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Novel-word learning deficits in Mandarin-speaking preschool children with specific language impairments

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ABSTRACT

Children with SLI exhibit overall deficits in novel word learning compared to their age-matched peers. However, the manifestation of the word learning difficulty in SLI was not consistent across tasks and the factors affecting the learning performance were not yet determined. Our aim is to examine the extent of word learning difficulties in Mandarin-speaking preschool children with SLI, and to explore the potent influence of existing lexical knowledge on to the word learning process. Preschool children with SLI ($n = 37$) and typical language development ($n = 33$) were exposed to novel words for unfamiliar objects embedded in stories. Word learning tasks including the initial mapping and short-term repetitive learning were designed. Results revealed that Mandarin-speaking preschool children with SLI performed as well as their age-peers in the initial form-meaning mapping task. Their word learning difficulty was only evidently shown in the short-term repetitive learning task under a production demand, and their learning speed was slower than the control group. Children with SLI learned the novel words with a semantic head better in both the initial mapping and repetitive learning tasks. Moderate correlations between stand word learning performances and scores on standardized vocabulary were found after controlling for children's age and nonverbal IQ. The results suggested that the word learning difficulty in children with SLI occurred in the process of establishing a robust phonological representation at the beginning stage of word learning. Also, implicit compound knowledge is applied to aid word learning process for children with and without SLI. We also provide the empirical data to validate the relationship between preschool children's word learning performance and their existing receptive vocabulary ability.

1. Introduction

Children with apparent language deficits, but without neurological, sensorimotor, or nonverbal cognitive deficits are called specific language impairment (SLI; Leonard, 1998). Many children with SLI demonstrate deficits in vocabulary development, such as late talking, smaller and less variety of vocabularies, and word finding problems (Leonard & Deevy, 2004). Vocabulary development deficits are particularly devastating in young children because lexical acquisition is strongly associated with oral and written language development (Catts, Fey, Tomblin, & Zhang, 2002; NICHD Early Child Care Research Network, 2005). Therefore, researchers and clinicians are working to understand the word-learning process in children with SLI and the factors that influence the learning process. However, the manifestation of the word-learning

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difficulty in SLI is not consistent across tasks and the factors affecting learning performance have not been determined. In designing an effective intervention program, it is necessary to identify the specific deficits and factors that influence the learning process. This study examines word-learning difficulties in Mandarin-speaking preschool children with SLI and explores the influence of existing lexical knowledge on the word-learning process.

1.1. Novel-word learning in SLI

Word learning is the process of lexical acquisition, including initial form-meaning mapping of new lexical items and continued learning through further exposure to various contexts. Three-year-old children can acquire a novel color word after being exposed to the word once in the classroom (Carey & Bartlett, 1978). Because this fast-mapping ability has been observed in typically developing children as young as 13 months old, this ability may be related to the vocabulary spurt during the second year of a child's life (Kay-Raining Bird & Chapman, 1998; Schafer & Plunkett, 1998). In addition to the early onset of emergence, studies have shown that fast mapping in children becomes increasingly mature and efficient during the preschool years (Mervis & Bertrand, 1994; Wilkinson, Ross, & Diamond, 2003), suggesting that this ability is still developing in early childhood.

In experiments that test fast mapping in children with SLI, children are usually presented with novel words that are embedded in sentences within certain contexts (e.g., a play situation) denoting novel objects. Their ability to comprehend or produce the target words is then tested. In the comprehension test, children are asked to select the corresponding object when they hear the novel word stimuli (by using a real object or picture). A naming task is used to test children's production of a novel word. Dollaghan (1987) used a game to test the ability of children with SLI to fast-map one novel word and found that preschool children with SLI comprehended the single novel word as well as their age-matched peers, but produced fewer of the word's phonemes than children with typical language development. This suggests that for children with SLI, the phonological representation of a novel word may be sufficient for them to distinguish the words from alternative options in the comprehension task. However, the stronger or more complete representation required to fulfill the production task was not established. In a series of studies examining fast-mapping abilities in preschool children with SLI, children were presented with four novel word–object pairs three times and asked to perform comprehension and production tasks (Gray, 2003, 2004, 2005, 2006; Gray & Brinkley, 2011). Although the studies produced marginally inconsistent results, children with SLI generally performed as well as their age-matched peers in the comprehension or production tasks, which contradicts the conclusion reached by Dollaghan (1987).

Based on the clinical need, researchers have also attempted to establish the instructional components for vocabulary intervention programs. This has been explored by examining the word-learning process with the supported learning context (SLC) provided (Gray, 2003, 2004, 2005; Kiernan & Gray, 1998). Therefore, SLC word-learning tasks involve more word presentation, and these studies administered various intervention strategies – including models, prompts, and feedback – after the fast-mapping tasks. To achieve the criterion for comprehending or producing a new word, children were required to respond correctly to three of four probes on two of three consecutive word-learning days. Results from studies that have used the SLC paradigm show that children with SLI performed more poorly than their age-matched counterparts at novel word comprehension and production beyond the initial fast-mapping stage, because they learned fewer words and required more trials to achieve the learning criterion.

