; Umanath & Marsh, 2014). Most important for the current study, if older adults can activate relevant schema and scripts when viewing an everyday activity, then perhaps they can use this information to guide their understanding and offset age-related declines in segmentation ability. Alternatively, the segmentation and encoding of everyday events may be largely driven by perceptual changes and thus may be unaffected by conceptual manipulations (Cutting et al., 2012; Hard et al., 2006; Huff et al., 2017).

In the current study, participants viewed two slideshows depicting activities for which older adults have more normative scripts compared to young adults (e.g., gardening and balancing a checkbook) and two slideshows depicting activities for which young adults have more normative scripts compared to older adults (e.g., grocery shopping and getting ready for work). We chose the viewing time procedure because it is a reliable covert measure of event segmentation (Hard et al., 2011). This procedure has at least two advantages over the standard overt segmentation task, particularly for our aging sample. First, the viewing time task puts very low demand on working memory relative to the segmentation task, which involves the dual task of encoding the activity and maintaining the goal of pressing a button for each event boundary. Second, the viewing time task does not explicitly draw participants' attention to the event structure in the videos. As such, it can be used as a covert measure of event segmentation.

Because event boundaries are moments of change and, thus, the most informative moments in an activity stream, we hypothesized that participants–including older adults—would view slides depicting event boundaries longer than non-boundary slides (i.e., the boundary advantage; Hard et al., 2011; Kosie & Baldwin, 2019a, 2019b). Because older adults segment more idiosyncratically in comparison to young adults (Kurby & Zacks, 2011, 2019; Sargent et al., 2013) they may not demonstrate the boundary advantage or may show it to a lesser degree than young adults. However, these prior studies that observed age-related declines in segmentation ability all used the overt segmentation task. Thus, with the use of the covert viewing time task, it is also possible that older adults would demonstrate the boundary advantage to the same degree as young adults, given their preserved ability to process information at the event model level (e.g., Radvansky & Dijkstra, 2007). Importantly, we predicted that relevant semantic knowledge would increase the size of the boundary advantage for both young and older adults.

We also predicted that participants would have better memory for activities for which they were more knowledgeable (Chi, Glaser, & Farr, 2014). Finally, to the extent that relevant knowledge improves event encoding, it may also result in better long-term memory for the activities. If this is the case, we expected to observe that more effective encoding (i.e., larger boundary advantage) would result in better episodic memory. Alternatively, prior research indicates that knowledge influences memory for everyday activities independent of segmentation ability (Newberry et al., submitted; Sargent et al., 2013). That is, people may rely on semantic knowledge structures, such as schemas and scripts, to help them retrieve information (Anderson & Pichert, 1978; Hasher & Griffin, 1978) rather than the event models created during encoding. If this is the case, we expected to observe that knowledge would improve long-term memory independent of how effectively information is encoded.

2. Method

2.1. Participants

Twenty-one young adults (*M* age = 20.38, *SE* age = 0.82) were recruited from Kansas State University's Department of Psychological Sciences research pool and received course credit for their participation. Twenty healthy older adult participants (*M* age = 73.74, *SE* age = 1.07) were recruited from the local Manhattan community. Older adults received $10 cash payment per hour for their participation plus an extra $5 for traveling to participate in the experiment. To screen for cognitive impairment, older adults completed the AD8 screening interview (Galvin et al., 2005) and the Blessed dementia scale for physical, mental, and neurological health over the phone prior to coming to the lab (Katzman et al., 1983). Although no prior studies have directly evaluated the effects of script knowledge on viewing times, related studies have evaluated the effects of schema on memory (Bransford & Johnson, 1972– Experiment 2: Cohen's d = 0.77; Experiment 3: d = 0.97) and also the effect of event boundaries on viewing time (Hard et al., 2011: *d* = 1.48). Using the most conservative estimate of effect size from Bransford and Johnson (1972) (*d* = 0.77), we conducted a power analysis in G*Power 3.1.7. Based on a two-tailed hypothesis, with the effect size of *d* = 0.77, alpha = 0.05 and power of 0.80, G*Power indicated that a total sample size of 16 would be needed (Faul, Erdfelder, Lang, & Buchner, 2007). Thus, a sample size of 40 (*n* = 20 per age group) should be more than sufficient to detect our effects of interest.

The experiment lasted for two sessions. The first session lasted for two and a half hours and the second lasted approximately an hour. Data from the second session for one young adult participant was removed because the participant failed to return to the lab on the second day. All participants began the first session by completing the Mini Mental State Exam (MMSE) (Folstein, Robins, & Helzer, 1983) and all had scores above the minimal requirement (> 27). Informed consent was obtained from each participant prior to participating in accordance with Kansas State University's Institutional Review Board. All the data and materials are available on the OSF project page associated with this manuscript (https://osf.io/dx4th/) (Smith et al., 2019).

2.2. Materials and tasks

2.2.1. Slideshows

The viewing time task was adopted from Hard et al. (2011). Four videos of everyday activities were shot at a rate of 25 fps and depicted activities that young and older adults were more or less knowledgeable of (see Fig. 1). College students served as actors in each of the four videos. Some activities were *Older Adult activities*: planting a pot of flowers (Gardening: duration = 297 s) and balancing a checkbook (Checkbook: duration = 258 s). Other activities were *Young adult activities*: grocery shopping (Grocery: duration = 195 s) and getting ready for school/work (Getting ready: 213 s). We classified these activities according to the scripts provided from young and older adults in previous research (Rosen, Caplan, Sheesley, Rodriguez, & Grafman, 2003). Rosen et al. (2003) had young and older adults list the steps, from beginning to end, involved in various everyday activities. For several activities, young adults produced more normative steps than older adults, who tended to produce more idiosyncratic steps. We chose two of the activities for which Rosen et al. (2003) found the largest age-related differences in script knowledge: Grocery shopping and getting ready for work.

2.2.1.1. Determining the older adult activities. Using similar methods, our lab identified activities for which older adults produced more

Fig. 1. Sample slides taken from each of the four slideshows. Top row are the older adult activities: planting flowers & balancing a checkbook. Bottom row are the young adult activities: getting ready for work/school and grocery shopping.

normative steps than did young adults. We had an independent sample of 20 older adults (M age = 68.65, SE age = 1.25) and 20 young adults (M age = 18.65, SE age = 0.25) list the sequence of steps associated with a variety of different activities: Ironing a shirt, setting up a record player, planting a garden, balancing a checkbook, going to the dentist. Following the instructions outlined by Rosen et al. (2003), we identified the 18 most common unique steps participants mentioned for each activity. For the grocery shopping and getting ready for work activities, we used the scripts provided in Rosen et al. (2003) as the norm. After identifying the steps of each activity, two independent coders, coded the participant responses. The age group of the participant was unknown to one of the coders. Coders agreed on 90.4% of cases, (interrater Kappa = 0.81). Disagreements were resolved through thoughtful discussion to determine the final coding. Participants received a point for each of the normative steps that they included in their descriptions. The means we provide correspond to the proportion of steps participants within the age group successfully produced. We conducted four logistic mixed effects models to analyze differences between scripts written by older and young adults. Participant was treated as a random effect.

