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<td><strong>Author(s)</strong></td>
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Phonological working memory
and speech production
in preschool children

Kwok Yee Tak, Esther

A dissertation submitted in partial fulfilment of the requirements
for the Bachelor of Science (Speech and Hearing Sciences), The
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Phonological working memory and speech production

in preschool children

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Abstract

This study investigates whether phonological working memory is associated with preschool children's spoken language development. Phonological memory abilities of 30 children aged 3-3.5 years were assessed through repetition of nonwords of various length. Analysis of mean length utterance in morpheme (MLU-m) and syntactic complexity in terms of (1) ratio between complex vs simple sentence production, (2) ratio between the verb phrase and verb production, and (3) noun phrase and noun production were taken through the children's conversation and video description. Significant correlational relationships were found between children's phonological memory capacities, length of utterance and the syntactic complexity in (1) and (2). No significant correlation was found between phonological working memory and noun phrase vs noun ratio. The possible mechanisms by which phonological working memory skills are linked to spoken language development in preschool children are discussed.
INTRODUCTION

Does phonological working memory, which is the memory system involved in temporary retention of verbal material, support the developing language processing system in childhood? In recent years, the working memory model introduced by Baddeley and Hitch (1974) has had considerable success in accounting for the complex developmental changes that take place in verbal short-term memory during childhood. According to the current version of this model (Baddeley, 1986), working memory is conceptualized as a multicomponent system, comprising of a "central executive" and two distinct "slave systems". One is a visuo-spatial sketchpad and the other is a phonological loop. The phonological loop that is specialized for the maintenance of linguistic material while other complex cognitive tasks are performed, is the focus of the present study. The phonological loop (i.e. phonological working memory) consists of two related but separable components: a capacity-limited phonological short-term store and the subvocal rehearsal process that acts both to translate nonauditory inputs such as pictures and printed words into phonological form suitable for representation in the phonological store and to refresh decaying phonological representations within the store.

Over the past decade or so, intensive research activity has established that young children's phonological memory capacities are critically related to at least
three important aspects of language development. Close links have been found with vocabulary acquisition (Gathercole & Baddeley, 1989; Gathercole, Willis, Emslie, & Baddeley, 1992), with comprehension of language (Smith, Mann, & Shankweiler, 1986), and with reading development (see Wagner & Torgesen, 1987, for review). A recent study (Adams and Gathercole, 1995) documented linkages between phonological working memory and speech production in young English-speaking children.

English is a stress-timed language and Cantonese is a syllable-timed language. There are significant differences between the phonological structures in the two languages. The present study was designed to explore whether phonological memory capacity plays a role in spoken language acquisition in Cantonese preschoolers.

Learning to speak is one of the child's major achievements during the preschool years. There are individual differences in the nature and speed at which children learn to speak. Children's utterances vary in both the length and syntactic complexity (e.g., Crystal, Fletcher, & Garman, 1976; Miller & Chapman, 1981; Scarborough, 1990). The aim of the present study was to investigate the relationship between these two aspects of children's speech production - length of utterance, and the syntactic complexity of the utterances and the ability to store phonological material in phonological working memory.
There is already some indirect evidence that phonological working memory capacity in young children and their speech production abilities are indeed related to one another. According to Scarborough, Tager-Flusberg, Fowler, & Sudhalter (1991) and Gathercole & Baddeley (1990), children with developmental language disorders, who typically have both short and syntactically immature utterances, also have very poor phonological memory skills indeed. This co-occurrence of impairments in both language production and phonological working memory is consistent with the view that phonological working memory plays a crucial role in supporting the developing speaking abilities of the child.

Case studies reported by Speidel (1989, 1993) also have provided evidence for a specific association between phonological working memory and speech production. A detailed longitudinal analysis reported the developing language abilities of two bilingual siblings, Mark and Sally, who had good and comparable intellectual and comprehension abilities in both English and German. Sally's language production was as good as her comprehension, however, Mark had difficulties with speaking in both languages that could be tracked back to infancy. Mark also performed poorer than Sally on conventional verbal short-term memory tests such as digit-span and auditory serial recall. As a consequence of relatively poor abilities to hold phonological material temporarily in phonological working memory, Speidel argued that Mark would also have inadequate long-term memory
storage of words and phrases that form the corpus for building syntactic patterns in spontaneous speech. Phonological memory capacities are therefore suggested to affect the temporary storage of the language input until they can be incorporated into long-term memory and the inventory of syntactic forms.

