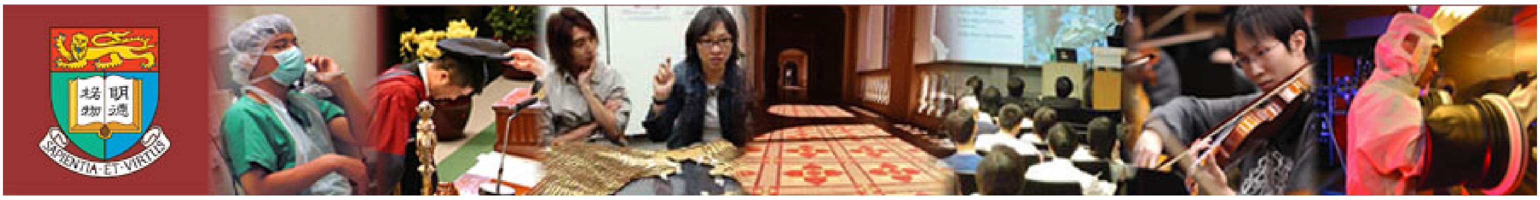

Title	**The development of phonological memory and fast mapping in preschool children**
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Citation	
Issued Date	**2009**
URL	**http://hdl.handle.net/10722/173691**
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The development of phonological memory and fast mapping in preschool children

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A dissertation submitted in partial fulfillment of the requirements for the Bachelor of Science (Speech and Hearing Sciences), The University of Hong Kong, June 30, 2009.

Abstract

This study investigated the development of fast mapping and phonological working memory in Cantonese-speaking preschool children. Fifteen three-year-old and 18 four-year-old normally developing children participated. The children's phonological memory was assessed using a nonword repetition test. The children's fast mapping abilities were evaluated by comprehension, production and/or recognition probes, immediately and after one week, following three exposures to the two novel words and their referents. The two age groups did not show significant difference in either fast mapping or phonological memory. Correlations between age, phonological working memory, and fast mapping abilities were also not statistically significant. Factors affecting the children's performance in the fast mapping and phonological working memory tasks were discussed.

Introduction

During early childhood, children's vocabulary grows in size at a rapid rate. As they go about their daily activities, young children learn on average nine new words a day without explicitly being taught to do so (Carey, 1978). In a pioneer study by Carey and Bartlett (1978), three-year-old children were observed to map novel color names with their referents upon just one single exposure in an experimental task. This initial word learning process, where children construct lexical representations for referents upon several exposures to the novel words, is known as fast mapping (Carey & Bartlett, 1978). With additional exposures, children refine and elaborate their lexical representations of the novel words. Over time, children develop a mental lexicon of words, which then provides the building blocks for the development of morphology and syntax.

Fast mapping

Quite a few studies have examined fast mapping in normal preschoolers (Carey & Bartlett, 1978; Dollaghan, 1985). In Dollaghan's study (1985), the fast mapping abilities of normal English-speaking children aged two to five were examined. Children were asked to fast map a simple CVC (C = consonant, V = vowel) structure nonword 'koob' with an oddly shaped object along with two familiar items presented in one single encounter. Then, comprehension and production probes were carried out to assess the children's ability to identify the target referent and to name the novel word. Results indicated that children as young as two years of age were capable of fast mapping, with positive results observed in the comprehension and naming of the novel word. Children who failed in naming the target were found to be able to recall non-linguistic information about the target referent as reflected in the recognition and location probes. This study presented evidence that shows how children fast map linguistic and non-linguistic information about a new word, a process that leads to subsequent lexical growth (Bishop, 1997).

Previous research on fast mapping in Cantonese-speaking preschoolers is rather scant, with only a few unpublished studies investigating fast mapping in normally-developing Cantonese-speaking children. Cantonese is a tone language with nine distinct tones, in which variations in tones are crucial for word identification (Matthews & Yip, 1994). It has a simple syllable structure (C) V (V) (C) $_t$ (t = tone) and does not allow complex sound combinations (e.g. consonant clusters) that are commonly found in English. Therefore, comparisons between fast mapping abilities of Cantonese and English-speaking preschoolers would shed light on the possible contributions of the nature of language on children's fast mapping abilities.

Cheung (1997) studied the fast mapping abilities of typically developing children in two groups with age ranging from 34 to 70 months. The children were presented with eight unfamiliar novel words with their referents one at a time. Following a single exposure, the children's comprehension responses were probed immediately, given five options (target object, two familiar objects, and two novel objects). Production and/ or recognition probes were carried out subsequent to the comprehension probe. Results revealed no significant differences on the comprehension and production scores across age groups. Similar results were also found in Chan (1995), which showed no significant differences in fast mapping abilities of spoken words in normally developing preschooler.

