Reading and Writing

The Relationship between the Processing of Semantic Relation Information and Morphological Awareness among Hong Kong Chinese Children

--Manuscript Draft--

Manuscript Number:	READ-D-17-00253R1
Full Title:	The Relationship between the Processing of Semantic Relation Information and Morphological Awareness among Hong Kong Chinese Children
Article Type:	Original research
Keywords:	compound-picture matching; morphological awareness; noun-noun combination; relation priming effect
Corresponding Author:	Duo Liu Hong Kong Institute of Education Hong Kong, CHINA
Corresponding Author Secondary Information:	
Corresponding Author's Institution:	Hong Kong Institute of Education
Corresponding Author's Secondary Institution:	
First Author:	ZHENGYE XU
First Author Secondary Information:	
Order of Authors:	ZHENGYE XU
	Duo LIU
Order of Authors Secondary Information:	
Funding Information:	Research Grants Council, University Grants Committee (18404114) — Dr. Duo LIU
Abstract:	In the present study, 151 third-grade Hong Kong children participated in two expression-picture matching experiments (a relation priming paradigm). In this paradigm, an unambiguous prime was first presented, followed by an ambiguous target that could be interpreted with either of two relations (i.e., Descriptor and Possessor). Children were asked to judge which picture matched with the compounds in both the prime and target sessions. The linear mixed model (LMM) analysis was applied to investigate the semantic relation processing in novel ambiguous combination and its relationship with children's performances on morphological awareness tasks. In Exp. 1, the relation priming effect (i.e., children preferred to select the target pictures involving the same relation with the primes) was observed. At the same time, children's morphological awareness showed a positive moderation effect on relation priming. Exp. 2 investigated whether visual features, rather than semantic relations, produced priming effect. The interaction between semantic relation processing and morphological awareness was observed as well in the situation that the hints of visual features were removed. The results indicated that children with skilled morphological awareness, but not the children with less skilled morphological awareness, showed significant relation priming effect, even without the visual cues. Compared to children with less skilled morphological awareness, children with skilled morphological awareness were better in activating semantic relation information when reading compounds. These findings may help us understand the mechanism of the association between MA and Chinese literacy acquisition.
Response to Reviewers:	Response to the reviewers Reviewer #1: Review for MS# READ-D-17-00253 In this study, the authors examined the question of whether the semantic relation priming effect existed in third-grade Hong Kong Chinese children by using the

expression-picture matching paradigm. They further investigated whether such an effect was influenced by morphological awareness. Results revealed that children with good morphological awareness (MA) had a better performance in semantic relation information processing when reading compounds.
In general, this is a paper with interesting research questions relevant to compound reading. The methodology was solid. However, there are some issues needed to reconsider or clarify.
1. My first concern is about the vocabulary of the two groups. If there is any formal assessment of vocabulary in the two groups.

Response: We did not assess children's vocabulary, however, we tested participants' Chinese character reading, and treated their performance of Chinese character reading as the covariate in the data analysis. The performance of Chinese character reading could be an indicator of children's reading at word level. On the other hand, based on the design of the current study, all the stimuli are novel combinations. These novel combinations do not have a close relationship with the daily life vocabulary. Moreover, the nouns in the novel combinations are simple character with high frequency. The novel combinations are presented with the corresponding picture and audio. In other words, the influence of children's vocabulary on the processing of the novel combinations has been well controlled in the present study.

2. My second major concern is about the data analysis. The authors used a grouping design with ANOVA. Whether analyses such as correlation, regression and mediating effect could be used given that the main purpose of this study to examine the relation between MA, semantic relation information processing and compound word reading?

Response: Thanks for your suggestion. In the revised manuscript, we utilize the linear mixed model to study whether the priming effect of semantic relation is significant in Chinese children's word comprehension and the possible relationship between semantic relation processing and children's morphological awareness. By using the linear mixed model, the data from more participants were been involved (the former ANOVA design only included 48 participants, the linear mixed model analysis included 151 participants) and more factors were taken into account. In details, in the models, the proportion of corresponding pictures selected for the target combination was considered as the DV, while the consistency of semantic relation in the prime-target pairs and children's performance of morphological awareness were considered as IVs. At the same time, the models include children's age, non-verbal intelligence, scores of Chinese character reading and phonological awareness, and the frequency and the complexity of the items, as controls. The results were similar with the ANOVA results. To illustrate, both in the concurrent and longitudinal models in Exp.1, the main effect of semantic relation priming and its interaction with morphological awareness were significant (ps < .01). In Exp.2, the main effect of semantic relation priming was not significant either in the concurrent or the longitudinal model. However, the interaction between semantic relation priming and morphological awareness was significant in both the concurrent and longitudinal models (ps < .05). In other words, morphological awareness significantly moderated that semantic relation priming effect, even without the visual cues.

3. Although the expression-picture matching paradigm was advanced, the key result lies in a marginally significant interaction between Priming relation and MA group ($p=0.07$) in experiment 2, with a very weak effect ($\eta p2=0.07$). The data do not provide convincing support for the authors' conclusion. One reason for this might be the small sample size. And there might be a big variation across individuals in children study. The data is thus very difficult to interpret, and might be insufficient for a stand-alone publication.

Response: Thanks for your suggestion, as mentioned before, we utilized the linear mixed model for the data analysis. The results of the linear mixed models of Exp. 1 and Exp. 2 are similar with the results from the ANOVA design. By enlarging the sample size from 48 to 151, we found that the interaction between semantic relation priming and children's morphological is significant rather than marginally significant.

4. What is the role of reading experience? Whether the authors selected children with

poor and good CCR using a similar grouping design and examined whether there was a group difference in the semantic relation information processing?

Response: As mentioned before, we conducted the linear mixed effect models for the data analysis. In order to control the influence of Chinese character reading on the interaction between semantic relation priming and morphological awareness, we treated it as the fixed factor. The results showed that both in the concurrent and longitudinal models of Exp.1 and Exp.2, the main effect of Chinese character reading was not significant (ps > .05).

Reviewer #2: The manuscript is well organized. However I think it has two weakness:
1. The study does not show the novelty. Many studies have showed the positive relationship between morphological awareness and semantic processing in this area. It is not convincing what the knowledge gap is and what the novelty is in this study.

Response: We agree that a number of previous studies have tapped the relationship between morphological awareness and vocabulary and/or reading comprehension in Chinese that are related to the “semantic processing” mentioned in this comment. However, on the one hand, what we focus on in the present study is “semantic relation processing”, rather than “semantic processing”. The former is about the processing of the detailed internal semantic relation of the constituent morphemes of compounds, while the latter is a general term about processing of semantic information. On the other hand, to our knowledge, there have been none studies in either Chinese or alphabetic languages that tapped the relationship between morphological awareness and semantic relation processing, and very few, if any, investigated the semantic relation processing in children. As we mentioned in the manuscript, such a study is interesting because it can help us understand the relationship between morphological awareness and semantic relation processing, and more importantly help us understand the mechanism of the role of morphological awareness in facilitating the learning of compounds in Chinese. Moreover, the results of the current study could also provide some practical suggestions for the children with poor morphological awareness. We found that the visual features could be an effective cue for children to understanding the novel words. With the help of the visual feature, children with less developed morphological awareness could perform as good as the children with more developed morphological awareness. All these could be the evidence of the novelty and significance of the present study.

2. The study design is short of validity. The researchers manually selected good and poor MA group, and examined the relationship with semantic processing in Chinese. The relationship is more intended to be significant. Why do not use the scores of morphological tasks instead?