Consistent with Rosen et al. (2003), the quality of older adults' scripts for Grocery shopping (Older adults: $M = 0.46$, $SE = 0.03$; Young adults: $M = 0.55$, $SE = 0.03$), $\beta = 0.39$, $z = 1.72$, $p = 0.08$, and Getting ready for work/school (Older adults: $M = 0.41$, $SE = 0.03$; Young adults: $M = 0.48$, $SE = 0.03$, $\beta = 0.30$, $z = 1.93$, $p = 0.05$) were marginally poorer than those produced by young adults. Older adults produced better scripts for Balancing a checkbook (Older adults: $M = 0.43$, $SE = 0.03$; Young adults: $M = 0.18$, $SE = 0.03$), $\beta = -0.63$, $z = -3.13$, $p = 0.002$, and Planting a pot of flowers (Older adults: $M = 0.43$, $SE = 0.03$; Young adults: $M = 0.34$, $SE = 0.03$), $\beta = -0.36$, $z = -2.84$, $p = 0.03$. Importantly, while participants may be familiar with each of these activities, to some extent, we categorized them into the Older or Young adult activities based on the difference in the *quality* of the scripts that each age group produced. Lastly, we used the normative scripts when filming the videos, from which our slideshows were created.

Slideshows were created from each video by extracting a single frame every 1 s (Hard et al., 2011). They ranged in length from 193 to 298 slides. A 150 ms neutral gray screen was interleaved between slides to reduce apparent motion. Slideshows were self-paced. Participants advanced through them by pressing the spacebar on the computer's keyboard. Participants could not return to previously viewed slides. Participants were told to spend as much time on each slide as they wished because they would be asked to remember the actions from the slideshow later in the experiment. Viewing time was calculated as the latency between the onset of each slide and the click of the spacebar. Order of each slideshow was counterbalanced across participants using a 4 × 4 Williams Latin Square.

2.2.2. *Event memory tests*

Participants completed three long-term event memory tests for each slideshow after completing a psychometric test that served as a filler task after each slideshow. Measures included free recall, recognition, and temporal order memory, in that order. The order of each memory test was the same across participants and slideshows.

2.2.2.1. Recall test. Participants were given 5 min to recall what happened in the slideshow they just viewed in as much detail as possible in the order in which the actions in the slideshow occurred. Participants typed their recall into a text box. To score the free recall data, we first constructed a list of the basic actions performed by the actor in the slideshow using the action coding system (ACS) described by Schwartz, Reed, Montgomery, Palmer, and Mayer (1991). The ACS constructs goal hierarchies of action sequences (Schwartz et al., 1991) in which A1 units are the basic actions involved in completing a higher-level goal (i.e., pick up wallet, open it, and take the debit card out) and A2 units are higher-level sub-goals that encompass many A1s (i.e., pay for food). There were 84 A1 and 27 A2 units in Checkbook, 94 A1 and 12 A2 units in Gardening, 84 A1 and 19 A2 units in Getting Ready, and 74 A1 units and 14 A2 units in the Grocery slideshows. Two coders blind to the age group of the participant coded data from ten participants for each video (interrater Kappa = 0.79, $p < 0.001$ for A1 units and interrater Kappa = 0.93, $p < 0.001$ for A2 units). They compared their ratings and resolved any discrepancies. One of the two coders coded the remaining participant recall responses. The number of correctly recalled actions was the dependent measure. Recall data from participants were removed if the participant either did not report the contents of the slideshow or reported the activities from the wrong slideshow. This resulted in the removal of 6 observations from 5 participants. Three older adults reported the contents of the wrong

Fig. 2. Example slideshow.

slideshow when asked to report the contents of Grocery Shopping, and one older adult failed to recall anything from the Grocery slideshow. One young adult failed to report anything from the Getting Ready slideshow and one older adult reported the contents from the wrong slideshow when asked about Getting Ready.

2.2.2.2. Recognition test. Recognition memory was assessed using a two-alternative forced choice test. There were 20 total trials that each contained a target image and a distractor image. Distractor items were chosen from videos of the same actor in the same setting performing the same activity in a different order. For instance, in the gardening video, the actor entered the shot with the flowerpot. In the foil video, the actor entered the shot with the potting soil. Image pairs were presented side-by-side on the computer screen, and participants responded by selecting with the computer's mouse the slide they viewed in the slideshow. Order of presentation of the pair of images was randomized for each participant and placement of the correct answer was counterbalanced (left and right).

2.2.2.3. Order memory test. Order memory was also assessed using a two-alternative forced choice procedure. In this task, pairs of A1 action units from the slideshows were presented side by side and participants' task was to indicate which action occurred first.

2.2.3. Segmentation task

During the second session, participants viewed and segmented the film versions of the four activities, presented in the same order as the slideshows in the first session using the overt segmentation task. Participants were instructed to press the spacebar on a keyboard whenever they felt that "one meaningful unit of activity ends, and another begins" (Newtson, 1973). Participants were not given any additional information on how to segment the activity but instead were told that the researchers were interested in how they understood the activity. They began by segmenting the practice video. If they identified fewer than 6 meaningful boundaries (this value was unknown to the participants), then they were told that participants typically identify more units than what they did, and they were asked to redo the task by re-watching the video again until at least 6 event boundaries were identified. After successfully segmenting the practice video, participants segmented the 4 experimental videos.

2.2.4. Self-report knowledge ratings

At the very end of the experiment, participants were asked of their subjective familiarity with each of the activities. On each trial, participants were shown descriptions of two activities on the computer screen. Participants were asked to select the activity (either the one on the left or the one on the right) from the two descriptions they were more familiar doing. After making their selection, participants were asked to rate on a scale from 1 to 7 how much more familiar they were doing the activity they chose over the opposing activity. To test whether the older adults reported that they were more familiar with the older adult than the young adult activities, we ran a mixed effects logistic regression. Participant was treated at its intercept as a random effect. If an older adult activity was selected, then the response was coded as a 1 and a 0 if a young adult activity was selected. Older adults ($M = 0.17$, $SE = 0.02$) were significantly more likely than young adults ($M = 0.04$, $SE = 0.05$) to report that they were familiar performing the older adult activities, $\beta = 1.22$, $z = -2.22$, $p = 0.03$.

