Psychology and Aging

Age differences in the Perception of Goal Structure in Everyday Activity

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Author Comments:	Dear Dr. Mayr, Please find attached one copy of a manuscript entitled "Age differences in the Perception of Goal Structure in Everyday Activity" by myself and Jeffrey M. Zacks. In this study, we report data showing that during event segmentation, older adults encode the hierarchical goal structure of activity less robustly than younger adults. Compared to younger adults, older adult event segmentation behavior was less predicted by changes in the goal structure of activity. Also, older adults descriptions of events, elicited concurrently during event segmentation, included less differentiation of higher vs lower levels goals than younger adults. We are submitting this manuscript for consideration as a regular article. This paper is not currently under consideration with another journal. This submission is not masked. Thanks much for your attention to this manuscript. We look forward to corresponding with you about as it goes through the editorial process. Sincerely, Christopher A. Kurby Christopher A. Kurby Associate Professor Grand Valley State University Department of Psychology

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Age differences in the Perception of Goal Structure in Everyday Activity

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Abstract

Human activity is structured by goals and subgoals. To understand an everyday activity, a viewer must perceive its goal structure, and viewers may segment activity into units that correspond to perceived goals. In this study, we examined age differences in the ability to perceive hierarchical goal structure in ongoing activity. A group of younger and older adults viewed short movies of an actor doing everyday activities, segmented them into events, and described the events as they segmented. We investigated how participants' event descriptions were related to the hierarchical goal structure, and whether participants' event segmentation was related to moment-by-moment changes in actor goals. We found that both coarse and fine event segmentation behavior was related to changes in the goal hierarchy. Participants descriptions of coarse-grained events were more likely to contain information regarding higher-level goals, and their descriptions of fine-grained evens were more likely to mention lower-level goals. Critically, in both segmentation behavior and event descriptions, younger adults showed these effects more strongly than older adults. These results show that event segmentation recovers the hierarchical goal structure of events, and that older adults may have difficulty perceiving that structure.

Keywords: Cognitive Aging; Event Segmentation; Goal Structure; Event Hierarchy

Age differences in the Perception of Goal Structure in Everyday Activity

Suppose you are at a dinner party and are helping a friend wash the dishes. Although this is a mundane activity, to accomplish it you need to plan and coordinate a goal-subgoal action hierarchy. The dishes and silverware need to be collected, then rinsed, then placed in the dishwasher. To accomplish these goals, you need to complete their subgoals. For example, collecting the dishes is accomplished by moving around the table and picking up each item. Collecting the dishes is not complete until the final dish is picked up. Rinsing the dishes is accomplished only after each dish is scraped and held under the water, and so on. People generate such hierarchical event representations when engaging in everyday activity (Cooper & Shallice, 2000; Schwartz, 2006), and also when watching the activity of others (Kurby & Zacks, 2011; J. M. Zacks & Tversky, 2001; J. M. Zacks, Tversky, & Iyer, 2001). The segmentation of activities into their constituent event-subevent structures is a natural concomitant of ongoing visual perception (J. M. Zacks, Braver, et al., 2001), and is important to the comprehension, execution, and memory for experience (Bailey, Zacks, et al., 2013; Bailey, Kurby, Giovannetti, & Zacks, 2013; Flores, Bailey, Eisenberg, & Zacks, 2017; Gold, Zacks, & Flores, 2017; Kurby, Asiala, & Mills, 2013; Kurby & Zacks, 2012; Sargent et al., 2013). This process critically relies on systems related to attentional control, episodic memory, and working memory, which are systems that tend to decrease in functioning with age (Balota, Dolan, & Duchek, 2000; Hasher & Zacks, 1988; Richmond, Gold, & Zacks, 2017; Sargent et al., 2013; J. M. Zacks & Sargent, 2010; J. M. Zacks, Speer, Swallow, Braver, & Reynolds, 2007; R. T. Zacks, Hasher, & Li, 2000). Accompanying this age-difference in cognitive functioning, older adults tend to perform worse on event segmentation tasks (Bailey, Zacks, et al., 2013; Kurby & Zacks, 2011; J. M. Zacks & Sargent, 2010; J. M. Zacks et al., 2007; J. M. Zacks, Speer, Vettel, & Jacoby, 2006). Less effective event processing may also impact the ability to perceive hierarchical structure in events. In this study, we investigated the nature of these age-related changes in hierarchical event perception during online event comprehension.

People segment the stream of behavior into separate events (Dickman, 1963; Newtson & Engquist, 1976; J. M. Zacks et al., 2007). Current theories of event cognition argue that the process of event segmentation is in service of maintaining an accurate working memory representation of "what is happening now" (Kurby & Zacks, 2008; Radvansky & Zacks, 2014; J. M. Zacks et al., 2007). These *event models* include information about who the agents are and their goals, the causality of actions, the objects present, and spatiotemporal properties of the scene. Event models facilitate explaining what is happening now and, importantly, predicting future input. Event models need to be updated from time to time, resulting in the segmentation of experience into new events and the subjective experience of boundaries at the junction of these events. Event segmentation is commonly measured by having people engage in a unitization task. Participants watch a movie and press a button to mark off the movie into events. Viewers have shown high agreement in their segmentation behavior, both across and within viewers (Speer, Swallow, & Zacks, 2003; J. M. Zacks et al., 2006). Event segmentation behavior is also systematic. Viewers tend to segment when there are changes in the situation or perceptual stream (J. M. Zacks et al., 2007), such as when there are changes in the characters, objects, space, time, causation, goals (Gernsbacher, 1997; Kurby & Zacks, 2012; Magliano, Kopp, McNerney, Radvansky, & Zacks, 2012; Magliano, Miller,

& Zwaan, 2001; Magliano, Radvansky, Forsythe, & Copeland, 2014; Magliano, Zwaan, & Graesser, 1999; Radvansky & Copeland, 2010; Speer, Zacks, & Reynolds, 2007; J. M. Zacks, Speer, & Reynolds, 2009), as well as when there are changes in predictability of the ongoing action (Reynolds, Zacks, & Braver, 2007; Wilder, 1978b, 1978a; J. M. Zacks, Kurby, Eisenberg, & Haroutunian, 2011; J. M. Zacks, Speer, et al., 2009), and changes in visual motion (Hard, Tversky, & Lang, 2006; J. M. Zacks, 2004; J. M. Zacks, Kumar, Abrams, & Mehta, 2009).

Normally aging adults, and adults with Alzheimer's dementia, tend to have worse event segmentation ability than younger adults (Kurby & Zacks, 2011; J. M. Zacks et al., 2006). Older adults, and those with dementia, typically segment events less normatively than younger adults, or the appropriate comparison group (Bailey, Zacks, et al., 2013; Bailey, Kurby, et al., 2013; Kurby & Zacks, 2011; J. M. Zacks et al., 2006; but see Sargent et al., 2013). Given that there is high inter- and intraindividual agreement in the location of event boundaries (Speer et al., 2003; J. M. Zacks et al., 2006), normative segmentation is likely functional to event understanding. Indeed, older adults who agree more with group norms on the location of event boundaries show uniquely better memory for the activities (Bailey, Zacks, et al., 2013; Kurby & Zacks, 2011; Sargent et al., 2013; J. M. Zacks et al., 2006), as well as execute action sequences better (Bailey, Kurby, et al., 2013). Interventions to improve segmentation can also improve event memory for older adults (Flores et al., 2017; Gold et al., 2017).

This age-related difference in event segmentation ability suggests that older adults may also have a less effective ability to perceive goal-subgoal structure in events. The segmentation of behavior into events and subevents is critical to the understanding of activity, in part, because human activity can typically be described as the pursuit of goals and subgoals (Cooper & Shallice, 2000; Newell & Simon, 1972). Indeed, people tend to represent sequenced action as hierarchical goal-subgoal structures in memory and action planning (Barsalou & Sewell, 1985; Bower, Black, & Turner, 1979; Brewer & Dupree, 1983; Cooper & Shallice, 2000; Galambos & Rips, 1982; Grafman, 1995; Lichtenstein & Brewer, 1980; Rosen, Caplan, Sheesley, Rodriguez, & Grafman, 2003; Schwartz, 2006; Trabasso & Wiley, 2005), and in perception as event-subevent hierarchies (Hard et al., 2006; Kurby & Zacks, 2011; J. M. Zacks & Tversky, 2001; J. M. Zacks, Tversky, et al., 2001).