Unlike typical fast-mapping studies where children receive prompting from adults to attend to new words, Rice, Buhr, and Nemeth (1990) introduced the quick incidental learning (QUIL) paradigm to investigate word learning in preschool children with SLI. In the QUIL paradigm, new words were used to replace common, but general, labels. For instance, "conduit" replaced a word like "hose" in a garden story. The new words were embedded in the sentence and presented in an animated story. Children watched the video without prior notice of the word-learning task. After watching the video, children were asked to select the corresponding picture from four pictures when presented with a target word to assess their comprehension of the new words. As well as the typical fast-mapping studies, the QUIL experiments tested the initial form – meaning mapping ability. However, the paradigm emphasized the incidental nature of the linguistic context of learning support. The results showed that children with SLI retained significantly fewer words than typically developing children matched either by chronological age or by mean length utterance (Rice & Bode, 1993; Rice et al., 1990). More exposure to each new word is also necessary for children with SLI to perform comparably to their matched peers (Rice, Oetting, Marquis, Bode, & Pae, 1994). These studies also examined the relationship between performance on the Peabody Picture Vocabulary Test – Revised (PPVT-R; Dunn & Dunn, 1981) and performance on the QUIL tasks, but no statistically significant correlations were observed.

In brief, studies on word-learning processes have shown that children with SLI exhibit overall deficits in novel-word learning compared to their age-matched peers, but these results are inconsistent across studies and tasks. Because children with SLI have shown deficits in phonological learning skills, such as phonological short-term memory or fine-grained phonological analysis (Archibald & Gathercole, 2006; Bishop, North, & Donlan, 1996; Robertson, Joanisse, & Ng, 2009; Ziegler, Pech-Georgel, George, & Lorenzi, 2011), this suggests that word-learning deficits should be more apparent in production tasks that require complete phonological representations. Although children with SLI tend to perform as well as their age-matched peers in comprehension tasks in fast-mapping settings, they perform worse on QUIL tasks. The task demands in the QUIL paradigm may explain this discrepancy, that is, children must deduce the meaning of new words from their context. Other possible confounding factors may be involved. For example, the story videos were 6–8.5 min long in previous QUIL studies (Rice et al., 1990; Rice, Buhr, & Oetting, 1992; Rice et al., 1994). Therefore, low performance may be caused by other extrinsic factors, such as children's interest and attention spans, rather than their mapping ability. The use of shorter video presentation may reduce the possible interference factors and reveal the true initial mapping abilities of children with SLI. For the production task, a meta-analysis unexpectedly showed that the magnitude of the group difference between SLI and their age peers was less obvious in production tasks than in comprehension and recognition tasks (Kan & Windsor, 2010). However, this result may be mainly driven by the floor effect in the production task for both the control and SLI groups, rather than reflecting the word-learning deficit in children with SLI. The floor effect in production tasks may be caused by the limited number of novel words ($n = 4$) used in the tasks. To solve the problem, a word learning task which provides more repetition and include all the trials in scoring may increase the sensitivity of learning measures. In exploring word-learning deficits in children with SLI, studies with refined methodology should clarify the underlying mechanism of word-learning deficits in children with SLI.

1.2. Effects of lexical knowledge on word learning

Since it was established that children with SLI exhibit word-learning difficulties, researchers have attempted to identify the factors that influence the process. From a word-learning process perspective, children's existing lexical knowledge specific to their native language features should play a role in learning new words. In English, it has been hypothesized that two aspects of lexical knowledge, phonotactic probability and neighborhood density, contribute to the word-learning process. Phonotactic probability refers to the relative frequency with which individual sounds or sound sequences occur in a language. For example, the sounds and sound combinations that appear in the word 'sit' (i.e., /s/, /ɪ/, /t/, /sɪ/, and /ɪt/) are highly likely to occur, therefore 'sit' is an English word with common phonotactic probability (Jusczyk, Luce, & Charles-Luce, 1994; Storkel, 2001). Neighborhood density refers to how many similar sounding words a word has in a language. Neighbors are words that differ from one another by a single phoneme addition, deletion, or substitution in any position (Vitevitch & Luce, 1999). For example, 'mash' has many neighbors (e.g., 'smash', 'ash', 'cash', 'mush', and 'mat'), therefore it exhibits high neighborhood density. However, 'fudge' has few neighbors (e.g., 'judge' and 'fun') and resides in a sparse neighborhood.

Studies have suggested that both aspects of lexical knowledge are involved in learning new words, but each may influence a different component of the learning process. For instance, Storkel, Armbruster, and Hogan (2006) analyzed the effects of phonotactic probability and neighborhood density on partially correct and completely correct responses in adult word learning. They assumed that a partially correct response indicates the initial representation formed in the early stage of word learning, whereas a completely correct response reflects a later stage of word learning where new and existing representations are integrated. Thus, analyzing these two types of responses allows the specific variables that affect learning at each stage to be explored. The results show that phonotactic probability influences partially correct responses; by contrast, neighborhood density influences completely correct responses. These findings led to the hypothesis that words with low phonotactic probability may help trigger new learning, whereas words with high neighborhood density may demand less from working memory, facilitating the integration of new lexical representations with existing representations.

