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The effects of age on the strategic use of pitch accents in memory for discourse: A processing-resource account

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Abstract

In two experiments, we investigated age-related changes in how prosodic pitch accents affect memory. Participants listened to recorded discourses that contained two contrasts between pairs of items (e.g. one story contrasted *British scientists* with *French scientists* and *Malaysia* with *Indonesia*). The end of each discourse referred to one item from each pair; these references received a pitch accent that either denoted contrast (L+H* in the ToBI system) or did not (H*). A contrastive accent on a particular pair improved later recognition memory equally for young and older adults. However, older adults showed decreased memory if the *other* pair received a contrastive accent (Experiment 1). Young adults with low working memory performance also showed this penalty (Experiment 2). These results suggest that pitch accents guide processing resources to important information for both older and younger adults, but diminish memory for less important information in groups with reduced resources, including older adults.

Keywords

pitch accenting; language comprehension; discourse; cognitive aging; recognition memory

An extended spoken discourse presents listeners with numerous pieces of information, not all of which can feasibly be attended to and encoded into memory. Success in discourse comprehension, then, entails identifying the most important information and prioritizing it for further processing (Benjamin, 2008; Finley, Tullis, & Benjamin, 2010; Nelson & Narens, 1990). In spoken speech, an important cue to the importance of information is pitch accenting. *Pitch accents* are phonological constructs, realized with increased intensity, increased duration, and changes in pitch, that are associated with information that is new to the discourse or that contrasts with other elements of the discourse (Ladd, 2008).

Not all listeners may be equally effective at using pitch accents to guide comprehension. There are extensive age differences in both what and how much is remembered (for review, see Hoyer & Verhaeghen, 2006), and it has been proposed that these differences may result in part from changes in the degree to which important information is prioritized for encoding. However, the nature of any such differences is unclear. Theories have alternately

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proposed that older adults are *less* strategic at preferentially encoding important or difficult information (Dunlosky & Connor, 1997; Titone, Prentice, & Wingfield, 2000) and that older adults *more* strongly prefer high-value information in memory (Castel, 2008).

Here we investigated age-related changes in the effects of pitch accents on memory for a discourse. We tested whether older adults exhibited enhanced, lessened, or equivalent sensitivity to pitch accenting in guiding the allocation of encoding resources. We further investigated whether these differences could be attributed to age-related changes in online processing resources by testing whether similar differences in sensitivity were evident between young adults with greater or more restricted resources.

Age Differences in Encoding Selectivity

Age differences in episodic memory have sometimes been attributed to differences in the ability to select information for further processing (e.g., Dunlosky & Connor, 1997; Healey, Campbell, & Hasher, 2008). Older adults may not be as effective as young adults at selectively attending to the most important or difficult items, and this may cause the age-related decline in episodic memory typically observed in laboratory tasks. For instance, Dunlosky and Connor (1997) found that older adults were less apt than young adults to selectively devote additional study time to those cue-target pairs that they had answered incorrectly on a previous cued recall test, even when information about their past performance was presented along with the item. In that case, differences in selectivity accounted for the majority of age-related variance in recall performance.

Differences in selectivity have also been observed in the domain of discourse comprehension. For example, older adults are sometimes less apt than younger adults to prioritize more important propositions over less important ones in their recall of a text, especially as the overall task difficulty increases (e.g. Dixon, Hultsch, Simon, & von Eye, 1984; Hartley, 1993; Stine & Wingfield, 1988). Although these effects have been most frequently tested in reading of written text, they have also been observed in comprehension of spoken discourse. For instance, Titone, Prentice, and Wingfield (2000) tested resource allocation using the auditory moving window paradigm, in which participants self-paced delivery of segments of spoken speech. They found that, compared to young adults, older adults' allocation of study time was less sensitive to syntactic boundaries and to discourse importance. Self-pacing of encoding also benefited older adults less than young adults on a later recall test for the material. These results suggest that older adults were less apt to preferentially allocate encoding resources to the most important or difficult materials, and that this difference led to a deficit in memory for the discourse. This view—that older adults are generally less strategic in their discourse comprehension—suggests that older adults should be less apt to capitalize on what pitch accents denote about the importance or status of information in a discourse.

An alternate view of memory aging, however, is that the value of information becomes an increasingly *strong* constraint over the lifespan. For instance, Castel (2008) has argued that, because older adults both have greater knowledge about what is important and may perceive their resources as more limited, they are more apt to focus on high value information. Consequently, it is in *less* important information where age differences should be greatest: older adults ignore less important material to focus on the high value material, whereas young adults attempt to remember everything.

This theory is supported by some memory tasks in which older adults appear to be equally or more selective than younger adults. Castel, Benjamin, Craik, and Watkins (2002) presented participants with word lists in which each word was paired with a number. This number determined how many points participants received for recalling the word during a subsequent test phase. Older adults were just as likely as younger adults to recall the most valuable words, although young adults were more apt to remember some less valuable items in addition. Older adults actually outperformed young adults on a measure of how well participants optimized their selection of high-value words given the total number of items recalled.

Similarly, Dixon, Hultsch, Simon, and von Eye (1984) found that adults with higher verbal ability, as assessed by a vocabulary test, were just as successful as younger adults at remembering the most important propositions in a written discourse. Age deficits emerged only for less important, subordinate details.

These results indicate that, in some situations, older adults can be as effective as young adults in remembering valuable information and it is in less important information that age differences in memory emerge. This value-directed processing account suggests that older adults may be just as sensitive as young adults, or even more sensitive, to what pitch accents signal about the importance of information to a discourse.

A limitation of some of these experiments, though, is that they relied on unfamiliar tasks, such as the auditory moving window paradigm, or on contrived laboratory manipulations of importance, such as assigning point values. In natural conversation, the importance of information is not likely to be so directly specified. Instead, it is likely to be indicated by cues such as pitch accents. This discrepancy is of particular importance because it has been argued that age differences in memory are smaller on more naturalistic tasks (Benjamin, 2010; Castel, 2008). Tullis and Benjamin (under review) have argued that strategy use in older adults is equivalent or superior to that of younger adults when the strategy in question reflects naturalistic demands on memory. Testing the extent to which older adults use more naturalistic cues such as prosody, then, provides an important test of the generality of age effects on encoding selectivity.

Pitch Accents and Language Comprehension

How can prosody contribute to discourse comprehension? Theories of intonation propose that the discourse status of referents is frequently denoted by pitch accents, phonological constructs realized acoustically as changes in fundamental frequency (F_0) and increased duration and intensity (for review, see Ladd, 2008). Referents receiving pitch accents are typically those that are new to a discourse, that contrast with other referents, or that have undergone a shift in discourse status (Watson, 2008).