A recent study documented that older adults are less able to segment events into hierarchically organized event structures (Kurby & Zacks, 2011), suggesting the possibility of an age-difference in the encoding of goal-subgoal structure. Kurby and Zacks (2011) had older and younger adults segment a set of videos of people performing everyday activities, such as someone building a tent, once at a coarse grain (longer timescales) and once at a fine grain (shorter timescales). Hierarchical segmentation is characterized as perceived fine events clustering within coarse events (J. M. Zacks, Tversky, et al., 2001). In two experiments, Kurby and Zacks (2011) found that younger adults had better hierarchical structuring in their coarse-fine segmentation than older adults. Additionally, within the older adults, better hierarchical segmentation predicted better recognition memory for the events. These results suggest that older adults perceive less hierarchical structure in everyday activity. However, those results did not address whether their segmentation behavior was specifically related to changes in the goal-subgoal structure, and they did not address the content of the viewers' event models during segmentation regarding their representation of the goal-subgoal structure. In their Experiment 2, Kurby and Zacks (2011) had younger and older adults engage in a description task concurrent with the event segmentation task. After participants pressed a button to indicate the end of a segment, the participants described the segment out loud. Kurby and Zacks (2011) reasoned that engaging in an explicit describing task would improve event knowledge activation and benefit older adults' segmentation. But, they found that concurrent describing did not affect their segmentation performance, nor their memory for the events. In the current study, we present an analysis of the content of those event descriptions from Kurby and Zacks (2011), and the corresponding event segmentation behavior from that experiment. Using these descriptions, we assessed whether the segmentation behavior, and content of older adult event models, was less likely to show a goal-subgoal structure of the ongoing activity.

For these analyses, our goal was to test the extent to which participants' event segmentation was related to changes in the goal-subgoal structure of the activity, and to what extent participants talked about that information as they described the events. To assess this, we took advantage of the Action Coding System (ACS) developed by Schwartz, Reed, Montgomery, Palmer, and Mayer (1991) to code the goal structure of the movies. The ACS was developed to track improvements from action disorganization syndrome in patients recovering from traumatic brain injury. Its developers focused mainly on the production of routine everyday activities, such as breakfasting or dressing. The ACS conceptualizes everyday action as a two-level hierarchy. Activities are described by their higher order goals (called A2 actions), which break down into their subactions (called A1 actions). For example, "pour milk into a bowl of cereal" defines a higher-order goal which is satisfied once the actor produces its constituent subactions, such as remove the cap, pick up the bottle, and pour milk. In this paper, we tested hypotheses regarding the relation between segmentation grain and the representation of higher and lower level goals. People simultaneously segment events at multiple grains; longer timescale events (coarse events) and shorter timescale events (fine events) (Speer et al., 2007; J. M. Zacks, Braver, et al., 2001; J. M. Zacks, Tversky, et al., 2001). Coarse boundaries tend to correspond with a subset of fine boundaries (Kurby & Zacks, 2011; J. M. Zacks, Tversky, et al., 2001). For segmentation behavior, the perception of an event boundary should be associated with a change in goals, with changes in higher level goals predictive of coarse segmentation and changes in lower level goals predictive of fine segmentation. For event descriptions, at fine boundaries that are not coarse boundaries people should mention lower-level action goals more so than higher-level action goals. At fine boundaries that are also coarse boundaries, the mention of higher-level action goals should increase in probability. Because Kurby and Zacks (2011) found that older adults showed less hierarchical structure in their segmentation, we hypothesized that older adults will show those aforementioned effects more weakly than younger adults, in both segmentation behavior and description behavior.

Method

In this study we analyzed the event description and segmentation data from the describe condition (Experiment 2) from Kurby and Zacks (2011). The methods were described in detail there, although they will be summarized here.

Participants

Thirty-two younger adults (mean age 19 years, range 18-21 years; 24 females, 8 males; mean years education = 13; mean self-reported health = 4.5 on a 5-point scale) were recruited from the Washington University Psychology Department participant pool, whose members are mostly current students. Thirty-one healthy older adults (mean age 77 years, range 65-85 years; 17 females, 14 males; mean years education = 15; mean self-reported health = 3.9 on a 5-point scale) 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. This study was approved by the Washington University Human Research Protection Office.

Materials and procedure

Segmentation and description task. Participants watched and segmented three movies of everyday activities: a woman assembling a tent (duration 379 s), a man planting two window boxes with plants and flowers (duration 354 s), and a man sorting and washing his laundry (duration 300 s). See Figure 1 for still images from the movies (the stimuli can be found at https://osf.io/amgn7/). The movies did not contain any cuts and were shot from a fixed head-height perspective. As participants watched each movie, they segmented them into events, across two viewings. In one viewing, participants marked off the smallest units of activity (fine events) by pressing a button on a button box. In another viewing, they marked off the largest units of activity (coarse events).

Each time the participant pressed the button to segment, they then described out loud, what had happened in the preceding unit. They were given practice with the task, but were not coached regarding how to describe the activity. Utterances were recorded with a digital audio recorder as they produced their descriptions. Participants first practiced the segmentation and description task on a short movie of someone making a sandwich (127 s).

Memory tests. After segmenting each of the three movies at both the coarse and fine grains, participants were asked to perform two memory tasks: a recognition task and an order memory task. 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. Order memory was tested with 12 visually distinctive images printed on 3 x 5 inch cards. Participants were instructed to arrange the images into the order in which they occurred in the movie. The memory data are reported in Kurby & Zacks (2011); we will not discuss them further here.

Counterbalancing across participants was used for both the order of segmentation grain and the order of movie presentation for both the segmentation and memory tasks. Within each participant, movie order was the same for fine and coarse segmentation.

Movie and description scoring

Movie scoring. The three movies were coded using the ACS (Schwartz et al., 1991), which yields a goal-based classification of the actions performed in activities of daily living. This system was originally developed to track action errors and recovery from action disorganization syndromes. The ACS constructs goal hierarchies of action sequences consisting of low-level A1 units grouped into higher-level A2 units. According to Schwartz et al. (1991), an A1 unit is an action on the first level of a goal hierarchy which results in a transformation of an object. It can be conceptualized as a basic unit of action that produces a single result, such as picking up a cup or closing a door. These are akin to the basic actions described by Cooper and Shallice (2000). An A2 unit is one step higher than an A1 on the hierarchy and is defined as being a grouping of A1's which serve to satisfy a higher subgoal. A subset of the A1 units are denoted *crux* units; a crux unit is the central A1 action for the satisfaction of an A2. For the purposes of this study, an additional unit to the ones described by Schwartz et al. (1991) was created and labeled *summary unit*. Similar to how A2 units group A1 units into subgoals, summary units group A2's into higher order goal units. Each video was first broken down into its component A1's, then grouped into A2 units. A crux unit was identified for each A2. Last, A2's were grouped into summary units.

To illustrate, consider a sequence in the laundry movie. In this sequence, the actor's goal is to put detergent into a washer – the A2 unit. He executes five basic actions – A1 units – which are grouped by the A2: 1) picks up detergent from floor, 2) unscrews cap from bottle, 3) pours detergent into cap, 4) pours detergent into washer from cap, 5) shakes out cap. A1 unit #4 is the crux action of the sequence because this action satisfies the goal of getting detergent into the washer. A1 unit #5 is the final action motivated by the A2 goal, although it is a non-crux action. After completion of this A2 unit, he proceeds to pursue another A2 unit: pour detergent into a second washer. Those two A2 units are grouped into a summary unit by the higher order goal of putting detergent in all washers. To mark the temporal locations for the completion of each action unit for the segmentation analyses, we identified the frame in the movie where the motion of the actor became inconsistent with the goal. For example, in the tent movie, the actor puts a tent pole down on the ground, which is an A1. After she releases the pole, she pulls her hand away. We marked the end of the "put pole down" A1 as the frame when her hand begins to pull away. The temporal locations for the completion of each action unit were used as predictors in the segmentation analyses. The description of each action unit was used as the rubric for coding of participant event descriptions.