Subsequent studies have demonstrated that unlike adults, preschool children with typical language use converging cues from phonotactic probability and neighborhood density to learn new words (Hoover, Storkel, & Hogan, 2010; Storkel & Hoover, 2010). Children's representations of an existing lexicon may not be as robust and detailed as those of adults, thus they tend to use converging form characteristics to assist in the word learning process. Children with phonological delays, however, do not appear to recruit the same lexical knowledge in the learning process (Storkel & Hoover, 2010). Working memory constraints may make the process of creating a relatively accurate and complete lexical representation too resource-intense, with insufficient resources available for applying multiple cues to the word-learning process. These results suggest that existing lexical knowledge plays an important role in the word-learning process and that children with language problems may not use cues as efficiently as children with typical language development.

1.3. Mandarin word structure and word learning

In discussing the influence of lexical knowledge on child word-learning, specific features of the studied language should be emphasized. In Mandarin, a single syllable generally represents each morpheme (i.e., the smallest unit of meaning). The syllable structure of Mandarin Chinese is relatively simple, with four primary syllable structures: V, CV, VC, and CVC. All syllables in Mandarin are equally stressed and no consonant clusters are permitted. In Mandarin, approximately 7000 characters represent the morphemes in daily use (Li, Anderson, Nagy, & Zhang, 2002). However, the simple syllable structure in Mandarin forms approximately 1200 spoken syllables, even when lexical tone is accounted for (DeFrancis, 1989). Thus, one syllable often corresponds to several separate morphemes. To avoid too many homophones, most words are multisyllabic. Although word length varies, most common Mandarin words are bisyllabic (Taylor & Taylor, 1995). Based on this distinctive lexical feature, the influence of existing lexical knowledge in Mandarin word-learning should be explored within a compound framework. Many Mandarin compound words exhibit right headedness, that is, the right morpheme in a compound word specifies the semantic category and the left morpheme acts as a modifier and identifies the subcategory. For example, the compound words '公園 /kung1 yuan2/' (public area: park) and '花園 /hua1 yuan2/' (flower area: garden) share the head morpheme, '園 /yuan2/'. Therefore, if a child understands a word that ends with '園 /yuan2/', indicating an open area, the meaning of another word, '校園 /shiao4 yuan2/' (school area: campus), is easier to grasp, even if they are unfamiliar with the precise type of open area indicated. Modifier-head compound words account for nearly 60% of the new words that are invented each year (China's State Language Commission, 2010).

Because lexical compounding is the primary word-construction process used in Chinese, researchers have attempted to explore the relationship between awareness of compounds and literacy development in Chinese-speaking children. Two major aspects of compound awareness have been investigated: the ability to identify the head of a compound noun and the ability to construct a new compound word from familiar morphemes. For example, children are asked to answer questions such as, "斑馬 (striped horse: zebra) is a type of horse with stripes on its body. What should we call a cow with stripes on its body?" (The answer is 斑牛: striped cow.) Compound awareness develops relatively early in Mandarin children and improves with age (Chen, Hao, Geva, Zhu, & Shu, 2009). Additionally, children's performance on these tasks explains the unique variance in Chinese vocabulary and character recognition between kindergarteners and second graders (Chen et al., 2009; McBride-Chang, Cheung, Chow, Chow, & Choi, 2006; McBride-Chang, Zhu, Zhou, Wat, & Wagner, 2003). These results suggest that compound awareness is critical to Chinese children's vocabulary development. This word formation method makes Chinese words more analytic and relatively semantically transparent. Children may use this transparency to learn new concepts or recognize associations among words, and a better understanding of the morphological structure of words should facilitate children's abilities to decipher, encode, and remember the meanings of unfamiliar words. To the best of our knowledge, no research has directly tested the influence of children's implicit compound knowledge on their word learning. It would also be useful to determine whether Mandarin-speaking children with SLI can apply compound knowledge to the word-learning process at the level of their age-matched peers.

1.4. Purpose of the study

This study examines the manifestation of word-learning difficulties in Mandarin-speaking preschool children with SLI. We used a QUIL format because it favors the incidental and authentic nature of this paradigm. We tested children's abilities to extract the meaning of a word after one exposure to that word in a story context. The length of video presentation is shortened to reduce possible influences from children's motivation and attention. We also designed a repetitive learning task to test children's abilities to produce novel words after intensive short-term exposure. Although both tasks in this study accessed children's form-referent mapping abilities in the initial stage of word learning, their emphasis differs according to the type of information the children provided in their responses. The first task was incidental in nature and children were only required to form a partial phonological representation to fulfill the comprehension task. By contrast, the repetitive learning task is more similar to a short-term training paradigm, where the children are informed of the word learning purpose. To obtain a full score on the production task, a child had to establish a complete phonological representation. We expected that children with SLI would retain their fast-mapping abilities and that their deficits would mostly appear in the production task.