2.3. Design

The experiment was a 2 (Age group: Young vs. Older) × 2 (Activity: Young vs. Older) × 2 (Boundary Type: Boundary vs. Non-boundary) mixed design. Age was a between-subject variable, and Activity and Boundary Type were both within-subject variables.

2.4. Procedure

Testing took place in two sessions, separated by 1 week. Participants entered the lab one at a time. The first session lasted for approximately 150 min and the second was approximately 60 min. To screen for cognitive impairment, participants began the first session by completing the Mini Mental State Exam (MMSE). After completing the exam, participants practiced the viewing time task by viewing a slideshow of a man building a boat from toy blocks. Participants progressed through the slideshow at their own pace and viewing time on each slide was recorded (see Fig. 2). After practicing the viewing time procedure, participants practiced the three memory measures. Feedback was given on practice trials. After each participant completed the practice trials, they viewed a slideshow. After each slideshow, they completed a psychometric measure that served as a filler task during a 5-minute distraction interval. Psychometric measures included tests of participants' working memory capacity, general semantic knowledge, and processing speed. Descriptive statistics for each of these psychometric measures for older and young participants are provided in Table 1 in the Supplementary materials. After a filler task, participants completed the three event memory measures for the activities in the slideshow. On the second day, participants entered the lab, segmented the video versions of the slideshows, and completed the reading span and the Trail Making tasks.

3. Results

We will first describe results from the encoding measures, then the results from the event memory measures. Finally, we will discuss the relationship between the encoding and event memory measures. All analyses were conducted using R statistical software (version 3.1.1) with the lme4 library (Bates, Mächler, Bolker, & Walker, 2014). All significant interactions were probed using the multcomp library and *p* values for linear mixed effects models were estimated using the afex library (Bretz, Hothorn, & Westfall, 2002; Singmann, Bolker, Westfall, Højsgaard, & Fox, 2015).

3.1. Viewing time

Given that prior work has shown a boundary advantage such that observers spend more time looking at event boundaries than non-boundaries (Hard et al., 2011), we hypothesized that participants' viewing time would be longer for boundary slides compared to non-boundary slides. Further, we extended the original effect by examining whether older adults demonstrate the boundary advantage. Finally, we hypothesized that event knowledge would influence viewing time such that the boundary advantage should be larger for familiar than the unfamiliar activities. To evaluate these hypotheses, a generalized mixed effects model was used to predict the effects of type of Activity, Age group, and Boundary type (boundary vs. non-boundary) on viewing time. To analyze the effects of event perception on viewing time, we used locations where the participants themselves perceived event boundaries. Given that response latency data has a positive skew, the model specified a Gamma distribution (Lo & Andrews, 2015; Van Zandt, 2000; Young & Crumer, 2018). A log link function was used to linearize parameters. The Gamma regression model contained the fixed effects of Boundary type [coded as Boundary = 1 and Non-boundary = −1], Age group [Older = 1, Young = −1], and the Activity [Older adult activity = 1, Young adult activity = −1]. Participant and image were treated at their intercept as random effects. All means are reported in milliseconds.

We used the participants' own boundaries as a predictor of slide viewing time. Remember, that the slideshows consisted of every 25th frame from the video; thus, not all frames were represented in the slideshow. We categorized the closest frame in the slideshow to the frame number where the participant made the segmentation response as the event boundary. All other slides in the slideshows were categorized as non-boundaries. We found a significant boundary advantage whereby participants spent more time viewing event boundaries ($M = 1677$, $SE = 31$) than non-boundaries ($M = 1506$, $SE = 10$), $\beta = 0.03$, $t = 5.69$, $p < 0.001$. This effect replicates previous findings (Hard et al., 2011; Kosie & Baldwin, 2019a, 2019b) and supports the hypothesis that processing demands increase at event boundaries. Further, both older and young adults demonstrated the boundary advantage to the same extent as evident from a nonsignificant Age group × Boundary type interaction, $\beta = -0.005$, $t = -0.79$, $p = 0.43$. To our knowledge, this is the first experiment to demonstrate the boundary advantage effect in older adults, who, on average, spent more time viewing slides ($M = 2112$, $SE = 49$) than younger adults ($M = 901$, $SE = 8$), $\beta = 0.42$, $t = 5.79$, $p < 0.001$.

Most importantly, we observed a significant three-way interaction between Boundary type, Age group, and type of Activity (see Fig. 3), $\beta = 0.02$, $t = 3.70$, $p < 0.001$. We performed a series of planned comparisons to assess the extent to which both older and young adults demonstrated the boundary advantage within each activity. Using a Bonferroni correction, we adjust alpha to ($0.05/4 = 0.0125$) to prevent inflation of Type I error. Older adults demonstrated the boundary advantage for the older adult activities [Boundaries: ($M = 2277$, $SE = 64$); Non-boundaries: ($M = 2002$, $SE = 20$)], $\beta = 0.13$, $z = 5.75$, $p < 0.001$, but not for the young adult activities [Boundaries: ($M = 2239$, $SE = 74$); Non-boundaries: ($M = 2315$, $SE = 31$)], $\beta = -0.01$, $z = -0.63$, $p = 0.78$. Likewise, young adults demonstrated the boundary advantage for the young adult activities [Boundaries: ($M = 978$, $SE = 43$); Non-boundaries: ($M = 896$, $SE = 10$)], $\beta = 0.10$, $z = 3.98$, $p < 0.001$, but not for the older adult activities [Boundaries: ($M = 963$, $SE = 34$); Non-boundaries: ($M = 893$, $SE = 14$)], $\beta = 0.05$, $z = 2.26$, $p = 0.05$. Both groups were more sensitive to the event structure in the activities for which they had relevant prior knowledge.[1]

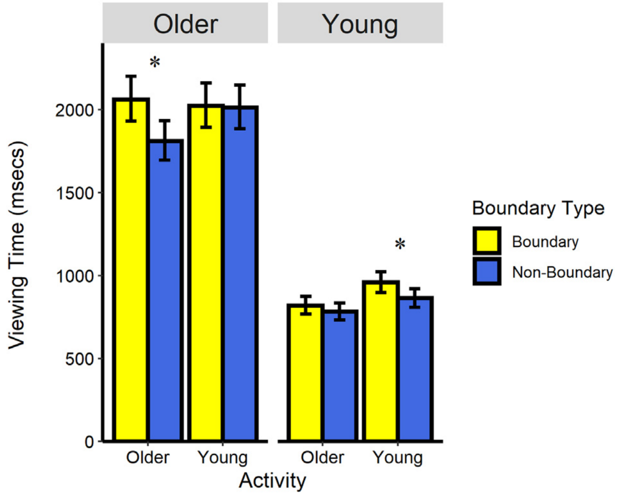

Fig. 3. Estimated viewing time as a function of age, boundary type, and activity. Event boundaries are self-identified. Asterisks above pairs of bars represent significant effects using an alpha level of 0.05. Error bars represent 95% confidence intervals to the estimated means.