Response: Thanks for your suggestion. In the revised manuscript, we use the scores of morphological tasks instead of dividing participants into two groups based on their morphological awareness. In addition, we utilize the linear mixed model for the data analysis, which allows all random factors to be considered simultaneously with fixed effects. By using the linear mixed model, the numbers of the participants is enlarged from 48 to 151. We constructed the linear mixed effect models for investigating the relationship between semantic relation priming effect and children’s morphological awareness (we applied the scores of the morphological awareness tasks as the index). At the same time, the models include children’s age, non-verbal intelligence, scores of Chinese character reading and phonological awareness, the frequency and the complexity of the items. The results were similar with the ANOVA design.
To illustrate, both in the concurrent and longitudinal models in Exp.1, the main effect of semantic relation priming and its interaction with morphological awareness were significant (ps < .01). In Exp.2, the main effect of semantic relation priming was not significant either in the concurrent or the longitudinal model. However, the interaction between semantic relation priming and morphological awareness was significant in both the concurrent and longitudinal models (ps < .05). In other words, morphological awareness significantly moderated that semantic relation priming effect, even without the visual cues.

The Relationship between the Processing of Semantic Relation Information and Morphological Awareness among Hong Kong Chinese Children

Zhengye Xu

Duo Liu

The Education University of Hong Kong

Corresponding should be directed to Duo Liu, Department of Special Education and Counselling, the Education University of Hong Kong, 10 Lo Ping Road, Tai Po, N.T., Hong Kong; phone: (852) 2948 8639; email: duoliu@eduhk.hk

Acknowledgements

This study was supported by RGC Grant 18404114 of the Education University of Hong Kong in Hong Kong Special Administrative Region. We thank all the children, their parents and teachers, for their participation.

This is the pre-published version.

Abstract

In the present study, 151 third-grade Hong Kong children participated in two expression-picture matching experiments (a relation priming paradigm). In this paradigm, an unambiguous prime was first presented, followed by an ambiguous target that could be interpreted with either of two relations (i.e., Descriptor and Possessor). Children were asked to judge which picture matched with the compounds in both the prime and target sessions. The linear mixed model (LMM) analysis was applied to investigate the semantic relation processing in novel ambiguous combination and its relationship with children's performances on morphological awareness tasks. In Exp. 1, the relation priming effect (i.e., children preferred to select the target pictures involving the same relation with the primes) was observed. At the same time, children's morphological awareness showed a positive moderation effect on relation priming. Exp. 2 investigated whether visual features, rather than semantic relations, produced priming effect. The interaction between semantic relation processing and morphological awareness was observed as well in the situation that the hints of visual features were removed. The results indicated that children with skilled morphological awareness, but not the children with less skilled morphological awareness,

showed significant relation priming effect, even without the visual cues. Compared to children with less skilled morphological awareness, children with skilled morphological awareness were better in activating semantic relation information when reading compounds. These findings may help us understand the mechanism of the association between MA and Chinese literacy acquisition.

Keywords: compound-picture matching; morphological awareness; noun-noun combination; relation priming effect

The Relationship between the Processing of Semantic Relation Information and Morphological Awareness among Hong Kong Chinese Children

Current research has found that morphological awareness, namely the ability to reflect upon and manipulate morphemes and apply word formation rules in one's language (Carlisle, 2000), contributes to word reading in both alphabetic languages (e.g., Ku & Anderson, 2003, Mahony, Singson & Mann, 2000) and Chinese (e.g., Li, Anderson, Nagy, & Zhang, 2002; Liu & McBride-Chang, 2010; McBride-Chang, Shu, Zhou, Wat & Wagner, 2003). However, as indicated by some researchers, currently the mechanisms underlying their association is still not very clear (Carlisle, 2010; McCutchen & Stull, 2015).

At the same time, there is evidence from English studies that the recent usage of semantic relation information, i.e., a relation structure linking the compound's constituents (Schmidtke, Kuperman, Gagné, & Spalding, 2016), could influence the way adults process novel compounds (Raffray, Pickering, & Branigan, 2007). The results demonstrated that adults could apply semantic relation information in a prime compound to help understand a subsequent novel conceptual combination in expression-picture matching tasks. It should be noted that in addition to the semantic relations, the morphological structure of compounds

also plays a role in connecting morphemes and constructing meaning. In this study, we examined whether Chinese children's morphological awareness could facilitate the processing of semantic relation information when processing novel compounds, in order to investigate the mechanism underlying the association between morphological awareness and Chinese word reading.

It was believed that one reason why morphological awareness is important for word reading is that it could help children analyse morphologically complex words that follow the morphological rules (Nagy & Anderson, 1984; Tyler & Nagy, 1990). For example, in view of derivational morphology, children could know that the word *happiness* is a noun because *ness* is a suffix that indicates the word class as a noun. Knowing some root morphemes and the functions of some affixes would help children understand the meaning of many complex words.

However, when it comes to compound words, analysing the morphological structure may not be adequate for accurate comprehension. For example, when processing the word *cupboard*, knowing that *cup* is a modifier and *board* is a head, and thus this is a modification structure, may be not enough for accurate understanding of the semantic content. On top of

specifying the morphological role of each constituent, one also needs to posit a specific connection between the constituents for an accurate understanding (e.g., the word *cupboard* should be understood as a *board* for storing *cup*, rather than a *board* made of *cups* or a *board* belonging to a *cup*). The processing of semantic relation information is required to provide the additional information above and aid access to meaning (Schmidtke et al., 2016).

Some empirical findings supported the importance of semantic relation information in word processing. For example, Coolen, van Jaarsveld, and Schreuder (1991) found that it took a longer time for Dutch adults to correctly respond to novel compounds (with the same morphological structure, i.e., subordinate) that involve semantic relations rated as highly interpretable (e.g., flu season), while a shorter reaction time was recorded in trials that involve semantic relations rated as less interpretable (e.g., soil key). They demonstrated that the processing of nominal compounds was not solely affected by the grammatical features (i.e., modifier and head) of the compound, but also by semantic relations.

There might be a close relationship between morphological awareness and semantic relation processing in Chinese because more than 75% of Chinese words are compounds (Sun, Sun, Huang, Li, & Xing, 1996), which are formed by combining two or more bound or free

morphemes. In addition, a great number of Chinese compound words are semantically transparent, which means that the meaning of each constituent morpheme contributes directly to the meaning of the compound (Chen, Hao, Geva, Zhu, & Shu, 2009). For instance, the compound word 房門/fong4 mun4/ (door of house), a combination of the morphemes 房 /fong4/ (house) that means house and 門/mun4/ (door) that means door. In addition to the morphological information, which is that 房/fong4/ (house) is a modifier and 門/mun4/ (door) is the head, the information about how the constituents are linked semantically (i.e., semantic relation) also plays a critical role in determining the meaning of the whole compound.

Also, semantic relation information may help Chinese children distinguish between similar compounds. For example, for subordinate compounds constructed with the morpheme 房/fong4/ (house) as a modifier, possible combinations include 房門/fong4 mun4/ (door of house) or 房車/ fong4 ce1/ (recreational vehicle). Based on the semantic relation knowledge, children could figure out that in the compounds 房門/fong4 mun4/ (door of house) and 房車 / fong4 ce1/ (recreational vehicle) the same modifier 房/fong4/ (house) is related to 門 /mun4/ (door) and 車/ce1/ (car) in distinctive ways. The former compound contains the POSSESS relation (house POSSESS door); while the later compound involves the

DESCRIBE relation (house DESCRIBE car).

