隱性與顯性音韻表徵：
閱讀經驗之角色 (II)

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本研究探討孩童隱性與顯性音韻表徵之發展。隱性音韻表徵（implicit phonological representations**）乃隱含於聽與說中無法直接操控之音韻表徵，顯性音韻表徵（**explicit phonological representations**）則為語音操弄時可直接操控之音韻表徵。本研究以兩項實驗檢測隱性與顯性音韻表徵是否會隨閱讀經驗之增長而產生結構性之變化。實驗一以剛上幼稚園中班、無閱讀經驗的學前孩童為研究對象。實驗二則是重新分析另一項以一年級學童為對象的研究資料，此研究持續三年，資料分析結果可與學前孩童發展模式比對。兩項實驗結果顯示：中國孩童於記憶工作中所犯語音錯誤的主要形式，為將目標字串中的音節內容（子音、母音）重新組合，形成新音節；就比例而言，這種音節內容重組的錯誤較把整個音節誤植的錯誤為高。音節內容重組的錯誤比率，在學齡前後的過渡期間顯著增加，增加趨勢於二年級時趨緩。此外，在孩童認讀注音符號能力開始快速成長期間，音節內容重組錯誤比率的增加量與認讀注音符號能力的增長量相關。而音節內容重組錯誤的比率與認讀注音符號的能力在學齡前後幾個過渡期間的施測點亦呈顯著相關。顯性音韻表徵之發展順序與隱性音韻表徵之發展順序相彷：學前孩童在識字之前無法直接操弄語音音節之內在結構；一年級孩童則有此基本能力。此外，操弄語音內在結構的能力與認讀注音符號能力在學齡前最後一次施測時呈顯著相關，此關係並持續至學齡後三年。隱性與顯性音韻表徵之發展順序雖然類似，但並無證據顯示後者之發展建構於前者之上。本文試以語言模組（**modularity**）的概念解釋兩種音韻表徵發展之異同。**

（關鍵字：語音記憶、音韻覺識、隱性音韻表徵、顯性音韻表徵、閱讀能力）

Implicit versus Explicit Phonological Representations: The Contribution of Reading Experience (II)

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This study examined the development of implicit and explicit phonological representations among Chinese-speaking children. Implicit phonological representations refer to those that are automatically handled by the language module. Explicit representations refer to those that are explicit control units in speech manipulation. It was hypothesized that these two types of phonological representations undergo restructuring with reading experience. The hypothesis was tested in two experiments. Experiment I studied the restructuring process among a group of preschoolers who had little knowledge of printed words when they were first tested. Results of Experiment II were from the reanalyses of a study which followed a group of novice readers from the beginning of the first grade until the end of third grade. The results, taken together from both experiments, revealed that Chinese-speaking children's memory errors contained more of errors transposing subsyllabic units available in the stimulus strings than errors of misordering entire syllables. The proportion of transposition errors increased from the preschool age to the first grade, and reached a plateau in Grade 2. The increase in the proportion of transposition errors was related to the increase in reading ability specifically during the period of rapid development in *Zhuyin fuhao* reading ability. These two variables were further associated during the period of transition between preschool age and elementary school age. The developmental sequence of explicit representations parallels that of implicit representations in that preschoolers could not cope with the phonological awareness task at the subsyllabic level before they demonstrated any ability in reading words written in *Zhuyin fuhao* whereas first grade children demonstrated fundamental control over the task. Children's performances on phonological awareness tasks was related to *Zhuyin fuhao* reading ability at the last testing session of preschool age and continued to be evident from first grade to third grade. Though parallel in the developmental sequence, the development of explicit representations did not depend on the development of implicit representations. The notion of modularity was adopted to account for the gap between the developments.

(Keywords: phonological memory, phonological awareness, implicit phonological representations, explicit phonological representations, reading ability)

INTRODUCTION

Recently, there is growing interest in the relationship between phonological ability and early reading ability of Chinese (Chen, Lau, & Yung, 1993; Ho & Bryant, 1993; Ho & Bryant, 1997a, 1997b; Ho & Bryant, in press; Hu, Kao, & Zhang, 1996; Hu & Catts, 1998; Huang & Hanley, 1995; **柯華葳** & **李俊仁**, 1996; **黃秀霜**, 1997). Most research found a measurable relationship between children's ability to process the phonological component of the language and their ability to learn to read the Chinese alphabet or Chinese characters. Yet very few studies have concerned how the two abilities are related developmentally. Almost none of the studies concerned the exact nature of various forms of phonological ability and the way it changes with reading experience. The interpretation of the relationship tends to go in the direction that phonological ability plays a nontrivial role in the acquisition of reading ability, where a conscious knowledge of certain units of the language (be it phonemic, morphophonemic, or morpho-syllabic) is necessary. The reverse direction of the influence was often recognized but seldom elaborated (Bowey & Francis, 1991; de Jong & van der Leij, 1999; Johnston, Anderson, & Holligan, 1996; Treiman, Tincoff, & Richmond-Welty, 1996; Wimmer, Landerl, Linortner, & Hummer, 1991). By this, the interaction between phonological ability and reading ability was viewed as some particular developmental state rather than a developmental process.

The issue is further complicated by the fact that phonological ability is not a single, homogeneous ability. From a developmental point of view, it is necessary to make a distinction between implicit and explicit phonological representations. *Implicit phonological representations* refer to those that are unconsciously or automatically handled by the language module during speech perception and production. *Explicit phonological representations* refer to those that are explicit, accessible control units in speech processing, such as the segments used in isolating and manipulating for decoding novel words. The ability to represent and process phonology at a subsyllabic level does not necessarily ensure the ability to operate and manipulate it at the same level.

For ease of discussion, the term *alphabetic reading* refers to both the reading of alphabetic letters and the reading of phonetic symbols (e.g., Z*huyin Fuhao*) in this paper. Despite differences in the matching regularity between printed units and speech units, both alphabetic letters and phonetic symbols transcribe spoken words at subsyllabic level, thereby placing particular demands on the quality of the reader's phonological representations.

To examine the interaction between implicit and explicit phonological representations and the role of reading experience on the interaction, it would be helpful to look at their respective developments first.

The Effects of Alphabetic Reading on Implicit Representations

It has long been assumed that phonemic units, standing above so much of the acoustic and phonetic variability, correspond approximately to the invariant forms of phonological representations in the speaker's lexicon (e.g., Shattuck-Hufnagel, 1983). However, evidence is emerging that the phonological representations of children in an alphabetic language undergo growth and change (Ferguson, 1986; Studdert-Kennedy, 1987; Studdert-Kennedy & Goodell, 1995; Also see Walley, 1993 for a review). Children's early phonology is not, as is often assumed, represented in a subsyllabic form of phonemes, but are instead represented as a holistic patterns of interacting elements such as features, gestures or articulatory routines corresponding to syllables (Browman & Goldstein, 1989). For example, Bertoncini and Mehler (1981) found that the syllable is the first unit of speech available to perception soon after birth. Gierut (1996; Gerken, Murphy, & Aslin, 1995) found that children as young as three were capable of classifying phonological information on the basis of distinctive features. Studdert-Kennedy and Goodell (1995) provided evidence that a child about two years of age attempted new words by means of labial-alveolar gestural routines such as ['bu:'di] for 'berry', 'bird', and 'booster', ['be:'d∂] for 'pillow' and 'playdough', and ['be:'di] for 'umbrella'. As Studdert-Kennedy (1986) pointed out, positing features or gestures as the basic components of the syllable is not only consistent with studies on infant perception (e.g., Eimas, Siqueland, Jusczyk, & Vigorito, 1971), but also makes it possible to move smoothly from infant abilities to early words without making reference to phonemes as some intermediate point.

Studies further show that these early holistic syllabic representations become more segmental with ages. For example, in a study of speech errors of two children between 1 and 5 years of age, Stemberger (1989) found that these children made errors involving the exchange of single phonemes ('grap-hossers' for 'grass-hoppers') but such errors were proportionately fewer than errors involving the exchange of features (e.g., 'that gall for pristmas' for 'that ball for Christmas') when compared to adults. Treiman and Breaux (1982) found that children tended to confuse names that were globally similar in features (e.g., [bɪs] and [diz]; [pɪm] and [tɛn]) whereas adults tended to confuse names with a common phoneme (e.g., [bɪs] and [bun]; [pɪm] and [pus]). Nittrouer and colleagues found that the contrast between syllable-initial fricatives were affected by the vocalic context more strongly in children than in adults (Nittrouer & Studdert-Kennedy, 1987; Nittrouer, Studdert-Kennedy, & McGowan, 1989; see also Repp, 1986). These results indicated that young chidden were not as adept as adults at recovering the individual phonemes from the syllable, but instead tended to perceive syllables as relatively undifferentiated wholes.

Exactly what has driven the phonological representation to be more segmental is unclear. In one view, the development is driven by vocabulary growth (Fowler, 1991; Studdert-Kennedy & Goodell, 1995). As indicated by Walley (1993) and Fowler (1991), the emergence of more fine-grained, sublexical units of representations, including phonemes, from the more holistic, early representations is driven by the need to discriminate a growing number of lexical items quickly and accurately. However, Elbro (1996) pointed out that the lexical restructuring hypothesis was hard to explain why it took normal children so long to develop phonological representations with phoneme-size segments considering the many minimal pairs in the expressive vocabularies of children as young as three years old.

In the other view, the developmental course is partly driven by reading experience (Elbro, 1996; Morais & Kolinsky, 1995). Direct evidence concerning this issue is scarce. However, there is some indication that the nature of phonological representations varies with reading ability. Dyslexic adults, for example, need time between an /s/ and the following vowel /a/ to distinguish /sta/ from /sa/ syllables (Steffens et al., 1992; See also Brady, Shankweiler, & Mann, 1983; Werker & Tees, 1987). Specifically, it has been found that the phonological output in nonreaders and poor readers is usually variable and underspecified, in which only the overall phonological shape or the most salient features are handled. For example, de Gelder and Vroomen (1991) found that normal adults tended classify words on the basis of a single common segment (e.g., [pIm]/[pas]) whereas dyslexic adults were more inclined to classify words on the basis of overall similarity (e.g., [pIm]/[bin]). Katz (1986) found that poor readers had difficulty naming objects with long complicated names. The mispronounced words were similar to the target names acoustically and syllabically but lacked full specification. For example, *tornado* or *blocasion* was produced in place of *volcano* and *thermometer* or *mankana* in place of *harmonica*. As pointed by Katz, the error often shared with the target word the same stress pattern, the same number of syllables, and several segments. This and other studies (Cornelissen, Hansen, Bradley, & Stein, 1996; Stirling & Miles, 1988) have suggested that poor readers' phonological representations are not sufficiently specific to enable them to recall the correct form. Note these findings are suggestive, but far from conclusive. While the underspecified phonological representations can be a consequence of reading experience, it can also well be the cause of reading difficulty.