3.2. Event memory

3.2.1. Recall

Event recall scores were the number of correctly recalled actions. Two different analyses were conducted. We first assessed the effect of knowledge on the number of A1 actions correctly recalled and then its effect on the number of A2 actions correctly recalled. Because the dependent measure is count data, we ran a mixed effects Poisson regression with the random intercept of participant and slideshow. Age group, Activity, and the interaction between Age group and Activity were treated as fixed effects. Older adults ($M = 15.24$, $SE = 0.84$) recalled significantly fewer A1 units than young adults ($M = 19.82$, $SE = 0.84$), $\beta = -0.13$, $z = -2.75$, $p = 0.006$, replicating previous findings (Sargent et al., 2013). Participants recalled the same number of A1 units in both older ($M = 15.57$, $SE = 0.83$) and young adult activities ($M = 19.82$, $SE = 0.86$), $\beta = -0.14$, $z = -1.18$, $p = 0.24$. Even though older adults more efficiently encoded the actions in the older adult activities compared to the young adult activities (see Fig. 3), they recalled the same number of A1 units in both activities, which is evident from a nonsignificant Age group by Activity interaction, $\beta = 0.02$, $z = 1.03$, $p = 0.30$.

For A2 units, older adults ($M = 9.13$, $SE = 0.47$) recalled significantly fewer units than young adults ($M = 11.94$, $SE = 0.40$), $\beta = -0.14$ $z = -3.66$, $p < 0.0001$. Again, neither the fixed effect of Activity [Older adult activities: ($M = 10.99$, $SE = 0.52$); Young adult activities: ($M = 10.18$, $SE = 0.38$)], $\beta = 0.03$, $z = 0.31$, $p = 0.76$, nor the Age group × Activity interaction was significant, $\beta = 0.002$, $z = 0.09$, $p = 0.93$.

3.2.2. Recognition

Cronbach's alpha for recognition performance across the four videos was 0.70. We analyzed recognition accuracy using a logistic mixed effects model (Agresti, 2007; Jaeger, 2008). The participant and the image were treated at their intercepts as random effects. The dependent variable was probability of correctly identification and age group [coded as Older = 1 and Young adult = −1] and activity [Older adult activities = 1, Young adult activities = −1] were predictors. Recognition performance did not differ by activity [Older adult activities: ($M = 0.71$, $SE = 0.01$); Young adult activities: ($M = 0.67$, $SE = 0.01$)], $\beta = 0.18$, $z = 1.93$, $p = 0.23$. Interestingly, recognition performance did not differ by age group [Older adults: ($M = 0.67$, $SE = 0.01$); Young adults: ($M = 0.70$, $SE = 0.01$)], $\beta = -0.10$, $z = -1.47$, $p = 0.14$. Importantly, we observed a significant Age group × Activity interaction, $\beta = 0.17$, $z = 4.02$, $p < 0.001$. Older adults had significantly better recognition memory for the older adult activities ($M = 0.72$, $SE = 0.02$) than for the young adult activities ($M = 0.62$, $SE = 0.02$), $\beta = 0.70$, $z = 2.27$, $p = 0.04$, but young adults' recognition memory did not differ between activities [Older adult activities: ($M = 0.70$, $SE = 0.02$); Young adult activities: ($M = 0.71$, $SE = 0.02$)], $\beta = -0.008$, $z = -0.03$, $p = 0.99$ (see Fig. 4). Older adults can utilize their intact knowledge structures when remembering content from novel, but relevant activities.

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[1] We conducted an analogous analysis using the normative boundaries determined from an independent sample of older adult participants. The results were similar (see Fig. 1 of the Supplementary materials).

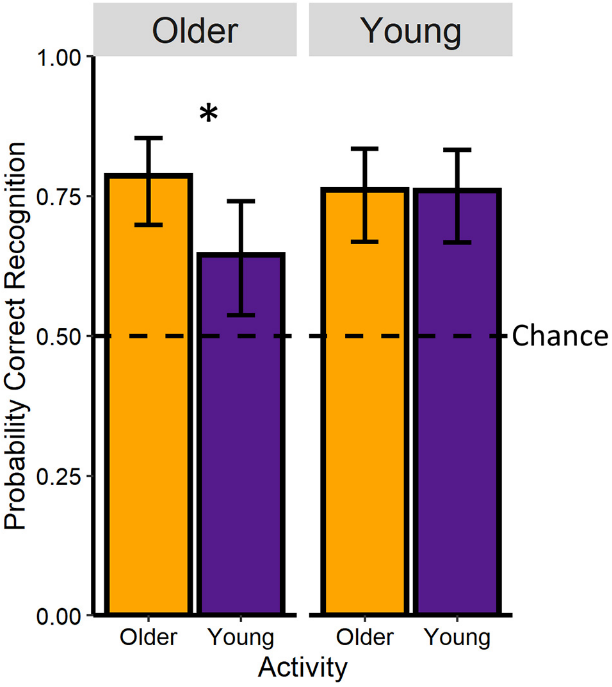

Fig. 4. Estimated recognition memory performance as a function of age and activity. Chance performance in the two-alternative forced choice task was 50%. Error bars represent 95% confidence intervals around the estimated means.

3.2.3. *Order memory*

Unfortunately, the reliability of the order memory measure was unacceptable ($\alpha = 0.19$). Given this poor reliability, order memory performance was removed from further analyses; however, the data is available to download at https://osf.io/dx4th/.

3.3. *Effects of viewing time on memory*

3.3.1. *Recall*

To evaluate the influence of effective encoding on event memory, we examined whether the size of one's boundary advantage predicted recall performance. Two analogous linear mixed effects models were conducted to explore how the boundary advantage predicted the number of A1 and A2 units participants successfully recalled. Age group, Activity, Boundary advantage, and all their interactions were included as fixed effects, and slideshow and participant were treated at their intercept as random effects. Prior to entry into the model, the boundary advantage was centered at its mean to remove nonessential multicollinearity between predictors. The boundary advantage did not predict either the number of correctly recalled A1 units, $\beta = 0.0004$, $t = 0.49$, $p = 0.63$, or A2 units, $\beta = 0.0005$, $t = 1.14$, $p = 0.26$. None of the other observed effects were statistically significant.

