Word length and age influences on forward and backward immediate serial recall

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Abstract The present research is aimed at understanding the processes involved in short-term memory and how they interact with age. Specifically, word length effects were examined under forward serial recall, backward serial recall, and item recognition tasks, with performance being interpreted within an item-order theoretical framework. The interaction of age, word length, and direction of recall was examined in two experiments, the first of which confirmed that the word length was present with forward recall and absent with backward recall. In addition, age effects were stronger in backward recall than in forward recall. In the second experiment, an item-order trade-off methodology was utilized with backward recall. When order memory was required, there was no word length effect and strong age effects. When memory was tested via an item recognition test, there was a reverse word length effect and no age effect. While word length effects can be interpreted within the item-order framework, age effects cannot.

Keywords Short-term memory · Word length · Forward recall · Backward recall · Aging

Immediate forward serial recall of short lists of words is influenced by the length of the to-be-remembered words, such that lists of short words are better recalled in order than lists of long words (Baddeley, Thomson, & Buchanan, 1975). The word length effect has been seen as one of the

benchmark phenomena of short-term recall that models of short-term memory must account for. However, almost all theory development has occurred in the context of forward serial recall, and very little attention has been devoted to explaining performance on backward recall, and where it has been addressed (Page & Norris, 1998), it has been assumed that the same structures and processes that underpin forward recall also support backward recall. Recently, this assumption has proved to be untenable in that many of the benchmark effects of forward recall, including the word length effect, are eliminated or severely attenuated in backward recall (Bireta, Fry, Jalbert, Neath, Surprenant, Tehan, & Tolan, 2010). Thus, one of the aims of the present experiments was to understand why the word length effect differs for backward and forward recall.

The second aim of the present study had to do with understanding age differences in short-term memory performance. Again, most of the focus in aging effects in short-term memory has concentrated upon forward serial recall, with very little research being conducted using backward recall. If forward and backward recall are not supported by the same mechanisms and processes, aging effects may well differ for forward and backward recall. At the very least, examining backward recall will provide additional empirical evidence with which to explore age-related influences on short-term memory.

Word length in forward and backward serial recall

In exploring word length effects, it appears that two forms of the effect need to be considered: the time-based effect and the syllable-based effect. The time-based effect refers to initial demonstrations that words could be matched on a variety of variables, including number of phonemes and

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syllable length, but that, provided that there was a difference in spoken duration for different types of words, those words with short spoken duration were better recalled in order than those with longer spoken durations (Baddeley et al., 1975). The empirical support for this version of the word length effect has been severely eroded over the years, and current consensus is that the time-based version of the word length effect is hard to maintain (Lewandowsky & Oberauer, 2008; Neath, Biretta, & Surprenant, 2003).

In contrast, the syllable-based effect, where length is determined by the number of syllables, is a robust phenomenon and is widely observed in a range of both short-term and long-term memory tasks where memory for order is required, such as reconstruction of order (Biretta et al., 2010; Nairne, Neath, & Serra, 1997; Surprenant et al., 2011), serial recognition (Baddeley, Chincotta, Stafford, & Turk, 2002), free recall (Tehan & Tolan, 2007; Watkins, 1972), serial position probe recall (Avons, Wright, & Pammer, 1994), supraspan list learning (Tehan & Tolan, 2007), and complex span (Tehan, Hendry, & Kocinski, 2001).

While the word length effect has been widely studied using forward recall, there are surprisingly few studies that have explored word length effects in backward recall. Initial studies did not present a consistent picture, in that three studies have shown that word length effects are present but weaker than in forward recall (Baker & Tehan, 2008; Cowan, Wood, & Borne, 1994 [standard serial recall]; Walker & Hulme, 1999), and two have indicated that the word length effect has been eliminated (Cowan et al., 1994 [continuous distractor]; Tehan & Mills, 2007). These initial studies suggested that the word length effect could be attenuated in backward recall. The studies above, however, did not examine forward and backward recall in the same experiment, so it is hard to evaluate the strength of the word length effects in the studies in which there were significant effects. When the two directions are manipulated in the same experiment, word length effects are present in forward recall but absent in backward recall (Biretta et al., 2010; Roche, Tolan, & Tehan, 2011; Surprenant et al., 2011).

In the research reported here, we explored word length effects within an item-order trade-off perspective because this framework, unlike many alternative models, can explain word length effects in both short-term and long-term domains. The fundamental notion here is that the recall process can involve multiple sources of information and that task demands determine what sort of information is utilized (Humphreys, Bain, & Pike, 1989). In the work that follows, order memory and item memory are identified as separate sources of information that underpin performance. It is further proposed that serial recall tasks predominantly tap into order memory, and item recognition tasks rely upon item memory. The trade-off component of the model is that

variables that have an effect on one type of information can have opposite effects on the other type of information.

