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Difficulties in Comprehending Affirmative and Negative Sentences: Evidence From Chinese Children With Reading Difficulties

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Abstract

Recent experimental results suggest that negation is particularly challenging for children with reading difficulties. This study looks at how young poor readers, speakers of Mandarin Chinese, comprehend affirmative and negative sentences as compared with a group of age-matched typical readers. Forty-four Chinese children were tested with a truth value judgment task. The results reveal that negative sentences were harder to process than affirmative ones, irrespective of the distinction between poor and typical readers. Moreover, poor readers performed worse than typical readers in comprehending sentences, regardless of whether they were affirmative or negative sentences. We interpret the results as (a) confirming the two-step simulation hypothesis, based on the result that the difficulty in processing negation has a general validity (persisting in pragmatically felicitous contexts), and (b) disconfirming that negation, as far as behavioral data are concerned, can be used as a reliable linguistic predictor of reading difficulties.

Keywords

reading difficulty, sentence comprehension, negation

It is well documented that negation is challenging for typically developing children as well as for adults (e.g., Clark & Chase, 1972; Klatzky, Clark, & Macken, 1973). It has been also suggested that comprehending negation is particularly challenging for children who have difficulties in reading and could be considered a linguistic predictor of reading difficulty (Vender, 2011; Vender & Delfitto, 2010). However, studies on adults with reading difficulties provide evidence that dyslexic adults experience difficulties in comprehending not only negative sentences but also affirmative sentences (Scappini, 2015; Scappini, Delfitto, Marzi, Vespignani, & Savazzi, 2015). Here, we address the issue of an explicit comparison between affirmative and negative sentences, by carrying out a study on Chinese children with reading difficulties. By comparing their comprehension of negative sentences with that of affirmative sentences, we aim at investigating whether (a) the two-step simulation hypothesis (TSSH; based on the experiential view of language comprehension; Kaup, Lüdtke, & Zwaan, 2005, 2006, 2007) holds in contexts involving pragmatically felicitous sentences, irrespective of the difference between poor readers and typical readers, and (b) whether poor readers perform worse than typical readers in processing negation, thus turning negation into a reliable linguistic predictor of reading difficulty. We begin by reviewing research on the processing of negation.

The Processing of Negation

Negation is a linguistic tool highly specific to human language, and its use and interpretation in natural language are far from simple. A number of studies have shown that negative sentences are more difficult to process than their affirmative counterparts, as demonstrated by higher error rates and longer response times. These results hold independently of the experimental tasks used (Carpenter & Just, 1975; Carpenter, Just, Keller, Eddy, & Thulborn, 1999; Clark & Chase, 1972; Hasegawa, Carpenter, & Just, 2002; Paradis & Willners, 2006; Trabasso, Rollins, & Shaughnessy, 1971; Wason, 1959, 1961).

Moreover, it seems that processing costs are enhanced when negative sentences are used in unsupportive contexts. For instance, Sentence 1 takes longer to process than Sentence 2, despite the fact that both sentences are negative and have the same truth value:

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(1) The whale is not a bird.
(2) The whale is not a fish.

Wason (1965) observed an association between the appropriateness of a negative sentence and the plausibility of its affirmative counterpart. To account for this observation, he proposed the notion of *context of plausible denial*, according to which the plausibility of a negative sentence is indissolubly connected to the presence of a prior expectation that has to be denied and to the plausibility of the prior statement itself. In reference to Sentences 1 and 2, it seems plausible to wonder whether a whale is a fish, whereas it seems strange to wonder whether it is a bird. According to Wason, this happens because only Sentence 2 is used in a supportive context, since there is a possible expectation to be denied (i.e., that the whale is a fish). In this sense, the plausibility of a negative sentence is linked to the presence of a prior statement that is being rejected (for an explicit proposal, see Horn, 1989).

On the basis of these and other considerations, Kaup and colleagues (2005, 2006, 2007) developed the TSSH, proposing that a negative sentence entails a presupposition of its affirmative counterpart that needs to be corrected, hence communicating to the listener a deviation from previous expectations. The theory rests on the experiential view of language comprehension, according to which sentence comprehension involves the construction of a mental representation of the described state of affairs—the so-called situation model (Zwaan & Radvansky, 1998). Consistently, a compelling body of neuroscience studies confirms that comprehenders mentally simulate the state of affairs, which is described in the utterances in a way that is similar to directly experiencing it (Pulvermüller, 2002). However, negation poses a potential problem for this view, since it does not have, by definition, an equivalent in experience. To solve this impasse, Kaup et al. (2006) suggested that negation is used to communicate to the listener a deviation from one's expectations and that it requires the manipulation of two temporally distinct stages. In the first stage, the comprehender constructs a mental representation corresponding to the negated situation described in the sentence (the "negated state of affairs"); in the second stage, she or he switches to a simulation matching the actual meaning of the sentence (the "actual state of affairs"). To exemplify, to interpret Sentence 3, the comprehender must first construct a simulation of the negated state of affairs (e.g., *an open window*) and then a simulation of the actual state of affairs (e.g., *a closed window*).

(3) The window is not open.

The assumption that the processing of negation requires two temporally distinct stages is supported by a substantial body of empirical evidence (Giora, Balaban, Fein, & Alkabets, 2005; Kaup et al., 2005, 2006, 2007). Hasson and Glucksberg (2006), for instance, conducted an experiment asking subjects to read affirmative and negated assertions, such as *This lawyer is/is not a shark*, and then to make lexical decisions to terms related to the affirmative or negative meaning (e.g., *vicious, gentle*). The delay between the onset of the metaphorical sentence and the presentation of the target word was manipulated in three conditions, with the target word appearing 150, 500, and 1,000 ms after the sentence onset. When the target word appeared after 150 and 500 ms from the sentence onset, lexical decision was facilitated just in the case of affirmative-related terms (e.g., *gentle*), indicating that negative sentences were still processed as affirmative ones in these stages. Conversely, after 1,000 ms, no facilitation for affirmative-related terms was found with negative metaphors, suggesting that negation had been meanwhile interpreted. These results are consistent with a late and nonincremental processing of negation, as stated by the TSSH, and contribute to explain why negative sentences generally require a more costly processing in comparison with their affirmative counterparts, relying on nonautomatic and working memory–dependent processes.