Table 1 presents the number of each action unit type, and their average durations, per movie. Overall, the average number of A1 units across the movies was 102.3, the average number of crux units was 31.3, the average number of A2 units was 30.3, and the average number of summary units was 8.3. Additionally, our analyses of goal structure revealed that some of the crux units had the same description as their parent A2 units. For example, for the tent movie, an A2 unit was “insert pole” and was accomplished by producing the crux action “insert pole.” Other crux units were not identical to their parent A2 units, but were highly semantically similar. For example, an A2 unit in the tent movie was “secure pole in tent” and its constituent crux unit was “hook pole to tent.” Other crux units had different action descriptions than their parent A2 units. For example, towards the end of the tent movie, the actor secures the tarp to the tent. The crux action to the “secure the tarp” A2 was “attach last corner of tarp.” Overall, the percentage of crux units that were identical or highly semantically similar to the description of the A2 unit was 64%. Lastly, 68% of the crux units occurred as the final unit of its parent A2 unit.

Description scoring. Participants’ event descriptions were transcribed and parsed into clauses, each containing a single main verb. A small percentage (2.8%) of the clauses described a state or outcome using verbs of being, verbs of containment, and verbs of possession (e.g., “last of the dark clothing is in”). The remainder of the clauses (97.2%) used action verbs to describe a single action (e.g., “Opening a bag”). These clauses formed the basic unit of all analyses. Three participants’ data were excluded from the analyses because they were missing complete segmentation runs for at least one movie due to digital recording errors.

For each described unit, for each participant, the nearest action unit to that event boundary was assessed regarding whether there was a match between the description and an A1 unit, A2 unit, crux unit, and summary unit. If a match was determined, then the description was given a 1. For example, in coding the planting video, one participant described a segment as “Putting on gloves for gardening.” Based on the location of the event boundary for that unit, the temporally nearest A1 unit to this description was, “He puts on the gloves,” and the temporally nearest A2 unit was “put on gloves.” The description was determined to match both of these units and credit was given accordingly. This A1 unit was also a crux unit, and so the description received a point in the crux category. However, this description did not mention the nearest summary unit “setting up workspace” and thus received a 0 for that category

In determining whether a description matched a unit from the rubric, a 1 was given if there was a verbatim match or if there was a close semantic match between the action described in the clause, indicated in part by the main verb, and the nearest action unit from the movie coding list. For example, a description from one participant in the planting movie was “Loosening up the soil in the pot”. This was scored as matching the nearest A1 unit “He digs a hole with the trowel in the planter box.” Another participant produced the description “he mixes up the soil with his tool,” which was also coded as matching this same A1 unit from the rubric. Both of these descriptions use a main verb that overlaps strongly with the A1 action “digs.” However, a description from one participant “prepares the soil for the first plant” was not coded as a match, even though it may have been describing the same action, because the verb “prepares” does not strongly overlap with “digs.” “Preparing the soil” could involve many things in addition to digging a hole or loosening up the soil.

Results

Association between goal structure in the activity and segmentation behavior

We computed two logistic mixed effect models (Jaeger, 2008) to assess age differences in the relation between goal structure and segmentation behavior, one for fine segmentation and one for coarse segmentation, using the R package lmerTest (Kuznetsova, Brockhoff, & Christensen, 2017). (See Kurby and Zacks (2012) and Kurby, Asiala, and Mills (2014) for similar uses of logistic mixed effect models in the analysis of segmentation behavior.) We created four goal structure predictors, one for each type of action unit, A1, crux, A2, and summary unit. Because A1s and cruxes were modeled simultaneously, the A1 predictor allowed us to estimate the role of non-crux A1s in segmentation. To create these predictors, for each action type, we constructed 1 s time bins and coded whether or not a goal completion occurred in that time bin. One model predicted fine segmentation from the four goal structure predictors, age (z-scored), and their interaction. The second model predicted coarse segmentation from the same predictors. Both models included subject and movie as random effects. We followed up each of these analyses with within-group models, separately by grain.

Fine segmentation. Figure 2 presents predicted probabilities of fine segmentation from the mixed effects model,[1] and Table 2 presents the statistical tests of the fine and coarse segmentation models. As these indicate, for fine segmentation, a completion of any of the four goal types was associated with increased odds of segmentation. There were two significant interactions with age: A1 X Age, and A2 X Age. The within-group analyses, presented in Table 3, showed that non-crux A1 completion significantly predicted segmentation for younger adults but not for older adults (see also Figure 2). Likewise, A2 completion was a significant predictor for younger adults but not for older adults.

Coarse segmentation. Figure 3 presents the predicted probabilities of coarse segmentation from the mixed effects model.[1] Non-crux A1 completion was associated with a decrease in the odds of segmentation (see Table 2 and Figure 3). Completion of cruxes and summary units were associated with an increased odds of segmentation. Summary unit completion interacted with age. The within-group analyses, presented in Table 4, showed that summary units were a stronger predictor of segmentation for younger adults than older adults (see also Figure 4).

Event descriptions

In these analyses of the event descriptions, we tested age differences in goal-based content of event models. We assessed hierarchical organization by dividing the fine units into *boundary fine* and *internal fine* units (J. M. Zacks, Tversky, et al., 2001). Boundary fine units were defined by identifying, for each coarse unit boundary, the fine unit whose terminal boundary was closest in time. The remaining fine units were defined to be internal fine units. To the extent that describers encode higher-level goals during coarse segmentation and lower-level goals during fine segmentation, coarse unit descriptions should be more likely to mention higher order goal units, such as summary units, and fine unit descriptions should be more likely to mention subordinate goals, such as A1 units. To the extent that describers encode activity hierarchically, and this guides their attention to goal information, boundary fine descriptions should be more likely to contain higher order goal information than internal fine descriptions. Further, if older adults are less likely to appropriately encode the goal structure of activity, younger adults should show a greater differentiation in the mention of goals between fine and coarse models than older adults.

Overall, across all participants and movies, there were 7,509 descriptions, and on average, they were 1.38 clauses long (SD = 0.80, $Mode$ = 1, min = 1, max = 17). For the analyses reported below, we excluded descriptions that were 3 SD greater than the grand mean (cutoff = 3.77; 2.3% of the descriptions).

For each goal type, we computed a logistic mixed effect model (Jaeger, 2008) to assess age differences in the relation between event type (Coarse vs. Boundary vs. Internal) and the mention of that goal. For each model, we predicted whether a description mentioned the goal of interest from event type (Coarse vs. Boundary vs. Internal), number of clauses in that description as a covariate, age (z-scored), and the interaction between age and event type. In the analyses, internal units served as the reference condition for the event type predictor. All models included subject and movie as random effects. We followed up each of these analyses with within-group models, separately by goal type.

Non-crux A1s. Figure 4 presents the predicted probabilities of a description mentioning A1 units by event type and age group. Table 5 presents the statistical results from the models. For the non-crux A1 analyses, we examined the mention of non-crux A1s by excluding descriptions that mentioned crux A1 units. Boundary unit and coarse unit descriptions both were significantly less likely to mention non-crux A1s than internal unit descriptions (see Table 5 and Figure 4). (According to the confidence intervals in Table 5, coarse unit descriptions were more likely to mention non-crux A1s than boundary unit descriptions.) Older adults were less likely to mention non-crux A1s than younger adults. Longer descriptions were more likely to mention a non-crux A1. Regarding interactions with age (see Table 5), as illustrated in Figure 4, the difference between coarse and internal units was larger for younger adults than older adults. The results of the within-group analyses, as presented in Tables 6 and 7, show that both younger and older adults showed a significant coarse vs. internal difference, but older adults produced a weaker effect.