Words may also vary in the type of pitch accent assigned to them, although it is presently debated whether such differences are categorical (Pierrehumbert & Hirschberg, 1990; Selkirk, 2002) or continuous (Ladd & Schepman, 2003). For instance, the ToBI system for prosodic transcription of American English (Beckman & Elam, 1997; Silverman et al., 1992) distinguishes between H* and L+H* accents, among others. An H* accent consists a single pitch target with F_0 high (*H*) in the speaker's range, aligned with the stressed syllable (*) of the word. An L+H* accent consists of a low pitch target (*L*) prior to the stressed syllable followed by a rise to a high pitch target on the stressed syllable. Pierrehumbert and Hirschberg (1990) argued that the H* accent is associated with information that is new to the discourse, while the L+H* accent is associated with information that is contrastive. For example, in (2b) below, *Kipling* is new to the discourse and would likely receive an H* in Pierrehumbert and Hirschberg's account. In (3b), however, *Kipling* contrasts with the already mentioned *Aaron* and would likely receive an L+H* accent.

(2a) Who invented snow golf?

(2b) KIPLING (H*) invented snow golf.

(3a) Did Aaron invent snow golf?

(3b) No, KIPLING (L+H*) invented snow golf.

Pitch accent distinctions influence young adults' memory for discourse. For instance, Fraundorf, Watson, and Benjamin (2010) presented young adults with a recognition memory test for the events in spoken discourses. In each discourse, a context passage such as (4) first established two contrasts, each between a set of two items (e.g. *British* vs. *French* and *Malaysia* vs. *Indonesia*). A subsequent passage, which we term the *continuation*, then picked out one item from each contrast set. (5) provides an example continuation. The pitch accent on each critical word in the continuation was manipulated between a presentational (H*) or contrastive (L+H*) accent through splicing. After listening to all of the recorded stories, participants completed a two-alternative forced choice recognition test for the referent chosen in each continuation.

(4) Both the British and the French biologists had been searching Malaysia and Indonesia for the endangered monkeys.

(5) Finally, the (British/French) spotted one of the monkeys in (Malaysia/Indonesia) and planted a radio tag on it.

Fraundorf et al. found that memory was more accurate for referents receiving L+H* accents than for referents receiving H* accents. Subsequent experiments showed that this benefit was driven by enhanced rejection of the contrast items, such as rejecting *French* when *British* received a contrastive accent, and did not generalize to rejecting lures that never appeared in the original discourse, such as *Portuguese*. These results imply that the mnemonic benefit of the L+H* accent relates to its contrastive interpretation and not merely its audibility or perceptual salience. (For a further review of how pitch accents and other elements of linguistic prosody affect language comprehension in young adults, see Cutler, Dahan, & van Donselaar, 1997, and Wagner & Watson, 2010).

Use of Prosody by Older Adults

Do older adults show similar effects of pitch accents in language comprehension? Prior work has found that older adults are less sensitive than young adults to some elements of prosody. For example, older adults are less successful than younger adults at identifying the emotional and attitudinal information conveyed by speakers' prosody (Orbelo, Testa, & Ross, 2003; Orbelo, Grim, Talbott, & Ross, 2005), and these changes are greater than would be expected given age-related changes in audition (Orbelo et al., 2005).

Use of the linguistic information conveyed by prosody, however, appears to be well-preserved across the life-span. Older adults and younger adults make similar use of lexical stress in identifying words (Wingfield, Lindfield, & Goodglass, 2000) and of prosodic boundaries in resolving syntactic ambiguities (e.g. Kjelgaard, Titone, Wingfield, 1999; Titone, Koh, Kjelgaard, Bruce, Speer, & Wingfield, 2006). Pitch accents may facilitate recall more for older adults than for younger adults (Cohen & Faulkner, 1986; Stine & Wingfield, 1987), although exaggerated use of contrastive accents actually impairs older adults' comprehension (Kemper & Harden, 1999). However, in past work, the presence or absence of pitch accents has often been manipulated across a discourse as a whole or has been confounded with the presence or absence of prosodic boundaries, so it is unclear how pitch accents affect older adults' allocation of attention to specific information.

Present Work

In two experiments, we tested whether younger and older adults differ in the effects of pitch accenting on their memory and whether those differences are best attributed to differences in processing resources or to experience with pitch accenting.

We used the task introduced by Fraundorf et al. (2010), reviewed above, which tested recognition memory for the events of a discourse. Recall that, in that task, a continuation passage for each item picked out one referent from each of two contrast sets. The type of pitch accent of each of the two critical words in the continuation was orthogonally manipulated between a presentational (H*) or contrastive (L+H*) accent, as in (6).

(6) Finally, the BRITISH (H*/L+H*) spotted one of the monkeys in MALAYSIA (H*/L+H*) and planted a radio tag on it.

Contrastive accents could affect memory in this task in two ways. First, a contrastive accent on one word might facilitate memory for that contrast set. For instance, a contrastive accent on *British* in (6) might improve memory for the *British* versus *French* distinction. We term this possibility the *accent boost*. Second, a contrastive accent on one contrast set might direct attention or resources away from *other* information in the story. For instance, a contrastive accent on *British* might impair memory for the fact that the monkey was found in *Malaysia*. We term this possibility the *other-accent penalty*. These effects are not mutually exclusive. The accent boost likely reveals the effects of pitch accenting on allocation behavior, whereas the other-accent penalty will only be revealed if insufficient resources are available to encode other information in spite of the additional attention given to the contrastive information.

Among young adults, Fraundorf et al. (2010) found the accent boost but no other-accent penalty. That is, contrastive accents improved memory for an accented contrast set but did not impair memory for the other contrast set.

In Experiment 1, we compared the effect of contrastive accents in this task for older and young adults. If older adults are less able to selectively encode information in a discourse, then contrastive accents—which provide an indicator of discourse status—should have smaller effects. However, if age differences are actually greater for *less* valuable details, then older adults should show similar or greater memory for the important, contrastively accented details. In addition, older adults may be more apt to show the other-accent penalty; that is, when a contrastive accent makes one contrast set particularly important, older adults would be less apt to encode the other, less valuable details.

Experiment 1

Experiment 1 directly compared how pitch accents affect younger and older adults' memory for discourse. If selectivity in memory encoding decreases across the lifespan, older adults may be less sensitive to pitch accenting. Alternately, if the value of information is particularly important for older adults, older adults may be *more* sensitive to pitch accents. These changes in sensitivity might be reflected in differences in the accent boost, an other-accent penalty, or both.

Experiment 1 also provides a test of whether the comprehension of pitch accents is preserved across the lifespan, as it is for other linguistic uses of prosody.