In the present study, therefore, we proposed that morphological awareness might facilitate the processing of semantic relation information. Both the processing of morphological information and of semantic relation involve the insight into the internal structure of compound words. In other words, both are about how the constituent morphemes are connected with each other in contributing to the overall meaning of the whole compound. However, they work at different levels. Morphological structure information could only convey the general type of the association between the morphemes (such as subordinate or coordinative), while the semantic relation information could inform of more fine details about the association (e.g., whether the modifier describes or possesses the head in a subordinate compound). In other words, morphological information could facilitate the approximate understanding of words (McCutchen & Logan, 2011), whereas semantic relations could aid access to the exact meaning of the compounds (Schmidtke et al., 2016).

Taken together, we proposed that awareness of morphological structure should be the foundation of analyzing semantic relations. Although there is a lack of empirical evidence to support this hypothesis, it has been found that knowledge of semantic relations was acquired

later than that of morphological information among children (Nicoladis, 2003). The processing of semantic relation information has been observed in a series of relation priming studies (e.g., Estes, 2003; Estes & Jones, 2006; Gagné, 2000, 2001; Gagné & Shoben, 2002). For example, Gagné (2001) found that after seeing a prime, such as *wood spoon*, which is a spoon made of wood (MADE OF relation), participants responded faster to compounds with the same relation, such as *glass cup* than to compounds with a different relation, such as *book shelf* (FOR relation, a *shelf* FOR *books*).

This relation priming effect was observed not only in real compounds, but also in novel ones (Raffray et al., 2007). Compared with real compounds, the semantic relations in novel compounds are relative unconstrained. To illustrate, in established real compounds like *tea cup*, the widely accepted semantic relation between the morphemes is FOR, and therefore it should be interpreted as a cup FOR tea. However, an ambiguous and novel combination such as *cake cup* can be interpreted either as *a cup for cake* (FOR relation) or *a cup made of cake* (MADE OF relation).

Raffray et al. (2007) utilised the expression-picture matching paradigm to investigate the relation priming effect in adults. In this paradigm, participants were first presented with a

prime expression that could be interpreted as involving either one of two possible relations (POSSESSOR, i.e., the modifier possesses the head; and DESCRIPTOR, i.e., the modifier is a feature of the head and thus can describe it). Then, they were presented with two pictures and were asked to choose an appropriate picture for the prime combination. One picture matched one of the two relations (i.e., POSSESSOR or DESCRIPTOR), while the other picture matched neither. The participants were then presented with a target combination that could be plausibly interpreted as involving either of the two relations. Afterwards, the participants were shown two pictures, each expressing one of the two relations. The participants were asked to select one among the two pictures that could represent the target expression as quickly and as accurately as possible.

The results illustrated that participants preferred to choose target pictures involving the same semantic relation as the prime compound, regardless of whether the morphemes are repeated between the prime and the target. The findings posited that adults (expert readers) have an ability to process and apply the semantic relations in novel compounds: when facing with the novel compounds that have the same form as the preceding one, they would rely on the recent usage of semantic relation to access the meaning of the new compounds.

To date, semantic relation processing has been scarcely studied in Chinese children. Therefore, it was one purpose of the present study to examine whether the semantic relation priming effect could be found in third-grade Hong Kong Chinese children. More importantly, we also would like to investigate whether morphological awareness could facilitate the processing of semantic relation information in compounds.

To focus on the process of learning novel compounds and to reduce the influence of past experience and knowledge, the expression-picture matching paradigm (Raffray et al., 2007) was adopted in the present study. Using novel combinations along with pictures could render the test more interesting and thus more suitable for children. To ease children's comprehension of the items, the compounds were presented both visually and aurally. Besides, to avoid the lexical priming effect, repetition of lexical items had been avoided in the prime-target pairs.

We used the same semantic relations included in Raffray et al. (2007), which are also common in Chinese: POSSESSOR (i.e., the modifier possesses the head, e.g., "狗糧", /gau2 uk1/ dog food, the dog possesses the food) and DESCRIPTOR (i.e., the modifier describes the head, e.g., "毛筆", /maau4 bat1/ writing brush, the brush describes the pen). Each

ambiguous target compound could be plausibly interpreted based on either of the two relations. For example, the combination "豬書" (/zyu1 syu1/ pig book) could be interpreted as "a book possessed by a pig" or "a book with a pig picture on it" (as shown in Figure 1).

[Insert Figure 1 here]

We selected third-grade students as subjects, since this population's lexical knowledge is fairly well developed but not yet reach the ceiling (Carlisle, 2000). Based on previous studies, we conducted two tasks to test children's morphological awareness: homograph awareness task and compounding production task (Liu, Li, & Wong, 2017). The following variables were included as controls: age, nonverbal intelligence, phonological awareness, and Chinese character reading. Phonological awareness was found to be closely related to morphological awareness (McCutchen & Logan, 2011). By controlling it, we could minimize the possibility that the effect we observed from morphological awareness is due to the influence of phonological awareness. On the other hand, Chinese character reading is not only related to morphological awareness (e.g., Ku, & Anderson, 2003; McBride-Chang et al., 2003), but might also be associated with the responses to the prime and target compounds. Thus, we included it as a covariate.

In sum, in the present study, third-grade Hong Kong Chinese children's processing of semantic relation information was investigated by using the expression-picture matching paradigm. Furthermore, we examined whether the processing of semantic relation information could be influenced by morphological awareness.

Experiment 1

Method

Participants.

A total of 151 children were recruited from two primary schools in Hong Kong. The same participants were tested approximately one year later. Their mean age was 8 years and 5 months (SD = .34 months) at Time 1 and 9 years (SD = .34 months) at Time 2. All participants were native speakers of Cantonese and had no physical or mental problems according to their teachers and parents.

Procedure and materials. The study included data from two time points: all children were administered the Raven's standard progressive matrices (sets A and B) for nonverbal intelligence at Time 1 (i.e., second grade) and expression-picture matching tasks (Raffray et al., 2007) for semantic relation processing at Time 2 (i.e., third grade). In addition,

participants completed the tasks for morphological awareness, phonological awareness, and Chinese character reading at both Times 1 and 2.

Morphological awareness. Homograph awareness task and compounding production task were used to test children's morphological awareness (Liu et al, 2017).

Homophone awareness task. Children were first presented with a target word and then were asked to select from three words the one that shared "a character that had the same meaning" (i.e., the same morpheme) as the target word. For example, 商量 (soeng1 loeng4, consult) was the target word, while 商店 (soeng1 dim3, store) and 商定 (soeng1 ding6, agree) were the two options. The correct answer is 商定 (agree). There were totally 32 items in this task and all of them were presented orally. One point was given for a correct answer, and thus the maximum score was 32. The Cronbach's alpha was .82.

Compounding production task. Children were presented with a scenario, and asked to create a novel word to properly represent the scenario. For example, one item in this task was "我們把專門吃鐵的怪獸叫做什麼? (How should we call a monster that can only eat iron?)" The answer for this item was 吃鐵怪 (iron-eating monster). Children's answers were rated based on a five-point scale (0-4). There were totally 31 items in this task, and thus the

maximum score was 124. All the items were orally presented. The Cronbach's alpha was .86.

Expression-picture matching task. The materials consisted of 32 item sets. Each item set contained a prime trial and a target trial. Each trial consisted of a compound, its corresponding audio, and two pictures. The compound always comprised an animate noun as the first constituent and a non-animate noun as the second constituent. The average frequency of all the constituents of the compounds was 167.46 (Poon & Hong, 2003), and thus all characters are of high frequencies. All Chinese words were presented in black on a gray background with a font size of 18 in Microsoft JhengHei. A college student majoring in Visual Arts created the picture stimuli. All pictures were presented with a white background at a size of about 400 x 564 pixels.

