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Working memory and short-term sentence recall in young children

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The primary objective of this study was to investigate links between phonological memory and short-term sentence recall. Errors in immediate sentence recall were compared for children with relatively good and relatively poor phonological short-term memory skills, matched on general nonverbal ability. The results indicate marked differences in the overall accuracy of recall between the two groups, with the high phonological memory group making fewer errors in sentence recall. Although the frequency of the different types of errors (lexical substitutions and nonsubstitutions) differed significantly between the groups, the serial position profiles of sentence recall accuracy was similar. Both groups were also more likely to substitute target words with synonyms rather than unrelated words, a finding suggesting that mechanisms responsible for maintaining semantic information may also play an important role in performance of sentence recall tasks.

Although detailed theoretical accounts of the cognitive processes involved in short-term memory for arbitrary verbal material have now been advanced (e.g., Brown, Preece, & Hulme, 2000; Burgess & Hitch, 1999; Page & Norris, 1998), the mechanisms underlying recall of meaningful sequences of words are not well understood. There are several key differences between recall of word lists and sentences. First, memory span for words in sentences is almost twice as great as the span for unrelated sequences of words (e.g., Baddeley, Vallar, & Wilson, 1987; Butterworth, Shallice, & Watson, 1990). Second, errors made in sentence recall tend to preserve the gist of the sentence (e.g., Jarvella, 1971; Saffran & Martin, 1975).

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Theorists agree that the recall advantage to words organised in sentences rather than meaningless sequences arises from the contributions of representations of the meaning of sentences to their immediate recall. On the basis of findings that participants are likely to falsely select a semantically related distracter to a target word occurring in an earlier sentence, Potter and Lombardi (1990,1998) suggested that the gist recall of sentences is mainly based on conceptual information in long-term memory, with recently activated lexical entries being incorporated into the recall attempt. Due to spreading activation to semantically associated items, related words may be erroneously selected. By this account, the reconstruction of sentences is similar to long-term recall in that it relies on deeper levels of processing, such as conceptual information (see Lee & Williams, 1997, for related findings).

There is also compelling evidence that short-term memory processes also contribute to the recall of sentences (Glanzer, Dorman, & Kaplan, 1981; see also von Eckardt & Potter, 1985, for a review). First, the influences of variables that are known to influence immediate recall of unrelated word lists appear to extend also to sentence recall. For example, a high degree of phonological similarity within sentences impairs both recall and comprehension of sentences, as well as of unrelated word lists (Baddeley, 1986). Increasing the length of words in sentences also leads to a significant reduction in recall accuracy (Engelkamp & Rummer, 1999; Rummer & Engelkamp, 2001; Willis & Gathercole, 2001). Second, individuals with impairments of phonological short-term memory are typically poor at recalling both word lists and sentences, although their comprehension of sentences is often intact (e.g., McCarthy & Warrington, 1987). Hanten and Martin (2000) investigated sentence recall and comprehension of two head-injured children. They found that a deficit in phonological short-term memory led to a greater impairment in sentence recall compared to sentence comprehension. Together with other evidence from adult neuropsychological patients, these data suggest phonological short-term memory contributes to the recall but not comprehension of sentences.

These data converge on the view that sentence recall is supported both by conceptual representations and by the short-term memory processes that also support the recall of unrelated verbal material. Martin and colleagues (e.g., Hanten & Martin, 2000; Martin, Lesch, & Bartha, 1999) have proposed that both phonological and semantic short-term memory systems contribute to immediate memory for sentences. According to this view, phonological, lexical, and semantic levels of representation are activated during the sentence recall task and are held in separate storage buffers. An alternative view advanced by Baddeley (2000) is that memory for sentences is served by the episodic buffer component of working memory, a system receiving inputs from components of working memory as well as from other cognitive systems that represents inputs in a multidimensional code. In the case of sentences, the phonological representation of the sentence is combined with the conceptual representations resulting from language processing.

