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Chinese EFL learners' conceptual combination of English noun–noun compounds: Effects of relational information and English proficiency

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Research Article

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Abstract

Recent research has uncovered relation-based conceptual combination in L1 English speakers' processing of noun–noun compounds. However, it remains unclear whether Chinese EFL learners undergo a similar relation-based conceptual combination when processing English noun–noun compounds, particularly given the similarities in compounding between English and Chinese. To address this inquiry, a cohort of 120 Chinese EFL learners with advanced and intermediate English proficiency were requested to interpret English noun–noun compounds online in contexts with modifier-based relational information only, or both modifier- and head noun-based relational information. Results showed that Chinese EFL learners' processing relied heavily on available relational information. Moreover, both modifier- and head noun-based relational information contributed to this process but played distinct roles at different phases, modulated by task demands. While English proficiency affected processing speed, both proficiency groups exhibited a similar pattern across experiments. These findings shed light on the nuances of L2 learners' conceptual combination of English noun–noun compounds.

1. Introduction

Compounding, as one of the most frequently used methods for creating new words, provides insights into the fundamental properties of morphology in language and the unique features of human capacity for conceptual combination. This seemingly straightforward process of coining new words often reveals its underlying dynamic structure (Libben et al., 2020). One of the most intriguing aspects of a compound is how we derive its meaning. Determining the meaning of a compound involves considering both the lexical meanings of its constituents and the particular relation between the constituents. Nevertheless, the fact that the meanings of the constituents seldom fully predict the meanings of compounds (Libben et al., 2020) and that the linking relations between the constituents are highly variable (Libben, 2006; Spalding et al., 2010) poses challenges for interpreting compound meanings.

Substantial research has demonstrated the semantic transparency effect of the constituents on compound meaning (Libben, 1998; Libben et al., 2003; Sandra, 1990; Zwitserlood, 1994). However, comparatively less attention has been devoted to exploring the role of relational information between the constituents in deriving compound meaning. Recent advancements have enhanced our understanding of the intricate linking relations between the modifier and head noun[1] in noun–noun phrases (Estes, 2003; Estes & Jones, 2006; Gagné, 2000, 2001, 2002; Gagné & Shoben, 1997; Gagné et al., 2005, 2009; Maguire et al., 2007; Spalding & Gagné, 2007; Storms & Wisniewski, 2005) as well as novel/established noun–noun compounds[2] (Gagné & Spalding, 2004, 2009, 2014; Ji et al., 2011; Spalding & Gagné, 2014; Wisniewski, 1996). These studies consistently demonstrate the pivotal role of relational information in interpreting both noun–noun phrases and noun–noun compounds. For example, Gagné and Shoben (1997) manipulated the frequency of relations between modifiers and head nouns using shared modifiers in lexical decision tasks. Their findings revealed a correlation between the difficulty of interpreting a phrase and the likelihood of a specific relation between the constituents. Similarly, Gagné and Spalding (2004) investigated whether relational information affects processing of transparent compounds like *seawater* and *sandshoes*. Through a priming paradigm, they compared three conditions: (1) the same modifier and the same relation, (2) the same modifier but a different relation, and (3) a different modifier and a different relation. The results from two experiments, which demonstrated significant differences in response

[1]In English, the modifier usually refers to the first constituent of a given semantically transparent noun–noun compound, and the head noun usually refers to the second constituent of that compound.

[2]Established noun–noun compounds are distinguished from noun–noun phrases in that the former are conventionalised or lexicalised expressions. For simplicity, established noun–noun compounds in the present study are referred to as noun–noun compounds.

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times across conditions, unveiled both repetition and relation priming effects in compound processing.

While the role of relation-based interpretation in deriving meaning from noun–noun phrases and compounds is widely acknowledged, there is inconsistency regarding the contribution of the modifier and head noun in this process. Some studies suggest an asymmetric effect, highlighting the greater influence of the modifier-based relational information over the head noun in determining interpretations (Gagné, 2001; Gagné & Shoben 1997; Gagné et al., 2005; Jones et al., 2008). This modifier-based relational information effect has been replicated in investigations of right-headed phrases in other languages, where the modifier follows the head noun (Storms & Wisniewski, 2005; Turco, 2000). Alternatively, a body of research has underscored the role of the head noun in relation-based interpretation, substantiated by the findings of Maguire et al. (2008) employing a speeded sensibility task, and Zhao and Hong (2015) utilizing a relation verification task. A third perspective proposes equal contributions from the modifier and head noun in noun–noun phrase interpretation (Spalding et al., 2010). These researchers argue that the head noun effect could be better captured if the task directly assesses relational interpretations.

Within the realm of L2 research, a multitude of studies have extensively investigated L2 compound processing, and reached a consensus that morphological decomposition (Andrews et al., 2004; Fiorentino & Fund-Reznicek, 2009; Fiorentino et al., 2014; Fiorentino & Poeppel, 2007; Juhasz et al., 2005; Schreuder & Baayen, 1995; Taft & Forster, 1976) and semantic composition (El-Bialy et al., 2013; Günther & Marelli, 2020; Libben, 2014) or early access to meaning were detected in L2 learners' online performance (Davis et al., 2019; Günther et al., 2020; Kuperman et al., 2008; Libben et al., 1999; Schmidtke & Kuperman, 2019). However, it is still unclear whether L2 English learners obtain the meanings of English noun–noun compounds through relation-based conceptual combination. To date, only two studies have initially examined Chinese EFL learners' relation-based interpretation of English noun-noun phrases. Their findings converge on the importance of relational information in Chinese EFL learners' phrase interpretation (Zhang et al., 2012; Zhao & Hong, 2015). On the other hand, only one study has discussed the role of the constituents in English noun–noun phrase interpretation. In their investigation employing a relation verification task, Zhao and Hong (2015) observed solely the head noun effect in Chinese EFL learners' interpretation. To the best of our knowledge, no research has examined L2 English learners' conceptual combination of noun-noun compounds.

Theoretically, the relational-interpretation-competitive-evaluation (RICE) theory provides a framework for understanding how people interpret noun–noun phrases and compounds (Spalding et al., 2010). According to the theory, upon encountering a concatenated noun–noun phrase/compound, individuals initially engage in morphological parsing, wherein they identify the distinct roles of each constituent as either the modifier or the head noun. For example, in the compound *birthmark*, *birth* is the modifier and *mark* is the head noun. Interpretation then proceeds through three phases, with emphasis on the relational information between the modifier and head noun in the first two phases: relation suggestion and relation evaluation. In the relation suggestion phase, the modifier activates potential relations based on past experience with that word in compounds. The head noun subsequently constrains possible relations in the relation evaluation phase, resulting in an interaction that settles on the intended interpretation. Thus, the RICE theory posits that the interpretation prioritises the modifier-based relational information, followed by a shift towards the head noun-based relational information. This phased process provides a model for how people derive meaning from noun combinations.

