Mem Cogn (2011) 39:75–91
DOI 10.3758/s13421-010-0027-2

Age differences in the perception of hierarchical structure in events

Christopher A. Kurby · Jeffrey M. Zacks

Published online: 5 November 2010

Abstract Everyday activities break down into parts and subparts, and appreciating this hierarchical structure is an important component of understanding. In two experiments we found age differences in the ability to perceive hierarchical structure in continuous activity. In both experiments, younger and older adults segmented movies of everyday activities into large and small meaningful events. Older adults' segmentation deviated more from group norms than did younger adults' segmentation, and older adults' segmentation was less hierarchically organized than that of younger adults. Older adults performed less well than younger adults on event memory tasks. In some cases, measures of event segmentation discriminated between those older adults with better and worse memory. These results suggest that the hierarchical encoding of ongoing activity declines with age, and that such encoding may be important for memory.

Keywords Event perception · Aging · Goals · Memory

Introduction

People conceive of everyday activity as composed of discrete events and seem to do so without effort. A baseball game breaks down into innings and at-bats; making a sandwich breaks down into collecting the ingredients, stacking them on the bread, and cleaning up. In these cases and in many others, everyday activity is hierarchically broken down into parts and subparts that are determined by social conventions or by hierarchical relations amongst goals (Dickman, 1963; Brewer & Dupree, 1983; Lichtenstein & Brewer, 1980; Zacks & Tversky, 2001). Yet, at times in healthy aging and aging with dementia, people may experience difficulty segmenting continuous activity into the appropriate parts and subparts. In the clinic, this may present as difficulties with tasks of daily living or with following conversations or television (Galvin et al., 2005). In this study, we investigated age-related variation in the ability to segment goal-directed activity into events and sub-events and how this segmentation is related to memory for events.

Understanding the hierarchical structure of activity is important for building a representation of what is currently happening in the world, developing event schemata, producing one's own actions, and remembering what has happened (Boltz, 1992; Bower, Black & Turner, 1979; Foley & Ratner, 2001; Grafman, Thompson, Weingartner, Martinez, Lawlor, & Sunderland, 1991; Newtson & Engquist, 1976; Zacks & Tversky, 2001). In Newell and Simon's classic General Problem Solver (Newell & Simon, 1972), plans are formulated by identifying a superordinate goal and a set of subgoals that must be executed to satisfy that goal. Children and adults alike show hierarchical patterns of recall for videotaped events and narrative text; they tend to group actions with their superordinate goals (Bauer & Mandler, 1989; Bower et al., 1979; Brewer & Dupree, 1983; Lichtenstein & Brewer, 1980; Travis, 1997). In narrative comprehension, hierarchical event schemata guide memory for text (Bower et al., 1979; Franklin & Bower, 1988; Rumelhart, 1977), and readers have been

C. A. Kurby · J. M. Zacks
Washington University in Saint Louis,
St. Louis, MO, USA

C. A. Kurby (✉)
Psychology Department, Grand Valley State University,
2224 Au Sable Hall, One Campus Dr.,
Allendale, MI 49401, USA
e-mail: kurbyc@gvsu.edu

found to track and coordinate the goal plans of fictive characters (see Trabasso & Wiley, 2005). Infants show evidence of grouping actions with higher-order goals, gazing longer at familiar action sequences that accomplish an unfamiliar goal compared to unfamiliar action sequences that accomplish a familiar goal (Sommerville & Woodward, 2005).

Segmenting events into parts and subparts

In order to understand the hierarchical structure of activity, it is important to identify the behaviors in the perceptual stream that correspond to that structure. In particular, one needs to segment the ongoing perceptual stream into meaningful events. Behavioral and neurophysiological evidence suggests that segmentation is an ongoing concomitant of event perception (for reviews, see Newtson, 1976; Zacks & Tversky, 2001; Zacks, Speer, Swallow, Braver, & Reynolds, 2007) and that there is a high level of agreement regarding the beginnings and ends of activity (Newtson, 1976; Speer, Swallow, & Zacks, 2003).

Consistent with the importance of segmentation to event perception, evidence suggests that participants' segmentation of events is hierarchically organized (Hard, Tversky, & Lang, 2006; Zacks, Tversky, & Iyer, 2001). A direct observation of this behavior is provided by having participants perform a segmentation task in which participants watch movies of an actor engaged in everyday activities and press a button when a meaningful unit of activity ends and another begins (Newtson, 1973). Participants segment the same activity twice, once identifying the largest meaningful units of activity (coarse grain), and once identifying the smallest meaningful units (fine grain). Event segmentation patterns are typically hierarchically aligned such that for every coarse event boundary, there tends to be a fine boundary nearby that is closer than expected by chance (Hard et al., 2006; Zacks et al. 2001), and such that the boundaries of fine events tend to be enclosed by the course events they make up (Hard et al., 2006). Consider making a sandwich. If a participant were segmenting hierarchically, then a coarse event boundary signaling the end of assembling the ingredients would coincide with the temporal location of a fine boundary that signals the end of the final subevent, such as applying the last piece of meat. The Appendix illustrates the kinds of units that people identify.

Effects of aging on event segmentation

Aging may affect how well one can encode and maintain event representations. Older adults tend to have worse episodic memory for events than younger adults (Balota, Dolan, & Duchek, 2000), as well as worse memory for the temporal order of words (Dumas & Hartman, 2003) and event sequences (Zacks, Speer, Vettel, & Jacoby, 2006). Recent work also suggests that older adults have difficulty binding event features, such as actors to actions, in memory for naturalistic activities (Kersten, Earles, Curtayne, & Lane, 2008). Maintaining and coordinating event representations likely relies on attentional control processes (Zacks et al., 2007); older adults tend to perform worse than younger adults on tasks relying on attentional control (McCabe, Roediger, McDaniel, Balota, & Hambrick, 2010), which may reflect a reduced capacity to maintain task and goal representations during ongoing task performance (Balota et al., 2000; Braver & Cohen, 2001; Miller & Cohen, 2001; Paxton, Barch, Racine, & Braver, 2008). Moreover, studies of task-switching tend to show that older adults have more difficulty shifting to new task sets than younger adults (e.g., Mayr, 2001), suggesting that older adults may have difficulty updating goal representations. This could well have significant practical consequences. A study in which older adults performed everyday activities, such as following a recipe to make pudding, found that successful performance correlated with measures of attentional control, working memory, and verbal memory (Baum, Edwards, Yonan, & Storandt, 1996). Thus, older adults may have difficulty perceiving hierarchical structure in activity.

A recent theory of event segmentation, called Event Segmentation Theory (EST), also suggests that older adults may have difficulty perceiving hierarchical structure in activity (Zacks et al., 2007). According to this account, people maintain working memory representations of the current event, called *event models*, which are updated at event boundaries. These are representations of "what is happening now," and are informed both by what has happened so far, as well as information from event schemata stored in long-term memory. EST proposes that event models are maintained by structures in prefrontal cortex, and event model updating is signaled by the midbrain dopaminergic system; both of which decline in integrity and functioning with age (Fearnley & Lees, 1991; Kanne, Balota, Storandt, McKeel, & Morris, 1998; Raz, 2005; Raz et al., 1997; Rympa, Prabhakaran, Desmond, & Gabrieli, 2001; Sakata, Farooqui, & Prasad, 1992; West, 1996).

One recent study directly asked whether there are age-related differences in the ability to segment and remember everyday activity (Zacks et al., 2006). In their study, older and younger adults segmented movies of an actor engaged in activities, such as making a bed. Participants then performed a recognition task for what happened in the movie and an order memory task in which they sorted images from the movie into their proper sequence. In order to assess segmentation ability, the authors created a measure termed *segmentation agreement*. This assessed the extent to which each participant's segmentation locations agreed with normative segmentation locations, as reflected by the event segmentation patterns of the entire sample. Given that there tends to be high within- and between-subject reliability in event segmentation locations (Newtson, 1976; Speer et al., 2003), if one's segmentation pattern deviates from normative segmentation patterns, chances are that the event segmentation system is not performing optimally. Zacks et al. (2006) found that older adults had lower segmentation agreement than younger adults, suggesting that their segmentation was less normative than younger adults. Corresponding with lower segmentation agreement, older adults also showed worse recognition and order memory for the events; older adults with dementia of the Alzheimer type were further impaired on all three measures.

Does lower agreement with group norms on the locations of event boundaries indicate worse event understanding? On the one hand, segmenting in the appropriate places may impact how well events are encoded. If this is the case, then more normative segmentation should correlate with better memory. On the other hand, older adults could segment less normatively because they have more varied life experiences than younger adults. If so, one might predict that those with less normative event segmentation would have better memory, or at least that memory would be unrelated to segmentation agreement. Zacks et al. (2006) reported data supporting the first interpretation: Those older adults with higher segmentation agreement performed better on both the recognition and order memory tests. This effect was not merely due to differences in general cognitive functioning; the relation between segmentation and recognition memory held even after controlling for measures of memory, visuospatial, and executive functioning (Zacks et al., 2006).