Method

Participants—48 undergraduate students at the University of Illinois participated in partial fulfillment of a course requirement. 48 community-dwelling adults (age range: 60 to 80 years; $M = 68$, $SD = 6.5$) were recruited through advertisements in campus publications and participated for a cash honorarium. All participants in both groups were native speakers of American English and all of the older adult participants scored at least 27 of 30 on the Mini Mental State Exam (Folstein, Folstein, & McHugh, 1975).

The older adults completed the 40-item Shipley Institute for Living Vocabulary Scale (Shipley, 1940) at the end of the session. Vocabulary scores were not collected from the present sample of young adults, but were available from a prior sample of 25 young adults from the same population. The older adults ($M = 35.2$, $SD = 3.0$) had greater vocabulary knowledge[1] (95% CI of the difference: [4.01, 7.60]) than the young adults ($M = 29.4$, $SD = 4.1$), $t(71) = 6.45$, $p < .001$, as is typically observed (Park, Lautenschlager, Hedden, Davidson, Smith, & Smith, 2002; Salthouse, 2004; Stine-Morrow, Miller, Gagne, & Hertzog, 2008).

Orbelo et al. (2005) have shown that older adults' comprehension of prosody is not predicted by hearing sensitivity beyond the ability to hear the speech stream. Consequently, we did not test participants' hearing beyond their ability to hear the recorded stories. Participants in both age groups were able to adjust the volume of the computer task to ensure that the stories were audible.

Materials—48 short recorded discourses from Fraundorf et al. (2010) were used. Each discourse began with a context passage, such as (4) above, that established two contrast sets, each of which contained two items. A subsequent continuation passage, such as (5) above, mentioned one referent from each contrast set.

In each story, the pitch accent on each critical word in the continuation was orthogonally manipulated across participants between a presentational (H*) or contrastive (L+H*) accent. Thus each story could be heard with a contrastive accent on the first contrast set, on the second contrast set, on both, or on neither.

The assignment of items to conditions was randomized across participants, with the constraint that each participant heard an equal number of items in each condition. Similarly, the item from each contrast set that was mentioned in the continuation (e.g. whether the British or the French scientists found the monkey) was also randomized across participants, with the constraint that for each participant an equal number of the items were those that had been mentioned first in the context passage as those mentioned second.

A female research assistant with an Inland Northern American English accent (Labov, Ash, & Boberg, 2006), appropriate for the region, recorded the discourses. Recordings were made at 48 kHz using a Studio Projects C1 Condenser microphone connected to a Marantz PMD670 Professional digital recorder. To minimize noise, the recordings were made in a quiet room with all electronic devices except the recorder unplugged.

To ensure that the stimuli differed only in the pitch accents on the target words, the different tokens of the critical word were spliced into a carrier sentence that did not vary across conditions. We administered a post-experiment survey to verify that the splicing did not

[1]We assume equal variance between samples in comparisons of the young and older adults because between-individual variance does not necessarily increase with age (Salthouse, 2004). The reported differences remain significant even if the Satterthwaite connection for unequal variance is applied.

result in stimuli that sounded unnatural. None of the participants in either of the present experiments noticed the splicing.

Acoustic analyses confirmed that the words with L+H* had greater mean F_0, duration, and intensity, consistent with past descriptions of contrastive accents (Selkirk, 2002). These effects obtained both when the measurements were made on just the syllable carrying primary word stress, where pitch accents are argued to be realized (e.g., Ladd, 2008), and on the entire word.

The complete list of materials and further details on the acoustic measurements are available in Fraundorf et al. (2010).

Procedure—Participants were informed that they would be listening to stories and that their memory for the stories would later be tested. The format of the memory test was not described to participants in advance. Participants performed the task on a computer running MATLAB 7.1 and the Psychophysics Toolbox (Brainard, 1997; Pelli, 1997).

Participants first listened to a sample recording of the speaker and adjusted the computer volume until they could easily hear the recording.

The experiment began with a study phase in which participants listened to all 48 stories, presented in random order. During this time, the computer screen was blank. There was a 5 s delay between stories. After 24 stories had been presented, the computer informed participants they were halfway through the study phase and could take a break.

After participants had listened to all 48 stories, they proceeded to a test phase. Each discourse was presented in text form, with the two critical words in the continuation replaced by blanks, as in (9). Participants did not hear the stories during the test phase and hence received no prosodic information during test.

(9) Both the British and the French biologists had been searching Malaysia and Indonesia for the endangered monkeys. Finally, the ______ spotted one of the monkeys in _____ and planted a radio tag on it.

Memory was tested one contrast set at a time. The two items in the contrast set were displayed on screen and participants chose one of them with a key press. The discourses were presented in the same order as during the study phase, with a 500 ms delay between the tests of each contrast set and a 1000 ms delay between discourses.

After the test phase, participants completed a structured debriefing questionnaire in which they were asked whether they had heard anything odd in the recordings. No participant reported anything that suggested they had detected the splicing.

Results

Accuracy of recognition memory was analyzed as a function of three factors: the accent on the critical word being tested, the accent on the other critical word in the continuation, and age. Mean accuracy in each condition is displayed in Figure 1.

While memory performance has often been analyzed by submitting the proportion of accurate responses in each condition for each participant to an analysis of variance, there are several limitations to such an approach. First, analysis of variance models assume normally distributed error terms, but proportions, even with a transformation applied, are not normally distributed (Jaeger, 2008). Second, since both participants and items were sampled (from the population of all possible participants and all possible discourses, respectively), it is desirable to model both participant and item variability. However, computing a proportion or mean over multiple items discards item-level information. Baayen, Davidson, and Bates (2008) and Jaeger (2008) have recommended mixed effects models to address these issues. Mixed effects models allow multiple random effects, including both participants and items, to be included in the model. These models also permit the use of link functions, such as the log odds (known as the *logit*), to relate experimental variables to binomially distributed outcomes such as recognition accuracy.

We used a mixed effects model to model the log odds of correct recognition for each contrast set. The model included fixed effects of age group, the accent on each target (H* or L+H*), and the interactions of these factors. Factors were coded into the model using mean-centered contrast codes. The model also included random intercepts for participants and items. To fully model the structure of the test items, in which two contrast sets were nested within each story, the model included one random intercept for story and, nested within story, a second random intercept for contrast set. All models reported were fit using Laplace estimation with the R software (R Development Core Team, 2008) and the *lme4* package (Bates, Maechler, & Dai, 2008).

In mixed effects modeling, variability in an effect across participants or across items is modeled with a random slope of that effect by participants or items. A random slope of target accent by story improved the fit of the model in a likelihood ratio test, $\chi^2_{(2)} = 7.63$, $p < .05$, indicating that the effect of the accent type on the target word (that is, the accent boost) varied across stories. The model was further improved by a random slope of age by contrast sets, $\chi^2_{(2)} = 20.13$, $p < .01$, indicating the age effect was larger for some facts than others. The model was also marginally improved by a random slope of target accent by participants, $\chi^2_{(2)} = 5.43$, $p = .07$. Since this random slope did not reach conventional levels of significance, we report results from the model without it, but all reported effects were reliable both with and without this slope. No other random slopes contributed reliably to the model.