Interpretation of Negation in Sentence-Picture Verification Tasks

The majority of the studies contrasting the processing of negative and affirmative sentences adopt a sentence-picture verification task, where participants have to verify sentences against pictures matching or mismatching the meaning of the sentence. Typically, these experimental designs include four distinct conditions: true affirmative (e.g., a sentence such as *The window is open* to be compared with a picture of an open window), false affirmative (e.g., a sentence such as *The window is open* against a picture of a closed window), true negative (e.g., a sentence such as *The window is not open* against a picture of a closed window), and false negative (e.g., a sentence such as *The window is not open* against a picture of an open window). Results generally display a significant effect of negation, indicating that negative sentences (both true negative and false negative) are more difficult to process in comparison with their affirmative counterparts, as shown by lower accuracy and slower response time. Moreover, a significant effect of truth is typically observed, with true negative sentences being the most difficult ones to process (Carpenter & Just, 1975; Clark & Chase, 1972; Dale & Duran, 2011; Kaup et al., 2005).

This latter result can be explained by means of the TSSH. As discussed, in the first step of negative sentence comprehension, the subject engages in the construction of a simulation corresponding to the negated state of affairs; therefore, she or he can take advantage of a picture illustrating it, which has a sort of priming effect, as happens in the false-negative condition. In the true-negative condition, however, where this facilitation effect is not present, processing costs increase.

Further support for this hypothesis comes from electrophysiological studies. Using a sentence-picture verification task, Lüdtke, Friedrich, Filippis, and Kaup (2008) reported the presence of enhanced N400 effects in the false-affirmative and true-negative conditions. This confirms that true affirmatives are easier than false affirmatives, whereas false negatives are easier than true negatives.

However, the experimental design adopted in this study was criticized by Nieuwland and Kuperberg (2008), who argued that the N400 modulations associated with the interpretation of negative sentences might have been brought about by the absence of an appropriately supportive discourse. Given these considerations, Scappini (2015) conducted an event-related potential (ERP) study in which they tried to avoid pragmatic infelicity by presenting two characters, one of which corresponded to the subject of the sentence, and two activities, one of which was described in the sentence (see also Scappini et al., 2015). Behavioral and ERP data provided evidence that even in pragmatically balanced conditions, the interpretation of negative sentences is significantly more effortful than that of affirmative sentences. In addition, a significant difference between true negatives and false negatives was observed in accuracy rates, though not in response time. The authors attributed the latter result to the different experimental paradigm adopted in their study and specifically to the complexity of the visual scene, which was introduced to produce contexts of plausible denial, ensuring pragmatic felicity, but which prevented the facilitation effects deriving from simple priming between the two stimuli, as found by Lüdtke et al. (2008).

All in all, Scappini's study indicates that even when the experimental conditions are controlled for pragmatic infelicity, negative sentences are more difficult to process than their affirmative counterparts, arguably because they require costly nonincremental two-stage processing, as predicted by the TSSH.

Interpretation of Negation Among Children With Reading Difficulties

Reading plays a critical role in children's development, and around 3% to 10% of the school population has difficulties in reading across languages; for example, about 5% to 8% of Chinese schoolchildren have difficulties in reading Chinese (e.g., Snowling, 2000; Stevenson et al., 1982). An extensive body of research has shown that this reading difficulty is characterized primarily by difficulties in constructing fine-grained mental representations of speech sounds: The presence of an underlying phonological deficit is demonstrated by poor phonological awareness and by marked difficulties in phonological short-term memory, as well as in the decoding of the phonological structure of a spoken linguistic input (Desroches, Joanisse, & Robertson, 2006; Ramus et al., 2003; Rispens, 2004; Schatschneider, Carlson, Francis, Foorman, & Fletcher, 2002; Snowling, 1995). More recent research reports difficulties in other domains of linguistic competence. At the level of morphosyntax, difficulties have been shown in the production of correct subject-verb agreement, the analysis of the argument structure of sentences, the recognition of grammatical errors, and the generation of plural forms of nonwords (Cantiani, Lorusso, Perego, Molteni, & Guasti, 2013; Joanisse, Manis, Keating, & Seidenberg, 2000; Wilsenach, 2006). At the level of interpretation, difficulties have been reported in the interpretation of passive sentences, control structures, pronouns, imperfective aspect, quantifiers, and scalar implicatures (Byrne, 1981; Fiorin, 2010; Vender, 2011; Waltzman & Cairns, 2000). Next to these specifically linguistic factors, a number of studies suggest that the cognitive profile of reading difficulties is characterized by poor working memory resources and executive functions (Jeffries & Everatt, 2004; Martin, 2013; Peng, Wang, Tao, & Sun, 2016; Vender, in press).

In light of the considerations about the processing of negation outlined so far, the interpretation of negative sentences is particularly interesting within the dyslexia debate, due to the complexity of negation processing in terms of cognitive resources.