Thus, there are theoretical reasons to propose that older adults will be less able than younger adults to identify the hierarchical structure of ongoing behavior, and there is evidence for age-related differences in some aspects of event segmentation. However, no studies to date have investigated age differences in the *hierarchical* segmentation of activity. Moreover, there is reason to doubt that older adults will have difficulty perceiving hierarchical structure in activity. Both semantic and schematic knowledge about events is generally preserved in older adults, with the former perhaps increasing with age (Rosen, Caplan, Sheesley, Rodriguez, & Grafman, 2003; Salthouse 2003). Additionally, studies of narrative comprehension have shown that older adults rely on mental models of the described events, *situation models*, just has heavily as younger adults (Radvansky & Dijkstra, 2007). Older adults, then, appear capable of generating and using event schemata during comprehension, and these schemata are hierarchically organized. Therefore it remains an important open question whether older adults will segment activity hierarchically, similar to younger adults.

Our study directly tested this hypothesis. Experiment 1 investigated age differences in hierarchical segmentation and event memory, and Experiment 2 expanded on this using a concurrent describing task in an attempt to improve older adults' segmentation and memory.

Experiment 1

In Experiment 1, younger and older adults segmented one set of everyday activities into events and completed memory tests for a different set of events. We used different movies for the segmentation and memory tasks to reduce potential shared method variance between the two; this departs from the procedure of Zacks et al. (2006). Our main question was whether older adults would segment less hierarchically than younger adults. Our secondary aim was to examine whether individual differences in hierarchical segmentation would predict individual differences in memory.

Method

Participants

Forty-two younger adults (mean age 19 years, range 18–23 years) were recruited from the Washington University Psychology Department participant pool, whose members are mostly current students. Forty-three healthy older adults (mean age 77 years, range 60–89 years) were recruited from the Washington University Psychology Department's Older Adults Volunteer Pool, whose members are mostly healthy community-dwelling adults not currently working full time or raising minor children. Older adults received $15 for participation, and younger adults had the option of receiving $15 or course credit.

Materials and tasks

Segmentation task and measures Participants segmented two movies of everyday events taken from Zacks et al. (2006): a woman washing a car (duration 432 s), and a man building a boat out of toy blocks (duration 246 s). A third movie depicting a woman making a sandwich (duration 127 s) was used for practice. The movies did not contain any cuts and were shot from a fixed head-height perspective. Participants were asked to watch the movies and concurrently segment them into meaningful units of activity by pressing a button on a button box. Participants performed this task twice, once at each of two grain sizes. For fine segmentation, participants were told to mark off the smallest units of activity, and for coarse segmentation, they were told to mark off the largest units of activity. The movies were presented using Psyscope (Cohen, MacWhinney, Flatt, & Provost, 1993) on a Macintosh computer with a 24-inch display.

We computed three measures characterizing participants' segmentation. *Event length* is simply the mean duration of events identified within each movie, calculated by dividing the movie duration by the number of identified events. *Segmentation agreement* is a measure of how well each participant's segmentation agreed with that of the group (Zacks et al., 2006). For each movie, we created 1-second bins and recorded whether or not each participant indicated a boundary within that bin. Then, for each movie and grain, we computed the point-biserial correlation between each individual's segmentation and the proportion of participants that segmented at each 1-second bin. The larger the correlation, the better the agreement with the group. Correlations were rescaled to control for individual differences in the number of boundaries identified.[1] *Hierarchical alignment* measures the mean temporal distance between each coarse event boundary and its nearest fine event boundary, relative to the distance expected by chance (see Zacks et al., 2001).[2] Larger scores indicate more hierarchical alignment. We used log-transformed distances to correct for positive skew (see Hard et al., 2006).

Memory tests and measures Participants watched three movies for the memory tests: a man sorting and washing clothes (duration 300 s), a woman building a tent (duration 379 s), and a man planting flowers in a window box (duration 354 s). Movies were presented as for the segmentation task. Memory was tested using the methods described in Zacks et al. (2006). Immediately after viewing each movie, participants performed a *recognition memory* test followed by an *order memory* test. The recognition memory test was a 25-item two-alternative forced-choice test, with distracter items chosen from movies of the same actor in the same setting. Pairs of pictures were presented side-by-side on the computer screen, and participants responded by pressing a corresponding button on a button box. Order of presentation of the pairs, and placement of the images (left or right), were randomized separately for each participant. Response times greater or less than 3 standard deviations from each individual participant's grand mean were identified as outliers and removed from the analysis, resulting in the removal of 1.7% of the total number of correct trials.

For each movie, order memory was tested with 12 visually distinctive images printed on 3 × 5 inch cards. Cards were presented in two rows of six on a table top, randomly ordered. Participants were instructed to arrange the images into the order in which they occurred in the movie. *Completion time* was measured with a timer. *Order error* was calculated from the absolute distance of each card's ordinal location from the correct ordinal location (Zacks et al., 2006)

Design

This experiment was conducted as a 2 (age group: younger vs. older) x 2 (segmentation grain: fine vs. coarse) mixed design with age group as the between subjects factor and segmentation grain as the within subjects factor. The order of segmentation grain and order of movie presentation for both the segmentation and memory tasks were counterbalanced across participants. Within each participant, movie order was the same for fine and coarse segmentation.

Procedure

Participants first segmented the toy boat and car washing movies into coarse or fine events, depending on instructions. Participants practiced segmenting with the assigned grain on the sandwich-making movie. We used a shaping procedure to constrain individual differences in segmenta-

[1] The range of the raw correlations is restricted by the number of boundaries the participant identified. (For example, in the extreme case, a participant that only identified one boundary would have a slightly positive correlation if that boundary were in a location selected by many others, and a slightly negative correlation if that boundary were in a location selected by no others—but could never have a correlation of large magnitude.) Segmentation agreement scores were rescaled to 0–1 agreement scores using the following procedure:

(1) Compute the correlation between the participant's binned event boundaries and the distribution for the group, r.
(2) Compute the minimum and maximum correlation possible given the number of boundaries the participant identified, r_{min} and r_{max}.
(3) Subtract r_{min} from r.
(4) Divide by the range of correlations possible, r_{max} - r_{min}. i.e., $Segmentation\ Agreement = \frac{r - r_{\min}}{r_{\max} - r_{\min}}$

[2] To calculate hierarchical alignment, we first computed the observed average distance between each coarse event boundary and the nearest fine event boundary. We then computed the expected temporal distance between coarse and fine boundaries, assuming independence between coarse and fine boundary locations and random uniform distribution of the coarse unit boundaries. Hierarchical alignment scores were calculated by subtracting the observed from the expected distance. Following Zacks et al. (2001), we also computed a discrete measure of hierarchical alignment. The discrete alignment measure reflects how frequently one-second time bins were identified as event boundaries at both a fine and coarse grain. In this experiment, the results of the discrete and continuous alignment measures did not qualitatively differ from one another, so only the continuous measure results are reported.

tion grain.[3] Once it was determined that participants understood the task they segmented the toy boat and car movies at the same grain size (either at a fine or coarse grain). They then performed the recognition and order memory tasks for the clothes-washing, planting, and tent movies. Finally, participants again performed the segmentation task, this time segmenting the toy boat and car washing movies at the grain other than the one used in the first segmentation phase, i.e., participants who had initially performed coarse segmentation now performed fine segmentation, and vice versa. As for the first segmentation phase, participants were trained on the new segmentation grain using the sandwich-making movie.

Results and discussion

Segmentation

The goals of these analyses were to assess age differences in (1) the degree of hierarchical segmentation, (2) the locations of participants' event boundaries, and (3) the perceived duration of events. For all analyses involving the entire sample, age was treated as a continuous variable (Preacher, MacCallum, Rucker, & Nicewander, 2005); in some cases we followed these up with separate analyses for each age group, and for descriptive purposes we present group means.[4] Data for all analyses were collapsed across movie.[5] Table 1 presents mean segmentation scores by group (and grain where appropriate). Table 2 presents the results of the analyses.

Hierarchical alignment Both the younger and older adults showed significant hierarchical alignment; the alignment between coarse and fine boundaries was closer than that expected by chance (see Table 1; younger: $t(39) = 17.33$, $p < 0.001$, $d = 2.74$; older: $t(39) = 13.51$, $p < 0.001$, $d = 2.14$). Critically however, alignment scores were significantly lower for older than younger adults (see Table 2). This suggests that older adults segment events less hierarchically than younger adults.

Segmentation agreement As can be seen in Tables 1 and 2, older adults had significantly lower fine and coarse agreement scores than younger adults. This replicates Zacks et al. (2006), and suggests that older adults segment events less normatively than younger adults.

Event lengths Participants were able to modify their segmentation grain as instructed: Event lengths were longer for coarse than fine events (coarse: $M = 36.3$ s, $SD = 17.7$ s; fine: $M = 13.0$ s, $SD = 6.9$ s). In addition, older adults produced significantly longer fine event lengths than younger adults (see Tables 1 and 2).

Recognition memory and order memory

Table 1 presents mean memory scores by group, and Table 2 presents the results of the analyses.

Recognition accuracy and speed Older adults had significantly lower recognition accuracy, and were significantly slower, than younger adults (see Tables 1 and 2).

Order errors and completion time For the order errors analysis, one person was excluded for missing order error data for one movie, and for the completion time analysis one participant was excluded because of an outlying completion time. Older adults made significantly more order memory errors than younger adults and took significantly longer to complete the order memory task than younger adults (see Tables 1 and 2).