3.3.2. *Recognition*

Similar analyses were run to evaluate whether one's boundary advantage predicted recognition performance. Results indicated that those who demonstrated a larger boundary advantage had better recognition memory for the activities, $\beta = 0.0004$, $t = 2.04$, $p = 0.04$. Importantly, we also observed a significant three-way interaction between the Age group, Activity, and Boundary advantage, $\beta = -0.00005$, $t = -2.83$, $p = 0.005$. If knowledge influences memory by improving how the information is encoded, then the boundary advantage should predict memory better in activities for which participants have more normative knowledge (i.e., the slope between boundary advantage and recognition memory would be steeper for the knowledgeable activities). However, we found the boundary advantage only predicted recognition memory for the *unfamiliar* activity, for both age groups (see Fig. 5). For older adults, the boundary advantage predicted recognition memory in the young adult activities but not for older adult activities. Conversely for young adults, the boundary advantage only predicted recognition memory in the older adult activities. These results suggest that event encoding and knowledge have independent influences on event memory.

4. Discussion

Even though segmentation ability declines with age, knowledge increases across the lifespan (Umanath & Marsh, 2014). The accumulation and use of such knowledge may become increasingly important as we age. Older adults may rely more upon the use of prior experiences when encoding novel information, especially as their sensory/perceptual abilities begin to decline and retrieval from episodic long-term

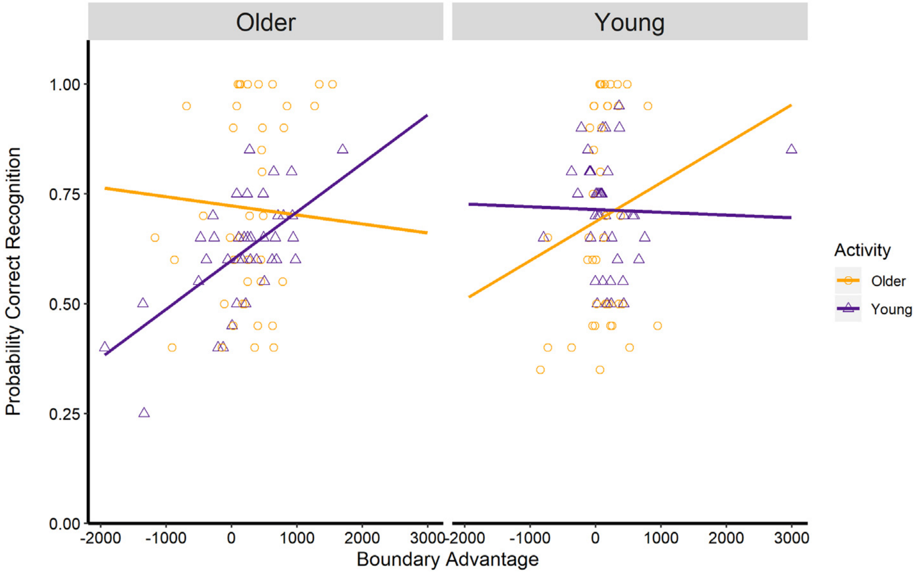

Fig. 5. Recognition performance as a function of age group, activity, and the boundary advantage. Points in the scatterplot represent the proportion correct recognition memory for each of the four activities. Lines were graphed from the line of best fit from the regression model.

memory becomes less reliable. Past research suggests that knowledge influences encoding (Amoruso et al., 2014) and episodic memory (Chi et al., 2014); however, less is known about how knowledge affects moment-to-moment encoding processes and whether these relationships change as we age.

In the current study, we examined the influence of semantic knowledge on event encoding and long-term memory for everyday events by having young and older adults view a series of self-paced slideshows depicting activities that were more versus less familiar to older and younger adults as evident from the quality of scripts that young and older adults produced for these activities. Consistent with prior research (Hard et al., 2011; Kosie & Baldwin, 2019a, 2019b), participants viewed slides depicting event boundaries longer than those depicting ongoing events (i.e., boundary advantage). Event boundaries correspond to moments when event models must be updated to reflect the perceptual and conceptual changes occurring in the activity. Presumably, viewing time increases because there is more information to process at boundaries than within events.

Extending prior research, we also observed that older adults demonstrate the boundary advantage, and they do so to the same degree as young adults. The lack of an age difference was quite surprising because previous research has found that older adults segment less normatively in comparison to young adults (Kurby & Zacks, 2011; Sargent et al., 2013) though neither of these studies manipulated the type of activity participants viewed. This finding is however consistent with research from the discourse comprehension literature, which suggests that processing at the event level is unaffected by aging (Magliano et al., 2012; Radvansky, 1999; Radvansky & Dijkstra, 2007) perhaps because they can rely upon schemas and the generation and use of inferences.

As mentioned previously, there are important differences between our study and studies that have found that segmentation ability declines with age. Older adults have more difficulty with goal maintenance in the face of secondary tasks than young adults and thus may struggle with the dual task nature of the segmentation task (McGatlin, Newberry, & Bailey, 2018). This could result in either poor segmentation performance (anecdotally, older adult participants sometimes reported they forgot to make a segmentation response while watching the videos), poor comprehension of the activity, or both. Thus, age related declines in segmentation ability may in part be due to an age-related deficit in dual task performance on the overt segmentation task.

4.1. Does knowledge affect event encoding?

Importantly, when relevant knowledge was available, both young and older adults demonstrated more effective patterns of encoding (i.e., larger boundary advantage). In fact, when participants had the prerequisite knowledge for the activity in the slideshow they spent an estimated 297 ms (Boundary = 1539 ms, Non-boundary = 1241 ms) longer viewing important event boundary images than images from the middle of an event, which is almost a 30% increase in viewing time.[2] This suggests that people may be able to rely on prior knowledge and experiences to more efficiently encode events (Umanath & Marsh, 2014), which is particularly important for older adults who may struggle with perceptual/cognitive declines. Interestingly, when participants did not have the prerequisite knowledge, they spent a similar amount of time viewing boundary and non-boundary images, showing little to no discrimination of the activity's event structure. Such an effect supports EST's claim that knowledge helps to guide future predictions. By enabling more accurate predictions, participants may have been more sensitive to the actors' goals. However, when viewing an unfamiliar activity, the characters' goals cannot be as readily inferred, which should impair the quality of perceptual predictions and prevent people from effectively identifying, and slowing down to encode, important event boundaries.