Studies on illiterates provide more illuminating evidence concerning the effect of reading experience on phonological representations. For example, Morais et al. (1987) compared the errors committed by illiterates, semi-literates, and literates in a dichotic listening task. Illiterates made proportionally fewer single-segment errors (such as giving *pano* for *cano*), and more global errors (such as *dono* for *cano*) than literates and semi-literates. More importantly, errors in segments increased with literacy (0.24, 0.29, and 0.39 in illiterates, semiliterates, and literates, respectively), whereas errors in syllables decreased with literacy (0.23, 0.29, and 0.13, respectively). It appeared that reading experience could direct one's attention to phonemes to improve speech recognition. Thus, reading appeared to have an effect on the restructuring of the reader's phonological representations.

The phonological representations of Chinese-speaking children are of particular interest. Despite different perspectives held by researchers, most propose that representations based on thousands of syllables that vary in the identity and precise timing of individual gestures would function less efficiently than the representations based upon dozens of phonemes (Elbro, 1996; Fowler, 1991; Studdert-Kennedy & Goodell, 1995). Given that Chinese is a syllabic language with a very simple syllabic structure (mostly CV) and a limited number of syllables, theoretically, not too much economy will be achieved by a segmental representation over a syllabic representation. This raises the first research question: Do implicit phonological representations of Chinese-speaking children undergo segmentation? How does the change, if any, unfold with reading acquisition and development? The next logical question takes the advantage of the specific features of the Chinese language. Given that Chinese is a tonal language, it would be interesting to see whether tonal features are separable from the segmental composition. A positive answer would lend further support to the segmental status of the mental representations of Chinese-speaking children.

The Effects of Alphabetic Reading on Explicit Representations

Although phonemes are the basic elements of language, they are no explicit control units in speech processing but only implicitly present in the lexicon. Yet an explicit awareness of phonemic segments is needed in learning to read an alphabetic script (Liberman & Liberman, 1990; Mutter, Hulme, Snowling, & Taylor, 1998) and perhaps even in learning to read a logographic script such as Chinese (e.g., Ho & Bryant, 1997a, 1997b; Hu & Catts, 1998; Huang & Hanley, 1995).

The exact nature of the transition from implicit to explicit control of the phonemes is not fully known. Basically, two views have been put forth. One asserts that explicit awareness of phonemes does not develop spontaneously during the normal course of linguistic development but only in the specific context of learning to read an alphabetic script. It has been found that adults who had not learned to read had much the same difficulties as pre-readers in tasks involving explicit judgments about phonemes (Morais, Cary, Alegria, & Bertelson, 1979; Morais et al., 1987; Bertelson, de Gelder, Tfouni, & Morais, 1989; Prakash, Rekha, Nigam, & Karanth, 1993). Moreover, the segmentation tasks are relatively trivial to readers but extremely difficult to pre-readers (Magnusson & Naucler, 1993; Wimmer, Landerl, Linortner, & Hummer, 1991) as well as to disabled readers (Siegel, 1993; Stanovich, 1994). In a classical study, Liberman, Shankweiler, Fischer, and Carter (1974) used a tapping task to examine the ability of 4-, 5-, and 6-year-olds to segment words by phonemes and syllables. None of the 4-year-olds could segment by phoneme but half could segment by syllable. Only 17% of the 5-year-olds could segment by phoneme. By age 6, 70% could segment by phoneme and 90% by syllable. The other view assumes that phonemic awareness can be developed without reading instruction if adequate training is provided (Lundberg, 1991).

Whatever the view, all the studies on the development of phonological awareness (Fox & Routh, 1975; Liberman et al., 1974; Stanovich, Cunningham, & Cramer, 1984; Walley, Smith, & Jusczyk, 1986) echo the findings in speech perception and production in showing that children's explicit phonological representations develop from a more syllabic level to a more segmental, phonemic level.

Given that Chinese is a syllabic language, do Chinese speakers attain an explicit control to manipulate speech sounds at the phonemic level? Such a control has proved to be significant in learning to read the Chinese alphabet and Chinese characters (Chen, Lau, & Yung, 1993; Ho & Bryant, 1993; Ho & Bryant, 1997a, 1997b; Hu & Catts, 1998; Hu, Kao, & Zhang, 1996; Huang & Hanley, 1994; **柯華葳** & **李俊仁**, 1996; **黃秀霜**, 1997). For example, Hu and Catts (1998) found that Chinese-speaking children's explicit control over the subsyllabic units of spoken words was related to their ability to read the Chinese alphabet and Chinese characters. More interestingly, the relationship between children's explicit control and the ability to read Chinese characters was specific, being specific after controlling for individual differences in children's ability to read the Chinese alphabet. Unfortunately, we are still not clear about how the explicit control develops in the first place.

One line of evidence suggests that explicit phonological representations develop in and only in alphabetic experience. The other suggests that they can grow spontaneously. Yet both lines of evidence are not without problems. For example, Read, Zhang, Nie, and Ding (1986) asserted that alphabetic reading experience played a critical role in the acquisition of explicit phonological representations. They compared two groups of adults living in mainland China: those who knew only the traditional logographic system, and those who knew that system and also knew the pinyin alphabet. The results suggested that the ability to delete phonemes depended on knowledge of pinyin. However, because the nonalphabetic literates were 16 years older and received fewer years of education than the alphabetic literates, the differences could be a result of some other factors. More importantly, some nonalphabetic literates had non-negligible scores in the phoneme deletion task.

Evidence suggesting that explicit phonological representations may develop spontaneously among Chinese-speaking speakers comes from some examples of Mandarin-based secret languages. Secret languages are a form of word play, which usually manipulates phonological structure by deleting, replacing, or reversing certain phonological units. The data about secret languages predates the use of the pinyin alphabet (Chao, 1931; Yip, 1982). In one of the Mandarin-based secret languages, *ma* 'mother' becomes *may-ka*, *pey* 'north' becomes *pay-key*, and *hwey* 'meeting' becomes *hway-kwey*. It has been suggested that Mandarin-based secret languages involve manipulations of C- and V-sized units of syllables (Yip, 1982; see also Bao, 1990), indicating an awareness of the segments of the language. On the other hand, other researchers such as Morais (1991) suggested that secret language may involve intentional control of the articulatory gestures without involving the manipulation of the segments in a syllable. Thus, the precise nature of the phonological representations in Chinese-speaking children is still unresolved.

The Interaction Between Phonological Representations and Reading Experience

Perhaps almost all agree that through reading experience, people are able to hear their speech in terms of the model provided by print (Ehri & Sweet, 1991; Olson, 1996). Yet still unknown is how reading experience exerts such an effect. Does reading experience reconstruct or just augment the representations implicit in speech perception and production of Chinese? If it is the former, we should not observe any segmental representations in children before they have any reading experience. If it is the latter, segmental representations should be measurable in the absence of reading experience. Another related question is how much the development of explicit representations depend on the organization of implicit representations. Do the explicit representations develop from the discovery of the implicit representations, or do they emerge from a reconstruction of the implicit representations into a distinctive set of meta-representations corresponding to the units of the script? If it is the former, when are implicit representations sufficiently well developed to allow for the manipulation of the segments? If it is the latter, what triggers the reconstruction in the first place? Finally, do explicit segmental representations develop spontaneously, or do they have to grow in and only in alphabetic reading experience?

Specifically, the study aimed to:

1. Determine the nature of implicit, unconscious phonological representation used in speech processing before and after reading instruction commences.

2. Determine the nature of explicit, conscious representations used in speech manipulation before and after reading instruction commences.

3. Explore the nature of the developmental relationship between implicit and explicit phonological representations before and after reading instruction commences.

Two experiments were conducted to investigate the issues. The first experiment examined the role of reading on the development of implicit/explicit phonological representations among a group of preschoolers, who had little knowledge about printed words in Chinese. The second experiment examined the development of implicit/explicit phonological representations among a group of first grade Chinese-speaking children. The children had have learned to read words printed in *Zhuyin fuhao* and Chinese characters when they were tested, thereby providing a good opportunity for the investigation of the effects of reading on the development of phonological representations, either implicit or explicit. The experiment was part of a larger three-year longitudinal study which examined the causal/reciprocal relationship between phonological abilities and early word reading abilities of Chinese. It served a valuable comparison group for the preschool subjects. The two developmental experiments with subjects from different age groups could provide valuable information concerning the effects of reading experience on the development of phonological representations.

I. EXPERIMENT ON PRESCHOOLERS

METHOD

Participants

Fifty-eight children who were in the middle-grade classes in two preschools participated in the study. One preschool was located in the suburb of the Taipei City and the other was in Taojuan County. The children were first tested when they were 57.1 months old (SD = 3.8; Ranges 50-63 months), and they were followed up for another year with the same set of tasks. According to classroom teachers' observation, the children had not and were not receiving attention due to their speech or hearing problems. These children were first tested in January and again in June/July of the school year. At each time of testing, each child was tested individually in two sessions in a maximum period of 3 days. Testing took place in a quiet area in the school.

Tasks and Procedure

Phonological memory. Each child was given a list of three bisyllabic nonwords for recall. Each of the six syllables was constructed by combining one of the six consonants *b, d, k, g, zh, sh* with one of the six vowels *u, a, ai, au, an, ang*. These consonants and vowels can be freely combined with each other without violating the phonological rules of Mandarin.