Relations between segmentation and memory for events

Recognition memory As can be seen in Fig. 1, both segmentation measures were moderately associated with recognition memory. Within-group correlations between each of the segmentation measures and recognition memory were positive, but only one of the correlations was statistically significant (between hierarchical alignment and recognition memory for older adults). Hierarchical regression analyses did not find a significant relation between either segmentation measure and recognition after controlling for age (see Table 3).

[3] We set a target number of units for participants to identify for each grain size, 6 for fine and 3 for coarse segmentation. After the practice, if participants fell below the target for a given grain size, participants were told that "a lot of times, people identify more units than you just did," and segmented the practice movie again (see Zacks et al., 2006 for a similar procedure). Eight older and three younger adults (not different according to a binomial test, $p = 0.23$) missed the targets and therefore repeated the training task, and two participants repeated it a second time. These two participants did not meet the target after the two additional training sessions. They were allowed to continue, after determining that they understood the instructions.

[4] For these and all subsequent analyses, a participant was excluded from an analysis if their score on the dependent variable of interest fell 3 standard deviations above or below the mean for their particular age group. Participants were excluded from all analyses if they did not identify more fine than coarse units for one of the experimental movies (two older adults) or only identified one unit for both experimental movies (one older adult). One younger adult was excluded for having outlying fine event lengths because abnormally long fine event lengths can artificially inflate scores of hierarchical alignment. Finally, one younger adult was excluded for failing to identify more fine than coarse units during the practice phase. This resulted in a final sample of 40 younger and 40 older adults.

[5] Analyses using movie as a factor did not produce qualitatively different results than those reported throughout this paper.

Table 1 Experiment 1 segmentation and memory performance by age group (standard deviations in parentheses)

Age group	Event duration (s)		Segmentation agreement		Alignment	Recognition accuracy	Recognition time (s)	Order memory error	Order memory time (s)
	Coarse	Fine	Coarse	Fine					
Younger	34.0 (14.0)	10.7 (5.3)	0.59 (0.12)	0.67 (0.09)	0.54 (0.20)	0.89 (0.06)	4.0 (1.1)	0.51 (0.39)	95.1 (23.7)
Older	38.5 (20.7)	15.3 (7.7)	0.50 (0.15)	0.61 (0.10)	0.42 (0.20)	0.82 (0.07)	7.0 (3.1)	1.27 (0.54)	180.0 (76.0)

For alignment, units are in log seconds and zero corresponds to chance performance (no evidence for hierarchical segmentation)

Order memory As can be seen in Fig. 2, order errors generally declined with increasing segmentation performance, but the relations were weak. Hierarchical regression analyses, conducted as above and presented in Table 3, revealed no significant effects of the segmentation measures or interactions with age.

Relations between segmentation agreement and hierarchical alignment

Older adults had less hierarchical segmentation and also less normative segmentation than younger adults. One possibility is that older adults simply perform the segmentation task less reliably than younger adults. Greater within-participant noise would produce lower segmentation agreement and also lower hierarchical alignment. If lower reliability is the cause of the reduced alignment in older adults, then the age effect on alignment should be accounted for by segmentation agreement. For both age groups, those with more normative segmentation showed greater hierarchical alignment (younger: $r(38) = 0.48$, $p < 0.01$; older: $r(38) = 0.55$, $p < 0.001$). Using methods described by Baron and Kenny (1986), we tested whether segmentation agreement mediated the relation between age and hierarchical alignment. The above analyses indicate that age is significantly correlated with alignment and agreement. An additional regression analysis with both segmentation agreement and age entered simultaneously revealed that the age difference in hierarchical alignment was not significant after controlling for segmentation agreement, but that agreement significantly predicted alignment while controlling for age (effect of agreement: $t(77) = 5.22$, $p < 0.001$; effect of age: $t(77) = -1.183$, $p = 0.241$). A Sobel test (Sobel, 1982) confirmed that the relation between age and alignment was significantly reduced after controlling for agreement, $z = -2.84$, $p = 0.004$, indicating full mediation. This suggests that older adults segment less hierarchically in part because their segmentation is generally noisier.

In sum, there was strong evidence for age differences in hierarchical segmentation. This is the first evidence showing an age difference in the perception of hierarchical structure in everyday activity. In addition, compared to younger adults, older adults segmented less normatively and remembered the temporal order and visual contents of events less well. This replicates and extends previous findings on age-related differences in event segmentation and memory (Zacks et al., 2006). Lastly, there was modest but not overwhelming support for a relation between hierarchical segmentation and recognition memory.

Table 2 Correlations between age and each segmentation, and memory measure, for Experiment 1

Measure	r	t	df	p
Alignment	-0.30*	-2.83	78	0.006
$Agreement_{coarse}$	-0.31*	-2.86	78	0.005
$Agreement_{fine}$	-0.31*	-2.89	78	0.005
Event $length_{coarse}$	0.06	0.52	78	0.605
Event $length_{fine}$	0.32*	2.97	78	0.004
Recognition memory	-0.52**	-5.37	78	< 0.001
Recognition RT	0.53**	5.58	78	< 0.001
Order memory	0.66**	7.64	77	< 0.001
Order completion time	0.62**	6.92	77	< 0.001

* $p < 0.01$, ** $p < 0.001$

Experiment 2

If older adults segment less well than younger adults, and if segmentation plays a causal role in determining later memory, then it may be that intervening to improve segmentation can be an effective means to improve memory for everyday events. In Experiment 2, we attempted to improve segmentation by coaching participants to describe ongoing activity as they segmented it. We hypothesized that concurrent description would improve segmentation by strengthening the influence of top-down knowledge on perceptual processing, and that this would lead to better memory. To preview, this was not the case: describing had little effect on segmentation and memory. The important findings from Experiment 2 were, first, a strong replication of the age differences in hierarchical segmentation and memory and, second, a replication of the relation between segmentation agreement and memory.

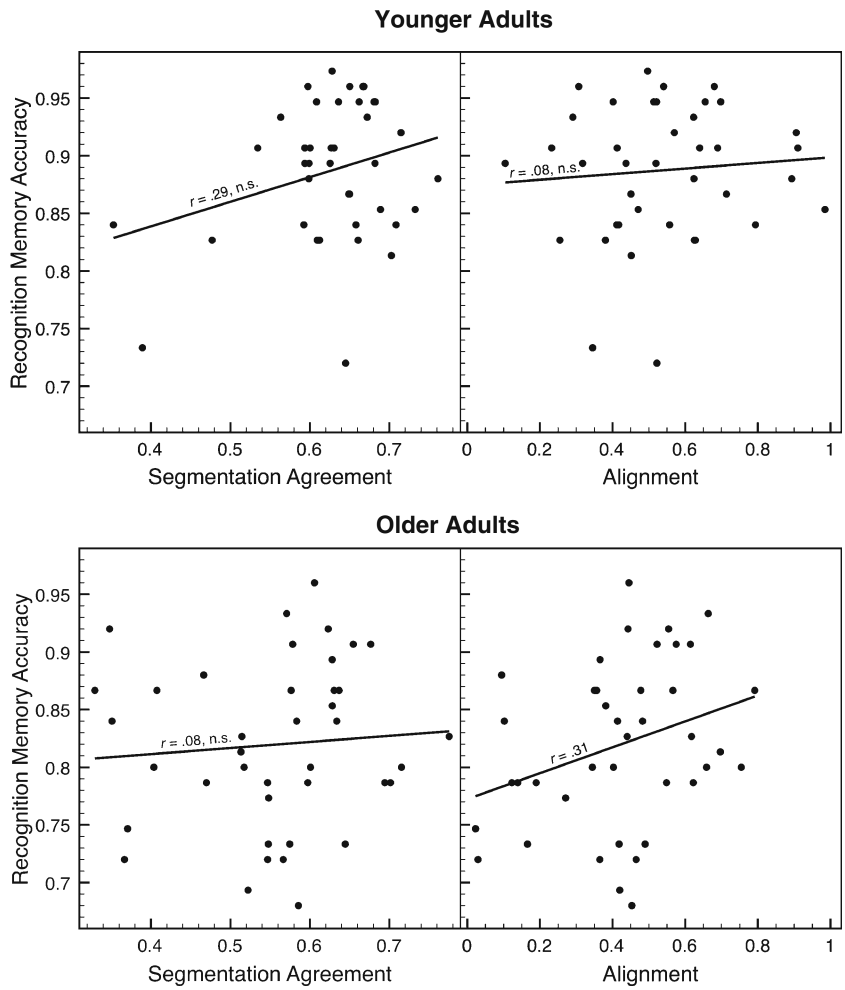


Fig. 1 Recognition memory accuracy as a function of segmentation agreement and alignment by age group for Experiment 1

Participants segmented activity as in Experiment 1. However, in Experiment 2 one group of participants described the events as they segmented them. There are at least three possibilities regarding the effects of describing on age differences in segmentation. Concurrent describing may activate knowledge structures such as event schemata. Event schemata represent the hierarchical organization of activity (Bower et al., 1979; Rumelhart, 1977), and such knowledge may be preserved with age (Radvansky & Dijkstra, 2007). One possibility, consistent with the results of Experiment 1, is that older adults have an impairment in perceptual processing that makes it more difficult for them to access

Table 3 Experiment 1 hierarchical regression results predicting recognition and order memory accuracy from the segmentation measures, controlling for the main effect of age