Crux A1s. For these analyses, we examined the mention of crux A1s by excluding descriptions that mentioned non-crux A1s. Additionally, as indicated above regarding the ACS coding for the movies, some crux A1s were identical in description as their parent A2s. To get a clear assessment of the mention of crux A1s only, for these analyses, we excluded descriptions that mentioned crux units that were also coded as an A2. Coarse unit descriptions were significantly less likely to mention a crux A1 than internal unit descriptions (see Table 5 and Figure 4). Older adults were less likely to mention crux A1s than younger adults. Longer descriptions were more likely to mention a crux A1. Regarding interactions with age, as illustrated in Figure 4, the difference between coarse and internal units was larger for younger adults than older adults. The results of the within-group analyses, as presented in Tables 6 and 7, show that both younger and older adults showed a significant coarse vs. internal difference, but older adults produced a weaker effect.

A2 units. Figure 5 presents the predicted probabilities of a description mentioning

A2 units, and summary units, by event type and age group. Similar to the analysis of the mention of crux A1s, to get a clear assessment of the mention of A2 units only, for these analyses, we excluded descriptions that mentioned A2 units that were also coded as a crux A1. Coarse unit descriptions were more likely to mention A2 units than internal unit descriptions (see Table 5 and Figure 5). Older adults were more likely to mention A2s than younger adults. Regarding interactions with age, as illustrated in Figure 5, the difference between boundary and internal units was larger for younger adults than older adults, as well as the coarse-internal difference. The results of the within-group analyses, as presented in Tables 6 and 7, show that younger adults showed a significant increase in the probability of mentioning an A2 for boundary units and coarse units compared to internal units. However, older adults did not show a significant increase for boundary units. Older adults did show a significant increase for coarse units, but weaker so than younger adults.

Summary units. Both boundary unit and coarse unit descriptions were more likely to mention summary units than internal unit descriptions (see Table 5 and Figure 5). (According to the confidence intervals in Table 5, coarse unit descriptions were more likely to mention non-crux A1s than boundary unit descriptions.) Older adults were more likely to mention summary units than younger adults. Longer descriptions were more likely to mention a summary unit. As illustrated in Figure 5, the difference between boundary and internal units was larger for younger adults than older adults, as well as the coarse-internal difference, leading to significant interactions of both boundary and summary unit status with age. The results of the within-group analyses, as presented in Tables 6 and 7, show that both younger and older adults showed a significant increase in the probability of mentioning an A2 for boundary units and coarse units, compared to internal units. However, these effects were weaker for older adults than younger adults.

Discussion

In this study, we examined viewers' continuous descriptions of ongoing activity, and their event segmentation, to test whether and how the hierarchical goal structure of the activity was encoded in their event representations. Moreover, we assessed to what extent there were age differences in the processing of hierarchical goal structure in continuous events. Multiple measures indicated that viewers encoded the hierarchical goal structure of activities during event segmentation. For event segmentation behavior, broadly speaking, these data suggest that the timescale organization of segmentation recovers the hierarchical structure of goal-directed activity. Changes in goals across the hierarchy were associated with an increased probability of perceiving an event boundary, with changes in summary units being a particularly strong predictor of coarse segmentation. In the event descriptions, the evidence suggests that coarse event models are more likely to contain higher-level goal information, and fine models are more likely to contain lower-level goal information. Additionally, there was some evidence of hierarchical separation of goals across grain with boundary units falling in between coarse and internal descriptions (most strongly for non-crux A1's and summary units).

We also observed important age differences in the encoding of hierarchical goal structure during segmentation. We found that the coarse-fine timescale organization of segmentation behavior was more tightly coupled with goal structure for younger adults than older adults—A1 units were predictive of fine segmentation for younger adults but not older, and summary units were more predictive of coarse segmentation for younger than older. Younger adult event descriptions revealed more sensitivity to the hierarchical goal structure than older adults. In particular, older adults were less likely than younger adults to differentially mention the higher-level goals across segmentation grain. For both A2 and summary units, younger adults showed a stronger separation of their mention between internal and boundary units than older adults.

These age differences in event perception are consistent with previous research on aging and event segmentation (J. M. Zacks et al., 2006). Additionally, the finding that older adults' descriptions were less likely to reflect the hierarchical goal structure of naturalistic activity is consistent with previous work showing older adults may have difficulty with the maintenance and updating of goal representations (Braver et al., 2001; Braver & West, 2008; Mayr, 2001; Mayr & Liebscher, 2001). Our data suggest that older adults are able to encode the hierarchical goal structure of activity, but do so less precisely and robustly than younger adults. Additionally, the results have two implications. The first is that older adults are less likely to direct attention to different levels of the goal hierarchy with changes in segmentation grain. For all measures of goal mention, the difference between the mention of goals between coarse and fine internal units was greater for younger adults than older adults. The second is that the age-difference in hierarchical goal encoding may feature mostly strongly in the monitoring of high-level goals. Based on the observed boundary vs interval differences, older adults showed less hierarchical structuring regarding encoding of A2s and summary units, but not A1s (lower-level goals). A possible explanation is that older adults may have a deficit in coarse event processing. This explanation has some precedent from studies investigating event segmentation in individuals with frontal cortex damage or impairments in goal processing. Zacks, Kurby, Landazabal, Krueger, and Grafman (2016) found that individuals with traumatic brain injury had reduced event segmentation functioning, and those with damage in ventromedial prefrontal cortex had a pronounced reduction in coarse segmentation ability. Zalla, Pradat-Diehl, and Sirigu (2003) presented evidence that individuals with frontal damage had reduced coarse segmentation performance, but not fine segmentation. Patients with schizophrenia have shown similar deficits (Zalla, Verlut, Franck, Puzenat, & Sirigu, 2004). Other studies with older adults, and those with Alzheimer's dementia, however, did not find differentially worse coarse vs. fine segmentation performance, instead showing equally worse coarse and fine performance (Bailey, Zacks, et al., 2013; Kurby & Zacks, 2011; J. M. Zacks et al., 2006), and a few have shown a lack of age-differences in segmentation performance (Kurby & Zacks, 2018; Sargent et al., 2013). A difference between our current investigation and that previous work may be that our experiment specifically focused on the encoding of goal structure, which correlates with event segmentation behavior, but is not synonymous with it. Thus, one possibility is that older adults' segmentation differs from that of younger adults due to differences in how goals are processed.

Our observed age differences may be at odds with research suggesting some age-preservation of event processing in story comprehension contexts (Radvansky & Dijkstra, 2007). Such studies show that when reading narratives, older adults typically show evidence that they rely on goal or schema information to a similar degree as younger adults (Radvansky & Curiel, 1998). (Although, it may be important to note that in those studies, there is typically a main effect of age with older adults performing worse on measures than younger adults.) An important difference between that research and the current study is one of genre. In our study, participants were viewing naturalistic activity, whereas in that work participants were experiencing narratives. Older adults may use narrative structure to support their event processing (Kurby et al., 2014; Magliano et al., 2012). Narratives structure event information to guide processing and mental model construction (Zwaan & Radvansky, 1998), and narratives allow for better knowledge integration (Graesser, Golding, & Long, 1991; Haberlandt, Berian, & Sandson, 1980; Hannon & Daneman, 2009; Mandler, 1987). Additionally, older adults do not show reductions in event schematic knowledge (Rosen et al., 2003) which may help in narrative comprehension (Graesser, Millis, & Zwaan, 1997; Radvansky & Dijkstra, 2007). These characteristics of narrative should reduce demands on declining working memory and attentional systems in older adults. Naturalistic experiences, however, do not provide such structuring and places the burden on the viewer to guide attention appropriately.

Regarding younger adults, in addition to their better overall goal encoding, we found that changes at all levels of the goal hierarchy predicted their fine segmentation, suggesting that they were simultaneously monitoring both lower- and higher-level goals. This is consistent with research suggesting that individuals track multiple timescales along the event hierarchy during event segmentation (Hard et al., 2006; J. M. Zacks, Braver, et al., 2001; J. M. Zacks & Tversky, 2001; J. M. Zacks, Tversky, et al., 2001). This may suggest that asking participants to segment at a fine grain constrains their reporting of events at a fine level, but does not change their monitoring of the rest of the hierarchy. An alternative account may be that, instead, participants were not distinguishing among goals during fine segmentation. However, this is unlikely because their description data clearly showed such discrimination.

