

Use of Phonological Representations of Taiwan Sign Language in Chinese Reading: Evidence from Deaf Signers

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Purpose: Deaf people in Taiwan use Mandarin Chinese and Taiwan Sign Language (TSL) to communicate. This study explored the nature of the representations that deaf signers use during Chinese reading by using the invisible boundary and display change technique, in which a preview word is replaced by a target word when the reader's eyes cross an invisible boundary to the left of the target word. A target word processed faster when the preview is related to the target word than when it is unrelated to the target word is considered a preview benefit effect. This study investigated the preview benefits of phonological information for Taiwan Sign Language (TSLph). **Methods:** This study invited 35 deaf signers and 30 hearing readers. We manipulated preview words with either phonologically related or unrelated words in TSL. Different TSL lexicons can be corresponded to either Chinese one-character or two-character words. To clarify the influence of inconsistency in translation of TSL to Chinese words on Chinese reading among deaf signers, one-character and two-character words frequently signed in TSL were used in Experiment 1 and 2, respectively. Experiment 1 had 45 reasonable sentences (30 with preview words and 15 with identical words) and 30 nonsensical sentences, and Experiment 2 had 36 reasonable sentences (24 with preview words and 12 with identical words) and 24 unreasonable sentences. The subjects were asked to decide whether a given sentence was reasonable according to their comprehension of the whole sentence. **Findings:** When considering the previous fixation location, the results demonstrated TSLph preview benefits among deaf signers for one-character words in the first-fixation duration (FFD) and first-run fixation count and for two-character Chinese words in FFD and gaze duration during a sentence comprehension task. The inconsistency in the

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translation of Chinese words to TSL did not disturb word segmentation in Chinese reading among these skilled deaf readers. **Conclusions/Implications:** The preview effects of words phonologically related in TSL were observed for deaf but not for hearing readers. These findings confirmed that deaf signers use TSL phonological representations during reading.

Keywords: Deaf, Eye movement, Phonology, Reading, Taiwan Sign Language

Introduction

Reading is difficult for most deaf people. However, even with a lack of auditory input, some deaf individuals learn to read beyond the eighth grade level (Traxler, 2000). The reading abilities of deaf people are likely influenced by their degree of hearing loss, the age that they learned their first language, language-specific knowledge, and general language knowledge (Musselman, 2000). In this study, we investigated the nature of the representations that deaf readers with knowledge of Taiwan Sign Language (TSL) activated during Chinese reading using the invisible boundary and display change technique of eye-movement.

Hearing children largely develop their visual word recognition abilities based on previous sound and articulatory knowledge of the corresponding spoken language. Reading employs the established sound system to access meaning from the printed words. Activation of phonological representations is also found during reading in proficient readers. This phonological mediation is fundamental to reading (Perfetti & Sandak, 2000). This begs the question, can deaf people process words phonologically? To answer this question, it is important to understand the similarities and differences in the reading processes between hearing and deaf readers.

The essential encoding processes in deaf people may be similar to those in hearing people. Even with limited auditory input and speaking ability, some deaf people are able to develop phonological representations. For instance, in a lexical decision task, target recognition was shown to be facilitated and accelerated by phonologically related words (Hanson & Fowler, 1987) and

pseudohomophones (Friesen & Joanisse, 2012; Transler & Reitsma, 2005). In categorization tasks, phonologically similar pseudowords (Transler, Gombert, & Leybaert, 2001) and words (Miller, 2002) were judged to be similar by deaf children. When encountering the incongruence between pseudohomophones of color names and their printed color in the Stroop paradigm, the vocal responses of deaf children were shown to demonstrate interference (Leybaert & Alegria, 1993). On a letter detection task, deaf subjects were shown to produce more errors on irregularly pronounced words than on regularly pronounced ones (Quinn, 1981). Moreover, when judging the semantic acceptability of written sentences, deaf participants were shown to make more errors on tongue-twister sentences compared with control sentences (Hanson, Goodell, & Perfetti, 1991). Additionally, while using a boundary and display change technique (Rayner, 1975), in which a preview word is replaced by a target word when a reader's eyes cross an invisible boundary, phonological preview benefits were shown in orally trained deaf individuals (Chiu & Wu, 2013). In sum, these findings suggest that deaf readers can access the phonological representation.

However, some studies have found that phonological awareness and phonological processing only contribute a small amount of variance to reading abilities in deaf people (Belanger, Baum, & Mayberry, 2012; Mayberry, del Giudice, & Lieberman, 2011). Additionally, despite the evidence of phonological representations in deaf readers, these encodings may be coarser-grained and less automatic in deaf people (Friesen & Joanisse, 2012; Stanovich, 1994; Waters & Doehring, 1990). The reading

difficulties for deaf people might not result from the activation of phonological codes.

Rather than assembling phonological representations from graphic and sound mappings, deaf people may adopt other encoding representations, such as orthographic, semantic, tactile, fingerspelling and sign encoding (Musselman, 2000). Signs are composed of include handshapes, locations, movements, and combination rules. In linguistic studies, handshapes, locations, movements are taken as the constituent components of sign-based phonological representations (Smith & Ting, 1979, 1984; Stokoe, 1960). The sign-based phonological components, especially handshapes, have been found to play similar roles as sound-based phonological representations do. For instance, the handshape features of signs are encoded and rehearsed in working memory, which may represent evidence of sign-based encoding. Additionally, the articulatory suppression of signs was shown to decrease memory performance for deaf individuals (Wilson & Emmorey, 1997). In a semantic acceptability task, “hand-twister” sentences were more difficult to judge than control ones for deaf participants (Treiman & Hirsh-Pasek, 1983). While deaf bilinguals were asked to judge the semantic relatedness of sequential-presented word pairs, both the semantically related pairs and sign-based phonological related American Sign Language (ASL) translations compared to their corresponding controls can benefit participants’ performance (Morford, Wilkinson, Villwock, Pinar, & Kroll, 2011).