	Segmentation				Interaction with age			
Measure	*F*	*df*	*p*	ΔR^2	*F*	*df*	*p*	ΔR^2
Predicting recognition accuracy								
Agreement	1.49	1, 77	0.227	0.01	0.65	1, 76	0.422	0.01
Alignment	2.65	1, 77	0.108	0.02	1.11	1, 76	0.296	0.01
Predicting order memory errors								
Agreement	0.00	1, 76	0.980	0.00	0.44	1, 75	0.508	0.00
Alignment	0.00	1, 76	0.955	0.00	0.01	1, 75	0.908	0.00

We conducted separate hierarchical regressions predicting recognition accuracy and order memory errors from each of the segmentation measures together with age. We began with models including the main effect of age. In the first step for each segmentation measure, we added the main effect of the segmentation measure. In the second step, we added the interaction between the segmentation measure and age

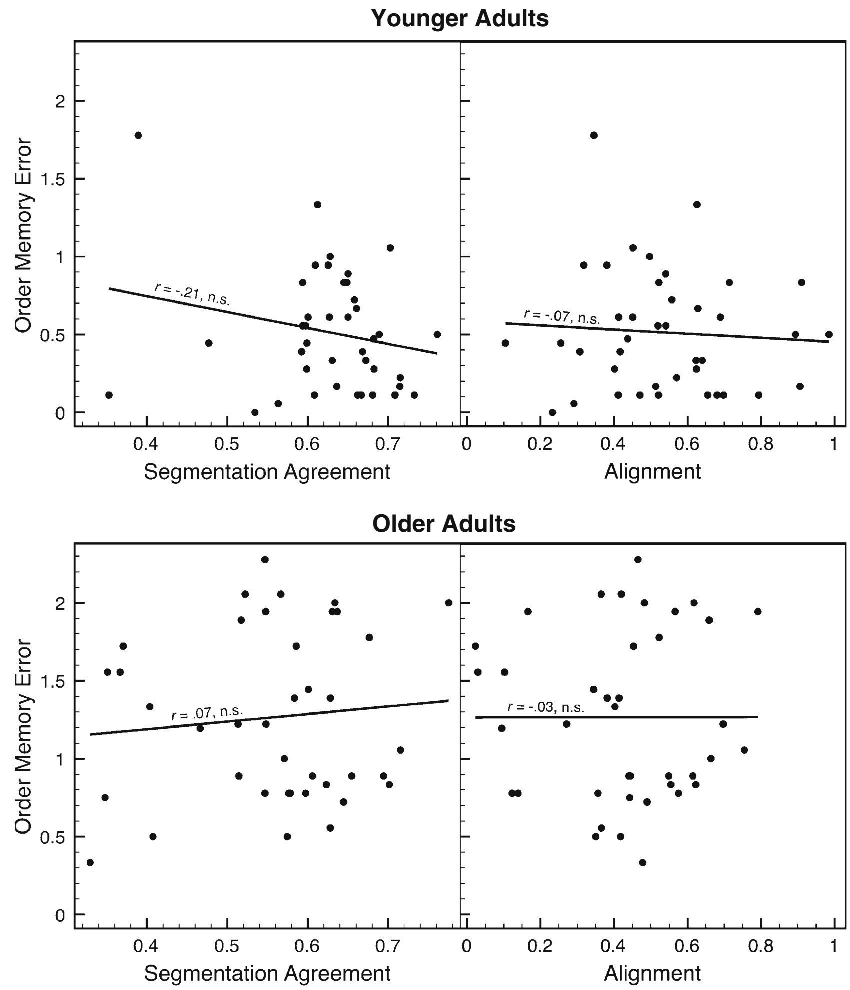


Fig. 2 Order memory error as a function of segmentation agreement and alignment by age group for Experiment 1

schematic knowledge about events and thereby segment hierarchically. This possibility would explain the fact that the age-related difference in hierarchical alignment was mediated by segmentation agreement. Also, given that older adults may have difficulty self-initiating cognitive processes (Luo & Craik, 2008), giving them a task that requires knowledge activation may improve performance, as we hypothesized. A second possibility is that concurrent describing is similar to simple think-aloud or introspection procedures in which the contents of working memory are reported while performing a cognitive task. It has been argued that such procedures have little effect on ongoing cognition (Ericsson & Simon, 1994). If so, then concurrent describing should have no effect on segmentation performance. A third possibility is that concurrent describing, being a demanding secondary task, may impose an additional cognitive load on participants and reduce performance. If so, one might expect this to differentially affect older adults (Riby, Perfect, & Stollery, 2004; Verhaeghen, Steitz, Sliwinski, & Cerella, 2003). Interestingly, the limited previous evidence on how describing influences segmentation is mixed. Zacks et al. (2001) found that concurrent describing increased hierarchical alignment, whereas Hard et al. (2006) found no effect of describing on alignment.

A second significant modification in Experiment 2 was that segmentation and memory were measured using the same movies. We separated the segmentation and memory tasks in Experiment 1 to reduce shared method variance between the tasks. Compared to what was reported in Zacks et al. (2006), it appears that this procedure may have slightly reduced the magnitude of the relation between segmentation and memory. However, we do not have a direct test of this possibility. We had participants perform both tasks on the same movies in Experiment 2 so that a direct comparison could be made to Experiment 1.

Method

Participants

Sixty-seven younger adults (mean age 20, range 18–22) and 63 healthy older adults (mean age 76 years, range 65–85 years) were recruited using the same procedures as in

Experiment 1. Six younger adults and five older adults were excluded from analysis because they failed to complete the protocol (e.g., fell asleep, answered a cell phone). In addition, one older adult produced more coarse than fine boundaries for one of the movies, one older adult reported a diagnosis of memory impairment, and one older adult reported an inability to see out of both eyes; these participants also were excluded.

Materials and tasks

Stimuli The three movies used in this experiment were the washing clothes, flower box, and tent movies from Experiment 1. As in Experiment 1, we used the sandwich movie for practice.

Segmentation task The segmentation task was identical to that used in Experiment 1. Participants segmented each of the three critical movies twice, once at a fine grain and once at a coarse grain. The order of both segmentation grain and movie was counterbalanced across participants. Half of the participants were asked to describe, after each button-press, the unit that preceded the button-press (*describe* condition). Participants' descriptions were recorded with a digital recorder using an external microphone. We used the same shaping procedure as in Experiment 1 to constrain segmentation grain.[6]

Memory tests The memory tasks and materials were identical to those used in Experiment 1, except that one item in the order memory task (the first picture for the tent movie) was replaced because it was placed correctly by all participants in Experiment 1 and thus had no variability. The new image was chosen from a point slightly later in the movie.

Design

This experiment was conducted as a 2 (segmentation grain: fine vs. coarse) x 2 (age group: younger vs. older) x 2 (describe condition: describe vs. silent) mixed design with segmentation grain as the within subject factor and age group and describe condition as between subjects factors. The order of segmentation grain and movie order was counterbalanced across participants. For each participant, the order of movie presentation was the same for fine and coarse segmentation.

[6] Thirty-two participants (17 older and 15 younger) did not initially meet the segmentation target for one of the grains and repeated the practice session. No participants required a third repetition for either grain.

Procedure

Similar to Experiment 1, this experiment proceeded in three phases; however, the order of occurrence was slightly different from Experiment 1. Participants first segmented the three movies twice (coarse and fine, with order counterbalanced). They then performed the recognition and order memory tasks for each of the three movies, with the recognition task always preceding the order memory task. Participants completed both memory tasks for each movie before moving to the memory tasks for the next movie.

Results and discussion

Computation of segmentation and memory measures, and exclusion of outliers, was the same as in Experiment 1. As in Experiment 1, age was treated as a continuous variable in the primary analyses; follow-up tests for each group were conducted to explore interactions involving age, and group means are presented for descriptive purposes.

Segmentation

The goals of these analyses were to investigate the effect of describing on (1) the degree of hierarchical segmentation for each age group, (2) segmentation agreement, and (3) the perceived duration of events. The ANOVA for the alignment analysis was conducted with describe condition as a between participants variable and age as a continuous predictor. Separate ANOVAs with describe condition as a between participants variable and age as a continuous predictor variable were conducted for the fine and coarse segmentation agreement scores and event lengths. Table 4 presents means and standard deviations for all segmentation and memory measures (averaged across movies). The results of the analyses are presented in Table 5.

Hierarchical alignment One participant was excluded as an outlier. Both younger and older adults had significant alignment for each describe condition, smallest $t(30) = 6.10$, $p < 0.001$, $d = 1.10$ (see Table 4). However, older adults had significantly lower alignment scores than younger adults (see Table 5; older: $M = 0.34$, $SD = 0.26$; younger: $M = 0.42$, $SD = 0.22$), replicating the alignment results of Experiment 1. No other effects were significant.