2. The present study

Despite the valuable insights provided by the RICE theory, its central hypothesis concerning the distinct phases of English noun-noun compounds' conceptual combination, such as relation suggestion and relation evaluation, lacks substantial empirical corroboration from prior research endeavours. Specifically, it remains to be elucidated how the relation priming effect may influence the distinct phases of conceptual combination, wherein the modifier and head noun assume divergent roles. Furthermore, while L2 researchers have confirmed the relation priming effect in Chinese EFL learners' interpretation of noun–noun phrases, it remains unclear whether this effect extends to their interpretation of noun–noun compounds. Evidence from L2 learners' conceptual combination of English noun–noun compounds would contribute valuable insights towards broadening the scope and generalizability of the RICE theory.

This study aimed to investigate the effect of relational information on Chinese EFL learners' conceptual combination of English noun–noun compounds. In particular, we delved into the roles of the modifier- and head noun-based relational information, as well as their interaction during this process, by investigating the performance of the same participants across two distinct tasks. Given that discrepancies in language proficiency among L2 English learners may impact mental representation of relational information associated with compounds, we also examined whether English proficiency exerts influence on Chinese EFL learners' conceptual combination.

Three research questions were addressed. First, we tested whether the relation priming effect, particularly the modifier-based relational information effect found in English native speakers' conceptual combination of noun–noun compounds, is evident in Chinese EFL learners. As postulated by the RICE theory, our hypothesis posited that if Chinese EFL learners engage in the conceptual combination of English noun-noun compounds by mapping specific relational information between constituents, we would anticipate faster response times to target compounds in the same modifier and the same relation (MS) condition compared to the same modifier but a different relation (MD) condition. This assumption arises from the notion that the availability of appropriate relational information activated by the prime compound would reduce the time necessary to accomplish conceptual combination for the target compound.

Second, we tested whether head-noun based relational information would play a role when the task is biased toward relation verification. According to the RICE theory, we hypothesised that if Chinese EFL learners' conceptual combination of English noun-noun compounds follows distinct phases, we would anticipate faster response times to target compounds in the same head noun and the same relation (HS) condition compared to the same head noun but a different relation (HD) condition. This is because accessing the head noun-based relational information activated by the prime compound would facilitate conceptual combination of the target compound. In addition, we anticipated a modifier-based relational information effect due to the interaction between the modifier and head noun during the relation verification phase.

Lastly, we tested whether Chinese EFL learners' English proficiency would affect the conceptual combination process across the two tasks. Considering that the processing of compounds depends

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on the connection of their constituents, higher proficiency learners may exhibit a more efficient retrieval of such relational information associated with compounds. Consequently, we hypothesised the English proficiency effect on Chinese EFL learners' conceptual combination of English noun–noun compounds.

3. Experiment 1

3.1. Method

3.1.1. Participants

A cohort of 120 students from Guangdong University of Foreign Studies (GDUFS) in South China participated in Experiment 1. All participants were Chinese EFL learners majoring in English. Half of the participants were undergraduate students in their third academic year (intermediate level), while the other half were postgraduate students in their second or third academic year (advanced level). They all had normal or corrected-to-normal vision, allowing them to read words on the computer without difficulty. Prior to their participation, the participants provided informed consent, indicating their voluntary agreement to take part in the experiment. They were explicitly informed of their right to withdraw from the study at any time without any penalty or consequence. Besides, they were compensated for their participation after the experiment, which served as a token of appreciation for their involvement in the study.

To assess potential differences in English proficiency between the two groups, all participants completed a language background questionnaire and a vocabulary size test. As indicated by the questionnaire, 92% of the postgraduate students passed the Test for English Majors-Band 8 (TEM-8), while the remainder passed either the Test for English Majors-Band 4 (TEM-4) or the College English Test-Band 6 (CET-6). Due to the coronavirus disease 2019 pandemic, none of the undergraduate students had an opportunity to take the TEM-4 test. In addition, participants self-assessed their English competence in listening, speaking, reading, writing and translation using a 10-point scale. One-way ANOVA tests were conducted to analyze the collected data. Results revealed significant differences between the two groups across the five skills: listening ($F(1, 118) = 244.612, p < .001$), speaking ($F(1, 118) = 84.863, p < .001$), reading ($F(1, 118) = 216.673, p < .001$), writing ($F(1, 118) = 182.910, p < .001$), and translation ($F(1, 118) = 243.731, p < .001$).

In line with the research focus of this study, the Vocabulary Size Test (VST) (Nation & Beglar, 2007), known for its reliability and comprehensive assessment of learners' receptive vocabulary knowledge, was deemed the most appropriate selection. Comprising 140 items, with 10 items sampled from every 1,000 word families, the VST requires participants to choose the most suitable meaning that matches the target item presented in a non-defining context. Each correct answer was scored one point, with the total multiplied by 100 to obtain each participant's receptive vocabulary size. The mean VST scores were 69.78 for the intermediate group and 89.87 for the advanced group. These scores correspond to receptive vocabulary sizes of approximately 6,900 word families and 8,900 word families, respectively. An independent samples t-test confirmed a statistically significant difference in English proficiency between the two groups ($t = -21.597, p < .001$).

3.1.2. Sense-nonsense judgment task

3.1.2.1. Critical items A preparatory study was conducted to identify English noun–noun compounds familiar to Chinese EFL learners. Initially, 655 English noun–noun compounds were selected from previous studies (Gagné & Spalding, 2009; Schmidtke et al., 2018b) and the CELEX lexical database (Baayen et al., 1995). The selected compounds were required to meet the following criteria: (1) consisting of two nouns, (2) containing at least one constituent productive in compounding (family size >2), and (3) exhibiting at least partial semantic transparency. Ninety third-year English majors with intermediate proficiency from universities in South China, who were separate from the formal experiment, participated in an online familiarity rating task. The task involved rating their familiarity with the pre-selected compounds, using a 5-point Likert scale (1 = totally unfamiliar, 5 = very familiar). Due to the overall low frequency of the target compounds, a mean familiarity rating of 3 or above (on the 5-point scale) served as the inclusion threshold for the experiment. In other words, only compounds rated as 3 or higher in familiarity by the participants were retained as potential test items. For example, the compound *aircraft*, which received an average familiarity rating of 4.18, exceeds the threshold and qualifies for further analysis. This selection process yielded 296 English noun–noun compounds for further investigation.