The item-order account has its genesis in explaining dissociations between serial (and free) recall and item recognition in long-term memory. The origins of the item-order framework are found in a study conducted by Nairne, Riegler, and Serra (1991). Participants studied lists of either intact words, which were read aloud, or word fragments from which the participants could easily generate the completed word. Some of the lists were subsequently tested on a standard long-term recognition test, in which the generated items were better recognized than the read items. Other lists were tested using an order reconstruction task, and here the read items were better remembered than the generated items. Nairne et al. argued that the resulting dissociation was attributable to generated words receiving more item-specific processing than the read items. The benefit of additional item processing was manifest on tasks that accessed only item information—namely, single-item recognition—but such additional item processing came at a cost by way of decreased order processing. In contrast, with the read items being relatively easy or quick to process at the item level, more time or resources were available for order processing, which again became manifest on the serial order task.

The item-order trade-off framework has been used as an explanatory mechanism for a number of dissociations in the long-term memory literature in which variables had one effect in serial recall, but that effect reversed in direction when tests of item memory were administered. The generation effect (Nairne et al., 1991), the perceptual interference effect (Mulligan, 1999), the word frequency effect (DeLosh & McDaniel, 1996; Hockley & Cristi, 1996), and the enactment effect (Engelkamp & Dehn, 2000) represent such examples.

The same framework has been applied to the word length effect in both short-term and long-term tasks (Baker & Tehan, 2008; Hendry & Tehan, 2005; Tehan & Tolan, 2007). Hendry and Tehan adapted the Nairne et al. (1991) paradigm to show that word length dissociated on short-term serial recall and item recognition tests. That is, they showed the typical short-word advantage in immediate serial recall but found an advantage for long words in item recognition. They interpreted these opposing word length effects as reflecting differential item processing of short and long words. The notion here was that short words were quickly identified, enabling subsequent time/resources to be devoted to encoding order. Long words were assumed to take longer or require more resources to identify (see Tehan & Tolan, 2007, for a justification of this assumption). The additional resources required for item processing ensured that fewer resources were available for encoding order. In short, short words were encoded with more order information

to the detriment of item information, while long words were encoded with more item information at the expense of order information. Tehan and Tolan replicated the finding of a dissociation of word length with type of test in the long-term memory domain by showing a short-word advantage in serial list learning and in the primacy region of free recall. They found a long-word advantage in long-term recognition and cued recall tasks.

While the dissociation of word length with forward serial order and item recognition is easily explainable within an item-order framework, the absence of word length effects in backward recall is somewhat problematic, given that this task also relies upon serial order information, albeit reverse order. However, Li and Lewandowsky (1993) argued for two distinct retrieval processes to explain the detrimental effect of distractor activity in forward recall and the absence of any such effect in backward recall. They suggested that forward serial recall is characterized by the use of rehearsal-based seriation. However, in the face of distraction or backward recall, participants abandon strict seriation in favor of a less effective (also less well specified) alternative. One consequence of abandoning seriation in backward recall is that any effect that is tied to seriation would be detrimentally affected. In the case of the word length effect, abandoning seriation would have a more detrimental effect on short words than on long words and would lead to weaker or absent word length effects. In addition, if item memory plays a role in backward recall, any short-word advantage that still remains could be canceled out by a long-word advantage in item memory.

Age effects

Age-related decrements are readily evident in long-term episodic recall tasks but are also prevalent in short-term retention tasks. Immediate serial recall appears to be on the cusp of where age differences in the verbal short-term domain become apparent. Relatively small age-related differences in recall are typically found in simple span tasks that do not require a large amount of concurrent processing, but age differences are more readily observed in complex span and other working memory tasks. Some studies have shown age effects in forward recall (see Kausler, 1994), although others (Craik, 1977) have shown no such effect. Likewise there are a small number of studies that have explored age effects in backward recall. Again the research is mixed, with some studies showing age effects (Babcock & Salthouse, 1990) and others, comparing forward and backward digit span, showing no significant age differences (Gregoire & van der Linden, 1997; Myerson, Emery, White, & Hale, 2003; Wilde, Strauss, & Tulsky, 2004). Meta-analytical studies of psychometric

testing using simple span, working memory, and backward span tests have indicated that, overall, age-related differences are present on all of these tasks (Bopp & Verhaeghen, 2005; Verhaeghen, Marcoen, & Goossens, 1993). In fact, Bopp and Verhaeghen's meta-analysis indicated that age differences were progressively larger in working memory tasks than in backward recall tasks and that age effects were typically larger for backward recall than for immediate forward serial recall.

There have been few studies examining aging and word length effects. In all cases, robust word length effects were still observed with the elderly groups (Belleville, Peretz, & Malenfant, 1996; Caplan, Rochon, & Waters, 1992; Morris, 1984; Peters, Majerus, Olivier, van der Linden, Salmon, & Collete, 2007). To the best of our knowledge, there have been no studies that have looked at age, word length, and backward recall.

Age and item-order processing

There are many theoretical accounts seeking to explain age-related decrements in memory. One such broad-brush framework asserts that older adults experience a decline in processing resources (Craik & Byrd, 1982). Encoding and retrieval processes are deemed to be more attention demanding for older adults, and consequently, they are less likely to successfully encode and retrieve information than are younger adults. The item-order account is a processing resources framework, and as such, it is plausible that age effects in the short-term domain could be explored using the item-order framework. The working assumption is that older participants will utilize more resources in encoding item information than will their younger counterparts and this will have follow-on effects for tests of order and item memory.