One reason for the lack of differences between the age groups on the comprehension probes was ceiling effects. Such a high level of performance could be due to the fact that the target word was the only unfamiliar word among the given choices when tested on comprehension, and the correct answer therefore was made very obvious. The production probe was however more demanding. Although each novel word was introduced with its referent, there were eight of these novel words they had to fast map within a short session. With such a large number of novel words, the children, even the older ones, were not able to remember them well enough to produce them accurately when tested. The children performed at floor level and no group differences were found.

Follow up analysis on the children's errors on the recognition probes, which required the child to select the target based on three choices (target, the child's error production, phonetically similar foil), showed that they did actively represent the novel words. The children were more prone to select the target and their production errors than the other phonologically similar foil. Following a single exposure, the children appeared to have registered some phonological information of the novel word and its referent, but the representation was incomplete. The incomplete knowledge only allowed them to recognize the correct word for the object, but not enough to produce the word adequately. Results from these studies suggest that future work should control the choices in the fast mapping comprehension probe, consider the optimal number of novel words and exposures required for fast mapping to be observed in experimental tasks.

Also of note was that in both studies, there was no report on the development of fast mapping abilities in typically developing children across age groups. Although there was a brief discussion on phonological memory as one of the possible contributing factors to the development of fast mapping, there was no report on the relationship between phonological memory and fast mapping. These are questions that warrant further investigation for a better understanding of lexical acquisition in young Cantonese-speaking children.

Phonological working memory

It is well documented that vocabulary development varies in rate in the early years. One plausible reason for this variability comes from age differences in the storage and retrieval of phonetic information associated with the words. In Baddeley and Hitch's (as cited in Gathercole & Baddeley, 1993) working memory model, there were key components for short-term processing and storage of information. (a) The central executive integrates and regulates all information within the working memory, (b) the phonological loop maintains and stores verbally coded information, and (c) the visual-spatial sketchpad helps processing materials that have strong visual or spatial component. As we encounter a new word, it will be fed into the phonological loop for temporary processing and storage for future recall (Gathercole & Baddeley, 1993). Reduced phonological storage of the new word in the working memory will lead to problems in immediate recall, as well as in subsequent speech and linguistic processing and construction of mental representation for future recall.

Nonword repetition task (NRT) and digit span task were typically used to examine phonological memory word learning. Both tasks involve the repetition of words, but the NRT used nonwords as stimuli. In theory, NRT is a more reliable measure of phonological memory than digit span task as it is claimed that success in NRT does not require preexisting lexical knowledge (Campbell, Dollaghan, Needleman & Janosky, 1997; Dollaghan & Campbell, 1998; Gathercole & Baddeley, 1989). In other words, children's performance in NRT was not likely to be confounded by the words they already know.

Relationship between phonological memory and fast mapping

Several studies have reported on the relationship between phonological memory and fast mapping abilities in normal language children. One of them was Gray (2006). In a fast mapping task, children who were three, four, five, and six years of age were asked to fast map two sets of stimuli. In each set, there were two familiar and two unfamiliar target words. The target words contained two syllables nonwords in CVCVC structure with phoneme combinations following phonotactic properties of English. These target words were modeled three times in three exposure phases with one model each time, and the comprehension and production probes were administered following each exposure phase. Results showed that the three-year-old children's phonological memory scored significantly lower than the four-, five-, and six-year-old children. Also, the children's fast mapping comprehension and production abilities were significantly better for five-year-old children, than the children of three, four, and six years of age. Significant correlations were found between age and fast mapping comprehension, and fast mapping comprehension and production. Phonological working memory was also significantly correlated with fast mapping production. Nevertheless, it failed to find significant age differences on fast mapping tasks, and phonological working memory for younger children. Correlations between fast mapping production probes and age, and phonological memory and fast mapping comprehension performances were insignificant.

Similar results were reported in Alt & Plante (2006) and Gathercole, Hitch, Service & Martin (1997), where correlations between NRT and fast mapping were significant. There were other studies which reported on NRT and vocabulary development in normal children. Gathercole & Baddeley (1989) reported that five-year-old children scored higher in phonological memory than four-year-old children, and NRT measured at age four was significantly associated with vocabulary knowledge at age five. These suggested that phonological memory could predict vocabulary acquisition one year later.

Further review of Gray's study (2004), the normally-developing children scored significantly better than the children with specific language impairment in the comprehension probe only, but not in the production probe. As in the previous studies (Alt & Plante, 2006; Gathercole et al., 1997; Gray, 2006), performance in the phonological working memory task was found to be a significant predictor for production and comprehension performance in fast mapping. It was suggested that other factors such as current lexical knowledge, as measured in vocabulary tests, might be a significant predictor for success in fast mapping (Gathercole et al., 1997).