The observed age differences hint at possibilities for improving event encoding in older adults. Indeed, previous interventions to improve event segmentation in older adults have been shown to improve event memory (Flores et al., 2017; Gold et al., 2017). This suggests that interventions to improve goal structuring in older adults may also confer comprehension benefits. An important goal of such interventions would be to assess how goal monitoring may improve hierarchical event encoding in older adults.

Regarding crux A1's, the results disconfirmed our expectation that their mention would be more frequent for boundary units than internal units; boundary units tend to be the end of a coarse event. It is unclear how to interpret those results. Some possibilities are that our participants did not recognize those units as particularly important to the goal structure, the crux units for these activities were not saliently central, attending to the centrality of an event is not consequential for event segmentation, and/or the event segmentation task is not sensitive to attention to crux A1s. Given that action centrality features prominently in script representations (Galambos, 1983; Rosen et al., 2003), action production (Schwartz, 2006; Schwartz et al., 1991) and memory for sequential action (Galambos & Rips, 1982; Lichtenstein & Brewer, 1980), the latter possibility may be the most likely.

Conclusion

Naturalistic activity is structured by goals and subgoals, and viewers tend to perceive it as such (Black & Bower, 1979; Brewer & Dupree, 1983; Lichtenstein & Brewer, 1980; J. M. Zacks, Tversky, et al., 2001). This experiment showed that observers' perception of events in everyday activity closely tracked the goal structure in the activity. Changes in higher level goals were associated with coarse segmentation, and changes in lower level goals were associated with fine segmentation. Participants' running descriptions of the activity also closely corresponded with the activity's goal structure, suggesting that goal features are functional for the comprehension of event structure and not merely correlated with it. Importantly, older adults showed a reduced ability to perceive the hierarchical goal structure of ongoing naturalistic activity. One possibility is that these age differences reflect a downstream consequence of some other cognitive difference, which could prove diagnostic of individual and group differences in comprehension. A more speculative possibility is that the ability to encode and update actors' goals is causally responsible for individual and group differences in event comprehension, such that it can be a target for interventions to improve event comprehension and memory.

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Footnotes

[1] To compute the probability of segmenting at a non-crux A1 completion, the A1 predictor was set 1, and the A2, crux, and summary unit predictors were set to 0. To compute the probability of segmenting at crux completion, the A1 and crux predictors were set to 1 and the A2 and summary unit predictors were set to 0. To compute the probability of segmenting at A2 unit completion, the A1 and A2 predictors were set to 1, the crux predictor was set to its mean (.09), and the summary unit predictor was set to 0. To compute the probability of segmenting at summary unit completion, the A1, A2, and summary unit predictors were set to 1, and the crux predictor was set to its mean (.09). To obtain probabilities separately by age group, the age predictor was set to the average age of the age group of interest (19 years for younger and 77 years for older).

Table 1

Number of Goal Types and Durations by Movie

Movie	Goal Type	Count	Mean Duration (SD)
Tent	A1	74	5.0s (3.8s)
	Crux	24	6.5s (4.5s)
	A2	24	15.4s (11.2s)
	Summary Unit	7	53.0s (43.7s)
Window box	A1	105	3.3s (2.6s)
	Crux	23	2.3s (1.3s)
	A2	22	15.8s (7.1s)
	Summary Unit	9	38.5s (48.0s)
Washing clothes	A1	128	2.3s (1.5s)
	Crux	47	4.4s (3.1s)
	A2	45	6.5s (3.7s)
	Summary Unit	9	36.6s (43.0s)

Table 2

Predicting Segmentation Behavior: Odds Ratios, and 95% Confidence Intervals, of the Predictors from the Logistic Mixed Effects Models for the Goal Change Analyses.

Model	Predictor	Odds ratio	95% CI	*z*	*p*
Fine	A1	1.19	1.11-1.28	4.68	<.001***
	Crux	1.58	1.36-1.74	6.86	<.001***
	A2	1.26	1.10-1.44	3.43	<.001***
	Summary Unit	1.87	1.61-2.17	8.16	<.001***
	Age	0.89	0.77-1.03	-1.58	0.114
	A1 X Age	0.85	0.79-0.92	-4.28	<.001***
	Crux X Age	0.97	0.85-1.09	-0.56	0.580
	A2 X Age	0.85	0.75-0.98	-2.29	0.022*
	Summary Unit X Age	1.09	0.94-1.27	1.14	0.253
Coarse	A1	0.70	0.61-0.80	-4.97	<.001***
	Crux	1.58	1.26-1.97	3.97	<.001***
	A2	0.79	0.60-1.03	-1.75	0.082
	Summary Unit	8.22	6.52-10.36	17.82	<.001***
	Age	1.00	0.88-1.14	0.04	0.966
	A1 X Age	1.03	0.89-1.09	0.37	0.716
	Crux X Age	0.95	0.76-1.12	-0.42	0.680
	A2 X Age	1.22	0.93-1.60	1.45	0.150
	Summary Unit X Age	0.58	0.46-0.73	-4.63	<.001***

Note. ***p < .001, *p < .05. The df for the z tests was 66167.

Table 3

Predicting Segmentation Behavior for Fine Segmentation: Odds Ratios, and 95% Confidence Intervals, of the Predictors from the Logistic Mixed Effects Models for the Goal Change Analyses.

Model	Predictor	Odds ratio	95% CI	*z*	*p*
Young	A1	1.37	1.25-1.50	6.67	<.001***
	Crux	1.57	1.35-1.82	5.79	<.001***
	A2	1.45	1.23-1.70	4.49	<.001***
	SummaryUnit	1.76	1.46-2.13	5.93	<.001***
Older	A1	1.03	0.92-1.16	0.57	.567
	Crux	1.51	1.25-1.83	4.20	<.001***
	A2	1.10	0.89-1.36	0.88	.378
	SummaryUnit	1.96	1.55-2.48	5.59	<.001***

Note. ***p < .001, **p < .01*, p < .05. The df for the z tests was 34118.

Table 4

Predicting Segmentation Behavior for Coarse Segmentation: Odds Ratios, and 95% Confidence Intervals, of the Predictors from the Logistic Mixed Effects Models for the Goal Change Analyses.

Model	Predictor	Odds ratio	95% CI	*z*	*p*
Young	A1	0.69	0.57-0.85	-3.57	<.001***
	Crux	1.64	1.21-2.23	3.16	.002**
	A2	0.64	0.43-0.93	-2.31	.021*
	SummaryUnit	13.73	9.97-18.91	16.04	<.001***
Older	A1	0.71	0.58-0.87	-3.33	.001**
	Crux	1.50	1.08-2.09	2.41	.016*
	A2	0.98	0.67-1.42	-0.13	.900
	SummaryUnit	4.88	3.49-6.81	9.31	<.001***

Note. ***$p < .001$, **$p < .01$*, $p < .05$. The df for the z tests was 32050.

Table 5

Predicting Description Behavior: Odds Ratios, and 95% Confidence Intervals, of the Predictors from the Logistic Mixed Effects Models.

Model	Predictor	Odds ratio	95% CI	*z*	*p*
Non-Crux A1	Boundary Unit	0.58	0.49-0.69	-6.08	<.001***
	Coarse Unit	0.15	0.12-0.19	-18.15	<.001***
	Age	0.68	0.54-0.87	-3.10	.002**
	Number of Clauses	1.70	1.50-1.92	8.38	<.001***
	Boundary Unit X Age	1.04	0.87-1.24	0.43	.670
	Coarse Unit X Age	1.44	1.18-1.77	3.55	<.001***
Crux A1	Boundary Unit	1.02	0.82-1.26	0.17	.866
	Coarse Unit	0.39	0.30-0.51	-7.06	<.001***
	Age	0.65	0.47-0.88	-2.74	.006**
	Number of Clauses	1.31	1.12-1.53	3.39	.001**
	Boundary Unit X Age	0.90	0.72-1.12	-0.95	.341
	Coarse Unit X Age	1.36	1.04-1.77	2.28	.023*
A2	Boundary Unit	1.64	1.34-2.00	4.81	.866
	Coarse Unit	2.29	1.91-2.75	8.89	<.001***
	Age	1.34	1.06-1.70	2.41	.016*
	Number of Clauses	0.97	0.84-1.12	-0.42	.675
	Boundary Unit X Age	0.73	0.59-0.89	-3.05	.002**
	Coarse Unit X Age	0.63	0.52-0.75	-5.02	<.001***
Summary Unit	Boundary Unit	4.68	3.84-5.71	15.25	<.001***
	Coarse Unit	10.98	9.08-13.27	24.80	<.001***
	Age	1.26	1.02-1.57	2.09	.036*
	Number of Clauses	1.46	1.28-1.66	5.70	<.001***
	Boundary Unit X Age	0.74	0.60-0.90	-2.98	.003**
	Coarse Unit X Age	0.75	0.62-0.91	-2.96	.003**

Note. ***$p < .001$, **$p < .01$*, $p < .05$. The Internal Unit served as the reference condition for these analyses. The df for the A1 analysis was 7028, the df for the Non-Crux A1 analysis was 5181, the df for the Crux analysis was 4953, the df for the A2 analysis was 5181, and the df for the Summary Unit analysis was 7027.