The starting point for an item-order account of age differences is establishing that older participants require more resources at the item identification stage. There is a body of research demonstrating strong relationships between perceptual and cognitive abilities, suggesting that a substantial portion of variance in cognitive performance is shared with vision and hearing abilities (Baltes & Lindenberger, 1997; Schneider, Daneman, & Pichora-Fuller, 2002). Moreover, the same pattern is observed in the memory domain to the extent that those with even mild visual or hearing impairment (or having to decode speech in a noisy background) show substantial memory loss, even though the participants are readily able to identify the words they see or hear (Pichora-Fuller, Schneider, & Daneman, 1995; Rabbitt, 1991; Salthouse, Hancock, Meinz, & Hambrick, 1996). The assumption that is often made in such experiments is that perceptual processing to the level of identification

depletes resources that might otherwise be used for enhancing memory.

The same relationship between sensory acuity and memory performance is also observed in serial recall. Surprenant, Neath, and Brown (2006) explored age effects in immediate memory, using an order reconstruction task from the perspective of perceptual-processing effects. Their younger sample had significantly better auditory acuity than did the older participants, an advantage that was also reflected in serial recall. They argued that the age decrement in recall was due to altered representations resulting from age-related perceptual deficits, rather than depleted resources per se. However, the two approaches are not necessarily mutually exclusive: Depleted resources could result in altered memory representations. In fact, in looking at the representational space of younger and older participants in their studies, the differences appear to be more quantitative than qualitative (see Surprenant et al., 2006). The more important aspect of the Surprenant et al. research for present purposes is that as one ages, it is plausible that processing at the item level consumes more time/resources to achieve the same level of item memory as the younger participants, and this has an adverse impact upon subsequent order processing. If so, the item-order framework suggests that age effects should be particularly evident in tests that involve order memory.

The present research explored age effects regarding the word length effect in forward and backward recall. At the empirical level, the dissociation between word length and direction of recall has not been explored with older participants. Even with younger participants, the conditions under which the dissociation has occurred have been limited to an order reconstruction task using a closed pool of items. It remains to be seen whether the same effects generalize when other materials and other memory tests are used. From the theoretical perspective, the item-order framework appears to be able to handle the dissociation between word length and recall directions and age effects in immediate memory. Thus, an important aim of the study was to further test the assumptions of this approach.

Experiment 1

In the case where word length and direction of recall have been studied together in the same experiment (Bireta et al., 2010; Surprenant et al., 2011), the task involved an order reconstruction task in which the items on each list were presented after study and participants used a computer mouse to select the items in the order in which they had occurred. The participants did not have to retrieve the items from memory, but only the memory for the order of those

items. Moreover, the memory items came from a small set of items that were repeated across trials. To test the generality of the elimination of the word length effect with backward recall, the present experiment included both an order reconstruction task and the more typical immediate serial recall paradigm where items are presented sequentially and participants have to recall both the items and their order. In addition, the memory items came from large pools, and each word appeared in the experiment only once.

If neither the type of task nor the size of the word pool is a critical determinant of performance, it would be expected that a strong short-word advantage would be found with forward recall and that this advantage should be eliminated with backward recall. The Bopp and Verhaeghen (2005) results would suggest that if there are age effects present in the data, they should be more pronounced in backward recall than in forward recall.

Method

Participants Twenty younger adults (10 of them male and 10 female) and 20 healthy, community-living, older adults (8 of them male and 12 female) took part in this experiment. Each participant was paid AUD15 for completing two individual data collection sessions. The younger group ranged in age from 18 to 26 years ($M = 22.2$ years, $SD = 1.8$). The older group were aged from 60 to 75 years ($M = 66.2$ years, $SD = 4.8$). Participants were screened for reading ability using the Wechsler Test of Adult Reading (WTAR; Psychological Corporation, 2001). All participants obtained a raw score of at least 30 on the WTAR, which corresponded to a minimum standard score of 96, indicating that no participant was below average in reading ability. The older participants had a significantly higher mean raw score ($M = 42.55$, $SD = 5.02$) than did the younger participants ($M = 38.85$, $SD = 5.70$), $t(38) = 2.17$, $p = .036$.

Materials Four experimental tasks were prepared: a standard serial recall task and an order reconstruction task, each in forward and backward order. Within each task, word length was also manipulated. The tasks were created using 200 short words and 200 long words drawn from the MRC Psycholinguistic Database (Coltheart, 1981). The short words were all monosyllabic, with 2 to 4 phonemes. The long words had two or three syllables, with 4 to 10 phonemes. All words were concrete nouns with a minimum concreteness rating of 500 (on a scale from 100 to 700) and a minimum frequency of 5 per million according to the Kučera and Francis (1967) norms. Mean frequencies were 41.09 for the short words ($SD = 43.71$) and 41.96 for the long words ($SD = 60.78$). There was no significant difference in frequency between the two word pools, $t(398) = 0.17$, $p = .87$.