Compounds sharing the same modifier were identified from the pool of 296 compounds. Out of the 296 compounds identified in the preparatory study, 233 were selected as candidate critical items. Levi's (1978) relational categories were used to identify the relational information for the 233 candidate English noun–noun compounds. This process involved two steps. In the first step, an online questionnaire was administered to 210 graduate students majoring in English at Chinese universities. The purpose of the questionnaire was to collect their judgments about the relationships between the constituents of each compound. To prevent an excessive cognitive load that could arise from a single questionnaire containing a large number of testing items, the 233 compounds were divided into three questionnaires, each containing 77–78 items. For each compound, participants selected one of the 16 possible relational categories (e.g., FOR, ABOUT, FROM and MAKE) (Schmidtke et al., 2018b) that best characterised the semantic relationship between the two constituents. Before the task, participants received a brief explanation and examples of Levi's relational categories. The target relation for each compound was determined as the category endorsed by ≥80% of the respondents. This selection process resulted in 187 compounds being retained for further confirmation of their relational properties.

In the second step, two PhD candidates majoring in linguistics/applied linguistics completed a relation confirmation task for the 187 compounds. First, they studied Levi's (1978) relational categories and examples from Gagné and Spalding (2009) and Schmidtke et al. (2018b). Then for each compound, they selected the intended relation from the top three options based on agreement rates from the questionnaire. When the relation was unclear, they consulted dictionaries and the present researchers until reaching a consensus. Inter-rater reliability between coders was 85.56% with a Cohen's kappa of 0.77, indicating strong agreement. Finally, the researchers reviewed the assigned relational information for each compound. Table 1 presents the 16 instantiated relation categories for the analyzed compounds.

Given the effects of familiarity (Chen et al., 2020; Juhasz, 2008; Schmidtke et al., 2018a; Yu, 2017) and frequency (Andrews et al., 2004; Baayen et al., 2010; Günther & Marelli, 2019; Marelli & Luzzatti, 2012) on compound processing, the selected compounds were matched in these two aspects. Besides, the length and syllables of the selected compounds were also manipulated. This process yielded 144 compounds (see Supplementary Table S1).

Although completely semantically opaque compounds (both constituents are opaque) were excluded from the experiment, it

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Table 1. Relational information coding

Relational information	Example of compound
h FOR m	*bookcase*
h OF m	*riverbed*
h FROM m	*seafood*
h HAS m	*landowner*
h MADE OF m	*snowball*
h DURING m	*daytime*
h LOCATE m	*farmhouse*
h ABOUT m	*rulebook*
h CAUSED BY m	*motorcar*
h BY m	*airmail*
h USED BY m	*handcart*
h PRODUCED BY	*paintwork*
h IS m	*pathway*
h MAKE m	*shoemaker*
h IN m	*airplay*
h USE m	*gunman*

Note: "h" stands for the head noun, and "m" stands for the modifier.

was still possible that semantic transparency could differ dramatically between prime conditions, affecting processing speed. Thus, an objective measure of semantic transparency, namely latent semantic analysis (LSA), was required. LSA statistically estimates semantic distance between words based on contextual co-occurrence in a corpus (Landauer & Dumais, 1997). Consistent with previous studies that employed LSA as a semantic transparency metric (Marelli & Luzzatti, 2012; Pham & Baayen, 2013), we obtained LSA scores for two semantic relationships: modifier to compound (M–C) (e.g., *snow – snowball*), and head noun to compound (H–C) (e.g., *ball – snowball*). Higher scores indicate greater semantic similarity. A total of 144 compounds were analysed, and LSA scores were collected to assess differences in semantic transparency between the targets and primes. A one-way ANOVA revealed no significant difference when considering both the modifier and head noun semantic similarity ($F(3, 232) = .349$, $p = .790$). Besides, semantic transparency in the M–C context ($F(3, 114) = .426$, $p = .735$) and H–C context ($F(3, 114) = .017$, $p = .502$) did not significantly differ between conditions, respectively.

The 144 critical items were then equally assigned as the target compounds and prime compounds. Among these, 36 were the target compounds and the remaining 108 were the prime compounds. Each target was paired with three primes. Two primes shared the modifier with the target but differed in relational information. Primes sharing relational information with the targets were termed "the same relation primes" (e.g., *fingertip* and *fingernail*, which involve the relational information "head noun OF modifier"). Primes with different relational information were termed "different relation primes" (e.g., *fingermark* meaning a mark PRODUCED BY finger). The third prime had no commonalities with the target and was termed "the neutral prime" (e.g., *earring*, which is a ring FOR ear). The inclusion of the neutral condition was to differentiate the potential effect of relation priming from that of repetition priming. By comparing the response times (RTs) across the same-modifier conditions (i.e., the MS and MD conditions) and the different-modifier condition (i.e., the neutral condition), we aimed to identify whether a significant difference emerged. Specifically, if the observed RT differences were solely detected between the same-modifier conditions and the different-modifier condition, without any significant difference between the MS and MD conditions, it would suggest the absence of a priming effect associated with relational information (see Supplementary Table S2).

3.1.2.2. Filler items A total of 144 filler items were created for Experiment 1. Similar to the critical items, two-thirds of the filler items shared common modifiers between the prime and target words. In addition, to prevent predictive responses, interpretable compounds were used as primes while nonsense compounds were used as targets. Both the prime and target fillers were constructed by randomly combining two common free words. Interpretable prime fillers were possible collocations verified through dictionaries and Google searches (e.g., *coffeecup* = "cup FOR coffee"). The same method produced nonsense targets like *servicecup*, *raceheart*, and *flagpiece*. Filler pairs were also matched on length and syllables (see Supplementary Table S3).

These filler items were then equally allocated in the three conditions. Among them, 36 were target compounds consisting of non-interpretable noun-noun combinations. The remaining 108 were interpretable noun-noun combinations: 72 assigned to the same modifier (SM) condition sharing modifiers with the targets, and 36 in the different modifier (DM) condition with different modifiers from the targets. As with the critical items, each target in the filler pairs was matched with three different primes (e.g., *kidplace* (target), *kidgame* (SM prime), *kidmurder* (SM prime), and *statelaw* (DM prime)) (see Supplementary Table S4).

3.1.3. Design

Experiment 1 employed a priming paradigm to conduct a sense-nonsense judgment task. The study utilised a 2 (English proficiency: intermediate versus advanced) × 3 (relational information conditions: MS versus MD versus neutral) factorial design with English proficiency as the between-subjects variable and relational information conditions as the within-subjects variable. The dependent variable was response times (RTs) to target items. Differences in the RTs across the prime conditions were considered priming effects, which served to validate the influence of relational information on Chinese EFL learners' interpretation of English noun–noun compounds.