The purpose of the present study was to examine the development of phonological memory and fast mapping abilities in typically developing Cantonese preschoolers. It aimed to address the following questions:

1. Does the fast mapping of novel words improve with age in Cantonese preschoolers?
2. Does phonological working memory improve with age in Cantonese preschoolers?
3. Is there a relationship between phonological working memory and fast mapping abilities in Cantonese preschoolers?

It was hypothesized that both phonological working memory and fast mapping abilities of Cantonese preschoolers improved with age on the basis on of prior findings on English-speaking children of the same age (Gray, 2006). Older children having a larger vocabulary and more word-learning experiences would be more efficient in fast mapping. They are able to register, process and store more information with the same number of exposures, and learn a new word well with fewer exposures, given development in phonological working memory. Phonological working memory improves with age, as children develop rehearsal strategies, and automaticity in the segmentation and processing of speech units.

Method

Participants

Thirty-three normally developing Cantonese-speaking children (18 males and 15 females) participated in this study. The children ranged in age from 38 to 61 months. This age span was selected as it covered the ‘word-learning wizardry’ period proposed by Carey (1978). All children’s responses were categorized into two groups according to their age. The three-year-old group included 15 children (9 boys and 6 girls) ranged in age from 38 to 48 months (M= 43.47; SD= 3.87); and the four-year-old group included 18 children (9 boys and 9 girls) ranged in age from 49 to 61 months (M= 54.17; SD= 3.79). All children from the three-year-old group and the four-year-old group are currently studying kindergarten one and two respectively, except two from the four-year-old group are studying kindergarten one. Cantonese was these children’s primary language. Subjects were recruited from two kindergartens in two neighborhoods to balance for differences in social economic status. According to teacher and parent reports, all 33 children had normal intelligence and learning abilities, and no signs of cognitive or neurological impairments. Ten children however presented concerns with hearing, speech or language problems. One child had a history of otitis media, one with a history of language delay, and two were reported to have speech errors. There were six children who were found to have speech errors unexpected for their age through informal observation.

Procedures

The experimenter met each child individually for a 15-minute session on day one, and a follow up 5-minute session on day two in their kindergartens. The first session consisted of (a) a short conversation, for building up rapport with the child and for an informal observation of the child's speech and language, (b) phonological memory assessment using the nonword repetition task, and (c) the exposure and test phases of the fast-mapping experiment in the order described below. The second session involved a second administration of the fast mapping experiment for testing the maintenance of knowledge on the novel words. The children were randomly assigned to one of the orders (fast mapping tasks and nonword repetition task, or vice versa), to counterbalance the effects of the two tasks on one another. All sessions were audiotaped for subsequent analysis and scoring.

(a) Phonological working memory

A simplified version of the original nonword repetition task reported in Stokes, Wong, Fletcher & Leonard (2006) was used to assess the children's phonological working memory. Sixteen nonwords, 4 for each of the four syllable lengths were chosen (Please refer to Appendix A for the lists of nonwords). All components chosen were within the phonetic inventory of a typically developing three-year-old child (So & Dodd, 1995). Besides, all consonant and vowel (or diphthong) combinations appearing in the nonwords for this task were uniquely different from those used in the fast mapping task to avoid potential confusion. All nonwords were presented to the children via free-field speaker, and responses were recorded for later transcription. The percentage of phonemes correct (PPC) was calculated for each child. It was calculated by the number of correct phonemes (consonant, vowel/ diphthongs, and tone), produced by the child divided by the total number of target phonemes.

(b) Fast mapping

The procedure for the fast mapping task was adopted and modified from Dollaghan (1985). Puppet play activity was used to keep the children interested in the task, and the activity involved three trials. In each trial, subsequent to the initial exposure of the novel words, children were assessed on their (1) comprehension, (2) production of the novel word, and/or (3) recognition of the novel word if they failed to produce the unfamiliar object's name correctly.

Target words. Two novel words were selected from the Hong Kong Cantonese Oral Language Assessment Scale (T'sou et al., 2006) – Nonword Repetition Test with Pseudo-syllables. Both (/jɵn1/, /wɪk7/) were monosyllabic (CVC_t), and they included phonemes that were all within the phonetic inventory of typically developing three-year-old children (So & Dodd, 1995). These phonemes were combined according to the phontotactic rules of Cantonese syllabary, but together they could not be associated with any meaningful words to native Cantonese speakers. They should be novel words to preschoolers as well.

It should be noted that a few children exhibited speech errors in the production of fricatives (e.g. /f/, /s/), and affricates (e.g. /ts/, /ts^h/). These phonemes are typically acquired by children between four to five-years of age (So & Dodd, 1995). None of the stimuli in the nonword repetition task and none of the novel words in the fast mapping task in this study included these phonemes.