Segmentation agreement For both fine and coarse segmentation, older adults had significantly lower agreement scores than younger adults (see Tables 4 and 5), replicating the

Table 4 Experiment 2 segmentation and memory performance by describe condition and age group (standard deviations in parentheses)

Age group	Describe condition	Event duration (s)		Segmentation agreement		Alignment	Recognition accuracy	Recognition time (s)	Order memory error	Order memory time (s)
		Coarse	Fine	Coarse	Fine					
Younger	Silent	40.4 (17.5)	11.5 (6.5)	0.48 (0.12)	0.64 (0.12)	0.39 (0.20)	0.90 (0.05)	4.0 (1.0)	0.53 (0.46)	90.9 (16.1)
	Describe	41.2 (18.4)	12.7 (6.5)	0.56 (0.14)	0.61 (0.11)	0.43 (0.22)	0.91 (0.04)	3.5 (0.9)	0.48 (0.27)	98.1 (35.2)
Older	Silent	39.3 (20.7)	13.5 (9.3)	0.48 (0.18)	0.59 (0.13)	0.40 (0.25)	0.82 (0.07)	6.7 (2.4)	1.24 (0.69)	189.7 (83.4)
	Describe	43.5 (19.6)	17.6 (8.6)	0.41 (0.17)	0.47 (0.13)	0.28 (0.25)	0.84 (0.08)	6.2 (1.9)	1.19 (0.44)	198.4 (113.0)

segmentation agreement results of Experiment 1. For fine segmentation, agreement scores were significantly higher for the silent condition than the describe condition (describe: M = 0.54, SD = 0.14; silent: M = 0.62, SD = 0.13). For coarse segmentation, age significantly interacted with describe condition such that for younger adults agreement scores while describing were higher than agreement scores while silent, $t(65)$ = 2.51, p = 0.01, d = 0.61, whereas for older adults, agreement scores for the describing and silent conditions did not significantly differ from each other, $t(61)$ = 1.67, p = 0.410, d = 0.42.

Event lengths Participants were able to modify their grain of segmentation as instructed. Event lengths were longer for coarse than fine events (coarse: M = 41.1 s, SD = 18.9 s; fine: M = 13.7 s, SD = 8.0 s). Older adults segmented fine events into significantly longer units than did younger adults (see Tables 4 and 5), which replicates the event length results of Experiment 1. Fine event lengths were marginally longer for the describe condition than the silent condition (describe: M = 15.08 s, SD = 7.93 s; silent: M = 12.44 s, SD = 7.95 s). There were no other effects of describe condition on event lengths.

Recognition memory and order memory

The goals of these analyses were to assess the effect of describing on recognition and order memory performance for each age group. Means and standard deviations for each condition (collapsed across movie) are presented in Table 4, and results of analyses in Table 5.

Recognition accuracy and speed Two participants were identified as outliers for recognition speed and removed from the recognition speed analyses.[7] Older adults had significantly lower recognition accuracy than younger adults (older: M = 0.83, SD = 0.07; younger: M = 0.91, SD = 0.05) and significantly longer response times (older: M = 6.6 s, SD = 2.4 s; younger: M = 3.8 s, SD = 1.1 s), as can be seen Tables 4 and 5. No other effects for recognition accuracy were significant.

Order errors and completion time Due to experimenter error, three participants were missing order error data and two participants were missing completion time data for one of the movies. These participants were excluded from the order errors and completion time analyses. Older adults committed significantly more order errors and had longer completion times than younger adults (see Tables 4 and 5), replicating the memory results of Experiment 1 and Zacks et al. (2006). There were no other significant effects for completion times.

Relations between segmentation and memory

Recognition memory Recognition performance for each age group and describe condition is plotted as a function of segmentation agreement and alignment in Fig. 3. Effects of age and segmentation on recognition accuracy were analyzed with hierarchical regression, and the results are reported in Table 6. For agreement, there was a significant main effect of agreement, and a significant agreement-by-age interaction. For older adults, increases in agreement were associated with increases in recognition accuracy, $r(61)$ = 0.40, p = 0.001, whereas for younger adults, agreement did not reliably predict recognition $r(65)$ = -0.16, p = 0.23. For alignment, there was no significant main effect, and no significant interaction with age, but there was a significant alignment-by-describe condition interaction. For the silent condition, increases in alignment were marginally associated with increases in recognition accuracy, $r(63)$ = 0.22, p = 0.08, whereas for the describe condition, alignment did not reliably predict recognition accuracy, $r(62)$ = -0.03, p = 0.84. The three-way interaction among alignment, age, and describe condition was not significant.

We note that, compared to the younger adults in Experiment 1, those in Experiment 2 had higher recognition

[7] Response times were calculated for correct responses only, and were trimmed as in Experiment 1, resulting in the exclusion of 1.8% of the total trials. Two participants were identified as outliers for the response time analyses.

Table 5 ANOVA results for the segmentation and memory measures for Experiment 2

	Describe condition				Age				Interaction			
Measure	*F*	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
Alignment	1.03	1, 125	0.312	0.01	6.75*	1, 125	0.010	0.05	2.40	1, 125	0.124	0.02
$\text{Agreement}_{\text{coarse}}$	0.04	1, 126	0.833	0.00	18.73***	1, 126	< 0.001	0.13	7.24**	1, 126	0.008	0.05
$\text{Agreement}_{\text{fine}}$	12.77***	1, 126	< 0.001	0.09	21.73***	1, 126	< 0.001	0.15	3.05†	1, 126	0.083	0.02
Event $\text{length}_{\text{coarse}}$	0.52	1, 126	0.472	0.00	0.51	1, 126	0.477	0.00	0.45	1, 126	0.504	0.00
Event $\text{length}_{\text{fine}}$	3.75†	1, 126	0.055	0.03	7.37**	1, 126	0.008	0.06	1.47	1, 126	0.228	0.01
Recognition memory	1.48	1, 126	0.225	0.01	20.49***	1, 126	< 0.001	0.14	1.58	1, 126	0.211	0.01
Recognition RT	2.90†	1, 124	0.091	0.00	40.27***	1, 124	< 0.001	0.25	0.10	1, 124	0.752	0.00
Order memory	0.40	1, 123	0.529	0.00	29.10***	1, 123	< 0.001	0.19	0.21	1, 123	0.648	0.00
Order completion time	0.45	1, 124	0.541	0.00	39.90***	1, 124	< 0.001	0.24	0.01	1, 124	0.936	0.00

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, † $p < 0.10$

memory scores, and these scores were not strongly related to the segmentation measures. A likely possibility is that this ceiling effect came about because in Experiment 2 participants viewed and segmented the movies twice before performing the recognition test.

Order memory Order memory performance for each age group and describe condition is plotted as a function of segmentation agreement and alignment in Fig. 4. We followed the same 3-step hierarchical regression procedure as above to predict order memory errors, the results of

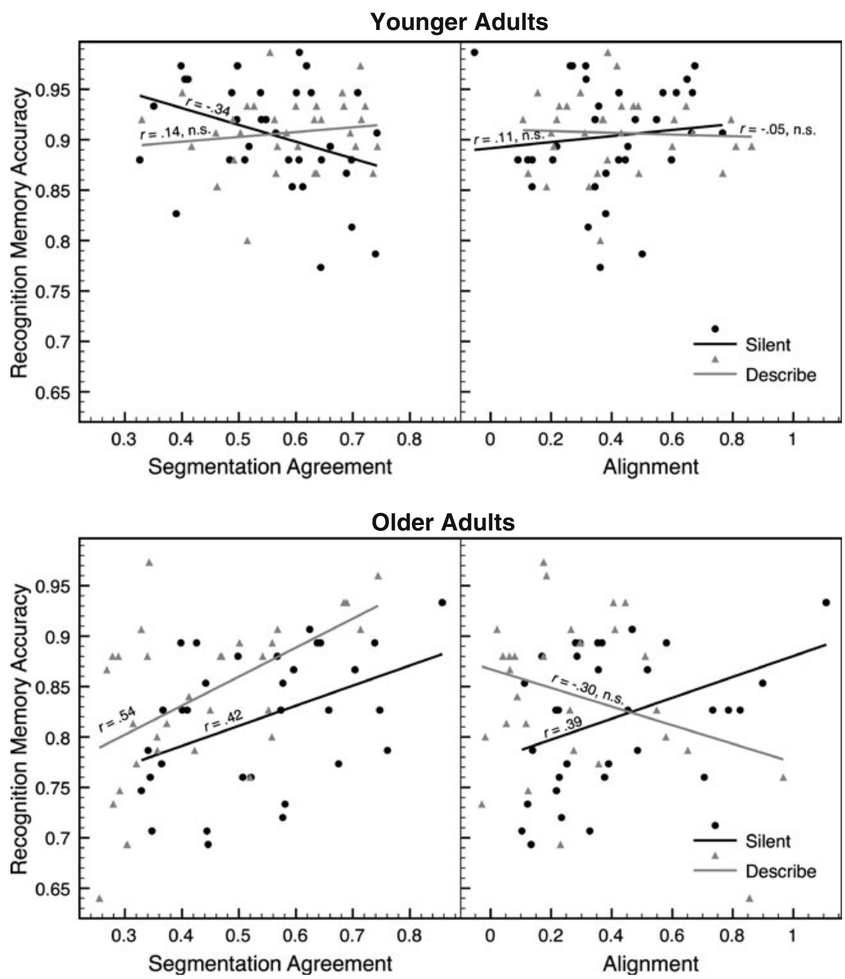


Fig. 3 Recognition memory accuracy as a function of segmentation agreement and alignment by age group and describe condition for Experiment 2

Table 6 Experiment 2 hierarchical regression results predicting recognition and order memory accuracy from the segmentation measures, controlling for the main effects of age and describe condition, and their interaction