In sum, the results within each of the paradigms previously used to study encoding properties during deaf reading are quite

controversial. These inconsistencies may result from the diversity of the deaf population. For instance, the properties of the languages that deaf people have learned should be taken into consideration. On the one hand, for transparent alphabetic languages, the activation of a phonological representation may be triggered by printed orthographic information. But, the low transparent of orthography in Chinese writing dissociated the word forms and their corresponding sounds. On the other hand, a signed language may be influenced by the local spoken language. To take ASL as an example, some sign handshapes are used to represent the initial letters of English words, which confounds the orthography of written languages and the phonology of signed languages. The phonology, especially handshapes, of TSL represents little knowledge of traditional Chinese word forms (Smith & Ting, 1979, 1984). Both Chinese and TSL may clarify the encoding used in deaf reading. Besides, inconsistent behavioral findings may be also due to the limitations of using error rates and reaction times when investigating cognitive processes. The present study investigated the preview benefits of other possible encodings for relatively fluent deaf readers using an eye tracker system together with the boundary and display change technique (Rayner, 1975).

Previous research of eye movements had showed that both foveal and parafoveal information influences dynamic linguistic processing (Kennedy, 2000; White, Rayner, & Liversedge, 2005). The location of an eye fixation is related to the cognitive processing of the text at that location, and the duration of fixation reflects the cognitive processing of the area or word. Furthermore, the linguistic processing of

a word can begin while in the parafovea and can continue after it has or has not been fixated. Using eye movement measures, word reading has been shown to benefit from orthographic previews (Drieghe, Rayner, & Pollatsek, 2005; Liu, Inhoff, Ye, & Wu, 2002; A. Pollatsek, Tan, & Rayner, 2000; Tsai, Lee, Tzeng, Hung, & Yen, 2004) and phonological previews (Ashby, Treiman, Kessler, & Rayner, 2006; Chace, Rayner, & Well, 2005; Alexander Pollatsek, Lesch, Morris, & Rayner, 1992; A. Pollatsek et al., 2000; Tsai et al., 2004). At the same time, the benefits of orthographic previews were shown for both orally trained and non-orally trained deaf people, while the benefits of Chinese phonological previews were found only for orally trained deaf participants (Chiu & Wu, 2013).

It is worthwhile to ask the question: do deaf signers activate other encoding representations, such as sign language information, during reading? Applying eye movement measures as well, researchers found that deaf readers activated Chinese sign Language representation in the parafovia, but the effect was cost of sign phonological preview in fixation durations (Pan, Shu, Wang, & Yan, 2015).

In Pan et al.'s study, the age of their deaf participants are around 19.1 years old from a deaf school and had used Chinese Sign Language (CSL) for communication for 11.1 years. In both Taiwan and China, however, the goal of main special education on deaf has emphasized oral communication rather than sign languages. In school, young deaf people are encouraged to rely more on phonology of Mandarin and the phonetic system which transcribing the Mandarin pronunciations of Chinese characters by the Latin

alphabet or phonetic symbols such as Bopomofo, but not phonology of Sign Language. When these deaf participants read, their sign languages' phonology might be automatically activated but might also have to compete with even stronger linked Chinese phonology. In Pan et al.'s study, the characteristics of deaf participants and their school training of Chinese phonology might be the causes of the cost preview effect of sign phonology on the one hand. Many deaf people in Taiwan improve their sign language abilities and use TSL more frequently after graduating from school and entering some deaf associations. The language abilities should consider not only the age of acquisition and duration of learning, but also situation and frequency of use.

On the other hand, the preview cost in Pan et al.'s study might also result from the stimuli they used. Within these twenty-three CSL phonologically related two-character word pairs, most pairs were identical in the phonological sign features of orientation (22/23) and location (23/23), and different in the handshape (6/23) and movement (7/23). However, these four phonological components have different importance in different tasks were shown as follows.

According to a study of cortical stimulation mapping in a deaf signer, the sign-based phonological errors were with reductions in handshape configuration and nonspecific movements when stimulating the left frontal opercular area of the deaf signer (Corina et al., 1999). Relatively, the study of categorical perception of signs manipulated signs that varied continuously in either location (e.g., a continuous location between the location of cheek of ASL

ONION and the location of chin of ASL APPLE) or handshape (e.g., continuous handshape changes between handshape B of ASL PLSASE and handshape A of ASL SORRY) (Emmorey, McCullough, & Brentari, 2003). The identification task asked deaf signers and hearing nonsigners to judge which one of the endpoint images a given signal was most like. The identification performance of both deaf signers and hearing nonsigners was discontinuous. At the same time, the discrimination task asked to judge whether two stimuli selected from the continua images were the same or not. Only deaf signers had better discrimination performance across the handshape categories than the one within handshape categories. The results suggested that categorical perception of handshape was found in deaf signers and influenced by language experience. In sum, some sign-based phonological features, such as handshape in signed languages, are categorized to process lexicons more efficiently.

In this study, we investigated the role of sign-based phonology in Taiwan Sign Language (TSLph) when deaf people read. This study set out to use previews to test phonologically related representation of signed languages to determine if they influence reading processing in deaf readers with knowledge of TSL. The deaf participants in our study were recruited from fluent deaf signers who graduated from school and have strong connections with deaf associations in Taiwan. The stimuli of TSL phonologically related words shared the same TSL handshapes as the target words.

Chinese words range in length from one to several characters, although most words are two characters long. Considering that TSL signs can be translated to either one-character, two-character

to several-character words, someone concerns that knowledge of sign languages might disturb learning of Chinese reading. On the other hand, according to English reading research, the word length significantly guided the eye movements during the first-pass reading (Kliegl, Grabner, Rolfs, & Engbert, 2004). However, the lengths of most Chinese words vary from one to four characters and no word length cues (e.g., spaces) are available to do Chinese word segmentation. It was shown that Chinese readers thus have to rely on lexical knowledge to segment characters into words (Li, Rayner, & Cave, 2009).

