Phonological Short-term Memory and Vocabulary Development: Further Evidence on the Nature of the Relationship

SUSAN E. GATHERCOLE,1* ELISABET SERVICE,2 GRAHAM J. HITCH,3 ANNE-MARIE ADAMS4 and AMANDA J. MARTIN1

1University of Bristol, UK  
2University of Helsinki, Finland  
3Lancaster University, UK  
4University of Manchester, UK

SUMMARY

The nature and generality of the developmental association between phonological short-term memory and vocabulary knowledge was explored in two studies. Study 1 investigated whether the link between vocabulary and verbal memory arises from the requirement to articulate memory items at recall or from earlier processes involved in the encoding and storage of the verbal material. Four-year-old children were tested on immediate memory measures which required either spoken recall (nonword repetition and digit span) or recognition of a sequence of nonwords. The phonological memory–vocabulary association was found to be as strong for the serial recognition as recall-based measures, favouring the view that it is phonological short-term memory capacity rather than speech output skills which constrain word learning. In Study 2, the association between phonological memory skills and vocabulary knowledge was found to be strong in teenaged as well as younger children, indicating that phonological memory constraints on word learning remain significant throughout childhood. Copyright © 1999 John Wiley & Sons, Ltd.

One of the major natural constraints on an individual’s ability to learn the sound patterns of new words in the native language is the capacity to hold a novel sound pattern in temporary phonological memory. Adults with acquired deficits of phonological short-term memory resulting from left hemisphere damage have been found to be completely unable to learn the phonological forms of new words (Baddeley et al., 1988; Trojano and Grossi, 1995). Corresponding links between phonological memory and the phonological aspect of vocabulary learning are also found in children. Children with good phonological memory skills have been consistently found to have
greater vocabulary knowledge in their native language than children with poorer memory function (e.g. Gathercole and Adams, 1994; Gathercole and Baddeley, 1989, 1990; Gathercole et al., 1991, 1992; Michas and Henry, 1994). Superior phonological memory function is also associated with greater facility in acquiring foreign vocabulary (Papagno and Vallar, 1995; Service, 1992; Service and Kohonen, 1995), and in more rapid learning of the phonological aspects of new words in experimental tasks (Gathercole Baddeley, 1990; Gathercole et al., 1997, Michas and Henry, 1994).

One explanation for the close associations observed between short-term memory and vocabulary learning is that they reflect the crucial role played by the phonological loop component of working memory in supporting the long-term phonological learning of new sound patterns (Baddeley et al., 1998; Gathercole and Baddeley, 1989, 1993). According to this view, stable phonological specifications of words are built by abstracting the core features from temporary representations held in the phonological loop (Brown and Hulme, 1996), providing a direct link between temporary storage and long-term learning.

An alternative account is that it is the speech output requirements rather than the prior encoding and storage component of short-term memory tasks that are critical to the link found with vocabulary knowledge (Snowling et al., 1991). Consistent with this view, conventional measures of phonological short-term memory do certainly require accurate planning and execution of speech-motor gestures. Consider two popular methods for assessing phonological memory function: digit span (a measure of the maximum sequence of spoken digits that can be reliably recalled) and nonword repetition (a measure of the accuracy with unfamiliar spoken stimuli such as ‘blonterstaping’ can be repeated). Both of these tasks place significant burdens on the child’s abilities to plan and execute the sequence of articulatory gestures which will yield a phonological output which corresponds to a retrieved memory representation. Articulatory accuracy is particularly important in the nonword repetition task, where a single phoneme deviation is scored as an error (Gathercole and Baddeley, 1996). Some children’s phonological production systems take a long time to mature and may never be fully accurate, and this will result in systematic underestimations of the true phonological memory capacities of children known to have such output problems if recall-only measures are used (Snowling and Hulme, 1989; Wells, 1995).