The interpretation of negation in children with reading difficulties was first investigated by Vender and Delfitto (2010). This study tested how dyslexic children (mean age, 9 years 8 months) interpret negative sentences in comparison with typically developing age-matched children through use of a sentence-picture verification task. It examined (a) true- and false-negative sentences with internal sentential negation (e.g., *The hen is not reading the newspaper*) and (b) true- and false-negative sentences with external negation (e.g., *It is not true that the hen is reading the newspaper*). Results revealed that dyslexic children were significantly less accurate (though not slower) than controls in all conditions, pointing to a difficulty in interpreting negative sentences in dyslexia, with the type of negation (i.e., internal vs. external negation) not affecting the performance. However, this study presents the same methodological flaw imputed to Lüdtke and colleagues' (2008) paradigm—namely, making use of pragmatically inappropriate contexts of utterance. In addition, although affirmative sentences were included as fillers, the study did not include the dyslexic children's performance with affirmative sentences. Therefore, it cannot be established whether dyslexic children's difficulty in sentence comprehension concerns only negative sentences or also extends to affirmative sentences. More generally, it is not clear whether the dyslexic children's poor performance is selectively triggered by negation or by a more general processing difficulty, plausibly due to the complexity of the experimental task.

Scappini (2015) compared the performance of adult dyslexics and controls using the same ERP paradigm described in the preceding section. The results revealed that, as compared with unimpaired age-matched adults, dyslexic adults manifested a poorer performance not only in negative sentences but also in affirmatives, which points to a general processing difficulty not specifically linked to negation but plausibly triggered by the complexity of the experimental task. In addition, the analysis of the ERPs showed that dyslexic adults display effects for affirmative and negative conditions already in the first stage of processing, unreported in the control adults, suggesting that they may interpret negative sentences by relying on different cognitive processes as compared with the control group.

To summarize, a few studies on poor readers have been conducted to examine the interpretation of negation in this population, and these studies indicate that the interpretation of negative sentences is particularly challenging for both children and adults with reading difficulties. However, several questions remain unanswered. Specifically, it is not clear whether the difficulty in comprehension exhibited by poor readers is selectively triggered by the processing of negative sentences or also extends to the processing of affirmative sentences. In this respect, we would like to know (a) whether the increased difficulty in processing negative sentences with respect to affirmative sentences crosscuts the distinction between typical and poor readers in pragmatically supportive contexts, hence providing strong evidence for the TSSH, and (b) whether the poor readers' processing difficulty is selectively triggered by negation, a finding that would turn negation into a predictor of reading difficulties. Moreover, it would be interesting, in this respect, to reach some conclusions about the possible relationship between negation, as an interpretive predictor of reading difficulties, and other (linguistic) predictors of reading difficulties that have been recently investigated, such as phonological and morphological awareness and rapid naming.

Present Study

The main goals of the present study were to investigate (a) whether there is increased processing difficulty with negative sentences with respect to positive sentences, extending to pragmatically supporting contexts and crosscutting the difference between typical and poor readers, and (b) whether negation processing can be taken as a reliable linguistic predictor of reading difficulties. We tried to achieve these goals by comparing the processing of negative sentences with the processing of affirmative sentences in poor and typical readers. According to the TSSH, negative sentences should be harder to comprehend than affirmative sentences for both groups. However, if negation is a predictor of reading difficulties, poor readers should experience more difficulties than typical readers with negative sentences while not experiencing more difficulties than typical readers with affirmative sentences. The present study used a specifically devised truth value judgment task to overcome the pragmatic infelicity found in some of the previously discussed studies. In the task, a puppet produces a sentence to describe a picture. By informing the participants that the puppet is looking at the picture while producing the sentence, we attempted to provide felicitous conditions for the participants to judge whether the sentence represents a "true" or "false" description of the sentence.

At the same time, we crucially intended to provide some preliminary results on the processing of negation among Chinese children with reading difficulties, while exploring whether their comprehension of negation shows any significant correlation with other predictors of reading difficulties that are well documented in the literature. The choice of Chinese poor readers is motivated as follows. The previous findings regarding the relationship between negation and reading difficulties were based on studies of alphabetic languages, such as Italian, and very little is known, so far, about how negation is processed by children who have difficulties in reading a nonalphabetic language, such as Chinese. What is interesting in this respect is the observation that Chinese children with reading difficulties are heterogeneous in characteristics, showing one or more deficits on cognitive and linguistic skills when compared with typically developing children (e.g., Chung & Ho, 2010). Given the complexity of negation processing in terms of cognitive resources, investigating negation might contribute to a more precise understanding of the cognitive profiles underlying the etiology of reading difficulties in this population. Several cognitive/linguistic traits have been identified in Chinese children with reading difficulties, such as phonological awareness, morphological awareness, rapid naming, visual-orthographic skills, and working memory (e.g., Chung & Ho, 2010; Chung, Ho, Chan, Tsang, & Lee, 2011; Peng et al., 2016; Shu, McBride-Chang, Wu, & Liu, 2006; Song, Georgiou, Su, & Hua, 2016). Among these, phonological awareness, morphological awareness, and rapid naming are arguably at the core of the Chinese learning process (McBride & Wang, 2015). Importantly, readers from different parts of China have been argued to show distinct cognitive profiles, as different languages or local dialects are spoken, but they all map to one simplified or traditional written script (e.g., Ding, Richman, Yang, & Guo, 2010; Wang, Georgiou, Das, & Li, 2012; cf. the meta-analysis conducted by Peng et al., 2016). For instance, children in Beijing speak Mandarin Chinese (i.e., the official language of China) and read the simplified Chinese script. Children in Hong Kong speak Cantonese (i.e., the language used primarily in the southern part of China) and read the traditional Chinese script. According to Luan (2005), morphological awareness and rapid naming deficits are common among poor readers in Beijing and Hong Kong, but a phonological awareness deficit is common only among poor readers in Beijing and not among poor readers in Hong Kong. The

Table 1. Characteristics of the Participants.