These results are in opposition to arguments that event model updating is primarily driven by bottom-up perceptual changes alone. Using top-down manipulations, previous researchers have failed to find evidence that conceptual factors influence event perception (Cutting et al., 2012;Hard et al., 2006; Huff et al., 2017). A major difference however in those studies and the current research is the nature of the task. Prior research has examined how the conceptual manipulations affect performance on the overt segmentation task (Hard et al., 2006; Huff et al., 2017), whereas in the current experiment, we used a covert measure of event perception. Viewing time may be a more sensitive measure of event encoding, particularly for detecting the effects of conceptual manipulations on event encoding. A second important difference is in the sample of participants used here. Prior work has only included young adults, whereas the current work included both young and older adults. Because older adults have degraded perceptual/cognitive abilities compared to young adults, they may rely more on prior knowledge and experiences (Umanath & Marsh, 2014). On the other hand, young adults tend to have better perceptual/cognitive abilities and thus may segment an activity from changes in the perceptual stream regardless of conceptual top-down influences. Future research should address these possibilities.

Our results suggest that participants may rely on their previous experience to identify important moments of change in self-paced slideshows. These results provide insights for designing interventions that may help improve older adults' ability to encode novel information (Richmond et al., 2017). Rather than training an ability that declines with age (i.e., processing speed, working memory capacity, attentional abilities) future interventions could be developed to help older adults utilize their intact abilities to offset those that are impaired. It remains unknown; however, how many repeated exposures would be necessary to find effects of knowledge on event encoding in older adults. Sebastian, Ghose, and Huff (2018) found that two exposures to an activity facilitated memory for coarse, but not fine event, information. Future research should address this important question in older adults.

4.2. Does knowledge improve event memory indirectly by improving event encoding?

Previous research found that encoding efficiency (i.e., segmentation ability) predicts event memory (Kurby & Zacks, 2011; Sargent et al., 2013; Zacks et al., 2006) and we observed a similar effect: those who demonstrated the boundary advantage had better recognition memory. Because event encoding uniquely predicts event memory (Sargent et al., 2013), knowledge may improve memory by improving how well the information was encoded. Despite our observation that participants encoded the knowledgeable activities more efficiently, the viewing time-memory relationship was not observed for these activities. Instead, the boundary advantage only predicted memory when the activities depicted in the slideshow were less familiar to viewers.

Our results seem to indicate that knowledge influences memory independently of event encoding strategies. This result may appear surprising because it is commonly assumed that knowledge improves memory by improving how information is encoded (Anderson & Pichert, 1978; Hasher & Griffin, 1978); however, our finding is consistent with Sargent et al. (2013) who found that general measures of event knowledge and segmentation ability independently predicted event memory. From our results and those of Sargent et al. (2013), we can speculate that when one has relevant knowledge of a depicted action, they rely upon those knowledge structures (schemas, scripts, etc.) to reconstruct the event. However, when one has little knowledge to rely upon, the only retrieval cues available are those represented in the event models created during encoding. Similar results have been reported in another study that used an expert-novice paradigm to

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[2] These values were estimated from the regression analysis by setting all predictors other than the boundary type predictor equal to zero.

evaluate the effects of knowledge on segmentation and memory (Newberry et al., under review). Such speculations are based upon correlational data; thus, future experimental research should experimentally test this possibility.

A possible limitation with our stimuli is the use of college actors in all the videos (i.e., own-age bias; Anastasi & Rhodes, 2005). Prior work has shown that older adults more accurately infer emotions of faces closer in age to themselves and remember own-age faces better than other-age faces (Anastasi & Rhodes, 2006). Thus, it is possible that older adults would more successfully track the actions of actors closer in age to themselves than the actors in the slideshows used in the current study. However, we do not believe this was a major concern because the older adults effectively encoded (i.e., demonstrated the boundary advantage) and remembered information from the older adult activities despite the age of the actor.

4.3. Conclusion

Even though the world as it is presented to us is continuous and fleeting, perception of actions in an activity is not. The perceptual system chunks the activity in the perceptual stream to enable more efficient encoding (Zacks et al., 2007). This study demonstrated that knowledge affects how well continuous information is chunked into multiple events. Furthermore, older adults, who have previously demonstrated age-related declines in event perception, may rely on knowledge acquired across the lifespan to enable more efficient encoding and memory of dynamic, everyday activities.

Authors' contribution statement

Dr. Heather R. Bailey conceived of the presented idea. Maverick E. Smith carried out the experiment, ran participants in the experiment, conducted analyses, and wrote the manuscript with support from Kimberly M. Newberry and Heather R. Bailey. Kimberly M. Newberry also contributed by creating the stimuli set used in the current work. All authors discussed the results and contributed to the final manuscript. Heather R. Bailey supervised the project.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cognition.2019.104159.

References

Agresti, A. (2007). *Building and applying logistic regression models. An introduction to categorical data analysis.* 137–172.

Amoruso, L., Sedeño, L., Huepe, D., Tomio, A., Kamienkowski, J., Hurtado, E., ... Sigman, M. (2014). Time to tango: Expertise and contextual anticipation during action observation. *Neuroimage, 98*, 366–385.

Anastasi, J. S., & Rhodes, M. G. (2005). An own-age bias in face recognition for children and older adults. *Psychonomic Bulletin & Review, 12*(6), 1043–1047.

Anastasi, J. S., & Rhodes, M. G. (2006). Evidence for an own-age bias in face recognition. *North American Journal of Psychology, 8*(2).

Anderson, R. C., & Pichert, J. W. (1978). Recall of previously unrecallable information following a shift in perspective. *Journal of Verbal Learning and Verbal Behavior, 17*(1), 1–12. https://doi.org/10.1016/s0022-5371(78)90485-1.

Bailey, H., Dunlosky, J., & Hertzog, C. (2009). Does differential strategy use account for age-related deficits in working-memory performance? *Psychology and Aging, 24*(1), 82.

Bailey, H., Kurby, C., Giovannetti, T., & Zacks, J. M. (2013). Action perception predicts action performance. *Neuropsychologia, 52*(11), 2294–2304.

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2014). *Fitting linear mixed-effects models using lme4.* arXiv preprint*1406*, arXiv5823.

Blasing, B. E. (2015). Segmentation of dance movement effects of expertise, visual familiarity, motor experience and music. *Frontiers in Psychology, 5*, 1500.

Boltz, M. G. (1995). Effects of event structure on retrospective duration judgments. *Perception & Psychophysics, 57*(7), 1080–1096.

Botwinick, J., & Storandt, M. (1980). Recall and recognition of old information in relation to age and sex. *Journal of Gerontology, 35*(1), 70–76.

Bransford, J. D., & Johnson, M. K. (1972). Contextual prerequisites for understanding: Some investigations of comprehension and recall. *Journal of Verbal Learning and Verbal Behavior, 11*(6), 717–726. https://doi.org/10.1016/S0022-5371(72)80006-9.