For the pictures in the prime condition, one of the pictures was a matching picture that depicted either a POSSESSOR or a DESCRIPTOR relation in the compound, and the other picture was a non-matching picture that depicted either the head or the modifier of the compound word but not both. For instance, "鯊碗" (/saa1 wun2/, shark bowl) was presented with a matching picture showing a shark holding a bowl and a distractor showing an elephant holding a bowl.

In the target condition, however, both of the presented pictures could be semantically related to the compound. One picture depicted the POSSESSOR relation, whereas the other depicted the DESCRIPTOR relation. For instance, the compound “豬書" (/zyu1 syu1/ pig book) could be depicted as a pig holding a book or a pig on the cover of a book, as shown in Figure 1. Each target was preceded by two distinct primes with different relation interpretations, one at a time. To avoid repetitive priming, each prime-target pair shared neither the same head nor the same modifier. In total, each relation condition consisted of 16 item sets.

The experiment also contained 64 fillers. Each filler contained a two-character word, its corresponding audio, and two pictures. As in the prime condition, the filler trials consisted of a matching picture and a non-matching picture. The two-character combination in the filler conditions could be a singular word (e.g., 相機/soeng3 gei1/ camera) or a compound (e.g., 狐豹/wu4 paau3/ fox leopard), both of which were constructed by either animate or non-animate items. In other words, all compounds were combined with either two animate or two non-animate constituents.

The experiment was conducted in a quiet room. The participants were asked to seat in

front of a computer screen, and E-prime was used to present the stimuli and collect the data. After reading the instructions, the participants were required to finish 8 practice trials before the experimental trials began. All practice trials used the filler items. Feedback was given after the participants finished each practice trial, but no feedback was given in the experimental trials.

One trial started with the presentation of a fixation cross at the centre of the screen for 250ms, with a "beep" sound to remind the participant that the test was about to start. After a blank screen presented for 500ms, a compound appeared at the centre of the screen for 1200ms. Simultaneously, the participant heard the corresponding pronunciation. Then, after another blank screen was shown for 500ms, two pictures appeared on the left and right part of the screen. Once the pictures appeared, the participants were allowed to respond by pressing the "F" key on the keyboard to choose the picture on the left or the "J" key for the picture on the right. They were encouraged to make judgments as quickly and as accurately as possible. The experimental procedure is illustrated in Figure 2.

[Insert Figure 2 here]

In total, the participants underwent 8 trials for the practice session and 128 trials (32 primes, 32 targets, 64 fillers) for the formal test. Two fillers were presented after each prime-target pair, and each relation would not appear sequentially more than three times. Moreover, the same target would not appear twice successively. The whole task lasted for about 15 minutes for each participant.

Raven's standard progressive matrices. Raven's Standard Progressive Matrices (Raven, 1996) is a non-verbal multiple-choice measure of children's reasoning ability. Sets A and B were administered to measure young children's nonverbal reasoning. There are 24 items, and the maximum score was 24. For each test item, children were asked to identify the missing element that completed a pattern from among six choices. The Cronbach's alpha was .78.

Chinese Character reading. A Chinese character reading task was used to examine children's reading ability at word level. In this task, children were required to read 3 character lists aloud one by one, each list contained 72 characters and was ordered in ascending difficulty. When children failed to recognise 15 consecutive characters in a list, testing

proceeded to the next list. One point was allocated to each correct answer, and thus the maximum score was 217. The Cronbach's alpha was .98.

Phonological awareness task. Children's phonological awareness was measured with a task consisting of 9 syllable deletion and 22 onset deletion items (McBride-Chang et al., 2003). In each syllable deletion item, children were asked to remove a syllable from a three-syllable word. For example, say "he6 kou1 peng2" without "kou1," the answer was "he6 peng2." In an onset deletion item, children were asked to remove the onset of a syllable. For example, say "gut3" without "g," the answer was "ut3." One point will give to each correct answer, and thus the maximum score was 31. The Cronbach's alpha was .95.

Results

Since the main purpose of the expression-picture matching paradigm adopted in the present study was to examine the influence of previously processed semantic relation information on the interpretation of a subsequent expression rather than the time course of comprehension for an ambiguous expression, the dependent measure was the proportion of corresponding pictures selected for the target combination rather than the response time. The accuracy of responses to the primes, targets, and fillers were recorded. The accuracy on the

prime trials was measured based on whether the participants chose the pictures that reflected a correct interpretation of the combinations. Since both pictures in the target trials reflected a plausible interpretation of the compounds, responses that matched the relation involved in the corresponding prime were recorded as correct, whereas responses that did not match the relation were recorded as incorrect.

Only the target trials with correct responses in the paired prime items were included in the analyses. On average, the accuracy of responses to the prime and filler trials was 98%. In total, 4.65% of the data were excluded because children made incorrect responses to the primes. Considering that on the target trials the selection of DESCRIPTOR responses and POSSESSOR responses were two alternatives in each priming condition, and that analysis of the difference in selection of either type of target between the 2 priming conditions would reflect that of the other, we focused on the difference in the selection of POSSESSOR targets between the two priming conditions (i.e., POSSESSOR primes and DESCRIPTOR primes). The results would have been exactly the same if we selected the difference of the selection of DESCRIPTOR targets for analysis.

Linear mixed model analysis

With reference to Raffray et al. (2007)'s study, we utilized the linear mixed model (LMM) for further comparison of the response preference. LMM allows all random factors (i.e., factors of participants and stimuli) to be considered simultaneously together with fixed effects of interests, such as the semantic relation priming effect (i.e., the preference difference between the trials that involved semantic relations that were consistent and inconsistent with corresponding primes), morphological awareness, Chinese character reading, and phonological awareness.

Stepwise regression analyses using the LMM method was adopted to answer two questions: a) whether the priming effect of semantic relation can be observed in third grade Chinese children; and b) whether the priming effect of semantic relation can be moderated by children's morphological awareness. The LMM analyses were conducted using the lmer program of the lme4 package in R 3.4.2 (R Core Team, 2017); the significance of fixed effect was assessed using the lmerTest package.

Response preference of the expression-picture matching task was analyzed by using the LMM model described below. In order to answer the research questions of the present study, we created two models. In both models, the consistency of semantic relation in the

prime-target pairs (i.e., POSSESSOR-POSSESSOR pair was defined as consistent and DESCRIPTOR- POSSESSOR pair was defined as inconsistent) was specified as the fixed factor. For investigating the semantic relation priming effect (i.e., the difference between the consistent and inconsistent conditions), we specified the semantic relation contrast by coding the consistent and inconsistent pairs as +0.5 and -0.5 respectively.

The first model focused on the concurrent interaction between semantic relation processing and morphological awareness at Time 2. Thus, morphological awareness, Chinese character reading and phonological awareness at Time 2 were involved as fixed continuous factors. The sum of the standard scores of the two morphological awareness tasks were taken as an indicator of morphological awareness. In addition, age, non-verbal intelligence, and frequency and visual complexity of stimuli (i.e., the sum of the corresponding values for the first and the second character of the combination) were entered as fixed continuous factors as well. All the continuous variables were centered by z-score transformation of raw scores to overcome the problem of collinearity. The random factors included the ones that were related to the participants (i.e., individual difference, age, non-verbal intelligence, and the scores of morphological awareness, Chinese character reading and phonological awareness) and the

trials (individual difference in stimuli, the semantic relation condition, the frequency and complexity of stimuli).