This account is similar to the view that short-term phonological storage is critical in learning the phonological forms of new words proposed by Gathercole & Baddeley (1989), although Speidel extends this to the long-term learning of phrases as well as individual words. By this account, deficits in phonological working memory will disrupt and delay the development of syntactic knowledge during childhood. Young children's phonological memory skills should therefore be directly related to spoken language development.

The study of Adams & Gathercole (1995) found that 3-year old children with poor phonological memory performance produced spontaneous speech that was less grammatically complex and contained shorter utterances than did the speech of children with better phonological memory abilities. This establishes a close link between phonological working memory and speech production in preschool children.

There has been far less research on the possible contribution of phonological working memory to speech production than to other aspects of language development, such as vocabulary acquisition, comprehension, and reading. The
The principle reason is that the earlier studies on skilled adult speakers failed to show any direct associations between short-term memory and language production (see Gathercole & Baddeley, 1993, for a review). Patients with acquired neuropsychological damage resulting in severe short-term memory deficits have normal speech production. A detailed qualitative and quantitative analysis by Shallice & Butterworth (1977) of the language produced by such patients revealed no obvious abnormalities of speech production in terms of phrase length and syntactics complexity.

Although there is absence of any apparent contribution of phonological working memory to skilled adult speakers, it does not rule out its involvement in children learning to speak. Bock (1982) suggested that the buffer for planning speech output for adults is not equivalent to the specialized phonological component of working memory. Fodor (1983) also claimed that speech production in adult speakers undergoes automatic procedures which place few demands on controlled effortful processing. For children, planning and execution of speech is controlled rather than automatic. As language development itself is an ongoing process of automatization of a complex and multifaceted skill, children's speech production does not depend on a highly specialized speech production module, but on general resources such as working memory.
In the present study, quantitative measures of children's spontaneous speech were conducted. The language corpora were collected from 3-year old children with normal language development. The measures of primary interest were phonological memory capacities, the length of their utterances and the syntactic complexity of their utterances. Two specific hypotheses were tested. First, children with superior phonological memory capacities should produce longer utterances. This is predicted by the proposal that phonological working memory may be used as an output buffer in young speakers. Second, children with better phonological memory skills would produce utterances with higher syntactic complexity. This is based on Speidel's (1989, 1993) theory, suggesting that phonological memory skills directly constrain the development of syntactic knowledge, by reducing the number of syntactic models the child has available to compose utterances.

**METHOD**

**Subjects**

30 children between the ages of 36-42 months of age (mean CA = 38 months) participated in a nonword repetition test and took part in conversation and video description. They were randomly selected from three kindergartens. The school documented that all the children had normal language skills, articulatory skills, I.Q. and had no hearing problems.
Two out of thirty children had atypical and extraordinarily supper performance throughout all the tasks. These infrequent observations were regarded as outliers and were not included in this study. The deletion of 2 outliers was an unfortunate and probably inevitable consequence of such a small number of subjects. Finally, there were only 28 children who formed a normally distributed data set were included. The 28 children ranged in age between 36-41 months, with a mean age of 37 months.

Procedure

1. Nonword repetition test

Phonological memory capacity in the present study was indexed by the ability to accurately repeat nonwords varying in length from one syllable to four. A set of 60 nonwords were constructed at a constant tone (tone 22). Fifteen nonwords (unfamiliar phonological forms) were created at each of four syllable lengths (1,2,3,4) (Appendix A). Gathercole & Baddeley (1990a, 1990b) argued that a nonword repetition test is a “purer” measure of phonological working memory than repeating real words because successful nonword repetition requires listeners to involve various phonological processes such as perception, encoding, storage, retrieval, and production independent of lexical knowledge, e.g. phonological and syllable structure, syntax, semantics, as suggested by Dollaghan, Biber, & Campell
In order to ensure that the stimuli were purely nonwords, the stimuli were judged by 20 native adult Cantonese speakers in terms of the degree of worklikeness. The result indicated that none of the stimuli was wordlike.