Two syllables were combined into a bisyllabic nonword and each nonword was assigned a tonal structure. None of the successive syllables in a nonword were assigned Tone 3. When two syllables with Tone 3s occur in succession within a word in Mandarin, the tone of the first syllable changes to Tone 2. Since the stimuli used in this task were nonwords, the change of tone would make it difficult to document the child's response. Nonwords were used because they had to be maintained and processed in memory without lexical support (Gathercole & Baddeley, 1990; Baddeley, Gathercole, & Papagno, 1998). Although nonwords may be processed differently from words, nonword memory is particularly correlated with a number of language abilities (Cheung, 1996; Gathercole, Hitch, Service, & Martin, 1997; Hansen & Bowey, 1994;

Stone & Brady, 1995; Taylor, Lean, & Schwartz, 1989; See Baddeley, Gathercole, & Papagno, 1998 for a review).

None of the three bisyllabic nonwords in each trial was assigned the same tonal structure. For example, if a nonword in a trial had a tonal structure with Tone 4 for the first syllable and Tone 3 for the second, neither of the other two nonwords in the same trial would have the same structure of tones. This would allow for an examination of whether the child kept the tonal structure of the stimulus string even when he or she made errors in segments.

There were a total of six trials preceded by two practice trials, during which the child repeated the bisyllabic word first one by one, then three together in a sequence, and the experimenter documented any pronounced articulatory errors. On each of the six trials, the child listened to the bisyllabic nonwords spoken by the experimenter. The child was instructed to repeat the nonwords in the order as they had been presented. The child's responses were audio recorded and were later transcribed by two independent college graduates. The child's nonword memory performance was scored in terms of the number of errors he or she made in the task. An error was a syllable which was either incorrectly recalled or was recalled in an incorrect position (Max = 6 x 6 trials).

Syllable substitution. This task concerns the awareness of constituents of words that are larger than phonemes. In this task, the child was asked to change a syllable in a given bisyllablic word. For each trial, the child was presented with a test word containing the syllable /feng/ and the child had to replace the /feng/ with a /dou/. The task was introduced by a stuffed toy, who invented a secret language and always said /dou/ instead of /feng/. The child was asked to repeat what the toy said instead of the given word. Practice trials followed in which the experimenter gave corrective feedback. There were three practice trials with /feng/ in the first syllable of the word (e.g., *fengzheng* 'kite'). Then ten test trials followed. Then three practice trials introduced the substitution of the second syllable of the word (*xinfeng* 'envelope'), followed by ten test trials with /feng/ in the second syllable of the word.

Vowel substitution. This task was similar to syllable substitution but required the child to change a vowel in a given word, following the format depicted in Wimmer, Landerl, Linortner, & Hummer (1991). For each trial, the experimenter provided a test word containing the vowel /a/ and the child replaced the /a/ by an /u/. The change from /a/ to /u/ was rather drastic since these two vowels were quite different with respect to articulatory and acoustic gestures. Thus, a slight change in articulatory gestures would not lead to successful performance. The task was introduced by another different stuffed toy, who invented a secret language and always said /u/ instead of /a/. The child was asked to repeat what the toy said instead of the given word. Practice trials followed in which the experimenter gave corrective feedback. There were three practice trials involving one-syllable word (e.g., *ma* 'mother'), followed by ten test trials.

Sound detection. The sound detection task required the child to identify a target sound /a/ in a syllable such as /da/ or /fei/. This task was expected to put a less heavy strain on the child's cognition than the vowel substitution task. An awareness of the similarity of the acoustic features of the two syllables /a/ and /da/ is sufficient for a response to come out right in the sound detection task. This task was included in the hope that a more incipient or primitive phonological awareness could be detected. There were three practice trials, followed by ten test trials.

Symbol Recognition. In this task, the child read a list of ten *Zhuyin fuhao* symbols. Children who failed to correctly name half of the symbols were not required to take the alphabetic word reading task described as follows.

Alphabetic word reading. In this task, the child read words written in *Zhuyin fuhao*. The fact that a "word" written in *Zhuyin fuhao* symbols correspond to a large number of homophones did not pose a problem to the study because this task was aimed to measure the child's ability to break the printed code (i.e., to pronounce the code rather than to access the meaning). There were 12 real words (6 diagrams and 6 triagrams) written in *Zhuyin fuhao,* arranged in an order of frequency count of sounds in Cheng (1982). Another 10 words were pseudowords that did not occur in Mandarin Chinese but that were allowed in the language such as *pou* (Wang, 1994). These words were usually termed "accidental gaps", which the child was not expected to have encountered in print.

The presentation of real words preceded that of pseudowords. The words were written in black ink on 3 X 5 in laminated cards, one word per card. The child was required to initiate a correct verbal response to each word within 10 seconds of its appearance. Testing was continued until 3 consecutive words were failed.

Transcription

Children's responses were transcribed phonetically on site by the task administrator and later from the tapes by two assistants who were familiar with the administrations of the experimental tasks but who did not know the purpose of the transcription. Broad transcriptions were employed because the analyses to be carried out did not require a detailed phonetic description. Though tape recorded, children's responses at T1 and T2 were difficult to transcribe from tapes because of the soft voice delivered by children of these ages. Thus, only on-site transcriptions were used for analyses at T1 and T2. The two transcribers were in agreement on 79.0% of the responses at T3 and 85.2% at T4. Discrepancies were resolved by discussion.

RESULT

The development of implicit phonological representations

Fifty-eight children completed the tasks at T1. Three moved to other communities at T2 and another seven left the preschools at T3. A small number of children were excluded from the analyses of phonological memory either because their erroneous responses were reduced to unintelligible murmurs and thus hard to document or because they gave correct responses but avoided the syllables that they were not sure of. Means and standard deviations of the major variables and the number of the subjects are presented in Table 1.

Table 1

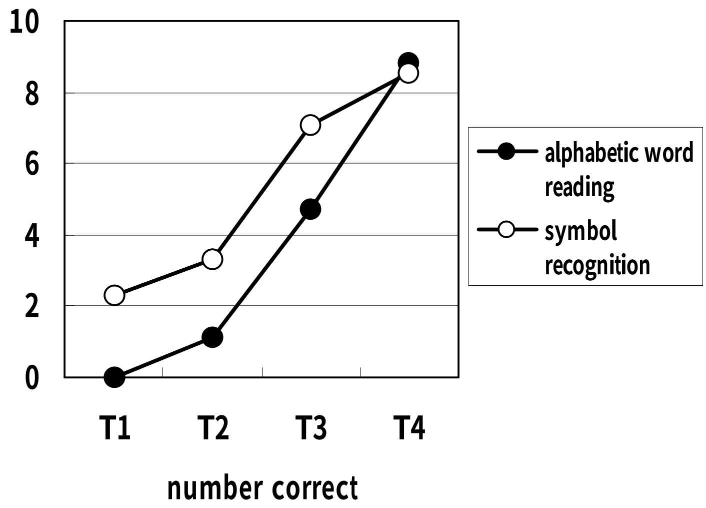
Means and Standard Deviations of Tasks Administered to Preschoolers

Measures	Testing Session	Mean	SD	N
Symbol recognition	T1	2.31	3.18	58
	T2	3.31	3.94	55
	T3	7.08	2.79	48
	T4	8.56	1.61	48
Alphabetic word reading	T1	.00	.00	58
	T2	1.11	3.37	55
	T3	4.73	5.99	48
	T4	8.83	7.04	48
PPVT raw score	T1	37.86	11.36	58
	T2	42.45	9.57	55
	T3	45.38	11.16	48
	T4	54.71	12.79	48
Phonological memory errors	T1	3.52	.89	49
	T2	3.29	.78	49
	T3	3.06	.96	44
	T4	2.97	1.09	46
Syllable substitution	T1	3.60	5.65	58
	T2	5.98	5.99	54
	T3	11.40	7.20	48
	T4	15.23	6.47	48
Sound detection	T1	5.67	2.39	58
	T2	6.78	2.11	55
	T3	7.02	2.15	48
	T4	7.77	1.78	48
Vowel substitution	T1	.14	1.05	58
	T2	.04	.19	54
	T3	.50	1.88	48
	T4	.90	2.63	48

As shown in Table 1, the children could read, on an average, 2.31 (out of 10) *Zhuyin fuhao* symbols when they were first tested. Regardless with some knowledge in *Zhuyin fuhao* symbols, virtually none of the children could read words written in *Zhuyin fuhao*, indicating that the participants had certain knowledge of *Zhuyin fuhao*, but only to the extent of naming individual symbols. At T2, the preschool children started to demonstrate some incipient ability to read words written in *Zhuyin fuhao* (1.1 out of 10 on an average), yet with 83.6% of children still scoring zero on the task. The percentage of children scoring zero on the alphabetic word reading task dropped sharply to 35.4 at T3 and further to 14.6 at T4. Children's performances on the symbol recognition task revealed a similar pattern of development. The percentage of children scoring zero on the symbol recognition task dropped from 46.6 at T1 to 38.2 at T2, 8.3 at T3, and 2.1 at T4, with a slump from T2 to T3.

Children's performances improved significantly from T1 to T4 both on symbol recognition ($F(3, 135) = 90.9$, $p < .001$) and on alphabetic word reading ($F(3, 135) = 40.1$, $p < .001$). As shown in Figure 1, though a general trend of improvement could be detected within the time of the testing, the improvement became particularly pronounced for both symbol recognition and alphabetic word reading from T2 to T3.

Figure 1. **The development of alphabetic word and symbol reading abilities**



Preschoolers' errors on the phonological memory task decreased from T1 to T4 ($F(3, 96) = 6.9$, $p < .001$). Post-hoc comparisons indicated that the decreases were significant from T1 to T2 ($t(43) = 2.1$, $p < .05$) and from T2 to T3 ($t(36) = 2.0$. $p < .05$) but not from T3 to T4 ($t(42) = .55$, $p > .05$). Likewise, children's performances on PPVT also demonstrated a developmental increase ($F(3, 135) = 32.3$, $p < .001$). I'll save the discussion of the results relevant to phonological awareness for the next section.

In order to understand the nature of children's implicit phonological representations, their errors in the memory task were subject to four categories for analyses:

1. Segmental transposition (TRANS): the syllable formed by recombining the consonants and vowels available in the stimulus string.

2. Entire syllable misordering (MISORD): the syllable recalled in the wrong position of the stimulus string but having correct phonological shape.