The second model examined the interaction between morphological awareness and semantic relation priming longitudinally by including the measures of morphological awareness, Chinese character reading and phonological awareness in Time 1. The results of the LMM model in Exp.1 are summarized in Table 1.

The results of the concurrent LMM model in Exp.1 showed that the main effect of semantic relation consistency and its interaction with morphological awareness were significant. Children showed preference for the relation (i.e., POSSESSOR relation) consistent with the one inovlved in the prime compound in interpreting the ambiguous target combination. At the same time, the semantic relation consistency showed a positive interaction with morphological awareness: the higher the score of morphological awareness tasks, the larger the difference between preference for consistent and inconsistent semantic relations.

Consistent with the results of the concurrent model, the results of the longitudinal model in Exp.1 showed that the main effect of semantic relation consistency was significant.

In addition, the interaction between semantic relation consistency and children's performance in morphological awareness at Time 1 was significant. Children with better performance in the tests for morphological awareness at Time 1 showed a larger priming effect of semantic relation at Time 2.

[Insert Table 1 here]

Discussion

The main effect of semantic relation priming was significant both in the concurrent and longitudinal LMM models of Exp.1, indicating that these children had the ability to process internal semantic relations of compounds. They preferred to utilise the semantic relation that had been used in the prime to interpret the ambiguous novel words.

In addition, the significant interaction between semantic relation priming and morphological awareness indicated that compared to the children with poor morphological awareness, a larger semantic relation priming effect was observed in the children with good morphological awareness. Interestingly, the significant interaction between semantic relation priming and morphological awareness was observed in both the T2 concurrent model and the T1-T2 longitudinal model.

However, in Exp. 1, since the modifier was visually larger in the POSSESSOR relation, while the head was visually larger in the DESCRIPTOR relation (as shown in Figure 1), the interpretation of ambiguous combinations might be influenced by the visual similarity between the prime and the target. In other words, similar visual features between the prime and the target might have decreased the difficulty of the task. Apart from using the semantic relation information, children might rely on visual cues to select answers on the target trials.

To investigate whether visual features of the stimuli would influence the semantic relation priming effect, we adopted the design in Raffray et al.'s (2007) study (Exp. 3 in their study), and modified the prime pictures so that they contained two possible relations at the same time (as shown in Figure 3). If children relied heavily on the visual features, rather than using the semantic relation information, in making their judgments, the relation priming effect would disappear as a result of this modification.

Experiment 2

In Exp.2, we considered the impact of visual similarity, and thus adopted the design in Raffray et al.'s (2007) study (Exp. 3 in their study) to examine whether the relation priming effect would remain after controlling for visual similarity of the materials.

[Insert Figure 3 here]

Method

Participants. Children who were included in Exp. 1 participated in Exp. 2.

Procedure and materials. Children were asked to complete another expression-picture matching task; the procedure of this task was the same with Exp.1. However, the materials consisted of 16 item sets, which were different from those used in Exp. 1. In each prime trial of Exp. 2, a prime picture and a distractor picture were presented. Each of the pictures involved two semantic relations (i.e., POSSESSOR and DESCRIPTOR) at the same time. For instance, a picture in which a sheep wore a bracelet with a rabbit decoration on it could be interpreted either as “羊環” (/joeng4 waan4/, sheep bracelet) based on a POSSESSOR relation or “兔環” (/tou3 waan4/, rabbit bracelet) based on a DESCRIPTOR relation. The distractor picture depicted one constituent of the word but did not match the complete meaning (e.g., a picture showing a sheep holding a book instead of a bracelet was the distractor picture for “羊環”). The two possible primes (“羊環” or “兔環”), which were depicted by the same picture, were expected to prime for two targets involving different semantic relations (POSSESSOR relation or DESCRIPTOR relation) respectively.

The target item, which was similar to that in Exp. 1, included two pictures depicting different interpretations of the target word. For instance, "鼠箱" (/syu2 soeng1/, rat box) was depicted by 2 pictures depicting a box owned by a mouse (POSSESSOR relation) and a box with a mouse's image on it (DESCRIPTOR relation) respectively. The response was expected to be primed by the ambiguous prime picture depicting either "羊環" (depicted POSSESSOR relation) or "兔環" (depicted DESCRIPTOR relation). The average frequency of the prime and target compound words was 135.01 (Poon & Hong, 2003). To avoid repetitive priming, each target and its corresponding prime did not share any constituent. In total, each relation condition consisted of 8 item sets. One example of the items used in Exp. 2 is shown in Figure 3. A total of 32 fillers were used in Exp. 2. All of them were randomly selected from the fillers used in Exp. 1.

Results

In the data analysis, only the target trials with correct responses in the paired prime items were included in the analysis. On average, the accuracy of responses to the prime and filler trials was 98%. In total, 6.71% of the data were excluded because children made incorrect responses to the primes.

Linear mixed model analysis

Same as Exp.1, we conducted two LMM models to investigate whether there was a priming effect of semantic relation and the role of children's morphological awareness in semantic relation processing of the expression-picture matching task of Exp.2. All the fixed and random factors in the LMM model in Exp.2 were the same as those in Exp.1. The results of the LMM model in Exp.2 are summarized in Table 2.

[Insert Table 2 here]

Different from the results of Exp.1, both the concurrent and longitudinal LMM models of Exp.2 showed that the main effect of semantic relation consistency was not significant. Overall, children showed no preference to select a relation consistent with that inovlved in the prime compound (i.e., POSSESSOR relation) in interpreting the ambiguous target combination.

However, the interaction between semantic relation consistency and morphological awareness was significant in both the concurrent and longitudinal models in Exp.2. The results showed that with the interference of visual similarity across primes and targets

removed, children with more developed morphological awareness, but not children with less developed morphological awareness, still showed the semantic relation priming effect.

Discussion

Different from Exp.1, the relation priming effect was not significant in Exp. 2, indicating that increased complexity of visual features indeed affected children's processing of relation information. Nevertheless, the significant interaction between semantic relation consistency and the scores of morphological awareness tasks in both concurrent and longitudinal LMM models, which indicated that children with more developed morphological awareness outperformed the children with less developed morphological awareness in processing semantic relation information. In other words, with the interference of more complex visual features, children with more developed morphological awareness still recognized the semantic relation involved in the prime and utilized it to interpret the subsequent target. On the other hand, children with less developed morphological awareness showed difficulty in processing and applying the semantic relation involved in the prime.

General discussion

The current study sought to examine the role of morphological awareness in

influencing children's semantic relation processing. We tested the semantic relation processing of children with expression-picture matching tasks and its relationshiop with children's morphological awareness. The results revealed that consistent with our hypothesis, children's morphological awareness facilitated the processing of semantic relation information of novel compounds.

The results in children with more developed morphological awareness were consistent with the results in adults in the previous study by Raffray et al. (2007). They were able to overcome the influence of visual information and processed the implicit semantic relation information. The results of Exp.2 provided further evidence to support that the relation priming effect of children with more developed morphological awareness in Exp.1 was attributable to processing of semantic relation information rather than visual priming. However, the results of children with less developed morphological awareness were different. Their performance in Exp.2 showed that they were impacted by the visual information when processing novel compounds. Taken together with the findings in adults (Raffray et al., 2007), our results suggest that children with good morphological awareness might have developed a strategy similar to that used by adults for word acquisition, while the children with poor

morphological awareness had not.