Characteristic	Poor readers (*n* = 22)	Typical readers (*n* = 22)	*t*	*p*
Boys, *n*	16	10		
Age[a]	9.8 (1.15)	9.7 (1.26)	0.88	.38
Raven IQ[b]	100.64 (7.13)	101.72 (9.20)	1.29	.20
Literacy performance[c]	62.01 (5.68)	84.30 (3.85)	5.54	.000***

[a]For age, the numbers indicate mean (*SD*) years (e.g., 9.8 = 9 years 8 months). [b]For the Raven IQ, the numbers indicate mean (*SD*) standardized scores. [c]For reading, the numbers indicate mean (*SD*) accuracy for each group.
****p* < .001.

children who participated in our study were all from Zhejiang, China, and they dominantly spoke Mandarin Chinese and read simplified Chinese characters. Therefore, guided by the previous results, we collected background measures of children's ability in phonological awareness, morphological awareness, and rapid naming skills to provide a full cognitive/linguistic profile of our participants and a database for the possible correlation between these dyslexia predictors and negation comprehension.

Method

Participants

Twenty-two poor readers and 22 typical readers were recruited to participate in the study. They were selected from a larger sample of 1,089 children participating in an ongoing longitudinal study of language and literacy development. All of these children attended the primary school in Zhejiang, China, and the medium of instruction at schools was Mandarin Chinese. All the children were assessed with a literacy test at school during school time. The test included character recognition, vocabulary knowledge, reading comprehension, and writing, which were similar to those reported in Leong and Ho (2012), and only accuracy was measured (see also Li, Shu, McBride-Chang, Liu, & Peng, 2012; Liu, Mcbride-Chang, Wong, Shu, & Wong, 2013).

Children were placed in the poor reader group if their scores on the literacy test were at least 1.5 *SD* below the average means for their grades and if they had difficulties in reading and writing Chinese according to daily observations in their teachers' reports. In addition, they obtained a standardized score ≥80, as assessed by the Chinese version of the combined *Raven's Progressive Matrices* (Zhang & Wang, 1985). As for the typical readers, they were chronologically age and IQ matched to poor readers and had an average standard score or above in the literacy test (see Table 1). All the children tested did not have any suspected brain damage, sensory impairments, or serious emotional or behavioral problems. Their vision was normal or corrected to normal.

The participants were administered seven measures: three phonological awareness tasks, two morphological awareness tasks, and one rapid naming task for measuring their backgrounds and one task for examining their comprehension of affirmative and negative sentences.

Background measures

Phonological awareness. A Chinese syllable is conventionally dissected into onset, rhyme, and tone. For instance, the syllable *bái* includes an onset *b*, a rhyme *ai*, and the second tone. Thus, phonological awareness was assessed with three tests—onset detection, rhyme detection, and tone detection. Similar tests have been used by Ho and Bryant (1997). All the tests were administered to children in a group, and the materials were presented orally.

Onset detection. The task consisted of a practice trial and 16 experimental trials. Children were asked to listen carefully to four syllables and to identify which sound differs from the others. In each trial, four syllables were presented, with three having the same onset (e.g., the onset *f* in *fā, fú*, and *fěn*) and one syllable having a different onset (e.g., *m* in *mō*). Then children were asked to select out the syllable with different onset (i.e., *mō* in this example). Tones and rhymes were randomly changed across the four syllables.

Rhyme detection. The task consisted of a practice trial and eight experimental trials. Children were asked to select out the syllable with a different rhyme. For instance, three syllables had the same rhyme (*ou* in *chōu, dòu*, and *mǒu*), and one syllable had a different rhyme (e.g., *o* in *pó*). Tones and onsets were randomly changed across the four syllables.

Tone detection. The task consisted of a practice trial and eight experimental trials. Children were asked to choose the syllable with a different tone. For instance, three syllables had the same tone (the third tone in *huǒ, liǎn*, and *shǒu*), and one syllable had a different tone (e.g., the second tone in *yuán*). Onsets and rhymes were randomly changed across the four syllables.

Morphological awareness. Morphological awareness was assessed with two tests: homophone awareness and homograph awareness. Both tests were modeled after Luan

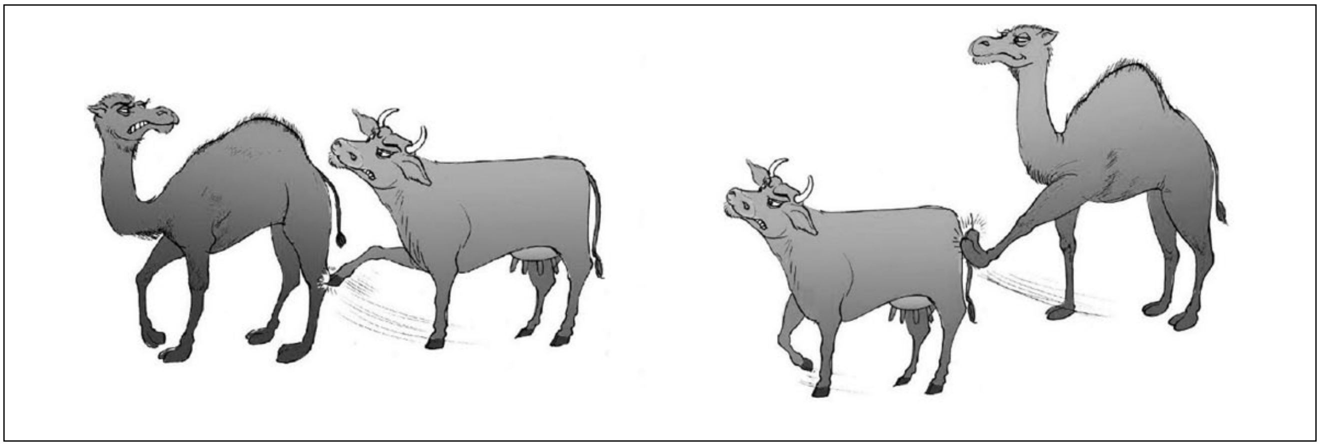

Figure 1. Example of a set of pictures: Picture A on the left and Picture B on the right.