Study 1 was designed to investigate whether such speech output constraints are critical to the close links found between phonological memory measures and vocabulary knowledge in children with no known developmental speech pathologies. One way to distinguish between the two accounts is to develop methods for assessing children’s ability to remember phonological material which do not require the spoken recall of the memory stimuli. We devised such a task for use with 4-year-old children, and compared its associations with vocabulary knowledge against those obtained with nonword repetition and digit span tasks. The task is serial nonword recognition, and involves auditory presentation of two sequences of nonwords which are either identical to one another (e.g. ‘mel, guk, lus ... mel, guk, lus’) or differ in the order of two of the stimuli (e.g. ‘mel, guk, lus ... guk, mel, lus’). As in the digit span and nonword repetition tasks, accurate performance requires the storage of the unfamiliar sequence in temporary phonological memory. In responding, however, the child simply has to indicate whether the sequences are the same or different, a minimal spoken output requirement compared with the usual recall-based memory procedures.
The 4-year-old children who participated in Study 1 were also tested on two such recall-based measures of phonological memory function: nonword repetition and digit span. In addition, they completed tests of vocabulary knowledge and non-verbal ability. The predictions were as follows. If it is the memory component of conventional short-term memory measures which underpins part or all of the close developmental association between nonword repetition and vocabulary knowledge, vocabulary scores will be significantly associated with all three memory scores irrespective of their spoken recall requirements. If, on the other hand, it is the spoken output component of recall-based measures that is crucial, vocabulary knowledge should be significantly associated with nonword repetition and digit span scores, but not with performance on the serial nonword recognition task.

STUDY 1

Design and Method

Participants

Eighteen children aged between 4 years 0 months and 4 years 3 months (mean chronological age 4 years 1 month) participated in this study, which was part of a longitudinal project of preschool short-term memory development. Recruitment to the study was achieved by a variety of means: placing requests for volunteers in local newspapers and on playgroup noticeboards, and on selection of individuals on the basis of birth registry records. The group of children participating in Study 1 consisted of 9 girls and 9 boys, living in urban and suburban areas of Lancashire and The Wirral, UK. None of the children had commenced full-time schooling at the time of the study, and each child was tested individually in this or her own home.

The Measures

At 4 years of age, each child completed three tests of phonological short-term memory, one vocabulary test and one test of non-verbal ability. We also report here data on an assessment of articulation rates for the children which was conducted 14 months later, when the average age of the group was 5 years 3 months. The inclusion of this measure in the present analyses permits direct assessment of whether the recall-based memory measures (nonword repetition and digit span) do indeed call upon articulatory skills to a greater degree than the serial recognition task.

Nonword Matching Span. All memory sequences in the test were formed using a set of six CVC non-words: lus, vip, kug, mel, dar and pes. Six pairs of non-word sequences were prepared at each of four list lengths (1, 2, 3 and 4). At each length, three of the six pairs of nonword sequences were identical (e.g. vip, pes, dar ... vip, pes, dar) and three pairs shared the same nonwords but contained two of the non-words transposed in the second sequence (e.g. mel, guk, vip ... guk, mel, vip). For list length one, the identical sequences consisted of a pair of repeated nonwords (e.g. pes ... pes); in the non-identical sequences, the first and last consonant in the initial nonword were transposed in the second item (e.g. kug ... guk). At each length, the identical and non-identical sequences were unpredictably ordered; all children received the sequences in a single common order. The six sequences of nonwords at list length 1 were presented first to the child. If four or more correct recognition responses (i.e. ‘same’ or
‘different’) were made, the six sequences at the next list length were presented. If the child made fewer than four correct recognition judgements, testing did not proceed to the next list length.

In each trial, the experimenter spoke aloud the nonword stimuli at an even pace of approximately one nonword every 750 milliseconds, with a longer silent interval of 1.5 seconds separating the final nonword in the initial sequence from the first nonword in the second. During presentation of the stimuli, the experimenter’s mouth was obscured from the child in order to eliminate the use of lipspoken cues.

Two measures of performance on this test were obtained for each child. A span score was calculated as the list length below which testing stopped. The mean span score was 1.3 (S.D. = 1.3, range = 0 to 4). Also, the number of correct responses to sequences across all list lengths tested was scored; the mean score was 9.6 (S.D. = 5.9, range = 2 to 22).

**Nonword Repetition.** The Children’s Test of Nonword Repetition (CNRep, Gathercole and Baddeley, 1996) was administered to each child. The test consists of 40 nonwords, 10 each containing two, three, four and five syllables. In the present study, the experimenter spoke aloud each nonword while seated opposite the child, with mouth obscured. The child was instructed to attempt to repeat each ‘funny, made-up word’ immediately after hearing it. The experimenter scored each repetition attempt as either correct or incorrect, and then presented the next item in the test. In those (relatively infrequent) cases where it was apparent from the child’s earlier speech that a particular phoneme was consistently misarticulated as another, credit was given if the child substituted the consistently substituted phoneme for the target one. All children received all 40 nonwords in a common sequence. The number of nonwords correctly repeated was calculated for each child. The mean score was 26.9 (S.D. = 4.9, range = 20 to 36).