For each of the 20 participants in a group, four sets of 20 five-word lists comprising 10 lists of short words (e.g., *note, gas, heel, lake, ink*) and 10 lists of long words (e.g., *balloon, messenger, candle, engineer, umbrella*) were composed using words drawn randomly without replacement from the two word pools. These formed the content for four tasks consisting of 20 trials each, with the short- and long-word trials ordered randomly for presentation within a task. Thus, all participants in a given group received all 400 words, distributed differently within their trials and across their four tasks, but with all content matched across the younger and older groups.

Five practice trials (three using short words and two using long words) were also prepared, using words not appearing in the experimental lists. The practice lists were the same for all four tasks and for all participants and were intended to ensure that the participant understood the task requirements.

Procedure After giving informed consent, each participant completed the four tasks in two separate 20-min sessions 1 week apart: one session for the two forward recall tasks and one for the two backward recall tasks. The direction of recall (forward and backward) and the task format (standard serial recall and order reconstruction) were counterbalanced. The participant was given printed instructions to read immediately before each task and completed the 5 practice trials in the relevant format and direction before commencing the 20 experimental trials.

Participants sat before a laptop computer with a monochrome screen. The screen prompted them to press any key to begin, and then, for each trial, a series of five short words or five long words appeared one at a time in black uppercase letters in the center of the screen, at a rate of one per second. The participant read each word aloud as it appeared. In the standard serial recall task format, two question marks then appeared on the screen, and the participant repeated the five words to the best of his/her ability, either in presentation order or in reverse order, according to the instructions received at the beginning of the task. For any words not remembered, the participant said “something” or “pass” so that the serial position of the recalled items was preserved. The researcher noted the items and serial positions recalled on a printed sheet showing the word lists for that individual’s trials. The participant then pressed any key to continue to the next trial, until all 20 (10 short-word trials and 10 long-word trials) had been completed.

In the order reconstruction format, the five words on a trial were presented and read aloud in the same way, but then the words reappeared on the screen all together in random order, in a staggered vertical list. In this case, the participant produced the required order with the words

visible, and the researcher noted the serial positions on the printed sheet for that person. Again, the participant pressed any key to continue to the next trial, until all 20 were completed.

Results

Figure 1 presents the recall data collapsed across serial position. The results in Fig. 1 suggest that the age differences are not all that great, that performance is better for order reconstruction tasks than for standard serial recall, that forward recall is better than backward recall, and most important, that standard word length effects are present with forward recall but are absent with backward recall.

A $2 \times 2 \times 2 \times 2$ mixed design ANOVA was conducted with age as a between-subjects factor and memory task (standard serial recall vs. order reconstruction), direction of recall (backward vs. forward), and word length (short vs. long) as within-subjects factors. Since none of the predictions involved serial position effects, performance was collapsed across serial position. An alpha level of .05 was used throughout, but p values are also reported. In addition, partial eta-squared statistics are presented as an index of effect size.

The main effect for age approached significance, $F(1, 38) = 3.84$, $MSE = .06$, $\eta^2 = .09$, $p = .057$. Of the other main effects, order reconstruction led to better performance than did standard serial recall, $F(1, 38) = 53.52$, $MSE = .008$, $\eta^2 = .59$, $p < .001$, forward recall was better than backward recall, $F(1, 38) = 41.16$, $MSE = .017$, $\eta^2 = .52$, $p < .001$, and short words were better recalled than long words $F(1, 38) = 32.69$, $MSE = .008$, $\eta^2 = .46$, $p < .001$. Of the interactions, only the length $\times$ direction interaction was significant, $F(1, 38) = 24.46$, $MSE = .008$, $\eta^2 = .39$, $p < .001$, reflecting strong word length

Fig. 1 Correct recall as a function of age, direction of recall, and type of order memory task. Error bars represent the standard error of the mean

effects with forward recall, $F(1, 39) = 39.27, p < .001$, and their absence with backward recall, $F(1, 39) = 0.94, p = .34$.

Two interactions involving age approached significance: age $\times$ recall task, $F(1, 38) = 3.18, MSE = .008, \eta^2 = .08, p = .083$, and age $\times$ length, $F(1, 38) = 3.15, MSE = .008, \eta^2 = .08, p = .085$. The interaction of age with direction of recall did not reach statistical significance, $F(1, 38) = 2.36, MSE = .017, \eta^2 = .06, p = .13$, but planned comparisons indicated that while there were no age effects on forward recall, $t(38) = 1.12, p = .27$, younger participants performed much better than their older counterparts on backward recall, $t(38) = 2.94, p = .006$.

Discussion

The outcomes of the experiment are quite clear. Most important, we have replicated and generalized prior research showing that strong word length effects are observed in forward recall and that these effects are eliminated with backward recall (Bireta et al., 2010; Surprenant et al., 2011). Thus, the attenuation of word length effects in backward recall is independent of the word pool used and the specific type of serial recall test.