The nonwords did not contain cluster /kw/, /kʰw/, affricate /ts/, /tˢʰ/ and velar nasal /ŋ/ at word-initial position. In order to minimize the articulatory demands of producing phonological sequences in children of such a young age, the nonwords were of low phonological complexity, constructed of early-developing phonemes (So, 1993; Tse, 1992).

During the test, the experimenter explained that the child would hear "funny made up words" and the child should repeat them exactly. The nonwords were spoken to the child with the experimenter's mouth hidden from the child's view. The child repeated the nonword immediately. The child's nonword repetition performance was audio-recorded. The stimuli were presented in a common randomized sequence for all the subjects. All children were assessed by the same experimenter.

A correct repetition attempt would be scored if the child produced the same sequence of phonemes as the experimenter. An incorrect repetition attempt would be counted if there was any phonemic difference.
2. Speech Corpora

a. Elicitation of natural language sample

The experimenter interviewed each subject individually in a quiet room. Rapport was initially gained through conversation and free play. The natural language sample analyzed in this study was taken from an audio-tape recording of a session in which the subject took part in conversation and video description. Experimenter’s interruptions throughout the session were minimized. The experimenter avoided asking specific questions that could be answered with a single word, or that could provide cues to the structure of the answers. Prompts such as 跟住 呢？ (what’s next?) 还有 呢？ (what’s more?) 繼續 呢 (Go on) or 发生 呢？ (what’s happened?) would be used if the child failed to continue.

b. Transcription of the language sample

The tape-recorded language sample was orthographically transcribed in Cantonese. The recognizable but mis-articulated words were transcribed phonetically in IPA with tone stated, alongside the correct phonetic transcription. Prosodic contours that could help in determining utterance boundaries were marked in the text: upward sloping lines are used to indicate rising intonation; downward sloping lines represent falling intonation; and straight lines indicate flat intonation.
c. Extraction & Segmentation of the natural language sample

From the child's transcript, 100 successive utterances were designated for later linguistic analyses according to priori selection and segmentation rules listed below:

1. Exact imitation of adult utterances, self-imitation and performed responses such as nursery rhymes were excluded.

2. Certain specific responses like stuttering attempts and fillers e.g. "mm", "ah.." were removed from transcript.

3. Include no more than two tokens per utterance and only non-adjacent tokens, to maximize intrasample variation but still reflect the repetitive aspects of young children's speech.

4. Allow no more than two clauses conjoined by connectives such as "and" or "but" per utterance.

5. Treat compound sentences as one utterance if they are marked as such by intonation.

6. Apparent terminal intonation contour suggests the end of an utterance.

7. A syntactically well-formed sentence should be taken as an utterance unless there are strong contradiction in prosody. Utterance particle is another indicator of utterance boundaries as it marks the end of an utterance.

8. Semantic completeness and well-formedness are useful in determining the utterance boundaries.
d. Quantitative measures of speech corpora

From each child's transcript, the final 100 successive utterances that fulfilled the above criterion formed the speech corpus for analysis. In this study, the (1) mean length utterance in morpheme (MLU-m) and the (2) syntactic complexity in terms of (i) ratio between complex vs simple sentence production, (ii) ratio between verb phrase vs verb production and (iii) ratio between noun phrase vs noun production have been classified as quantitative indices of children's speech production.

In recent years, there have been some attempts to describe the grammar of spoken Chinese (e.g. Chao, 1968; Li & Thompson, 1981). Grammatical descriptions of Cantonese, a dialect of Chinese, are also available (Cheung, 1972; Ko, 1980). Nevertheless, a consensus as to which grammar is the "best" description of Cantonese, has not been reached. There are also very few attempts to apply those grammatical descriptions in the study of syntactic development in young children.