Target and common objects. To identify appropriate objects for the fast mapping task, ten adults were asked to label ten objects. The adults gave the same name to five objects and a variety of names to the other five. These ten objects were then tested on 10 three-year-old children not included in this study for determining their presence or absence of these words in their repertoire. Of these, three objects were consistently given the same name by the children and hence were included as familiar objects in the study. Two of the objects evoked different names and hence included as unfamiliar objects, that is the referents for the novel words. This process was necessary to ensure that the children would not be able to associate the novel words with any familiar objects to which they already had a name for (Dollaghan, 1985).

1. Exposure phase. Children were invited to engage in puppet play with the experimenter, where three familiar (cup, comb and bowl) and two unfamiliar objects (spaghetti measurer and wooden instrument) were introduced. (Please refer to Appendix B for the referents used.) The experimenter spoke for the puppet. The child was then asked to randomly pull the objects from a bag one at a time to see if the forgetful puppet remembered their names. Joint attention was ensured explicitly before the experimenter gave the names, especially the names (novel words) for the unfamiliar objects, to maximize the likelihood of fast mapping. The experimenter first said ‘Look’, and when the child responded with eye contact, the experimenter gave the novel word for the unfamiliar object. Repetition of the novel words was not elicited, and any spontaneous imitation was ignored. The presentation order of the novel and familiar objects was not the same for the children as each child picked the objects from the bag himself/herself. After the child had taken out all five objects and the experimenter named them all, the child was tested for the comprehension, production and recognition of the known and novel words. No feedback regarding the accuracy of the child's responses was provided. After the first round, there were two more rounds of exposure and immediate testing. In the first session, the child heard the novel words with their referents three times during exposure, and another three times without the referents during comprehension testing.

2. Comprehension probe. How much the children learned about the novel words during fast mapping was tested using three different tasks. In the comprehension probe, the children were tested if they could identify the unfamiliar object each of the novel words referred to. The five objects (three familiar and two novel objects) introduced in the exposure phase were lined up in front of the child in a randomized order. The clinician asked the child to bring the puppet the object he requested. There were six possible correct responses (2 novel words x 3 probes). The child received one point if s/he selected the correct object for the word given.

3. Production probe. In the production probe, the children were tested if they could give the name of the unfamiliar object. The experimenter held up the objects one at a time and asked 'What's this?'. For those children who were hesitatant, they were encouraged to try until they either attempted or refused to respond three times. Again, there were six possible correct responses (2 novel words x 3 probes). The children's responses were transcribed online and checked subsequently against audio record. Given the greater contribution of vowels than consonants in word recognition (Cole, Yonghong, Mak, Fanty, & Bailey, 1996), and the importance of tone for Cantonese speech perception, two scoring methods were used to capture the children's emerging abilities in learning new words. A response was scored as correct, if (a) two out of the three phonemes (either consonant or vowel), and the tone were correctly produced in their right sequence, or (b) two out of the three phonemes (at least one of them was the vowel) were produced in their right sequence.

4. Recognition probe. This task was the least demanding and only required the child to choose the word that sounded like the one for the unfamiliar object. It was administered only to those children who failed to label the unfamiliar objects in the production probe. Children were taught to point to the number cards labeled 1, 2, or 3 for the word that corresponds to the name for the unfamiliar object. The three options were: the correct novel word, a phonetically similar and a phonetically dissimilar foil. (Please refer to Appendix C for the choices) The child was given training on this response mode before actual testing.

5. Maintenance phase. Recall that the children's fast mapping abilities were assessed immediately after the initial exposure phases. To test the children's maintenance of knowledge on the novel words, they were re-tested within a week, using the same comprehension, production, and/or recognition probes as described above. There was not an exposure phase before testing, although the children heard the novel words once during the comprehension probe.

Reliability

Fast mapping production responses from all children, and NRT responses from 15% of the children were independently transcribed by two raters who were blind to the experimental stimuli. The raters were final year students from the Speech and Hearing Sciences with training in phonetic transcription. Inter- rater point-to-point agreement reached 85% for fast mapping responses and 79% for nonword repetition responses. Discrepancies were resolved through another round of transcription by another naïve rater. Raters were also asked to rate the children's responses two weeks later. Intra-rater point-to-point agreement reached 83% for fast mapping responses and 92% for nonword repetition responses.

Results

Recall that the children's responses to the production probes were scored in two different methods. Given that a similar pattern of results was found, only the results on the scoring method which required the child to produce two out of the three phonemes (at least one of them was the vowel) in their correct sequence was reported here.