This study also examines the influence of existing lexical knowledge on the word learning process in children with and without SLI. Two lexical properties of Mandarin compound word stimuli were manipulated: the syllable length and the addition of a semantic head to the word stimulus. The research determines whether Mandarin-speaking children with typical development or language impairment could use the semantic cues provided by compound morphology to aid their word learning processes. We expected that syllable length would affect the production task and that adding a semantic head would benefit initial mapping and repetitive naming. Children's existing lexical knowledge should affect the relationship between their oral vocabulary ability and word-learning performance. However, previous word learning studies have not found a stable relationship between children's fast-mapping performance and their oral vocabulary ability (indicated by the PPVT score). We use the cumulative measures by adding correct responses in each test phases in the repetitive learning task. By modifying the word-learning task design, we attempted to provide more sensitive learning measures and test the correlation between children's oral vocabulary and their novel word learning performance.

2. Method

2.1. Participants

Thirty-seven Mandarin-speaking preschool children with SLI (SLI group, 29 boys) and 33 children with typical language development (TLD group, 21 boys) participated in this study. The mean age of the SLI group was 65.4 months (SD = 6.5) and 65.6 months for the TLD group (SD = 6.7). The children in the two groups were recruited from local public and private preschools or through an ongoing longitudinal study on late-talking children, which was conducted by the Infant Language Laboratory at the National Taiwan Normal University. All children exhibited normal hearing sensitivity and none had a history of cognitive, emotional, and social disorders or delays, according to parental reports. The education level of the children's mothers was investigated using a 6-point scale (1, elementary school; 2, junior high-school; 3, senior high-school; 4, college; 5, university; and 6, master's degree or above). No significant differences existed between the average chronological ages, gender distributions, and maternal education levels of the two groups ($p > .05$). Of particular relevance to the purpose of this study, language-match group were not included because of the numerous problems that this methodology introduces (Plante, Swisher, Kienan, & Restrepo, 1993). The potential cognitive and attentional differences

Table 1
Scores[a] on language and cognitive measures for SLI ($n = 37$) and TLD ($n = 35$) groups.

	CLDS-AC[b]	CLDS-EC[c]	PPVT-R	Articulation	TONI-3
SLI Mean (SD)	28.7 (9.1)	32.4 (7.9)	95.9 (10.8)	31.7 (5.4)	96.3 (8.8)
TLD Mean (SD)	53.2 (5.9)	50.1 (5.0)	113.6 (12.6)	35.0 (2.6)	102.7 (10.2)

Notes: CLDS-R = Child Language Disorder Scale – Revised (preschool and school children versions: Lin, Huang, Huang, & Hsuan, 2008, 2009); PPVT-R = Peabody Picture Vocabulary Test – Revised (Lu & Liu, 1998); TONI-3 = Test of Nonverbal Intelligence, 3rd Edition (Wu et al., 2006).
[a] *t*-Score in CLDS; standard score in PPVT-R and TONI-3; number of correct responses in articulation test (total = 37).
[b] Auditory comprehension subtest.
[c] Expressive communication subtest.

arising from matching younger typically developing children to older children with SLI would likely affect performance on the word learning tasks employed.

All participants completed a series of standardized language and cognitive tests to determine their eligibility for participation. All participants achieved a standard score above 85 on the Test of Nonverbal Intelligence, 3rd Edition (TONI-3). Children's overall language performance and receptive vocabulary are tested using Child Language Disorder Scale-Revised (CLDS-R, in Chinese) and PPVT-R. The CLDS-R is a norm-referenced test with good test-retest reliability and validity, and has been widely used for clinical screening and assessment in Taiwan. The test comprises two core subtests: auditory comprehension and expressive communication, assessing children's language comprehension and expression in semantic, syntactic and pragmatic domains. Two additional subtests evaluate children's voice quality and articulation abilities. The score in the articulation subtest was used as an index of a child's articulation ability in this study. To be included in the study, children with SLI were required to score lower than 1 SD below the mean on both the auditory comprehension and expressive communication subtests of CLDS-R. Table 1 shows the language and cognitive measures for the two groups. The SLI group achieved significantly lower scores than the TLD group on all measures at the $p < .05$ level.

2.2. Stimuli and design

Two sets of novel words were created to be used in separate stories. Each set consisted of six novel words, including two 2-syllable words, two 3-syllable words, and two 3-syllable words with a semantic head. Each novel word was formed by legal syllables in Mandarin. Because most monosyllable in Mandarin represent one morpheme, to reduce possible semantic interference from the morpheme level, each syllable has less than four homophones. Phonemes that develop late in childhood (Cheung & Hsc, 2000) were not included in the word list, to reduce the pronunciation load. An unfamiliar object was selected as the referent for each novel word. Appendix A shows the novel words and the corresponding objects used in the study.