One method of quantitative measure is utterance length such as MLU-m (Brown, 1973). Referring to the measures of length alone may lead to a superficial judgement of subjects' syntactic ability, and the nature of the underlying grammatical skills may be obscured. Therefore, length measures alone are not sufficient for revealing the subject's spoken language ability. Another quantitative measure used in this study is syntactic complexity. The framework of the present simple and reflective analysis is based on the essence of Saffran et al's (1989)
analysis procedure, Chao’s (1968) Chinese grammar and Cantonese grammar of Cheung (1972). The procedure involves the quantification of 3 types of ratios between grammatical categories such as: (1) ratio between total complex vs simple sentence production, (2) ratio between total verb phrase vs verb production, and (3) ratio between total noun phrase vs noun production. An advantage of this procedure is the derivation of a set of indices, which can reflect complexity at both phrasal and clausal production.

d i) Mean length utterance in morphemes (MLU-m)

Rules for calculating mean length utterance in morphemes were based on Brown (1973):

1. Only fully transcribed utterances are used; none with blanks.

2. Stuttering is marked as repeated efforts at a single word; count the word once in the most complete form produced. In the few cases where a word is produced for emphasis e.g. ”no, no, no”, count each occurrence.

3. Do not count the fillers such as ”mm” or ”oh” but do count ”no”, ”yeah” and ”hi”.

4. All compound words (two or more free morphemes), proper names and ritualized reduplication count as single word. Justification is that there is no evidence that constituent morphemes function as such for these children.
5. Count all auxiliaries such as "is", have, can, must, and could as separate morpheme.

d ii) Syntactic complexity

Syntactic complexity of the children's utterances was designated as follows:

1. Complex vs simple sentence ratio, computed as the ratio of the total number of complex sentence vs simple sentence production. There are three types of complex sentences. One is the embedded sentence, in which the child clause is embedded in the mother sentence as one of its essential constituent as suggested by Chao (1968).

e.g. (1) 媽咪看佢喺街上見到兩隻狗.

   Mom say she at street see asp two cl dog.

   Mother says she saw two dogs at street.

Another type of complex sentence consists of a dependent clause and a principal clause and each clause is complete in itself.

e.g. (2) 我去學 媽咪去工

   I go asp school, mother go work.

   I went to school and mother went to work.
Sentences with relative clauses are also classified as complex sentence.

e.g. (3)  

that cl eat asp apple part. girl walk that side.

The girl who is eating apple walks to that way.

Generally, connectives are seldom used in complex sentence but connectives (usually adverb) may occur especially in the second type of complex sentence. E.g.

and...(although...but...), και...έτσι(If...then...), γιατί...προς. (because...so...) and...έπειτα(...before/after...).

2. Verb phrase vs verb ratio, computed as the ratio of the total number of verb phrases vs verb production. A verb phrase must contain more than one verb constituent. (Quirk, 1972)

3. Noun phrase vs noun ratio, computed as the ratio of the total number of noun phrases vs noun production. Count all occurrence of phrases that have nouns as their heads.
RESULTS

1. Nonword repetition test

Five scores were calculated; the number of nonwords at each of the four syllabic level that were correctly repeated and the total number correct, as referred to Table 1.

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<th>Maximum</th>
<th>S.D.</th>
<th>Range</th>
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<tr>
<td>1 syllable</td>
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<td>15</td>
<td>1.69</td>
<td>9-15</td>
</tr>
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<tr>
<td>4 syllables</td>
<td>5.32</td>
<td>10</td>
<td>1.03</td>
<td>2-10</td>
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Table 1. Total nonword test score and score at each of 4 syllable length

Fig.1 Nonword test score at each of 4 syllable length.
Fig. 1 showed that the accuracy declined with increasing number of syllables in the nonwords, although there was a smaller reduction in accuracy with the 2-syllable items than the 3-syllable and 4-syllable ones.

2. Quantitative analysis of spoken language performance

To examine the relationship between phonological working memory and spoken language abilities, a Pearson product-moment correlation was computed for nonword repetition performance and speech production.