Fast mapping: (a) General

In the immediate test phase, on the comprehension probe, the four-year-old group received a higher score (*M* = 3.78, *SD* = 1.59) than the three-year-old group (*M* = 3.33, *SD* = 1.54). Given that all children were 100% correct on the comprehension of the three words for the unfamiliar objects, the chance for the children to choose the right object for each of the two unfamiliar words in each probe was 50%, and the chance-level score for the three probes was therefore 3. Both of the children's performances on comprehension probes were above chance level of 3 points. Only 13.33% of three-year-old children (2/15), and 16.67% of four-year-old children (3/18) scored correctly for all six trials. On the production probe, the four-year-old group (*M* = 1.00, *SD* = 1.19) did somewhat better than the three-year-old group (*M* = .73, *SD* = .96). As the maximum score for each comprehension and production probe was 6, both age groups, in fact, performed almost at floor level. Despite verbal encouragement, 41.11% (37/90) of the responses from the three-year-old children and 25.93% (28/108) of the four-year-old group were no responses. No children from either group were able to correctly name the two unfamiliar objects in the three instances when they were elicited. Results in the recognition probe will be discussed separately. In the maintenance test phase, the same pattern of results was observed. Please refer to Table 1 and Table 2, which report the mean and standard deviation of the children's responses for the three probes in the immediate and maintenance testing phase respectively. The alpha level was set at .05 for subsequent analysis.

Table 1

Means and standard deviations for the correct and incorrect responses of the fast mapping probes in the immediate testing phase.

Fast mapping probes	**Age group**			
	Age 3 (n = 15)		**Age 4** (n = 18)	
	M	**SD**	**M**	**SD**
Comprehension (max = 6)	3.33	1.54	3.78	1.59
Production (max = 6)	.73	.96	1.00	1.19
Recognition (Percentage):				
Target	59.22	33.00	75.37	23.96
Phonetically similar	23.33	23.40	16.30	17.14
Phonetically dissimilar	17.44	21.01	8.33	16.89

Table 2

Means and standard deviations for the correct and incorrect responses of the fast mapping probes in the maintenance testing phase.

Fast mapping probes	**Age group**			
	Age 3 (n = 15)		**Age 4** (n = 18)	
	M	**SD**	**M**	**SD**
Comprehension (max = 6)	1.07	.80	1.33	.84
Production (max = 6)	.33	.49	.72	.83
Recognition (Percentage):				
Target	53.57	41.44	67.86	46.44
Phonetically similar	28.57	32.31	14.29	36.31
Phonetically dissimilar	17.86	31.67	17.86	37.25

A Age (2) x Probe type (2) x Test phase (2) three-way repeated measures ANOVA was carried out to determine if there was a significant effect of age, probe types, and test phases. The between-group factor was age group (three-year-old, four-year-old), and the within-group factors were probe types (comprehension and production), and test phases (immediate and maintenance).

Although the four-year-old scored higher (M = 1.72, SD = .15) than the three-year-old (M = 1.37, SD = .17), significant main effects however were found for probe type, $F(1, 31) = 55.44$, $p < .01$, $\eta^2 = .641$, and test phase, $F(1, 31) = 85.01$, $p < .0001$, $\eta^2 = .733$. In addition, there was a significant Probe type x Test phase interaction effect, $F(1, 31) = 38.04$, $p < .0001$, $\eta^2 = .551$. The follow-up Tukey's HSD comparisons showed that the children performed significantly better in the comprehension than the production probe only in the immediate test phase ($p < .05$), but not in the maintenance test phase ($p > .05$). In the immediate test phase, the children's mean comprehension score was 2.38 (*SD* = .18), and the children's mean production score was .71 (*SD* = .14).

Table 3

Pearson's correlations between age (months), phonological working memory scores, fast mapping comprehension and production probes.

	Age	NRT	FM comprehension	FM production
Age 3 and age 4 (n = 33)				
1. Age (months)	--	.39 *	.13	.33
2. NRT		--	.24	.15
3. FM comprehension			--	-.01
4. FM production				--

Note. NRT = nonword repetition task; FM = fast mapping
**p* < .05. ***p* < .01.

Table 3 shows Pearson's correlations between the children's age in months, phonological working memory scores, and scores on the comprehension and production probes. As shown, the relationship between age and comprehension scores $r(33) = .13$, and age and production scores $r(33) = .33$, were not statistically significant ($p > .05$). The correlation between comprehension and production scores $r(33) = -.01$, were also not statistically significant ($p > .05$).

Fast mapping: (b) Recognition responses

As the children were administered the recognition probe only on the novel word(s) they could not produce or did not attempt in the production probe, their scores were presented in terms of percentage correct on the number of trials presented. Decisions on the administration of the recognition probe were made on the basis of online judgment of the children's production responses. Inter-rater reliability checking of scores on the production probes revealed that one production from three children were misjudged as being correct online. These children should have been given a recognition probe for these inaccurate productions. Due to this technical error, there were 163 recognition responses than it should be. Please refer to table 1 and 2 for the children's scores on the recognition probe and the distribution of their errors.