The main effect for age and several of the interactions approached statistical significance. Because the mean age of the older sample was relatively young at 66 years of age, we interpret these results as further evidence that immediate serial recall is less sensitive to cognitive decline than are other, more taxing cognitive tasks. While there were no significant age effects with forward recall, the data for backward recall are consistent with the Bopp and Verhaeghen (2005) meta-analysis showing that age effects are more consistent and more readily observed in backward recall.

Experiment 2

The first experiment provides some evidence for an item-order trade-off account, in that word length effects were present with forward recall but not with backward recall, the assumption being that with backward recall, the differential effects of word length on item and order memory cancel each other out. However, the strong test of the framework argues that even with backward recall, there still should be a long-word advantage on a test of item memory. In addition, if age effects are due in part to differences in item processing, then while it might be possible for older participants to process items to the same level of item memory by using more resources or more time, there should be a subsequent decrement in order processing.

The second experiment used the Hendry and Tehan (2005) procedure to explore word length effects in

backward serial recall and in single-item recognition to obtain a more detailed account of word length effects. As was mentioned earlier, Hendry and Tehan found a long-word advantage in recognition performance, but they did not explore the locus of that effect. Some models of recognition memory view such decisions as involving a single dimension of familiarity or trace strength, whereas others regard them as involving retrieval processes based on (1) familiarity or strength of activation of the item and (2) the recollection of contextual experience of the item (Diana, Reder, Arndt, & Park, 2006; Dobbins, Kroll, & Yonelinas, 2004). This distinction between recollection and familiarity is captured in the remember/know paradigm, devised originally by Tulving (1985). Tulving showed that individuals could state whether their recall or recognition of an item was based on consciously recollecting having encountered it in the learning context (remember) or being aware that it had been there through a general feeling of familiarity but no specific memory of it (know). The intent of using the remember/know paradigm in the present experiment was to explore the locus of the long-word advantage in the item-order paradigm.

The Hendry and Tehan (2005) procedure was modified slightly to include remember/know judgments in the recognition test in order to further specify the locus of the long-word advantage in recognition, should it occur. Again, samples of younger and older participants were used. To the best of our knowledge, age effects on item-order tasks have not been explored in the previous literature.

Method

Participants Participants were 20 younger adults (9 of them male and 11 female) and 20 healthy, community-living, older adults (6 of them male and 14 female), none of whom had taken part in Experiment 1. Each participant was paid AUD10 for completing a single individual data collection session. The younger group ranged in age from 18 to 30 years ($M = 22.9$ years, $SD = 2.8$). The older group were aged from 60 to 75 years ($M = 66.6$ years, $SD = 6.9$). Participants were screened for reading ability using the WTAR. All participants obtained a raw score of at least 26 on the WTAR, which corresponded to a minimum standard score of 90, indicating that no participant was below average in reading ability. There were no significant age differences in WTAR raw scores, $t(38) = 0.78, p = .44$, with the younger participants having a mean raw score of 40.30 ($SD = 4.44$) and the older participants having a mean raw score of 38.85 ($SD = 6.97$).

Materials The two tasks in Experiment 2 (backward serial recall and remember/know recognition) were created from pools of 160 short words and 160 long words selected

according to the same criteria for frequency and concreteness as in Experiment 1, and again matched for mean frequency. The short words were monosyllabic with 2 to 4 phonemes, and the long words had between two and five syllables and 6 to 11 phonemes.

To create the study trials for each participant, 50 short words and 50 long words were randomly drawn (without replacement) from their respective pools and were compiled into 20 five-word lists by randomly assigning the 50 items of each length to trials and serial positions within trials. Thus, 10 trials consisted of short words (e.g., *pin*, *veil*, *slave*, *tank*, *dock*) and 10 consisted of long words (e.g., *monument*, *infant*, *planet*, *camera*, *auditorium*). Five lists of short words and five lists of long words were designated as recall trials, which meant that these trials were tested via backward recall. The remaining lists (a further five each of short and long words) were designated as recognition trials, for use in the remember/know recognition task. The order of the 20 trials was then randomized.

The remember/know recognition task involved a paper-and-pencil-test consisting of 70 words that were presented in columns on an A4 sheet of paper. These words consisted of the 50 words from the recognition trials (25 short words and 25 long words), plus a further 20 distractor words that had not appeared on the previous trials and that were randomly assigned to positions on the test sheet. The distractor words were made up of 10 short words and 10 long words drawn without replacement from the original pool of remaining words.

Procedure In the initial phase of the experiment, participants were told that they were going to be presented with a number of five-word sequences that they had to learn as best they could. They were also told that at the end of each sequence, either a row of question marks (????) or a row of asterisks (*****) would appear and that these were cues to perform one of two tasks. If the row of question marks appeared, they were to attempt to recall the five words in backward order. However, if the row of asterisks was presented, they were simply to wait until prompted on the screen to press the space bar to commence the next trial. No rationale was provided for the latter instruction.