Correlational analyses of MLU-m vs phonological working memory:

There was a significant correlation between mean length of utterance (MLU-m) in children's spontaneous speech and the ability to repeat three syllable nonwords, \( r = .67, p < .05 \); the repetition of four syllable nonwords, \( r = .73, p < .05 \); and the total score of nonword production, \( r = .72, p < .05 \). The data are consistent with the hypothesis that children with superior phonological memory capacity produced lengthier utterances, in terms of mean length utterance in morpheme.

Correlational analyses of syntactic complexity vs phonological working memory:

There is significant correlation between the total nonword repetition score and the quantitative measure of speech production in terms of complex vs simple
sentence ratio (C vs S ratio) ($r=5.2$, $p<.05$), and verb phrase vs verb ratio (VP vs V ratio) ($r=.46$, $p<.05$). The relationship with the noun phrase vs noun ratio (NP vs N ratio)($r=.22$, $p>.05$) was not significant. The significant results evidenced the relationship between phonological working memory and syntactic complexity of spoken language. The insignificant correlation between phonological working memory and noun phrase vs noun ratio is due to the reasons of testing context and null subject hypothesis which are explained in discussion.

Correlational analyses of MLU-m vs syntactic complexity:

A significant correlation was found between the mean length utterance in morpheme and the complex vs simple sentence ratio ($r=.75$, $p<.05$), the verb phrase vs verb ratio ($r=.69$, $p<.05$), and the noun phrase vs noun ratio ($r=.38$, $p<.05$). This implied a relationship between the length and the syntactic complexity of the utterance.

Correlational analysis of complex vs simple sentence ratio and verb phrase vs verb ratio: There was significant correlation between the complex vs simple sentence ratio and verb phrase vs verb ratio. These ratios had significant correlations with the phonological working memory respectively. The significant relationship between these ratios not only indicates that production of complex
sentences is related to more verb phrase production, it also further implied that phonological working memory was linked to increased syntactic complexity in children's development of speech production.

**Reliability**

To investigate the reliability of the analysis procedure, intrarater and interrater reliability were examined. A sample of 20% of the nonword repetition test was independently transcribed by a second rater. Mean interrater reliability for nonword repetition score was 99.8%. Mean intrarater reliability for utterance boundaries and language performance was 99% and 98% respectively.

**DISCUSSION**

This study was designed to evaluate the relationship between phonological working memory and spoken language abilities of preschoolers. Subjects completed a nonword repetition test and provided a natural speech corpora through a session of conversation and video description. The 3-year old children with relatively better phonological working memory produced syntactically complex speech in terms of more productions of verb phrases and complex sentences, and longer utterances. The present findings indicate that the phonological working memory of young preschool children is related to their spoken language abilities.
The implication of these findings for theories relating phonological memory capacity to speech production and language acquisition are discussed.

1. **Nonword repetition test**

   The results of the nonword repetition test (index of phonological working memory) revealed that the accuracy of nonword repetition decreased with the increasing length of the stimulus. Unlike the normal subjects of Gathercole & Baddeley study (1990a), the subjects of present study showed length effect on phonological working memory. Differences between the two studies in subject number, sampling and experimental stimuli might account for this variance in findings. Poorer performance on longer words than shorter words (i.e. length effect) presumably reflects the capacity-limited nature of the phonological working memory system according to Gathercole & Baddeley (1990b).

2. **Phonological working memory and Mean length utterance in morpheme**

   Phonological working memory ability is significantly correlated with the mean length utterance in morpheme. This finding is consistent with the hypothesis that phonological loop component of working memory may serve as a phonological output buffer in which an intended utterance is held until the articulatory programme can be applied (see Gathercole & Baddeley, 1993 for a review).
In the past, research (e.g. Shallice & Butterworth, 1977) failed to demonstrate a comparable link between short-term memory function and speech production in adult speakers. This contradicts the findings of the present study which establishes linkage between phonological working memory and speech production. One plausible account of this discrepancy is that phonological working memory plays a developmental role in speech production for children.