Parameter estimates for the final model are displayed in Tables 1 and 2. The accent placed on a referent reliably affected memory; the odds of correct recognition for words receiving a contrastive accent (M = 85%) were 1.82 times greater (95% CI = [1.54, 2.14]) than for words receiving a presentational accent (M = 77%), consistent with the results of Fraundorf et al. (2010).

Age did not reliably interact with the accent placed on a particular item, Wald $z = -0.42$, $p = .68$. That is, younger and older adults showed an equivalent benefit to memory from a contrastive accent. However, age interacted with the accent placed on the *other* critical word in the story. For older adults, targets were less likely to be remembered if the other critical word had a contrastive accent (M = 81%) than if it did not (M = 83%). There was no evidence of such an effect for young adults; in fact, young adults' memory was numerically *better* if the other contrast set received a contrastive accent (M = 81%) than if did not (M = 79%). This age difference can be described by an odds ratio between young and older adults: odds of recognition when the other critical word had a contrastive accent were 0.77 times lower (95% CI = [0.61, 0.98]) for older than for young adults.

The overall effect of age on recognition was not reliable, $z = 1.13$, $p = .26$.

Discussion

In Experiment 1, contrastive accents facilitated memory to an equal degree for young and older adults. This finding is consistent with other work showing that the influence of prosody on other linguistic processes, such as syntactic processing (Kjelgaard et al., 1999;

Titone et al., 2006) and word recognition (Wingfield et al., 2000), also remains well-preserved with age.

If anything, older adults showed evidence of *greater* sensitivity to pitch accents. When one critical word was heard with a contrastive accent, older adults appeared to prioritize that item to the detriment of others. For instance, a contrastive accent on *British* impaired older adults' memory for the *Malaysia/Indonesia* distinction. Young adults, consistent with Fraundorf et al. (2010), did not show this effect. To the extent that contrastive accents suggest importance, these results are broadly consistent with the results of Castel et al. (2002), who found that older and young adults are equally successful at remembering high value information, but that older adults are less successful than young adults at remembering less valuable information.

Because the discourses were presented aurally, one question is whether the age difference simply reflects age-related declines in hearing sensitivity. But, there are several reasons that hearing sensitivity is unlikely to account for the results of Experiment 1. First, both age groups could adjust the volume of the stories until they could be comfortably heard. Second, other studies have found that differences in pure-tone thresholds do not account for age differences in prosody comprehension (e.g. Orbelo et al., 2005). Finally, and most importantly, the difference between older and young adults in Experiment 1 is not consistent with a hearing sensitivity account. Although it is plausible that differences in audition could have lead to lower overall performance in older adults or to older adults showing smaller benefits from contrastive accents (e.g., from a decreased ability to detect the prosodic cues), neither of these effects obtained. Overall performance was equivalent between age groups, as was the benefit of contrastive accents. Rather, the age difference was in how a contrastive accent on one detail affected memory for the rest of the story. This effect is not one that can be clearly attributed to hearing differences.

Why, then, do older, but not young, adults show the other-accent penalty? Castel (2008) has argued that mnemonic selectivity may increase across the lifespan for multiple reasons, including both limitations in processing resources and increased knowledge of what information in the world is important. This proposal is consistent with studies of cognitive change across the lifespan, which have found that processing resources such as working memory and speed of processing decrease with age, whereas verbal knowledge increases (Park et al., 2002; Salthouse, 2004). It also accords with models of discourse comprehension (Stine-Morrow et al., 2008) that model age-related changes in reading time as a function of decreases in processing resources and increases in verbal ability.

Either of these changes could potentially drive the other-accent penalty observed in Experiment 1. For instance, limited processes resources could force older adults to encode only the most important details. When one contrast set receives a contrastive accent, it gains importance and leads older adults to focus less on the other details, creating an other-accent penalty. This *limited resources hypothesis* predicts that an other-accent penalty might also be evident in those young adults who are also restricted in online processing resources such as working memory ability.

Another possibility is that older adults, as a consequence of more years of exposure to spoken English, have more experience with the distribution of contrastive accents. Offline linguistic knowledge, such as vocabulary, generally increases over the lifespan (Park et al., 2002; Salthouse, 2004; Stine-Morrow et al., 2008), and, in Experiment 1, the older adults indeed had a higher mean vocabulary score than the young adult population. This increased linguistic knowledge may make older adults better attuned to the association between contrastive accenting and discourse importance. They might prioritize contrastively accented information for encoding even if they would have resources to encode additional information. This *linguistic knowledge hypothesis* does not predict that differences in resources underlie the other-accent penalty. If anything, a relationship with working memory might obtain in the opposite direction: young adults who score higher on working memory tasks typically show greater sensitivity to other constraints such as plausibility (Pearlmutter & MacDonald, 1995), although the reasons for this relationship remain debated (MacDonald & Christiansen, 2002).

In Experiment 2, we pit these hypotheses against each other by testing young adults who varied in their working memory span.

Experiment 2

Experiment 2 sought to tease apart the limited resources and linguistic knowledge accounts of older adults' other-accent penalty. The limited resources hypothesis proposes that older adults' selectivity for contrastively accented referents occurs because older adults cannot encode the entire discourse and must focus on the information that is mostly likely to be important. This hypothesis predicts that young adults with low scores on working memory tasks should show a similar pattern as the older adults in Experiment 1.

By contrast, the linguistic knowledge hypothesis—that older adults' selectivity is driven by greater familiarity with constraints on the distribution of contrastive accents—makes no prediction that young adults with low span scores should behave like older adults in this task. If anything, *high* span individuals should be most apt to show the other-accent penalty, since these individuals typically make greater use of constraints in online language processing (e.g., Pearlmutter & MacDonald, 1995).

Thus, in Experiment 2, we tested how working memory scores predicted the other-accent penalty in young adults.

Method

Participants—56 students at the University of Illinois participated in partial fulfillment of a course requirement or for a cash honorarium.

Materials—The materials for the prosody and memory task were the same as in Experiment 1.

Materials for the reading and listening span tasks were taken from Stine and Hindman (1994) and comprised sentences that defined common English nouns. Half of the statements were true, such as (10), and half were false, such as (11). Different sentences were used between the two tasks. The spoken sentences used in the listening span task were recorded by a different female research assistant than in the prosody and memory task.

(10) An elected official who manages a state is called a governor.

(11) One animal that is bright orange in color is the zebra.