3.1.4. Procedure

The experiment was programmed in E-Prime 2.0 and administered on laptops. Participants completed the task in groups of three in a quiet room. Each participant was randomly assigned to one of the three stimulus lists (see Supplementary Table S5). The experiment began with a practice block of 10 trials to familiarise participants with the procedure. Participants were required to repeat the practice until achieving 90% accuracy. After completing the practice, participants pressed the spacebar to continue. Each trial began with a fixation cross in the centre of the screen. After it disappeared, the prime compound appeared and participants indicated whether it was interpretable by pressing "F" for interpretable or "J" for non-interpretable. Next, the fixation cross reappeared and participants pressed the spacebar to display the target compound, judging it as interpretable or noninterpretable. Trials were self-paced. The entire experiment lasted approximately 20 minutes.

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3.1.5. Data processing and analysis

As the main variable of interest, correct target compound RTs were retained. Initially, outliers exceeding 2.5 standard deviations were trimmed, eliminating 115 cases (3.06% of the data).

Log-likelihood ratio tests were used to assess the validity of the mixed effects analyses. A model with relational information conditions as a fixed effect was compared to a null model with only participants and items as random effects. Relational information conditions significantly improved model fit ($\chi^2 = 76.84$, $p < .001$). Next, English proficiency was added as a second fixed effect along with relational information conditions, while retaining participants and items as random effects. This model demonstrated significantly better fit compared to the model with only relational information conditions as a fixed effect ($\chi^2 = 208.89$, $p < .001$). Finally, the interaction between relational information conditions and English proficiency was added as a third fixed effect. The model with the interaction significantly improved fit relative to the model without it ($\chi^2 = 16.94$, $p < .001$).

Linear mixed effects (LME) models were fitted with log response times as the dependent variable, and relational information conditions and English proficiency as the predictor variables. Participants and items were treated as random effects in the models (Baayen et al., 2008). The relational information conditions were encoded using sum contrast coding (MS condition: −1; MD condition: 1/2; neutral condition: 1/2). Similarly, the English proficiency levels were also contrasted using the same coding scheme (intermediate level: −1; advanced level: 1). LME analyses were conducted because this approach allows accounting for the influence of relational information conditions, English proficiency, and other related psycholinguistic variables (e.g., compound lemma frequency, constituent family size, and family frequency) within a single model. Moreover, the inclusion of participants and items as random effects allows for generalization of the results to new participants and items simultaneously.

Analyses were performed in R (Team, 2014) using the lme4 (Bates & Maechler, 2009) and language R (Baayen, 2009) packages. LME model assumptions of normality and homogeneity were satisfied.

3.2. Results

Table 2 presents the mean RTs and accuracy rates for the three prime conditions for each group after outlier exclusion.

3.2.1. Modifier-based relational information effect and English proficiency effect

Relational information conditions significantly predicted log response times ($F(2, 3635) = 78.78$, $p < .001$). Specifically, responses were slower in the neutral condition compared to the MS and MD conditions. The MS condition differed significantly from the neutral condition ($t = -12.80$, $p < .001$). There was also a significant difference between the MD and neutral conditions ($t = -9.01$, $p < .001$). The same relation primes (MS) led to faster response times than the different relation primes (MD) ($t = -5.76$, $p < .001$). English proficiency also significantly predicted log response times ($F(1, 3635) = 215.58$, $p < .001$), with the advanced group responding 1.03 times faster than the intermediate group. This difference between the intermediate and advanced groups was significant ($t = 5.55$, $p < .001$). A significant interaction between relational information conditions and English proficiency was detected as well ($F(2, 3635) = 8.48$, $p < .001$). Specifically, the difference between the neutral and MD conditions was significantly greater for the advanced group compared to the intermediate group ($t = 2.11$, $p < .05$). Furthermore, the neutral–MS difference was larger for the advanced group (302 ms) than the intermediate group (238 ms) ($t = 4.12$, $p < .001$). In summary, shortened response times in the MS and MD conditions were more pronounced with increasing levels of English proficiency.

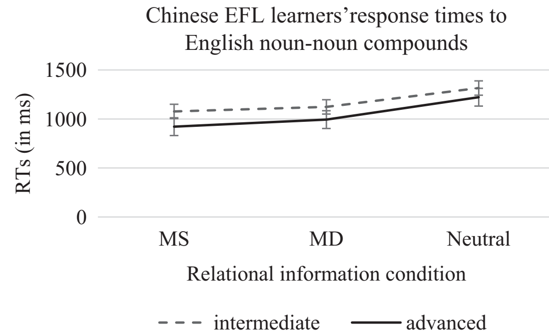

Figure 1. Chinese EFL learners' RTs in the sense-nonsense judgement task.

Separate LME analyses were conducted for each proficiency group (see Figure 1). For the intermediate group, the relational information conditions significantly predicted the RTs ($F(2, 1792) = 31.25$, $p < .001$). Overall, the RTs were longer in the neutral condition than the MS and MD conditions. The neutral–MS difference was significant ($t = -7.56$, $p < .001$), as was the neutral–MD difference ($t = -5.79$, $p < .001$). Furthermore, the RTs were shorter for the same relation (MS) condition compared to the different relation (MD) condition ($t = -2.32$, $p < .05$). For the advanced group, the relational information conditions also significantly predicted the RTs ($F(2, 1843) = 77.57$, $p < .001$). Similar to the intermediate group, the RTs were shorter in the MS and MD conditions than the neutral condition. The neutral–MS difference was significant ($t = -12.12$, $p < .001$), as was the neutral–MD difference ($t = -8.53$, $p < .001$). Likewise, the RTs were shorter for the same relation (MS) condition compared to the different relation (MD) condition ($t = -6.31$, $p < .001$).

Table 2. Mean RTs (in ms), accuracy rates (%) and standard deviations (in parentheses) for target items that received correct responses in Experiment 1

Data	Group	MS	MD	Neutral
Mean RTs	Intermediate	1077.89 (345.83)	1123.32 (358.43)	1316.35 (367.58)
	Advanced	920.61 (266.40)	993.28 (217.00)	1223.32 (325.95)
Accuracy rates	Intermediate	86.39 (4.93)	85.56 (5.38)	84.86 (7.83)
	Advanced	89.44 (3.89)	88.33 (3.56)	87.36 (4.46)

Note: "MS" stands for "the same modifier and the same relation" condition; "MD" stands for "the same modifier but a different relation" condition; and "Neutral" stands for "a different modifier and a different relation" condition.

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Table 3. Summary of regression analysis for factors predicting log response times in Experiment 1

Factors	df	MS	F	*p*
Relational information condition	2	0.37	40.58	= .000
English proficiency	1	0.25	27.72	= .000
Modifier's family frequency	1	0.45	49.23	= .000
Relational information condition * English proficiency	2	0.06	6.31	= .002
Relational information condition * compound lemma frequency	2	0.08	8.60	= .000
Relational information condition * English proficiency * compound lemma frequency	2	0.04	4.61	= .010

Note: The *df* for the denominator was 3,630; the model had random intercepts for participants and items.