The aim of the present study was to provide an exploratory analysis of links between phonological short-term memory and the recall of sentences, by investigating the nature of the errors in sentence recall associated with poor phonological memory skills in young children. Sentence recall was compared in 4- and 5-year-old children selected on the basis of either relatively low or high phonological memory scores, matched on general nonverbal ability. In order to provide a broad-based assessment of sentence repetition ability, two separate sentence recall tests were developed. In one test, all sentences had a simple active structure; in another, sentences incorporated a range of different syntactic structures. On the basis of the evidence reviewed above that phonological memory capacity impairs the accuracy of sentence recall, it was expected that the high phonological memory group would show superior accuracy of sentence recall.

A further issue of interest concerns the distribution of errors as a function of position within the sentence was investigated. If sentence recall is mediated by the same cognitive processes as immediate serial recall, serial position functions should be similar (see e.g., Burgess & Hitch, 1999). Specifically, accuracy should be greatest for words located at initial sentence position, intermediate at final list positions in the sentence, and poorest in middle list positions.

Finally, categories of errors in sentence recall were analysed. Studies of errors in speech production have identified a number of common categories, including additions, deletions, and substitutions (e.g., Bock & Levelt, 1994). On the basis of the substantial overlap in the requirements of the production and recall of sentences, in particular the ordering of syntactic and semantic information, similar types of lexical errors may be expected in sentence recall in young children. The assessment of the different types of errors as a function of phonological memory capacity provides additional insight into short-term sentence recall in young children.

METHOD

Participants

Data from a total of 194 children from state primary schools in an urban area in North-East England were collected as part of an earlier study investigating the relationship between working memory and scholastic achievement (Alloway, Gathercole, Adams, & Willis, 2003). The data from this study were used to identify children with low and high performance on the phonological short-term memory measures. Three measures of the phonological loop component were administered: the *digit recall* and the *word recall* tests from the Working Memory Test Battery for Children (Pickering & Gathercole, 2001), and the Children's Test of Nonword Repetition (Gathercole & Baddeley, 1996). Standard scores on all three phonological memory tasks were averaged to produce a composite score. Children were identified as having either low or high phonological memory if their composite scores for the phonological loop tasks were either more than one standard deviation below or above the composite score for the full sample group based on 194 children. Based on this criterion, 28 children were selected for each memory group. The difference between the composite scores of the two groups was highly significant, $t(54) = 14.22$, $p < .001$. The children in the groups were matched on nonverbal scores (two subtests of the performance scales of the Wechsler Preschool and Primary Scale of Intelligence-Revised: Block design and Object assembly; Wechsler, 1990). The scale scores of these two performance subtests were converted to standard scores and then averaged to produce a composite score of nonverbal intelligence. The composite performance intelligence scores of both memory groups were in line with the composite performance intelligence scores of the overall sample population. Their profiles are summarised in Table 1.

Materials

Two sets of 10 sentences were given to each child. Both tests consisted of 10 sentences with vocabulary appropriate for the age group. Set 1 consisted of 10 sentences with simple active grammatical structures (e.g., ''The cup is in the box'') used by Potter and Lombardi in a study of children aged 4 to 5 years

TABLE 1
Descriptive statistics of age in months, standard scores, and composite scores for profile measures for the separate phonological memory groups and the sample as a whole

	Phonological memory group		*Sample*
	High	*Low*	
Age (months)	61.96 (2.89)	59.89 (2.44)	60.93 (2.85)
Number of boys	13	16	97
Number of girls	15	12	97
Phonological loop:			
Nonword repetition	116.07 (11.62)	78.04 (9.42)	94.52 (16.60)
Digit recall	107.11 (11.97)	79.61 (9.38)	94.71 (13.10)
Word recall	113.46 (14.48)	85.86 (19.50)	100.86 (15.40)
Composite score	112.21 (7.72)	81.17 (8.59)	96.69 (12.08)
Nonverbal intelligence:			
Block design	98.27 (9.99)	100.19 (12.69)	100.03 (14.35)
Object assembly	101.30 (12.17)	103.75 (10.45)	103.89 (16.83)
Composite score	100.11 (7.99)	101.67 (9.72)	101.96 (13.19)

Standard deviations shown in parentheses.