**Digit Span.** In each trial, the experimenter spoke aloud a sequence of digits which the child attempted to repeat immediately in the same forward sequence. The digits were sampled randomly and without replacement from the sequence 1 to 9. At least two lists of digits were given at each list length, starting at length two. If the first two sequences at each length were correctly repeated, the length of the next list was increased by one, and a further two lists given. If the child failed to repeat both of the two lists at one length, no further lists were given. In the cases where the child correctly recalled only one of the first two lists, a third list at that length was given. If the third list was correctly repeated, trials at the next length were given. If the child incorrectly repeated the third list, testing stopped. Span was scored as the maximum length at which the child correctly recalled at least two lists. Mean span score was 3.2 (S.D. = 0.61, range = 2 to 5).

**Vocabulary.** The Oral Vocabulary subtest of the Word Knowledge test in the McCarthy Scales of Children’s Abilities (McCarthy, 1970) was administered to each child. In this subtest, the child is asked to provide information in the form ‘What is . . . ?’ about ten words. Each attempt at a definition is classified as either showing detailed word-specific knowledge (receiving a score of two), some word knowledge (score of one) or no word knowledge (score of zero). Testing was discontinued when a child received a score of zero on three successive words. Score on the test was
calculated by summing the scores on the individual words. The mean score was 5.1 (S.D. = 3.2, range = 0 to 12).

**Non-verbal Ability.** The Puzzle Solving subtest of the McCarthy Scales of Children’s Abilities (McCarthy, 1970) provided a measure of the child’s non-verbal ability. This test requires the child to assemble a series of six puzzles to form pictures of familiar objects. Successive puzzles increase in complexity, with increasing number of points available for the successful completion of later puzzles. Bonus points are also awarded for fast completion times. Maximum score on the test is 27. The mean score was 12.6 (S.D. = 5.7, range = 3 to 24).

**Articulation Rate.** At 5 years of age, measures of rates of articulation for pairs of three-syllable words were obtained for each child. The speed with which the child repeated each of the following pairs of words five times was measured: piano, elephant, pineapple, ladybird, and banana, telephone. For each stimulus pair, the procedure was as follows. The experimenter spoke aloud the two words and asked the child to repeat them very quickly until instructed to stop. For the first stimulus pair, the experimenter modelled the repetition task, demonstrating rapid articulation of a pair of words. The child was stopped after six accurate repetitions of the word pair had been made; the experimenter timed the period from the end of the first repetition to the end of the sixth, using a stopwatch with millisecond timing. All repetition trials were recorded onto audio cassette, which was used later to obtain a further estimate of the time taken by the child to complete five stimulus pair repetitions. The live and recorded estimates were then averaged. Using this method, three individual times were obtained for the three-syllable words, and the mean of the three times was used to calculate the mean number of words spoken per second. Mean articulation rates were 1.29 words per second (S.D. = 0.21, range 0.94 to 1.68 words per second).

**Results**

Table 1 summarizes the correlations between the six principal measures. All three phonological memory measures correlated significantly with the vocabulary measure: nonword repetition,  $r(16) = 0.54$, $p < 0.05$; nonword recognition, $r(16) = 0.72$, $p < 0.001$; digit span, $p < 0.01$. There were no significant pairwise differences between any of these three correlation coefficients ($p > 0.05$, in all cases).

Table 1. Correlations between phonological memory, vocabulary, and articulation rate measures in Study 1

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<td>5 Articulation rate</td>
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<td>0.29</td>
<td>−0.07</td>
<td>–</td>
</tr>
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</table>

d.f. = 16, in each case.
Coefficients in bold are significant at the 5% level.
The three memory tests were, however, differentiated in their degrees of association with the articulation rate measure. Articulation rates were significantly linked with scores on the nonword repetition test, \( r(16) = 0.61, p < 0.01 \), but not scores on either the nonword recognition or digit span tests, \( r(16) = 0.29 \) and \( 0.34 \), respectively; \( p > 0.05 \) in both cases). The association between nonword repetition scores and vocabulary knowledge remained significant when differences associated with articulation rates were partialled out, \( r(15) = 0.49, p < 0.05 \). Finally, non-verbal test scores did not correlate significantly with any of the other measures.