3.2.2. Other effects

The effects of additional psycholinguistic variables related to the critical targets were also investigated. Compound lemma frequency, constituent family size, and constituent family frequency were examined due to previous research highlighting their influence on L1 English speakers' lexical decisions and familiar compound interpretation (de Jong et al., 2002; Gagné & Spalding, 2009). Each variable was systematically entered into the mixed-effects model described previously, which included relational information conditions and English proficiency as fixed effects and participants and items as random effects. Log-likelihood ratio tests compared model fit between the simpler model (i.e., the interaction of relational information conditions by English proficiency) and more complex models with each new variable added. These tests assessed whether the inclusion of each new variable was warranted. The log-likelihood was 3255.9 for the simpler model.

The addition of compound lemma frequency significantly improved the model fit ($\chi^2 = 9.36$, $p < .01$). Furthermore, including constituent family size, specifically modifier family size, as predictors resulted in a significant enhancement of the model fit ($\chi^2 = 11.80$, $p < .01$). Similarly, the inclusion of constituent family frequency, particularly modifier family frequency, significantly improved the model fit ($\chi^2 = 42.03$, $p < .001$). These findings indicated that compound lemma frequency, modifier family size, and modifier family frequency were successful predictors of log response times (see Table 3).

4. Experiment 2

4.1. Method

4.1.1. Participants

The same groups of students from Guangdong University of Foreign Studies participated in Experiment 2 after a one-month interval. Utilizing the same participants facilitated a direct comparison between Experiments 1 and 2. While the task in Experiment 1 emphasised the "suggestion" process, the task in Experiment 2 underscored the "evaluation" process. The two experiments altogether represent a continuum of the relational interpretation phase, as proposed by the "suggestion-evaluation" framework (Spalding et al., 2010). Thus, the results from the two tasks offer insights into how modifier-based and head noun-based relational information affect Chinese EFL learners' compound interpretation at various stages. Besides, participants had no prior knowledge of the task form or content before the second experiment. By conducting the experiment one month later, we aimed to address potential testing effects that could arise from the previous experiment (Toppino & Cohen, 2009).

4.1.2. Relation verification task

4.1.2.1. Critical items Compounds sharing either the same modifier or the same head noun were selected from the 296 English noun–noun compounds judged as familiar by Chinese EFL learners in Experiment 1. This resulted in the exclusion of 18 compounds, with 278 compounds retained for further analysis.

The procedure for delimiting relational information for the remaining 278 compounds was identical to Experiment 1. Out of these 278 compounds, 233 were derived from the preparatory study of Experiment 1 and 45 were newly added which required confirmation of relational information. Two PhD students majoring in linguistics/applied linguistics, who had performed the relation confirmation task in Experiment 1, independently selected a target relation from the 16 relational categories for each of the 45 new compounds, consulting dictionaries as needed. Inter-rater reliability was 93.3% with a Cohen's kappa of 0.90, indicating highly strong agreement. Finally, the researchers examined the relational coding by the PhD students.

Converging with the goal of Experiment 2, both the relations and the two constituents (i.e., the modifier and the head noun) were manipulated between primes and targets. Consequently, 120 experimental compounds were yielded (see Supplementary Table S6).

To control for potentially confounding effects of semantic transparency, Latent Semantic Analysis (LSA) scores were collected as measures of semantic transparency for the experimental compounds. One-way ANOVA conducted on the LSA scores suggested that there were no statistically significant differences between constituents and the whole compound ($F(4, 183) = 1.083$, $p = .367$), and between individual constituents and the whole compound (M–C context: $F(4, 89) = .073$, $p = .990$; H–C context: $F(4, 89) = 2.184$, $p = .077$).

Of the 120 critical items, 24 were used as target words. The remaining 96 were equally distributed across four prime conditions. Each target compound was primed by four compounds – two sharing the same modifier, and two sharing the same head noun. The relational information of the primes was either the same as or different from the target. Primes with identical relational information were considered the same relation primes. For example, *seawater* was primed by *seaweed* and *riverwater*, both of which employ the "head noun LOCATE modifier" relation. In contrast, different-relation primes have divergent relational information from the target. *Seawater* was also primed by *seashore* (relation: "head noun BY modifier") and *dishwater* (relation: "head noun FOR modifier") (see Supplementary Table S7).

4.1.2.2. Filler items A total of 120 filler items were generated for Experiment 2. Similar to the critical items, half of the filler items shared identical modifiers and the other half had the same head nouns between primes and target words. The relations for filler prime words were designed to be plausible and verifiable, while the relations for filler target words were implausible. This controlled for an equal number of yes/no responses across targets and prevented predictability from consistent prime-target relations. Filler prime and target words were created by randomly combining two common free words. The acceptability of priming filler collocations was verified by checking dictionaries or Google search results (e.g.,

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artform interpreted as "form ABOUT art"). The same method generated nonsense targets such as *artlift*, *carpaper*, and *cashface*. Filler items were matched on length and syllables (see Supplementary Table S8).

These filler items were then equally distributed across the four conditions. Among them, 24 were non-interpretable target words and the remaining 96 were interpretable prime words. As with the critical pairs, half the filler primes shared modifiers (SM condition) and half shared head nouns (SH condition) with the targets. Each filler target was matched with four different primes (e.g., *flustove* (target), *flupills* (the same modifier), *fluvirus* (the same modifier), *breadstove* (the same head noun), and *woodstove* (the same head noun) (see Supplementary Table S9).

4.1.3. Design

Experiment 2 employed a relation verification task under a priming paradigm with a 2 (English proficiency: intermediate versus advanced) × 2 (relational information conditions: the same versus different) × 2 (constituent types: the same modifier versus the same head noun) factorial design. English proficiency was a between-subjects variable, while relational information conditions and constituent types were within-subjects variables. The dependent variable was response times to target items. Differences in response times across the four prime conditions represented priming effects, demonstrating the influence of the modifier and head noun on Chinese EFL learners' English noun-noun compound interpretation.

4.1.4. Procedure

The experiment was administered on laptops using E-Prime 2.0 software. The testing took place in a quiet room, with participants randomly assigned to one of the four lists (see Supplementary Table S10). First, participants completed 10 practice trials to familiarise themselves with the procedure. They had to repeat the practice block until they achieved a 90% correct response rate. After practice, participants pressed the spacebar to begin the self-paced trial. Each trial displayed four sequential stimuli: a central fixation cross for 1,000 ms, replaced by the prime compound. Participants pressed "F" if the prime was interpretable, or "J" if non-interpretable. The fixation reappeared for 1,000 ms before the target compound. Participants again pressed "F" for an interpretable target or "J" for noninterpretable. The duration of the experiment was approximately 20 minutes.