(2005). They were administered to children in a group, and the materials were orally presented.

Homophone awareness. The test consisted of a practical trial and 20 experimental trials. In each trial, children were asked to listen to four two-morpheme words. In each of the four words, one morpheme shared the same sound but corresponded to different written forms (e.g., *bì* for 必 and 毕). Three of the four words had the same morpheme (e.g., 必 in 必然 [*bìrán* 'definitely'], 必定 [*bìdìng* 'certainly'], 必须 [*bìxū* 'must']), and one had a different morpheme (毕 in 毕业 [*bìyè* 'graduate']). Children were asked to choose the different one (i.e., 毕业 in this case).

Homograph awareness. The test consisted of a practical trial and 20 experimental trials. In each trial, four words were presented, and in each word, one syllable was identical in sound and written form (e.g., *shāng*, 商). Three of the four words had the same meaning (e.g., 商店, *shāngdiàn* 'shop'; 商品, *shāngpǐn* 'goods'; 商场, *shāngchǎng* 'market'), and one had a different meaning (商量, *shāngliàng* 'discuss'). Children were asked to choose the different one (i.e., 商量 in this case).

Rapid number naming. We tested rapid naming for digits, rather than objects or colors, because rapid naming for digits shows a stronger correlation with Chinese reading than rapid naming for objects and colors (Liao, Georgiou, & Parrila, 2008; Peng et al., 2016). This test includes five digits (2, 4, 6, 7, 9), the same as the *Hong Kong Test of Specific Learning Difficulties in Reading and Writing* (Ho, Chan, Tsang, & Lee, 2000). The five digits were repeated five times in random order. In total, 25 experimental items were presented. In addition, there were five practice items. A self-paced reading task was used. The digits were presented one by one in the center of a computer screen through E-Prime 2.0. Children were asked to name each digit as quickly as possible and then press the key to see the next digit. Naming speed of each digit was recorded for subsequent analyses.

Affirmative and negative sentence comprehension. The comprehension task was constructed according to a 2 × 2 design so that Sentence Polarity (affirmative vs. negative) and Truth Value (true vs. false) were manipulated, generating four conditions: true affirmative, false affirmative, true negative, and false negative.

We created 12 events for the task, including 12 transitive verbs (*gen* 'follow,' *tui* 'push,' *la* 'pull,' *hua* 'draw,' *bao* 'hug,' *yao* 'bite,' *ti* 'kick,' *zhui* 'chase,' *wei* 'feed,' *mo* 'touch,' *da* 'hit,' and *qin* 'kiss') and familiar animals (e.g., *muniu* 'cow' and *luotuo* 'camel'; see Figure 1). To control the influence of the thematic role, each event involved a set of two pictures (e.g., see Pictures A and B in Figure 1). In total, there were 24 pictures. Each event was associated with a set of four sentences, as exemplified below, and in total there were 48 sentences. We used a Latin square design and created eight lists with counterbalanced items. In addition, there were six filler sentences in which the agent and the patient were not reversible, such as *tuzi* 'rabbit' and *xin* 'letter' in *Tuzi zai xiexin* 'The rabbit is writing a letter.' Each list included three practice sentences, 12 experimental sentences, and six filler sentences.

a. Muniu zai ti luotuo.
cow be kick camel
'The cow is kicking the camel.'
b. Luotuo zai ti muniu.
camel be kick cow
'The camel is kicking the cow.'
c. Luotuo mei zai ti muniu.
camel not be kick cow
'The camel is not kicking the cow.'
d. Muniu mei zai ti luotuo.
cow not be kick camel
'The cow is not kicking the camel.'

Table 2. Phonological Awareness, Morphological Awareness, and Rapid Number Naming for Each Group.

Measure	Poor readers		Typical readers	
	M	*SD*	*M*	*SD*
Phonological awareness				
Onset detection	0.57	0.49	0.78	0.41
Rime detection	0.45	0.49	0.63	0.48
Tone detection	0.66	0.47	0.87	0.34
Morphological awareness				
Homophone awareness	0.63	0.48	0.82	0.39
Homograph awareness	0.47	0.50	0.65	0.48
Rapid number naming				
Speed of each digit, ms	906.38	235.92	839.46	273.89

We used a truth value judgment task that was created with E-Prime 2.0. Speed and accuracy were recorded. In the warm-up session, children were familiarized with all the animals used in the pictures and with a puppet, Small Bear, who was going to play a "true" or "false" game with children. Children were informed that Small Bear, who was looking at a series of pictures (e.g., Picture A), produced a series of sentences to describe the pictures. After the sentence was produced, children would see the same picture that Small Bear saw, and their task was to judge whether the sentence was true or false on the basis of the picture. The interval time between each sentence and each picture was 1,000 ms, as Scappini (2015) observed that this interval time was minimally necessary for children to execute the task.

Data Analysis

Response accuracy and response latency were analyzed by employing mixed effects models (Baayen, Davidson, & Bates, 2008), based on the *lme4* and *lmerTest* packages in the R environment (R Development Core Team, 2015). The categorical accuracy data were analyzed via generalized linear mixed effects models, and the response latency data were analyzed with linear mixed effects models.

For the tests of background measures, the data were fit into a series of mixed effects models, including group (poor readers vs. typical readers) as fixed factors and subjects and items as random factors. In the test of rapid number naming, reading speeds faster than 200 ms (0.27% of the data) and slower than 2,000 ms (0.45% of the data) were considered outliers and removed from data analysis.