[1] It bears noting that although the sentences in set 1 were taken from Potter and Lombardi (1990), the paradigm was modified. In the present study, the children recalled the sentences immediately after presentation rather than after an intermediate word recognition task. Intrusion errors arising from Potter and Lombardi's use of semantic lures therefore do not arise in the present study.

(1990; Exp. 7).[1] Set 2 consisted of 10 sentences from the Test for the Reception of Grammar (Bishop, 1982), a test of language comprehension suitable for children aged 4–9 years. Each sentence shared a different grammatical structure, with active and passive voices, and embedded clauses modifying either the subject (e.g., ''The boy chasing the horse is fat'') or the object (e.g., ''Everyone should wear gloves when it snows''). The sentences ranged between six and nine words in length, with a mean length of 7.9 words in set 1 and 6.8 words in set 2 (see Appendix). Test–retest reliabilities for recall accuracy were calculated for a subset of 105 children from the original sample. For set 1, $r(103) = .67$; for set 2, $r(103) = .69$.

Procedure

Each child was tested individually in a quiet area of the school on the short-term sentence recall task. The experimenter spoke each sentence aloud and the children were required to recall the sentence immediately. The children's responses were tape recorded and subsequent scoring was based on these recordings.

Scoring

Performance on the sentence recall task of the two groups was scored in three ways. First, the overall accuracy of sentence recall was calculated. A sentence was considered to have an error if one or more lexical errors occurred in the sentence. Although this score did not take into account the variability in syntactic complexity or sentence lengths, it provides a useful overview of the performance of the two phonological memory groups across all sentences. The maximum possible score for both sentence sets 1 and 2 was 10. For the items score, the maximum possible score for both sentence sets 1 and 2 was 28, representing the total number of children in the high and low phonological memory groups.

Second, the accuracy of recall was scored using a strict serial scoring criterion according to which a word was only scored as correct if it was recalled in its original position within the sentence. The total number of errors occurring in each of the serial positions as a function of phonological memory capacity was calculated. For example, if the following sentence ''The cup is in the box'' was recalled as ''The cup in the box'' omitting the word *is*, errors in serial positions 3, 4, 5, and 6 were recorded. Using a strict serial scoring criterion provides a useful comparison between accuracy in the beginning and end points of sentences and unrelated word lists. One disadvantage of this scoring criterion is that the errors produced in sentence recall may be restricted by syntactic information.

An alternative method of measuring serial recall accuracy while taking into account the varying syntactical structures of the sentences is to calculate the frequency of errors for the initial, median and final positions. These divisions were based on previous research on phrasal boundaries as natural chunking units in sentences, such as the canonicity of thematic role assignment and branching direction of embedded clauses (see Small, Kemper, & Lyons, 2000, for a similar classification; also Wingfield, Lahar, & Stine, 1989). Canonical sentences are expressed in the active voice and are common in English; for example, ‘‘The cup is in the box’’. An example of a noncanonical sentence presented in this study is: ‘‘The girl is chased by the horse’’. Branching direction refers to whether the embedded clause modifies the subject (left branching) or the object (right branching). An example of a left-branching sentence is: ‘‘The boy (chasing the horse) is fat’’; and a right-branching sentence is: ‘‘Everyone should wear gloves (when it snows)’’. The initial position in sentence recall consisted of the subject or first noun phrase in all sentences. The medial position was the verb phrase in the canonical, noncanonical sentences and right-branching sentences, and the embedded clause in the left-branching sentences. The final position was the last noun phrase in the canonical, noncanonical sentences and left-branching sen-