Measure	Segmentation				Interaction with age				Interaction with describe condition				3-way interaction			
	F	*df*	*p*	ΔR^2	*F*	*df*	*p*	ΔR^2	*F*	*df*	*p*	ΔR^2	*F*	*df*	*p*	ΔR^2
Predicting recognition accuracy																
Agreement	6.82*	1, 125	0.010	0.03	11.71***	1, 124	< 0.001	0.06	3.73†	1, 124	0.056	0.02	0.73	1, 122	0.726	0.00
Alignment	0.01	1, 124	0.913	0.00	0.10	1, 123	0.752	0.00	6.89*	1, 123	0.010	0.04	3.62†	1, 121	0.060	0.02
Predicting order memory errors																
Agreement	3.28†	1, 122	0.073	0.02	0.27	1, 121	0.610	0.00	0.09	1, 121	0.760	0.00	1.32	1, 119	0.315	0.01
Alignment	1.60	1, 121	0.208	0.01	0.60	1, 120	0.809	0.00	1.29	1, 120	0.259	0.01	1.43	1, 118	0.234	0.01

We conducted separate hierarchical regressions predicting recognition accuracy and order memory errors from each of the segmentation measures together with group and describe condition. We began with models including the main effects of age and describe condition, as well as the age-by-describe interaction. In the first step for each segmentation measure, we added the main effect of the segmentation measure. In the second step, we entered the two-way interactions of the segmentation measure with age and describe condition. In the third step we entered the three-way interaction between the segmentation measure, age, and describe condition.

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, † $p < 0.10$

which are presented in Table 6. Except for a marginally significant main effect of segmentation agreement, none of the hierarchical regressions indicated significant effects for the segmentation measures or their higher-order interactions with age or describe condition.

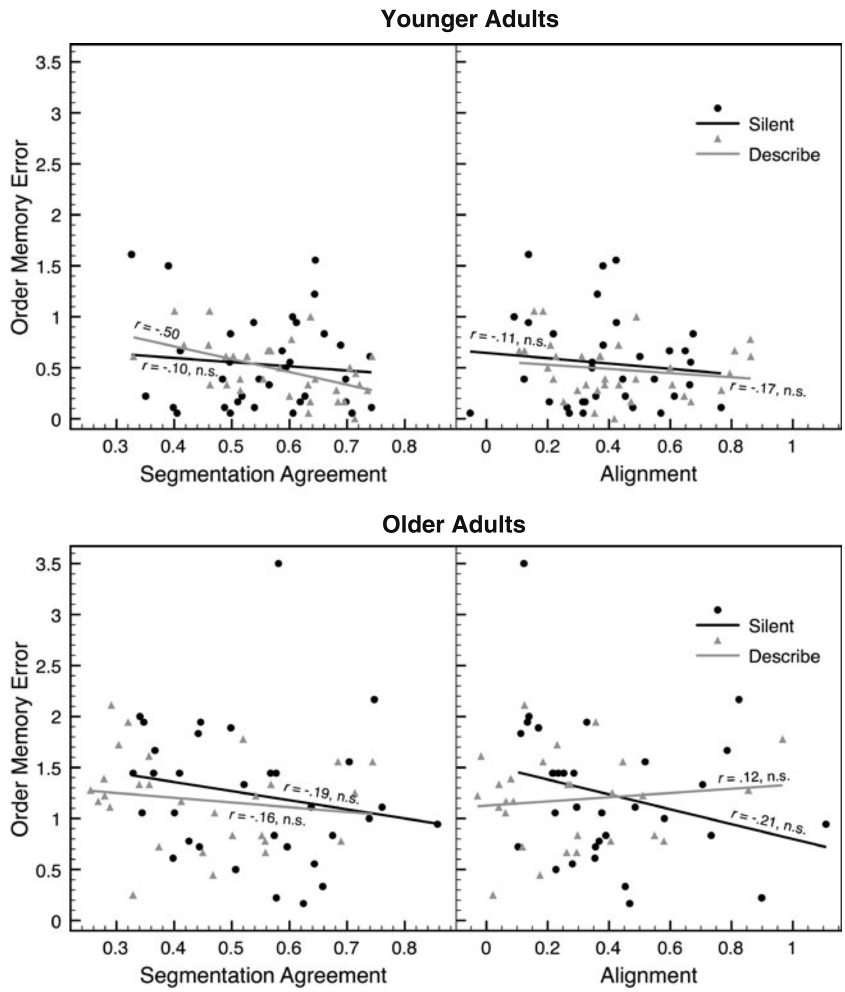
In sum, older adults segmented events less hierarchically than younger adults, replicating the main result from Experiment 1. Older adults also segmented events less normatively and remembered them less well than younger adults, replicating Experiment 1. In addition, describing had little effect on segmentation and memory performance. In the single case in which it did have an effect, it improved coarse segmentation agreement for younger adults.

Experiment 2 also provided further evidence that segmentation performance is related to later memory. Older adults' recognition scores were correlated with segmentation agreement, replicating Experiment 2. Hierarchical alignment again predicted older adults' recognition memory, but only when not describing the activity during encoding.

We failed to find evidence that describing activity while segmenting improved older adults' memory. This supports the possibility that the describe task does not encourage the use of knowledge when constructing event representations. Similar arguments have been made regarding the effects of think-aloud and introspection tasks on language comprehension (Ericsson & Simon, 1994). We return to the issue of interventions for segmentation in the general discussion.

Finally, Experiment 2 allowed us to ask whether the relation between segmentation and memory is at least partially driven by shared method variance between the segmentation and memory tasks. In this experiment, participants performed the segmentation and memory tasks on the same movies. In this design, it is possible that correlations between segmentation and memory could emerge either as a result of stable individual differences, or as a result of subject-by-item interactions or moment-to-moment fluctuations in cognitive performance. Experiment 1 separated the two tasks with two different movie sets, reducing the potential contribution of factors other than stable individual differences. The magnitude of the first order correlation between segmentation agreement and recognition memory for older adults was numerically larger for Experiment 2 (silent condition) than Experiment 1. However, a linear regression predicting recognition memory accuracy, controlling for the main effects of agreement and experiment, showed no interaction between experiment and agreement, $F(1, 68) = 1.25$, $p = 0.268$, $\Delta R^2 = 0.02$. An analogous analysis for alignment (silent condition only for Experiment 2) also shows no interaction between experiment and alignment, $F(1, 68) < 1$, $p = 0.904$, $\Delta R^2 = 0.00$. These results suggest

Fig. 4 Order memory errors as a function of segmentation agreement and alignment by age group and describe condition for Experiment 2



that the correlation between segmentation ability and memory reflects a stable attribute of a person's cognition, rather than attributes specific to the interaction of that person with a particular stimulus.

General discussion

In this study, we found evidence for age-related differences in the ability to perceive hierarchical structure in events. In both experiments, older adults segmented events less hierarchically than younger adults. In addition, older adults' segmentation agreed less well with group norms, for both coarse and fine events. Segmentation was related to memory performance, particularly for older adults. This effect was most strong in the segmentation agreement measures, although occasionally hierarchical alignment predicted memory. These results, as well as those presented in Zacks et al. (2006), suggest that older adults may have difficulty in identifying meaningful units of behavior in everyday activities, and that this difficulty is significant for event encoding.

Age differences in event segmentation

Our results are consistent with the possibility that aging may affect how well one can encode and maintain event representations. Previous evidence suggests that older adults' episodic memory for events is impaired (Balota et al., 2000; Zacks et al., 2006), as well as attentional processes related to goal maintenance and updating (Mayr, 2001; McCabe et al., 2010). The corresponding age-related change in event perception ability appears to manifest itself in at least two ways, less ability to segment events into normative units and less ability to perceive hierarchical structure in activity. These changes are consistent with EST, a recent theory of event segmentation (Zacks et al., 2007). This theory proposes that the maintenance of event models is subserved by regions in the lateral PFC, and signals for event model updating are, at least partially, subserved by the midbrain dopaminergic system. Age is associated with declines in structural and functional integrity in the PFC (Kanne et al., 1998; Raz et al., 1997; Rympa et al., 2001; West, 1996), and reductions in dopamine functioning (Fearnley & Lees, 1991; Sakata et al., 1992). Previous work is consistent with the possibility that these brain regions are important for adaptive event segmentation. Zalla and colleagues have shown selective decreases in coarse segmentation performance in individuals with PFC lesions and individuals with schizophrenia (Zalla et al., 2003, 2004), which also affects the functioning of the PFC and dopaminergic functioning (Braver et al., 1999).

The evidence suggests that older adults have a reduced ability to perceive how a series of fine events are grouped by higher-level units.[8] Based on work on aging and situation model construction, this result may be a bit unexpected. Studies examining narrative comprehension between older and younger adults suggest that younger and older adults rely equally on situation models during text understanding (Radvansky & Dijkstra, 2007). Critically, however, these studies have not assessed the quality of situation models between age groups. It is possible that how strongly one relies on event models is unrelated, or weakly related, to their quality. The present data suggest that although older adults may rely on schematic knowledge about event structure for memory encoding and retrieval, they are less able to perceptually identify that structure during on-line comprehension.