The novel words were presented in a story, based on the QUIL format of word-learning tasks. The two story scripts used were '*The Missing Pencil*' and '*Our Colorful World*,' selected from the teaching websites of the BBC and the British Council in Taiwan, respectively. The stories were modified and translated into Mandarin, and recorded by a female native-Mandarin speaker. Each set of six novel words was presented in a separate story, with each novel word embedded in a sentence and only occurring once in the story. No explicit definitions of the words were provided, but semantic information could be deduced from the linguistic or pictorial context. The story was presented as a PowerPoint slide show with simple animation and a pre-set sound file. Each story was approximately 2.5 min long.

2.3. Word-learning task

Children were asked to watch and listen to the story without being informed about the word-learning task. The tests were administered immediately after the story was presented. The word-learning task comprised three parts: initial mapping, story content understanding, and short-term repetitive learning. A picture-selection task was used to test children's initial mapping abilities. A sound clip of a novel word was played and children were asked to select the corresponding object from four pictures on a screen. The four pictures represented the target word and three distracters, including another target word from the story, a familiar object that appeared in the story, and an unrelated novel object without a real name. A practice trial with a real object (*umbrella*) was used to familiarize the children with the procedures. After the initial-mapping test, a story content understanding task containing three basic questions on the story content were administered. The use of this task is to ensure that children are engaged in the story and have basic understanding about the content.

The short-term repetitive learning task was administered last, with a 2-min break before it began. The same exposure-test procedure was repeated ten times in this task. In the exposure phase, the six novel objects appeared individually on a screen with their corresponding names played through a loudspeaker. Children were asked to remember the pair. After the exposure, each novel object was individually presented on the screen and the children were asked to name the object. All the words were randomly presented. The children's responses were not limited by time in the test phase. If a child could not name an object, the experimenter encouraged the child, but no feedback was given whether he or she had given the correct answer. Children's responses were recorded using a stereo IC recorder.

All the stimuli in the word-learning task were presented and controlled with a laptop and E-prime software (Psychology Software Tools, Pittsburgh, PA). The word-learning task required approximately 20 min. Children were tested in a quiet room in a school or laboratory. The order of the two story scripts was counterbalanced across participant order. The two word learning tasks were administrated in two separate sessions, which were scheduled within 2 weeks of each other.

2.4. Scoring and data analysis

The word-learning measures were calculated by adding the scores from the two word-learning tasks. Initial mapping and story content understanding scores were converted into proportion-correct measures to indicate the accuracy rate. For the short-term repetitive learning task, a novel word was scored as completely correct if a child produced all of the target phonemes in the correct order. Correct responses reflect a complete and accurate representation of the novel word. Two word-learning measures were calculated: the number of correct responses in each test phase and the cumulative score of the correct responses from previous test phases. Another experimenter, who was blind to the participant language groups, scored 20% of the participant responses to the production of novel words in the repetitive learning task. A Pearson correlation was used to estimate the inter-rater agreement for the coding. The level of agreement for the total cumulative number of correctly produced words was 97%.

Statistical analyses were performed using word-learning measures as the dependent variables in an analysis of covariance (ANCOVA), with novel word type (2 syllable, 3 syllable, or 3 syllable with a semantic head) as the within-subject variable and group (SLI or TLD) as the between-subject variable. The covariates included the child's age (in months), nonverbal IQ, and articulation ability. Because a larger nonverbal IQ gap between SLI and age-matched groups is associated with a larger word-learning performance group effect (Kan & Windsor, 2010), the standard score in TONI-3 was used as a covariate to mitigate the influence of the nonverbal IQ gap. Children's articulation scores were also used as repetitive learning covariates because of the expressive nature of the task. A Pearson correlation was also used to examine the relationship between children's novel-word learning performance and their oral vocabulary comprehension ability (PPVT raw score), after controlling for their age and nonverbal IQ.

3. Results

3.1. Initial mapping task

Children's basic understanding of the story content is examined first. The mean accuracy rates of the SLI and TLD groups were 0.82 and 0.96 (SD of 0.18 and 0.1, respectively). Results showed a significant group effect ($F(1,66) = 9.87$, $MSE = .22$, $p = .003$, $\eta_p^2 = .13$), suggesting that the ability to deduce the overall meaning of a story is poorer in children with SLI. For the initial mapping abilities, mean accuracy for each novel word type from the two children groups is shown in Table 2. No significant group difference emerged after controlling for age and nonverbal IQ ($F(1,66) = 3.695$, $p = .06$). Although children with SLI showed poorer story content understanding, it did not affect how they extracted the meaning of novel words from the story. For the word type, there was a main effect of word type ($F(2,136) = 39.06$, $MSE = .05$, $p < .001$, $\eta_p^2 = .37$), showing that children were more accurate when novel words had a semantic head. The word type by group interaction was not significant.

The frequency of error choices of the two groups is shown in Table 3, demonstrating that children's choice is not limited to the specific kind of distracter in the test. The converging results from the accuracy and error pattern analyses suggest that, after controlling for age and nonverbal IQ, children with SLI performed as well as their age-matched peers in the initial-mapping task. That is, both groups of children used the semantic head cue in the form-meaning mapping process.