The five words on each trial appeared one at a time, in the center of the computer screen, at a rate of one word per second. The participants were required to read the words aloud as they appeared on the screen. Following the presentation of each five-word trial, a series of question marks (????) or a series of asterisks (*****) appeared in the center of the screen. On the recall trials, participants were asked to recall these words in backward order. In order to preserve the serial position of the items, participants were asked to say “pass” or “something” for any word they could not remember. The on-screen prompt to press the space bar

to continue appeared 6 s after the appearance of the question marks or asterisks. This did not actually impose a time limit on the recall trials but served to make both types of trials similar in length. The serial recall (question marks) and recognition recall (asterisks) trials were randomly presented, such that participants were not aware of whether or not they would have to serially recall a trial until all the words on the trial had been presented. The participant’s response was recorded by the experimenter on a prepared response sheet.

Following the presentation of the 20 question-mark/asterisk trials, there was a brief pause while the experimenter supplied the recognition test and asked the participant to read the recognition instructions. These instructions requested the participants to go down each column word by word, marking each word as follows. If they thought that the word had not been among those read out from the computer screen in the previous task, they were to mark it with a cross and move straight on to the next word. If, on the other hand, they did recognize the word as having appeared previously on the screen, they were to mark it in one of two ways. If they consciously recollected having seen that word in the previous task and had a specific memory of it, it was to be marked “R” (denoting a *remember* response). However, if the word just seemed familiar from the previous task and the participant just somehow knew that it was there without having a specific memory of it, it was to be marked “F” for *familiar* (corresponding to a *know* response). Taken together, these remember and know responses constituted overall word recognition by a given person.

Results

The results of the experiment are summarized in Fig. 2, where correct serial recall, correct recognition (hits), false alarms, and hits minus false alarms are presented. In recognition tasks, d' estimates of discriminability are frequently used as the dependent variable. Since many participants made no false alarms, the use of d' was considered inappropriate in this instance. However, collapsed across word length, the mean proportion of hits was .59 and .58 for the younger and older participants, respectively, and the corresponding mean proportion of false alarms was .28 and .29, producing overall d' s of .87 for the younger participants and .76 for the older ones.

It is clear in Fig. 2 that there is no word length effect in backward serial recall, but a strong age effect. With recognition, there is no age effect, but a strong long-word advantage. The long words also show greater remember/know differences than do the short words. The results were analyzed with 2×2 mixed design ANOVAs for serial recall

Fig. 2 Retrieval outcomes as a function of age and memory task (top panel); conditional probability of making a remember or a know response given that the list item has been correctly recognized (middle panel); and the probability of making a remember or a know response to a false alarm (bottom panel). BSR, backward serial recall; Rec, recognition; FA, false alarm. Error bars represent the standard error of the mean

and two recognition scores: correct recognition (hits) and hits minus false alarms.

For serial recall, there was no significant word length effect, $F(1, 38) = 0.11$, $MSE = .009$, $\eta^2 = .003$, $p = .74$, and younger participants recalled more items than did older participants, $F(1, 38) = 20.21$, $MSE = .023$, $\eta^2 = .34$, $p < .001$. While the interaction between word length and age approached significance, $F(1, 38) = 3.80$, $MSE = .009$, $\eta^2 = .09$, $p = .059$, a simple effects analysis of this interaction indicated that there were no significant word length effects for either age group.

For correct recognition, there was a long-word advantage when hits were the dependent variable, $F(1, 38) = 19.85$,

$MSE = .020$, $\eta^2 = .34$, $p < .001$, and when hits minus false alarms were used, $F(1, 38) = 9.35$, $MSE = .016$, $\eta^2 = .20$, $p < .004$. There was no age effect, nor was the interaction between age and word length significant ($F < 1$ in all cases for both dependent measures).

Remember/know results for the hits are presented in the middle panel of Fig. 2. The proportion of remember responses was significantly higher for the long words than for the short words, $F(1, 38) = 14.10$, $MSE = .018$, $\eta^2 = .27$, $p = .001$. The remember/know responses for the false alarms are presented in the bottom panel of Fig. 2. It is clear that most of the false alarms represent know responses, with the exception of the older participants' responses to long words. Here, more false alarms are assigned to the remember category.

Discussion

The results replicate the main findings of Experiment 1 in showing that there are strong age effects in backward recall and that word length effects are eliminated in backward recall. This pattern is reversed on the recognition task, in that age differences are eliminated and reverse word length effects emerge, with long words being better recognized than short words. The long-word advantage in recognition replicates the findings of Hendry and Tehan (2005).

The remember/know data were included to establish the locus of the recognition advantage. The younger participants' results suggest that the long-word advantage represents enhanced episodic memory for these items, in that remember responses were more prevalent with correct recognition, and know responses dominated the false alarms. The older group's performance on the long words is suggestive of a general willingness to attribute episodic qualities to any long word, in that there is a remember advantage to both correct recognition and false alarms. With the short words, both age groups report little episodic memory for the false alarms, but both report lower levels of episodic memory for correct recognition, as compared with the long words. In sum, the younger age group's performance indicates that the long-word advantage is due to better episodic information for the long words. The case is not as compelling for the older group.