Bretz, F., Hothorn, T., & Westfall, P. (2002). On multiple comparisons in R. *R News, 2*(3), 14–17.

Castel, A. D. (2005). Memory for grocery prices in younger and older adults: The role of schematic support. *Psychology and Aging, 20*(4), 718.

Chi, M. T., Glaser, R., & Farr, M. J. (2014). *The nature of expertise.* Psychology Press.

Commissaris, C., Ponds, R., & Jolles, J. (1998). Subjective forgetfulness in a normal Dutch population: Possibilities for health education and other interventions. *Patient Education and Counseling, 34*(1), 25–32.

Cornelius, S. W., & Caspi, A. (1987). Everyday problem solving in adulthood and old age. *Psychology and Aging, 2*(2), 144.

Cutler, S. J., & Grams, A. E. (1988). Correlates of self-reported everyday memory problems. *Journal of Gerontology, 43*(3), S82–S90.

Cutting, J. E., Brunik, K. L., & Candan, A. (2012). Perceiving event dynamics and parsing in Hollywood films. *Journal of Experimental Psychology: Human Perception and Performance, 38*(6), 1476–1490.

Dunlosky, J., & Hertzog, C. (2001). Measuring strategy production during associative learning: The relative utility of concurrent versus retrospective reports. *Memory & Cognition, 29*(2), 247–253.

Ericsson, K. A., & Smith, J. (1991). *Toward a general theory of expertise: Prospects and limits.* Cambridge University Press.

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G* Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods, 39*(2), 175–191.

Folstein, M. F., Robins, L. N., & Helzer, J. E. (1983). The mini-mental state examination. *Archives of General Psychiatry, 40*(7), 812.

Galvin, J., Roe, C., Powlishta, K., Coats, M., Muich, S., Grant, E., ... Morris, J. (2005). The AD8: A brief informant interview to detect dementia. *Neurology, 65*(4), 559–564.

Gernsbacher, M. A. (1990). *Language comprehension as structure building. Vol. xi.* Hillsdale, NJ, US: Lawrence Erlbaum Associates, Inc.

Gilewski, M. J., Zelinski, E. M., & Schaie, K. W. (1990). The Memory Functioning Questionnaire for assessment of memory complaints in adulthood and old age. *Psychology and Aging, 5*(4), 482.

Gold, D. A., Zacks, J. M., & Flores, S. (2017). Effects of cues to event segmentation on subsequent memory. *Cognitive Research: Principles and Implications, 2*(1), 1. https://doi.org/10.1186/s41235-016-0043-2.

Hard, B., Recchia, G., & Tversky, B. (2011). The shape of action. *Journal of Experimental Psychology: General, 140*(4), 586.

Hard, B., Tversky, B., & Lang, D. (2006). Making sense of abstract events: Building event schemas. *Memory & Cognition, 34*(6), 1221–1235. https://doi.org/10.3758/bf03193267.

Hasher, L., & Griffin, M. (1978). Reconstructive and reproductive processes in memory. *Journal of Experimental Psychology: Human Learning and Memory, 4*(4), 318.

Hasher, L., & Zacks, R. T. (1988). Working memory, comprehension, and aging: A review and a new view. *Psychology of learning and motivation. Vol. 22. Psychology of learning and motivation* (pp. 193–225). Elsevier.

Huff, M., Meitz, T. G., & Papenmeier, F. (2014). *Changes in situation models modulate processes of event perception in audiovisual narratives. 40(5)*, 1377–1388.

Huff, M., Papenmeier, F., Maurer, A. E., Meitz, T. G. K., Garsoffky, B., & Schwan, S. (2017). *Fandom biases retrospective judgments not perception. 7(43083)*, 1–8. https://doi.org/10.1038/srep43083.

Jaeger, T. F. (2008). Categorical data analysis: Away from ANOVAs (transformation or not) and towards logit mixed models. *Journal of Memory and Language, 59*(4), 434–446. https://doi.org/10.1016/j.jml.2007.11.007.

Katzman, R., Brown, T., Fuld, P., Peck, A., Schechter, R., & Schimmel, H. (1983). Validation of a short Orientation-Memory-Concentration Test of cognitive impairment. *The American Journal of Psychiatry, 140*, 734–739.

Kausler, D. H., Lichty, W., & Freund, J. S. (1985). Adult age differences in recognition memory and frequency judgments for planned versus performed activities. *Developmental Psychology, 21*(4), 647.

Kosie, J. E., & Baldwin, D. (2019a). Attention rapidly reorganizes to naturally occurring structure in a novel activity sequence. *Cognition, 182*, 31–44.

Kosie, J. E., & Baldwin, D. (2019b). Attentional profiles linked to event segmentation are robust to missing information. *Cognitive Research: Principles and Implications, 4*(1), 8.

Kramer, A. F., Bherer, L., Colcombe, S. J., Dong, W., & Greenough, W. T. (2004). Environmental influences on cognitive and brain plasticity during aging. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences, 59*(9), M940–M957.

Kurby, C. A., & Zacks, J. M. (2011). Age differences in the perception of hierarchical structure in events. *Memory and Cognition, 39*, 75–91.

Kurby, C. A., & Zacks, J. M. (2019). Age differences in the perception of goal structure in everyday activity. *Psychology and Aging, 34*(2), 187.

Levine, D., Hirsh-Pasek, K., Pace, A., & Michnick Golinkoff, R. (2017). A goal bias in action: The boundaries adults perceive in events align with sites of actor intent. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 43*(6), 916.

Light, L. L., & Anderson, P. A. (1983). Memory for scripts in young and older adults. *Memory & Cognition, 11*(5), 435–444.

Lo, S., & Andrews, S. (2015). To transform or not to transform: Using generalized linear mixed models to analyse reaction time data. *Frontiers in Psychology, 6*, 1171.

Magliano, J. P., Kopp, K., McNerney, M. W., Radvansky, G. A., & Zacks, J. M. (2012). Aging and perceived event structure as a function of modality. *Aging, Neuropsychology, and Cognition, 19*(1–2), 264–282. https://doi.org/10.1080/13825585.2011.633159.

Matzen, L. E., & Benjamin, A. S. (2013). Older and wiser: Older adults' episodic word memory benefits from sentence study contexts. *Psychology and Aging, 28*(3), 754.

McGatlin, K. C., Newberry, K. M., & Bailey, H. R. (2018). Temporal chunking makes life's events more memorable. *Open Psychology, 1*(1), 94–105.

Miller, L. M. S., Cohen, J. A., & Wingfield, A. (2006). Contextual knowledge reduces demands on working memory during reading. *Memory & Cognition, 34*(6), 1355–1367.