3.2. Repetitive learning task

The mean correct response from each test phase for SLI and TLD groups is shown in Fig. 1. Results from ANCOVA showed the significant group main effect ($F(1,65) = 25.17$, $MSE = 14.58$, $p < .001$, $\eta_p^2 = .28$) and interaction between the test phase and group ($F(9,585) = 5.59$, $MSE = .89$, $p < .001$, $\eta_p^2 = .08$). A post hoc comparison showed that the group effect was significant in each test phase ($F(1,65) = 11.93$, 11.63, 4.97, 12.52, 13.81, 12.71, 22.82, 27.32, 30.46, 23.03, $ps < .05$). Using the cumulative score as dependent variable revealed a similar pattern, with a significant group main effect ($F(1,65) = 20.63$, $MSE = 367.51$, $p < .001$, $\eta_p^2 = .24$) and interaction between the test phase and group ($F(9,585) = 23.02$, $MSE = 17.05$, $p < .001$, $\eta_p^2 = .26$).

Table 2
Initial mapping (proportion correct) to novel word types.

	2-Syllable	3-Syllable	3-Syllable with head
SLI Mean (SD)	0.53 (.23)	0.44 (.26)	0.80 (.23)
TLD Mean (SD)	0.59 (.30)	0.61(.29)	0.87 (.15)

Table 3
Frequency distribution of error choice in the initial mapping task.

	Another target in story	Familiar object in story	Novel object without name	Total
SLI	69 (38%)	36 (20%)	79 (43%)	184 (100%)
TLD	51 (40%)	30 (24%)	45 (36%)	126 (100%)

Because the range of mean correct responses in each test phase was narrow (0.46–3.64), the cumulative number of correct responses was used in the following analysis to explore the effect of word type. The children's learning performance for different types of words is shown in Fig. 2. Results show that main effects of word type ($F(2,136) = 24.9$, $MSE = 16.79$, $p < .001$, $\eta_p^2 = .27$), group ($F(1,68) = 36.63$, $MSE = 50.35$, $p < .001$, $\eta_p^2 = .35$), and word type by group interaction ($F(2,136) = 4.01$, $MSE = 16.79$, $p = .02$, $\eta_p^2 = .06$) were all significant.

To test the source of the interaction, a one-way ANOVA was used to compare the effect of word type on each group. The results show that word type exhibits a significant main effect on both the TLD ($F(2,64) = 15.16$, $MSE = 25.57$, $p < .001$, $\eta_p^2 = .32$) and SLI groups ($F(2,72) = 8.94$, $MSE = 8.99$, $p < .001$, $\eta_p^2 = .2$). In the TLD group, post hoc analysis using a Bonferroni comparison shows that no significant difference exists between the total cumulative number of correct responses to 2-syllable words and 3-syllable words with semantic heads ($p = .091$), and both produced more correct responses than the 3-syllable words ($ps < .005$). In the SLI group, the post hoc results show that 3-syllable words with semantic heads produced higher scores than 3-syllable words ($p < .001$).

In sum, results from the short-term repetitive learning task suggest that children with SLI learned fewer novel words than children with TLD. Children with SLI also exhibited slower learning rates, reflected by the gap between the two groups which increased with the test phases. However, both groups benefited from the information provided by the semantic head when learning novel words.

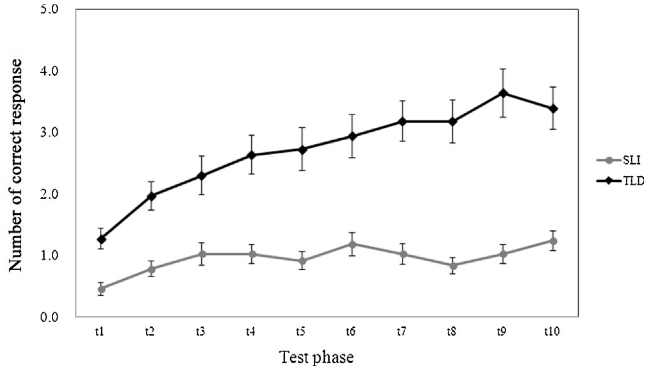

Fig. 1. Mean number of correct responses in each test phase in short-term repetitive learning task by SLI and control group (error bar = 1 s.e.).

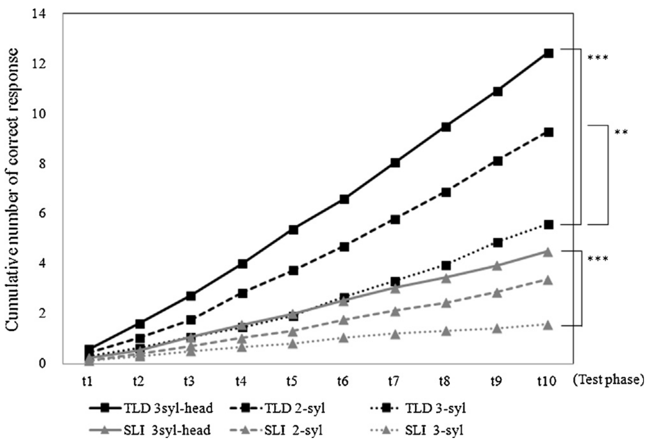

Fig. 2. Mean cumulative number of correct responses to different novel word types in short-term repetitive learning task by SLI and control group (*$p < .05$, **$p < .01$, ***$p < .001$).