In combining the results of the present experiment with those of Hendry and Tehan (2005), where forward serial recall was studied, it would appear that long words are better recognized than short words, irrespective of direction of recall. However, there is a strong short-word advantage in forward serial recall that is absent in backward recall.

General discussion

Given the experimental procedures used in the two experiments, there are a number of conclusions that can be drawn

with some confidence. First, there are age effects when backward recall is required, but those effects are much weaker in forward recall, and there are no age effects in recognition. Second, with forward serial recall, there is a short-word advantage that is eliminated with backward recall. Third, with item recognition tests, there is a robust long-word advantage. Fourth, the pattern of word length effects is the same for both younger and older participants.

The word length effect has traditionally been explained in terms of differential rehearsal, as most notably reflected in Baddeley's (1986) notion of a phonological loop. In essence, items in the proposed phonological loop decay rapidly unless they are refreshed via rehearsal. Short words are better recalled because more short words can be refreshed in a given period of time than long words. The attenuation of word length effects in backward recall could be explained within this model if it is assumed that participants abandon rehearsal in backward recall. While plausible, we think that this notion can be rejected, given other evidence that indicates that the word length effect is not time based (Lewandowsky & Oberauer, 2008; Lovatt, Avons, & Masterson, 2000; Neath et al., 2003). In addition, one computational model of the phonological loop (primacy model; Page & Norris, 1998) has modeled backward recall on the basis of the assumption that in doing backward serial recall, people perform a series of forward recalls. The participant mentally runs through each item in the list, beginning with the first item, until the final item is reached, in which case it is output as the response. Then the participant again recalls the list from the first item but now stops one item earlier and outputs that item. The repeated forward recalls act like rehearsal within the model, which allows the model to predict quite high levels of recall performance in backward recall. Because backward recall is basically multiple forward recalls, the model predicts that word length effects should be observed with backward recall and that the magnitude of the effect should be comparable to that seen with forward recall. Clearly, the data do not support this specific instantiation of the phonological loop model. The failure of the phonological loop model to adequately explain the word length effect has meant that alternative accounts of the word length effect are necessary.

Alternative accounts of the word length effect based on complexity (Caplan et al., 1992) or assembly errors (Neath & Nairne, 1995) are likewise based on forward serial recall and, like the phonological loop account, assume that recall is based on a degraded short-term memory trace in one form or another. While these models might plausibly be extended to account for word length effects in backward recall, a short-word advantage in long-term tests of serial order (Tehan & Tolan, 2007) and the long-word advantage in item recognition are beyond the scope of these models.

The item-order framework was chosen because it has its origins in serial order and item recognition dissociations in the long-term domain and, as such, has the potential to account for such dissociations in the short-term domain as well. The central tenet of this approach argues that difficulties in item processing can have subsequent effects on order processing. In the case of word length, we have assumed that long words are more difficult to process at the item level and require additional resources to reach the point of identification. The extra processing for long words leads to better performance on tasks that index item memory, but there is a cost in that there is less time available for processing order information, and this shows up as a decrement in performance for long words on tasks that require serial order. Such a framework can explain the basic findings that, across both short-term and long-term domains, short words are better recalled than long words in a diverse range of serial order tasks (immediate forward serial recall, order reconstruction, free recall, serial position probe recall, serial recognition, complex span, serial list learning) but that there is a long-word advantage in various tests of item memory (item recognition, cued recall).

In accounting for the absence of word length effects in backward recall within an item-order trade-off framework, the assumption has been made, following Li and Lewandowsky (1993), that in backward recall, participants abandon a reliance upon strict seriation (order memory). This change in strategy has less of an impact on long words than on short words, given that the long words are not strongly encoded on the order dimension at encoding. With weakened order memory for all items, any item memory effect is likely to be more pronounced. Thus, any weakened short-word advantage is canceled out by a long-word advantage in item memory.

We have also attempted to include age effects within the same item-order framework, with the assumption that older participants require more resources in processing item information and this should have detrimental effects on order processing. The results are not consistent with such an explanation, because age effects should be strongest in the tasks that most rely on order memory (forward serial recall). The strongest age effects were found with backward recall, where it is assumed that there is decreased reliance upon order memory. The pattern of word length effects is no different from that observed in the younger cohort, indicating that common processes are occurring across all participants. The pattern of overall age differences appears to be consistent with levels of task difficulty and/or environmental support (Luo & Craik, 2008).

The present results rely upon the notion that different tasks involve different contributions of item and order information that result in differential word length effects. At a more microlevel, the strength of the word length effect

across different serial recall tasks should be predictable on the degree of item memory involved in the task. For example, it is often assumed that immediate serial recall and order reconstruction differ in the extent to which item memory is involved. In immediate serial recall, the items themselves have to be retrieved, as well as their order within a list. In order reconstruction, the items are represented at test, and only order has to be retrieved. Consequently, word length effects should be stronger in order reconstruction than in immediate serial recall. This was not the case in [Experiment 1](#). However, while the distinction between the differential use of item and order information in various tasks might be possible at the conceptual level, in reality this might be impossible, given that item information still appears to have a considerable role in order reconstruction tasks (Neath, 1997; Whiteman, Nairne, & Serra, 1994).