Results from the Kolmogorov-Smirnov indicated that the data for both three-year-old and four-year-old group were normally distributed ($p > .05$). One-way ANOVA indicated that the four-year-old group ($M = 75.37$, $SD = 23.96$) did not perform significantly better than ($p > .05$) the three-year-old group ($M = 59.22$, $SD = 33.00$). A two-way repeated measures ANOVA on age (2) and error type (2) also indicated no significant main effect of age [$F(1, 22) = 1.95$, $p > .05$, $\eta^2 = .08$], error type [$F(1, 22) = 2.27$, $p > .05$, $\eta^2 = .09$], and age and error type interaction [$F(1, 22) = .13$, $p > .05$, $\eta^2 = .01$].

Fast mapping: (c) Effect of exposure

Recall that the children's fast mapping performance was probed three times in the immediate test phase, once after each of the three exposures. To test if the scores of the two age groups on the comprehension and production probe improved with exposure, a three-way repeated measures ANOVA Age (2) x Number of exposure (3) x Probe (2) was carried out. A significant main effect was found for probe, $F(1, 31) = 57.38$, $p < .0001$, $\eta^2 = .65$. The Tukey's HSD post hoc comparisons showed that the children's performance on the comprehension probe ($M = 1.19$, $SD = .09$) was significantly better than the production probe ($M = .30$, $SD = .07$) during the immediate test phase. The main effect for the number of exposure was also found, $F(2, 62) = 5.66$, $p < .0001$, $\eta^2 = .15$. Follow-up Tukey's HSD post hoc test indicated that the children did significantly better after two than one exposure. No interaction effects were statistically significant ($p > .05$).

Phonological working memory

All children completed the entire nonword repetition task, except the two three-year-old children who failed to attempt the three- or four-syllable nonwords respectively. A one-way ANOVA was carried out to compare the children's nonword repetition performance across the age groups (three-year-old, four-year-old). Results showed that the three-year-old group (*M* = 72.76, *SD* = 15.19) did not differ significantly [$F(1, 31) = 3.47$, $p > .05$, $\eta^2 = .10$] from the four-year-old group (*M* = 79.89, *SD* = 5.39). As shown in Table 3, the correlation between phonological working memory and age [$r(33) = .39$] was statistically significant, ($p < .05$), indicating a positively but moderate relationship.

Discussion

This study investigated the development of fast mapping abilities and its relationship with phonological working memory in normally developing three- and four-year-old Cantonese children. Although the four-year-old children scored higher than the three-year-old children in both the comprehension and the production probes used for examining their fast mapping abilities, the differences were not statistically significant. The children did significantly better in the less demanding comprehension than in the more demanding production probe where they performed at floor level. The children were fast mapping the novel word as their performance on the probes seemed to improve with additional exposure. The four-year-old children did not do better than the three-year-old in the nonword repetition task, indicating no developmental differences in these children's ability to store phonological information short term memory. The lack of a correlational relationship between fast mapping abilities and phonological working memory showed that the ability in comprehending and producing novel words was independent of phonological working memory.

Factors influencing fast mapping abilities

a. The effect of increased exposures

As shown in the present study, the children's fast mapping abilities improved with additional exposures. Frequencies of exposure (i.e. number of presentation) have shown to be beneficial to word learning. With increased exposure, there would be more comprehensive processing of the phonological and semantic information related to the novel word, resulting in a more holistic lexical representation in long term memory (Childers & Tomasello, 2002). Given that the probe effect was significant only in the immediate test phase, and not in the maintenance test phase, the long term mental representation of the novel words the children developed after three exposure was not adequate for success in the maintenance phase. As unstable phonological representations were particularly vulnerable to memory loss with time, it is expected that with continued exposure and overt practice, the children's underlying lexical representations could be further enriched and refined. Articulatory rehearsals could help refresh the phonological representations in short term memory, which would otherwise fade within two seconds (Gathercole & Baddley, 1990). However, when their repetitions were erroneous, the incorrect mental representation would be strengthened through overt rehearsal, thus adversely affecting their recall accuracy. Informal observation during the exposure phase of the fast mapping task revealed that a majority of children would spontaneously repeat the novel words immediately after the experimenter. As some of these repetitions were erroneous, the children's performance in the production probes failed to benefit from this rehearsal, which could explain the floor level of performance in the production probes.

b. Nature of language

In addition, the nature of language could also justify the lack of significant developmental changes observed in the children's fast mapping abilities. In the current study, the presence of tones might have posed additional demands on fast mapping task for

Cantonese speaking children. Taft and Chen (1992) suggested that tonal information is jointly stored with segmental information in working memory, and it provides important cues for the discrimination of stored syllables. When presented with word-nonword minimal pairs that differed only in tones, adults were slower and less accurate in judging sameness or making lexical decisions than when the stimuli differed in segmental information (Cutler & Chen, 1997). These results indicated that suprasegmental information was especially important in Cantonese spoken word processing. With this additional processing demand, Cantonese-speaking children might have more difficulty in encoding and representing the novel words adequately. This might be the reason why differences were only not seen in the two relatively young groups of children.