Table 6

Predicting Description Behavior for Younger Adults: Odds Ratios, and 95% Confidence Intervals, of the Predictors from the Logistic Mixed Effects Models.

Model	Predictor	Odds ratio	95% CI	*z*	*p*
Non-Crux A1	Boundary Unit	0.56	0.44-0.71	-4.86	<.001***
	Coarse Unit	0.11	0.08-0.14	-15.27	<.001***
	Number of Clauses	1.39	1.13-1.69	3.19	.001**
Crux A1	Boundary Unit	1.15	0.89-1.50	1.08	.281
	Coarse Unit	0.29	0.20-0.41	-6.70	<.001***
	Number of Clauses	1.49	1.18-1.89	3.32	<.001***
A2	Boundary Unit	2.21	1.67-2.92	5.58	<.001***
	Coarse Unit	3.56	2.79-4.54	10.20	<.001***
	Number of Clauses	0.86	0.68-1.08	-1.30	.193
Summary Unit	Boundary Unit	6.21	4.78-8.07	13.66	<.001***
	Coarse Unit	13.90	10.84-17.83	20.74	<.001***
	Number of Clauses	1.81	1.46-2.24	5.47	<.001***

Note. ***$p < .001$, **$p < .01$. The Internal Unit condition served as the reference condition for these analyses. The df for the A1 analysis was 4203, the df for the Non-Crux A1 analysis was 2895, the df for the Crux analysis was 2829, the df for the A2 analysis was 2895, and the df for the Summary Unit analysis was 4202.

Table 7

Predicting Description Behavior for Older Adults: Odds Ratios, and 95% Confidence Intervals, of the Predictors from the Logistic Mixed Effects Models.

Model	Predictor	Odds ratio	95% CI	*z*	*p*
Non-Crux A1	Boundary Unit	0.61	0.47-0.78	-3.82	<.001***
	Coarse Unit	0.21	0.16-0.28	-10.50	<.001***
	Number of Clauses	1.91	1.63-2.23	8.05	.001**
Crux A1	Boundary Unit	0.92	0.65-1.30	-0.46	.642
	Coarse Unit	0.55	0.38-0.80	-3.10	.002**
	Number of Clauses	1.18	0.96-1.44	1.55	.120
A2	Boundary Unit	1.18	0.89-1.58	1.14	.255
	Coarse Unit	1.44	1.10-1.90	2.62	.009**
	Number of Clauses	1.04	0.87-1.24	0.45	.655
Summary Unit	Boundary Unit	3.60	2.67-4.85	8.38	<.001***
	Coarse Unit	8.94	6.71-11.92	14.96	<.001***
	Number of Clauses	1.28	1.08-1.51	2.91	.004**

Note. ***p < .001, **p < .01*. The Internal Unit condition served as the reference condition for these analyses. The df for the A1 analysis was 2825, the df for the Non-Crux A1 analysis was 2285, the df for the Crux analysis was 2124, the df for the A2 analysis was 2285, and the df for the Summary Unit analysis was 2825.

Pitching a tent

Planting a window box

Washing clothes

Figure 1. Still images from: Tent, Window box, and Washing clothes.

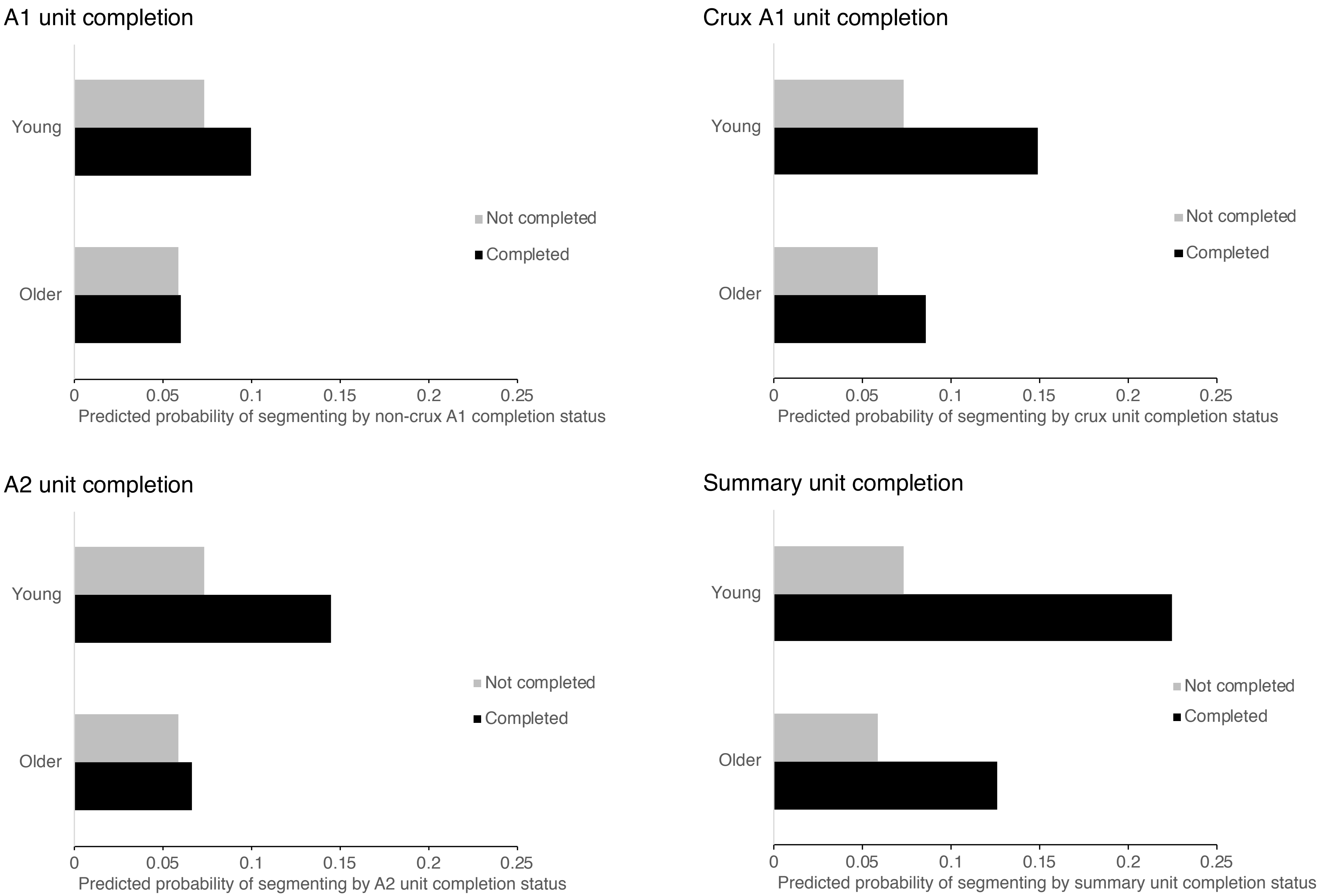


Figure 2. Predicted probability of fine segmentation by goal completion and age.