3. Substitution (SUBS): the syllable containing consonants or vowels that are not in the stimulus string.

4. Omission (OMIT).

Table 2 presents examples of each error category. The children sometimes resorted to legitimate lexical items for recall. Examples included *zhu^{1}gan^1* (pig liver) or *gu^{1}dan^1* (lonely) for *zhu^{1}ban^1*, *sha^{1}bao^1* (sandbag) or *shao^{1}kai^1* (boiled) for *sha^{1}ga^1*, *dan^{4}gao^1* (cake) for *zhan^{1}da^1*, *dan^{4}zhu^1*(marble) for *ba^{4}gu^1*, and *da^{1}gai^1*(generally speaking) for *dao^{4}ga^4*. Since such errors occurred infrequently, they were categorized according to their phonological shape without taking their lexical content into account. Thus, if the child reported *dan^{4}gao^1* (cake) for *zhan^{1}da^1* in the stimulus string *zhan^{4}da^1 shu^{4}gao^3 bai^{1}kang^4*, *dan^4* was considered an error of segmental transposition, *gao^1* an error of entire syllable misordering.

Table 2

Examples of Error Categories

Error type	Target	Examples of errors
TRANS	*Shao^{1}ga^1 ban^{4}zhu^4 kang^{1}dai^3*	***sha^{1}gao***^{1} *ban^{4}zhu^4 kang^{1}dai^3*
		gao^{1}sha^1 *ban^{4}zhu^4 kang^{1}dai^3*
	zhan^{4}da^1 shu^{4}gao^3 bai^{1}kang^4	*zhan^{4}da^1 shu^4**kao^3** bai^1**gang**^{4}*
MISORD	*ga^{1}shao^3 bang^{4}ku^3 dan^{3}zhai^1*	***bang^4****shao^3* ***ga***^{1}*ku^3* ***ga^3****zhai^1*
	ba^{3}gan^1 zhao^{1}dai^3 ku^{4}shang^4	*ba^3**dai**^{1} zhao^1**gan^3** ku^{4}shang^4*
SUBS	*Ga^{1}shao^3 bang^{4}ku^3 dan^{3}zhai^1*	*ga^{1}shao^3* ***mai^4****ku^3* ***mai^{3}chai***^{1}

Note. TRANS = errors of segmental transposition; MISORD = errors of entire syllable misordering; SUBS = errors of substitution; OMIT = errors of omission. The superscription indicates the four tones of Mandarin Chinese. 1 = level tone; 2 = rising tone; 3 = falling-rising tone; 4 = falling tone.

Table 3 presents the proportions of error categories. Proportions of each error category rather than absolute number of errors were examined because the children did not make equal number of errors. The assumption underlying this analysis is that error categories reflect different phonological representations or the extent the various representations are used. If the Chinese syllable is a cohesive unit and the segments of a syllable are well integrated, we expect to find relatively more MISORD errors. If, on the other hand, each segment is relatively independent of all the others, we expect to see more TRANS errors.

Table 3

Proportions of Error Categories (Standard Deviation) for Preschoolers

%	TRANS	MISORD	SUBS	OMIT
T1	53.5 (19.2)	11.3 (8.5)	12.9 (11.1)	22.6 (22.2)
T2	57.9 (17.7)	11.0 (9.1)	15.7 (11.3)	15.4 (18.5)
T3	64.8 (17.2)	13.7 (8.7)	12.9 (9.3)	8.8 (13.2)
T4	70.0(14.2)	12.0 (8.7)	10.2 (9.1)	8.1 (9.8)

Note. TRANS = errors of segmental transposition; MISORD = errors of entire syllable misordering; SUBS= errors of substitution; OMIT = errors of omission.

Table 4

Adjusted Proportions of Error Categories (Standard Deviation) for Preschoolers

%	TRANS	MISORD	SUBS
T1	69.0 (13.3)	15.1 (10.8)	15.9 (12.5)
T2	68.7 (14.3)	13.0 (10.8)	18.3 (12.7)
T3	70.2 (15.9)	15.3 (10.2)	14.6 (11.9)
T4	75.7(12.3)	13.2 (9.5)	11.1 (9.8)

Note. TRANS = errors of segmental transposition; MISORD = errors of entire syllable misordering; SUBS = errors of substitution; OMIT = errors of omission.

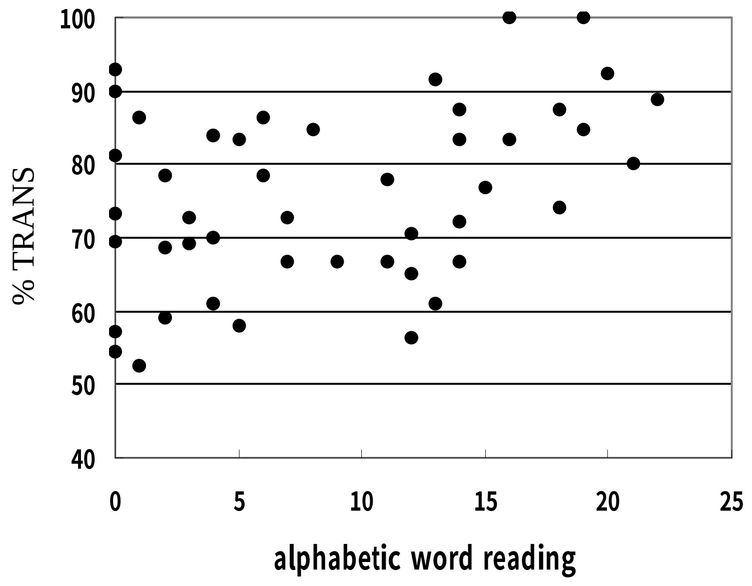
Table 3 shows that the predominant type of errors at the segmental level was TRANS. It accounted for 53.5%, 57.9%, 64.8% and 70.0% of the memory errors the children made at T1, T2, T3, and T4, respectively. An initial examination of the errors revealed that the proportions of TRANS errors increased significantly from T1 to T4 ($F(3, 96) = 6.8$, $p < .005$) whereas proportions of MISORD errors did not differ from T1 to T4 ($F(3, 96) = 1.1$, $p > .05$). Proportion of SUBS errors differed from T1 to T4 ($F(3, 96) = 3.6$, $p < .05$) but no general tendency of increasing or decreasing was detected. Errors of OMIT decreased significantly ($F(3, 96) = 6.74$, $p < .001$) as would be expected if children's memory efficiency increased as a result of either maturation or experience.

The decrease of OMIT errors made the increase of TRANS errors open to at least two interpretations. First, the increase of TRANS errors may reflect a gradual segmentation process of the phonological representations in the children. Second, the increase of TRANS may well just be another facet of the decrease of OMIT errors. OMIT decreases proportionally because the functional capacity of memory increases, not because the structure of the memory undergo qualitative changes. As such, a large portion of errors originally shared by the OMIT category shifts to the TRANS category, making the latter increase in proportion. To disentangle the segmentation hypothesis from the functional capacity hypothesis, the proportions of each error type were adjusted by dividing the number of a particular error type by the sum of the TRANS, MISORD and SUBS errors, excluding OMIT errors. By this, only the errors with segmental composition were taken into account, thereby adjusting the differential portions of OMIT errors across times. These adjusted proportions will be used for later analyses. The means and standard deviations of the adjusted proportions are displayed in Table 4. Of the particular interest was that the proportion of TRANS errors still demonstrated an incremental trend of development after being adjusted ($F(3, 96) = 3.1$, $p < .05$).

It has been suggested that segmental restructuring of phonological representations of a word begins with vocabulary growth spurt in late infancy and extends over the preschool years with continued vocabulary growth (Walley, 1993). Walley, however, did not specify it is the overall vocabulary size or the spurt (frequent and rapid additions to the lexicon) that drives the segmentation process. Correlational analyses revealed that children's TRANS were not correlated with their PPVT raw scores– a standardized measure of vocabulary knowledge– at any time of testing ($r = .11, -.07, .15$, and $.15$ at T1, T2, T3, and T4, respectively, all $p > .05$). Nor was the amount of the increase in TRANS correlated with the amount of the increase in PPVT raw scores ($r = .01$ from T1 to T2; $r = -.04$ from T2 to T3; $r = .00$ from T3 to T4, all $p > .05$).

To investigate the relationship between segmental restructuring and reading, correlational analyses were performed on adjusted TRANS and children's abilities to read *Zhuyin fuhao* symbols and words written with *Zhuyin fuhao* symbols (alphabetic word reading). Results of the analyses revealed that the proportion of TRANS was not significantly correlated with children's ability to read letters ($r = .03, -.14, .17$, and $.18$ at T1, T2, T3, and T4, respectively). The correlation between TRANS and alphabetic word reading ability was not available at T1 because none of the children could read any words written in *Zhuyin fuhao* when they were tested. TRANS and alphabetic word reading were not significantly correlated at T2 and at T3, but the correlation reached the significant level at T4 ($r = .38$, $p < .01$) and remained evident after controlling for individual differences in PPVT raw scores ($r = .37$, $p < .05$). Figure 2 indicates that there were some children who performed poorly on the alphabetic word reading task but had high TRANS, suggesting that alphabetic word reading, though as a correlate, is not the nascent trigger of segmental restructuring.

Figure 2. The relationship between SEG and alphabetic word reading at T4



Also related to our understanding of the role of reading on segmental restructuring is whether the "spurt" in reading ability is related to the "growth" in segmental restructuring. As shown in Figure 1, a rapid increase in reading abilities took place from T2 to T3. The amount of increase in reading ability was calculated by the combined *z* scores of the increases in symbol recognition and in alphabetic word reading. The combined *z* scores were then correlated with the amount of increase in TRANS. Results indicated that the amount of increase in the combined reading scores was not correlated with the amount of increase in TRANS from T1 to T2 (r = -1.9, p > .05) or from T3 to T4 (r = .25, p > .05), but was from T2 to T3 (r = 42, p = .01), a period during which rapid growth in reading ability began to take place. Furthermore, the correlation remained evident even after controlling for the amount of increase in PPVT raw scores of the same period (r = .42, p = .01).