c. Nature of experimental methods

This study did not replicate previous research results, which reported developmental changes in children's fast mapping abilities with age. These conflicting results could be a result of differences in the research methodologies between the present and previous Cantonese studies. Firstly, the difference in the order of presentation of experimental stimuli of the current study could account for the lack of developmental improvement in children's fast mapping abilities. In the previous studies on Cantonese speaking children, the order of presentation of the experimental stimuli was controlled with familiar objects presented first before the unfamiliar objects (Chan, 1995), or the presentation of only one unfamiliar object in each exposure trial (Cheung, 1997). These presentation methods minimized distractions from the other familiar objects' names and the other novel words that were also introduced within the short time. In the present study, however, the order of presentation of the unfamiliar objects for each child was not controlled as the children were asked to randomly select objects from a bag. It was found that a few children selected the two unfamiliar objects back to back and therefore heard the two novel words immediately one after the other. Such an occurrence could have overloaded the children’s phonological working memory, resulting in poor recall in subsequent comprehension and production probes.

Secondly, the difference in the nature of the experimental tasks could also account for the absence of significant developmental changes in the present fast mapping tasks. It was plausible that the relatively structured learning paradigm in the present fast mapping task did not reveal the children’s ability in acquiring novel words in naturalistic settings. The children might not be interested in the objects presented, and were therefore not motivated to engage in the fast mapping. Early findings by Katz, Baker & McNamara (1974), as reported by Carey (1978), observed children’s fast mapping abilities through informal play, where children were able to relate newly introduced words to different lexical categories following a few exposures. It has been shown that learning in a more lively and naturalistic play context like a two-way interactive hiding game between the clinician and the child could raise the children’s incentive to learn, resulting in a more facilitative learning effect (Dollaghan, 1985). In these ways, the delivery of administration procedures of the present study may not be natural enough to mimick the context in which fast mapping was observed in natural environment, which accounted for the lack of significant differences across the fast mapping tasks.

Error pattern of fast mapping production probes

The children’s inadequate mental representation of the novel words could also be revealed from their error responses in the production probes. Analysis revealed that 30.10% of them (31/103) were confusion errors, in which the children named the unfamiliar object with the name of the other unfamiliar object. Other errors included naming of the attributes of the unfamiliar objects (e.g. colour), or use of their current knowledge to infer their names (e.g. a cover /kɔi3/, a screwdriver /lɔ4 si1 p^{h}ɐi1/). These errors suggested that the children registered the phonemes of the novel words, but they mapped them with the wrong and equally unfamiliar object referents.

In addition, analysis of the error pattern in the recognition probes further suggested that the children learned an incomplete phonological representation of the novel words or made an inaccurate mapping of the novel words with the unfamiliar objects following a few exposures. There were more children each of the two groups of children, seven in the three-year-old group and eight in the four-year-old group, selected phonologically similar foils than those phonetically dissimilar ones. When they were presented with another phonologically similar form, these children would easily confuse it with the target novel word. These erroneous responses indicated that the young children have difficulties in acquiring sufficient information for developing a full mental representation of the novel words within a short time.

Factors affecting phonological working memory

The two groups of children's performances in the nonword repetition task failed to show developmental changes in phonological memory. There are several reasons for this. One possible explanation to the insignificant difference in NRT between age groups could be a result of the rapid presentation of the stimuli. The children could have been given too many nonwords to repeat in a short time. Within five-minutes the children had to listen to and repeat sixteen stimuli of varying length and complexity, and such a presentation rate could have caused confusion and poor performance. According to the feature overwriting model (Nairne, 1990, as reported by Oberauer & Lange, 2008), the more items one has to encode concurrently, the greater is the overlapping between the phonemic features, and the poorer is the recall accuracy. In this case, although the phonemes in each of the stimuli in the NRT were not organized in the same order with other stimuli, there could still be a high degree of overlap in which the phonemic features of a nonword may be shared with the other nonwords. This rapid rate of presentation could cause perseverations in young children at this early age and could therefore lead to the lack of significant difference in the two age groups, accounting for the insignificant difference in phonological memory.

Another possible explanation to the lack of developmental changes observed in the nonword repetition task could be resulted from the way in which the NRT was administered. It is possible that the children's performances were hindered through the use of free-field speaker, when compared to the use of headphones, where phonological details of the stimuli especially for stops and fricatives could be distorted.