Recently, researchers have called attention to the fact that older adults are more variable in their performance across items than younger adults, and noted that this may explain some age-related differences in cognition (Hultsch, Strauss, Hunter, & MacDonald, 2008). Intra-individual variability certainly could affect the hierarchical alignment measure, which assesses segmentation across viewings. To assess whether age-differences in reliability was related to the observed differences in segmentation performance, we computed Cronbach's alphas between the two movies in Experiment 1 and the three movies for Experiment 2. Interestingly, alphas were consistently higher for older adults than younger adults for both hierarchical alignment (Experiment 1: older = 0.37, younger = 0.25; Experiment 2: older = 0.71, younger = 0.22), and segmentation agreement (Experiment 1: older = 0.70, younger = 0.50; Experiment 2: older = 0.90, younger = 0.80). Thus, differences in reliability cannot account for the age differences in segmentation reported here.

In both experiments, older adults tended to identify fewer fine events than younger adults. One possibility is that older adults may fail to recognize some of the subunits that make up a larger activity. However, another possibility is that this difference is specific to the segmentation task used here; perhaps older and younger adults interpret differently the instructions to mark off the smallest or largest meaningful units. The shaping procedure we used to reduce extraneous variance in segmentation grain did not, however, completely eliminate these group differences. This provides weak evidence in favor of the first possibility over the second. In future research, it will be important to test whether this result is robust across tasks and experimental procedures in order to establish whether it reflects a true group difference in the mechanisms of event segmentation.

[8] When segmenting for the second time, participants may use their memory for the initial segmentation to guide their second segmentation. This could affect the alignment measure. If so, then alignment should differ depending on whether coarse or fine units were identified first, and this should interact with age. We tested for such effects in both experiments and did not observe them.

Improving event segmentation to improve memory

In this study, older adults whose segmentation was more normative and more hierarchical tended to remember the events better (see also Zacks et al., 2006). However, these effects were not large, nor perfectly consistent. Although modest, it is important to note that previous work has demonstrated that segmentation and recognition memory are uniquely related (Zacks et al., 2006). One possibility is that recall measures would provide more opportunity to observe relations between memory and segmentation—particularly the hierarchical organization of segmentation. In free recall tasks participants cluster information based on semantic, taxonomic, source, and temporal features, among others (Bower, Clark, Lesgold, & Winzenz, 1969; Hintzman, Block, & Inskeep, 1972; Kahana, 1996; Murdock & Walker, 1969; Puff, 1979). Some recent work has suggested that older adults cluster information in a free recall test to a lesser extent than younger adults (Taconnat, Raz, Bouazzaoui, Sauzeon, & Isingrini, 2009; but see Rankin, Karol, & Tuten, 1984). Most research on memory hierarchies for events has used free recall tasks (e.g., Bower et al., 1979; Brewer & Dupree, 1983; Lichtenstein & Brewer, 1980). These tasks may be particularly sensitive to the nature of event structures built during the perceptual experience of ongoing activities (Brewer & Dupree, 1983).

We assessed whether concurrent describing during segmentation would influence segmentation and memory performance, and whether it could help alleviate age differences in performance. The mixed previous results on the effects of describing on event segmentation left this an open question (Hard et al., 2006; Zacks et al., 2001). In our study, describing while segmenting had a limited effect on segmentation and no effect on memory. Describing reduced fine segmentation agreement for all participants and it increased coarse agreement for younger adults. This suggests that describing is not effective for encoding fine-grained units of activity, but leaves open the possibility that stronger manipulations of one's attention to one's coarse level segmentation may facilitate adaptive encoding for memory. In particular, attending to coarse level segmentation may help engage relevant knowledge structures (Zacks, 2004; Zacks, Kumar, Abrams, Mehta, 2009), which may in turn help activate the right information at the right time. Knowledge structures about events have been shown to play a major role in action planning (Grafman, 1995; Hommel, 2006) and memory for events (Abelson, 1981; Bower et al., 1979), and to allow for effective understanding and memory in older adults (Radvansky & Dijkstra, 2007). Knowledge structures for events prominently represent information about actors' goals and their relations, which is related to the part–subpart structure of activity. Recent work has suggested that event knowledge and inferences about goals are more likely to influence coarse than fine event segmentation (Zacks, 2004; Zacks, Speer and Reynolds 2009), which is consistent with the finding that when describing had a positive effect, it was on coarse segmentation. However, it is important to keep in mind that older adults received no benefit from describing.

Other interventions may affect attention to segmentation more powerfully than the description task used here. For example, Boltz (1992) used commercial placement in film to highlight event boundaries. Participants who watched films that had commercials placed at event boundaries recalled the films better than those who watched the films that had commercials inserted within events, and better than those who watched films without commercials. Another possibility is that the segmentation task itself may be an effective memory encoding strategy. In our studies participants always segmented while viewing the movies. In future research it would be valuable to compare segmentation to viewing without segmentation. However, to maximize potential benefits of attending to segmentation, it may be important to provide assistance in segmenting well.

Conclusion

As people age they report problems tracking everyday activities, such as difficulty with learning how to use new tools and following conversations and television programs (Galvin et al., 2005). These seemingly simple tasks require a complex process of parsing and organizing a set of actions and events into meaningful parts and subparts. The results from the current study suggest that older adults may perceive less hierarchical structure in the activity units that make up these tasks. Interventions that support more effective event segmentation may prove helpful in addressing these concerns.

Acknowledgements Preparation of this manuscript was partially supported by grants T32 AG000030–31 and R01-MH70674 from the National Institutes of Health. Christopher A. Kurby is now at Grand Valley State University.

Appendix

The table below is one participant's coarse and fine event descriptions for the "Putting up a tent" movie in Experiment 2. The placement of the coarse descriptions indicates the hierarchical grouping of the activity as segmented by this participant.

Coarse-Unit Description	Fine-Unit Description
Preparing to set up tent	Opening a bag
	Taking out contents of the bag
Setting up the frame of the tent	Unfolding the contents in the bag
	Setting up the frame of the tent
	Setting the other side of the tent frame
	Slide the frame into the canvas
	Making it set so the tent will stand up
Pegging the tent to the ground	Taking the nails out of the bag
	Pegging the tent on the ground
	Pegging the other side of the tent on the ground
	Taking more pegs out of the bag
	Nailing the sides of the tent on the ground
Covering tent	Unfolding the cover of the tent
	Putting the cover over the tent and securing it
	Checking the tent… Leaving

References

Abelson, R. P. (1981). Psychological status of the script concept. *American Psychologist, 36*, 715–729.

Balota, D. A., Dolan, P. O., & Duchek, J. M. (2000). Memory changes in healthy older adults. In E. Tulving & F. I. M. Craik (Eds.), *The Oxford handbook of memory* (pp. 395–410). New York: Oxford University Press.

Baron, R. M., & Kenny, D. A. (1986). The moderator–mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of Personality and Social Psychology, 51*, 1173–1182.

Bauer, P. J., & Mandler, J. M. (1989). One thing follows another: Effects of temporal structure on 1- to 2-year olds' recall of events. *Developmental Psychology, 25*, 197–206.

Baum, C., Edwards, D., Yonan, C., & Storandt, M. (1996). The relation of neuropsychological test performance to performance of functional tasks in dementia of the Alzheimer type. *Archives of Clinical Neuropsychology, 11*, 69–75.

Boltz, M. (1992). Temporal accent structure and the remembering of filmed narratives. *Journal of Experimental Psychology: Human Perception & Performance, 18*, 90–105.

Bower, G. H., Clark, M. C., Lesgold, A. M., & Winzenz, D. (1969). Hierarchical retrieval schemes in recall of categorized word lists. *Journal of Verbal Learning and Verbal Behavior, 8*, 323–343.

Bower, G. H., Black, J. B., & Turner, T. J. (1979). Scripts in memory for text. *Cognitive Psychology, 11*, 177–220.

Braver, T. S., & Cohen, J. D. (2001). Working memory, cognitive control, and the prefrontal cortex: Computational and empirical studies. *Cognitive Processing, 2*, 25–55.

Braver, T. S., Barch, D. M., & Cohen, J. D. (1999). Cognition and control in schizophrenia: A computational model of dopamine and prefrontal function. *Biological Psychiatry, 46*, 312–328.

Brewer, W. F., & Dupree, D. A. (1983). Use of plan schemata in the recall and recognition of goal-directed actions. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 9*, 117–129.

Cohen, J. D., MacWhinney, B., Flatt, M., & Provost, J. (1993). PsyScope: A new graphic interactive environment for designing psychology experiments. *Behavioral Research Methods, Instruments & Computers, 25*, 257–271.

Dickman, H. R. (1963). The perception of behavioral units. In R. G. Barker (Ed.), *The stream of behavior* (pp. 23–41). New York: Appleton-Century-Crofts.

Dumas, J. A., & Hartman, M. (2003). Adult age differences in temporal and item memory. *Psychology and Aging, 18*, 573–586.

Ericsson, K. A., & Simon, H. A. (1994). Verbal reports as data. *Psychological Review, 87*, 215–251.

Fearnley, J. M., & Lees, A. J. (1991). Ageing and Parkinson's disease: Substantia nigra regional selectivity. *Brain: A Journal Of Neurology, 114*, 2283–2301.