At T4 (but not at earlier sessions), there was indication that a more segmental representation was a more efficient representation for verbal memory performance, as evidenced by the negative correlation between proportions of TRANS errors and the total number of errors children committed while performing the memory task (r = -.52, p < .001).

The development of explicit phonological representations

As shown in Table 1, children's performances in syllable substitution increased significantly from T1 to T4 ($F(3, 132) = 64.3$, $p < .001$). The percentage of children who scored zero on the syllable substitution dropped from 53.4 at T1 to 8.4 at T4. Their performances in sound detection also improved from T1 to T4 ($F(3, 132) = 8.4$, $p < .001$). There were 5.2% of children scoring zero on the sound detection task at T1 and none at T4. In contrast to syllable substitution and sound detection, vowel substitution appeared to pose great difficulty. Although the average score of vowel substitution increased with age, the increase was not significant ($F(3, 132) = 2.1$, $p > .05$). Furthermore, 98.3% of children scored zero on the vowel substitution task at T1 and there were still a substantial 85.4% at T4.

As to the role of reading in the development of explicit phonological representations, correlational analyses revealed that children's alphabetic word reading was not related to syllable substitution at all testing sessions (r = .24, .08, and .25 at T2, T3, and T4, all $p > .05$). It was, however, related to sound detection ($r = .45$, $p = .001$) and vowel substitution ($r = .31$, $p < .05$) at T4, but not at earlier testing sessions. These results were similar to what was found for the development of implicit representations: Not until at T4 was the correlation between alphabetic word reading and proportions of TRANS statistically significant. Children's ability to read *Zhuyin fuhao* symbols was not related to syllable substitution or vowel substitution. It was related to sound detection at T4 ($r = .31$, $p < .05$) and barely at T3 ($r = .28$, $p =.05$).

It should be noted that the lack of correlation meant that the variables did not relate to each other at certain points of time, in a linear way, but it did not exclude other possibilities. Is it possible that alphabetic word reading experience triggers the development of phonological awareness but individual differences in reading ability are not linearly related to phonological awareness at the initial stages of development? To explore this possibility, children who scored zero on alphabetic word reading were compared to children who could read at least one word written in *Zhuyin fuhao*. Results indicated that children who could read some words written in *Zhuyin fuhao* performed better on the sound detection task than children who could not read any words at T2 ($t(15.9) = 2.3$, $p < .05$) and at T3 ($t(33.8) = 2.3$, $p < .05$). There was no reading-group differential effect on vowel substitution or syllable substitution at T2 or T3.

With the regard to the relationship among the three phonological awareness tasks, syllable substitution was related to sound detection at T2, T3, T4 (r = .33, .29, .50, respectively, all $p < .05$), and to vowel substitution at T1 and T3 (r = .39, .30, respectively, both $p < .05$). Sound detection and vowel substitution were related to each other at T3 and T4 (r = .29 and .37, respectively, both $p < .05$)

Children's performances on the phonological awareness tasks, including syllable substitution, sound detection, vowel substitution were not related to the proportions of TRANS errors. The only exception was that children's performance on syllable substitution was related to the proportions of TRANS errors at T1 (r = 40, $p < .01$).

II. DATA FROM FIRST GRADERS

To better understand the development of implicit and explicit phonological representations among Chinese speaking children, the data from a three-year longitudinal study were reanalyzed. This study was originally designed to investigate the role of phonological processing skills in the development of reading abilities among a group of children from first grade to third grade. Information relevant to our present discussion is detailed as follows.

METHOD

Participants

Seventy-two children were recruited from five classrooms in a predominantly middle-class elementary school in Taipei when they were in the first grade at the time the study began. Fifteen children moved to other neighborhoods during following years of study, leaving a total of 57 children completing the study. Classroom teachers reported that the children did not have any evidence of neurological damage, emotional problems, or sensory deficits. The children also had no history of articulation or language impairments. These children were tested in November and in April of the first two academic years and in April of the third.

Tasks and procedure

The children were tested individually and followed for three years. Tasks of phonological memory and phonological awareness were administered individually each semester throughout the first two academic years and at the end of the third year.

Phonological memory. The task was the same as the memory task administered to preschool children, allowing for a direct comparison across groups. The only difference was the number of test trails. There were ten trials for the older participants. The child's responses were audio recorded and were later transcribed by two independent college graduates. The scorer agreement on the transcriptions of the tape was 98.5%.

Phonological Awareness. Because the study was not originally designed to be comparable to the study on preschoolers, the task used to measure phonological awareness for first graders was not the same as those used for preschoolers. First graders' phonological awareness was assessed by a sound categorization task, which placed a heavier demand on children's phonological memory as more items had to be processed in memory while the task was being carried out. The child had to choose from a set of three words (e.g., *jia*, *xia*, *hua*) the word that sounded differently from the others (*hua*). There were sixteen test trials. The trials differed in the type of the sounds the child had to contrast. Half of the sixteen test trials required the child to contrast the stimulus words according to their onset consonants (e.g., ***m****ao,* ***m****ei,* ***n****iou*). The other half of the sixteen trials required the child to contrast the stimulus words according to their rimes (e.g., *h**u**, mi**ao**, d**ao***) In Mandarin Chinese, the medial and the rime form one of the immediate syllabic constituents, namely, the final (e.g., the medial *i* and the rime *ao* form the final of the syllable *miao*). The final and the initial then form the syllable. As such, the onset consonant trials would only require the child to decompose a syllable at the juncture of immediate syllabic constituents while the rime trials would further within the constituents (i.e., the final). Under this condition, the rime trials would be relatively difficult and the onset consonant trials relatively easy (Treiman, 1988, 1992). All of the items in a trial were of the same tone to avoid any confusion over different tones.

The child were told that the experimenter would read three words aloud. The child had to listen carefully to the onset consonants or the rimes each word (depending on which type of trial occurred) and chose the word that was different from the others. The experimenters explained which sound (the opening or the end sound of the syllable) was the important one, having checked first that the child knew what the experimenters meant by “onset consonants” and “rimes”. The child was given similar instructions for each trial, following the model: "Say the words *hu, miao,* and *dao*". The child repeated the words. "One of them has a different opening sound. Can you tell me which of these words has a different opening sound-- *hu, miao,* or *dao*?“

The sixteen test trials were preceded by three to five practice trials during which the experimenter ensured that the child understood the task. On these trials, the experimenter gave feedback on the correctness of the child's response. In the case of an incorrect response, the child would be told the correct answer and why it was correct.

Alphabetic word reading. In this task, the child read a list of 60 words written in *Zhuyin fuhao*. Twenty-four of the words were familiar to young children and another 24 words were less familiar. The familiarity of the words were determined by the frequency count in Cheng (1982). The remaining 12 words were pseudowords that did not occur in Mandarin Chinese but that were allowed in the language such as *pou* (Wang, 1994). These words were usually termed “accidental gaps”, which the child was not expected to have encountered in print.

The presentation of familiar words preceded that of less familiar words, which preceded the presentation of pseudowords. The words were written in black ink on 3 X 5 in laminated cards, one word per card. The child was required to initiate a correct verbal response to each word within 5 seconds of its appearance. The test might be slightly more sensitive than untimed tests to the rapid word recognition necessary for fluent reading (Olson, Wise, Conners, Rack, & Fulker, 1989).

RESULTS

Means and standard deviations of the tasks are presented in Table 5. The mean number of memory errors committed decreased from 2.77 at T1 to 2.17 at T5 ($F(4, 224) = 10.1$, $p < .001$), indicating an improvement in children's nonword memory. Note a significant decrease in errors was found from T1 to T2 ($t(56) = 4.3$, $p < .001$), but not at other adjacent points ($t(56)$ = 1.08, 1.88, and 1.55 for T2-T3, T3-T4, and T4-T5, respectively, all $p > .05$).

Table 5

Means and Standard Deviations of Tasks Administered to First Graders

Measure	Testing Sessions	Mean	SD
Phonological memory errors	T1	2.77	1.02
	T2	2.39	1.00
	T3	2.39	.92
	T4	2.23	1.10
	T5	2.17	1.14
Phonological awareness	T1	7.72	2.28
	T2	7.44	3.10
	T3	8.14	2.92
	T4	8.89	2.76
	T5	10.35	3.27
Alphabetic word reading	T1	49.95	7.37
	T2	48.79	8.30
	T3	48.67	7.37
	T4	50.30	6.24
	T5	48.39	7.78

Children's performances on the phonological awareness task also improved from T1 to T5 ($F(4, 224) = 15.4$, $p < .001$). The improvement was evident from T4 to T5 ($t(56) = 3.5$, $p < .001$), but not at other adjacent points ($t(56)$ = .73, 1.7, and 1.9 for T1-T2, T2-T3, and T3-T4, respectively, all $p > .05$). In contrast to the incremental trend of development on phonological memory and phonological awareness, the tend of development on alphabetic word reading was less obvious (F(4, 224) = 2.42, p = .05). In fact, a regressive trend was observed from T4 to T5 (t(56) = 3.3, p < .01).

The development of implicit phonological representations

To understand the development of implicit phonological representations among first graders, children's memory errors were subject to four categories as depicted earlier for preschoolers. Table 6 shows that the predominant type of errors at the segmental level was TRANS. It accounted for 75.7%, 84.3%, 84.5%, 85.9%, and 85.3% of the memory errors the children made at T1, T2, T3, T4, and T5, respectively. The second frequent type of errors was MISORD, but in much smaller proportions than TRANS (10.3%, 6.7%, 8.3%, 6.5%, and 11.1% at T1, T2, T3, T4, and T5, respectively). SUBS and OMIT together, accounted for less than 10% of the errors at all testing points except at T1.

Table 6

Proportions of Error Categories (Standard Deviation) for First Graders

%	TRANS	MISORD	SUB	OMIT
T1	75.7 (21.4)	10.3 (8.6)	3.3 (5.2)	10.8 (19.9)
T2	84.3 (9.7)	6.7 (7.2)	4.8 (4.9)	4.2 (7.8)
T3	84.5 (13.9)	8.3 (7.1)	5.0 (11.0)	2.6 (6.5)
T4	85.9 (9.9)	6.5 (6.5)	4.8 (6.3)	2.8 (7.3)
T5	85.3 (10.9)	11.1 (8.7)	3.1 (4.6)	0.7 (2.0)

Note. TRANS = errors of segmental transposition; MISORD = errors of entire syllable misordering; SUB = errors of substitution; OMIT = errors of omission.