Procedure—Participants first completed four working memory tasks, followed by the Experiment 1 task. In each of the four working memory tasks, detailed individually below, each trial consisted of a series of stimuli of varying *span length* (e.g. a trial with 2 stimuli had span length 2). At the end of a trial, participants were asked to recall some aspect of the stimuli by typing their answers.

Following the recommendations of Conway, Kane, Bunting, Hambrick, Wilhelm, and Engle (2005), all participants were presented with two trials at all span lengths in a random order. Conway et al. have argued that this format offers multiple advantages over a traditional format in which participants attempt span lengths in ascending order until the participant is unable to recall all the stimuli. First, performance typically decreases over multiple memory tests due to proactive interference from previous tests. Presenting spans in order of ascending length confounds span length with amount of proactive interference, and differences in span score might reflect differences in vulnerability to proactive interference rather than working memory *per se* (Lustig, May, & Hasher, 2001). Second, participants may succeed or fail at a particular span length for reasons unrelated to working memory (e.g. the idiosyncratic memorability of particular words). Presenting all spans to all participants maximizes the amount of information obtained from each participant.

Listening span: Participants listened to recorded sentences and then pressed one of two keys to indicate whether the statement was *true* or false. Participants were allotted 2000 ms after the end of the sentence to make the judgment. The targets to be remembered were the last words from each sentence, such as *governor* in (10). The span length ranged from 2 to 7.

Reading span: Participants read aloud a sentence and pressed one of two keys to indicate whether the statement was *true* or *false*. Participants had 7000 ms to read the sentence and make the judgment. The targets were the last words from each sentence and the span length ranged from 2 to 7.

Alphabet span: Following Waters and Caplan (2003), participants read aloud single words and then recalled them in alphabetical order. Each word was displayed visually for 1000 ms. The span length varied from 2 to 7.

Subtract 2 span: Also following Waters and Caplan (2003), participants read aloud digits from 2 to 9 and then recalled them in order while subtracting 2 from each number (e.g. *3* was to be recalled as *1*). Each digit was displayed visually for 1000 ms. The span length varied from 2 to 8.

Scoring—Scores on each of the four working memory tasks were computed as followed. Trials in which the participant remembered all of the items were scored as 1 point. Trials in which the participant remembered some but not all of the items were scored as the proportion of items correctly recalled; for instance, a participant who remembered 3 items from a span 4 trial would receive a score of 0.75. In comparisons of multiple scoring methods, Conway et al. (2005) found this method (termed *partial-credit unit scoring*) to produce the least skewed, most normal distribution of scores.

Finally, the mean of each participant's scores on the four working memory tasks was taken to create an aggregate measure. Aggregating over multiple tasks has the advantage of reducing variance in scores due to task-specific factors (e.g. familiarity with the alphabet) unrelated to the construct of interest (Waters & Caplan, 2003).

Results

Mean performance on the discourse memory task is displayed in Figure 2 and on the working memory tasks in Figure 3.

As in Experiment 1, recognition accuracy was modeled using a mixed effects model with fixed effects of the accents on the target contrast set and on the other contrast set. Average working memory score was entered as a centered continuous predictor at the subject level, as were the interactions of working memory with the pitch accenting variables. Including working memory score as a continuous predictor, rather than classifying participants into *high* and *low* groups, increases statistical power and accurately reflects the fact that span scores vary continuously rather than categorically in the population (Conway et al., 2005).

The fit of the model was again improved by a random slope of target accent by story, $\chi^2_{(2)}$ = 8.12, $p < .05$, and further improved by a random slope of other-accent penalty by contrast set, $\chi^2_{(2)}$ = 7.96, $p < .05$. No other random slopes approached significance.

Parameter estimates for the final model are displayed in Tables 3 and 4. The odds of correct recognition for facts receiving contrastive accents (M = 85%) were 1.64 times greater (95% CI: [1.34, 1.99]) than for facts receiving presentational accents (M = 79%), replicating the accent boost observed in Experiment 1. Across all participants, the accent on the other critical word did not reliably affect recognition, consistent with Experiment 1, in which young adults as a whole did not display the other-accent penalty.

The effects of a low working memory span in Experiment 2 mirrored those of age in Experiment 1. Working memory span did not affect the size of the accent boost, Wald z = −0.03, p = 98, but it did modulate the size of the other-accent penalty, Wald z = 2.46, $p < .05$. The size of the other-accent penalty is captured in the ratio between the odds of recognition when the other critical word received a contrastive accent and when it received a presentational. This ratio was 0.85 times smaller (95% CI: [0.74, 0.97]) for every one-point increase in mean working memory score. That is, the other accent penalty was smallest for participants with high working memory scores and largest for participants with low scores.

Working memory score also had a main effect on performance. A one-point increase in mean working memory score translated to a 1.47 times increase in the odds of correct recognition (95% CI: [1.18, 1.84]).

Discussion

In Experiment 2, we pitted two accounts of the age differences in Experiment 1 against each other by testing young adults who varied in their scores on working memory tasks.

The results provided a conceptual replication of the effects in Experiment 1. Young participants in Experiment 2 with *lower* working memory scores resembled the older participants in Experiment 1: they showed an equivalent benefit from a contrastive accent on the target contrast set, but displayed the other-accent penalty to memory when a different contrast set received a contrastive accent.

These results support a processing resources account of the age effects. The most important information in a discourse may always be processed and encoded even when online processing resources such as working memory are limited. But, when one piece of information gains prominence, limitations in online resources may restrict the ability to encode less important information. Consequently, only those participants with greater processing resources—the higher-span young adults—do not show an other-accent penalty.

This processing resource account presupposes that older adults are more restricted in online processing ability than the average young adult. This is typically the case (Park et al., 2002; Salthouse, 2004; Stine-Morrow et al., 2008), but to verify that this was true in this sample, nine of the older adult participants from Experiment 1 visited the lab on another day to complete the four working memory tasks. The older adults (M = 7.37, SD = 1.18) indeed had an average span score that was 1.02 points lower (95% CI: [0.24; 1.81]) than the young adults (M = 8.41, SD = 1.08), $t(63) = 2.62$, $p < .05$. Thus, it was found both that older adults had lower span scores than young adults and that low-span younger adults resembled older adults in the effects of prosody on their memory for discourse.

The lower-span young adults in Experiment 2 did differ from the older adults in Experiment 1 in one respect. While older adults had equivalent overall performance to young adults, lower-span young adults had lower overall memory than higher-span young adults. One possibility is that the relationship between working memory score and discourse memory reflects variance shared with a more basic construct such as motivation or arousal, which could affect performance on both the working memory and discourse tasks.