**Discussion**

Study 1 demonstrates that the degree of association between scores on tests of phonological short-term memory and vocabulary knowledge is independent of the speech output demands of the memory task. Vocabulary scores were as highly associated with performance on the nonword recognition test, which simply requires the child to judge whether two sequences of nonwords are identical or not, as on the more conventional recall-based measures of phonological memory, digit span and nonword repetition. This finding fits well with studies of adults with developmental and acquired deficits of the phonological loop who have shown poor memory for nonwords and impaired abilities to learn the phonological forms of new words despite retaining intact speech production processes (Baddeley, 1993; Baddeley et al., 1988; Baddeley and Wilson, 1993), and is fully consistent with the view that phonological short-term memory plays a crucial role in vocabulary acquisition (Baddeley et al., 1988). By this account, individuals with relatively poor phonological storage capacities will therefore encounter difficulties in learning the phonological forms of new words.

The data from Study 1 do, however, provide evidence of differential articulatory constraints operate in phonological memory tasks with and without significant speech output requirements. Measures of articulation rate obtained from the children a year or so later were highly associated with nonword repetition performance, although not with the children’s scores on either the nonword recognition or digit span tasks. The selective links between articulatory skill and nonword repetition but not digit span have also been documented in previous studies (Gathercole and Adams, 1993, 1994), and are likely to reflect the greater degree of articulatory accuracy required to correctly repeat a nonword (where any phoneme error results in an error score) than to produce a digit (where the child need only produce an unambiguous attempt at the correct digit name rather than an attempt which comprises no phoneme errors). The current finding of independence of nonword recognition from the articulatory skill measure is fully consistent with this account, as the child does not have to be able to articulate the stored phonological sequence accurately in order to make an accurate recognition judgement.

The nonword repetition task therefore does indeed appear to be limited by children’s speech output skills, as demonstrated in previous studies of individuals with pathological impairments of the phonological output system (Snowling and Hulme, 1989). Two features of the present data, though, indicate that the output component in nonword repetition does not lie at the root of its close links with vocabulary knowledge. First, nonword repetition and vocabulary scores remain significantly associated after variance attributable to differences in articulation rate are
partialled out. Second, the same robust link with vocabulary knowledge is found with the nonword recognition measure which is not constrained by speech-motor output skills.

**STUDY 2**

A second unresolved issue concerning the close links between performance on tests of phonological short-term memory and vocabulary knowledge is whether the relationship persists across the life span. Investigations of children aged between three and seven years of age have typically found robust links between phonological memory and measures of vocabulary knowledge (e.g. Gathercole and Adams, 1993, 1994; Gathercole and Baddeley, 1989; Gathercole et al., 1991; Michas and Henry, 1994). Phonological memory constraints may, however, become less important in learning new words in the later childhood years, for native vocabulary at least. By the final years of a longitudinal study of children aged between four and eight years of age, we found associations between phonological memory measures and vocabulary knowledge to be much weaker than in earlier years, although still significant (Gathercole et al., 1992). On the basis of these findings, Gathercole et al. speculated that the pace of word learning in later childhood may be dictated more by powerful factors such as the amount and choice of reading material (West, Stanovich and Mitchell, 1993) than by basic limits in phonological short-term memory.

Other evidence on this issue is inconsistent. Service (1992) found that the abilities of 10- and 11-year-old Finnish children to repeat English pseudowords significantly predicted their later English language learning achievements and in particular their later knowledge of English vocabulary (Service and Kohonen, 1995). Phonological memory constraints may therefore remain significant in the learning of foreign vocabulary into adolescence, while playing a rather minor role only in continuing acquisition of the native vocabulary. This interpretation certainly fits well with evidence that adults’ learning of the new words in experimental settings is sensitive to phonological memory factors only if the phonological structures of the new words are characteristically distinct from those of the native language (Papagno, Valentine and Baddeley, 1991). During the adult years, too, there may be further developmental changes in the role played by the phonological loop in vocabulary learning. Service and Craik (1993) compared younger and older adults, and found that new word learning was more sensitive to phonological memory skills in the older group.

The aim of Study 2 was to investigate whether the relationship between phonological memory abilities and vocabulary knowledge remains constant throughout childhood, or has its peak in the early childhood years as previous data suggest (Gathercole et al., 1992). The phonological memory skills and vocabulary knowledge of children aged approximately 5 and 13 years of age were compared. Assessment of phonological memory function in both age groups was based on two tasks: digit span and nonword memory. For the younger children, the nonword task involved repetition of single nonwords, as in Study 1. As ceiling levels of performance on the test of single nonword repetition we have developed are reached by about nine years of age (Gathercole and Baddeley, 1996), the older children were tested on a more difficult nonwork memory task involving the recall of nonword pairs.
Design and method

Participants
Two groups of children participated in the study. One group was composed of 65 children with a mean chronological age of 5 years 7 months (range 5 years 1 month to 6 years 3 months). The children were recruited from two state primary schools with heterogeneous intakes with respect to socio-economic status, one in an urban area and one in a suburban area of Bristol. Children with speech and hearing problems and children for whom English was not their native language were excluded from the study. Each child was tested individually in three sessions in a period of two weeks, as part of a larger-scale study of memory and learning (Gathercole et al., 1997). Testing took place in a quiet area of the school.