Thus, to clarify whether the inconsistent relationships between TSL signs and number of Chinese characters influence the Chinese reading, we differentiated TSL signs frequently translated into one-character words in Experiment 1 and two-character words in Experiment 2. If deaf readers segment Chinese sentences only character by character, the TSLph preview effect among deaf signers can be only found in one-character words of Experiment 1, but not in two-character words of Experiment 2. However, if deaf signers can also apply Chinese lexical knowledge to segment characters and group them into words, the preview effects of TSL sign representation can be shown at both one-character and two-character word levels. The measures of eye movements can provide an early lexical process index, such as fist fixation duration, a rather late lexical process index, such as gaze durations/first run fixation count, and a more post-lexical process index, such as total fixation count, to clarify the operations of Chinese word segmentation. Without TSL knowledge, preview benefits of TSLph cannot be found in hearing groups.

Experiment

In Experiment 1 and 2, we examined whether deaf signers obtained a phonological preview benefit from TSL for one- and two-character words, respectively. Although some phonological properties of signed language, such as location and movement, are important, this study focused on the phonological properties of handshapes in TSL, which was most well studied (Smith & Ting, 1979, 1984; Stokoe, 1960). For deaf signers, we predicted that we would find a phonological preview benefit for TSL (TSLph) when words shared the same handshapes. We also predicted that for hearing controls without knowledge of TSL, the manipulation of TSLph would not be beneficial.

Methods

Subjects

Without a standardized reading assessment for Chinese adult readers in Taiwan, deaf individuals were asked to accept a questionnaire of their backgrounds, language experience and proficiency before experiments. In Experiment 1 and Experiment 2, deaf participants ($n = 35$, 11 males and 24 females; age range: 22 to 51 years, mean age: 33.2 years) were prelingually and profoundly deaf, with hearing losses of 85 dB or more. All of these participants had learned TSL at least 5 years ago (mean: 12.4 years), and TSL was their first or dominant language for communication with other deaf people. Twenty-seven of the deaf participants had received oral language training but had little or poor speech ability. None of the deaf participants had received a cochlear implant. All

deaf participants had, at minimum, completed the senior high school level, and 12 participants had a college degree. On average, these deaf participants reported being in the habit of reading 2.5 hours/day and of using the Internet 7.5 hours/day. At the same time, most (33) deaf participants participated actively in deaf associations in Taiwan. They enthusiastically promoted Deaf culture and TSL. Six deaf signers are TSL teachers in deaf associations.

Hearing undergraduates ($n = 30$, 12 males and 18 females; age range: 19 to 23 years) participated in Experiment 2 as a control group. All of hearing participants are native Chinese speakers. All participants had normal or corrected-to-normal vision.

In Taiwan, standard Chinese reading comprehension tests are developed for primary and junior high school students for a diagnosis of dyslexia or remedial teaching (Lin & Chi, 2000), Chinese reading comprehension test for Chinese native adults is not available. At the same time, most standard Chinese reading comprehension tests include subsets of phonetic notation or Chinese phonological recoding which are difficult to apply for deaf people. Thus, in the present study, the design of Chinese sentences is quite easy for both groups. The use of these simple sentences can minimize the impact of significantly different reading abilities between average deaf and hearing readers and investigate the similarities and differences of these two groups under this easy and fluent reading condition. Before the start of the study, each subject got and the informed consent, which informed him/her the goal and procedure of this study and the subject's right to quit the study at any time.

Materials

In Experiment 1, Chinese one-character words were used as target and preview words. There were 45 reasonable sentences (30 with preview words and 15 with identical words) and 30 nonsensical sentences. Each sentence was composed of 12 to 18 Chinese characters, and the target words were located between the fourth and the eighth characters. An example sentence, with the target word in boldface, is as follows: “路邊的那朵花開得十分美麗” (That flower blooms beautifully by the roadside). In the preview sentence trials, the target word “花” (flower) was replaced by preview words, including the TSL phonologically related word (TSLph) “燈” (lamp) and the unrelated word (U) “窗” (window). TSL phonologically related words share the same TSL handshapes as the target words. Preview and target words corresponded with commonly used TSL signs. Because of the limitations of finding common TSL words composed of one Chinese character, there were only 15 acceptable target/preview pairs. We created two sentences for each pair. The words assigned to either sentence were counterbalanced across participants.

In order to control the semantic relationships between preview and target words, twenty-six undergraduates without TSL knowledge (11 males and 15 females; age range: 19 to 21 years) were asked to rate (range from highly unrelated 1 to highly related 10) the semantic relationships of 15 TSL phonologically related and 15 TSL phonologically unrelated pairs. The rating results showed that semantic relation strength between TSL phonologically related (1.71) and unrelated

pairs (1.68) were not significantly different [$t(25) = -.52, p > .05$].

In Experiment 2, the target and preview words were two-character Chinese words. There were 36 reasonable sentences (24 with preview words and 12 with identical words) and 24 unreasonable sentences. Each sentence was composed of 12 to 17 Chinese characters, and the target words were located between the fourth and the seventh characters. An example sentence, with the target word in boldface, is as follows: “他所戴的手錶已經使用二十年了” (The watch he wears has been used for twenty years). The target word “手錶” (watch) was replaced by preview words, including the TSLph word “耳環” (earrings) and the U word “茶杯” (cup). Because of the limitations of finding common TSL words composed of two Chinese characters, there were only 12 acceptable target/preview pairs. We created two sentences for each pair. These sentences were counterbalanced across participants.

In order to control the semantic relationships between preview and target words, eighteen undergraduates without TSL knowledge (8 males and 10 females; age range: 19 to 21 years) were asked to rate (range from highly unrelated 1 to highly related 10) the semantic relationships of 12 TSL phonologically related and 12 TSL phonologically unrelated pairs. The results showed that semantic relation strength between TSL phonologically related (1.96) and unrelated pairs (2.19) were not significantly different [$t(17) = 1.64, p > .05$].