For the test of comprehending affirmative and negative sentences, the analysis of response latency was performed only on correct responses, and response latency was logarithmically transformed. Response latencies slower than 10,000 ms or faster than 200 ms were considered outliers, and 1.3% of the data were excluded from the analysis. All the fillers were answered correctly and excluded from the analysis. In the analysis, group (poor readers vs. typical readers), sentence polarity (affirmative vs. negative), and truth value (true vs. false) were introduced as potentially significant fixed factors and subjects and items as random factors. The reference categories were typical readers for the Group factor, affirmative for the Sentence Polarity factor, and false for the Truth Value factor. We began with a full model, which was progressively simplified by removing the fixed factors that did not significantly contribute to the goodness of fit of the model. Effects were evaluated one by one on the basis of likelihood ratio tests; first-level effects and the interactions between the fixed factors were tested. Statistics in the best-fitting model are reported.

Results

Background Measures

The means and standard deviations of the tasks on phonological awareness, morphological awareness, and rapid number naming are presented in Table 2 for the two groups. Phonological awareness and morphological awareness are reported as means of correct responses. Rapid number naming is reported as the average reading speed of each digit. Table 2 shows that poor readers are less accurate than typical readers in phonological awareness and morphological awareness and are slower in rapid number naming.

Phonological awareness. The analysis revealed a main effect of group in onset detection task (ß = −1.32, $z = -3.68$, $p < .001$), rhyme detection task (ß = −0.98, $z = -2.46$, $p < .05$), and tone detection task (ß = −2.67, $z = -2.45$, $p < .05$), reflecting the fact that typical readers were more accurate than poor readers in detecting phonological differences.

Morphological awareness. The analysis revealed a main effect of group in the homophone awareness task (ß = −1.20, $z = -3.91$ $p < .001$) and homograph awareness task (ß = −0.84, $z = -3.61$, $p < .001$), reflecting the fact that

Table 3. Accuracy and Response Latency for Each Group.

	Poor readers		Typical readers	
Accuracy / response latency	*M*	*SD*	*M*	*SD*
Accuracy	0.80	0.40	0.89	0.31
True affirmative	0.95	0.21	0.98	0.12
False affirmative	0.88	0.32	0.90	0.30
True negative	0.51	0.50	0.72	0.45
False negative	0.83	0.38	0.95	0.22
Response latency, ms	3,414.62	1,738.63	2,720.72	1,279.47
True affirmative	3,084.77	1,884.13	2,414.91	1,169.50
False affirmative	3,123.47	1,173.33	2,636.63	1,256.67
True negative	4,293.69	1,926.51	3,374.42	1,372.07
False negative	3,615.62	1,824.83	2,691.85	1,325.38

typical readers were more accurate than poor readers in identifying homophones and homographs.

Rapid number naming. Although typical readers named digits faster than poor readers (see Table 2), we did not find a main effect of group (ß = .04, $t = 1.38$, $p > .05$).

To sum up, there are significant differences between poor readers and typical readers in all the tasks measuring phonological awareness and morphological awareness but not in rapid number naming.

Affirmative and Negative Sentence Comprehension

The means and standard deviations of the accuracy and the response latency for all the conditions in the task are presented in Table 3. As shown in the table, poor readers' performance is less accurate and slower than that of typical readers in all conditions. In addition, the true negative condition is the most difficult for both groups.

Accuracy. We fit the accuracy data to generalized mixed effects models. Notably, the three-way interaction among group, sentence polarity, and truth value did not significantly contribute to the goodness of fit of the model, and we therefore removed it, as shown by the likelihood ratio test, $\chi^2(1) = 1.09$, $p = .30$. The best-fitting model included group, sentence polarity, truth value, and the interaction of sentence polarity and truth value as fixed factors. Table 4 shows the output of the analysis. The main effect of group was significant, suggesting that poor readers tended to be less accurate than typical readers. Crucially, the analysis revealed an effect of sentence polarity, showing that processing of negative sentences was less accurate than affirmative sentences. The main effect of truth value was significant and so the interaction Sentence Polarity × Truth Value, showing that true negative was less accurate than false negative, whereas true affirmative was more accurate than false affirmative.

Table 4. Fixed Effects in the Mixed Effects Model for Accuracy in Sentence Comprehension.

Effect	Estimate	*SE*	*z*	*p*
Intercept	4.53	.66	6.88	.000***
Group	−1.00	.47	−2.13	.03*
Sentence polarity	3.37	.58	5.80	.000***
Truth value	−1.38	.60	−2.28	.02*
Sentence Polarity × Truth Value	3.34	.73	4.58	.000***

*$p < .05$. ***$p < .001$.

To unpack the interaction Sentence Polarity × Truth Value, we further analyzed the accuracy data to a mixed effects model, including condition (true affirmative vs. false affirmative vs. true negative vs. false negative) as fixed factors and subjects and items as random factors. By changing the reference categories, we compared each condition with other conditions. Table 5 reports a summary of the results of the statistical analysis. The processing of the true negative condition was significantly less accurate than the processing of all other conditions, and processing the true affirmative was significantly more accurate than processing all other conditions. In addition, there was no difference between false affirmative and false negative.

Response latency. We fit the log-transformed data for response latency to mixed effects models. Again, the three-way interaction among group, sentence polarity, and truth value did not significantly contribute to the goodness of fit of the model; therefore, we removed it, as shown by the likelihood ratio test, $\chi^2(1) = 0.14$, $p = .70$. The best-fitting model included group, sentence polarity, truth value, and the interaction Sentence Polarity × Truth Value as fixed factors. The output of the analysis is shown in Table 6. On a par

Table 5. Condition Factor in the Mixed Effects Model for Accuracy in Sentence Comprehension.