The second group consisted of 60 children aged between 13 years 4 months and 14 years 5 months, with a mean age of 13 years 10 months. Each child was a pupil at one of three mixed-ability secondary schools with heterogeneous intakes in the Bristol area. Testing was conducted in two individual sessions with each child in a quiet room, plus a single group session with a maximum of 10 children.

The measures
Test of phonological short-term memory, vocabulary knowledge, and nonverbal ability were administered to each child. The young children were given two memory tests (digit span, and nonword repetition), three vocabulary tests (assessing receptive vocabulary, object naming, and knowledge of verbal definitions), and two tests of nonverbal ability. The older children received two memory tests (digit span, and nonword recall), two vocabulary tests (receptive vocabulary, and written vocabulary knowledge), and two nonverbal tests. Data from the young group are reported by Gathercole et al. (1997).

Phonological short-term memory. Digit span. This study used the same procedure for assessing digit span as Study 1. All children participating in this study completed this test twice in order to ensure high reliability of the digit span measure.

Nonword repetition. The young children were given the Children’s Test of Nonword Repetition (Gathercole and Baddeley, 1996). The procedure for administering this test was identical to that described in Study 1 in all but one respect: the nonword stimuli were prerecorded and presented on an audio cassette player. Nonwords were separated by a silent interval of 3 seconds to allow sufficient time for the child to make the repetition attempt.

Nonword recall. This test, given to the older group only, consisted of 16 pairs of nonwords, four pairs each containing nonwords of two, three, four and five syllables (stimuli are listed in the Appendix). For each nonword, ratings of wordlikeness were obtained from a sample of 10 adults, using a scale ranging from 1 (very unlikely to pass for a real English word) to 5 (very likely to pass for a real English word). The mean wordlikeness rating for the 32 nonwords employed in this test was 2.42.

The 16 nonword pairs were presented in a common randomized sequence to all children. The stimuli were prerecorded onto an audio cassette, with the nonwords in each pair separated by an interval of 500 milliseconds. A silent interval of 3 seconds separated successive nonword pairs on the tape, during which the child attempted to recall the pair. An experimenter scored the accuracy of the participant’s recall at the
time of test. Repetition attempts were scored either as correct (with a score of 1) or incorrect (with a score of 0). The total number of correct recalls was calculated for each individual.

Vocabulary knowledge. The young children were tested on three vocabulary measures. The British Picture Vocabulary Scale (Dunn and Dunn, 1983) involves the child matching pictures with spoken words. The mean raw score on the Long Form of this test was 49.0 ($S.D. = 14.4$) corresponding to a standard score of 97 for the mean chronological age of the group. The Expressive One-Word Picture Vocabulary Scale-Revised (Gardner, 1990) was developed as a picture-naming analogue of the British Picture Vocabulary Scale. The mean score on this test was 45.1 ($S.D. = 14.1$), corresponding to a standardized score for the group of 101. The Oral Vocabulary component of the Word Knowledge test in the McCarthy Scales of Children’s Abilities (McCarthy, 1970). Details of administration of this test are provided for Study 1. The group mean score was 7.9 ($S.D. = 3.9$).

The older children were given two vocabulary tests. On the Short Form of the British Picture Vocabulary Scale (Dunn and Dunn, 1983), the mean score of the group was 24.7 ($S.D. = 3.2$), corresponding to a standard score of 97. The Junior version of the Mill Hill Vocabulary Scale (Raven, Court & Raven, 1988) is a written test organized into two parts: in the first part the participant has to supply definitions for single words, and in the second part the task is to select synonyms to a target word six alternative choices. The mean total score for the group was 31.4 ($S.D. = 7.1$).