For identical sentences, the target word, presented here in boldface, was located in the sixth and seventh positions: “你們喜愛的明星







在世界各地都受到歡迎” (Your favorite stars are welcomed all over the world). An example sentence of an unreasonable sentence is as follows: “研究電器的專家最擅長讓拖鞋去喝水” (Electrical experts are good at making slippers drink), which is inappropriately composed of real Chinese lexicons.

Apparatus

Eye movements were recorded by an Eyelink

1000 Tower Mount tracking system manufactured by SR research (SR Research, Canada) with a 2000 Hz camera. The sampling rate was 1000 Hz. The resolution of the monitor was 800 × 600 pixels. The experiment was programmed in Experiment Builder, and the eye movement data were analyzed in Data Viewer. The sizes of the characters presented on the screen were 24 × 24 pixels, and there was a space of 4 pixels between characters. The width of an individual character

Table 1 Examples of target words and two preview words (Taiwan sign language phonologically related and unrelated) from Experiments 1 and 2

Character (s)		Target	Preview words	
			TSLph	U
One	Semantics	FLOWER	LIGHT	WINDOW
	Chinese word	花	燈	窗
	Chinese Pronunciation	/hua1/	/deng1/	/chuang1/
	Chinese mean strokes	11.3	12.2	10.7
	TSL			
Two	Semantics	ANGRY	OFTEN	VACATION
	Chinese word	生氣	常常	放假
	Chinese Pronunciation	/sheng1-qi4/	/chang2-chang2/	/fang4-jia4/
	Chinese mean strokes	9.9, 12.4	12.5, 10.6	12.0, 10.5
	TSL			

Note: The TSL signs are based on previous studies (Chang, Su, & Tai, 2005; Smith & Ting, 1979,1984). Taiwan Sign Language phonological related (TSLph), Unrelated (U).

and the space before it subtended 1.05 degrees of visual angle, when participants were seated 65 cm from the monitor. All stimuli were presented in white on a black background and in Times New Roman font. Eye movements were recorded from only the dominant eye. The dominant eye of each subject was tested by alternatively closing each eye. The dominant eye is the one that gives better vision while it remains open.

Experimental design and procedure

A chinrest was utilized to control the head position and minimize the head movements of participants. At the start of the experiment, a nine-point calibration procedure and a validation procedure were performed to determine the correspondence between pupil position and gaze position. At the beginning of each trial, a dark circle was presented at the initial left position of the sentence. Participants were asked to fixate on the circle to initiate each trial. An invisible boundary was located 4 pixels to the left of the target location. At first, one of the preview words occupied the target location. When the eyes of the participants moved across the boundary, the preview words immediately changed to the target words. Participants were instructed to read the sentences for comprehension and to indicate whether the sentences were reasonable and acceptable by pressing one of two buttons. Participants were informed that they could rest whenever needed. The order of Experiment 1 and 2 was counterbalanced across participants. Two experiments lasted 40-50 minutes.

The target regions for eye movement analysis included the area of the one-character target words in Experiment 1 and two-character target

words in Experiment 2 and the 4-pixel spaces immediately preceding and following each target word as well. Two fixation times and two fixation counts were measured within the target regions: first fixation duration (FFD, the duration of the first fixation on the target words regardless of the number of fixations), gaze duration (GD, the sum of all first pass fixation durations on the target words), first run fixation count (FFC, the sum of all first pass fixation counts on the target words), and total fixation count (TC, the sum of all pass fixation counts on the target words). The oculomotor viewing duration/count is determined by the word's linguistic processing. First fixation duration and gaze duration/first run fixation count might be sensitive to pre-lexical and lexical processing, respectively. And total fixation count might represent a more post-lexical processing (Inhoff & Radach, 1998).

Results

Experiment 1: One-character words

Table 4 shows the means and the standard error of the means (SEMs) for FFD, GD, FFC, and GC. The rates of correct judgments of sentence acceptability (mean \pm SEM) for deaf and hearing individuals were 0.94 ± 0.01 and 0.93 ± 0.01 , respectively. In this comprehension task, both groups had high accuracy which revealed that both groups understood these sentences well.

The perceptual span of written Chinese is approximately three characters to the right and one character to the left of fixation (Inhoff & Liu, 1998). Trials in which the pretarget region (one character in length) were skipped or in which the first fixation durations were shorter than 100 msec or longer than 1200 msec were eliminated.

Because of the relatively simple linguistic properties of one-character words, targets were skipped frequently in both groups. Four hearing subjects had perfect comprehension performance but skipped many of the target regions. Twenty-six hearing participants (10 males and 16 females) were included in the data analyzed. Following the analysis, 50% and 46% of the deaf and hearing participant data, respectively, remained. Nevertheless, the high skipping rate of the one-character condition is reasonable because of its narrower target region and high word frequency (Drieghe et al., 2005).

As hearing participants were lacked knowledge of TSL, the condition of TSLph manipulation for them was treated as baseline control data. We focused on the data from the deaf group, and data from deaf and hearing individuals were analyzed separately by using SPSS 18.0 statistical software.

As expected, hearing participants had no significant differences between TSLph and U for FFD [$t(25) = -.62, p > .05$, Cohen's $d = .25$], FC [$t(25) = 1.11, p > .05$, Cohen's $d = .44$], GD [$t(25) = .34, p > .05$, Cohen's $d = .14$], or TC [$t(25) = 1.69, p > .05$, Cohen's $d = .68$].