General Discussion

In two experiments, we tested whether the effects of pitch accenting on memory for a discourse changed with age, and what mechanisms might account for those changes. Young and older adults showed equivalent benefits to memory from items that received a contrastive accent rather than a presentational accent. To the extent that this benefit reflects prioritization in encoding, this result demonstrates that older adults can be just as strategic as younger adults in at least some aspects of discourse comprehension. This result also extends the finding that older adults exhibit normal sensitivity to aspects of linguistic prosody such as prosodic boundaries and word stress (Kjelgaard et al. 1999; Titone et al., 2006; Wingfield et al., 2000).

However, older adults *did* differ from young adults in that only older adults showed decreased memory for one contrast set when a different contrast set received a contrastive accent. That is, when *British* in (12) received a contrastive (L+H*) accent, older adults' memory for *Malaysia* decreased. Most young adults did not show this other-accent penalty.

(12) Finally, the BRITISH (H*/L+H*) spotted one of the monkeys in MALAYSIA (H*/L+H*) and planted a radio tag on it.

This pattern is consistent with Castel's (2008) proposal that older adults are *more* sensitive to the value or importance of information. When a contrastive accent makes one detail particularly important, older adults are less likely to encode the other, presumably less important information, resulting in the other-accent penalty. That is, age differences in episodic memory are greater for *less* valuable information.

Why were older adults more sensitive to value? In Experiment 2, we found both that older adults had lower working memory scores on average and that young adults with low working memory scores resembled the older adults: they showed an other-accent penalty but no difference in the boost from an accent on the target word. The similarity of low-span young adults to older adults in this task suggests a processing resources explanation. Older adults may be more selective than young adults because they have fewer resources available for discourse processing and consequently must restrict themselves to encoding only the most important information.

An interpretation based on the allocation of resources raises the question of why the accent boost was of greater magnitude than the other-accent penalty. A contrastive accent on *British* benefited memory for the *British/French* contrast set more than it impaired memory for *Malaysia/Indonesia*, but one might have expected these effects to be of equal magnitude if contrastive accents simply reallocated encoding resources. However, the discourses contained numerous other details that participants were likely attempting to encode because they did not know which information they would be tested on. For example, continuation (12) also mentions that the animal found was a monkey and that a radio tag was planted on it. Some of the resources that were shifted to *British* when it received a contrastive accent may have been resources that would have otherwise been devoted to these extraneous details, and the decline in memory for those details was simply invisible because memory for them was never tested.

Selectivity in Older Adulthood

Why are older adults less strategic than young adults in some memory tasks (e.g. Dunlosky & Connor, 1997) but equally strategic in others? Clearly, more research must be done to determine when older adults do and do not succeed in strategic memory encoding.

But, one possible moderating variable may be the presence of external cues supporting selectivity. Experiments that have found equivalent selectivity across the life span have typically included cues to the importance of information, such as pitch accents (in the present work) or point values (Castel et al., 2002). It has been proposed that age differences in memory are smaller for tasks or materials that do not require controlled or self-initiated processing (e.g., Craik, 1983, 1986). External cues to importance like pitch accents or point values may allow older adults to exhibit selective control of memory by reducing the need to initiate selection on one's own. This explanation is also consistent with age differences in acquiring new metacognitive knowledge. Older adults, unlike young adults, often appear not to learn from experience about the effectiveness of different strategies. However, they *do* learn about the difficulty of various types of items (e.g. words of different frequency) when the item type can be discerned from the stimulus itself (Tullis & Benjamin, under review).

The discrepant results concerning selectivity also underscore the importance of testing older adults' memory with naturalistic materials. Pitch accents are a common cue to importance with a discourse. If older adults make use of such frequently occurring cues, than their ability to strategically process a discourse may be greater than thought.

What Underlies Online Processing Resources?

The similarity in this task between young adults who score low on working memory tasks and older adults, and the fact that older adults on average scored lower on the working memory tasks, supports a processing resources account of age differences in prosody use. One question that might be asked is exactly what underlies these differences in resources. Variance in working memory performance between individuals or across the lifespan has frequently been attributed to more fundamental constructs such as processing speed (Salthouse, 1996), executive control (Engle, 2002), linguistic knowledge or skills (MacDonald & Christiansen, 2002), or inhibitory processing (Hasher, Zacks, & May, 1999). In the present work, we used measures of working memory as a proxy for general online processing ability. It is entirely possible that a more basic construct ultimately accounts for the difference between age groups.

To be certain, older adults do not differ from young adults *only* in their online processing ability. For instance, older adults typically have greater linguistic knowledge (Park et al., 2002; Salthouse, 2004; Stine-Morrow et al., 2008) and may also show more wisdom (Grossmann, Na, Varnum, Park, Kitayama, & Nisbett, 2010). In light of older adults’ greater vocabulary, is particular noteworthy that the older adults in this task resembled the low-span young adults. In young adults, working memory scores typically correlate *positively* with vocabulary; this correlation has been interpreted as suggesting that many effects attributed to working memory may instead reflect linguistic experience (MacDonald & Christiansen, 2002). However, the fact that older adults, in spite of their increased vocabulary, resemble *low*-span young adults in this task suggests that biological changes across the lifespan may ultimately overwhelm gains in linguistic knowledge (see MacDonald & Christiansen, 2002, for further discussion).

Comprehension of Prosody by Older Adults

Age differences in the comprehension of prosody appear to vary with the type of prosody under investigation. Although comprehension of linguistic uses of prosody is little affected by age, as in the present experiment, older adults have been shown to be less successful than young adults at comprehending affective and attitudinal prosody (Orbelo et al., 2003, 2005).

One explanation of these data has been age-related changes in the processing of pitch. Orbelo et al. (2003) propose that emotional prosody relies heavily on pitch and that processing of pitch is lateralized in the right hemisphere of the brain, which may be more strongly affected by age. In the present experiment, however, older adults showed preserved use of pitch accents, which suggests that not all aspects of pitch processing necessarily decline with age.

A related but different view is that affective elements of prosody are strongly right-lateralized (Ross, Thompson, & Yankosky, 1997), while elements of prosody that have linguistic meaning for the listener may be biased to the left hemisphere (Gandour, Tong, Wong, Talavage, Dzemidzic, Xu, Li, & Lowe, 2004). This proposal is consistent with findings that comprehension of pitch accenting, a linguistic use of prosody, does not decline with age, while comprehension of emotional aspects of pitch does. However, such an account remains speculative and in need of further investigation.

Conclusion

Older adults are at least as sensitive as young adults to pitch accents in discourse comprehension. Young and older adults showed equal benefits to memory when words received contrastive accents. However, older adults showed diminished memory for a particular fact when a *different* detail received a contrastive accent. This penalty was also evident in young adults who scored low on working memory tasks, suggesting it may reflect diminished processing resources. That is, when online resources are limited, only the most important information may be encoded.