Condition	Estimate	*SE*	*z*	*p*
True affirmative vs.				
False affirmative	−1.38	.61	−2.28	.02*
True negative	−3.37	.58	−5.79	.000***
False negative	−1.41	.61	−2.33	.019*
False affirmative vs.				
True negative	−1.98	.40	−5.03	.000***
False negative	−0.03	.24	−0.07	.94
True negative vs. false negative	1.95	.39	4.94	.000***

*$p < .05$. ***$p < .001$.

Table 6. Fixed Effects in the Mixed Effects Model for Response Latency in Sentence Comprehension.

Effect	Estimate	*SE*	*t*	*p*
Intercept	3.33	.03	114.07	.000***
Group	0.09	.04	2.62	.012*
Sentence polarity	0.16	.02	7.10	.000***
Truth value	0.04	.02	2.08	.038*
Sentence Polarity × Truth Value	−0.14	.03	−4.54	.000***

*$p < .05$. ***$p < .001$.

with the results of the analysis for accuracy, the analysis for response latency revealed an effect of group, sentence polarity, truth value, and significant interaction of Sentence Polarity × Truth Value. The interaction reflects the fact that the response latency of true affirmative was faster than that of false affirmative, whereas true negative was slower than false negative.

As expected, this reflection was further supported by fitting the response latency data to a mixed effects model including condition (true affirmative vs. false affirmative vs. true negative vs. false negative) as fixed factors and subjects and items as random factors. As shown in Table 7, the true negative was significantly slower than all the other conditions, and the true affirmative was significantly faster than all the other condition. In addition, there was no difference between false affirmative and false negative.

To sum up, the analyses of the accuracy data and the response latency data lead to the following main findings. First, poor readers performed worse than typical readers in comprehending sentences, irrespective of whether they were affirmative or negative sentences. Second, as predicted by the TSSH, negative sentences were harder to process than affirmative ones, irrespective of the group. To be specific, the true negative condition was the most difficult to process; the true affirmative was the easiest to process; and no significant difference between false affirmative and false negative was observed.

Table 7. Condition Factor in the Mixed Effects Model for Response Latency in Sentence Comprehension.

Condition	Estimate	*SE*	*t*	*p*
True affirmative vs.				
False affirmative	0.04	.02	2.08	.03*
True negative	0.16	.02	7.05	.000***
False negative	0.06	.02	3.19	.0015**
False affirmative vs.				
True negative	0.12	.02	5.12	.000***
False negative	0.02	.02	1.09	.27
True negative vs. false negative	−0.09	.02	−4.15	.000***

*$p < .05$. **$p < .01$. ***$p < .001$.

Table 8. Correlation Between Background Measures and Response Latency of Comprehending Affirmative and Negative Sentences.

Group: Sentence polarity	Phonological awareness	Morphological awareness	Rapid number naming
Poor readers			
Affirmative	−.04	−.22*	−.27**
Negative	−.32**	−.27*	.16
Typical readers			
Affirmative	−.04	−.21*	.18*
Negative	−.08	−.09	.28**

Note. Person correlation coefficients are displayed.
*$p < .05$. **$p < .01$.

Correlation Analyses

No correlation was found between background measures (i.e., phonological awareness, morphological awareness, and rapid number naming) and the accuracy of comprehending affirmative and negative sentences, while several correlations were found between the background measures and the response latency of comprehending affirmative and negative sentences. Table 8 shows Pearson correlations between variables for typical readers and poor readers.

As shown in Table 8, the response latency of affirmative sentences correlated with the accuracy of morphological measures and the speed of rapid number naming among poor readers, and a similar correlation was also found for typical readers. Unexpectedly, the same pattern was not observed regarding negative sentences. The response latency of negative sentences correlated with the accuracy of phonological awareness and morphological awareness among poor readers, while the response latency of negative sentences correlated with the speed of rapid number naming for typical readers.

Discussion

We conducted a study on young Chinese poor readers' comprehension of affirmative and negative sentences as compared with young Chinese typical readers. The background measures collected show a significant difference between poor and typical readers in both phonological and morphological awareness. This finding is consistent with the majority of previous studies showing that phonological awareness and morphological awareness are indicators of a reading impairment among Mandarin speakers (e.g., Luan, 2005; Song et al., 2016). The results of the rapid naming task, however, did not show a significant difference between the two groups. This is an unexpected finding. Although rapid naming has been sometimes regarded as an independent source of reading disability (Denckla & Rudel, 1976; Di Filippo, Zoccolotti, & Ziegler, 2008; Wolf et al., 2002) and has been reported to lose sensitivity in some children with reading disability (Ding et al., 2010), the meta-analysis findings of Peng et al. (2016) strongly support the view that rapid naming is a strong predictor of Chinese reading development and that rapid naming deficits differentiate children with reading difficulties from age-matched typically developing children (see also Song et al., 2016). On this basis, we suggest that our results might be an artifact of the experimental method that we have applied. The point is that, in our study, naming stimuli were presented one by one at the center of the computer screen, and children were asked to name each digit and then press the key to see the other digit. Previous studies have argued that the relationship of rapid naming with reading disability is specifically due to the serial characteristics of the task (Georgiou, Parrila, Cui, & Papadopoulos, 2013; Logan, Schatschneider, & Wagner, 2011). This suggests that our results might depend on the fact that naming stimuli were not presented in serial order. In what follows, we focus on discussing the findings regarding the sentence comprehension task.