3.3. Correlations between word learning and vocabulary ability

We also examined the relationship between children's existing oral vocabulary comprehension ability and word-learning performance. The PPVT raw scores were significantly correlated with the proportion of correct responses in the initial-mapping test ($r = .543$, $p < .001$) and the total cumulative number of correct responses in the repetitive learning task ($r = .451$, $p < .001$). These correlations remained significant when controlling for age and nonverbal IQ ($r = .488$, .380, $p < .001$).

4. Discussion

This study explores the extent of word-learning difficulties in Mandarin-speaking preschool children with SLI. We designed two equivalent word-learning tasks to test initial mapping and short-term repetitive learning. Children's age and nonverbal IQ were controlled in all the group comparisons. This study used novel-word stimuli with different Mandarin compound features to examine how children's implicit lexical knowledge influences their word-learning performance. We also tested the correlation between children's existing receptive vocabulary abilities and their word-learning processes.

4.1. Word-learning difficulty and SLI

For the word-learning task, we adopted a QUIL paradigm by presenting novel words in meaningful contexts and testing children's initial word-object mapping abilities. In the QUIL task, children were required to identify the novel words in a linguistic context, use limited contextual information to infer their meaning, and form an initial phonological and semantic representation of the words to successfully complete the comprehension test. The results show that preschool children with SLI performed comparably to their age-matched peers in the initial-mapping comprehension test, even when they did not fully remember and understand the story content.

This result is inconsistent with previous QUIL studies, which found that children with SLI tend to perform worse than their age-matched peers. In our study, the mean accuracy rate for the SLI group's comprehension test was higher than that reported in the literature, which has shown that children between the ages of 5 and 7 years old with SLI exhibited an average accuracy from 0.18 to 0.39, even when novel words presented in a video were repeated (Oetting, Rice, & Swank, 1995; Rice et al., 1990, 1994). Distraction or a lack of interest in a relatively long story presentation may have caused this low performance. We modified the task by using a 2.5-min long story, thus reducing possible interference factors. Another possible source of the difference is that we only used six words in each story. This may have reduced the memory load for the preschool children. However, this initial-mapping memory constraint hypothesis must be verified by a direct comparison that applies different stimuli to the same group of children. Moreover, the mean accuracy level for the TLD group in this study was 0.69, reflecting an ability to extract meaning from context and create an initial form is still being developed in early childhood. Future studies should systematically investigate this ability and its underlying mechanism.

We also used a repetitive learning task to test children's abilities to produce novel words after a short-term training. This task allowed us to observe the learning process in the two groups. The results show that children with SLI learned fewer words than their age-controlled TLD peers in each test phase of the repetitive learning task. In a production task, children must establish a complete phonological representation of a word to accurately recall it. Criddle and Durkin (2001) have found that children with SLI were less able to form fully specified phonological representations of morpheme, as reflected by having difficulty detecting small phonological changes in newly learned morphemes. Also, Nash and Donaldson (2005) showed that children with SLI improved significantly less at naming tasks when they were exposed to new words, suggesting that the main word-learning barrier to children with SLI is establishing a phonological representation. Our results show that children with SLI exhibit good initial mapping, but are worse at repetitive production tasks than their age-matched peers. This provides supporting evidence that the word-learning deficit in children with SLI is phonologically based. Since children with SLI have shown extensive and persistent deficits in phonological processing deficits (Vandewalle, Boets, Ghesquière, & Zink, 2012), future studies could explore the training effect of children's wide range of phonological processing abilities on their word-learning performance.

Our study also found that the learning-performance gap between the two groups increased as the number of test phase trials increased. This is consistent with the conclusions of a recent meta-analysis (Kan & Windsor, 2010). The effect of exposure on learning performance demonstrates that children with SLI exhibit slower word learning than TLD children. Rice et al. (1994) showed that children with SLI require more exposure to learn a new word. Our task provided repeated exposure and multiple retrieval opportunities during the test phase. Multiple retrievals may enhance the ability to learn novel words (Karpicke & Roediger, 2008). Because children with SLI did not benefit from a repeated learning context as much as their age-matched peers, the short-term repetitive learning paradigm used in this study could be used to determine optimal learning contexts – such as how to expose children to words, practice spacing, test forms, and the number of repetitions required based on children's vocabulary levels – to develop effective interventions to improve word learning in children with SLI.