These results are consistent with a view in which older adults can be quite strategic in their memory encoding and are adept at remembering the most important information from a discourse. They also provide further evidence that comprehension of linguistic prosodic remains spared across the lifespan. In fact, prosodic pitch accenting may be an important cue for guiding older adults' encoding of the myriad details present in a spoken discourse.

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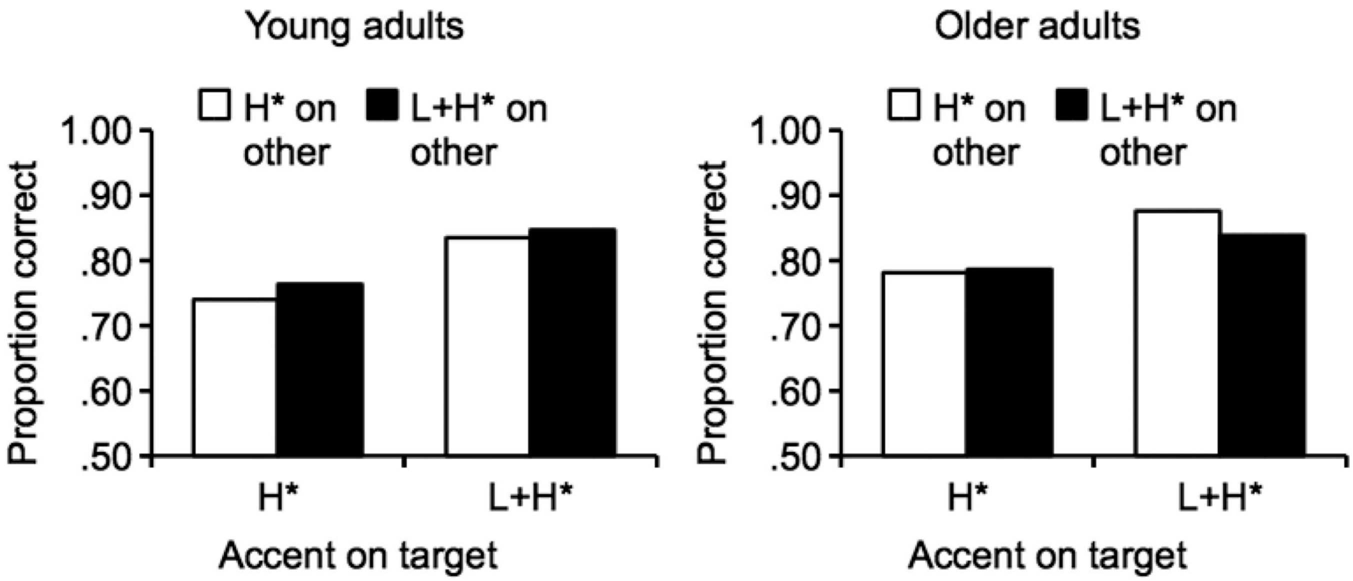

Figure 1.
Proportion correct recognition in Experiment 1 as a function of age, accent on target contrast set, and accent on other contrast set.

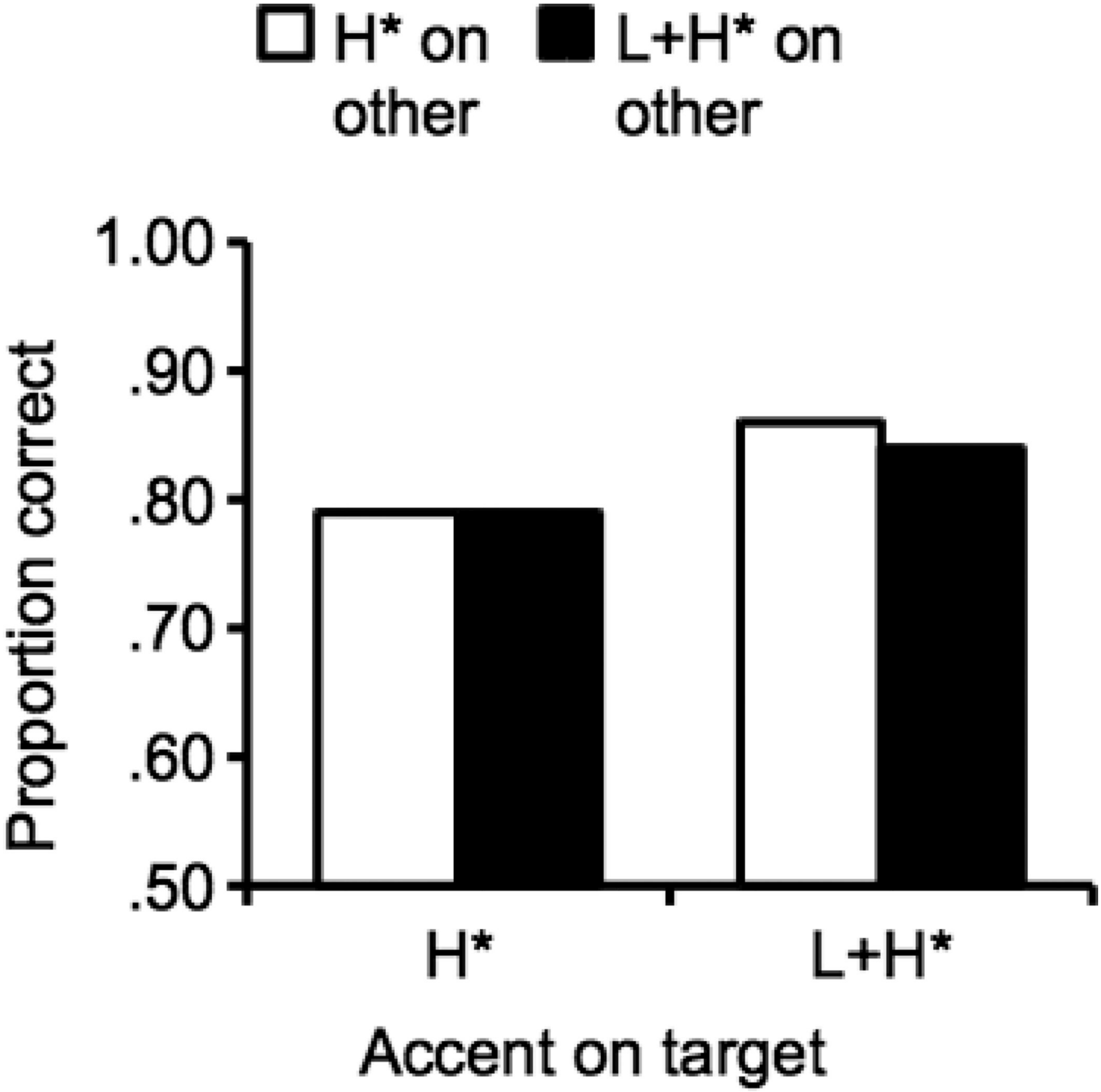

Figure 2.
Proportion correct recognition in Experiment 2 as a function of accent on target contrast set and accent on other contrast set.