4.1.5. Data processing and analysis

The primary variable of interest was correct target response times (RTs). Outliers exceeding 2.5 standard deviations from the mean correct RTs were excluded, eliminating 143 cases (5.99% of data).

Log-likelihood ratio tests were employed to assess the LME analysis validity. Adding relational information conditions as a fixed effect significantly improved model fit compared to a null model (χ^2 = 58.95, p < .001). Including English proficiency also improved fit compared to the relational information model (χ^2 = 276.43, p < .001). Adding the interaction between relational information conditions and English proficiency increased fit further (χ^2 = 19.72, p < .001). However, including constituent type did not improve the model (χ^2 = 0.18, p = .671). Finally, the three-way interaction did not enhance fit either (χ^2 = 0.84, p = .933).

LME models were fitted with log response times as the dependent variable, and relational information conditions, constituent types, and English proficiency as fixed effects. Participants and items were treated as random effects. For the relational information conditions, sum contrast coding was applied (same relational information condition: −1/2; different relational information condition: 1/2). Similarly, constituent types were contrasted using sum contrast coding (same modifier: −1/2; same head noun: 1/2). In addition, the contrast coding for English proficiency levels followed a sum contrast approach (intermediate level: −1; advanced level: 1).

Analyses were conducted in R (Team, 2014) using the lme4 (Bates & Maechler, 2009) and language R (Baayen, 2009) packages. After checking data normality and homogeneity, the main effects and interactions were examined.

4.2. Results

Table 4 shows the mean RTs and accuracy rates for the four prime conditions for each group after outlier exclusion.

4.2.1. Head noun-based relational information effect and English proficiency effect

Relational information conditions significantly predicted log response times (F(1, 2239) = 96.50, p < .001), with significantly slower responses for different relation primes compared to the same relation primes (t = −10.70, p < .001). English proficiency also significantly predicted response times (F(1, 2239) = 295.96, p < .001). The advanced group responded 1.03 times faster overall than the intermediate group (t = 8.98, p < .001). However, constituent types did not predict response times (F(1, 2239) = 0.17, p = .679), though responses were generally faster after the same head noun primes. The difference between constituent types was non-significant (t = 0.42, p = .679). Furthermore, a significant interaction between the relation types and proficiency was observed (F(1, 2239) = 19.77, p < .001), indicating that as proficiency increased, response times for the same relation primes were shorter compared to those of different relation primes (t = 4.45, p < .001).

Separate LME analyses were then conducted for the intermediate and advanced groups (see Figure 2). For the intermediate group, a significant main effect of relational information conditions on the RTs was observed (F(1, 1077) = 19.21, p < .001), indicating

Table 4. Mean RTs (in ms), accuracy rates (%) and standard deviations (in parentheses) for target items that received correct responses in Experiment 2

Data	Group	MS	MD	HS	HD
Mean RTs	Intermediate	2348.67 (421.69)	2482.13 (567.91)	2317.54 (419.11)	2453.07 (444.67)
	Advanced	2045.12 (280.57)	2269.28 (311.59)	2020.88 (282.96)	2268.74 (280.34)
Accuracy rates	Intermediate	81.11 (7.36)	80.28 (7.30)	81.39 (6.07)	80.83 (6.64)
	Advanced	84.44 (4.58)	83.89 (4.13)	86.11 (3.40)	85.00 (4.67)

Note: "MS" represents "the same modifier and the same relation" condition; "MD" represents "the same modifier but a different relation" condition; "HS" represents "the same head and the sane relation" condition; and "HD" represents "the same head but a different relation" condition.

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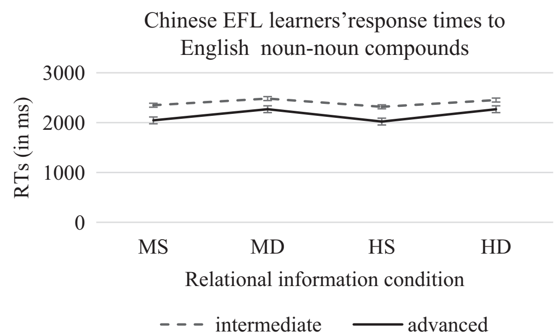

Figure 2. Chinese EFL learners' RTs in the relation verification task.

Table 5. Summary of regression analysis for factors predicting log response times in Experiment 2

Factors	*df*	*MS*	*F*	*p*
Relational information condition	1	0.37	97.78	= .000
English proficiency	1	1.12	296.66	= .000
Compound lemma frequency	1	0.02	4.83	= .039
Head noun's family frequency	1	0.09	23.93	= .000
Head noun's family size	1	0.03	8.48	= .008
Relational information condition*English proficiency	1	0.08	19.81	= .000

Note: The *df* for the denominator was 2237; The model had random intercepts for participants and items.

that responses were longer in the different relation conditions compared to the same relation conditions ($t = -4.38, p < .001$). However, no significant main effect of constituent types was found ($F(1, 1077) = 0.13, p = .718$). The difference between the same modifier and the same head noun conditions was non-significant ($t = 0.36, p = .718$). No interaction between predictors was detected. Similarly, the advanced group exhibited a significant main effect of relational information conditions ($F(1, 1161) = 117.08, p < .001$), indicating that responses in the different relation conditions were slower than in the same relation conditions ($t = -10.82, p < .001$). Again, no significant constituent types effect emerged ($F(1, 1161) = 0.08, p = .779$), with a non-significant difference between the same modifier and the same head noun conditions ($t = 0.28, p = .779$). No interaction was found.

4.2.2. Other effects

Beyond the three predictors, the effects of other psycholinguistic variables relevant to the target compounds were examined by systematically adding compound lemma frequency, constituent family size, and constituent family frequency into the model of interaction between relational information conditions and English proficiency. Log-likelihood ratio tests were performed to compare model fit between this simpler model and more complex models with each new variable added. The simpler model log-likelihood was 3012.4.

Similar to Experiment 1, the addition of compound lemma frequency significantly improved the model fit ($\chi^2 = 10.39, p < .01$). Besides, the inclusion of constituent family size, specifically the head noun family size, showed a marginal improvement in the model fit ($\chi^2 = 3.77, p = .052$). Furthermore, the incorporation of constituent family frequency, particularly the head noun family frequency, significantly enhanced the model fit ($\chi^2 = 18.49, p < .001$). These findings suggested that compound lemma frequency, head noun family size, and head noun family frequency successfully predicted log response times (see Table 5).