Table 7

Adjusted Proportions of Error Categories (Standard Deviation) for First Graders

%	TRANS	MISORD	SUBS
T1	84.4 (13.8)	11.5 (10.1)	4.1 (9.1)
T2	88.1 (7.8)	7.0 (7.4)	4.9 (5.0)
T3	86.4 (13.1)	8.4 (7.2)	5.1 (11.5)
T4	88.4 (8.0)	6.8 (6.7)	4.8 (6.3)
T5	85.7 (10.7)	11.2 (8.7)	3.2 (4.6)

Note. TRANS = errors of segmental transposition; MISORD = errors of entire syllable misordering; SUB = errors of substitution; OMIT = errors of omission.

When errors were viewed developmentally, the proportion of TRANS errors increased with age ($F(4, 224) = 6.0$, $p < .001$). The proportion of TRANS errors increased significantly from T1 to T2 ($t(56) = 2.9$, $p < .01$), the very initial stages of reading acquisition, and stayed at approximately the same level thereafter ($t(56) = .25$, .63, and .34 for T2-T3, T3-T4, and T4-T5, respectively, all $p < .05$). On the other hand, MISORD errors posed a different pattern of development. The proportion of MISORD errors decreased significantly from T1 to T2 ($t(56) = 2.7$, $p = .05$) and then stayed at roughly the same level from T2 to T4 ($t(56) = 1.2$, $p > .05$ from T2 to T3; $t(56) = 1.4$, $p > .05$ from T3 to T4), and increased from T4 to T5($t(56) = 3.3$, $p < .01$).

The adjusted proportions of error types were displayed in Table 7. Recall that the adjusted proportions were the proportions of each error type excluding the consideration of OMIT errors, which had no segmental substance for analyses. The adjusted scores displayed a similar pattern of development as the unadjusted scores, with errors of TRANS increasing from T1 to T2 ($t(56) = 2.0$, $p < .05$), but with no differences observed at other adjacent points ($t(56) = .9$. 1.0, and 1.5, for T2-T3, T3-T4, and T3-T5, respectively, all $p > .05$).

Correlational analyses were performed to investigate the relationship between the segmental level of phonological representations and reading. As the analyses done with preschoolers, only the correlations of reading with adjusted scores were reported given that the adjustment did not affect the correlational patterns. See Table 8 for results of correlational analyses, which showed that proportions of TRANS errors were significantly correlated with alphabetic word reading ability at T1 ($r = .45$, $p < .001$) and at T2 ($r = .35$, $p < .01$), but not thereafter ($r = .16$, .06, and .17 at T3, T4, and T5, respectively, all $p > .05$). Of particular interest was that proportion of TRANS measured at T1 was also related to subsequent alphabetic word reading ability measured at T2, T3, T4, and T5 (r ranged from .36 to .49).

Errors children made while performing the memory task were negatively correlated with proportions of TRANS errors at all testing sessions, except at T4 ($r = -.28$, -.29, -.56, and -.43 at T1, T2, T3, and T5, respectively, all $p < .05$).

Table 8

Correlations Between Variables for First Graders

	TRANS errors					Phonological awareness					Alphabetic word reading				
	T1	T2	T3	T4	T5	T1	T2	T3	T4	T5	T1	T2	T3	T4	T5
TRANS errors															
T1		.26	.30	.14	.32	.10	.14	.15	-.04	-.12	.49	.39	.42	.38	.36
T2			.21	-.13	.22	.03	.00	.20	.13	.22	.06	.32	.06	.07	.15
T3				.10	.21	.11	.05	.06	.15	.25	.01	.09	.16	.06	.17
T4					-.10	-.06	.06	-.03	-.11	-.05	.18	.10	.05	.06	.17
T5						.19	.16	.39	.23	.04	.07	.16	.20	.11	.17
Phonological awareness															
T1							.45	.32	.43	.28	.33	.29	.35	.35	.37
T2								.47	.48	.27	.11	.15	.21	.18	.26
T3									.47	.38	.11	.24	.30	.17	.36
T4										.46	.06	.26	.34	.32	.47
T5											.00	.28	.28	.35	.42
Alphabetic word reading															
T1												.54	.63	.60	.62
T2													.75	.74	.72
T3														.81	.79
T4															.83
T5															

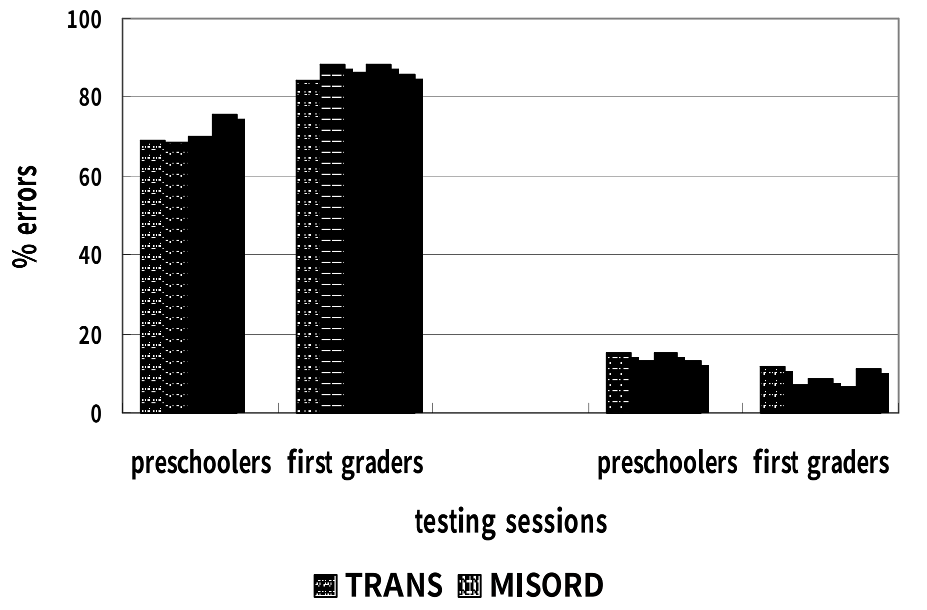
The development of explicit phonological representations

In reference to Table 5, children's performance on the phonological awareness task improved from T1 to T5 ($F(4, 244) = 15.41$, $p < .001$). This improvement was particularly true from T4 to T5 ($t(56) = 3.48$, $p = .001$), but not at other adjacent testing sessions ($t(56) = .73$, $p < .05$ from T1 to T2; $t(56) = 1.71$, $p < .05$ from T2 to T3; $t(56) = 1.94$, $p = 0.57$ from T3 to T4). At all testing sessions, children's performances on the phonological awareness task were better than the chance level (chance level = 16/3; $t(56) = 7.90$, $p < .001$ at T1; $t(56) = 5.13$, $p < .001$ at T2; $t(56) = 7.25$, $p < .001$ at T3; $t(56) = 9.73$, $p < .001$ at T4; $t(56) = 11.06$, $p < .001$ at T5).

Children's performance on the phonological awareness task was correlated with children's alphabetic word reading ability at all testing sessions except T2 (*r* = .33, .30, .32, and .42 at T1, T3, T4, and T5, respectively, all $p < .05$). However, performance on the phonological awareness task was not correlated with the proportions of TRANS measured at the same testing session (*r* = .10, .02, .06, -.11, and .04 at T1, T2, T3, T4, and T5, respectively, all $p > .05$), indicating that the two phonological representations might have developed independently along two different courses.

Compared with preschoolers, first graders did not seem to have superior performance on the phonological memory task measured at T1 than the preschoolers' performance measured at T4 ($t(94.4) = .84$, $p > .05$). However, the nature of errors children made on the phonological memory task differed between the two groups ($X^2(2) = 55.3$, $p < .001$). Compared with preschoolers, first graders made proportionally more TRANS errors ($t(100) = 3.37$, p = 001) but fewer of SUBS ($t(93) = 3.74$, $p < .001$). The proportions of MISORD errors did not differ between these two groups of participants ($t(98.6) = .84$, $p > .05$). The developmental trend of error types is presented in Figure 3, which shows that there was a significantly incremental trend in children's TRANS errors but a slightly decreased trend in MISORD errors.

Figure 3. **The developmental trend of TRANS and MISORD errors**



Finally, related to our understanding of the nature of phonological representations in Chinese children is whether tonal features are well-integrated with segments in a syllable. If tonal features and segments are well integrated, tonal features would be expected to be wiped out and changed when the content of the segments changes. Yet, the results showed that most of the errors preserved the tonal structure of the stimulus string (e.g., one child recalled *chuan^{2}guo^3* ***mian^{4}tuei^1*** *shi^{4}shuei^3* for *chuan^{2}guo^3 mu^{4}tian^1 shi^{4}shuei^3*). For first graders, the percentages of segmental errors that preserve the tonal structure of the target strings were 84.5 (SD= 12.5) at T1, 86.1 (SD = 12.9) at T2, 87.3 (SD = 10.0) at T3, 89.0 (SD = 10.2) at T4, and 86.1 (SD = 12.0) at T5. For preschoolers, the percentages were 71.5 (SD = 20.4) at T1, 78.3 (SD = 17.9) at T2, 85.2 (SD = 14.8) at T3, and 80.7 (SD = 17.1) at T4. These results suggest an autonomous status of the tonal features in the memory of Chinese. To some extent, tonal features in Chinese are independently retrieved rather than parasitize the segmental composition as a lexical integer. This finding is similar to the results of Chen (1999), where analyses of the data collected from naturalistic slips of tongue revealed that tones were never affected by the movement of segments. Examples include *gang^1* ***kai^1****-shi^3 de shi^2-hou^4* 'in the right beginning' for *gang^1* ***gai^1****-shi^3 de* *shi²-hou⁴*. Another example is *de²-dao⁴ hen³-duo¹ de* ***xun⁴-xi²*** 'got a lot of message' for *de²-dao⁴ hen³-duo¹ de* ***xin⁴-xu²***.