TABLE 2
Example of errors detected in the short-term sentence recall task in young children; error italicised in each case (omission in parentheses)

Error category	*Example of error*
Omission of words	
The horse is taller than the wall	The horse is taller (*than*) the wall
Insertion	
The boy chasing the horse is fat	The boy chasing the horse *he* is fat
Order	
Take off your coat and hang it up	Take *your coat off* and hang it up
Substitution: unrelated	
The puppy wants to go for a walk	The *mickey* wants to go for a walk
Substitution: grammatical	
The boy rode a horse at the zoo	The boy *rided* a horse at the zoo
Substitution: article (a, the)	
The teacher will read a story after lunch	*A* teacher will read a story after lunch
Substitution: repeat word from sentence	
The horse is taller than the wall	The *wall* is taller than the wall
Substitution: synonym	
An adult will help with the scissors	*Somebody* will help with the scissors
Substitution: pronoun	
My friend got a rabbit for her birthday	My friend got a rabbit for *my* birthday
Substitution: phonological	
The boy rode a horse at the zoo	The boy *rose a horde* at the zoo

tences, and the embedded clause in the right-branching sentences.

Finally, the nature of the errors in the sentence recall task was classified. In addition to identifying broad error categories, such as lexical substitutions and omissions (e.g., Bock & Levelt, 1994), the categories were refined on the basis of several inspections of the types of errors produced by the two memory groups. Substitution errors were classified as errors where the whole word was replaced with another word. The different groups of substitution errors were classed as unrelated, grammatical, article, repeat, synonym, pronoun, and phonological substitutions. No nonword substitutions were produced by either memory group. The remaining error categories were omissions, nonresponses, insertions, and order errors. For convenience, these types of errors are referred to as non-substitution errors. Examples of all error categories are listed in Table 2. In cases where the children made multiple errors in a sentence, all errors were recorded. For example, one child recalled the sentence ''An adult should help with the scissors'' as ''The adult help with the scissors''. In this case, the sentence was scored as containing both a substitution error (*an* was replaced with *the*) and an omission error (*should*). Another example of a sentence with multiple errors is: ''An adult should help''. In this case, the sentence was scored as containing three omission errors (*with the scissors*). The frequency of the type of errors (i.e., the total substitution and nonsubstitution errors) committed by both phonological memory groups were recorded.

RESULTS

The overall accuracy of sentence recall was 82% for the high phonological memory group and 52% for low phonological memory children. The perfor-

TABLE 3
Mean scores of the two phonological memory groups on the sentence recall tasks

	Phonological memory group	
	High	*Low*
Set 1:		
Participants score	8.07 (1.49)	4.61 (2.35)
Items score	22.50 (5.53)	13.10 (5.53)
Set 2:		
Participants score	8.39 (0.92)	5.71 (1.70)
Items score	23.50 (7.29)	15.80 (9.88)

Standard deviations shown in parentheses. The maximum possible score for the participants score is 10; for the items score it is 28.

mance of the two groups is summarised in Table 3. In order to take into account multiple comparisons, a Bonferroni adjustment was made and the α criterion for significance was accordingly set to .01. The low memory group performed worse on both sentence set 1 and 2. *T*-tests confirmed that the two groups differed significantly in their recall accuracy, $t_1(54) = 6.60$, $p < .001$; $t_2(9) = 8.65$, $p < .001$ for set 1 and $t_1(54) = 7.35$, $p <.001$; $t_2(54) = 3.92$, $p < .004$ for set 2.

The frequency of errors in each serial position in the sentences as a function of phonological memory was calculated. The strict serial recall data scored by each input position is summarised in Figure 1. The most striking feature of the data is the superior recall at early sentence positions, followed by a reduction in recall accuracy at middle and later positions. The extent of the primacy advantage appears to vary across sentence lengths, ranging from the first word only (in six- and eight-word sentences) to the first three words in nine-word sentences. There is some evidence of a recall improvement at final-word positions at all lengths, but the effect is very small in magnitude.