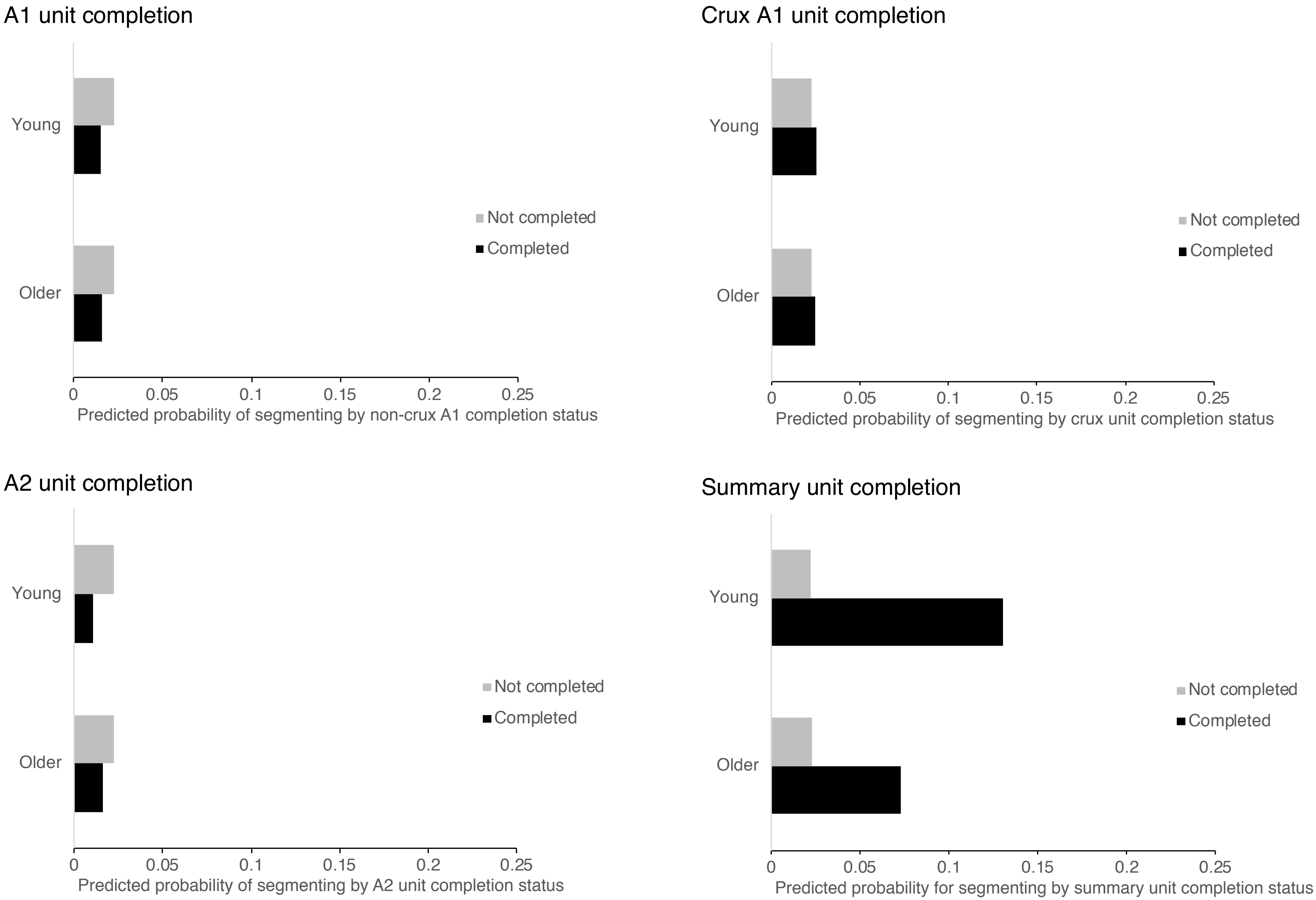
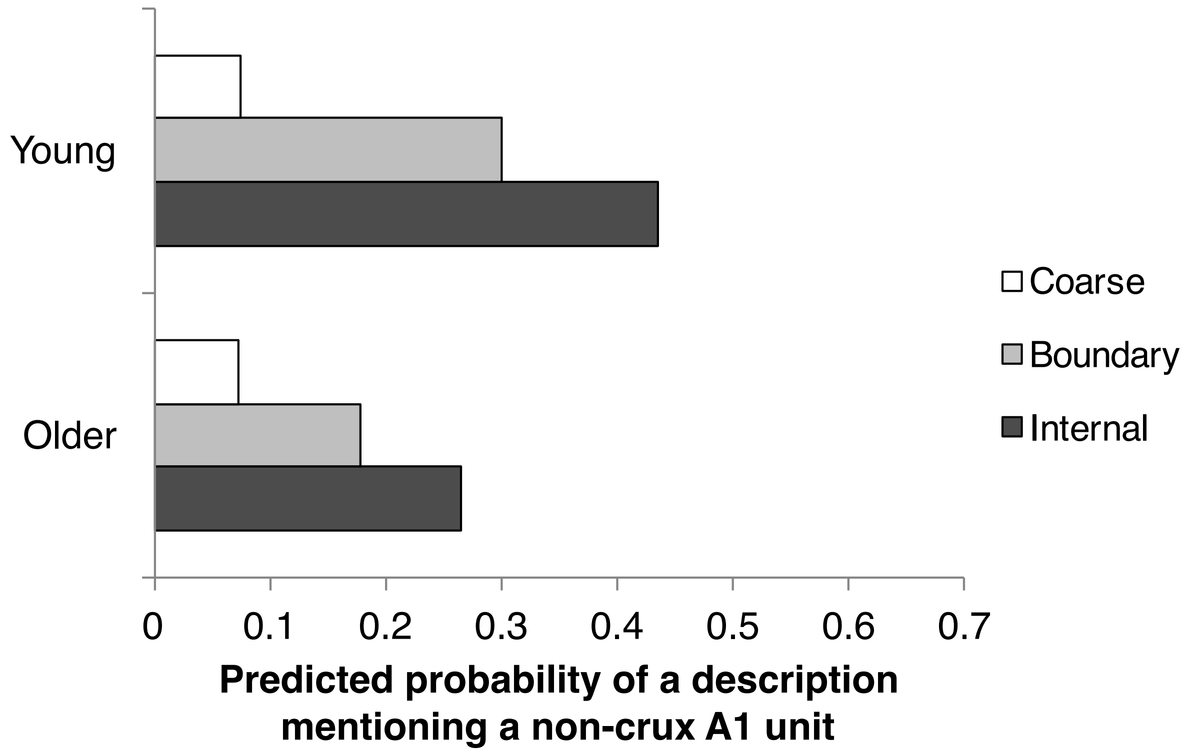


Figure 3. Predicted probability of coarse segmentation by goal completion and age.