5. General discussion

This study investigated whether relational information and English proficiency were successful predictors of L2 learners' conceptual combination of English noun-noun compounds. Following Gagné and Spalding (2004), participants were asked to interpret whether target noun-noun compounds primed by different relational information conditions with manipulated modifiers were interpretable or noninterpretable. We hypothesised that participants would exhibit faster response times in the same modifier and the same relation (MS) condition compared to the same modifier but a different relation (MD) condition. Moreover, we tested whether the same head noun and the same relation (HS) pairs would, in the relation verification process, predict a stronger facilitation effect compared to the same head noun but different relation (HD) pairs, thus providing evidence for a continuum of "suggestion-verification" in relation-based conceptual combination of noun–noun compounds. Finally, we examined whether English proficiency would modulate L2 learners' conceptual combination process. The findings supported most, but not all, of these hypotheses, suggesting that (1) prime compounds in both the MS and HS conditions facilitated conceptual combination compared to those in MD and HD conditions, respectively; (2) response times to target noun-noun compounds primed by words in the HS condition did not significantly differ from those primed by words in the MS condition; (3) higher English proficiency correlated with increased speed and increased accuracy across the two tasks and all conditions. Interestingly, the processing pattern between the intermediate and advanced proficiency groups was similar.

As hypothesised, results in Experiment 1 demonstrated that compounds in the same relational information condition were much easier for Chinese EFL learners to interpret. This indicates that the meaning construction of English noun–noun compounds involves the utilization of modifier-based relational information, rather than merely juxtaposing constituents. Besides, Chinese EFL learners showed greater ease in interpreting English noun–noun compounds when primed by a preceding compound sharing the same modifier. This repetition priming effect supports the notion that even noun–noun compounds undergo decomposition to facilitate meaning computation (Gagné & Spalding, 2004). Whereas previous research characterised decomposition as a "backup" process occurring only when access to the whole compound fails (Andrews, 1986; Butterworth, 1983; Jaarsveld & Rattink, 1988), the present study suggests that decomposition occurs concurrently with whole compound access, even when successful. Since participants were familiar with all the critical items in Experiment 1, it was unlikely that they experienced substantial difficulty accessing the whole compounds during the sense-nonsense judgement task.

The results of Experiment 2 revealed that the relation priming effect occurred in both the modifier and head noun repetition conditions. While more research is needed on the role of head constituents in compound processing, the present finding of a head noun-based relational information effect aligns with the claim that head noun-based relational information can be detected in tasks directly assessing the evaluation of a possible relational interpretation (Spalding et al., 2010). Furthermore, the modifier-based

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relational information effect in the "evaluation" stage echoes the proposal that modifiers and head nouns interact to verify relation-based interpretations (Spalding et al., 2010). On the other hand, Experiment 2 did not reveal constituent repetition effects on Chinese EFL learners' noun–noun compound interpretation. Specifically, no significant difference occurred between the same modifier and the same head noun conditions. This suggests that there may not be a clear demarcation between "suggestion" and "evaluation" stages in noun–noun compound interpretation, indicating a potential overlap despite the linear RICE framework. Furthermore, our finding of 22 ms faster RTs for the same head noun primes compared to the same modifier primes aligns with Spalding et al. (2010), who reported an even stronger influence of head noun repetition. The current finding also echoes Zhao and Hong (2015), who found a similar robust effect of head noun-based relational information on Chinese EFL learners in a relation verification task.

Both Experiments 1 and 2 indicate that English proficiency impacts Chinese EFL learners' conceptual combination processing, with the advanced group exhibiting significantly faster response times compared to the intermediate group across all prime conditions. As hypothesised, higher-proficiency learners access the relational information of English noun–noun compounds more readily than lower-proficiency learners. Faster initial retrieval of potential relational information facilitates quicker responses when deciding on an intended relational interpretation. Despite advanced learners likely establishing relational information faster, it is anticipated that an overall processing pattern would be similar between the two groups. Likewise, though meanings of noun–noun compounds are lexicalised, recombination of constituents still requires meaning construction when morphological decomposition occurs. English proficiency is anticipated to affect the speed of accessing pre-existing relational information, with advantages for the higher-proficiency group in entrenchment and retrieval. However, the overall pattern of conceptual combination through morphological decomposition and meaning construction is predicted to be analogous across groups.

The finding regarding the effect of English proficiency offers valuable insights into L2 learners' compound processing. Firstly, it reveals the presence of a dual process in L2 learners' compound processing, which encompasses both morphological decomposition and meaning construction. This perspective supports the notion that both constituents and compounds as a whole are independently represented in L2 learners' mental lexicon (Zhao, 2014). Secondly, English proficiency appears to influence the automaticity of retrieving both constituents and compounds. Higher English proficiency level leads to stronger entrenchment and automatic retrieval, resulting in faster access to the target compounds. Thirdly, as demonstrated by Chen et al. (2024), semantic associations are present in the mental lexical networks of Chinese EFL learners across different proficiency levels, with the difference being quantitative rather than qualitative. Building on their findings, we can explain the similar processing pattern observed in both proficiency groups in our study. Both groups possess relational information in their mental representation of English noun–noun compounds, with advanced learners exhibiting stronger semantic associations, thereby facilitating faster meaning construction of compounds. Lastly, previous researchers have reported the activation of Chinese translations in compound processing among Chinese–English bilinguals (Thierry & Wu, 2007; Wen & van Heuven, 2018). Therefore, future research should consider the influence of L1 equivalents and explore their interaction with English proficiency, as they collectively impact the outcomes of EFL learners' compound processing.

The interaction effect between relational information conditions and English proficiency in both experiments suggests that while both groups demonstrated modifier- and head noun-based relational information effects, divergence existed in their responses to different relation prime types. For different relation primes, there was no significant difference between the advanced and intermediate groups, suggesting similar difficulty in selecting the intended relational information without relation repetition. In other words, both groups showed comparable processing speed impediment without prime relation repetition. However, the higher-proficiency group exhibited greater facilitation with the same relation primes. Therefore, advanced learners seemed to benefit more from relation repetition than intermediate learners during the interpretation of English noun–noun compounds.

Previous research has demonstrated the effect of compound lemma frequency on L1 English speakers' noun–noun compound interpretation (Gagné & Spalding, 2009), a finding further confirmed by Chinese EFL learners in Experiments 1 and 2. Despite profiling different relational information, whole compound lemma frequency impacts EFL learners' familiarity and availability of associated relational information. Furthermore, the finding of the modifier family frequency effect in Experiment 1 aligns with previous research on compound processing (Gagné & Spalding, 2009). A key feature of the family frequency effect in Experiment 1 is their position-bound nature. Specifically, only the modifier-related effect emerged in the sense-nonsense judgement task, whereas the head noun family frequency effect was absent. This partially conflicts with Gagné and Spaldin's (2009) equal effects finding. A potential explanation is that modifier and head noun family members play an equally important role in L1 speakers' mental lexicon organization. Thus, even in tasks emphasizing modifier-based relational information, the head noun effect persists. In contrast, the number of represented compounds is smaller in Chinese EFL learners' mental lexicon, with organization biased towards either a modifier or head noun. This renders relational information accessibility prone to task influences. Since Experiment 1 focused on the modifier-centric first stage of the "suggestion-evaluation" framework, the modifier role was prominent. Consequently, modifier-associated variables like modifier family frequency exerted greater influence on Chinese EFL learners' conceptual combination of English noun–noun compounds.