Bock (1982) suggested that the programming of speech and its maintenance in a response buffer is automatic in skilled adult speakers. Their output was achieved by means of direct activation of a phonological representation stored in the lexicon, possibly combined with a specialized speech output buffer. For children who are still acquiring language and learning to produce connected speech, the planning and execution of articulatory gestures may be a controlled rather than automatic process. As a result, the child who is acquiring language has to fully create detailed articulatory specifications of words and/or syntactic constructions for each instance of speech production. The proposal here is that in unskilled language production, phonological working memory may function as a response buffer for storing the intermediate and/or final stages of the formulation of the speech output until articulation is achieved. Therefore restrictions in phonological memory capacity may constrain the amount of information that can be held in this response buffer. Time and capacity allowed in the phonological working memory may directly limit
the length of utterance that could be registered in phonological working memory and finally produced.

3. Phonological working memory and syntactic knowledge

The phonological memory capacity may also constrain the acquisition of syntactic structures, which may be related to the complexity of speech output. According to Speidel (1989, 1993), children have to store enough models of legal syntactic forms in acquiring syntax. It is hypothesized that stored syntactic knowledge is accomplished by listening, observing and reproducing what is heard and observed from language used by adults in natural environments. The language input is initially held in phonological working memory and may subsequently be transferred to long-term memory. This corpus forms the building blocks for syntactic speech. The phonological working memory indeed plays a crucial role in transferring language input to the long term memory for storage.

The remembered units of language that transferred from phonological working memory can provide the raw material for the creative way in which language becomes used by the proficient speaker. Those information will undergo various cognitive operations such as chaining, insertion, replacement/equivalent and building sense of temporal position so that syntactic knowledge accumulates.

First there is the discredited process of chaining. For example, from Mark sit
and Daddy sit and from sit lap, sit there and sit chair. Mark could create through chaining six novel three-word utterances such as Mark sit lap, Daddy sit lap, Mark sit there, Daddy sit there, Mark sit chair and Daddy sit chair.

Utterances can be expanded on the basis of insertion. Mark ball and play ball provide the foundation for Mark play ball. Learning further word combinations such as big ball, Mark could create variations of all his other existing two-word combinations with ball, for example, Mark big ball and Mark play big ball.

A third process is replacement/equivalence. If Mark has mastered Mark sit, Daddy sit, Mommy sit, Mark read, Daddy read, Mom read, Mark eat it, Dad eat it and Mom eat it, the process of co-occurrence and similarity can combine to produce a replacement/equivalence operation than results in generalization as whenever there is Mark, one can put Mommy, or Daddy, and vice versa. The development of equivalence of words in similar positions is a powerful way of building syntax. The complex equivalence/replacements that could develop out of the above simple process has been shown in the work by Braine (1987) in his theoretical analysis of the development of grammatical word classes.

A sense of temporal position for words develops when similar sequences of words are heard (Braine, 1963). For instance, when a child can produce a number of copula sentences, e.g. "The house is big; the doll is cute," the child knows that the "is" never placed at the end of an utterance. As a result, a relational position
sense develops out of experiences with how words occur together, with word
sequences, with the meaning they convey in different situational contexts, and with
the grammatical roles of words and their position in the sentences. Such a sense of
position allows two separate productions to be put together without a common link
having ever been heard, that is without chaining. For instance, Braine (1976)
suggested that a child had a clear sense that *want* goes early in an utterance. The
child also used "more balloon","sit down" and "gimme". Even without his ever
having heard of the combinations such as "want more balloon", "want sit down",
"want gimme", the child may produce them. With the transfer of language input
through the phonological working memory for the four cognitive operations, the
child will create more novel and longer utterances with increasing syntactic
complexity from those first word combinations already available as organized units
of activity in the speech-planning network.