For deaf participants, significant differences between TSLph and U were found for FFD [$t(34) = 2.21, p < .05$, Cohen's $d = .79$] and FC [$t(34) = -2.43, p < .05$, Cohen's $d = -.83$]. However, no differences between TSLph and U were shown for GD [$t(34) = .98, p > .05$, Cohen's $d = .34$] or TC [$t(34) = .13, p > .05$, Cohen's $d = .04$]. Notably, deaf signers fixated more times on TSLph compared with U previews for FC.

Experiment 2: Two-character words

The rates of correct judgments of sentence acceptability (mean \pm SEM) for deaf and hearing individuals were 0.91 ± 0.01 and 0.96 ± 0.01 , respectively. Both groups had high accuracy.

Trials in which the pretarget region (one-character length) was skipped or with first fixation durations shorter than 100 ms or longer than 1200 ms were eliminated. Following the analysis, 91% and 83% of data from deaf and hearing participants, respectively, remained.

For hearing participants, no significant differences were found for FFD [$t(29) = 1.91, p > .05$, Cohen's $d = .71$], GD [$t(29) = .36, p > .05$, Cohen's $d = .13$], FC [$t(29) = -.28, p > .05$, Cohen's $d = .10$] or TC [$t(29) = -1.06, p > .05$, Cohen's $d = .39$].

For deaf participants, significant differences between TSLph and U were found for FFD [$t(34) = 2.71, p < .01$, Cohen's $d = .93$] and GD [$t(34) = 3.18, p < .01$, Cohen's $d = 1.09$]. However, no differences between TSLph and U were found for FC [$t(34) = 1.42, p > .05$, Cohen's $d = .49$] or TC [$t(34) = -.06, p > .05$, Cohen's $d = -.02$]. In sum, these results demonstrate that deaf signers extract TSL phonology parafoveally when reading in Chinese.

Discussion

This study investigated the preview benefits of phonological information for Taiwan Sign Language in one- and two-character Chinese word levels. Experiment 1 and 2 demonstrated that TSLph preview benefits are found among deaf signers for both one- and two-character Chinese words during a sentence comprehension task. These results suggest that deaf readers use TSL phonology representations parafoveally during

Table 2 Means and standard error of the means for viewing durations and fixation counts for one-character and two-character preview words

	Identical	One-character words				Identical	Two-character words			
		TSLph	U	<i>t</i>	<i>p</i>		TSLph	U	<i>t</i>	<i>p</i>
Deaf	<i>(n = 35)</i>									
FFD	246 (.8)	288 (.13)	310 (.13)	2.21	.02	233(7)	257 (.8)	281 (.11)	2.71	.01
GD	253 (.9)	310 (.15)	320 (.14)	.98	.17	260(13)	297 (.20)	334 (.27)	3.18	.00
FC	1.03 (.01)	1.11 (.02)	1.06 (.01)	-2.43	.01	1.13 (.04)	1.20 (.06)	1.24 (.08)	1.42	.17
TC	1.45 (.08)	1.70 (.08)	1.62 (.08)	-1.12	.13	2.04 (.12)	2.31 (.15)	2.30 (.17)	-.06	.94
Hearing	<i>(n = 30)</i>									
FFD	219 (.6)	298 (.18)	289 (.13)	-.62	.54	234 (8)	276 (.11)	290 (.11)	1.91	.07
GD	226 (.8)	311 (.19)	317 (.18)	.34	.74	259 (12)	345 (.17)	351 (.19)	.36	.72
FC	1.04 (.02)	1.07 (.13)	1.11 (.03)	1.11	.28	1.13 (.03)	1.29 (.04)	1.28 (.04)	-.28	.78
TC	1.40 (.06)	1.43 (.06)	1.59 (.10)	1.69	.01	2.23 (.15)	2.51 (.17)	2.43 (.16)	-1.06	.30

Note: Taiwan Sign Language phonologically related (TSLph) and Unrelated (U), first fixation duration (FFD), gaze duration (GD), first run fixation count (FC), and total fixation count (TC).

Chinese reading. The TSL phonological effect on FFD was observed for both one- and two-character words, which reflected relatively early lexical processing. This result revealed that deaf readers segment Chinese sentence by words as native Chinese hearing readers.

However, the differences between one- and two-character words among deaf signers were shown as well. The TSL phonological effect on GD was sustained only in two-character words. This phenomenon may result from the fact that many Chinese characters can be coupled with a variety of other characters to form compound words with a single, new meaning. To correctly comprehend sentences, readers have to first activate sublexical information while processing more coherent information, suggesting a more serial lexical processing model (Reichle, Rayner, & Pollatsek, 2003).

Also, according to Li et al.'s (2009) word segmentation and word recognition mode, recognizing a Chinese word involves multiple levels of processing: a visual perception module, a character recognition module, word segmentation and recognition level, and an attention module (Li, Rayner, & Cave, 2009). The perceptual module processes visual features and location of each character. In character recognition module, multiple character recognizers work in parallel and receive bottom-up perceptual information and top-down feedback of word level. In word recognition level, word recognition combines the activation degree of each character. If two or more characters provide consistent activation for a target word, the corresponding word activates stronger and is selected. On the contrast, when two or more characters activate different target words, the word recognition level sends feedback information to

the character recognition level and takes longer to compromise. And neighborhood size of each character also accounts for the word recognition level. The attention module considers the order of characters from left to right. The first character of each word plays an important role to word recognition. If the first character matches target words perfectly, the attention shifts to next right character to do further word recognition. If not, the word recognition units would expend not only the first character, but also the second character or also the third character. Thus, recognition of a two-character Chinese word might take more processes than a one-character Chinese word, which was also applied to our deaf readers. Furthermore, based on the results of one- and two-character words among deaf readers, it is possible that human mind is developed to solve even more complex relationships when two languages are processed simultaneously languages.