As the sentences varied in word length, the number of trials completed by each participant at each sentence length differs considerably. In order to obtain a more general analysis of recall accuracy across all sentence lengths, errors were scored across three broad serial position categories corresponding to the initial, median, and final positions of the sentence as described earlier. Recall performance of the phonological memory groups is summarised in Figure 2. Both groups produced similar patterns of serial position errors, with fewer errors in the initial sentence position compared to the median and final positions. A two-

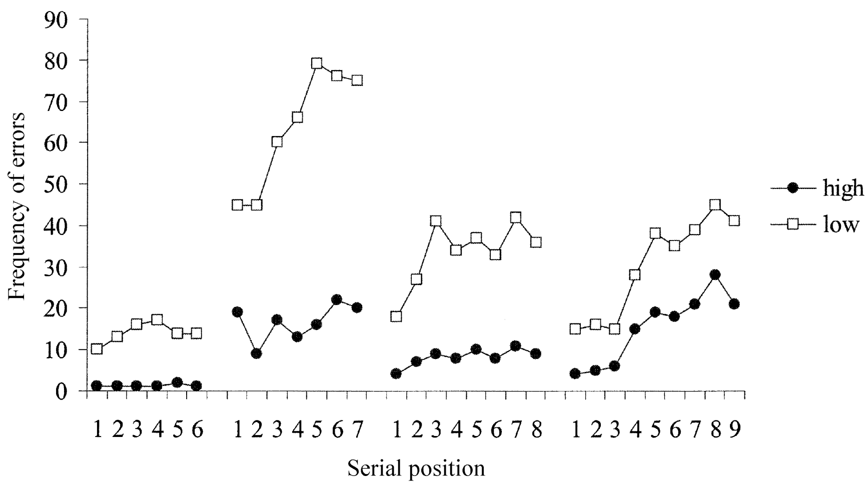

Figure 1. Total number of errors produced by both memory groups as a function of serial position across each of the four sentence lengths.

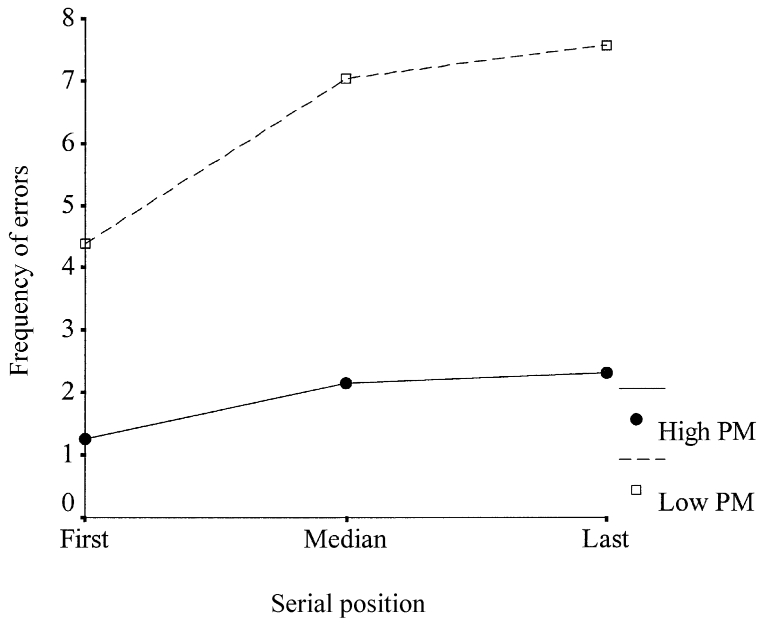

Figure 2. Frequency of errors produced by both memory groups as a function of first, median, and last serial positions.