At the same time, the significant interaction between semantic relation consistency and morphological awareness in the concurrent and longitudinal model of Exp.1 and Exp.2 suggested that children's processing of the semantic relation information could be moderated by their morphological skills. Previous study found that children could leverage their understanding of the morphological structure of words when they encountered unfamiliar complex morphological words, even in the absence of instruction (Bowers & Kirby, 2010; Wysocki & Jenkins, 1987). Children are able to take advantage of familiar morphological structure even in lexical items that had never been encountered (McCutchen & Logan, 2011). The findings of current study extended the role of morphological awareness in word acquisition. Children could rely on the word formation rules at morphological structure level (e.g., subordinate structure) to infer similar rules at semantic relation level

To illustrate, children with better morphological awareness have better performance in processing morphological structure information, which in turn facilitates their acquisition of the rule that words with the same form usually share the same internal structure. If the morphological structure information is not adequate for access to meaning, such as

interpreting the ambiguous compounds in the current study, children with better morphological awareness have an ability to apply the word formation rule at a more detailed structure level (i.e., semantic relation). Thus, it is possible that morphological awareness facilitates children's development of an efficient strategy for acquiring and retaining words (McCutchen & Logan, 2011).

As suggested by Ku and Anderson (2003), children's insights into the internal structure of words play an important role in reading development. In light of this perspective, the findings in the present study indicated that compared to children with less developed morphological awareness, children with more developed morphological awareness not only could better process the morphological structure of words, but also showed the ability to parse more detailed internal structural information of the component morphemes, i.e., semantic relation information. In other words, morphological information is helpful not only for children's acquisition of novel words, but also for their ability to categorize the words (Kuo & Anderson, 2006). Thus, the results of the present study provided a possible explanation for the underlying mechanism of the role of morphological awareness in word learning.

As for children with less developed morphological awareness (i.e., low score of the morphological awareness tasks), the results of Exp.2 demonstrated that, visual features might influence their processing of implicit semantic relation information. However, based on their performance in Exp.1, there is a possibility that additional visual features might facilitate the processing of implicit semantic relations, at least to some extent. The results of Exp.1 in the current study indicated that with the extra information provided by the visual features, children with poor morphological awareness could process semantic relation information as good as the children with good morphological awareness.

It is possible that the similar visual features (e.g., the larger animal image) between primes and targets may help children to realize the same implicit semantic relations between them. Referring to this, providing additional visual information might be an efficient method to assist children in developing the ability to process implicit information of words (i.e., morphological structure and semantic relation). For example, when children learn novel compounds, teachers could provide corresponding pictures to visualize the inner structure of the words. Previous studies have found that visualizing the content for reading could improve children's literacy performance (Glenberg et al., 2004). Taken together with our findings,

visualization might facilitate children, especially those with poor morphological awareness, to discover the similarity in morphological structure and semantic relations between words.

The current study is among the first to demonstrate the association between morphological awareness and the processing of semantic relations among Chinese children. Although we provided empirical evidence that children with good morphological awareness showed a better ability in processing semantic relation information, only third grade students were included as participants in the present study. In order to investigate the relationship between morphological awareness and semantic relation processing from a development point of view, children with different ages should be considered in the future. Furthermore, we only investigated the processing of semantic relation information in one morphological structure, namely subordinate structure. There are other morphological structures in Chinese compounds, such as coordinative, subject-predicate, and verb-object. The processing of semantic relation information under these morphological structures may be influenced by the level of morphological awareness in different ways. These issues can be further addressed in the future in order to gain a comprehensive understanding of the relationship between morphological awareness and semantic relation processing.

Despite these limitations, the present study was among the first to investigate the relationship between morphological awareness and semantic relation processing. Different from most previous studies related to the association between morphological awareness and word processing in children (e.g., Li et al., 2002; Ku & Anderson, 2003), the current study is original in focusing on the detailed internal semantic relations in word processing when examining the role of morphological awareness. The findings in the present study help us better understand the mechanism underlying the association between morphological awareness and word reading. One possible explanation, as supported by the current findings, is that morphological awareness can facilitate the processing of semantic relation information, and in turn help children understand the meaning of the whole compound by parsing the relations between the component morphemes. The findings in the present study have some implications. First, besides the morphological structure, the semantic relation information may also be highlighted in the future in applying the analytical approach in helping children to improve their reading performance. Intervention studies conducted in both alphabetic languages (e.g., Carlisle, 2010; Kirk & Gillon, 2007) and Chinese (e.g., Shu, McBride-Chang, Wu, & Liu; 2006; Chow, McBride-Chang, Cheung, & Chow, 2008) have evidenced the

effectiveness of training on morphological awareness in improving children's literacy performance. The training effect may be further enhanced by incorporating semantic relation information into the intervention. Second, considering the influence of visual features on processing of semantic relation information, appropriate use of visual cues in instruction may help improve children's acquisition of implicit information (i.e., morphological structures and semantic relations).

Reference

Bowers, P. N., & Kirby, J. R. (2010). Effects of morphological instruction on vocabulary acquisition. *Reading and Writing, 23*(5), 515-537. doi: 10.1007/s11145-009-9172-z

Branigan, H. P., Pickering, M. J., & McLean, J. F. (2005). Priming prepositional-phrase attachment during comprehension. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 31*(3), 468-481. doi: 10.1037/0278-7393.31.3.468

Carlisle, J. F. (2000). Awareness of the structure and meaning of morphologically complex words: Impact on reading. *Reading and writing, 12*(3), 169-190. doi: 10.1023/A:1008131926604

Carlisle, J. F. (2010). Effects of instruction in morphological awareness on literacy

achievement: An integrative review. *Reading Research Quarterly, 45*(4), 464-487. doi: 10.1598/RRQ.45.4.5

Chen, X., Hao, M., Geva, E., Zhu, J., & Shu, H. (2009). The role of compound awareness in Chinese children's vocabulary acquisition and character reading. *Reading and Writing, 22*(5), 615-631. doi: 10.1007/s11145-008-9127-9

Chow, B. W. Y., McBride-Chang, C., Cheung, H., & Chow, C. S. L. (2008). Dialogic reading and morphology training in Chinese children: Effects on language and literacy. *Developmental Psychology, 44*(1), 233-244. doi: 10.1037/0012-1649.44.1.233

Coolen, R., Van Jaarsveld, H. J., & Schreuder, R. (1991). The interpretation of isolated novel nominal compounds. *Memory & Cognition, 19*(4), 341-352. doi: 10.3758/bf03197138

Estes, Z. (2003). A tale of two similarities: comparison and integration in conceptual combination. *Cognitive Science, 27*(6), 911-921. doi: 10.1016/j.cogsci.2003.01.001

Estes, Z., & Jones, L. L. (2006). Priming via relational similarity: A copper horse is faster when seen through a glass eye. *Journal of Memory and Language, 55*(1), 89-101. doi: 10.1016/j.jml.2006.01.004

Gagné, C. L. (2000). Relation-based combinations versus property-based combinations: A

test of the CARIN Theory and the Dual-Process Theory of conceptual combination. *Journal of Memory and Language, 42*(3), 365-389. doi: 10.1006/jmla.1999.2683

Gagné, C. L. (2001). Relation and lexical priming during the interpretation of noun-noun combinations. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 27*(1), 236-254. doi: 10.1037/0278-7393.27.1.236

Glenberg, A. M., Gutierrez, T., Levin, J. R., Japuntich, S., & Kaschak, M. P. (2004). Activity and imagined activity can enhance young children's reading comprehension. *Journal of Educational Psychology, 96*(3), 424-436. doi: 10.1037/0022-0663.96.3.424

Gagné, C. L., & Shoben, E. J. (2002). Priming relations in ambiguous noun-noun combinations. *Memory & Cognition, 30*(4), 637-646. doi: 10.3758/bf03194965