The preview benefit of TSL phonology in the present study was different from the preview cost in Pan et al.'s study (Pan et al., 2015). The difference might result from the characteristics of deaf participants and experimental stimuli mentioned in the introduction. The present study contributed to the understanding of fluent TSL signers among deaf adults. Without doubt, it is of great importance to uncover the impact of TSL on Chinese reading among deaf children in the future. Besides, our data analysis eliminated the trials in which the pretarget region (one character in length) were skipped which was absent in Pan et al.'s study. This data processing helped to confirm that the preview target regions were exactly on readers' parafoveal areas. Without this data processing, the eye movement measures

might include not only the effects of parafoveal information, but also those of peripheral visual signals which hardly impacted the linguistic processing (Kennedy, 2000; White et al., 2005).

In our study, evidence of a TSL phonology effect in deaf readers is difficult to dispute based on two facts. First, there is little association between Chinese words and natural TSL. Although some TSL signs depict the strokes of Chinese, such as “人” (people), these types of signs are applied more often to characters with few strokes or to family names, which were not included in our study. Second, the lack of an effect in hearing readers rules out the notion that this effect is based on visual or tactile information, which hearing readers share with deaf readers.

In addition, for deaf readers, TSL phonological preview benefits were demonstrated, revealing that multiple representations are activated during sentence reading. The strength of each code may be due to the diverse hearing abilities and language backgrounds of deaf participants (Miller, 2002). At the same time, flexible-encoding strategies for deaf individuals may vary according to task demand and mode of acquisition (MOA) for the stimulus, which denotes how the word's meaning is acquired. The meaning of a word can be acquired perceptually, linguistically, or both (Wauters, van Bon, Tellings, & van Leeuwe, 2006).

Adaptable encoding abilities might also be one of the reasons for inconsistent findings regarding the relationship between encoding and reading performance. Some researchers have suggested that both phonological and orthographic encodings are positively associated with working memory performance. Although the use of sign language has been negatively related to reading

and writing performance (Lichtenstein, 1998), other researchers in advance have found that neither speech comprehension skills nor the use of phonological codes can predict reading level (Mayberry et al., 2011). Reading development was predicted not from the use of phonological representations of spoken language (Belanger et al., 2012) but rather from language ability (Mayberry et al., 2011). Even in native signers, a positive relationship was shown between phonological awareness of American Sign Language and that of English (Corina, Hafer, & Welch, 2014). Although some determinant factors might also contributed more on reading abilities, the gains of fluent sign language abilities were reflected in the lexical access of written words (Miller, Kargin, & Guldenoglu, 2015).

Language input for children should consider not only just the quantity but also the quality. Sign languages can help most deaf people to get world knowledge more easily. The development of cognition and language are interacted. Some studies suggested that more fluent deaf signers may become better readers (Chamberlain & Mayberry, 2000, 2008). The benefits of automatic native language processing on second language reading might be found in the deaf readers of our study as well. The scaffold of language knowledge, regardless of modality and relation to written language, provides the metalinguistic rules and appears to facilitate reading. On education of the deaf, language learning could involve not only phonics-based methods which emphasize word decoding, but also a whole language perspective which focus on making meaning in reading and expressing meaning in writing. Uncovering the interplay between spoken, signed, and written

languages in deaf individuals may shed light on deaf education and the process of reading in general (Goldin-Meadow & Mayberry, 2001). More experimental studies on word segmentation for deaf readers are necessary as well.

Summary

In sum, the present study investigated the parafoveal use of TSL phonological codes during Chinese sentence reading for deaf readers with TSL knowledge. Our results have demonstrated that deaf signers activated TSL phonological representations during Chinese sentence reading. Deaf signers were flexible to adopt different encoding representations in sentence reading. Furthermore, the inconsistency translation of TSL to Chinese words did not disturb word segmentation in Chinese reading among these deaf readers.

References

- Ashby, J., Treiman, R., Kessler, B., & Rayner, K. (2006). Vowel processing during silent reading: Evidence from eye movements. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 32*(2), 416-424. doi: 10.1037/0278-7393.32.2.416
- Belanger, N. N., Baum, S. R., & Mayberry, R. I. (2012). Reading difficulties in adult deaf readers of French: Phonological codes, not guilty! *Scientific Studies of Reading, 16*(3), 263-285. doi: 10.1080/10888438.2011.568555
- Chace, K. H., Rayner, K., & Well, A. D. (2005). Eye movements and phonological parafoveal preview: Effects of reading skill. *Canadian Journal of Experimental Psychology, 59*(3),