way mixed design ANOVA was conducted with participants (F_1; phonological memory group = between, serial position = within) and items (F_2; phonological memory group = within, serial position = between) as random factors, on the frequency of errors. The participant analysis revealed a significant difference in the position of errors, $F_1(2, 108) = 38.76$, $p < .001$; this was not significant in the item analysis, $F_2(2, 57) < 1.00$. There was a significant difference between the phonological memory groups, $F_1(1, 54) = 58.28$, $p < .001$; $F_2(1, 57) = 120.42$, $p < .001$. The interaction between memory group and serial position was significant in the participant analysis, $F_1(2, 108) = 9.52$, $p < .001$; not the item analysis, $F_2(2, 57) = 1.05$, $p = .36$.[2]

Finally, categorisation of error types was carried out by TPA and an independent judge. Both judges scored all errors in the sentence recall data and

[2] The item analysis was conducted with sentence set (1 and 2) as random variables, but there was not a significant main effect of sentence set, and the interaction between sentence set and frequency of errors was not significant. An additional items analysis was also conducted with sentence type (canonical, noncanonical, left-, and right-branching) as a random factor. However, the interaction between the frequency of errors and sentence type was not significant. These findings indicate that although the syntactic complexity in the sentences varied, this did not significantly affect recall accuracy. For simplicity, the item analyses that are reported in the study do not include sentence set or type as independent variables.

assigned each error to one of the categories outlined in Table 2. The agreement rating based on the classification of all errors between the two scorers was 89.8%. The frequency of each error type as a function of memory group is presented in Table 4. The findings indicate that the children in the high memory group were more likely to make substitution errors compared to the low memory group (67% and 45%, respectively), whereas the low memory group made more nonsubstitution errors compared to the high memory group (55% and 33%, respectively). A Bonferroni adjustment was made and the α criterion for significance was accordingly set to .01. *T*-tests confirmed that the two groups differed significantly in their production of substitution errors, $t_1(54) = 5.02$, $p < .001$; $t_2(19) = 4.16$, $p = .001$; and for nonsubstitution errors, $t_1(54) = 5.24$, $p < .001$; $t_2(19) = 5.50$, $p < .001$. These findings indicate that the high memory group made significantly more substitutions compared to the low memory group, whereas the low memory group made significantly more nonsubstitution errors compared to the high memory group.

TABLE 4
Frequency of different error types as a function of phonological memory group

	Phonological memory group	
Error category	*High*	*Low*
Nonsubstitution:		
Omissions	33 (73%)	193 (71.5%)
Insertions	8 (18%)	42 (15.5%)
No response	3 (7%)	24 (9%)
Order	1 (2%)	11 (4%)
Total	45 (33%)	270 (55%)
Substitution:		
Synonym	34 (37%)	93 (42%)
Article	19 (21%)	27 (12%)
Repeat word	12 (13%)	19 (9%)
Phonological	9 (10%)	12 (5%)
Unrelated	7 (8%)	35 (16%)
Grammatical	6 (7%)	23 (10%)
Pronoun	4 (4%)	14 (6%)
Total	91 (67%)	223 (45%)
Overall total	136	493

Percentages of nonsubstitution and substitution errors are shown in parentheses; percentages of the subcategories of nonsubstitution are calculated based on the total of nonsubstitution errors, and percentages of the subcategories of substitution are calculated based on the total of substitution errors.

DISCUSSION

The data indicate marked differences between the two phonological short-term memory groups in the overall accuracy of sentence recall. Specifically, the low phonological memory children were significantly poorer in recall scores of the sentences. Their performance is also markedly poorer than the high phonological memory group when examining recall accuracy as a function of first, median and last sentence positions. These findings are in line with previous evidence of links between phonological short-term memory and immediate recall of sentences (e.g., Hanten & Martin, 2000; Martin, Shelton, & Yaffee, 1994; Engelkamp & Rummer, 1999; Willis & Gathercole, 2001).