One may argue that the observed preservation of the tonal structure of the stimulus strings could be a trivial, uninteresting consequence of acoustic imprints of the melody of the stimulus strings as a whole rather than the result of disintegrity of the tonal features from the segments. Because the majority of the syllables incorrectly recalled also lost their segmental identity, it can be argued that tonal features should be wiped out naturally together with the segments, leaving only the acoustic imprint for recall. To take this into account, a subset of the data were examined. For this subset, the tonal status of the individual misordered syllable rather than the tonal structure of the stimulus string as a whole was examined. Misordered syllables were the syllables that maintained segmental identity but were moved to a new position as a whole. In other words, we were interested in looking at whether the syllables that were misordered still maintained their tones under the situation that their segments were intact. Despite the segmental integrity of these syllables, only 29% of the misordered syllables maintained their tones. Among these 29% syllables, 48% of them had their tones in accordance with the tones in the new position, which made it hard to determine whether their preservation of the tones was a result of the integrity of the tone with the syllabic representations or a result of preservation of the tonal structure of the target strings. In other words, among the 29% of the misordered syllables, 48% exhibited doubtful status, and only 52% could be said, without a hint of doubt, to preserve their tones as an integral as they were moved to the new positions. Note this 52% accounted for only 15% (29% X 52%) of the total misordered syllables. As such, the preservation of tonal structures could not be reduced to merely acoustic phenomenon.

DISSCUSSION

The present study incorporated the results of two experiments which investigated the developmental changes of phonological representations among Chinese-speaking children and the role of reading experience on such changes. Three separate but related questions were asked. First, how do the implicit, unconscious phonological representations used in speech processing change before and after reading instruction commences? Second, how about the explicit, conscious representations used in speech manipulation? Third, how do implicit and explicit phonological representations interact in relation to reading experience?

The Development of Implicit Phonological Representations

In the analyses of the errors children made in the phonological memory task, we found that when recalling failed, Chinese children were more likely to recombine the consonants and vowels available in the stimulus string than to move the entire syllable around. This was true for both preschoolers and first graders. If a Chinese syllable is an intact, cohesive processing unit, we should have observed that the phonological shapes of the syllables were well preserved even when they were not recalled in the right position. Yet, the results showed that the syllables wrongly recalled were mostly constructed by the segments available in the stimuli, but the segments were not linked as a syllable in a way as they were in the original stimuli. Therefore, even though Chinese has a very simple syllabic structure and a limited number of syllables, the syllable does not appear to be the only processing unit available in memory. Representations at the subsyllabic level are also available to Chinese-speaking children as young as 4.8 years old given that 69% of their memory errors with segmental substance were segmental transposition errors. The question then becomes not what level of representations are functional but how the various levels of representations develop with children's growing experience with different modalities of language processing.

Does reading experience play a role in restructuring the implicit phonological representations used in speech perception and production? One way to attack the question is to examine the changes in the proportions of transposition errors before and after children develop the ability to read. Through such examination, it is apparent that reading experience is not the initiator of the restructuring process given that a large portion of children's memory errors were of segmental transposition at the time they displayed no evidence of reading ability. However, the proportion of segmental transposition errors does change in succession to the development of reading ability. For example, children's implicit phonological representations seemed to be further restructured into more discrete, subsyllabic units from the preschool age to first grade, as evidenced by the larger proportion of transposition errors committed by first graders when compared to preschoolers. The restructuring process goes on during the initial stages of first grade. For first graders, the increase in errors of segmental transposition and the concomitant decrease in error of entire syllable misordering from T1 to T2 suggest a shift away from a more syllabic level of representation towards a more subsyllabic, segmental level of representation. This is the time formal, intensive reading instruction begins.

Another way to investigate the role of reading in the development of implicit phonological representations is to see whether they are correlated with each other. It should be noted that the lack of correlation does not necessarily mean that reading does not play a role in the development of implicit phonological representations. Reading may trigger the development but individual differences in the development of implicit representations may not be explained by individual differences in reading. To use Hunt's (1985) analogy, two legs are needed to run. Yet "number of legs" will not account for individual differences in speed or skill on the track. Nonetheless, if the development of implicit phonological representations is correlated with reading ability, then we can say in a more definite way that reading plays a role in the development of implicit phonological representations. This is what was found in the present study. For example, in the preschool age, we found that children's reading ability began to develop rapidly from T2 to T3, and this was the time that the amount of increase in alphabetic reading ability was significantly related to the amount of increase in the proportions of transposition errors. This correlation was evident even after controlling for individual differences in vocabulary growth. This means that the relationship between the growth in transposition errors and the growth in reading is unique and cannot be attributed to the simultaneous growth in vocabulary. The results of the study also show that the association between reading ability and proportions of transposition errors began to be evident at T4 of the preschool age even after controlling for individual differences in vocabulary knowledge. The association continued to be evident at the first two testing sessions of the elementary school age.

The question now is why reading ability and transposition errors were related to each other during the period of transition between the preschool age and the elementary school age, but not at earlier or later testing sessions. It is speculated that the segmental restructuring process is first triggered by other factors. It is not clear what the other factors are. Vocabulary growth might be one of them as many other researchers have suggested (e.g., Walley, 1993), though this study failed to identify it as a correlate. Nonetheless, the fact that children's memory errors contained a large portion of segmental transposition before they started to learn to read indicate that reading could not be the factor that initiated the restructuring process. Rather, reading appears to be a late-coming factor which drives the restructuring process to go further. It takes time for the effect of reading to emerge. As shown by the scatterplot between alphabetic word reading and the proportions of transposition errors at T4 of the preschool age, even though the two variables were significantly correlated, there were still some children who performed poorly on the alphabetic word reading task but already had high proportions of transposition errors. Added on that, the fact that more than one-third of the preschool children could not read a single word written in *Zhuyin fuhao* before T4 may also explain the lack of correlation before T4. It is hard to see why alphabetic word reading stopped to be a correlate of transposition errors after T2 of the elementary school age. One possibility is that the alphabetic word reading measured at earlier times tapped more of the word decoding ability whereas that measured at later times tapped more of the sight word reading ability.

Taken together, the results suggest that reading experience augments, rather than initiates, the segmental restructuring process. The restructuring process seems to undergo long before children have reading experience. Soon after children learn to read printed words, the experience of reading speech through discrete visual symbols appears to further strengthen the restructuring process. The facilitation effect of reading is evident when children's reading ability begins to grow rapidly at the very initial stages of reading acquisition as evidenced by the then correlation between the amount of increase in reading ability and the amount of increase in transposition errors even after controlling for children's vocabulary growth during the same period.

Another interesting finding of the study was that children's phonological memory efficiency began to be associated with the types of errors they made in memory processes at T4 of the preschool age and thereafter until T5 of the elementary school age (except at T4). Correlational analyses showed that the children who operated at a more segmental and thus made proportionally more transposition errors are more likely to have superior verbal memory performance than those who operated at a less segmental level and thus made proportionally fewer transposition errors. Note the transposition variable *per se* is not dependent upon the variable of memory errors since it is a proportion score rather than the raw score.

The association between memory performance and the nature of error types is very interesting for syllabic Chinese. Although the number of syllables in Chinese is limited, it is possible that phonological representations at a syllabic level are less distinct than that at a segmental level. Crude and less distinct phonological representations are probably more difficult to remember, to recall, and to articulate than fine-grained, more distinct phonological representations (Elbro, 1996). Similarly, Fowler (1991) suggested that a segmental representation may enable a child to convert (or "encode") the acoustic signal into a sequence of discrete elements for storage and later reproduction of the correct articulatory shape. In contrast, a syllable-level or word-level encoding, in which a greater quantity of gestural information must be specified, may more readily overload the limited storage system, particularly in the case of phonologically complex items or lengthy strings of nonsense syllables. In other words, a less segmental representation may render it difficult to assign novel stimuli (non-words) into a recoverable representation. If an unfamiliar word can be analyzed and encoded as a string of well-known, refined prototypes of the segmental units it may be easier to represent and reproduce than if it is perceived as one lengthy chunk of gestural information.

Related to our understanding of the nature of phonological representations among Chinese-speaking children is whether tonal features are well integrated with segmental composition as a whole in a syllable. Two relevant views of phonological representations have been put forth. One view asserts that syllables are considered chunks of information in which suprasegmental structure and segmental composition are not represented separately (Dell, Julliano, Govindjee, 1993). In the other view, syllables are represented as abstract frames that are separable from their segmental composition (Costa & Sebastian-Galles, 1998; Dell, 1988; Levelt, 1992; Meyer, 1991; Sevald, Dell, & Cole, 1995; Stemberger, 1990). The former view is more widely held to be true for the phonological representations of Chinese, given that Chinese has a relatively simple syllable structure and not too many distinct syllables (Chao, 1966; Repp & Lin, 1990). However, the findings that tonal features are not an inseparable part of the segments support the notion of syllable as an abstract frame that is separable from its content. If we push our findings concerning tonal structure a little bit further, such findings in fact reinforce the suggestion that subsyllabic segmental representations are available in the memory of Chinese-speaking children. If tonal features are well-integrated with the segments and make reference to the entire syllable, tonal structure of the stimuli would not have been preserved to such an extent when the segments were changed.

Chinese tones may have functions other than discriminating lexical meanings. Indeed, relevant evidence has suggested that the retrieval of segmental phonology is primed by the availability of a word's prosody, variously named as suprasegmenals, metrical information, or word's frame in different theories. Although terminologies differ, prosody specifies at least the word's number of syllables and its accent structure. The priming effect of prosody in word retrieval is demonstrated in a recent study which employed a word-onset gating technique to investigate the role of prosody in word recognition (Cutler & Norris, 1988; Norris, McQueen, & Culter, 1995; Lindfield, Wingfield, & Goodglass, 1999). In this study, spoken words were recognized faster when word onset was colored by prosodic information than when it contained segmental onset information alone. The prosody priming effect is also evident in speech production (Hura & Echols, 1996; Levelt & Wheeldon, 1994). For example, Levelt and Wheeldon (1994) found that words ending in a high-frequent syllable were named faster than words ending in a low-frequency syllable. The differential speed of naming was not an artifact of the effect of word frequency on naming latency. Prosody is postulated as a mechanism which is retrieved in the earliest stages of access to word phonology, serving as a framework on which to assemble the phonological segments (Levelt, 1992, 1994). It is possible that such function is fulfilled by tones in Chinese.