Newberry, K. M., & Bailey, H. R. (2019). Does semantic knowledge influence event segmentation and recall of text? *Memory & Cognition,* 1–15.

Newberry, K. M., Feller, D., & Bailey, H. (2019). *The influence of domain knowledge on segmentation and memory.* (submitted).

Newtson, D. (1973). Attribution and the unit of perception of ongoing behavior. *Journal of Personality and Social Psychology, 28*(1), 28–38.

Newtson, D., & Engquist, G. A. (1976). The perceptual organization of ongoing behavior. *Journal of Experimental Social Psychology, 12*(5), 436–450.

Newtson, D., Engquist, G. A., & Bois, J. (1977). The objective basis of behavior units. *Journal of Personality and Social Psychology, 35*(12), 847–862.

Norman, K. A., & Schacter, D. L. (1997). False recognition in younger and older adults: Exploring the characteristics of illusory memories. *Memory & Cognition, 25*(6), 838–848.

Park, D. C., Lautenschlager, G., Hedden, T., Davidson, N. S., Smith, A. D., & Smith, P. K. (2002). Models of visuospatial and verbal memory across the adult life span. *Psychology and Aging, 17*(2), 299.

Park, D. C., Morrell, R. W., Frieske, D., & Kincaid, D. (1992). Medication adherence behaviors in older adults: Effects of external cognitive supports. *Psychology and Aging, 7*(2), 252.

Radvansky, G. A. (1999). Memory, and comprehension. *Current Directions in Psychological Science, 8*(2), 49–53.

Radvansky, G. A., Copeland, D. E., & von Hippel, W. (2010). Stereotype activation, inhibition, and aging. *Journal of Experimental Social Psychology, 46*(1), 51–60.

Radvansky, G. A., & Dijkstra, K. (2007). Aging and situation model processing. *Psychonomic Bulletin & Review, 14*(6), 1027–1042.

Richmond, L. L., Gold, D. A., & Zacks, J. M. (2017). Event perception: Translations and applications. *Journal of Applied Research in Memory and Cognition, 6*(2), 111–120.

Rosen, V., Caplan, L., Sheesley, L., Rodriguez, R., & Grafman, J. (2003). An examination of daily activities and their scripts across the adult lifespan. *Behavior Research Methods, Instruments, & Computers, 35*(1), 32–48.

Salthouse, T. A. (1992). Influence of processing speed on adult age differences in working memory. *Acta Psychologica, 79*(2), 155–170.

Sargent, J. Q., Zacks, J. M., Hambrick, D. Z., Zacks, R. T., Kurby, C. A., Bailey, H. R., ... Beck, T. M. (2013). Event segmentation ability uniquely predicts event memory. *Cognition, 129*(2), 241–255. https://doi.org/10.1016/j.cognition.2013.07.002.

Schwan, S., & Garsoffky, B. (2004). The cognitive representation of filmic event summaries. *Applied Cognitive Psychology: The Official Journal of the Society for Applied Research in Memory and Cognition, 18*(1), 37–55.

Schwan, S., Garsoffky, B., & Hesse, F. W. (2000). Do film cuts facilitate the perceptual and cognitive organization of activitiy sequences? *Memory & Cognition, 28*(2), 214–223. https://doi.org/10.3758/bf03213801.

Schwartz, M. F., Reed, E. S., Montgomery, M., Palmer, C., & Mayer, N. H. (1991). The quantitative description of action disorganisation after brain damage: A case study. *Cognitive Neuropsychology, 8*(5), 381–414.

Sebastian, K., Ghose, T., & Huff, M. (2018). Repeating virtual assembly training facilitates memory for coarse but not fine assembly steps. *Journal of Computer Assisted Learning, 34*(6), 787–798.

Silva, M., Baldassano, C., & Fuentemilla, L. (2019). Rapid memory reactivation at movie event boundaries promotes episodic encoding. *BioRxiv, 511782*.

Singmann, H., Bolker, B., Westfall, J., Højsgaard, S., & Fox, J. (2015). *Package 'afex'*.

Smith, M. E., Newberry, K. M., & Bailey, H. R. (2019). Differential effects of knowledge and aging on the encoding and retrieval of everyday activities (Smith, Newberry, & Bailey). *Open Science Framework*. 10.17605/OSF.IO/DX4TH.

Speer, N. K., Zacks, J. M., & Reynolds, J. R. (2007). Human brain activity time-locked to narrative event boundaries. *Psychological Science, 18*(5), 449–455 doi:PSCI1920 [pii] 10.1111/j.1467-9280.2007.01920.x.

Swallow, K. M., Zacks, J. M., & Abrams, R. A. (2009). Event boundaries in perception affect memory encoding and updating. *Journal of Experimental Psychology: General, 138*(2), 236–257. https://doi.org/10.1037/a0015631.

Thompson, A. N., & Radvansky, G. A. (2016). Event boundaries and anaphoric reference. *Psychonomic Bulletin & Review, 23*(3), 849–856.

Umanath, S., & Marsh, E. J. (2014). Understanding how prior knowledge influences memory in older adults. *Perspectives on Psychological Science, 9*(4), 408–426.

Van Zandt, T. (2000). How to fit a response time distribution. *Psychonomic Bulletin & Review, 7*(3), 424–465.

West, R. L., Crook, T. H., & Barron, K. L. (1992). Everyday memory performance across the life span: Effects of age and noncognitive individual differences. *Psychology and Aging, 7*(1), 72.

Young, M. E., & Crumer, A. (2018). Reaction time. *Encyclopedia of animal cognition and behavior* (pp. 1–10). .

Zacks, J. (2004). Using movement and intentions to understand simple events. *Cognitive Science, 28*(6), 979–1008.

Zacks, J., Kurby, C., Eisenberg, M., & Haroutunian, N. (2011). Prediction error associated with the perceptual segmentation of naturalistic events. *Journal of Cognitive Neuroscience, 23*(12), 4057–4066. https://doi.org/10.1162/jocn_a_00078.

Zacks, J., Speer, N., Swallow, K., Braver, T., & Reynolds, J. (2007). Event perception: A mind-brain perspective. *Psychological Bulletin, 133*(2), 273–293 doi:2007-02367-005 [pii] 10.1037/0033-2909.133.2.273.

Zacks, J., Speer, N., Vettel, J., & Jacoby, L. (2006). Event understanding and memory in healthy aging and dementia of the Alzheimer type. *Psychology and Aging, 21*(3), 466.

Zacks, J., Tversky, B., & Iyer, G. (2001). Perceiving, remembering, and communicating structure in events. *Journal of Experimental Psychology: General, 130*(1), 29–58.