Implications for Future Research

The current study provided new insights into the study of word learning in young children. As for the younger children in Gray (2006), there were no differences in the comprehension scores for the three- and four-year-old children for examining their fast mapping abilities. Floor level performances in fast mapping production probes were also noted. In future studies, researchers should consider reducing the number of items to be fast mapped. However, the overall difficulty of the task has been raised, leading to a catch 22 situation. Young children, whose word learning abilities are still at an early stage of development, are particularly vulnerable to task effects, despite minor adjustments. Further work on fast mapping should involve older children and identify task characteristics and presentation methods that would be appropriate for optimal learning.

In addition, this study showed the values for controlling the complexity of the target novel words in fast mapping experimental tasks. Success in fast mapping depends highly on the complexity of the novel word (Alt & Plante, 2006). If the novel words to be fast mapped are composed of phonemes with a high frequency of occurrence, i.e. high phonotactic probabilities, the processing load for the novel word will be reduced, and it is more likely that the word is recognized and correctly produced. On the other hand, if the novel word has high neighbourhood density, that is there are a large number of real words that differ from the novel word by one phoneme, it is likely that the word is harder to fast map. Children might get these words mixed up. These showed that the fast mapping performance would be greatly restrained by the lexical label property. Since there was no control of the phonotactic probabilities and neighbourhood density of the novel words in the present study, further research that attempts to take the children's individual differences in sensitivity to phonotactic patterns into considerations is encouraged.

Furthermore, to ensure success in fast mapping, children have to attend to the word when it is introduced before any relevant phonological information can be extracted from the ongoing speech stream for further processing and storage. They have to remember the phonemes in their correct sequence, and to produce them adequately to have the word recognized as such. One plausible explanation for poor performance in fast mapping, and in the production measure in particular, is inadequate joint attention when the adult introduced the word to be fast mapped. Tomasello (2003) argued that initial joint attention is critical to success in word learning. Thus, in addition to differences in the complexity of the novel words used, and the number of exposures to the novel words, inconclusive findings from prior studies might be related to the investigators' failure to secure joint attention with the child in the fast mapping exposure phase. Therefore, future studies should ensure that joint attention with the child is secured for an optimal learning context for fast mapping to take place.

This study also highlighted the importance in examining the effect of the children's current vocabulary and linguistic knowledge on fast mapping abilities. The children in this study showed a large variability in performance, especially in the production probe. Children with more linguistic knowledge were found to be more capable in semantic and syntactic bootstrapping, which refer to the ability in understanding word meanings through analyzing the semantic and syntactic structures with which the word was presented (Bishop, 1997). It is hypothesized that in addition to phonological memory, other factors including an individual child's current vocabulary and linguistic knowledge can also play an important role in word learning. As there was no control on the children's current lexical knowledge in our present study, future work should examine the effects of vocabulary skills on fast mapping.

In addition to assessing a child's word knowledge through elicited responses, future study using clinical neurophysiological techniques would be more sensitive to capture the young children's emerging word learning knowledge. Previous research showed that one's underlying cognitive brain activity could also reveal the evolving signs of learning. The electroencephalography (EEG), which records the spontaneous electrical brain activity, was found to show different pattern of activities when presented with novel stimuli or stimuli with previous exposures (Wallaa, Endl, Lindinger, Lalouschek, Deecke, & Lang, 1999). It is expected that EEG would augment the assessment of one's knowledge of the newly-introduced words through comprehension and production probes, and to better reveal the young children's underlying fast mapping abilities.

Acknowledgments

The author would like to thank her dissertation supervisor, Dr. Anita Wong, for her advice and guidance and her classmates for their generous support throughout the study. Special appreciation is also expressed to the teaching staff and students of the following kindergartens for their participation: Kam Lam Catholic Kindergarten, St. Margaret Mary's Catholic Kindergarten, and The Alliance Kindergarten.

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Appendix A

The stimuli for the nonword repetition task

Number of syllable	**Stimuli**
One-syllable	/wɛŋ3/
	/pʰɐm3/
	/kʰou3/
	/myn3/
Two-syllable	/ky5 tʰɐk7/
	/wɔi5 kʰan1/
	/tui5 fɐp7/
	/tʰɛ5 lun1/
Three-syllable	/lɵy3 pɵy1 jɔt9/
	/mɔi3 wœ1 pʰam6/
	/nœ3 fɔi1 tʰœk9/
	/kʰy3 jou1 pœŋ6/
Four-syllable	/hu1 lɵy2 pʰɵy4 nɛn6/
	/fɵy1 ly2 tʰɛ4 fap9/
	/kʰou1 pœ2 mɔi4 lun6/
	/wɔi1 tʰei2 ny4 fam6/

Appendix B **Referents of the experimental stimuli**

	
1. /jɵn1/: a spaghetti measurer	2. /wik7/: a wooden instrument

Appendix C

The choices of the recognition probe in the fast mapping task

Target novel words	**Phonetically similar foil**	**Phonetically dissimilar foil**
/jɵn1/	/bɵn1/	/mau2/
/wɪk7/	/mɪk7/	/hyn4/