On the contrary, only the head noun family size and family frequency effects were observed in the relation verification task, whereas the modifier family size/frequency effect was absent. Given the modifier family frequency effect in Experiment 1, these variables appear to depend on the morphosyntactic role the constituent played in Chinese EFL learners' compound processing. Task-specific profiling of modifier- or head noun-based relational information activates and strengthens biased relational representations. To the best of our knowledge, no research has examined L1 speakers' noun–noun compound interpretation through relation verification task. Thus, it remains unclear if family-based measures (i.e., family size and family frequency) for both constituents would impact L1 speakers' conceptual combination of compounds in the relation evaluation stage.

Critically, the generalizability of our results to other L2 contexts should be approached with caution due to limitations of the present study. First, owing to Chinese EFL learners' generally limited knowledge of English noun–noun compounds, the number of experimental items in Experiments 1 and 2 was relatively small. Although compounds sharing the same modifiers or the same head nouns were matched for familiarity, log lemma frequency, word

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length and syllables, maintaining equal semantic transparency across stimuli was impossible. The present study adopted latent semantic analysis to control for the potential confounding effect from semantic transparency. However, some compounds were more semantically transparent than others, which might have introduced confounding effects. Second, the degree of translatability of the test items varied. Some compounds (e.g., *backyard*, *backdoor*, *snowball*) have direct English-to-Chinese translations, while others (e.g., *sunstroke*, *bedtime*) do not. Ko et al. (2011) demonstrated cross-language activation in bilingual readers' compound processing through a lexical decision task. Similarly, Zhao (2014) corroborated this view by investigating Chinese EFL learners' visual word recognition. Although these studies primarily adopted lexical decision tasks, cross-language activation might influence other tasks, such as sense-nonsense judgement and relation verification tasks. Third, since this study was conducted on Chinese university students, the results may only be generalised to highly educated populations with similar linguistic competence.

6. Pedagogical implications

The factors identified in this study, such as relational information associated with the modifier or head noun, as well as position-based family size and family frequency, hold significant implications for both the teaching and learning of English compound structures and the compilation of English learners' dictionaries.

The present study offers valuable insights into the effective teaching and learning of compounds within instructed L2 contexts. Traditionally, English noun–noun compounds have been taught to L2 learners either as indivisible units or as a combination of two separate words, neglecting the underlying relational information that connect their constituents. Consequently, L2 learners often rely on mapping the modifiers' and head nouns' equivalents from their L1 to derive meaning in English noun–noun compounds. Previous research has noted cross-language activation in Chinese EFL learners' compound processing, highlighting the potential for L1 influences (see Zhao, 2014). However, this approach of solely combining L1 equivalents is only effective when the target compounds in the source language share identical concepts and are integrated in the same manner, with matching relational information linking the modifier and head noun. For instance, Chinese EFL learners find it easy to interpret *birdcage* due to its similarity to its Chinese equivalent niǎolóng (鸟笼) in terms of concept and relational information. However, such perfect equivalence between noun–noun compounds across different languages is rare. Therefore, a more effective pedagogical approach for L2 teachers is to explicitly address the "hidden" relational information associated with the modifier and head noun in English noun–noun compounds, excluding semantically opaque compounds. This approach allows L2 learners to systematically categorise compounds into different groups based on general relational information (e.g., FOR, OF, and MAKE), thereby facilitating a more appropriate understanding of their meanings. Besides, attention to position-based family size and family frequency helps L2 learners distinguish between compounds that share the same constituents but have different morphosyntactic roles (e.g., *housedog* versus *doghouse*). Furthermore, it assists learners in establishing connections among related compounds, and contributes to their structural representation of English noun–noun compounds within their mental lexicon.

The present study also offers a viable approach for the effective treatment of English noun-noun compounds in English learners' dictionaries, aiming to enhance the acquisition of these compounds by L2 learners. Currently, English learners' dictionaries present compounds as indivisible words, lacking the necessary links (e.g., similarities and differences) between compounds that share the same constituents or relational information. This deficiency hampers L2 learners' awareness of the relationships among these compounds. To address this issue, it is crucial to make full use of relational information for a systematic treatment of English noun–noun compounds, as these relations serve as a "bridge" connecting the form and meaning of compounds. According to Booij (2010), nominal compounds can be considered "morphological constructions" that can be represented as a schema. For instance, the schema for noun-noun compounds can be expressed as "[[a]xk[b]Ni]Nj [SEMi with relation R to SEMk]j" (Booij 2010: 17), where the relation R is unspecified. Building upon this claim, English noun–noun compounds sharing the same constituents and relational information can be generalised within a single schema, presenting a schematised group of compounds that are semantically relevant. This approach visually presents the links among family members and captures the attention of L2 learners. Moreover, establishing cross-references between compounds and their constituents (either the modifier or head noun) as independent entries in English learners' dictionaries is essential. For example, compounds like *snowball* and *snowman* can be represented using the same schema "[[snow][x]Ni]Nj [xi MADE OF snow]j." Given the complexity of this schema, a simplified version should be provided in English learners' dictionaries. In addition, to facilitate learners' recognition of the similarities (both morphological and semantic) between the two compounds, it is suggested to highlight the modifier and relational information in bold (e.g., snow-x: x **MADE OF** snow).

7. Conclusion

Overall, this study made an initial endeavour to investigate the effects of relational information and English proficiency on the conceptual combination of English noun–noun compounds by EFL learners. In line with relation-based accounts of conceptual combination, our results demonstrate that when tasks promote relation suggestion (e.g., the sense-nonsense judgement task), modifier-based relational information exerts a stronger influence on processing. Besides, head noun-based relational information impacts processing when relation verification is required. Crucially, English proficiency shows a consistent effect across tasks. While advanced learners derive greater benefits from exposure to identical relational information compared to their intermediate counterparts, both groups exhibit a similar processing pattern.

Despite the limitations mentioned above, the findings of this study provide empirical evidence supporting L2 compound processing theories and conceptual combination models. Moreover, they have implications for teaching and learning of English compounds, and for future research on EFL learners' conceptual combination of English noun-noun compounds. By verifying theoretical models, this work furthers our understanding of L2 compound processing and paves the way for additional studies in this line of research.

Supplementary material. To view supplementary material for this article, please visit http://doi.org/10.1017/S1366728924001044.

Data availability statement. The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Competing interest. None declared.

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