Let us first consider the difference between poor and typical readers in response accuracy and in response latency. The difference between the two groups shows up in all conditions, as confirmed by the lack of interaction among the group, sentence polarity, and truth value. This is in line with the results reported by Scappini (2015), where Italian dyslexic adults were found to have more difficulties than controls in processing affirmative and negative sentences, essentially disclosing the same pattern for speakers of Mandarin Chinese. We suggest that the poor readers' difficulty with affirmative sentences is an experimental artifact of the truth value judgment task, which, being based on a sentence-picture evaluation, is likely to introduce a significant additional processing load. Following this line of reasoning, poor readers' difficulties with affirmative sentences could be explained by the demand of the task. Significantly, we observed that poor readers also performed worse than typical readers in the tasks measuring their phonological awareness and morphological awareness. Both outcomes, taken together, suggest the presence of a common underlying procedural cause, resulting in processing difficulties for poor readers, detected at a nonlinguistic level and at a linguistic level. From this perspective, the present study does not provide specific evidence for one of the two conflicting views of dyslexia found in the literature—that is, dyslexia as rooted in executive function limitations giving rise to a general processing deficit and dyslexia as a more specific linguistic impairment. Remember one of our questions of interest: Do specific linguistic factors, such as sentential negation, have a significant effect on dyslexic children's performance, turning sentential negation into a linguistic predictor of dyslexia? In this respect, the absence of interaction among group, polarity, and truth value highlighted by the present study suggests that there are no grounds for adding negation processing to the set of significant linguistic predictors of reading difficulties. However, it should be emphasized that this result is limited to negation. In fact, the results that we obtained in the present study concerning the phonological and morphological awareness of Chinese poor readers confirm that there are forms of linguistic impairment that can be taken as significant predictors for dyslexia, as actually envisaged by some of the studies discussed in the introduction. Moreover, note that we detected a statistically significant different correlation between negation comprehension on one side and background measures in typical and poor readers on the other side. Namely, for typical readers, the response latency of negative sentences correlates with the speed of rapid number naming, while for poor readers, the response latency of negative sentences correlates with the accuracy of phonological and morphological awareness. In a nutshell, while negation processing is not a predictor of reading difficulties, children with reading difficulties appear to process negation in a way that is more dependent on linguistic impairment than is the case with typically developing children. We think that this unexpected but interesting difference is relevant to future attempts at disentangling the cognitive and linguistic factors involved in the etiology of reading difficulties, although further studies are required for a more precise assessment.

Second, the other research question that we were interested in concerns the existence of a processing difficulty triggered by negation, extending to pragmatically supportive contexts and crosscutting the difference between typical and poor readers. In this respect, the fact that in our study negative sentences turned out more difficult to process than affirmative ones, irrespective of the groups, is in line with the predictions of the TSSH. As discussed in the introduction, the interpretation of negation envisaged by the experiential model involves two steps: In the first step, the comprehender simulates the "negated state of affairs"; in the second step, the comprehender switches one's attention to a simulation of the "actual state of affairs." For sake of illustration, consider one of our experimental sentences (e.g., *Luotuo mei zai ti muniu* 'The camel is not kicking the cow'). When processing the sentence, the comprehender first constructs a mental representation of the state of affairs corresponding to the positive sentence *The camel is kicking the cow* and only at a later stage shifts toward the representation of the negated state of affairs, *The camel is not kicking the cow*. Thus, our study adds to the existing evidence in favor of a nonincremental account of negation, showing that the interpretation of negative sentences, as significantly more demanding than the interpretation of affirmative sentences, equally applies to typical and poor readers in pragmatically supportive contexts.

Also note that our results do not reveal a difference between false affirmatives and false negatives, contrary to the well-documented fact that false negatives are harder to process than false affirmatives. We are inclined to believe that in this particular case, the significance of polarity for the poor readers' performance might not be of a quantitative nature but might rather revolve around the actual processing mechanisms that poor readers rely on when interpreting negative sentences, along the lines of the results achieved in Scappini (2015). In other words, we suggest that a polarity effect might still exist with false negatives versus false affirmatives but that behavioral methods are too coarse to capture the qualitative differences in processing that only online methods are suited to reveal.

Conclusions

The present study was concerned with the comprehension of affirmative and negative sentences by young Chinese poor readers as compared with aged-matched typical readers. We aimed at finding a nontrivial confirmation of the validity of the TSSH and at checking whether the processing of sentential negation can be taken as a reliable predictor of reading disabilities. First, the results clearly show that poor readers have greater difficulty than controls in comprehension, regardless of sentence polarity, which in turn suggest that (a) children with a reading disability face some general processing difficulties, probably arising, in our case, as a consequence of the complexity of the experimental task and (b) sentential negation cannot be interpreted as a significant linguistic predictor of Chinese children's reading difficulties, partly replicating the findings of Scappini (2015) for Italian. Second, we found an important experimental confirmation for the hypothesis that negative sentences are more difficult to comprehend than affirmative sentences, regardless of the distinction between poor readers and typical readers, suggesting that the polarity effect that manifests itself in the systematic difference in accuracy and response latency is rooted in a nonincremental strategy of negation processing, along the lines of the TSSH. The results obtained here, with the ERP results discussed in the introduction, provide substantial evidence for the experiential model of negation processing.

However, we emphasize that this study has limitations, mainly due to some practical constraints that we had to face. Our participants are poor readers with difficulties in character recognition and other reading measures but not children with diagnosed reading disabilities or diagnosed dyslexia. Clearly, Chinese dyslexic children would have been the ideal population for applying our experimental protocol. Thus, the findings in this study might not fully generalize to dyslexic children across languages. Future studies are clearly invited with the aim of (a) replicating the current findings with Chinese children with and without dyslexia and (b) corroborating the hypothesis concerning the cognitive load on negation processing with detailed measures of directly relevant cognitive factors, such as working memory and attention, hence extending the correlational analysis of the linguistic factors that have been addressed in the present contribution.

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