The item-order account is a broad-brush framework that is largely silent about the mechanisms underpinning both order and item memory. We have adopted a model-free account to this point because there are many computational models of immediate serial recall, all of which have a different mechanism for establishing and maintaining serial order. There are models where order is maintained via temporal recency (Brown, Neath, & Chater, 2007), through interitem chaining (Lewandowsky & Murdock, 1989), through serial position cues (Burgess & Hitch, 1999; Henson, 1998), or through differences in item strength (Page & Norris, 1998). Furthermore, with two notable exceptions, few computational models make a distinction between item and order memory.

The two models that do specifically distinguish item and order information are TODAM (theory of distributed associative memory; Lewandowsky & Murdock, 1989) and SIMPLE (scale invariant memory and perceptual learning; Brown et al., 2007). Li and Lewandowsky (1993) point out that TODAM predicts that item variables that influence forward recall in the model generally have little impact upon backward recall, although their simulations did not explicitly test this prediction. In SIMPLE, item and order are inextricably linked such that they trade off in any memory task. As such, SIMPLE represents one instantiation of the underlying principles that define the item-order trade-off perspective, and this model has been applied to backward recall.

SIMPLE (Brown et al., 2007) sees recall as solving a discrimination problem within a multidimensional psychological space. The primary dimension in the model involves order memory. In the model, order is operationalized as a temporal discriminability function that is determined by presentation rate and retention interval timing parameters. They argue that temporal memories become less discriminable as they recede in time. Consequently, the temporal

dimension has a profound recency bias: Recently presented items that are tested immediately are highly discriminable, whereas items from earlier in the list are less so.

The second dimension reflects differences in item discriminability. When word length effects have been modelled, it has been assumed that item representations of short words are more discriminable than those of long words. The locus of the word length effect is thus identified as occurring in order memory. It should be apparent that the assumption of short words being more discriminable than long words is the exact opposite of what has been assumed in our account of the item-order framework.

The notion that item and order memory trade off is a central tenet of the model and is operationalized via a weighting parameter. In any task, the weighting parameters for item and order memory can change, but they must always sum to 1. Where SIMPLE has been applied to the word length effect in forward and backward recall (Bireta et al., 2010), a higher weighting was assigned for backward recall than for forward recall. This was the only parameter among many that differed in modeling forward and backward recall. Given the inherent recency bias on the temporal dimension, it seems reasonable to suppose that temporal order would be of more benefit on backward recall, where the most discriminable items are recalled first, than on forward recall, where the least discriminable items have to be recalled first. Bireta et al. showed that the model with the sole change in the weight assigned to the order dimension provided an excellent fit of both forward and backward recall serial position data and the attenuation of the word length effect in backward recall. Note that in this model, backward recall is deemed to be more reliant upon order memory than is forward recall, which again is the opposite of the item-order framework described earlier. SIMPLE has not been applied to word length effects in recognition, but there is no facet of the model that would lead to a prediction of reverse word length effects.

An alternative view is that there are three distinct types of information underpinning performance in these tasks: position, temporal, and item memory. Lewandowsky, Brown, and colleagues have examined temporal isolation effects under a range of short-term recall conditions (see Morin, Brown, & Lewandowsky, 2010, for a review). They have consistently shown that temporal effects are typically weak and often not statistically significant in forward recall. In most other forms of short-term recall, temporal effects are statistically robust. This has led to the proposition that there are two distinct sources of order memory. Forward serial recall is seen as being based on positional information, whereas temporal order effects are readily observable in most other short-term recall tasks. Lewandowsky, Nimmo, and Brown (2008), have presented evidence showing that both types of order memory are obligatorily

encoded, but the relative weighting of each dimension differed at recall depending on task demands. A straightforward application of these ideas to the proposed item-order framework described above would maintain that item and order effects still trade off but that the trade-off is dependent on the degree to which order memory is utilized. On the basis of the present results, it might be argued that serial position and item dimensions are jointly involved in forward serial recall, but that the temporal dimension is dominant in backward recall, and that item and, perhaps, temporal dimensions (see Morin et al., 2010) are involved in single-item recognition.

At the empirical level, we have combined two sets of empirical findings associated with the word length effect. First, we have shown the ubiquitous short-word advantage in forward recall and its elimination in backward recall (Bireta et al., 2010; Surprenant et al., 2011). Second, we have replicated the findings of a long-word advantage in recognition (Hendry & Tehan, 2005). In combination, using the same methodology, all effects have been replicated: a short-word advantage with forward serial recall, the absence of any effect with backward recall, and a long-word advantage in item recognition. We would argue that an item-order trade-off framework provides a straightforward account of the results. With regard to age, we have replicated past findings that age effects are easier to detect with backward recall than with forward recall and that, where there is adequate environmental support, as is the case with item recognition, there are no observable age effects. Finally, we have shown that the processes that produce the word length effect are similar for older and younger participants. While there may be quantitative differences in short-term recall with age, there are few qualitative differences, with possible biases in recognition being one exception.

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Serial position data are available from either of the first two authors.

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