The present study extends previous research and provides additional insight into the different types of errors produced as a function of memory capacity. Analysis of the error categories indicated marked differences between the high and low memory groups. A notable feature of the data is that the low memory children made a significantly greater proportion of nonsubstitution errors (i.e., lexical omissions, additions, no-responses, and order errors), whereas the high memory children made a greater proportion a higher number of lexical substitution errors. One possible explanation is that phonological short-term memory assists the preservation of the structure of a sentence, such as the word order and inflectional markers (see Caramazza, Basili, Koller, & Berndt, 1981). This suggestion is consistent with findings that phonological memory skills are strongly associated with lexical knowledge in 4-year-old children (e.g., Gathercole & Baddeley, 1989; Gathercole, Hitch, Service, & Martin, 1997). In the present study, children with low phonological short-term memory capacity were more likely to omit and insert words and confuse the order of words in the sentence. In contrast, performance of the children with high phonological short-term memory capacity did not suffer in this respect. Instead, they committed more lexical substitution errors. However, as additional measures of language ability, such as vocabulary skills and grammatical awareness, were not taken, we cannot exclude the possibility of these skills also contributing to sentence recall. Thus, the role of phonological memory with respect to the type of errors produced must be treated cautiously.

An alternative interpretation of these findings is that semantic memory may also contribute to immediate sentence recall (e.g., Hanten & Martin, 2000; Jarvella, 1971; Potter & Lombardi, 1990; Rummer & Engelkamp, 2001). As semantic memory was not directly measured in the present study, we cannot determine whether semantic and phonological short-term representations are independent from each other. However, the data indicate that while both memory groups differed in recall performance, semantic information in sentence recall is preserved. Inspection of the substitution errors reveals that both groups were more likely to produce synonym substitutions (37% and 42% for high and low memory groups, respectively) than unrelated words (8% and 16% for high and low memory groups, respectively). An explanation that may account for the preservation of conceptual information in sentence recall is that there may be additional cognitive systems involved in short-term sentence recall. Both the Baddeley (2000) and Martin (e.g., Hanten & Martin, 2000; Martin et al., 1999) models are able to account for the dissociation between recall accuracy and preservation of semantic information in the phonological memory groups. In the Baddeley model, a component known as the episodic buffer, has access to lexical and semantic information, and is responsible for integrating information from temporary and long-term memory systems. In the Martin model, separate storage buffers for semantic and phonological information contribute to performance in sentence recall.

In summary, the findings from this study indicate that the two phonological memory groups differed in the overall accuracy in short-term recall of sentences. The groups also differed with respect to errors in the initial, median, and final sentence positions. Analysis of the error categories indicates that the high memory children were more likely to make lexical substitutions, whereas the low memory children made more nonsubstitution errors, such as omissions, insertions, and order errors. The present data also support the proposal that performance in sentence recall receives additional support that helps to retain semantic information. Both groups were more likely to substitute words with synonyms rather than unrelated words, an effect interpreted to reflect the contribution of a dynamic and integrated memory system (Baddeley, 2000; also Martin et al., 1999). Taken together, the error analyses of sentence recall for high and low phonological memory groups extend previous research on the roles of phonological memory and semantic input in short-term sentence recall.

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APPENDIX

Sentences in set 1

1. My friend got a rabbit for her birthday.
2. Everyone should wear gloves when it snows.
3. Don't step in the puddle with your new shoes.
4. The teacher will read the story after lunch.
5. An adult should help with the scissors.
6. At home I have a red balloon.
7. He asked his mother for a glass of milk.
8. The puppy wants to go for a walk.
9. Take off your coat and hang it up.
10. The boy rode a horse at the zoo.

Sentences in set 2

1. The girl is sitting on the table.
2. The cow is looking at them.
3. The man is chasing the dog.
4. The horse is taller than the wall.
5. The girl is chased by the horse.
6. The cup is in the box.
7. The boy chasing the horse is fat.
8. The boy is sitting but not eating.
9. The pencil is above the flower.
10. The box is not only big but also blue.