- 209-217. doi: 10.1037/h0087476
- Chamberlain, C., & Mayberry, R. I. (2000). Theorizing about the relation between American Sign Language and reading. In C. Chamberlain, J. P. Morford, & R. I. Mayberry (Eds.), *Language acquisition by eye* (pp. 221-259). Mahwah, NJ: Lawrence Erlbaum Associates Publishers.
- Chamberlain, C., & Mayberry, R. I. (2008). American Sign Language syntactic and narrative comprehension in skilled and less skilled readers: Bilingual and bimodal evidence for the linguistic basis of reading. *Applied Psycholinguistics*, 29(3), 367-388. doi: 10.1017/S014271640808017X
- Chang, J.-H., Su, S.-F., & Tai, J. H.-Y. (2005). Classifier Predicates Reanalyzed, with Special Reference to Taiwan Sign Language. *Language and Linguistics*, 6(2), 247-278.
- Chiu, Y.-S., & Wu, M.-D. (2013). The parafoveal preview benefits of Chinese orthography and phonology among deaf readers with high reading abilities. *Bulletin of special education*, 38(1), 31-54. doi: 10.6172/BSE.201303.3801002
- Corina, D. P., Hafer, S., & Welch, K. (2014). Phonological awareness for American Sign Language. *Journal of Deaf Studies and Deaf Education*, 19(4), 530-545. doi: 10.1093/deafed/enu023
- Corina, D. P., McBurney, S. L., Dodrill, C., Hinshaw, K., Brinkley, J., & Ojemann, G. (1999). Functional roles of Broca's area and SMG: evidence from cortical stimulation mapping in a deaf signer. *Neuroimage*, 10(5), 570-581. doi: 10.1006/nimg.1999.0499
- Drieghe, D., Rayner, K., & Pollatsek, A. (2005). Eye Movements and Word Skipping During Reading Revisited. *Journal of Experimental Psychology: Human Perception and Performance*, 31, 954-969. doi: 10.1037/0096-1523.31.5.954
- Emmorey, K., McCullough, S., & Brentari, D. (2003). Categorical perception in american sign language. *Language and Cognitive Processes*, 18(1), 21-45. doi: 10.1080/01690960143000416
- Friesen, D., & Joannis, M. (2012). Homophone effects in deaf readers: evidence from lexical decision. *Reading and Writing*, 25(2), 375-388. doi: 10.1007/s11145-010-9275-6
- Goldin-Meadow, S., & Mayberry, R. I. (2001). How do profoundly deaf children learn to read? *Learning Disabilities Research and Practice*, 16(4), 222-229. doi: 10.1111/0938-8982.00022
- Hanson, V. L., & Fowler, C. A. (1987). Phonological coding in word reading: Evidence from hearing and deaf readers. *Memory and Cognition*, 15(3), 199-207. doi: 10.3758/BF03197717
- Hanson, V. L., Goodell, E. W., & Perfetti, C. A. (1991). Tongue-twister effects in the silent reading of hearing and deaf college students. *Journal of Memory and Language*, 30(3), 319-330. doi: 10.1016/0749-596X(91)90039-M
- Inhoff, A. W., & Liu, W. (1998). The perceptual span and oculomotor activity during the reading of Chinese sentences. *Journal of Experimental Psychology: Human Perception and Performance*, 24(1), 20-34. doi: 10.1037//0096-1523.24.1.20
- Inhoff, A. W., & Radach, R. (1998). Dification

- and computation of oculomotor measures in the study of cognitive processes. In G. Underwood (Ed.), *Eye guidance in reading and scene perception* (pp. 29-53). Oxford, England: Elsevier Science. doi: 10.1016/B978-008043361-5/50003-1
- Kennedy, A. (2000). Parafoveal processing in word recognition. *Quarterly Journal of Experimental Psychology*, 53(2), 429-455. doi: 10.1080/027249800390556
- Kliegl, R., Grabner, E., Rolfs, M., & Engbert, R. (2004). Length, frequency, and predictability effects of words on eye movements in reading. *European Journal of Cognitive Psychology*, 16(1-2), 262-284. doi: 10.1080/09541440340000213
- Leybaert, J., & Alegria, J. (1993). Is word processing involuntary in deaf children? *British Journal of Developmental Psychology*, 11(1), 1-29. doi: 10.1111/j.2044-835X.1993.tb00585.x
- Li, X., Rayner, K., & Cave, K. R. (2009). On the segmentation of Chinese words during reading. *Cognitive Psychology*, 58(4), 525-552. doi: 10.1016/j.cogpsych.2009.02.003
- Lichtenstein, E. H. (1998). The relationships between reading processes and English skills of deaf college students. *Journal of Deaf Studies and Deaf Education*, 3(2), 80-134. doi: 10.1093/oxfordjournals.deafed.a014348
- Lin, B.-G., & Chi, P.-H. (2000). The development of test of reading comprehension. *Bulletin of special education*, 19, 79-104.
- Liu, W., Inhoff, A. W., Ye, Y., & Wu, C. (2002). Use of parafoveally visible characters during the reading of Chinese sentences. *Journal of Experimental Psychology: Human Perception and Performance*, 28(5), 1213-1227. doi: 10.1037//0096-1523.28.5.1213
- Mayberry, R. I., del Giudice, A. A., & Lieberman, A. M. (2011). Reading achievement in relation to phonological coding and awareness in deaf readers: A meta-analysis. *Journal of Deaf Studies and Deaf Education*, 16(2), 164-188. doi: 10.1093/deafed/enq049
- Miller, P. (2002). Communication mode and the processing of printed words: Evidence from readers with prelingually acquired deafness. *Journal of Deaf Studies and Deaf Education*, 7(4), 312-329. doi: 10.1093/deafed/7.4.312
- Miller, P., Kargin, T., & Guldenoglu, B. (2015). Deaf native signers are better readers than nonnative signers: Myth or truth? *Journal of Deaf Studies and Deaf Education*, 20, 147-162. doi: 10.1093/deafed/enu044
- Morford, J. P., Wilkinson, E., Villwock, A., Pinar, P., & Kroll, J. F. (2011). When deaf signers read English: Do written words activate their sign translations? *Cognition*, 118(2), 286-292. doi: 10.1016/j.cognition.2010.11.006
- Musselman, C. (2000). How do children who can't hear learn to read an alphabetic script? A review of the literature on reading and deafness. *Journal of Deaf Studies and Deaf Education*, 5(1), 9-31. doi: 10.1093/deafed/5.1.9
- Pan, J., Shu, H., Wang, Y., & Yan, M. (2015). Parafoveal activation of sign translation previews among deaf readers during the reading of Chinese sentences. *Memory and Cognition*, 43(6), 964-872. doi: 10.3758/s13421-015-0511-9
- Perfetti, C. A., & Sandak, R. (2000). Reading optimally builds on spoken language:

- Implications for deaf readers. *Journal of Deaf Studies and Deaf Education*, 5(1), 32-50. doi: 10.1093/deafed/5.1.32
- Pollatsek, A., Lesch, M., Morris, R. K., & Rayner, K. (1992). Phonological codes are used in integrating information across saccades in word identification in reading. *Journal of Experimental Psychology: Human Perception and Performance*, 18, 148-162. doi: 10.1037//0096-1523.18.1.148
- Pollatsek, A., Tan, L. H., & Rayner, K. (2000). The role of phonological codes in integrating information across saccadic eye movements in Chinese character identification. *Journal of Experimental Psychology: Human Perception and Performance*, 26(2), 607-633. doi: 10.1037/0096-1523.26.2.607
- Quinn, L. (1981). Reading skills of hearing and congenitally deaf children. *Journal of Experimental Child Psychology*, 32, 139-161. doi: 10.1016/0022-0965(81)90099-0
- Rayner, K. (1975). The perceptual span and peripheral cues in reading. *Cognitive Psychology*, 7, 65-81. doi: 10.1016/0010-0285(75)90005-5
- Reichle, E. D., Rayner, K., & Pollatsek, A. (2003). The E-Z Reader model of eye-movement control in reading: Comparisons to other models. *Behavioral and Brain Sciences*, 26(4), 445-526. doi: 10.1017/S0140525X03000104
- Smith, W. H., & Ting, L. F. (1979). *Shou Neng Sheng Chyau [Your hands can become a bridge]: Sign language manual. (vol. 1)*. Taipei, Taiwan: Deaf Sign Language Research Association of the Republic of China.
- Smith, W. H., & Ting, L. F. (1984). *Shou Neng Sheng Chyau [Your hands can become a bridge]: Sign language manual. (vol. 2)*. Taipei, Taiwan: Deaf Sign Language Research Association of the Republic of China.
- Stanovich, K. E. (1994). Constructivism in reading education. *Journal of Special Education*, 28(3), 259-274. doi: 10.1177/002246699402800303
- Stokoe, W. C. (1960). Sign language structure: An outline of the communication systems of the American deaf. *Studies in linguistics: Occasional papers (No. 8)* Buffalo Deptment of Anthropology and Linguistics, University of Buffalo.
- Transler, C., Gombert, J.-E., & Leybaert, J. (2001). Phonological decoding in severely and profoundly deaf children : similarity judgment between written pseudo-words. *Applied Psycholinguistics*, 22, 61-82. doi: 10.1017/S0142716401001047
- Transler, C., & Reitsma, P. (2005). Phonological coding in reading of deaf children: Pseudohomophone effects in lexical decision. *British Journal of Developmental Psychology*, 23, 525-542. doi: 10.1348/026151005X26796
- Traxler, C. B. (2000). The Stanford Achievement Test, 9th Edition: National norming and performance standards for deaf and hard-of-hearing students. *Journal of Deaf Studies and Deaf Education*, 5, 337-348. doi: 10.1093/deafed/5.4.337
- Treiman, R., & Hirsh-Pasek, K. (1983). Silent reading: Insights from second-generation deaf readers. *Cognitive Psychology*, 15, 39-

65. doi: 10.1016/0010-0285(83)90003-8
- Tsai, J. L., Lee, C. Y., Tzeng, O. J. L., Hung, D. L., & Yen, N. S. (2004). Use of phonological codes for Chinese characters: Evidence from processing of parafoveal preview when reading sentences. *Brain and Language, 91*, 235-244. doi: 10.1016/j.bandl.2004.02.005
- Waters, G. S., & Doehring, D. G. (1990). Reading acquisition in congenitally deaf children who communicate orally: Insights from an analysis of component reading, language, and memory skills. In T. H. Carr & B. A. Levy (Eds.), *Reading and its development* (pp. 323-373). San Diego, CA: Academic Press.
- Wauters, L. N., van Bon, W. H., Tellings, A. E., & van Leeuwe, J. F. (2006). In search of factors in deaf and hearing children's reading comprehension. *American Annals of the Deaf, 151*(3), 371-380. doi: 10.1353/aad.2006.0041
- White, S. J., Rayner, K., & Liversedge, S. P. (2005). Eye movements and the modulation of parafoveal processing by foveal processing difficulty: A reexamination. *Psychonomic Bulletin and Review, 12*(5), 891-896. doi: 10.3758/BF03196782
- Wilson, M., & Emmorey, K. (1997). A visuospatial "phonological loop" in working memory: Evidence from American Sign Language. *Memory and Cognition, 25*(3), 313-320.

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中文閱讀時臺灣手語音韻之周邊預視 效益

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臺灣失聰者可以使用中文與台灣手語來溝通，本研究欲瞭解失聰台灣手語使用者之台灣手語音韻表徵對於於中文閱讀時的影響。實驗使用眼動邊界典範與眼動誘發呈現改變技術 (Rayner, 1975)，研究假設若受試者若可在周邊視野擷取到詞彙相關訊息，則當眼睛通過設定邊界使得預視詞立即取代為目標詞時，眼睛凝視目標詞的處理便會受到影響。實驗操弄目標詞與預視詞的台灣手語音韻相關性 (相關、無關)，其中音韻相關手語之中文詞組指的是台灣手語手形相同，受試者被要求閱讀理解句子並判斷合理性，記錄其眼動指標與句子理解的正確性。此外，由於台灣手語翻譯為與中文詞時，可能為一個或兩個字的中文詞，透過於實驗一為預視詞與目標詞為一個字的中文詞，實驗二為預視詞與目標詞改為兩個字的中文詞，可以協助瞭解失聰手語者於中文閱讀時，台灣手語知識對於中文對詞的影響。結果發現：在一個字的中文詞中，手語音韻預視效果可在失聰手語者的第一凝視時間與凝視次數中顯示出來；在兩個字的中文詞中，手語音韻預視效果則是在第一凝視時間與凝視時間中發現，但在非口語失聰組中未出現；此外，由實驗一與實驗二的結果顯示，失聰手語者在閱讀中文時，無論中文詞為單字詞或雙字詞，手語音韻不僅會被自動激發，同時，中文斷詞的運作也會與一般中文閱讀者一樣，先是次詞彙，之後再整合為詞彙地進行；一般聽人組則未有任何台灣手語音韻的預視效果。簡而言之，失聰手語者於中文閱讀理解時，會激發包含台灣手語音韻的表徵。

關鍵字：失聰、台灣手語、音韻、眼球運動、閱讀