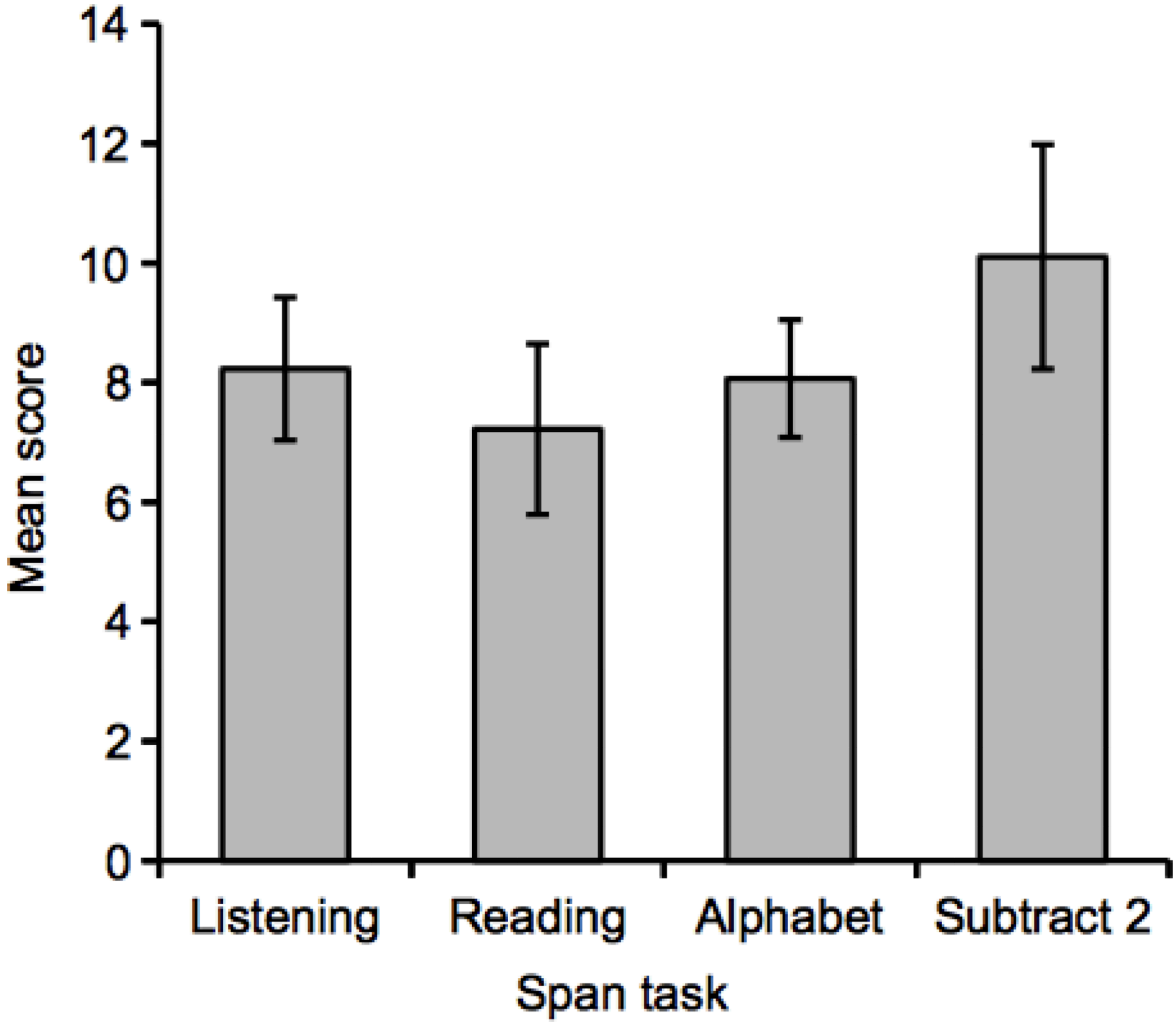

Figure 3.
Mean score on span tasks in Experiment 2. The scoring procedure is described in the Method of Experiment 2. Error bars indicate one standard deviation in each direction.

Table 1

Fixed Effect Estimates for Multi-Level Logit Model of Recognition Accuracy in Experiment 1 (N = 7680, log-likelihood = −3523).

Fixed effect	β	*SE*	Wald *z*	*p*
Intercept	1.66	0.10	17.17	<.01
L+H* accent on this word	0.60	0.08	7.17	<.01
L+H* accent on other word	−0.02	0.06	−0.25	.80
Age	0.18	0.16	1.13	.26
L+H* accent on this word×L+H* on other word	−0.20	0.12	−1.58	.11
Age×L+H* accent on this word	−0.05	0.12	−0.42	.68
Age×L+H* accent on other word	−0.26	0.12	−2.09	<.05
Age×L+H* accent on this word×L+H* on other word	−0.34	0.25	−1.36	.17

Note. SE = standard error.

Table 2

Summary of Random Subject and Item Effects and Correlations in Model of Recognition Accuracy in Experiment 1.

Random effect	s^2	Correlation with random intercept
Subject		
Intercept	0.45	
Story		
Intercept	0.13	
L+H* on word	0.12	.13
Contrast set (nested in story)		
Intercept	0.02	
Age	0.28	−.59

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Table 3

Fixed Effect Estimates for Multi-Level Logit Model of Recognition Accuracy in Experiment 2 (N = 4480, log-likelihood = −1907).

Fixed effect	β	*SE*	Wald *z*	*p*
Intercept	1.85	0.14	13.66	<.01
L+H* accent on this word	0.49	0.10	4.91	<.01
L+H* accent on other word	−0.01	0.09	−0.09	.92
Working memory (WM) score	0.39	0.11	3.37	<.01
L+H* accent on this word×L+H* on other word	−0.20	0.17	−1.18	.24
WM×L+H* accent on this word	> −0.01	0.07	−0.03	.98
WM×L+H* accent on other word	0.17	0.07	−2.46	<.05
WM×L+H* accent on this word×L+H* on other word	0.10	0.14	0.76	.45

Note. SE = standard error.

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Table 4

Summary of Random Subject and Item Effects and Correlations in Model of Recognition Accuracy in Experiment 2.

Random effect	s^2	**Correlation with random intercept**
Subject		
Intercept	0.74	
Story		
Intercept	0.07	
L+H* on word	0.11	>.99
Contrast set (nested in story)		
Intercept	0.09	
L+H* on other word	0.13	>.99