4.2. Influence of lexical knowledge on word learning

Based on the features of Mandarin words, we manipulated the syllable length and the modifier-head compound word structure. The results show that syllable length did not affect children's initial-mapping performance. However, children in the TLD group learned 2-syllable and 3-syllable words differently in the production task. This difference did not occur in the SLI group, probably because of the limited range of the word production scores. These results suggest that syllable length does not make the initial-mapping process more difficult. Rather, stimuli with various syllable lengths may provide differential cues in the coarse phonological representation of the words. For instance, early studies on the tip-of-the-tongue phenomenon have shown that the response to the number of syllables in words that participants cannot correctly recall was above the level of chance (Brown & McNeill, 1966), showing the number of syllables in a word provides basic phonological information on a word. Our results show that children with SLI may be able to grasp the basic phonological information of a new word in the initial stage.

The effect of modifier-head structure knowledge on word-learning performance showed that Mandarin-speaking preschool children learned novel words with semantic heads better in both the initial-mapping and repetitive learning tasks. Because Chinese words are more semantically transparent than English words, Mandarin-speaking children may use this transparency to learn new concepts or to recognize associations among words. Thus, semantic information can help children exclude irrelevant answers in the picture-selection portion of the initial-mapping task. The repetitive learning task results indicated that knowing the modifier-head structure may reduce children's memory loads in the semantic domain and release more resources to process the detailed phonological information from the unfamiliar word. Our results show that children with SLI applied their implicit lexical knowledge to facilitate producing an unfamiliar new word in the learning task. Because the literature rarely discusses the influence of lexical knowledge on word learning from a morphological aspect, the compound structure of Mandarin was used as a tool to explore this issue. A more complex compound structure could be used to examine the possible levels of influence on the word-learning process.

4.3. Relationship between word learning and existing vocabulary

As well as their lexical form knowledge, children's existing semantic knowledge should also contribute to the word-learning process. Our results showed that children's raw PPVT scores are moderately correlated to their initial-mapping and repetitive learning performances. Previous studies have not consistently found a correlation between word learning and existing vocabulary because of the limited range of preschool children's performance (Gray, 2003; Kiernan & Gray, 1998; Rice et al., 1990). By using the cumulative number of correct responses, we increased the individual variation range of the word-learning performances. Another benefit of using cumulative measure was to include all the successful trials during the learning process instead of setting an arbitrary learning criterion, as conducted in previous studies. It is noteworthy that children's recently learned words and existing vocabularies share a reciprocal interaction relationship (Gaskell & Dumay, 2003), and the correlations found in this study should be treated as groundwork. Future studies that use a longitudinal design could provide insight into the interaction and accumulated processes in vocabulary development.

5. Conclusion and implications

This study shows that after incidental exposure to novel words in a story context, Mandarin-speaking preschool children with SLI performed similarly to their age-matched peers in the initial form – meaning mapping task. Their word-learning difficulties only emerged in a short-term repetitive learning task that required word production, and their learning speed was slower than that of the control group. These results suggest that word-learning difficulties in children with SLI occur while establishing a robust phonological representation at the beginning of word learning. Our tests on the influence of lexical knowledge show that children with and without SLI use their implicit compound knowledge to aid the word-learning process. The data also show that preschool children's word-learning performance is related to their existing receptive vocabulary abilities.

In terms of clinical implications, researchers have attempted to use the processing-dependent word-learning measures as a dynamic assessment measure in SLI groups (Burton & Watkins, 2007; Hasson & Botting, 2010). By refining the QUIL procedures, our task design provides a possible method for testing children's word-learning performance. Our findings also emphasize the importance of providing opportunities for repeated exposure to and testing of new words in intervention programs to enhance the word learning of children with SLI. Explicit teaching on the morphological structure of a new word should also assist children's learning processes. A key intervention component should be developing a child's capacity to learn new words by strengthening or supporting the cognitive mechanisms that contribute to developing lexical representations. Because the word-learning difficulties of children with SLI may be phonologically based, intervention programs incorporated with phonological processing training related to early stages of vocabulary acquisition, such as speech perception sensitivity and phonological working memory, may promote children's vocabulary abilities.

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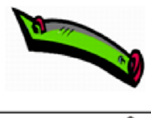
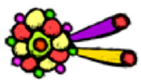
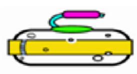
Appendix A. Novel word stimuli and corresponding objects in the word learning task

Script 1: The missing pencil		Script 2: Our colorful world	
novel word	referent	novel word	referent
/ba4 tuɔ1/		/t^{h}aŋ4 fəŋ2/	
/p^{h}a1 maɪ4/		/iɛ3 nʊŋ4/	
/xuan1 kʰɯʌ3 laɪ2/		/tʰiŋ1 mi3 kʰaɪ1/	
/kuan3 ta1 naɪ4/		/kɤʊ1 la4 p^{h}eɪ2/	
/tueɪ4 kən1 nɪau3/ (/nɪau3/: 'bird')		/piən1 tian3 tɕi1/ (/tɕi1/: 'machine')	
/pʰaŋ2 fəŋ4 xua1/ (/xua1/: 'flower')		/uan4 liaʊ4 ʈʂʰɯʌ1/ (/ʈʂʰɯʌ1/: 'vehicle')	

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