Children do not learn language production only by listening and observing.
They learn speaking also by speaking. They test out their hypotheses of syntax and
language production through the process of producing what they heard and learn in
the form of direct imitation, deferred production and expanded production. When
all of these operating strategies and experience of speech production are added
together, a very powerful sentence-generating system emerges that is founded
initially on separately imitated units, and then combinations of two units, and so on
to ever-increasing complexity, flexibility, and creativity. As a result of repeated activation of temporary storage of phonological material of language input and output through the phonological working memory, the syntactic knowledge in their long-term memory is enriched and consolidated. By this hypothesis, higher complexity in speech production would be expected to link with better phonological working memory. Certainly, there are many steps between phonological working memory and the long-term storage of syntactic knowledge. However, phonological working memory is working at the front line.

The data are consistent with this view. A correlation was found between the three-year old's phonological memory capacity and their production of complex sentences and verb phrases. As the ratio of complex vs simple sentence and ratio of verb phrase expansion correlated with each other as well as with the MLU-m, it is implied that there is a relationship between more production of verb phrases, complex sentences and length of utterances. It also suggests that phonological working memory may indeed be vital for learning and producing complex syntactic construction such as verb phrases and complex sentence, which may be lengthier and require more time to process. Higher phonological working capacity may imply a longer time for processing more phonological information, as a result allowing more time to store longer and more complex sentences for incorporation into the store of syntactic knowledge.
Although phonological working memory was not correlated with the ratio between noun phrase vs noun production, it could be well understood by the testing context and the characteristics of subject drop in Cantonese. The children's speech corpora were collected during video description and in conversation with the experimenter. The context was not obligatory for the children to produce complicated noun phrases for describing either subjects or objects as the video served as a common reference between the child and the experimenter. It is also not uncommon for native Cantonese speakers to produce null subject after the topic of discourse is developed as mentioned by Matthew and Yip (1994). This explains why the noun phrase ratio was not correlated with phonological working memory in this study.

The present findings support the proposal that children with better phonological memory capacities may master more complex syntactic structures. The increasing syntactic knowledge supports both the complex speech output and the process of automatization of speech production.

**IMPLICATION & FURTHER STUDY**

The structure of present study is essentially correlational, to examine the link between phonological working memory capacity, mean length of utterance in morphemes, complexity of speech output and syntactic knowledge. The
correlational information provided by this study could not unambiguously determine the direction of causation between different abilities. Correlational data does, however, have a useful disconfirming function in the early stage of theory building, when the absence of positive associations between elements that were hypothesized to be causally related to one another provides the opportunity for ruling out candidate hypotheses.

The findings clearly indicate that there is wide range of important issues for investigation such as the causal underpinnings of this relationship and the exact role of phonological working memory in online speech production. A understanding of the role of children's articulation skills in the relationship between phonological memory capacity and language development must also await detailed research.

This study demonstrates that there is indeed a link between phonological working memory skill and language production in the Cantonese preschoolers. Clinically, the application of nonword repetition may test phonological memory capacity and track the early signs of language and learning deficits in preschool populations in the Hong Kong context.
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### Appendix A.

**NONWORD_STIMULI**

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<tr>
<th>1-syll</th>
<th>2-syll</th>
<th>3-syll</th>
<th>4-syll</th>
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<td>/p/</td>
<td>/t^g fam/</td>
<td>/fiu p^ai li/</td>
<td>/hu t^ei hi poem/</td>
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<tr>
<td>/jai/</td>
<td>/nm ki/</td>
<td>/k^ou ni la/</td>
<td>/f.i t^g jai nm/</td>
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<td>/wi/</td>
<td>/p^i j/</td>
<td>/tn t^n p/</td>
<td>/wi piu ju ta/</td>
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<td>/wau l^m poem/</td>
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<tr>
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<td>/fm t^au sim/</td>
<td>/lo p^n ly tui/</td>
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<tr>
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<td>/wau h^/</td>
<td>/hiu k^i t^i/</td>
<td>/p^i jan ki p^m/</td>
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<tr>
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<td>/fim p^in/</td>
<td>/kam fou wa/</td>
<td>/f. mn lum wi/</td>
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<tr>
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<tr>
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<td>/fe ka/</td>
<td>/jan moe sn/</td>
<td>/fam kou hui tau/</td>
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<tr>
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<tr>
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<tr>
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*P.S. All nonwords are of low-level tone.*