Foley, M. A., & Ratner, H. H. (2001). The role of action-based structures in activity memory. In H. D. Zimmer, R. L. Cohen, M. J. Guynn, J. Engelkamp, R. Kormi-Nouri, & M. A. Foley (Eds.), *Memory for action: A distinct for of episodic memory?* (pp. 112–135). New York: Oxford University Press.

Franklin, N., & Bower, G. H. (1988). Retrieving actions from goal hierarchies. *Bulletin of the Psychonomic Society, 26*, 15–18.

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

Grafman, J. (1995). Similarities and distinctions among current models of prefrontal cortical functions structure and functions of the human prefrontal cortex. *Annals of the New York Academy of Sciences, 769*, 337–368.

Grafman, J., Thompson, K., Weingartner, H., Martinez, R., Lawlor, B. A., & Sunderland, T. (1991). Script generation as an indicator of knowledge representation in patients with Alzheimer's disease. *Brain and Language, 40*, 344–358.

Hard, B. M., Tversky, B., & Lang, D. (2006). Making sense of abstract events: Building event schemas. *Memory & Cognition, 34*, 1221–1235.

Hintzman, D. L., Block, R. A., & Inskeep, N. R. (1972). Memory for mode of input. *Journal of Verbal Learning and Verbal Behavior, 11*, 741–749.

Hommel, B. (2006). How we do what we want: a neuro-cognitive perspective on human action planning. In R. J. Jorna, W. van Wezel, & A. Meystel (Eds.), *Planning in intelligent systems: Aspects, motivations and methods* (pp. 27–56). New York: John Wiley & Sons.

Hultsch, D. F., Strauss, E., Hunter, M. A., & MacDonald, S. W. S. (2008). Intraindividual variability, cognition, and aging. In F. I. M. Craik & T. A. Salthouse (Eds.), *The handbook of aging and cognition* (3rd ed., pp. 491–556). New York: Psychology Press.

Kahana, M. J. (1996). Associative retrieval processes in free recall. *Memory & Cognition, 24*, 103–109.

Kanne, S. M., Balota, D. A., Storandt, M., McKeel, D. W., Jr., & Morris, J. C. (1998). Relating anatomy to function in Alzheimer's disease: Neuropsychological profiles predict regional neuropathology 5 years later. *Neurology, 50*, 979–985.

Kersten, A. W., Earles, J. L., Eileen, S. C., & Lane, J. C. (2008). Adult age differences in binding actors and actions in memory for events. *Memory & Cognition, 36*, 119–131.

Lichtenstein, E. H., & Brewer, W. F. (1980). Memory for goal directed events. *Cognitive Psychology, 12*, 412–445.

Luo, L., & Craik, I. M. F. (2008). Aging and memory: A cognitive approach. *The Canadian Journal of Psychiatry, 53*, 346–353.

Mayr, U. (2001). Age differences in the selection of mental sets: The role of inhibition, stimulus ambiguity, and response-set overlap. *Psychology & Aging, 16*, 96–109.

McCabe, D. P., Roediger, H. L., McDaniel, M. A., Balota, D. A., & Hambrick, D. Z. (2010). The relationship between working memory capacity and executive functioning: Evidence for a common executive attention construct. *Neuropsychology, 24*, 222–243.

Miller, E. K., & Cohen, J. D. (2001). An integrative theory of prefrontal cortex function. *Annual Review of Neuroscience, 21*, 167–202.

Murdock, B. B., & Walker, K. D. (1969). Modality effects in free recall. *Journal of Verbal Learning and Verbal Behavior, 8*, 665–676.

Newell, A., & Simon, H. A. (1972). *Human problem solving*. Englewood Cliffs, NJ: Prentice Hall.

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

Newtson, D. (1976). Foundations of attribution: The perception of ongoing behavior. In J. H. Harvey, W. J. Ickes, & R. F. Kidd (Eds.), *New directions in attribution research* (pp. 223–248). Hillsdale, NJ: Erlbaum.

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

Paxton, J. L., Barch, D. M., Racine, C. A., & Braver, T. S. (2008). Cognitive control, goal maintenance, and prefrontal function in healthy aging. *Cerebral Cortex, 18*, 1010–1028.

Preacher, K. J., Rucker, D. D., MacCallum, R. C., & Nicewander, W. A. (2005). Use of the extreme groups approach: A critical reexamination and new recommendations. *Psychological Methods, 10*, 178–192.

Puff, C. R. (1979). Memory organization research and theory: The state of the art. In C. R. Puff (Ed.), *Memory organization and structure* (pp. 3–17). New York: Academic Press.

Radvansky, G. A., & Dijkstra, K. (2007). Aging and situation model processing. *Psychonomic Bulletin & Review, 12*, 1027–1042.

Rankin, J. L., Karol, R., & Tuten, C. (1984). Strategy use, recall, and recall organization in young, middle-aged, and elderly adults. *Experimental Aging Research, 10*, 193–196.

Raz, N. (2005). The aging brain observed in vivo: Differential changes and their modifiers. In R. Cabeza, L. Nyberg, & D. Park (Eds.), *Cognitive neuroscience of aging: Linking cognitive and cerebral aging* (pp. 19–57). New York, NY: Oxford University Press.

Raz, N., Gunning, F. M., Head, D., Dupuis, J. H., McQuain, J., Briggs, S. D., et al. (1997). Selective aging of the human cerebral cortex observed in vivo: differential vulnerability of the prefrontal gray matter. *Cerebral Cortex, 7*, 268–282.

Riby, L. M., Perfect, T. J., & Stollery, B. T. (2004). The effects of age and task domain on dual task performance: A meta-analysis. *European Journal of Cognitive Psychology, 16*, 863–891.

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

Rumelhart, D. E. (1977). Understanding and summarizing brief stories. In D. Laberge & S. J. Samuels (Eds.), *Basic processes in reading: Perception and comprehension* (pp. 265–303). Hillsdale, NJ: Erlbaum.

Rympa, B., Prabhakaran, V., Desmond, J. E., & Gabrieli, J. D. E. (2001). Age differences in prefrontal cortical activity in working memory. *Psychology and Aging, 16*, 371–384.

Sakata, M., Farooqui, S. M., & Prasad, C. (1992). Post-transcriptional regulation of loss of rat striatal D2 dopamine receptor during aging. *Brain Research, 575*, 309–314.

Salthouse, T. A. (2003). Interrelations of aging, knowledge, and cognitive performance. In U. Staudinger & U. Lindenberger (Eds.), *Understanding human development: Lifespan psychology in exchange with other disciplines* (pp. 265–287). Berlin, Germany: Kluwer Academic.

Sobel, M. E. (1982). Asymptotic intervals for indirect effects in structural equations models. In S. Leinhart (Ed.), *Sociological methodology 1982* (pp. 290–312). San Francisco: Jossey-Bass.

Sommerville, J. A., & Woodward, A. L. (2005). Pulling out the intentional structure of action: the relation between action processing and action production in infancy. *Cognition, 95*, 1–30.

Speer, N. K., Swallow, K. M., & Zacks, J. M. (2003). Activation of human motion processing areas during event perception. *Cognitive, Affective & Behavioral Neuroscience, 3*, 335–345.

Taconnat, L., Raz, N., Tocze, C., Bouazzaoui, B., Sauzeon, H., Fay, S., et al. (2009). Ageing and organization strategies in free recall: The role of cognitive flexibility. *European Journal of Cognitive Psychology, 21*, 347–365.

Trabasso, T., & Wiley, J. (2005). Goal plans of action and inferences during comprehension of narratives. *Discourse Processes, 39*, 129–164.

Travis, L.L. (1997) Goal-based organization of event memory in toddlers. In P. W. van den Broek et al. (Eds.), *Developmental spans on event comprehension and representation: Bridging fictional and actual events* pp. 111–139, LEA.

Verhaeghen, P., Steitz, D. W., Sliwinski, M. J., & Cerella, J. (2003). Aging and dual-task performance: A meta-analysis. *Psychology and Aging, 18*, 443–460.

West, R. L. (1996). An application of prefrontal cortex function theory to cognitive aging. *Psychological Bulletin, 120*, 272–292.

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

Zacks, J. M., & Tversky, B. (2001). Event structure in perception and conception. *Psychological Bulletin, 127*, 3–21.

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

Zacks, J. M., Speer, N. K., Vettel, J. M., & Jacoby, L. J. (2006). Event understanding and memory in healthy aging and dementia of the Alzheimer type. *Psychology and Aging, 21*, 466–482.

Zacks, J. M., Speer, N. K., Swallow, K. M., Braver, T. S., & Reynolds, J. R. (2007). Event perception: A mind/brain perspective. *Psychological Bulletin, 133*, 273–293.

Zacks, J. M., Kumar, S., Abrams, R. A., & Mehta, R. (2009). Using movement and intentions to understand human activity. *Cognition, 112*, 201–216.

Zacks, J., Speer, N., & Reynolds, J. R. (2009). Segmentation in reading and film comprehension. *Journal of Experimental Psychology: General, 138*, 307–327.

Zalla, T., Pradat-Diehl, P., & Sirigua, A. (2003). Perception of action boundaries in patients with frontal lobe damage. *Neuropsychologia, 41*, 1619–1627.

Zalla, T., Verlut, I., Franck, N., Puzenat, D., & Sirigu, A. (2004). Perception of dynamic action in patients with schizophrenia. *Psychiatry Research, 128*, 39–51.