Errors in phonological memory might derive from lapses in auditory perception, imprecise encoding, a limited phonological storage, retrieval problems, or difficulties with articulation. Wherever the errors come from, the present work does not exclude a syllabic representation in favor of a segmental representation. A segmental representation should not be conceptualized as an all or none phenomenon, nor should segmental representations and syllabic representations be regarded exclusive to each other. The two frames may be assigned different weights in different individuals. For some individuals, the constituents are more readily dissociated, providing a highly efficient representational code for encoding, storing, and retrieving phonological structure (especially that of complicated nonwords) in verbal memory. For others, the constituents are just more well-integrated.

The Development of Explicit Phonological Representations

In contrast to the development of implicit phonological representations where segmental restructuring takes place before reading ability develops, the development of explicit awareness of speech sounds at segmental level appears to be dependent on reading experience. The results of the study indicate that children did not attain full development of explicit phonological awareness until they learned to read words written with discrete symbols representing speech segments. However, they could perform quite well on simpler measures of phonological sensitivity tasks. For example, when they were first tested, except one child[1], almost none of the preschool children were able to perform the vowel substitution task. In contrast, only about half of the children could not perform the syllable substitution task and a minimal 5% of the children could not perform the sound detection task. First grade children had basic command over the sound categorization task even though there were a wide range of individual differences. Their performances on sound categorization were better than the chance level, indicating that they did not attack the task by guessing. Thus, explicit phonological representations at subsyllabic level does not emerge spontaneously; rather, it appears to emerge during learning to read. Once children are able to manipulate speech sounds at segmental level, the development of this ability appears to be intimately associated with the ability to read. Such association is demonstrated by the correlation between alphabetic word reading ability and children's performances on the phonological awareness tasks at T4 of the preschool age and at most testing sessions of the elementary school age.

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[1] The child scored eight (out of ten) on the vowel substitution task. The child could not read any *Zhuyin fuhao* symbols nor any words written in *Zhuyin fuhao*. Yet the child could read 40 Chinese characters (the highest of my sample) when children of his age could read an average of 2.5 characters. The effect of character reading experience on the development of phonological awareness is worth further investigation.

In the present study, children's performances on the phonological awareness tasks were affected by two factors. One was the linguistic unit: Bigger units like syllables appeared to be easier than smaller units like segments. The other factor was task demand: Detection appeared to be easier than substitution. In this study, detection could be accomplished by the ability to attend to the similarity between sounds whereas substitution required more than that. It required one to segment a unit from the stimulus and hold the remaining part of the unit in memory while adding another unit into the empty slot. It explains well why in the present study children's sound detection ability developed earlier than the syllable substitution ability, which developed earlier than the vowel substitution ability. The findings are consistent with the findings from other studies in that manipulating speech sounds at the subsyllabic level is extremely difficult to preschool children but relatively easy to children who have had certain amount of alphabetic reading experience (Liberman, Shankweiler, Fischer, and Carter, 1974; Magnusson & Naucler, 1993; Wimmer, Landerl, Linortner, & Hummer, 1991).

Recall that our preschool children made proportionally more errors of transposition than errors of entire syllable misordering on the phonological memory task. This suggests that subsyllabic units were already available to the children of this age during language processing. Thus, our preschool children seemed to have developed subsyllabic representations without developing a concept of subsyllabic units that could be used in any kind of mental manipulation.

So far the data on preschoolers does not exclude the possibility that the development of explicit phonological representations depends on the development of implicit phonological representations. One may argue that the implicit subsyllabic representations available to preschoolers were just not sufficiently decomposable for them to develop explicit subsyllabic representations. If preschool children's phonological representations can be decomposable as first grade children, they may develop the ability to explicitly control speech sounds at the subsyllabic level. After all, first graders appeared to have more implicit subsyllabic representations and at the same time were more able to manipulate the subsyllabic components of speech sounds. This view seems reasonable but is not supported by the findings of the study. Children's performances on the phonological awareness task were not determined by the extent the implicit representations were or could be decomposed. The issue is further elaborated in the following section.

The Interaction Among Explicit/Implicit Representations and Reading Experience

How do explicit/implicit phonological representations and reading experience interact? If the development of explicit phonological representations depends on the development of implicit phonological representations, the measures of these two representations should be related to each other. The lack of correlation between phonological awareness and memory error types suggests that the development of implicit phonological representations does not play a determining role in the development of explicit presentations. First grade children who made larger proportions of transposition errors on the phonological memory task did not appear to be equipped with better ability to categorize sounds according to their subsyllabic components. This is also true the other way around. Children who were more able to manipulate speech sounds at the subsyllabic level were not necessarily those who had more decomposable implicit representations. How can the lack of synchronicity in developments be explained?

The notion of modularity can contribute to a better understanding of the gap in developments between implicit and explicit representations. Modular systems are usually conceptualized as those that are fast, automatic, and informationally encapsulated (Fodor, 1983; Liberman & Mattingly, 1985; Stanovich, 1992). The latter is the most important aspect of modularity. Encapsulation means that a module is self-contained. The process taking place in the module is not penetrable by higher-order cognitive processes such as context, strategies, and expectations. It is the output of the module that is influenced. For children of first grade age, a highly subsyllabic representation may be generated within the language module as to identifying words (or nonwords), remembering them and pronouncing them. Yet such a representation is not accessible or recoverable for one to solve the phonological awareness task at the subsyllabic level.

Then how could the notion of modularity account for the development of explicit phonological representations? It should be noted that the notion of modularity did not exclude the possibility that the explicit representations can be elaborated through other cognitive growth. Correlational analyses showed that first graders' performances on the phonological awareness task were related to alphabetic word reading ability. This correlation could be the result of the facilitation effect that phonological awareness has exerted on reading. Yet this interpretation still leaves unanswered the question of how phonological awareness emerges in the first place. The preschoolers in the present study could not read any words written in *Zhuyin fuhao* when they were first tested and had great difficulty solving the vowel substitution task which requires explicit awareness of the sound structure at the segmental level. Virtually all of them attained zero in substituting vowels, a contrast with first graders who attained 7.72 in the sound categorization task when they were first tested, suggesting that reading experience also plays a role in the development of explicit phonological representations. Alphabetic word reading experience makes the structure of words clear: Spoken words contain phonemes; written words contain discrete symbols corresponding to phonemes. Thus, the old familiar words written in discrete letters or *Zhuyin fuhao* symbols provide a new way to represent the phonology of the word and at the same time help develop extra-modular strategical processes for explicit manipulation.

By the account of modularity, the picture is getting clear regarding the relationship among the developments of implicit/explicit phonological representations and reading experience. Here we have implicit phonological representations, which are self-contained, informationally encapsulated and not accessible through conscious control (Fodor, 1983; ; Liberman & Mattingly, 1985; Stanovich, 1992). The implicit representations undergo restructuring from a more holistic syllabic unit to a more discrete subsyllabic unit probably due to the increase in vocabulary and reading experience. The output of the module which operates on the implicit phonological representations is open to consciousness. For nonreaders or prereaders, the subsyllabic constituents of the syllable are hidden under the global representations of the output and could not be freely accessed and manipulated unless certain strategies are learned. The strategies, as far as we can know, are best learned through printed words which represent the hidden subsyllabic components with discrete units.

Given this, the segmentation process triggered by reading experience within the language module may increase the efficiency in language processing as evidenced by the correlations between overall memory performance and memory error types. However, the segmentation process taking place within the module does not have a direct effect on the output of the module. The output of the module can certainly be segmented by the extra-modular strategical processes developed along with reading acquisition. But as the module is impenetrable, the strategical process is operated on the output rather than on the content within the module. Thus, reading experience may have independent effects on implicit and explicit representations. One piece of evidence for this comes from illiterate adults who normally do not have explicit subsyllabic representations when their implicit presentations are believed to involve subsyllabic units. Another piece of evidence is that the segmentation process on implicit phonological representations and that on explicit phonological representations did not develop in tandem in the present study.

In sum, this is among the first studies which demonstrate the developmental restructuring of phonological representations among Chinese-speaking children. The present work suggests that the syllable representation of Chinese-speaking children is not a cohesive unit and is or can be subdivided into smaller units. The development of implicit segmentation may start much earlier than the time examined in this work. Yet, the developmental course is very likely to be partly (or largely) driven by reading experience. The development does not appear to unfold at a constant pace but with a bigger jump in the initial stages of reading acquisition and a more slow, gradual unfolding in later stages. Likewise, explicit phonological representations become more decomposable with the growth of reading experience. A more segmental explicit representation seems to develop only in alphabetic word reading experience. It is not the natural outcome of the segmental restructuring process taking place in implicit phonological representations.

Finally, while it is suggested that one of the forces that drive phonological representations to be more segmental derives from reading experience, there is reservation as to the interpretation of the results of the study. Given the developmental nature of the study, any observed changes after formal reading instruction begins can be spurious and reflect nothing but a common factor of cognitive maturation. One way to resolve the problem is to introduce a group of first graders who do not have any reading experience. However, such a control group is hard, if not impossible, to obtain in Taiwan. Another way to disentangle the age-related effects from the experience-related (e.g., schooling) effects is to adopt a natural experiment using “school cut-off methodology” as suggested by Bowey and Francis (1991), Ferreira and Morrison (1994), and Morrison, Smith, and Dow-Ehrensberger (1995). This method takes advantage of the fact that children whose birth date precedes some specified date (e.g., September 1 in Taiwan) are allowed to go to first grade whereas other children who just miss the cutoff are not. These two groups are theoretically matched in cognitive maturation but will differ in the amount of reading experience. By comparing the degree of change in phonological representations from pre- to post-test in children who just make versus those who just miss the cutoff, one can assess the impact of the reading experience on the restructuring of phonological representations more conclusively. As phonological memory has been shown to be important to a variety of language performances, research adopting different methodological philosophies is needed to substantiate and consolidate the findings of the present study.

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行政院國家的科學委員會之專題研究計畫成果報告

隱性與顯性音韻表徵：
閱讀經驗之角色 (II)
Implicit versus Explicit Phonological Representations: The Contribution of Reading Experience (II)

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