Nonverbal ability. Both groups of children were tested on the Block Design subtest of the Wechsler Intelligence Scales for Children–Revised (Wechsler, 1974). Mean scores were 9.0 ($S.D. = 5.3$) for the younger children, and 47.6 ($S.D. = 9.7$) for the older group. In addition, the young group were tested on Raven’s Coloured Progressive Matrices (Raven, 1980), and the older group on Standard Progressive Matrices (Raven, 1986). The mean raw score was for the young group was 16.7 ($S.D. = 3.7$), and 44.0 ($S.D. = 5.9$) for the older group. These scores correspond to the 50th centile points for age, for both groups.

Results

The vocabulary scores obtained for each child were combined to produce a single composite score for the purposes of analysis. The composite score was the mean $z$-score for each vocabulary measure (of which there were three for the young group, and two for the older group). A composite non-verbal ability score was also calculated for each child, based on the mean $z$-scores for the two nonverbal tests. Table 2 summarizes the correlations between the two phonological memory measures and the composite vocabulary and nonverbal scores for each age group.

Consider first the data from the 5-year-old group. All four measures were significantly correlated with one another, $p < 0.001$, in each case. Most importantly, the vocabulary composite score was highly correlated with both nonword repetition scores, $r(63) = 0.61$, and digit span scores, $r(63) = 0.44$. Each of these correlations with vocabulary scores remained significant when variance associated with nonverbal ability scores was partialled out: nonword repetition, $r(62) = 0.49$, $p < 0.001$, and digit span, $r(62) = 0.29$, $p < 0.05$. 
Phonological memory scores were also significantly correlated with vocabulary composite scores in the older children: for nonword recall, $r(58) = 0.39, p < 0.001$, for digit span, $r(58) = 0.45, p < 0.001$. Neither of the phonological memory measures was significantly correlated with non-verbal ability in this age group, $p > 0.05$, in both cases. Non-verbal ability scores were, however, significantly associated with vocabulary knowledge, $r(58) = 0.36, p < 0.001$. The significant links found between the vocabulary and phonological memory measures remained after variance associated with non-verbal ability scores was partialled out: nonword recall, $r(57) = 0.37, p < 0.001$, and digit span, $r(57) = 0.39, p < 0.001$.

**Discussion**

Phonological memory skills, as indexed by digit span and nonword memory, were significantly associated with vocabulary knowledge at both 5 and 13 years of age. These data provide no evidence for a loss of influence of phonological memory skills on vocabulary acquisition in later childhood, in contrast to previous findings (Gathercole *et al.*, 1992), and point instead to developmental continuity in the contribution of the phonological loop to vocabulary development. This conclusion fits well with findings from experimental studies of word learning in adults showing that conditions which limit phonological memory involvement impair the long-term learning of novel phonological forms (Papagno *et al.*, 1991; Papagno and Vallar, 1992, 1995).

The possibility that there are subtle variations across the lifespan in the relative strength of the role played phonological memory in long-term phonological learning cannot, though, be ruled out on the basis of the present findings. Phonological memory capacity and vocabulary knowledge are by no means perfectly correlated with one another, and the strength of the natural association may be governed in part at least by fluctuations in the impact of other factors on natural vocabulary development over different lifetime periods which may mask phonological memory contributions to word learning. For example, the range and content of reading material to which an individual is exposed appears to be a powerful influence on vocabulary knowledge (West *et al.*, 1993), and may determine the pace of vocabulary gain during the middle and later childhood years into early adulthood in particular. By early adulthood, much of the individual variation in vocabulary knowledge may have been lost, as lack of vocabulary-learning opportunities associated with minimal reading experience become compensated by general exposure to language over the years. It
may also be the case that a range of strategies can be flexibly deployed to offset the phonological memory demands of learning the sound structures of new words in the early and middle periods of adulthood, when central executive resources available to individuals are greatest (Siegal, 1994). It may be for this reason that phonological memory skills constrain foreign vocabulary learning to a greater degree in old age than earlier in adulthood (Service and Craik, 1993).

CONCLUSIONS

The present studies extend the generality of previous demonstrations of close links between phonological memory skills and native vocabulary knowledge in two respects. Study 1 establishes that the links persist even when phonological memory is assessed by a serial recognition method which, unlike conventional recall techniques, does not place significant demands on speech output processes. This finding favours the view that the memory–vocabulary association is not due to a confounding influence of speech output skills on measures of both phonological memory and vocabulary knowledge, but instead arises from the contribution of phonological memory to the learning of new words. Study 2 establishes developmental continuity to the natural association between phonological memory and vocabulary development by showing that its persistence from the early to late childhood period.

ACKNOWLEDGEMENTS

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REFERENCES


# APPENDIX: STIMULI USED ON NONWORD RECALL TEST IN STUDY 2

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