Ku, Y. M., & Anderson, R. C. (2003). Development of morphological awareness in Chinese and English. *Reading and Writing, 16*(5), 399-422. doi: 10.1023/a:1024227231216

Kuo, L. J., & Anderson, R. C. (2006). Morphological awareness and learning to read: A cross-language perspective. *Educational Psychologist, 41*(3), 161-180. doi: 10.1207/s15326985ep4103_3

Kirk, C., & Gillon, G. T. (2007). Longitudinal effects of phonological awareness intervention

on morphological awareness in children with speech impairment. *Language Speech and Hearing Services in Schools, 38*(4), 342-352. doi: 10.1044/0161-1461(2007/036)

Li, W., Anderson, R. C., Nagy, W., & Zhang, H. (2002). Facets of Metalinguistic Awareness that Contribute to Chinese Literacy. *Chinese Children's Reading Acquisition*, 87-106. doi: 10.1007/978-1-4615-0859-5_5

Liu, D., Li, H., & Wong, K. S. R. (2017). The anatomy of the role of morphological awareness in Chinese character learning: The mediation of vocabulary and semantic radical knowledge and the moderation of morpheme family size. *Scientific Studies of Reading, 21*(3), 210-224. doi: 10.1080/10888438.2017.1278764

Liu, P. D., & McBride-Chang, C. (2010). What is morphological awareness? Tapping lexical compounding awareness in Chinese third graders. *Journal of Educational Psychology, 102*(1), 62-73. doi: 10.1037/a0016933

McCutchen, D., & Logan, B. (2011). Inside incidental word learning: Children's strategic use of morphological information to infer word meanings. *Reading Research Quarterly, 46*(4), 334-349. doi: 10.1002/rrq.003

Mahony, D., Singson, M., & Mann, V. (2000). Reading ability and sensitivity to

morphological relations. *Reading and writing, 12*(3), 191-218. doi: 10.1023/a:1008136012492

McCutchen, D., & Stull, S. (2015). Morphological awareness and children's writing: accuracy, error, and invention. *Reading and Writing, 28*(2), 271-289. doi: 10.1007/s11145-014-9524-1

McBride-Chang, C., Shu, H., Zhou, A., Wat, C. P., & Wagner, R. K. (2003). Morphological awareness uniquely predicts young children's Chinese character recognition. *Journal of educational psychology, 95*(4), 743-751. doi: 10.1037/0022-0663.95.4.743

Nicoladis, E. (2003). Compounding is not contingent on level-ordering in acquisition. *Cognitive Development, 18*(3), 319-338. doi: 10.1016/s0885-2014(03)00037-6

Nagy, W. E., & Anderson, R. C. (1984). How Many Words Are There in Printed School English? *Reading Research Quarterly, 19*(3), 304-330. doi: 10.2307/747823

Poon, W. Y., & Hong, P. M. (2003). *A study of the Chinese characters recommended for the subject of Chinese language in primary schools.* Retrieved from http://lcprichi.hkbu.edu.hk/ [Google Scholar]

Raven, J. (1996). The Raven's Progressive Matrices: Change and Stability over Culture and Time, *Cognitive Psychology, 41*(1), 1-48. doi: 10.1006/cogp.1999.0735

R Core Team (2017). R: A language and environment for statistical computing. Vienna: R Foundation for Statistical Computing.

Raffray, C. N., Pickering, M. J., & Branigan, H. P. (2007). Priming the interpretation of noun-noun combinations. *Journal of Memory and Language, 57*(3), 380-395. doi: 10.1016/j.jml.2007.06.009

Schmidtke, D., Kuperman, V., Gagné, C. L., & Spalding, T. L. (2016). Competition between conceptual relations affects compound recognition: the role of entropy. *Psychonomic Bulletin & Review, 23*(2), 556-570. doi: 10.3758/s13423-015-0926-0

Shu, H., McBride-Chang, C., Wu, S., & Liu, H. (2006). Understanding Chinese developmental dyslexia: Morphological awareness as a core cognitive construct. Journal of Educational Psychology, 98(1), 122-133. doi: 10.1037/0022-0663.98.1.122

Sun, H., Sun, D., Huang, J., Li, D., & Xing, H. (1996). The description on the corpus system of modern Chinese studies. In Z. S. Luo & S. L. Yuan (Eds.), *Studies of Chinese and Chinese Character in the computer era.* Tsinghua University Publisher.

Tyler, A., & Nagy, W. (1990). Use of derivational morphology during reading. *Cognition, 36*(1), 17-34. doi: 10.1016/0010-0277(90)90052-l

Wysocki, K., & Jenkins, J. R. (1987). Deriving Word Meanings through Morphological Generalization. *Reading Research Quarterly, 22*(1), 66-91. doi: 10.2307/747721

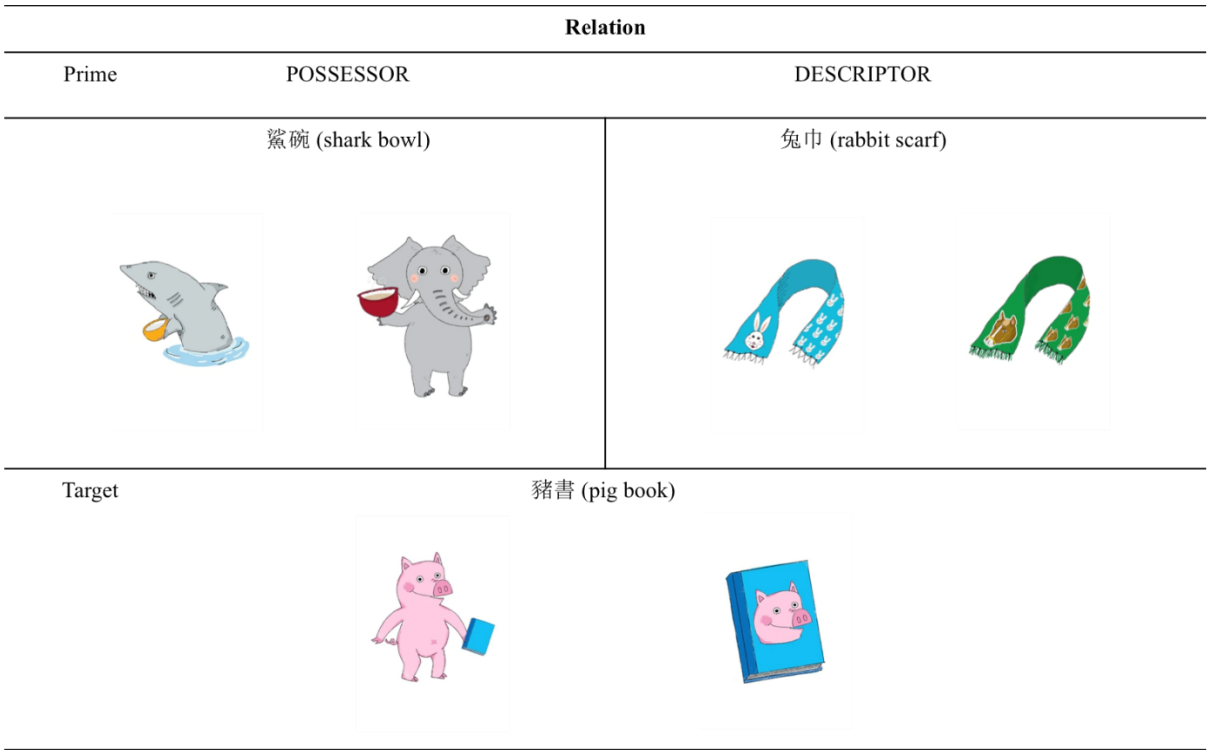

Figure 1. Sample stimuli for Exp. 1.