Non-crux A1 units



Crux A1 units

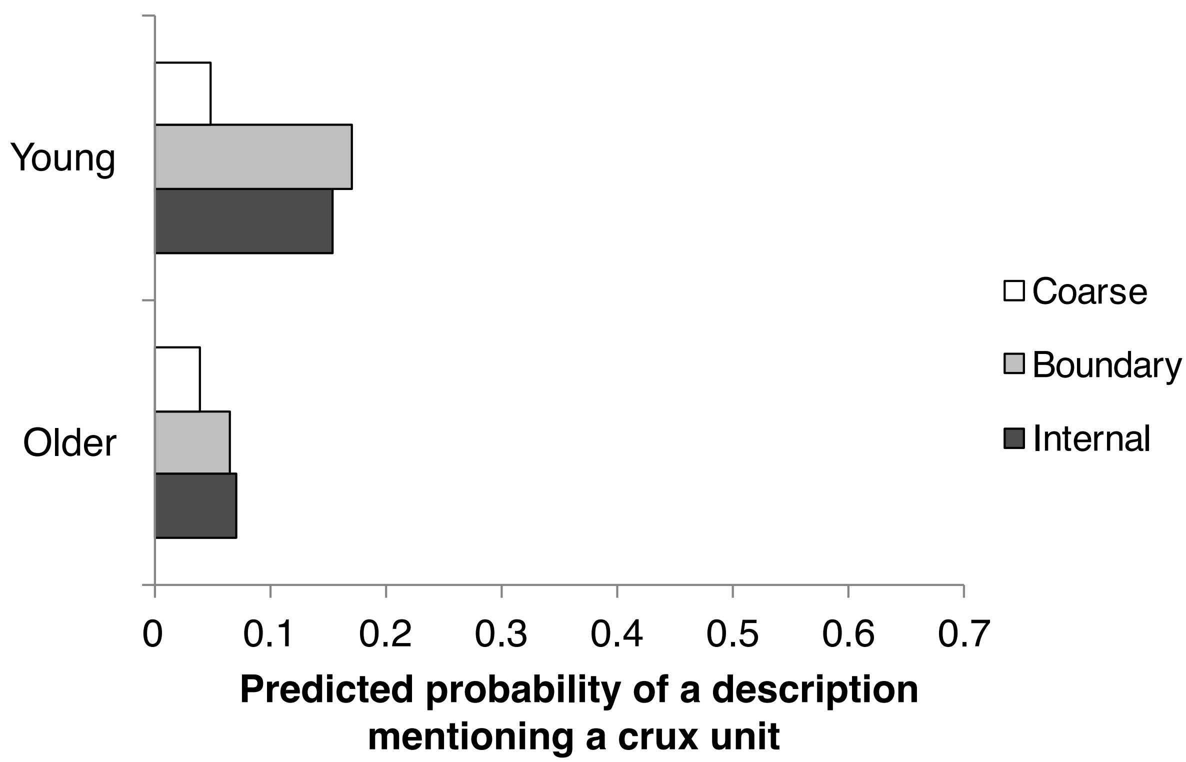
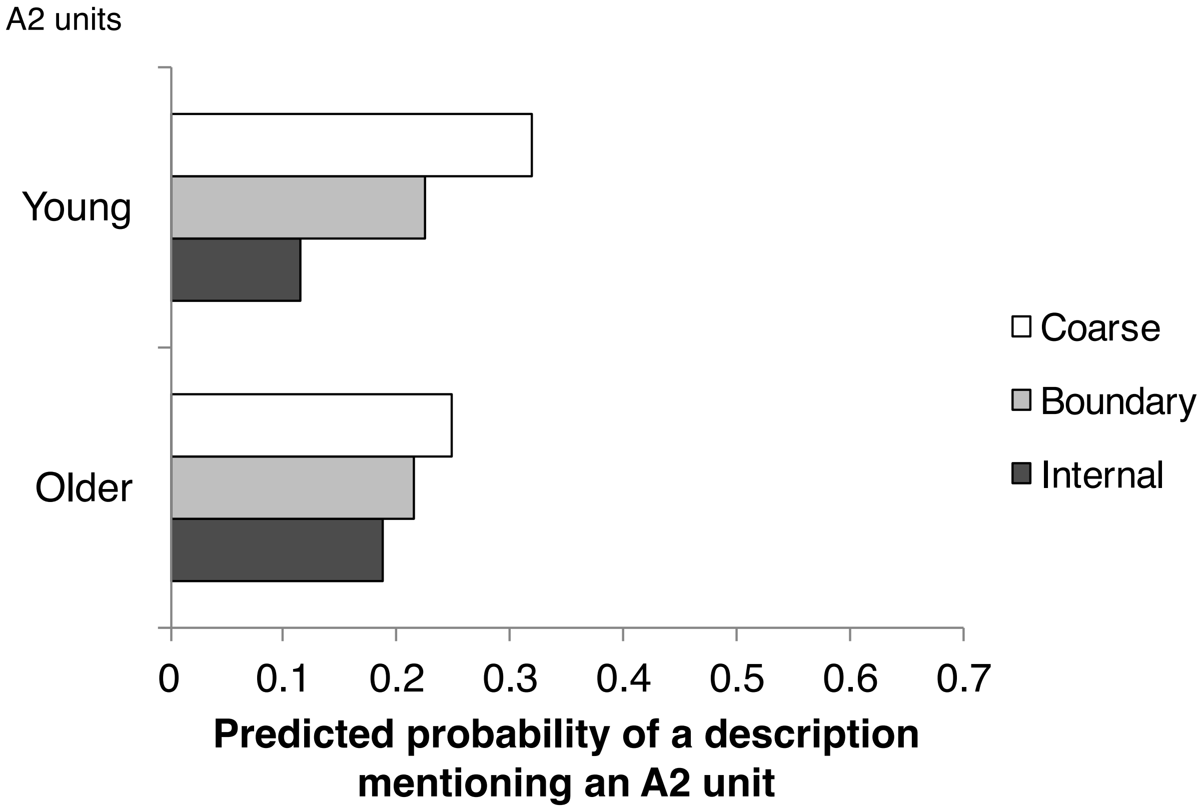


Figure 4. Predicted probability of mentioning A1 units by event unit type.



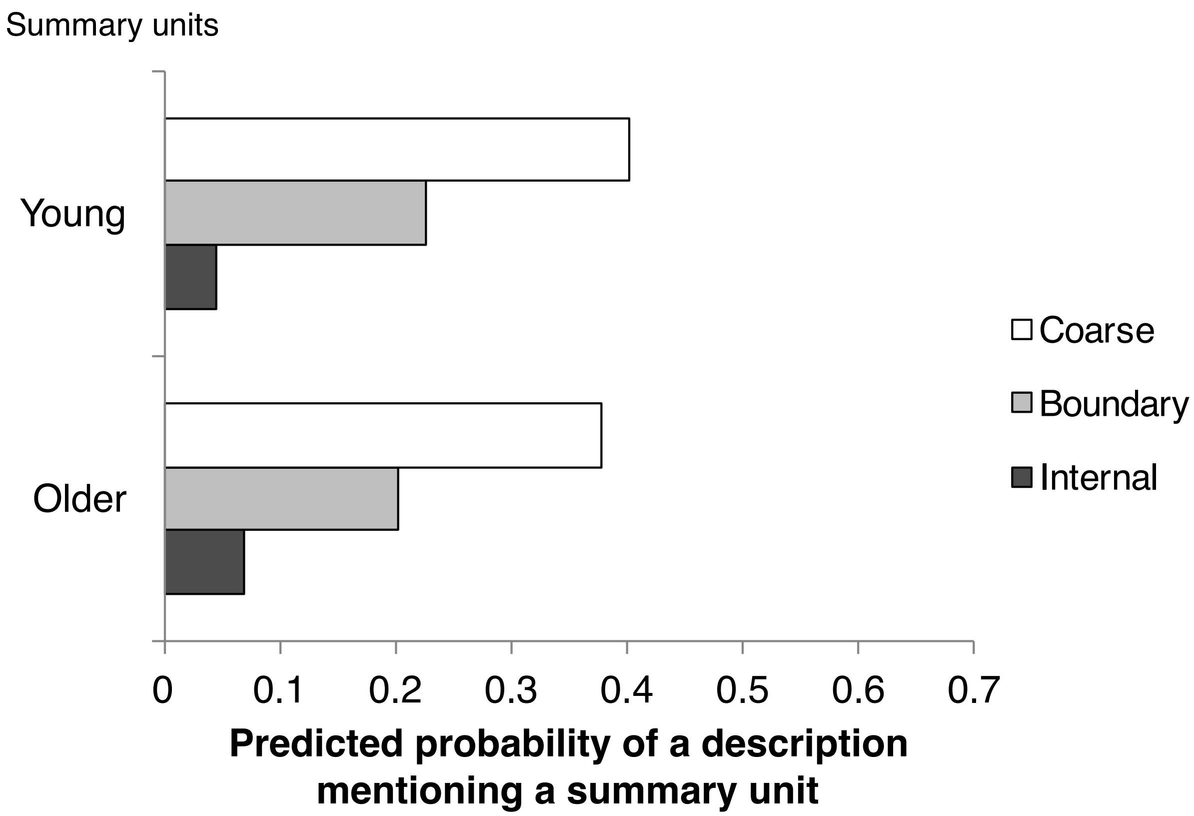


Figure 5. Predicted probability of mentioning A2 and summary units by event unit type.