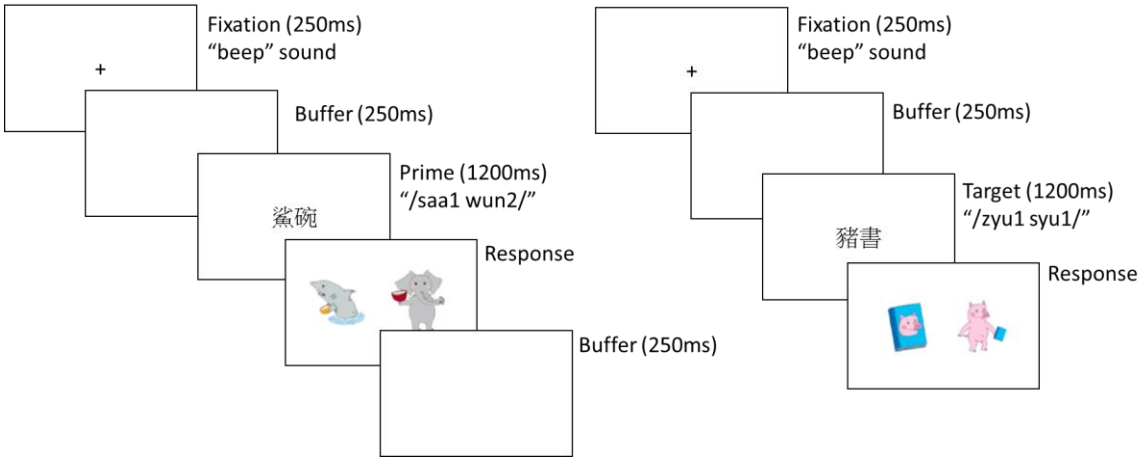

Figure 2. The procedure of Exp. 1.

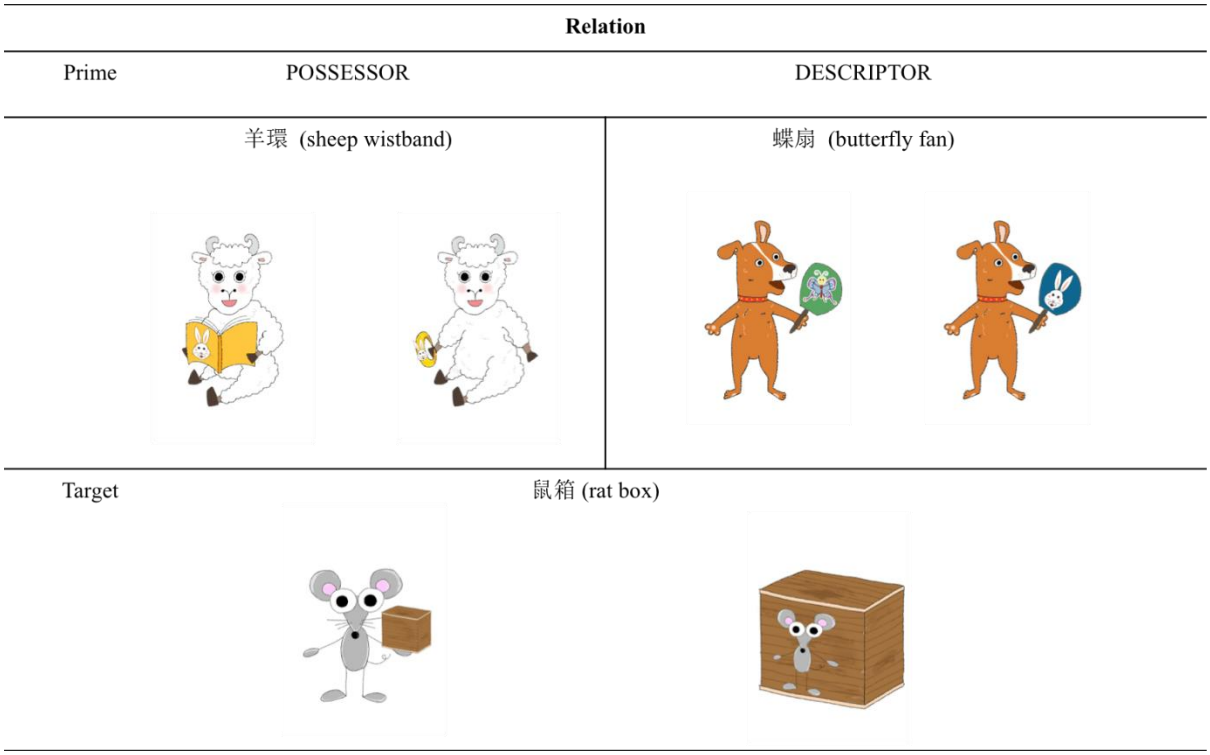

Figure 3. Sample stimuli for Exp. 2.

This is the pre-published version.

Table 1

Linear mixed model estimates of fixed effects of Exp.1

	Variables	Beta	Standard error	*t*-value	*p*
Concurrent model	Semantic relation consistency	.06	.004	16.48	< .01
	Morphological awareness (Time 2)	.003	.01	.26	.79
	Semantic relation consistency × Morphological awareness (Time 2)	.008	.003	3.28	.001
	Age	-.003	.02	- .21	.83
	Non-verbal intelligence	.04	.02	2.42	.02
	Chinese character reading (Time 2)	.002	.02	.12	.91
	Phonological awareness (Time 2)	.02	.02	1.22	.22
	Item complexity	-.001	.001	- .80	.42
	Item frequency	-.0001	.001	- .09	.93
Longitudinal model	Semantic relation consistency	.06	.004	15.83	< .01
	Morphological awareness (Time 1)	.01	.01	1.23	.22

Semantic relation consistency × Morphological awareness (Time 1)	.01	.002	4.64	< .01
Age	- .003	.02	- .21	.83
Non-verbal intelligence	- .03	.02	1.88	.06
Chinese character reading (Time 1)	.02	.02	1.14	.26
Phonological awareness (Time 1)	.01	.02	.64	.52
Item complexity	- .0003	.001	- .26	.80
Item frequency	- .0002	.002	.16	.88

Table 2

Linear mixed model estimates of fixed effects of Exp.2

	Variables	Beta	Standard error	*t*-value	*p*
Concurrent model	Semantic relation consistency	- .006	.006	- .90	.45
	Morphological awareness (Time 2)	- .002	.01	- .17	.83
	Semantic relation consistency × Morphological awareness (Time 2)	.008	.003	2.34	.02
	Age	- .02	.02	-1.01	.31
	Non-verbal intelligence	.08	.02	3.88	< .01
	Chinese character reading (Time 2)	- .01	.02	- .59	.56
	Phonological awareness (Time 2)	- .02	.02	-1.11	.27
	Item complexity	.002	.002	1.11	.26
	Item frequency	.001	.006	.23	.81
Longitudinal model	Semantic relation consistency	.004	.006	.68	.50
	Morphological awareness (Time 1)	.01	.02	.70	.48

Semantic relation consistency × Morphological awareness (Time 1)	.01	.004	2.57	.01
Age	- .02	.02	-1.14	.26
Non-verbal intelligence	.07	.02	3.29	.001
Chinese character reading (Time 1)	- .01	.02	- .59	.56
Phonological awareness (Time 1)	- .003	.02	- .18	.86
Item complexity	.002	.002	1.15	.28
Item frequency	.001	.006	.17	.87